# What is Science?

*Ole J. Forsberg*

Science is a method of inquiry whose objectives are to describe observed reality and predict outcomes. A discipline cannot be a science, only scientific in nature.

**When is a discipline scientific in nature?**

A discipline is scientific in nature if the sole accepted modes of inquiry are scientific in nature. That does not mean that one cannot do science in a non-scientific discipline, only that those scientific methods are not the norm. Physics is a scientific discipline because those who practice physics and work in the discipline utilize scientific modes of inquiry to create scientific theories and hypotheses. Political Science, while it can be studied scientifically, is not a scientific discipline yet, since there are still several popular non-scientific methods of inquiry that fail to create scientific theories and hypotheses.

**What are scientific theories?**

In science, theories serve as the primary means of understanding the world. These scientific theories provide a general understanding of the relationships between observables. Theories are general; that is, they seek to give empirical meaning to a wide scope of observations. Scientific theories produce falsifiable hypotheses against which they can be tested. If testable hypotheses are not a result of the theory, then the theory is neither scientific nor useful.

**What is the difference between scientific laws and theories?**

Scientific laws are much narrower, much more specific in scope. They apply to one (or very few) class(es) of observations. In science, they are treated as facts. Furthermore, laws cannot be broken—'cannot', not 'are not'.

> *Example*. According to the Law of Conservation of Momentum, in any collision in a closed system, the total momentum of that closed system remains constant.
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> While this seems to be general, it only applies to calculations of momentum in a collision—its scope is very limited. Also, it can never be violated. Once a violation is detected, it is no longer a law.

Theories cannot be laws, as they seek to give broader meaning to a greater number of cases. Furthermore, the life cycle of theories is completely different than that of laws. Theories are more robust; that is, they can withstand counterexamples. Laws cease to exist at the discovery of a single counterexample.

**What is a scientific hypothesis?**

A hypothesis is a proposed answer to a research question that fits three requirements: falsifiable, empirical, and general.[1] To be falsifiable, there must theoretically exist some empirical manner of proving the hypothesis wrong. In more precise language, a hypothesis is falsifiable if it divides the universe of conceivable observations into two non-empty sets, those that contradict the hypothesis and those that do not. To be empirical, the manner of testing the hypothesis must be done through observation and measurement (not necessarily using numbers). Finally, hypotheses must apply to more than just a single case; that is, the hypothesis must speak to more than just one example.

> *Example*. The statement "Democracies do not go to war with other democracies" is, indeed, a scientific hypothesis. It meets the three requirements above: It is falsifiable, for it *could be observed* that there are two democracies that went to war. Second, under certain operationalizations, all aspects of the hypothesis are measurable (empirical). One can easily define both 'democracy' and 'war' in ways that can be measured. In fact, a great deal of the research on war has done just this. Finally, the hypothesis is general. It applies to more than just one pair of democracies in one time period. Furthermore, it is not a theory. It speaks solely to those things called democracies and their conflict paths towards war (it does not incorporate a vast number of hypotheses into a simple framework). Furthermore, had the statement been "Norway did not go to war with Luxembourg in 1990," it still would not have been a theory (or a hypothesis); it would have been a fact. It lacks any suggestion of generality.

The scientific theory involved here is: Political liberalism tends to lead to higher levels of regime pacifism. Both concepts are measurable. The statement divided all observations into those that conflict with it (a liberal regime that has increased levels of belligerency). Finally, it is quite general, going beyond the simple democracy-war connection to a fuller explanation of the connection between regime liberalization and pacifism.

**What is a fact?**

A fact is an agreed-upon interpretation of an observation made by competent observers. Is it a fact that the rebels won the American War of Independence? Yes. Competent observers (historians) have interpreted observations made (through reading first-hand accounts of the war or through experiencing the war) and have agreed that the statement is true. Interestingly enough, facts have the ability to change; facts are not perfectly portable. This means that facts can change if the examining discipline is changed. This often occurs when the information travels into a different realm with different competency requirements.

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[1] For a more complete discussion of the requirements of science and pseudo-science, see Karl R. Popper. 1959. *The Logic of Scientific Discovery*. (New York: Basic Books).

*Example*. Is it a fact that my parent's living room is blue? To the average person, the answer is yes. If that question is asked of an interior decorator, however, the answer might be no; the color is Fifth Avenue. To a physicist, the answer might also be no; the color is 4500Å.[2]

**If facts can change, what's the point?**

One option is to throw up our hands and never attempt to find order in the world. The other option is to continue searching, because the facts we find are the best we can do **at that point**. This is pragmatism—we do the best we can with what we are given. This also leads to exposure of the greatest myth about science: objective reality.

**What is objective reality?**

D'Oliveiro, a philosopher, defined objective reality as whatever remains true whether you believe in it or not.[3] In essence, this definition specifies that objective reality is the world 'out there', the world that exists 'in reality'. As such, subjective reality is the world we perceive.[4] It is how we interpret the objective reality (if it exists). Many people think science is objective; it focuses on the object of study—the real world. Some hold, however, that since we must interpret (through our senses, our brains, and our theories) the world, then science must be subjective. As subjective reality varies from one person to the next, it is relative. If one holds to the belief that reality is relative to the observer, then relativism (and all of its weaknesses) invariably results.

The reality of the situation is that science is neither objective nor subjective; it is inter-subjective. Recall that science uses facts that depend on the agreement of many competent observers. Inter-subjectivity accepts the reality 'created' by this agreement. It denies both that it has perfectly described the objective world and that reality is completely subjective. This shows the importance of those competent observers, of checking the facts yourself.

**What is the life cycle of a theory?**

Whenever a discussion of scientific inquiry takes place, three names must be mentioned. The holy trinity of the philosophy of science is Karl Popper, Thomas Kuhn, and Imre Lakatos. These three have written extensively on what makes an enterprise scientific and how a scientific enterprise differs from a non-scientific one. The summary of each of the three is presented here.

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2 The wavelength of pure blue light is 4000Å. Interestingly enough, the Ångstrom is no longer used as a measure of wavelength, being deprecated in favor of the nanometer (nm).

3 Lawrence D'Oliveiro. 2000. "The Nature of Objective Reality." March 27. http://www.geek-central.gen.nz/peeves/objective reality.html (January 10, 2005).

4 An interesting side note: The terms objective and subjective come from grammar placement. The object of the sentence receives the action, while the subject of the sentence performs the action.

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Karl Raimond Popper focused on what constituted scientific exploration.[5] His primary concentration was to determine the line of demarcation between physics and metaphysics. What makes a hypothesis scientific, and what makes it pseudo-scientific? Popper knew of Kant's line of demarcation, induction, but Popper saw the inherent logical inconsistencies in Kant's line of demarcation. After much though, Popper decided the line of demarcation was falsifiability of the statements. About falsifiability, Popper wrote,

According to this criterion, a statement, or a system of statements, convey information about the empirical world only if they are capable of clashing with experience; or more precisely, only if they can be systematically tested, that is to say, if they can be subjected (in accordance with a 'methodological decision') to tests which might result in their refutation.[6]

Thus, a statement is scientifically, is empirically valuable if it is testable. Non-testable statements are either tautologies (like mathematics) or metaphysics (like philosophy). Either way they convey no new information about the world. They may be useful in other ways, but they are not science. When he was forced to describe the life cycle of a theory, Popper centered it on the concept of falsifiability. If a theory had been falsified, i.e. if a counter example existed, then the theory had to be abandoned.

This obviously did not happen.

Thomas Samuel Kuhn realized that theories were never easily abandoned. He focused his thoughts on creating a general theory of scientific development that showed the process of science.[7] For Kuhn, there were two different kinds of science: normal and revolutionary. Normal science occurs when scientific progress is marked with a generally accepted paradigm, the research agenda for the discipline focuses on this paradigm, and the practitioners tests the paradigm.

The tests of the theories will not always support the theory. The paradigm is found lacking. But, scientists do not throw away the paradigm because of a few negative results. However, eventually, those negative results become the focus of exploration. As they become less and less the exception and more the rule, the paradigm is replaced; the benefits from adhering to it are

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5 This discussion is from Karl R. Popper. 1959. *The Logic of Scientific Discovery*. (New York: Basic Books).

6 Popper: 315.

7 This discussion is from Thomas S. Kuhn. 1996. The Structure of Scientific Revolutions. (Chicago: University of Chicago Press)

vastly outweighed by the wrong answers it gives in addition to the loss of elegance.[8] During the time between when the paradigm is found all but worthless until the time it is successfully replaced with another paradigm, there is no single direction in the discipline. This period is called revolutionary science. This is how science advances for Kuhn.

Imre Lipschitz Molnár Lakatos was a rationalist, someone who believed that "Reason can and will prevail over Will".[9] As he grew up under the occupation of Nazi Germany in Hungary, and who lived under the Soviet system, he understood the dangers of dogmatism. He also read Popper thoroughly and understood that the idea of falsification was not the appropriate line of demarcation between science and pseudo-science.[10] All scientific theories, according to Lakatos, are falsified innumerable times by data that does not fully fit them. Thus, if we assert Popper's views on current theories of physics, they would all be falsified.[11] In place of falsification, and in place of Popper's and of Kuhn's centrality of the theory in science, Lakatos employed the research programme.

To Lakatos, the research programme consisted of a logical collection of ideas, theories, and paradigms which comprised the "hard core" of the programme, along with a "protective belt" of hypotheses which, in essence, shield the core from falsification. The hypotheses get falsified, but the theory does not. The protective belt constantly changes to account for hypotheses that were falsified, but the hard core remains intact. When a programme changes in response solely to external forces, it is degenerating. When it changes in response to internal forces, it is progressing. That is, if the programmes are changed ad hoc to account for anomalous outcomes, it is degenerative. If the change in the programme explains past theories and predicts future ones, it is progressive.

For Lakatos, a discipline is scientific as long as progressive programmes triumph over degenerating ones.

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[8] A theory is elegant if it can be concisely stated. In both science and mathematics, elegance is desirable. The inclusion of too many ad hoc additions not only reduces elegance, but it also demonstrates the number of exceptions to the theory that have yet to be included.

[9] Brendan Larvor. 1998. Lakatos: An Introduction. (New York: Routledge, 1).

[10] This discussion is from Imre Lakatos. 1978. The Methodology of Scientific Research Programmes. (New York: Cambridge University Press) and from Brendan Larvor. 1998. Lakatos: An Introduction. (New York: Routledge).

[11] This argument overstates Popper's original intent and replaces it with dogmatic falsificationism. If one adheres to dogmatic falsificationism, any finding that contradicts a scientific theory disproves it fully. Popper did not hold this extreme view. In its place, he held that counterexamples merely weaken a theory—something called methodological falsificationism.

**So, which view is correct?**

To *me*, disciplines are neither science nor non-science. Methods can be categorized in such a manner, but disciplines cannot. Advancing disciplines use scientific methods to achieve results. The pluralization on the word 'methods' indicates a definite support methodological pluralism. There is no problem with a discipline that uses a historico-traditional method, a behavioralist method, and a post-behavioralist method—as long as the created theories are testable in the Popperian sense and the discipline advances in the Lakatosian sense.

**How does all this affect this course?**

The only questions that can be explored in the research paper are questions that can be answered in an empirical manner. Proposed answers to the research question (hypotheses) must meet the three requirements of scientific theories. These hypotheses must reflect the current theories and literature on the topic. That means that the hypotheses must be the answers to the research question according to the extant literature. Finally, the hypotheses must be operationalizable.

**How does one operationalize a hypothesis?**

When a hypothesis is operationalized, each of the concepts in the hypothesis is clearly defined and they have an explicit manner of measurement. To operationalize a hypothesis, one must first be completely aware of the concepts mentioned in the hypothesis. One must then propose measures and methods of measure of those concepts.

> *Example*. Hypothesis: Democracies do not go to war against other democracies. The two main concepts here are war and democracy. War is defined as a protracted conflict with 1,000 or more battle deaths. This is the normally accepted empirical definition. It is also easily measured.[12] Democracy is not as easily defined. Several measures of democracy are currently available. One method focuses on the structures of the government (constraints on the executive and regular elections). To measure democracy, we would then examine the constitutions for effective limits on the executive and combine that with the existence of regularly held, competitive elections. If a country has both, then it is a democracy. If it lacks either, then it is not.

Note what was done. The concepts were pulled from the hypothesis. Those concepts were reduced to the point of observation. That process of reduction is connected to the original concepts; that is, the measures actually seem, prima facie,[13] to measure what they are supposed to measure.

A quick check to determine if your hypothesis was properly operationalized is to determine if one can readily determine how to test it and what results would disprove the hypothesis. For

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[12] In this sense, easy is a synonym for 'straight-forward'.

[13] The term prima facie is Latin for 'first sight'.

instance, is the above operationalization satisfactory? Can we tell what a democracy is? Can we tell what a war is? Can we tell if a democracy has gone to war with another democracy? The answer to each of these three questions is yes. Therefore, the hypothesis is properly operationalized.

> *Example (a Bad Operationalization.)* Hypothesis: The Electoral College does not work like the framers of our Constitution intended. Operationalization: Work—Performing a duty or task. Intended—To have in mind or plan. The Electoral College does not perform its task like the framers of our constitution had in mind. Why is this not a good operationalization? The terms are properly defined, at least according to Webster. So, what is it missing? This: How can we tell if the Electoral College works like the framers of our Constitution intended? From what was provided, we cannot tell. Thus, we cannot determine before hand what it would take to falsify the hypothesis.

> *Example*. Hypothesis: Minorities are more likely to have jobs and a higher education in states that enforce Affirmative Action than those that do not. Operationalization: Affirmative Action is a policy or a program that seeks to redress past discrimination through active measures to ensure equal opportunity, as in education and employment. Minorities are a group having little power or representation relative to other groups within a society. The state is the body politic, especially one constituting a nation. To enforce is to compel observance of or obedience to. The socioeconomic status (SES = GSP per capita/cost of living) and the unemployment rate of minorities in a state will reveal if Affirmative Action is economically effective in the state or not. The education levels will reveal if Affirmative Action has impact on the amount of education that minorities receive in a state. Is this a good operationalization or not? Can we tell if minorities have jobs and higher education using the operationalization? Can we tell if a state enforces Affirmative Action using the operationalization? If the answer to both is yes, then it is a good operationalization.

**Causation**

Causation is a concept in both philosophy and science. The concept of causality refers to the set of all particular "causal" or "cause-and-effect" relations. Unfortunately, a neutral definition is hard to provide, as every aspect of causation has been subject to much philosophical debate, including its very existence.

For us, causation is a relationship that holds between events, properties, variables, or states. Causality always implies at least some dependent relationship between the cause and the effect. For example, deeming something a cause may imply that, all other things being equal, if the cause occurs, then the effect does as well (absolute causation), or at least that the probability of the effect occurring increases (probable causation). It is also usually presumed that the cause chronologically precedes the effect (temporal precedence).

The concept of causation in science is quite similar. However, one cannot prove causation. This should not be surprising, as nothing is proven in science; hypothesized relationships are only supported. However, causation does offer something that mere correlation does not. It allows one to suggest a manner of changing the outcomes.

Showing causation is quite simple in theory. In an absolute sense of causality, if Event A causes Event B, then every time we observe Event A, we will also observe Event B; Event A always precedes an Event B; and there must be a theoretical reason for Event A to cause Event B. In a probabilistic sense of causality, the same three requirements exist (correlation, temporal precedence, and theoretical feasibility), only without the requirement of it *always* happening, only that the probability of the effect happening increases significantly.

> *Example*. It has been shown that increases in temperature always precede increases in the violent crime rate. Is causation shown? No. Correlation is shown: when Event A occurs (higher temperatures), then Event B always occurs (higher violent crime rates). Temporal precedence is shown: Event A (higher temperatures) happens before Event B (higher crime rates). However, there is no solid theory as to why Event A causes Event B. The reality is that there is an intervening cause, people are out later in the day in the summers (higher temperatures), which increases the chances that a violent event will take place.

> *Example*. It has also been shown that people with larger shoe sizes (Event A) also tend to score higher on the SAT (Event B). Is causation shown? No. Again, the first two requirements are made. There lacks, however, a theoretical reason for the causation. Here, there is a common factor: age. Older people tend to have larger feet (compare a toddler with a college student). Older people also tend to do better on the SAT (again, compare a toddler with a college student).

> *Example*. It has been shown that terrorist groups are less active under left-leaning governments than under right-leaning governments. Is causation shown? Yes. There are fewer terrorist attacks under left-leaning governments than under right-leaning governments (Correlation). When a left-leaning government is elected, the number of terrorist attacks drops in that state (Temporal Precedence). Left-leaning governments are more willing to negotiate with a terrorist group, thus terrorist groups are more willing to have a left-leaning government in power. Right-leaning governments tend to eschew negotiations in place of military action, which terrorist groups do not want to happen (Theoretical Feasibility).