Scientific 'Laws', 'Hypotheses' and 'Theories'

How are They Related?

J R Lakshmana Rao

Some commonly held erroneous notions about the terms laws, hypotheses and theories are pointed out with specific examples from different branches of science.

J R Lakshmana Rao was a Professor of Chemistry in Yuvaraja's College, Mysore. Interpreting science to laymen in his mother tongue, Kannada and popularising science through writing and talks have been his favourite pursuits.

See Part 1 on 'Meanings and Distinctions', *Resonance*, Vol.3, No.10, 1998.

Hypotheses

Hypotheses are suppositions or assumptions put forward to explain observed phenomena and the laws governing them. John Stuart Mill, who is spoken of as the father of induction and who, in the opinion of the present author, is responsible for spreading the erroneous ideas concerning laws, hypotheses and theories, defines a hypothesis as "any supposition which we may make (either without actual evidence or on evidence avowedly insufficient) in order to endeavour to deduce from it conclusions in accordance with facts which are known to be real; the supposition being made under the idea that if the conclusions to which the hypothesis leads are known truths, the hypothesis itself either is, or at least is likely to be true". This definition is satisfactory *in so far as it describes the function of a scientific hypothesis.* But it is necessary to emphasise that what is assumed or supposed by the hypothesis (the subject matter of it) need not necessarily be of the nature of a law (a regularity in nature). Only sometimes it is so. But, quite often it is not. It may just be a supposition about the existing situation, or the nature of a physical entity, which we are unable to perceive directly through our senses. It may also be a supposition about past events. For instance, Dalton supposed that matter is built up of atoms and Huygens supposed that light rays consist of waves. The *former* supposition was helpful in giving a satisfactory explanation for the laws of chemical combination and the *latter* for optical phenomena such as diffraction and interference. The success of these suppositions resulted in 'establishing' that matter is

Hypotheses which become well-established need not become scientific laws.

granular and not continuous, and that light is undulatory and not corpuscular. What are unravelled in these cases are the *natures* of matter and of light, but not any *law*. This, I believe, is the reason why, in spite of being well-established, these hypotheses are not called 'atomic law of matter' and 'wave law of light', as they should have been if the logicians' view were correct.

In Geology, we come across problems concerning the origin of mineral substances such as coal and petroleum. We make guesses as to how coal and petroleum have come to be there in the earth's crust. Such guesses are hypotheses about past events. We examine the available evidence to ascertain whether our guesses are supported by evidence. Cosmogonic hypotheses about the origin of the solar system are also hypotheses of this type. They are about the birth of the planets, an event, which has happened, in the past history of our Universe. If a hypothesis concerning the origin of planets is 'established', or even if it gains universal acceptance, it does not result in the exposure of any law.

It is the failure to appreciate this diversity of the nature of what is assumed in scientific hypotheses, which has given rise to the erroneous generalisation that every hypothesis becomes a law when it is fully established. Considering the prestige which Mill enjoys as one of the founders of inductive logic, and the influence he seems to have had on subsequent writers, it may be desirable to examine the extent to which he is responsible for the spread of this erroneous notion. After giving the definition of *hypothesis* (already quoted), he goes on, "Since explaining in the scientific sense means resolving a uniformity which is not a law of causation into the laws of causation from which it results, or a complex law of causation into simpler and more general ones from which it is capable of being deductively inferred; if there do not exist any known laws which fulfil this requirement, we may feign or imagine some which would fulfil it; and this is making a hypothesis". Thus he has restricted the scope of a scientific hypothesis by implying that a hypothesis, of necessity, is a supposition of some thing in the nature of a law. He has described how Newton put forward his law of gravitation as a hypothesis from which it was possible to 'deductively infer' the laws of planetary motion enunciated earlier by Kepler. He concludes by declaring: "It is thus perfectly possible, and indeed is a very common occurrence, that what is a hypothesis at the beginning of the inquiry becomes a proved law of nature before its close". Later writers appear to have been influenced by this to a very large extent.

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Elsewhere he has, no doubt, recognised hypotheses of other kinds also. But he has drawn a distinction between hypotheses which assume the cause of a phenomenon and those which assume the law according to which a cause (real and already known) acts and he has chosen to dismiss the first kind as not having any value. "... Most thinkers of any degree of sobriety" says Mill, "allow that a hypothesis of this kind is not to be received as probably true because it accounts for all the known phenomena; since this is a condition often fulfilled equally well by two conflicting hypotheses ...". He is not prepared to give any importance to such a hypothesis even when it can anticipate and predict other facts, which can be verified by experience later. "Such predictions and their fulfilment", according to Mill, "are indeed, well calculated to strike the ignorant vulgar whose faith in science rests solely upon similar coincidence between its prophecies and what comes to pass". He expresses astonishment that a philosopher of Whewell's abilities "recognises absolutely no mode of induction except that of trying hypothesis after hypothesis until one is found which fits the phenomena".

A close examination of the development of science, particularly since the time of Mill, will reveal that his remarks are not justifiable. The advance of science, in fact, is proceeding precisely in the manner of Whewell's description. Of several hypotheses put forward, the one which fits the phenomena best is accepted. If, at a later stage, a new hypothesis is found to explain a wider range of phenomena, it replaces the previous one. Einstein's postulates, which constitute the relativity theory, can explain a

A scientific hypothesis can be about the cause of a phenomenon as well as the mode of operation of the cause.

wider range of phenomena than Newton's gravitational hypothesis could. The result is that, today, we can do away with the concept of gravity and substitute it with the geometry of space. Secondly, contrary to what Mill says, scientific practice places a high premium on the capacity of a hypothesis to predict new results. It may not be an exaggeration to say that the value of a hypothesis increases, not in arithmetic progression, but in geometric progression as more and more consequences of the hypothesis turn out to be true.

Mill's contention that a true scientific hypothesis is one which assumes *only the mode of action of a cause*, which itself is already known to be real, is to impose an alien, artificial and unnecessary restriction on the scope of scientific hypotheses. "There is probably no hypothesis in the history of science" says Mill, "in which both the agent and the law of its operation were fictitious." This is not true. Dalton explained the laws of chemical combination by assuming the existence of atoms (the cause), and that they combine with each other only in small numbers (the law of its operation). Similarly Darwin explained the diversity of life on our planet by assuming that evolution has occurred, and that its course is determined by the struggle for existence and natural selection. The modern gene theory of heredity explains the Mendelian laws of inheritance assuming the reality of the gene, and that it is passed on to the offspring in a particular manner by the shuffling of the chromosomes.

These considerations are enough to show that a scientific hypothesis can have, as its subject matter, a variety of things: the cause of a phenomenon, the mode of operation of the cause, the nature of a physical entity such as matter, light, heat or electricity, the structure of a molecule, the shape of an atom (van't Hoff's hypothesis of the tetrahedral model of the carbon atom), or the past history of something. If the hypothesis achieves its purpose by explaining what it seeks to explain, it becomes just a 'successful hypothesis' and not a theory or law. However, a hypothesis, whose subject matter is something of the nature of law, can acquire that title as in the case of Avogadro's hypothesis which is being referred to as 'Avogadro's law' by modern writers.

Theories

The word 'theory' is sometimes used to mean the sphere of thought as opposed to that of action or practice. It means, elsewhere, the body of knowledge pertaining to a specific field. But what we are concerned with, in the present discussion, is the meaning of the word in the technical sense, as it is used in relation to *scientific theories* such as the atomic theory, the quantum theory, the kinetic theory of gases, the gene theory of heredity and so on. It is possible to examine the contents of these theories and to state precisely what a scientific theory is.

As pointed out earlier, a theory has often been described by logicians as a hypothesis which has been verified and found to be true. "When a hypothesis is thus established as true it is called a theory" explains Welton. Westaway, in a footnote on 'atomic Hypothesis', states: "The hypothesis is now regarded as well established, and is therefore often called the atomic theory". This view cannot account for the fact that discarded theories like the Phlogiston theory or Newton's corpuscular theory of light are still referred to as theories. While dealing with phenomena requiring satisfactory explanation, one often comes across the statement that "there are several theories put forward to account for the phenomena. But none of them is satisfactory." If we go by the definition given by Welton and Westaway, phrases like 'unsatisfactory theories' and 'discarded theories' are contradictions in terms. However, we do come across these phrases quite often in scientific works.

What, then, is a scientific theory? In answering the question, it is necessary to stress again that it is the content of a doctrine which makes it a theory and not its certainty or respectability. It is the view of the present author that theories also are of the nature of hypotheses. But, while a hypothesis is simply an assumption, a theory is often made up of several assumptions related to each other. It is a co-ordinated *system* of hypotheses

A theory is a co-ordinated system of hypotheses and their corollaries having an internal unity and represents a conceptual framework.

and their corollaries having an internal unity. It is a conceptual framework, thus built up, to provide a new way of looking at the subject under consideration. That matter is composed of atoms was a hypothesis in the hands of the ancients. It became a theory in the hands of Dalton who built it up into a system by adding other necessary suppositions, so that experimentally verifiable conclusions could be deduced from it: Matter is composed of atoms; atoms are eternal; atoms of one element are different from those of another element; they combine in small numbers during chemical combination; etc. The totality of these suppositions is what constitutes the atomic theory. Avogadro's hypothesis, on the other hand, contains a *single idea* that equal volumes of different gases contain the same number of molecules. Consequently, even when the hypothesis was accepted as true, it continued to be called a hypothesis and not a theory. If it is also referred to as a law, it is because it denotes a regularity in nature, and not because it is 'firmly established'.

One may raise the question as to why terms 'atomic hypothesis' and 'quantum hypothesis' are also found, sometimes, in scientific literature. If works of discerning writers are carefully examined, it can be noticed that the phrase 'atomic hypothesis' is used only when the intention of the author is to focus our attention on the central hypothesis in the atomic theory, its pivot, the assumption that matter is not continuous but is made up of discrete particles. Similarly, the term 'quantum hypothesis' refers to the supposition that radiation energy does not flow continuously, but in discrete packets. Other adjuncts to the hypothesis, all of which together constitute the quantum theory, are considered unimportant in the context. A similar situation is met with while dealing with gravitation. That there is such a thing as gravitational force between two objects in the Universe is Newton's *gravitational hypothesis*. Newton proposed a second hypothesis concerning the magnitude of that force. It is the famous *Universal law of gravitation*. The system built upon these hypotheses is what we call the gravitational theory.

It may be pointed out that the language we use in relation to the

Results, Models, Hypotheses, Theories, Facts!

True Science is a wild adventure. True scientists interrogate the world without preconception or regard to repudiation. Results are structured into models, models that successfully predict become hypotheses; well-established and reliable hypotheses become theories; and only with the passage of time can unbreakable theories be tentatively designated as fact.

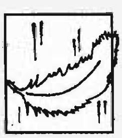
Steve Menear, Letters, *The Economist*, p.6, 21 September 1996.

terms *law* and *theory* indicates the difference between them. We usually speak of "discovering a law" and "inventing or building up a theory". It is desirable to point out that it is more common to speak of theories and hypotheses being *put forward, suggested or proposed*. The language we use also shows up the distinction between a theory and a hypothesis likewise. Theories, being systems, are *built up or constructed*, whereas hypotheses, being isolated suppositions, are just *proposed or suggested*.

Suggested Reading

[1] H E Cunningham. *Text Book of Logic*. Macmillan, New York.
[2] John Stuart Mill. *System of Logic*. Chapter on 'Hypothesis'.
[3] James Welton. *A Manual of Logic*. University Tutorial Press, Vol. II.
[4] F W Westaway. *Scientific Method*. Blackie & Son.

Address for Correspondence
J R Lakshmana Rao
'Maithri', 12th Main
Saraswathipura,
Mysore 570009, India.



It is remarkable to what extent Indian mathematics enters into the science of our time. Both the form and the spirit of arithmetic and algebra of modern times are essentially Indian and not Grecian.

F Cajori
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