This essay, which lays out the nature of a scientific theory, is partially motivated by a recent article by Joyce Lucas-Clark entitled ‘Framing the discussion: what to tell students about science’¹. It is intended for students of science and researchers who will obtain an overall and coherent view of what a scientific theory is and discover that its characteristic features, discussed in this commentary, are common in the physical sciences and engineering. Lucas-Clark writes about science as follows:

‘Science refers to knowledge that can be demonstrated, objectively, in the concrete, factual realm of reality. Matters that are inherently outside of objective reality, those things that are subjective or internal and cannot be demonstrated objectively, are outside of the realm of natural science.’

Further on, she states:

‘Scientific inquiry is characterized by objectivity. A scientist, ideally, does not become attached to a certain hypothesis and seek to prove it. Rather, he or she adopts multiple working hypotheses and seeks to eliminate them. Scientists also accept that there will always remain a degree of uncertainty in their conclusions. It is the hallmark of a good scientific principle or theory that one can state clearly how it could be disproved.’

In this paper, we will subject these thoughts to a critical reflection.

All scientific knowledge of objective reality is acquired through the senses, and its interpretation by the mind of a perceiving human subject. Without the human being, there would be no such thing called ‘science’, since science is a creation of humans. All data from the objective world are thus filtered, coloured and processed through the physiological and psychological (i.e. conceptual) lenses of the perceiver. Since the most important task of science is to impart order into the panoply of external observations and bring them into a coherent or logical scheme so as to make them understandable to the human mind, let us examine the nature of a scientific theory. In his essay ‘What is the theory of relativity?’, Einstein² distinguished between two types of scientific theories. He wrote:

‘We can distinguish various kinds of theories in physics. Most of them are constructive. They attempt to build up a picture of the more complex phenomena out of the materials of a relatively simple formal scheme from which they start out. Thus the kinetic theory of gases seeks to reduce mechanical, thermal, and diffusional processes to movements of molecules – i.e., to build them up out of the hypothesis of molecular motion. When we say that we have succeeded in understanding a group of natural processes, we invariably mean that a constructive theory has been found which covers the processes in question.’

‘Along with this most important class of theories there exists a second, which I will call “principle-theories”. These employ the analytic, not the synthetic, method. The elements which form their basis and starting-point are not hypothetically constructed but empirically discovered ones, general characteristics of natural processes, principles that give rise to mathematically formulated criteria which the separate processes or the theoretical representations of them have to satisfy. Thus the science of thermodynamics seeks by analytical means to deduce necessary conditions, which separate events have to satisfy, from the universally experienced fact that perpetual motion is impossible.’

‘The advantages of the constructive theory are completeness, adaptability, and clearness, those of the principle theory are logical perfection and security of the foundations. The theory of relativity belongs to the latter class.’

According to Einstein, at the base of most scientific theories (i.e. of the constructive type), there are certain hypotheses whose nature is arbitrary, i.e. they are speculative constructions or free inventions of the human mind.³ The validity of such hypotheses cannot be proved directly, but is indirectly confirmed by agreement between predictions of the theory and external facts. In a letter written to his friend Maurice Solovine on 7 May 1952, Einstein⁴ offered a sketch of the nature of a scientific theory. Figure 1, taken from the work of Mittal⁵ on the kinetics of hemicellulose extraction in the autohydrolysis of sugar maple wood, shows a practical adaptation of Einstein’s scheme. We see that the foundation of the theoretical edifice consists of two types of...
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language, i.e. there is no freedom of choice

(e.g. calculus), the rules of that particular

system have to be followed strictly, very

contrast to a mathematical theorem like

that of Pythagoras, which is eternal since

it does not depend upon external experi-

ence for its truth, and can be proved from

logical considerations alone. Another

feature of a constructive theory is that

there can be more than one such theory

based on different speculative construc-
tions or premises that agree with experi-

mental data taken at a particular level to

a prescribed degree of tolerance. Since

direct verification of the various hypothe-

ses of the theory or measurement at a

finer level is often not possible due to

limitations in technology, there is no way

of privileging one theory over the other,

which are thus essentially of a fictitious

character. Frequently, there are assump-
tions made in a theory that are mutually

contradictory, e.g. the theory may con-
tain both true and false propositions. One

element theory has recently been provided by

Frisch, who has also proposed a further

refinement of Einstein’s views. Accord-
ing to theoretical physicist David Bohm, the

word ‘theory’ is derived from the Greek ‘theoria’, which has the same root as ‘theatre’. It means to view or to make

a spectacle, and is a form of insight, i.e. a

way of looking at the world, and not

a form of knowledge of how the world is.

 COMMENTARY
Theories (i.e. insights) are neither true nor false – they are clear in certain domains and unclear when extended beyond these domains.

To conclude, the remarks on the nature of scientific theory advanced in this paper, which also have a bearing on the philosophy of science, may not be applicable to sciences like biology and related disciplines. Over the past few decades, an extensive literature has grown pertaining to the structure of scientific theory in biology. There are two ways to present a philosophy of biology in the opinion of Mayr. One can base it on the chief philosophical concepts of biology like population thinking, the dual causation of biological processes, teleology or its absence, reductionism, modes of selection, pluralism, prediction, emergence, etc. An alternative foundation would be that of major biological phenomena or processes like the nature of life, genes, phenotype development, gene regulation, speciation, adaptation, biodiversity, extinction, etc. Unlike physics or chemistry, laws are rare or nonexistent in biology since exceptions to such ‘laws’ are very common according to Mayr, and Craver and Darden. We refer the reader, interested in such matters, to the works of these and other philosophers of biology like David Hull.


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