b10 The scientific method < the habit of truth [1] >

> The society which scorns excellence in plumbing because plumbing is a humble activity and tolerates shoddiness in philosophy because it is an exalted activity will have neither good plumbing nor good philosophy. Neither its pipes nor its theories will hold water.
>
> — John William Gardner.[2]

> I have had off all people a historian tell me that science is a collection of facts, and his voice had not even the ironic rasp of one filing cabinet reproving another.
>
> It seems impossible that this historian had ever studied the beginnings of a scientific discovery. — Jacob Bronowski.[3]

Science is an extension of art of which Edwin Denby has said: "Art takes what in life is an accidental pleasure and tries to repeat and prolong it." [4]

The method of science involves three activities, titled: *observation, hypothesis*, and *theory*. A scientist is a person who consciously performs any, or all, of these activities. In cycling through these activities, to add to knowledge, the method is iterative and finds *patterns*. The goal of science is understanding; not the making of a better mousetrap, which is technology. Even so, government's funding of Science and Technology as a bundle, is to focus scientists on the specific goals of wealth creation and improving the quality of life rather than a no-strings-attached request to find out how the world works.[5] Far from coercive, this triumphs the ethos of science. "The measure of any technology is the degree to which we live better by it" is posited by David D. Nolte in *Mind at Light Speed*, 2002, as the principle thesis of technological humanism.[6] Indeed, the motto of the American Association for the Advancement of Science (AAAS) is "Advancing Science, Serving Society."[7]

Observation **(experienced truth)** (Statistics finds truth when error is honestly recorded.)

Recognition of objects, their collection, and their classification.

Observations that test a theory loop back. If these do not corroborate the theory, they can inspire other hypotheses. A danger is that theories, which have become ruling theories, can bias observation. And *perception*, by nature and nurture, is individual and societal. "What we see resonates in the memory of what we have seen; new experience always percolates through old, leaving a hint of its flavor as it passes. We live, in this sense, in a "remembered present," writes Adam Zeman in *Consciousness*, 2003.[8]

The venture is to describe components (coherent structures, which preserve their identity and recur time and again) that are emergent at levels of organization of other components.

Hypothesis **(possible truth)**

Induction of possible explanations for what has been observed. Explanations can be thought of by analogy and/or dreamlike imagination.[9]

There are no set rules other than that an explanation, to be scientific, must be falsifiable. The literal meaning of the Greek word *hypothesis* is "a foundation." (Usage has made the word *hypotheses* more familiar than the equivalent Latin *apologia* "justification," derived from the Greek *apologos* "a full account," which calls for an interpretive explanation.)[10]

Principles are used to select or reject hypotheses. That is, principles act as a filter to separate out hypotheses that seem to be reasonable and those that are not reasonable. As principles are the common sense of the day (a posteriori generalizations), they themselves will change as scientific knowledge accumulates. When one or several principles are replaced, or come to be, we talk about a revolution in thought.

Fashion in science, also known as "peer review," blinkers it. This, ostensibly to lessen clamor and distraction, makes science fit, or shape, the mold. We do not know which. Scientific enquiry is less than John Toland (1670-1722) in *Christianity not mysterious*, 1699, urged for religion: "... and leaving the speculative opinions to be confuted or approved by whoever pleases; then

you are sure to hear the whole truth, and till then very scantily, or obscurely, if at all."[11] Anthony Gottlieb in *The Dreams of Reason*, 2001, reminds us that Platonic and Aristotelian teleology, which is to ask of each natural object what its function and purpose is, and which gave impetus to investigation of "the messy details of the world," is not modern science, which, as a matter of principle, makes a virtue of explaining the world in nonpurpositive terms.[12]

Theory (found truth) [13]

Deduction of an hypothesis' (or hypotheses') consequence(s) (knowable using the laws of nature) allows for the construction of physical or thought (imaginary-working) models (representations of systems by components that are simpler and easier to manipulate as assemblages than the actual systems).[14] This allows for testing. That is, the rejection of a hypothesis, or its acceptance as a theory, depends on our being able to predict, or forecast, something observable that did not in the first place (a priori) suggest the hypothesis: In short, a finding that does not beg the question.[15]

Francis Bacon rated poor terminology as the most menacing of the four sets of idols he defined in his *Novum organum* of 1620 as befuddlers of the human mind. Badly coined words, the 'Idols of the Market Place', thoughtless phrases minted for the moment, 'wonderfully obstruct the understanding'. The incautious wordsmith of science can 'throw all into confusion, and lead men into numberless empty controversies.'

—J. L. Heilbron.[22]

By the nineteenth century – when the French physiologist Claude Bernard coined the aphorism 'Art is I; Science is We' – the scientific author became increasingly submerged in either the first-person plural ('We did X, we saw Y') or in the passive voice now standard in scientific papers ('X was done, Y was seen'). —Steven Shapin.[23]

The scientific method has its roots in empiricism. Empiricist David Hume (1711-1776) in *A treatise of Human Nature*, 1739-40, persuaded that only testable hypothesis yield valid results for knowledge.[16] What is found is novel and is *not* bound to the culture that produces it. Among the obstacles to the steady advance of science are the words invented to denote its conquests.

In 1620, **Francis Bacon**[17] (1561-1626), who persuaded that "knowledge is power,"[18] recognized that perception, by nature and nurture, is (as was mentioned above) individual and societal. In *Novum Organum*[19] he recommended the *method of induction* to arrive at explanations that break with ideology (religion, politics, and fakery: the "Idols of the Tribe, Cave, Marketplace, and Theatre" as Noretta Koertge has paraphrased his Aphorism XXXIX)[20] and yet prove to be beneficial. His recommendation was a reaction against the a priori method beloved by medieval scholasticism, which befuddles, and the numerism of such as Galileo Galilei (to particle physicists's Standard Model) whose mathematical descriptions of falling bodies provide no understanding in any fundamental way of the described phenomena. Baconian induction was made *the* way of scientific enquiry by John Stuart Mill who held that from simple, unbiased, innocent observations of a disorderly array of facts would emerge in the mind an orderly theory. In practice the premise of "simple, unbiased, innocent" is dubious. Even so, the Geologic Column is an example of a scientifically useful result of Baconian induction.[21]

It is not possible to reach by inductive steps a last-word-on-it explanation of what happens in nature. Every explanation goes beyond our experience and thereby becomes a speculation. Christian Huygens in 1690 offered that an explanation should therefore be called probable. He means, J. Bronowski clarifies, "that no induction is unique; there is always a set—an infinite set—of alternatives between which we must choose." So: "The man who proposes a theory makes a choice—an imaginative choice which outstrips the facts."[24] While absolute truth is elusive; science successfully lessens ignorance.

Figure b10.1

Karl Raimund Popper (1902-1994) Philosophically, social equality would seem a bold ideal but when pursued it (Communism) closes out the happiness that liberty allows (for some and he). In the contingent moment of history, value judgements are at best personal and their appropriateness to the general case cannot ever be proven.

By contrast, a scientific idea (theory) can be bold and have justifiable application so long as no single contrary experiment, for which vulnerability it must provide, proves it forever false.

So, as induction can only arrive at hypothesis and not scientific truth, falsification, which Popper likened to Darwinian selection, weeds out the false and lets the best survive, some as theories.

A theory allows the objects, which it explains, to be classified according to their origin or relatedness.

Falsification is a tenet devised by Karl Popper (***Figure b10.1***) to distinguish between nonempirical questions of philosophy and empirical ones of interest to science.[25] Technology (how to) preceded science (so thus). The symbioses between the two began to switch over during the 13th and 14th centuries which witnessed spectacular advances in the art of timekeeping. The early Middle Ages are marked by "some radical and extraordinary changes in human thought," says Corey Keeble, "largely because of the influence of Thomas Aquinas ["I am a man of one book"] who argued that God could be discerned through human reason,"[26] which indulgence is not universally granted today. Mark Kingwell summarizes: "The progress of scientific enquiry is, in the end, contrary to the process of human expectation." [27]

A theory is established by its novel (after the fact) predictions that prove to be true and by its better (often useful) explanation of known phenomena. The hypothetico-deductive method of science feeds innovative technology. This, and the realization that energy can be converted from one form to another, and be the motive power of machines, initiated the Industrial Revolution,

A theory is described as revolutionary when it makes new principles acceptable. For such, Thomas Samuel Kuhn (***Figure b10.1***) employed the term paradigm. In his book *The Structure of Scientific Revolutions,* paradigm refers to a collection of procedures or ideas that help scientists solve an array of puzzles.[28] It allows the normal science of its world to proceed. David A. Hollinger provides an historical account:

> Before Kuhn, most people understood scientific progress in terms of a series of heroic individual discoveries that contributed to an accumulating body of knowledge warranted, ultimately, by nature itself. Kuhn argued that tightly organized communities of specialists, not individual minds, were the central actors in scientific development, and that these communities made progress in two distinctive modes. In "normal science," researchers did narrow, technical work guided by a "paradigm," a view of the field that served as a set of predictions for what investigators would find. When these researchers observed, instead, a lot of things that did not fit, the community entered a period of "revolutionary science." In this mode, the community debated the utility of alternative paradigms and eventually selected one that explained a greater range of relevant phenomena and promised to guide the next phase of normal science.[29]

Kuhn went on to suggest that scientific development is best seen not as progress toward a fixed goal set by nature but as progress from existing knowledge toward more fully confirmed answers to questions scientists put to nature. Since the questions themselves sometimes change, the progress of science is discontinuous.

David Deutsch in *The Fabric of Reality* makes the case that scientific theories are not just handy tools but are serious descriptions of how the world works. His epistemology (theory of knowledge) is that science is an ever-improving map of the real world and is not, merely, a human construct of "get by" convenience.[30] Observation, hypotheses, to theory for the age, to unexpected observation that demands revision, is a forward moving cycle in which, as T. H. Huxley put it, "new truths ... begin as heresies and end as superstitions" [31] (as believing in "without seeing," *Punch* had parodied,

"Ancestral apes" on "materialist foundations / Now so dear to common sense).[32]

For, as Richard L. Gregory puts it, "science develops [with added data from instruments] general concepts that are extremely different from ancient object-knowledge [how things appear] (***Footnote b10.1***)."[33]

The scientific method is a rational process that from skepticism finds truth (*Dubitando enim ad inquisitionem venimus, inquirendo veritatem percipimus*)[34] and generates knowledge of intrinsic value, wide in diversity and mutually confirming detail that, even more so in a largely irrational world, is of equal and binding value to all people and cultures.

Science is about discovery; by assuming less we free ourselves to discover more.[35] ❑

Figure b10.1
Thomas S. Kuhn (1922-1996)

Footnote b10.1

Our search relegates truth, as a "tangible entity," to philosophies that antedate notions of infinity and chaos—*"The Universe is One"* posits sage Chuang Tzu, third-century BC; and, *"The cosmos is a tension like that in a lyre"* posits philosopher Heraclitus, fifth-century BC.

Relegated to authoritarianism are: what Divinities tell if we can only learn how to hear them (*Apollo speaks through the mouth of an old peasant woman in a room thick with the smoke of bay leaves* is *an ancient Greek belief, and revelation in the behavior of poisoned chickens is traditional Sudan Azande*), the content of Sacred books, just so stories, apparitions (waking dreams), and pre-birth information embedded in the psyche (soul).

Those searchings for truth are discussed in *A History and Guide for the Perplexed* by Felipe Fernandez-Armesto who finds two more: reasoning (logic) and sense perception (evidence from repeatable experience and experimentation) which "like voices that in a duet that sing different tunes" happily keep time together.[36]

Chuang Tzu in China and Heraclitus in Egypt separately used reasoning (logic) to help them describe the universe. This tool was later independently discovered and used in India and ancient Greece and is passed to us beginning with the writings of Plato and his student Aristotle who pioneered techniques of aporetic and syllogistic analysis, and dissent: "Plato is my friend, but a greater friend is truth."[37]

Aristotle was first to find dissatisfaction with just logic (mathematics) and the Platonic precept that *aletheia* (the Greek word for truth and which means "what is not forgotten") could be discovered only by abstract reasoning innocent of sense perception, and to observe the natural world to extract from it a practical understanding of experience (which, with logic as a tool, is science). However, his science was hampered by the doctrine of final causes (purpose), so logically (illogically, for we who reject final causes for the inanimate) he could find for the free fall of a stone: "It is trying to get to the ground: just as a horse moves faster when it gets near to its stable, so the stone moves faster, the nearer it gets to the ground." [38]

René Descartes' (1596-1650) Method of Doubt pursued in *Meditations on First Philosophy*, allows him to reject all beliefs except for the absolute certainty of his own existence and the plausibility that God exists.[39]

Table b11.1 Examples of facts and theories

Fact	*Theory*
Global warming, b11	CO_2 build up caused global warming since 1950, b30
The Great Ice Age, b32	Milankovitch forcing, b33
Wide deep-oceans have opened and closed, j23	Paleogeographic reconstructions, c1
Evolution, f14	Cladistics, f35
Fossiliferous dolomite, c6	Dolomitization, c6