Red Flags for Deduction

As discussed in the section *Einstein's Quandary*, Einstein himself was a great deductive investigator but he did make different choices than Bohr on the issue of the completeness of quantum mechanics. What are possible extraneous factors that may influence one's choice along the deductive path? In a talk for Planck's sixtieth birthday in 1918, Einstein describes the significance for him of having a complete world-picture, perhaps suggesting that this may partly motivate such choices [562, p. 19]

> *Man tries to make for himself in the fashion that suits him best a simplified and intelligible picture of the world; he then tries to some extent to substitute this cosmos of his for the world of experience, and thus to overcome it. This is what the painter, the poet, the speculative philosopher, and the natural scientist do, each in his own fashion. Each makes this cosmos and its construction the pivot of his emotional life, in order to find in this way, the peace and security which he cannot find in the narrow whirlpool of personal experience.*
> The Cambridge Companion to Einstein, M. Janssen and C. Lehner (Editors), Cambridge University Press 2014.

In 1919, Einstein identified and contrasted two types of theory, *constructive* and *principle* [563],

> *We can distinguish various kinds of theories of 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…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.*

Note the similarities to the top-down versus bottom up theories of Newton and Descartes, respectively. In these terms, Einstein regarded the standard approach to quantum mechanics as a principle-theory and his disagreements with Bohr came in part from his insistence on a constructive theory. In developing quantum mechanics, Heisenberg claimed to base his approach on another criterion of Einstein's: only that which is directly observable should be introduced into a theory, as he thought Einstein had done in developing relativity. Heisenberg describes a conversation with Einstein on this issue where Einstein responds [182, p. 63]:

> *But you don't seriously believe that none but observable magnitudes must go into a physical theory? … on principle, it is quite wrong to try founding a theory on observable magnitudes alone. In reality, the very opposite happens. It is the theory which decides what we can observe.*

Einstein later illustrated how this occurs in the construction of theories with the case of Kepler's laws, the concept of an elliptical orbit had to exist first, to then inform the empirical data [564],

> *Now came the second and no less arduous part of Kepler's life work. The orbits were empirically known, but their laws had to be guessed from the empirical data. First, he had to make a guess at the mathematical nature of the curve described by the orbit, and then try it out on a vast assemblage of figures. If it did not fit, another hypothesis had to be devised and again tested. After tremendous search, the conjecture that the orbit was an ellipse with the sun at one of its foci was found to fit the facts. Kepler also discovered the law governing the variation in speed during one revolution, which is that the line sun-planet sweeps out equal areas in equal periods of time. Finally, he also discovered that the squares of the periods of revolution round the sun vary as the cubes of the major axes of the ellipses.*

Another outside factor that can cause deviations from the deductive path is beliefs that are imposed or censored by authorities of church or state. The transition to an independent examination of the world began to take hold during the 17th century as part of the scientific revolution, though many exceptions have persisted. Though the scientific community needs to cautiously protect its knowledge base, Figure 5.22, and close ranks against speculative developments unsupported by observation, this trend can also move to become overly protective and only support *safe* research. This phenomenon results in the occasional insistence that "everything important is already known," and this is seen repeatedly throughout the history of science. In 1871, Maxwell commented on the state of science [399]

The opinion seems to have got abroad that in a few years all the great physical constants will have been approximately estimated, and that the only occupation which will then be left to men of science will be to carry out these measurements to another place of decimals…But we have no right to think thus of the unsearchable riches of creation, or the untried fertility of those fresh minds into which these riches will continue to be poured…

Indeed, in 1903, Albert Michelson (1852-1931), who had performed the landmark interferometer experiments in clarifying the basis of the theory of relativity, stated [565]

The more important fundamental laws and facts of physical science have all been discovered, and these are now so firmly established that the possibility of their ever being supplanted in consequence of new discoveries is exceedingly remote…Our future discoveries must be looked for in the 6th place of decimals.

Just a few years after the development of quantum theory, one of the pioneers of quantum mechanics and quantum electrodynamics, Paul Dirac (1902-1984) similarly proclaimed in 1929 that the underlying basis for a large part of physics and the whole of chemistry is completely known [566],

The underlying physical laws necessary for the mathematical theory of a large part of physics and the whole of chemistry are thus completely known, and the difficulty is only that the exact application of these laws leads to equations much too complicated to be soluble.

P.A.M. Dirac, Quantum Mechanics of Many-Electron Systems, Proceedings of the Royal Society of London; Series A 123 (792), 714 (1929).

This statement of Dirac's was widely quoted for decades afterwards and was interpreted as signifying the triumph of quantum theory. However, we will see in Chapter 6 that such statements signify ignorance of the measurement problem.

We have seen in this exploration of *Deductive versus Inductive Thought* through history that the method of physical deduction constrained by empirically established great principles repeatedly produces deep results in investigating the foundations of physics. Typical examples of great principles are the conservation laws, e.g., energy and momentum. Occasionally, there have been attempts to identify other more unconventional principles and explore the consequences of deduction constrained by these. A sometimes controversial example is the *Anthropic Principle*, that the laws of nature and parameters of the universe take on values that are consistent with conditions for life as we know it because we are here to observe them. Robert Dicke (1916-1997), a pioneer of quantum optics and gravitation, explored one of the first modern applications of this, though it is another idea that traces back to the ancient

Greeks. Dicke’s colleague John Wheeler gives a description of the scale of the universe, constrained by the fact that we are here [567]:

> *My Princeton colleague, Robert Dicke, expressed it this way: “What good is a universe without somebody around to look at it?” That, to be sure, was an old idea, going back not only to the Bishop Berkeley of the time of Newton, but all the way back to Parmenides, the precursor of Socrates and Plato. But it was new in the form that Dicke put it. He said if you want an observer around, you need life, and if you want life, you need heavy elements. To make heavy elements out of hydrogen, you need thermonuclear combustion. To have thermonuclear combustion, you need a time of cooking in a star of several billion years. In order to stretch out several billion years in its time dimension, the universe, according to general relativity, must be several billion years across in its space dimensions. So why is the universe as big as it is? Because we're here!*