Methodology of Deduction

So perhaps we have convinced the reader—deduction is the best approach to take regarding the resolution of the measurement problem. Now one may ask, "How does one best perform deduction?" In order to examine methods that have been used in deduction, consider comments from many of the practitioners of deduction.

Galileo [635, p. 225]:

> *Now you see how easy it is to be understood. So are all truths once they are discovered; the point is in being able to discover them.*
>
> Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican, Second Revised edition, Galilei, Galileo, Translated by Stillman Drake, 1962, reprinted with permission of University of California Press Books.

Einstein [636, p. 221]:

> *… one comes closer to the distinguished scientific goals with a minimum of hypotheses or axioms to encompassing a maximum of empirical content by logical deduction*

Bohr [2]:

> *An expert is a man who has made all the mistakes which can be made, in a very narrow field.*

Darwin [637, p. 28]:

> *I must begin with a good body of facts and not from a principle (in which I always suspect some fallacy) and then as much deduction as you please.*

Maxwell [638, p. 157]:

> *It is by the use of analogies of this kind that I have attempted to bring before the mind, in a convenient and manageable form, those mathematical ideas which are necessary to the study of the phenomena of electricity. The methods are generally those suggested by the processes of reasoning which are found in the researches of Faraday and which, though they have been interpreted mathematically by Prof. Thomson and others, are very generally supposed to be of an indefinite and unmathematical character, when compared with those employed by the professed mathematicians.*

Planck [639, p. 109]:

> *When the pioneer in science sets forth the groping feelers of his*

thought, he must have a vivid, intuitive imagination, for new ideas are not generated by deduction, but by an artistically creative imagination.

Popper [632, p. 278]:

We do not know: we can only guess. And our guesses are guided by the unscientific, the metaphysical (though biologically explicable) faith in laws, in regularities which we can uncover—discover.

Hoyle [640, p. 194]:

What happens in practice is that by intuitive insight, or other inexplicable inspiration, the theorist decides that certain features seem to him more important than others and capable of explanation by certain hypotheses. Then basing his study on these hypotheses the attempt is made to deduce their consequences. The successful pioneer of theoretical science is he whose intuitions yield hypotheses on which satisfactory theories can be built, and conversely for the unsuccessful.

Wheeler believed that the major results were a result of *radical conservatism* [542]:

“He was also developing an approach to physics that he called radical conservative-ism: Insist on adhering to well-established physical laws (be conservative), but follow those laws into their most extreme domains (be radical), where unexpected insights into nature might be found. He attributed that philosophy to his own revered mentor, Niels Bohr.”

Ampère [641, p. 159]:

By combining at random simple truths with each other, more complicated ones are deduced from them. This is the method of discovery, the special method of inventions, contrary to popular opinion.

Ayrton [642, p. iii]:

The attempt to correlate all the known phenomena, and to bind them together into one consistent whole, led to the deduction of new facts, which, when duly tested by experiment, became parts of the growing body, and, themselves, opened up fresh questions, to be answered in *their turn by experiment.*

Holmes [537]:

> *How often have I said to you that when you have eliminated the impossible, whatever remains, however improbable, must be the truth?*
>
> *Sir Arthur Conan Doyle, The Adventure of the Blanched Soldier, Strand Magazine, 1926*.

What can we learn from the statements from those who have successfully practiced deduction? Generally, there is agreement that the deductive method requires an approach that moves by proposing general hypotheses in a manner to test these by analogy, experiment, or otherwise and seeks to eliminate hypotheses to eventually reach a narrow or particular conclusion. The process is one of making errors and this is reaffirmed by Bohr's statement that, "An expert is one who has made all the mistakes which can be made."

It is certainly not desired to make *all* the errors that can be made, for there could be an astronomical number of such potential errors, but rather to develop a deductive process in which the number of errors is minimized. Unlike induction, there does not appear to be a concise methodology that has been laid out for successful application of deduction. Ampère recommends combining, at random, simple truths. According to Hoyle, deduction requires intuition or other inexplicable inspiration and appears to Maxwell as a process of indefinite and unmathematical character. This is reaffirmed by Planck who says that artistically creative imagination is required. These statements indicate that hypotheses are developed through intuition and then combined in various manners and tested.

It is therefore desirable to determine what initial hypotheses should be used. Here Hoyle states, "The successful pioneer of theoretical science is he whose intuitions yield hypotheses on which satisfactory theories can be built, and conversely for the unsuccessful." Hence it appears that the initial hypotheses can be critical for the successful development of a theory. Suppose that one lacks intuition to go forward and proposed the initial hypotheses. The statement by Wheeler of radical conservatism, that is to be conservative by sticking to well-established physical principles, but probe them by exposing their most radical conclusions, should be considered. That is, consider initial constraints that are well-established principles and consider radical possibilities that can resolve the deductive problem for which the established principles are maintained. An example of a well-established principle is no-signaling whereby information cannot be transmitted faster than the speed of light.

A point regarding scientific revolutions noted by Kuhn [1, p. 52] is that,

> *Discovery commences with the awareness of anomaly, i.e., with the recognition that nature has somehow violated the paradigm-induced expectations that govern normal science. It then continues with a more or less extended exploration of the area of anomaly. And it*

closes only when the paradigm theory has been adjusted so that the anomalous has become the expected.

The measurement problem does appear to be along the lines discussed by Kuhn, in that unitary evolution, while apparently sufficient to explain a large number of phenomena, is not sufficient to explain measurement and thereby lies the anomaly.

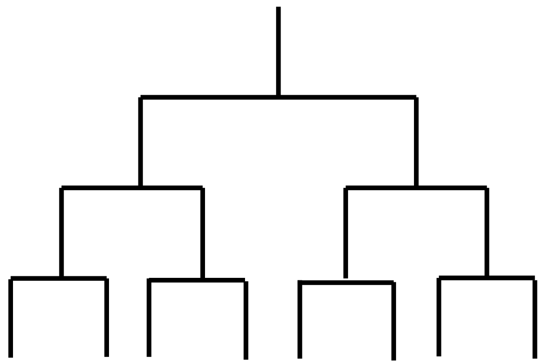

Figure 6.16 Deductive decision tree.

Mathematics is a primary tool in induction. In scientific deduction, mathematics is *not* a primary tool but a secondary tool. Hypotheses, formulation of Gedanken or thought experiments, and logic are primary tools in deduction. Once the problem is fully understood, and hypotheses are formed, one can begin to investigate and narrow the possibilities which would form the basis of a theory. Certainly, it is conceivable to consider all the possibilities and all the different theories, one-by-one. However, this is rather inefficient if there are a large number of possibilities, and in this respect, it is suggested that the problem be further broken down. Questions regarding the theory and/or properties that need to be tested should be defined for each possibility. Some properties will be common to more than one theory, and hence by testing or investigating properties that distinguish the most theories initially will lead to the fastest resolution of the problem. We denote a *deductive decision tree* by a diagram where each fork with two paths represents a binary question, and where the depth of the tree is *m*, as shown schematically in Figure 6.16. One sees that the number of possibilities that would need to be considered from the outset increases exponentially with *m*. It would be typically more efficient to eliminate possibilities starting from the top and working downward. This can reduce 2^m possibilities to a single correct solution in only *m* steps. Hence it is desirable to begin by investigating properties or questions as high as possible on the tree, that can be evaluated by theoretical and experimental means in a reasonable time period. That is, if the question that defines the first fork is too difficult to currently answer, move down the tree until one can address those questions that are currently within reach. Each question that is answered in the lower parts of the tree will provide new results that had not been known in the initial stages of the investigation. One will then utilize all such new results to aid in moving up the tree.

In this sense, these first questions that are addressed might be considered as the most important as they eliminate the most possibilities. Formulation of the questions should proceed carefully in order to efficiently break the problem down. The good news is that if one gets an answer incorrect, then eventually there should be contradictions as one works down an incorrect path. This will eventually lead one back to the correct path. The bad news is that this is inefficient as in the worst case it would require to reach contradictions on all the incorrect paths in order to deduce where the incorrect path was taken. Another pitfall is that if one starts too high on the tree and reaches a wrong conclusion, then it may take a substantial amount of time to recover from this, if ever. Hence the saying, “don’t bite off more than you can chew” is particularly important when addressing the first questions.