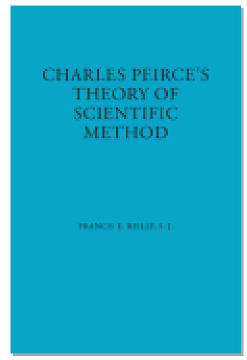
IV The Stages of the Method (ii): Deduction and Induction



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Chapter IV

THE STAGES OF THE METHOD (*ii*): DEDUCTION AND INDUCTION

At the beginning of the section on abduction, I made mention of Peirce's description of science as a living process, busied mainly with conjectures that are being framed or tested (1.234). Systematized items of knowledge may become subject to scientific inquiry only when they are brought down from the shelves to be purified or transformed. It is then that they enter the dynamic process again. But the process itself is one of framing and testing conjectured explanations of phenomena. Science progresses by means of the brilliant imaginative leaps of abduction coupled with carefully controlled evaluation in the verification phase.

There are two main steps in the process of scientific verification of hypotheses: deduction and induction. In order to get a clearer understanding of the whole movement of verification, a general picture of this process will be drawn before the steps are treated separately. In addition the ability of the inductive phase to converge on the truth must be discussed, since this is the guarantee of the whole process of inquiry. The divisions of the fourth chapter, therefore, are the following: 1.) a general picture of the verification process; 2.) the deductive phase; 3.) the inductive phase; 4.) two requirements for scientific induction; 5.) the parts of induction; 6.) the convergence on truth.

I. A GENERAL PICTURE OF THE VERIFICATION PROCESS

In a lecture delivered at Harvard in 1869 Peirce makes mention of the important contributions to science which the testing process has made. He will not go quite so far as to say with George Henry Lewes, a Comtean of sorts, that the true cause of the success of modern science is verification.[1] Rather a combination of the observation of nature, theorizing, and verification has led to the triumphs of science. Scientists, at work in the laboratory and field, "have been observing—that is, perceiving by the aid of analysis—and testing suggestions of theories" (1.34). This short sentence is obviously not intended to be a carefully chiseled definition of the scientific method. Yet it makes reference to the chief stages of the method: observation, abduction, and verification.

In the verification stage, the scientist is trying to see how close to the truth his hypothesis comes. He draws certain experiential conclusions from the hypothesis, and then tries to see whether the predicted conclusions actually occur.[2] The hypothesis must be fruitful of some predictions, which under certain specified conditions should be observable. After making these predictions, the scientist must fulfill the conditions and see whether his predictions come true (2.755).[3]

The same steps are again listed in a set of rules designed to test the probability of a hypothesis:

1. The hypothesis should be distinctly put as a question, before making the observations which are to test its truth. In other words, we must try to see what the result of predictions from the hypothesis will be.
2. The respect in regard to which the resemblances are noted must be taken at random. We must not take a particular kind of predictions for which the hypothesis is known to be good.
3. The failures as well as the successes of the predictions must be honestly noted. The whole proceeding must be fair and unbiased [2.634].

This quotation points out some of the requirements for verification, but the important thing to note here is that science demands that its hypotheses be verified, and that the verification process be carried out according to reasonable rules. The inquirer must be so detached from

[1] The notes for this chapter begin on page 172.

his hypothesis as to make repeated attempts to refute it. An ascetical detachment from his suggested explanations, together with a reasonable method of testing these explanations, must characterize his activity. With such an attitude the scientist will be able to propose his hypothesis, if verified, as a genuine step forward in the progress of science (6.216).

Instinct may suggest the correct choice right at the beginning of the process of abduction, but this does not exempt the suggested explanation from testing. Instinct has frequently erred. Similarly no antecedent likelihood of a hypothesis can be regarded as safe. Likelihoods are mostly subjective, and so are of little value in directing us toward the truth. "Every hypothesis should be put to the test by forcing it to make verifiable predictions," independently of its subjective likelihood (5.599).

II. THE DEDUCTIVE PHASE

The testing begins with an examination of the hypothesis, and with a gathering of experiential consequences which would follow from its truth.[4] This step, Peirce asserts, is a process of deduction (6.470).[5]

After an explanatory hypothesis capable of being tested experimentally has been chosen, the investigator deduces experiential predictions from it, and watches for the predictions to come true. By deduction he draws virtual predictions of possible experiments from his hypothesis. A "virtual prediction," Peirce explains, is an experiential consequence, deduced from the hypothesis, and selected as a consequence independently of whether or not the inquirer knows its truth. He must not prejudice the issue in his favor by selecting predictions which he knows will turn out in virtue of that knowledge. Rather he should select a prediction of whose truth he is ignorant; or at least he must not make a selection which he would not have made, had he been so ignorant (2.96; 2.784).

In a paper entitled "Hume on Miracles," composed about 1901, Peirce discusses the testing of hypotheses. As an illustration of abduction and verification he chooses the hypothesis: this man believes in the infallibility of the pope. If the hypothesis is true, the same man most likely will also believe other doctrines commonly held by Catholics, and will engage in Catholic devotional practices. Furthermore the members of his family will most likely do the same. These propositions, reached by deduction, are predictions which can be put to the test, in order to verify the hypothesis. Granted that this is a poor example of a scientific hypothesis, and granted that the predictions are to be fulfilled mostly by asking the man concerned (although partly by observing his conduct); still, by making the proper adjustments, we can see what Peirce is getting at when he speaks of the predictions which a scientific hypothesis should lead to, and of the deductive character of forming these predictions (6.527).

A more informative statement of Peirce's position can be found in his article entitled "A Neglected Argument for the Reality of God," where he treats the process of inquiry at some length. After describing the observation phase and the formation of the hypothesis, he writes:

> Retroduction does not afford security. The hypothesis must be tested.
>
> This testing, to be logically valid, must honestly start, not as Retroduction starts, with scrutiny of the phenomena, but with examination of the hypothesis, and a muster of all sorts of conditional experiential consequences which would follow from its truth. This constitutes the Second Stage of Inquiry. For its characteristic form of reasoning our language has, for two centuries, been happily provided with the name Deduction [6.470].

Deduction, then, is an unfolding of experiential consequents from the explanatory hypothesis. Its main function is to explicate the hypothesis, by drawing experiential consequences from it.

Although Peirce is careful in his earlier logical works to show that deduction is the inference of a result from a rule, he still does not give any clear explanation of how the explication of consequents from a hypothesis constitutes an instance of deduction. However, there may be some value in attempting such an explanation from what Peirce says elsewhere.

It has already been noted that an explanatory hypothesis is a predication of generality. It classifies an event, or it places a class of events under a more general class. At least the predicate of the hypothesis, like the perceptual judgment, conveys a meaning. The text most recently under examination stated that in a scientific inquiry deduction explicates meaning, by collecting experiential consequences of the hypothesis

(6.469–475).[6] The problem is to show how the prediction of experiential consequences from a hypothesis deserves the name deduction.

One might answer that for Peirce an abduction concludes with a case. The typical example of deduction for Peirce is the syllogism in Barbara with a rule for a major premise, a case for a minor, and a result for a conclusion (2.620). Using the same terms, an abduction concludes with a case, i.e., a predication of a class about an object or event, or about a less inclusive class. In the process of generating verifiable predictions from the hypothesis, then, the investigator may concentrate on the meaning of the predicate of the hypothesis. In explicating the hypothesis, he may analyze the class, and draw out into clear view the characteristics of the class. This would be a process of rendering the hypothesis clear and understandable. However, for this analysis to rank as a phase of the verification process, the characteristics which the investigator chooses for checking must be experimentally verifiable. It is a real deduction, in which the hypothesis functions as a minor premise. For example: All the members of class B have observable characteristics *x*, *y*, and *z*. But event A may belong to class B. Therefore, event A should have observable characteristics *x*, *y*, and *z*.

The conclusion or result of this inference has no more certainty by virtue of the deduction than the minor premise. The minor in this inference is the hypothesis, whose value is being tested. It is only a tentative explanation of observed phenomena, and is therefore proposed only as a question—or, at best, as a plausible suggestion. What Peirce would call the result of the deductive inference is, by virtue of the inference, only plausible, only a question. It is, however, a question put to nature, an interrogation which nature is expected to answer. The characteristics predicated in the result must be observable. Hence the truth of the result is reached, not by a reasoning process, but by *experience*. This deductive step must generate *observable* predictions from the hypothesis. If the predictions turn out as expected, then we have reason for placing some trust in the hypothesis; in this case nature has answered our question by saying that we have some ground for thinking that event A belongs to class B. The hypothesis has been verified at least partially.

The deductive process in a scientific inquiry must terminate with genuine predictions of the "if–would" variety. This means that at this stage, the results of testing must be unknown, or virtually unknown.[7]

The scientist asks nature whether event A has observable characteristics *x*, *y*, and *z*. And, in ignorance, he waits for an answer from nature. If the hypothesis is right, the predictions will come true. But before observing the results of his experiments, he is still in doubt about the truth of the hypothesis. Peirce asserts that in calling the consequents of the hypothesis "predictions" he does not mean that they must be future events. They are predictions only in the sense that they antecede the investigator's *knowledge* of their truth (2.759). As was mentioned above, this may be only a virtual antecedence, but it must be at least this.[8]

The deductive phase, therefore, of a scientist's investigation terminates with observable predictions which have been drawn from the explanatory hypothesis. The scientist must now see whether or not the predictions come true. This is the inductive phase of scientific inquiry.

III. THE INDUCTIVE PHASE

After the scientist has deductively inferred observable predictions from his explanatory hypothesis, he begins to test the predictions by a process of induction. Peirce notes that it is not the fact predicted by deduction that necessitates the truth of the hypothesis; but it is "the fact that it has been predicted successfully and that it is a haphazard specimen of all the predictions which might be based on the hypothesis and which constitutes its practical truth" (6.527). The success of the prediction is evaluated by the inductive phase of the scientific method.

Induction, therefore, is the process by which the inquirer scrutinizes nature to see whether the predicted observable consequences of the hypothesis actually occur; he then judges the hypothesis according to its success in predicting; and from this evaluation he proceeds to adopt, adjust, modify, or reject the hypothesis.

In Baldwin's *Dictionary* Peirce presents a carefully constructed description of induction and its role in inquiry, under the heading "Reasoning."

Induction takes place when the reasoner already holds a theory more or less problematically (ranging from a pure interrogative apprehension to a strong leaning mixed with ever so little doubt); and having reflected that if that theory be true, then under certain conditions certain phenomena ought to appear (the stranger and less antecedently credible the better), proceeds to *experiment*, that is, to realize those conditions and watch for the predicted phenomena. Upon their appearance he accepts the theory with a modality which recognizes it provisionally as approximately true. The logical warrant for this is that this method persistently applied to the problem must in the long run produce a convergence (though irregular) to the truth; for the truth of a theory consists very largely in this, that every perceptual deduction from it is verified. It is of the essence of induction that the consequence of the theory should be drawn first in regard to the unknown, or virtually unknown, result of experiment; and that this should virtually be only ascertained afterward [2.775].[9]

The article is a brief outline of scientific method, with emphasis placed on the inductive phase.

Both here and in the fifth of the lecture series on pragmatism delivered at Cambridge, Massachusetts, in the spring of 1903, he mentions the justification of inductive testing of explanatory hypotheses. The justification is that induction, if perseveringly followed, must converge on the truth. Induction can evaluate the proximity of the theory to the facts and can then, if necessary, serve as a basis for a more satisfactory theory. In this way, induction gradually closes in on truth. Verification, therefore, in addition to its evaluative judgment, also has a corrective function, such that continual application of the inductive method affects a gradual convergence of the hypothesis on truth.

But this ability of induction to approach the truth will be considered at length later. The primary aim here is to present the fundamental aspects of induction in scientific inquiry.

These can be found in the fifth and sixth lectures of the series just mentioned. In the course of the fifth lecture, Peirce lists the three types of reasoning: abduction, induction, and deduction. Induction, he says, is "the experimental testing of a theory" (5.145). It presupposes that a hypothesis has already been adopted, and then it proceeds to measure the concordance of the consequences of that hypothesis with fact.

In the sixth lecture of the same series, Peirce again states that induction is a course of experimental reasoning. It is a question put to nature, based on a supposition (5.168).[10]

The same lecture outlines in brief the whole process of verification, and then goes on to point out the generalizing character of the inductive phase of verification. "Induction consists in starting from a theory, deducing from it predictions of phenomena, and observing those phenomena in order to see *how nearly* they agree with the theory" (5.170).[11]

In a selection which his editors have called "The Varieties and Validity of Induction," Peirce presents some of the possible evaluations that the investigator may place upon his hypothesis.[12] After examining the predictions drawn from the hypothesis, the scientific inquirer

> goes on to judge of the combined value of the evidence, and to decide whether the hypothesis should be regarded as proved, or as well on the way toward being proved, or as unworthy of further attention, or whether it ought to receive a definite modification in the light of the new experiments and be inductively re-examined *ab ovo*, or whether finally, that while not true it probably presents some analogy to the truth, and that the results of the induction may help to suggest a better hypothesis [2.759].

It is very likely, then, that a scientific inquiry will not come to a halt as soon as the first hypothesis is framed and tested. Most probably the hypothesis will have to be modified somewhat to meet the recommendations of the testing. A modified hypothesis results from the testing and from a new abduction. The modified hypothesis will then have to submit to the same sort of testing as its predecessor.

Both the positive and the negative results of the verification help the progress of science. A hypothesis that fails can be fruitful and economical in the sense that its testing can cut off a large number of useless areas, and highlight the still useful possibilities. Verification, whether it accepts or rejects the conjectured hypothesis, helps the forward progress of science by pointing to more fruitful areas for future conjectures, by closing off certain useless avenues previously open, by furnishing new observations for the next abduction, and by increasing both the experience and the skill of the observer.

> If Nature replies "No!" the experimenter has gained an important piece of knowledge. If Nature says "Yes," the experimenter's ideas remain just as they were, only somewhat more deeply engrained. If Nature says "Yes" to the first twenty questions, although they were so devised as to render that answer as surprising as possible, the experimenter will be confident that he is on the right track [5.168].

The inquirer is supposed to make an economical use of any experience gained in testing his hypothesis.

IV. TWO REQUIREMENTS FOR SCIENTIFIC INDUCTION

Before explaining the details of the inductive phase of scientific inquiry, the two principal requirements for any scientific induction should be treated. The main source for this will be "A Theory of Probable Inference," an essay which Peirce contributed to a book which he edited, The Johns Hopkins *Studies in Logic.*[13] The two requirements are these: the character for which the objects are being tested must be predesignated, and the instances for testing must be drawn fairly.[14]

Peirce repeatedly insists that the character for which objects or events are inductively tested be predesignated.[15] The investigator must determine what he is testing for, before he begins to test. In the inductive phase of the scientific method, if the inquirer decides to examine the objects for common characteristics which he has not previously designated, his results are liable to be disastrous.

The general context of the pertinent section of the *Studies in Logic* is his treatment of probable inference. One of the premises of a probable inference expresses a ratio, and the conclusion repeats the ratio with probability. When the inference is deductive, the form is:

> The proportion *r* of the *M*'s are *P*'s,
> *S′*, *S″*, *S‴*, etc. are a *numerous* set, taken at random from among the *M*'s;
> Hence, *probably* and *approximately*, the proportion *r* of the *S*'s are *P*'s [2.700].

Peirce insists that the predicate *P* must be known before instances of the *M*'s are drawn, i.e., before we know whether *S′*, *S″*, etc. are really *P*'s or not.

> But if we draw the instances of the *M*'s first, and after the examination of them decide what we will select for the predicate of our major premiss, the inference will generally be completely fallacious. In short, we have the rule that the major term *P* must be decided upon in advance of the examination of the sample [2.736].

Peirce is here concerned with deductive inference. But he immediately applies the same rule to induction. "The same rule follows us into the logic of induction and hypothesis" (2.737). If the predicate *P* has not been designated before the investigation, there is serious danger that the investigator may find some recondite character, common to the objects chosen, but not found in any other members of that class. This requirement is closely linked with the deductive stage of inquiry, the operation that predicts observable phenomena from the hypothesis, since prediction involves a predesignation. One cannot merely be content with asserting that, if his hypothesis is true, a given class of objects should then be characterized by *some* observable quality. The observable quality must be named, and not merely left vague. Otherwise, an investigator could find, with sufficient ingenuity, some characteristics common to the few chosen instances, but not at all common to the class.[16]

Peirce's position here is not that the *ratio* of successful predictions to cases tried must be predesignated. It is only the *character*, or the predicate of the prediction, that must be specified beforehand. The inductive process may conclude with a ratio, but it must be given a predicate to seek, before it begins to function (2.739).[17]

The same position on predesignation of the character in an inductive process is found in several articles composed by Peirce for Baldwin's *Dictionary*. Under the heading of "Predesignate," Peirce writes that the word is applied "to relations, characters, and objects, which, in compliance with the principles of the theory of probability, are in probable reasonings specified in advance of, or, at least, quite independently of, any examination of the facts" (2.789). Quantitative induction is an instance of the probable inference to which Peirce makes reference.

Under the heading "Reasoning" in Baldwin's *Dictionary*, Peirce states that "it is of the essence of induction that the consequence of the theory should be drawn first in regard to the unknown, or virtually unknown, result of experiment; and that this should virtually be only ascertained afterward" (2.775).[18] The predictions which flow from an explanatory hypothesis should be drawn deductively before the investigator tests and learns whether or not they are true. If we make use of the opposite procedure and scrutinize the phenomena to find agreements with our hypothesis, "it is a mere question of ingenuity and industry how many we shall find" (2.775). But in this case we would not be really testing the hypothesis.[19]

As is frequently the case with Peirce, he repeats his basic teachings in numerous writings. I shall cite only one more work in which he speaks of the necessity of predesignating the character in question in a process of induction. The text occurs in "Hume on Miracles," in which he again says that a hypothesis must be tested by experience, by drawing consequences from it with *certain results,* and then noting how frequently the predictions come true. He then goes on to say that induction is an inference that, in a whole class, about the same ratio of a certain characteristic will exist as has been found in a random sample, "provided the nature of the ratio for which the sample is to be examined is specified (or virtually specified) in advance of the examination" (6.526).

The reference to the random sample introduces the next requirement for induction in a scientific inquiry. Besides predesignating the character for which he will test, the investigator must also honestly pledge that the instances examined constitute a *fair sample* of the class of instances under question. The principle of statistical inference, whether deductive or inductive, is that a representative sample selected for testing probably exhibits a given characteristic in about the same ratio as the whole class from which the sample was drawn. Hence the scientist, in testing his hypothesis, must collect a fair sample of the objects under examination,

> taking due account, in doing so, of the intention of using its proportion of members that possess the predesignated character . . . and [he will presume] . . . that the value of the proportion . . . probably approximates, within a certain limit of approximation, to the value of the real probability in question [2.758; also 2.702; 2.515].[20]

It is important to realize that there is a double restriction here, on the value of knowledge gained through such an induction. First, the ratio reached through examination of instances only approximates the ratio of the whole class. Secondly, even this is only a probable approximation.[21] But, in order to achieve as close an approximation as possible, the inquirer must do what he can to secure a representative cross-section of the class for experimental testing.

In one of his descriptions of quantitative induction, Peirce makes reference to "scientific principles," according to which the random sample should be chosen.[22] He does not list the principles in the same work. However, by a careful study of his other remarks on sampling we can gather together the main rules which should govern the selection of instances for testing. In general, the process of sampling must be fair and honest. It must not be so random and so unregulated as to be absolutely free from any control. The investigator, it must be remembered, is carrying on a disinterested pursuit of the truth, and must be guided more by his love for truth than by any enthusiasm for his explanatory hypothesis. Hence some control on the testing process is necessary (2.757f).

Peirce gives a clear picture of what random sampling amounts to, in an article "The Laws of Nature and Hume's Argument Against Miracles." At the beginning of this article he answers the question: what is a law of nature? And in reply he mentions that a law of nature is a generalization formed from the results of observation. The observations must be made so as to conform to outward conditions. In other words the instances observed must represent the whole class as far as possible. They must not be chosen with an eye to finding the character sought for. The inquirer must not prejudice the verification process by looking for instances which will confirm the theory; instead, the testing must be fair, unbiased, and representative.[23]

Obviously the instances chosen must be of the class to be tested. Peirce in a discussion of probable deduction, whose rules can be applied with equal force to induction, says that the particular instances chosen for inspection must belong to the subject-class[24] under examination, but the investigator must "not allow his will to act in any way that might tend to settle what particular [instance] is taken, but should leave that to the operation of chance" (2.696). His interest is in the kind, not in the individual. Naturally, testing can only function on individuals; but even granted that each individual tested has its own peculiar determinations, the inquirer must not select it for testing on the basis of its individual traits (2.727).

The method of fair sampling must be such that it will lead closer and closer to the truth (2.696; 2.730). This method of selecting individual instances is the basis of induction.

Synthetic inference is founded upon a classification of facts, not according to their characters, but according to the manner of obtaining them. Its rule is, that a number of facts obtained in a given way will in general more or less resemble other facts obtained in the same way; or, *experiences whose conditions are the same will have the same general characters* [2.692].[25]

As Peirce points out in the next paragraph, the scientific inquirer knows the trustworthiness of his procedure. Since synthetic inference (abduction and induction) is the only type of inference achieving new ideas, Peirce concludes that human certainty amounts merely to a knowledge that the processes of deriving knowledge have in general led to true conclusions. And the process of inductive knowledge depends on the representative character of the individuals chosen for testing (2.693).[26]

Finally, we are dealing with *probabilities* in quantitative inductions, and "probability is wholly an affair of approximate, not at all of exact, measurement" (2.733). The inductive conclusion will reach the approximate evaluation of a ratio drawn from a limited sample, and applied to a whole class. However, with all the requirements, restrictions and regulations, it still remains true that "sampling is . . . a real art, well deserving an extended study by itself: to enlarge upon it here would lead us aside from our main purpose" (2.727).

V. THE PARTS OF INDUCTION

A more precise understanding of induction can be gained from considering the three parts or phases of this process. In "A Neglected Argument for the Reality of God," Peirce mentions and briefly describes classification, probation, and the sentential part of induction.

The mind, engaged in induction, performs first of all an operation of classification. "[Induction] must begin with Classification, which is an Inductive, Non-argumentational kind of Argument, by which general Ideas are attached to objects of Experience; or rather by which the latter are subordinated to the former" (6.472). The scientific inquirer tests his hypothesis by judging how accurately it generates observable predictions, and a prediction is a tentative classification. The singular experience, when it takes place, will present itself to the observer as something meaningful, and meaning is always general. In predicting, the scientist has not yet experienced the individual predicted events; yet he knows what *sort* of thing he should find if the hypothesis is true (2.515; 2.710–712; 2.784).

When the inquirer does fulfill the conditions of his prediction, he is performing what Peirce calls the operation of inductive *probation*. What is required at this step is that the inquirer should observe the number of times that the hypothesis has predicted successfully as related to the total number of times that the conditions of the prediction were fulfilled. In some cases, this will amount to a mere counting of instances of equal value, an operation which Peirce has called *quantitative* induction. At other times, simple counting will not be enough; in addition an estimate of the importance of the various characteristics of the subject-class under investigation will be required. This he calls *qualitative* induction. Peirce gives a clear but quite unscientific example of what he means when he says that, in testing the hypothesis that a certain man is a Catholic priest, the inquirer should put more value on the man's role in ceremonial functions than on the style of clothing that he wears.

Quantitative and qualitative induction are similar in that they both lead to probable conclusions, and they both effect a closer and closer convergence on truth but never quite attain full certitude.

"The whole [scientific] inquiry will be wound up with the Sentential part of the Third Stage, which, by Inductive reasonings, appraises the different Probations singly, then their combinations, then makes self-appraisal of these very appraisals themselves, and passes final judgment on the whole result" (6.472).[27] This sentence written in 1908 is a clear expression of the evaluative function of induction.

Earlier in his literary career, Peirce stressed the generalizing movement of induction without strong emphasis on its function in a scientific inquiry. In 1867 he defined induction as an "argument which assumes that a whole collection, from which a number of instances have been taken at random, has all the common characters of those instances" (2.515). About ten years later (1878), the notion of an inductive inference of a ratio appeared in his writings, accompanied by the generalization:

Induction is where we generalize from a number of cases of which something is true, and infer that the same thing is true of a whole class. Or, where we find a certain thing to be true of a certain proportion of cases and infer that it is true of the same proportion of the whole class [2.624].

In 1883, although he is concerned with probabilities and ratios, he nevertheless retains the generalizing movement of induction. We can learn by experience the ratio of a certain characteristic among a sample, and from this infer the ratio to be found in the whole class. The two ratios, he says, are "probably and approximately equal" (2.702; see also 2.732).

In his later writings Peirce did not reject what he wrote earlier but stressed that induction is the process which verifies hypotheses by testing the consequences deduced from them. In "The Varieties and Validity of Induction," he writes:

The only sound procedure for induction, whose business consists in testing a hypothesis already recommended by the retroductive procedure, is to receive its suggestions from the hypothesis first, to take up the predictions of experience which it conditionally makes, and then try the experiment and see whether it turns out as it was virtually predicted in the hypothesis that it would. Throughout an investigation it is well to bear prominently in mind just what it is that we are trying to accomplish in the particular stage of the work at which we have arrived. Now when we get to the inductive stage what we are about is finding out how much like the truth our hypothesis is, that is, what proportion of its anticipations will be verified [2.755].

It is important to note in this selection that the inductive process asks how closely the hypothesis corresponds with truth—that is, *it investigates what proportion of the consequences generated by the hypothesis will be verified*.[28] Induction is both a generalizing movement and an evaluative judgment.

The inductive conclusion that, for example, the *predictions* of a hypothesis are probably about 90 percent correct is the basis for affirming that the *hypothesis itself* is about 90 percent correct. Peirce's article in Baldwin's *Dictionary* on "Reasoning" presents induction both as a generalizing inference and as the means of testing hypotheses (2.775).

Through induction, the inquirer should be able to pass sentence on his explanatory hypothesis: it may be regarded as proved, partially proved, unworthy of further investigation, in need of modification, still highly dubious, and so forth. These are the various modalities of acceptance to which Peirce refers when he says, writing of induction in Baldwin's *Dictionary,* that upon the appearance of the predicted phenomena the reasoner "accepts the theory with a modality which recognizes it provisionally as approximately true" (2.775).

Finally, in a section of his "Minute Logic" composed about 1902, Peirce says that through induction the inquirer "concludes that the hypothesis is true in the measure in which those predictions are verified, this conclusion, however, being held subject to probable modification to suit future experiments" (2.96). The author, of course, is again presenting the same teaching about the evaluation which an investigator places on his theory, through induction. But there is an addition: reference is made to probable modifications of the hypothesis. The theory can be changed so as to come closer to the truth. Such changes and modifications constitute the final topic in our consideration of induction.

VI. THE CONVERGENCE ON TRUTH

One of the striking things about induction is that, besides leading to a proper appraisal of hypotheses, it also is a method of making indefinite progress toward the truth. In a scientific inquiry the process of verification is more than an umpire judging hypotheses; it also corrects them.[29] In a work composed about 1903 Peirce says that induction is a method [30] that "will in the long run yield the truth, or an indefinite approximation to the truth, in regard to every question" (2.269). And in another work written about 1905 he asserts that quantitative induction "always makes a gradual approach to the truth" (2.770). Similarly, qualitative induction either confirms the theory, or shows the need of some alterations in it. Even though the required alteration be small, some progress toward the truth, no matter how insignificant, is achieved (2.771). These texts and others like them do not define sharply how induction gradually closes in on the truth. Like many others, they merely assert that induction, if pursued long enough, comes closer and closer to a knowledge of the way things really are.[31]

There are two ways by which induction leads to an increasingly better knowledge of reality. First, if the process of sampling is protracted, the knowledge of the true ratio within the class will be sharpened. It is not that we ever come near to exhausting the instances, but we do come closer to a knowledge of the true ratio by knowing more instances.

The topic under discussion here is closely related to Peirce's treatment of the leading principle or guiding principle of inference. In general a leading principle is a habit of thought controlling and validating inference from premise to conclusion (2.462–465; 2.588f; 3.160–168; 4.69; 5.365–369). In the case of induction the leading principle is the scientific attitude that a random sample of a class represents the whole class, and that the significance of the sample grows in strength as the testing process goes on, leading toward an increasing approximation to the truth in the long run (5.275; 5.349; 7.131–134).

Peirce's work on probable inference to which I have already referred asserts that it is the "constant tendency of the inductive process to correct itself." He then goes on to explain that "the probability of its [induction's] conclusion only consists in the fact that if the true value of the ratio sought has not been reached, an extension of the inductive process will lead to a closer approximation" (2.729). An inference based on a limited number of instances may well be erroneous; but when the sample tested is enlarged, the ratio begins to approximate the truth, as Peirce says earlier in the same work (2.709). If the inquirer prolongs his testing of individual instances of a class he will achieve an increasingly accurate expression of the truth.

> It is mathematically certain that the general character of a limited experience will, as that experience is prolonged, approximate to the character of what will be true in the long run, if anything is true in the long run. Now all that induction infers is what would be found true in the usual course of experience, if it were indefinitely prolonged. Since the method of induction must generally approximate to that truth, that is a sufficient justification for the use of that method, although no definite probability attaches to the inductive conclusion [6.100].

This kind of convergence on truth is attained by the method of prolongation of experiences.

This is clearly brought out in several of Peirce's articles in Baldwin's

Dictionary. For example, in the article on "Probable Inference" he writes:

> The general character of the whole endless succession of similar events in the course of experience will be approximately of the character observed. . . . Therefore, if the character manifested by the series up to a certain point is not that character which the entire series possesses, still, as the series goes on, it must eventually tend, however irregularly, towards becoming so; and all the rest of the reasoner's life will be a continuation of this inferential process [2.784].

The same view of the corrective character of induction is also found in the *Dictionary* article on "Reasoning." He writes there that "induction is justified as a method which must in the long run lead up to the truth, and that by a gradual modification of the actual conclusions" (2.777).

Again, in an article on "Validity" Peirce repeats the same view. He asserts that what induction does is "to commence a proceeding which must in the long run approximate to the truth" (2.780). The context reveals that Peirce is writing this with great care, distinguishing finely between what others have claimed induction does, and what it really does. In the very nature of things, he insists, the method which induction follows must lead to results which approximate the truth indefinitely (2.781).[32] There is no postulate here that future samplings will be the same or nearly the same as those already examined. But if the sampling process is prolonged, the ratio discovered will be increasingly representative of the true ratio in all possible experiences of the class under consideration (6.39–42).

This characteristic of the method, as he repeatedly says, is the justification for its use in the experimental testing of a theory. It may at first lead to error, but sufficient persistence in the inductive method will gradually diminish the error (5.145; 6.474; 2.781; 6.100).[33]

There is, however, *a second sense* in which induction contributes to progress in knowledge. It advances our knowledge of scientific hypotheses, not only by evaluating them, but also by aiding in their correction. The experience gained in the process of testing the predictions can be used as a basis for forming a revised hypothesis. Even though the revised hypothesis is formed by a new abductive inference, the experience on which the new abduction is formed is still gained in testing the consequences of the old hypothesis.[34] After one hypothesis is tested and found imperfect, the inquirer has at his command a greater wealth of experience since the knowledge now comprehends not only the experiences from which the original hypothesis sprang, but also the new experiences gained in testing the observable consequences of that hypothesis. The inquirer, then, is in a much better position to form abductively a more correct hypothesis, because the experiences which he can use to guide him are much richer.

His revised hypothesis will be closer to the truth also because of the evaluation that he has placed on the previous hypothesis. The careful method of evaluating his first hypothesis not only has increased his experience, but has also sharpened his sense of values. His "feel" for the ways of nature has become more accurate. His instinct, the faculty of selecting the most suitable of the suggested explanations, has acquired a more extensive background, not only of sense-experience, but of experience in selecting. Instinct, of course, is not a blind faculty; it depends on the inquirer's knowledge of nature and his experience. What is said here of the individual inquirer is also true of the community of inquirers. The enterprise of aiding in the progress of science is necessarily a community undertaking, in which the successes and failures of one or another member are of value for the whole scientific community.

> Coming down to the more immediate and more pertinent causes of the triumph of modern science, the considerable numbers of the workers, and the singleness of heart with which . . . they cast their whole being into the service of science lead, of course, to their unreserved discussions with one another, to each being fully informed about the work of his neighbour, and availing himself of that neighbour's results; and thus in storming the stronghold of truth one mounts upon the shoulders of another who has to ordinary apprehension failed, but has in truth succeeded by virtue of the lessons of his failure [7.51].

The testing of a hypothesis, therefore, whether successful or not, aids the progress of science in two ways. The new experiences of phenomena in the testing process function as the basis for a new, more accurate hypothesis. And the investigator becomes more qualified to select a better hypothesis, because of his more adequate background.[35] The new abductive inference is formed by a mind enlivened by increased experience, and sharpened by a more accurate instinct for the truth. Selective instinct has been perfected by an increased fund of observation, and by the even more important addition of evaluative experience. This, perhaps, is what Peirce refers to when he says that induction is really ampliative reasoning; although abduction is the only process of inference which is genuinely additive of ideas, the inductive process prepares the scientist for making new abductions.

As was briefly mentioned above, the convergence on truth which the inductive process is able to achieve is the justification for the validity of this process.[36] Around 1905 Peirce wrote: "the true guarantee of the validity of induction is that it is a method of reaching conclusions which, if it be persisted in long enough, will assuredly correct any error concerning future experience into which it may temporarily lead us" (2.769).

Although it is true that scientific inquiry makes a gradual approach to the truth by forming and testing increasingly better hypotheses, the key step in the process of improvement is the strictly inductive phase of generalizing from a limited and random sample, since it is the sampling of real instances that puts the scientist in touch with the universe he is endeavoring to understand, and enables him to track down the secrets of that universe. Of course the cleverness of the observer is very important; but that cleverness has been developed by empirical contact with real individual events, and by forming and testing explanatory conjectures about the experienced reality. Furthermore the exercise of the observer's skill is dependent on those experiences of the universe which he gains largely in testing explanations through generalizing on instances chosen at random.

It is for this reason that Peirce can say that the validity of induction depends on *"the manner in which these* [instances] *were brought to the inquirer's attention"* (2.763). The instances must be chosen in such a way as to be as representative as possible of the class to which they belong.[37] As I indicated in the section on random sampling, induction is based on the manner of obtaining the facts from which it constructs its general propositions (2.692f).

In discussing these problems Peirce is clearly trying to refute the opinion of John Stuart Mill that induction is really a process of deduction with a major premise asserting the uniformity of the universe and a minor reporting the observed events. Peirce rejects this explanation of induction by denying that induction is so dependent on deduction, and refusing to accept the absolute uniformity of nature.

About 1905 he listed five reasons, and asserted that there were others besides, for rejecting Mill's opinion. In addition to stating that induction must go beyond its premises, while syllogistic deduction must not, he asserts that induction rests not only on the facts observed, but on the "manner in which those facts have been collected" (2.766). The facts observed must be representative, and therefore they have to be chosen in a corresponding manner.

A proposition stating the uniformity of nature Peirce regards as an assumption, and he maintains that inductive inference "does not depend upon any assumption that the series will be endless, or that the future will be like the past, or that nature is uniform, nor upon any material assumption whatever" (2.784; 2.102).[38]

It would be a serious mistake to think that Peirce is eliminating uniformity from the universe. What he is objecting to is the use of a proposition asserting uniformity as the major premise in an inductive inference, and the understanding of such a proposition as an assumption. Actually the scientist depends on the uniformity of the universe, which for Peirce is closely linked with its intelligibility. He explicitly states that induction is "manifestly adequate, with the aid of retroduction and of deductions from retroductive suggestions, to discovering any *regularity* there may be among experiences" (2.769). No series of experiences, he says, can be so lacking in uniformity as to be outside the reach of induction. Regularity is a feature of the universe, and it is because science studies the real, characterized by regularity, that it can gradually converge on the truth. "Reality is only the object of the final opinion to which sufficient investigation would lead" (2.693; 5.345).

The next chapter will develop at length the ideas of Peirce on the regularity of the universe, and other important topics related to the value and limits of the scientific method.