pairwise comparisons. As noted earlier, the Scheffé should not be used for only pairwise tests. However, both programs allow the user to specify contrasts, although the user will have to calculate the critical value himself or herself, which is hardly a problem. SPSS allows the user to specify contrasts for the "One-way ANOVA" procedure, and SAS allows the user to define contrasts under "Proc GLM." Neither program will print out confidence intervals, so the user needs to do that by hand.

The Changing Landscape

When Tukey started working on multiple comparison procedures, he largely set the field moving in the direction of familywise error rates, which is where Scheffé's test fits. But the problem with the familywise error rate approach is that it is an extreme case. If a family consists of a large number of contrasts (pairwise or not), then any error is considered a failure of the entire set—the confidence intervals no longer cover *all* parameters. That is why the critical values are as large as they are. In the last decade of Tukey's life, he began to take an interest in Benjamini's False Discovery Rate, which aims to control the *number* of false discoveries (Type I errors) that a procedure will make, rather than focusing on allowing no errors. As the field moves further in that direction, tests such as Scheffé's, and perhaps even Tukey's, are likely to play a smaller role.

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See also A Priori Monte Carlo Simulation; Bonferroni Procedure; *F* Test; Multiple Comparison Tests; Null Hypothesis; Omnibus Tests; Post Hoc Comparisons; Tukey's Honestly Significant Difference (HSD)

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Scientific Method

The term *method* derives from the Greek *meta* and *odos* meaning *following after,* suggesting the idea of order. Applied to science, method suggests the efficient, systematic ordering of inquiry. Scientific method, then, describes a sequence of actions that constitute a strategy to achieve one or more research goals. Relatedly, scientific *methodology* denotes the general study of scientific methods and forms the basis for a proper understanding of those methods.

Modern science is a multifaceted endeavor. A full appreciation of its nature needs to consider the aims it pursues, the theories it produces, the methods it employs, and the institutions in which it is embedded. Although all these features are integral to science, science is most illuminatingly characterized as method. Method is central to science because much of what we have learned from science has been acquired through use of its methods. Our scientific methods have been acquired in the course of learning about the world; as we learn, we use methods and theorize about them with increased understanding and success.

In this entry, scientific method is contrasted with other types of method. Then, some criticisms of the idea of scientific method are considered. Thereafter, four major theories of scientific method are outlined and evaluated. Finally, the place of methods in science is addressed.

Four Methods of Knowing

The American philosopher and scientist Charles Sanders Peirce maintained that there are four general ways of establishing beliefs. The poorest of these, the *method of tenacity,* involves a person stubbornly clinging to a familiar idea when challenged. The belief is sustained by an attitude of tenacity and unquestioned acceptance. The *method of authority* maintains that ideas are held to be true simply because they are the ideas of a person who is deemed an expert or perceived to be in a position of power. Peirce noted that this method is superior to the method of tenacity, because some beliefs can be fixed by adopting the method. The *a priori method,* which is better than both of the methods just mentioned, involves an appeal to the powers of reason independent of scientific observation. It involves accepting beliefs on the grounds that they are intuitive, self-evident, and based on reason rather than experience. The *method of science* is the method that Peirce himself advocated. It is superior to the other three methods because it establishes belief by appeal to an external reality and not to something merely human. Unlike the other methods, which are prescientific, the method of science has the characteristic of self-correction because it has built-in checks along the way. For Peirce, only this method has the ability to lead eventually to the truth.

Criticisms of the Idea of Scientific Method

Despite the importance of method in science, the idea that there is a scientific method characteristic of scientific inquiry has been the subject of many criticisms. Perhaps the most frequently voiced criticism of scientific method is that there is no such thing as *the* scientific method; that is, there can be no fixed universal account of scientific method appropriate for all disciplines and at all times. This criticism should be readily accepted because it speaks against an unrealistic view of scientific method.

Another prominent criticism of scientific method was proposed by Karl Popper, who often remarked that scientific method does not exist. By this he meant that there is no method of discovering a scientific theory, that there is no method of verification, and that there is no method for establishing whether a hypothesis is probably true or not. However, these claims are part of Popper's preference for a falsificationist construal of the hypothetico-deductive method. These claims might, or might not, be part of other conceptions of scientific method. For example, advocates of an inductive conception of scientific method will not accept the first claim; those who accept the idea of confirmation, as distinct from falsification, will argue against the second claim; and Bayesian methodologists will reject the third claim.

In a book, which was provocatively entitled *Against Method,* Paul Feyerabend presented a different criticism of scientific method. He argued that there are no methodological rules that are part of scientific method that have not been broken at some time or other in the interests of genuine scientific progress. Thus, for Feyerabend, the only rule that does not inhibit progress is the rule "anything goes." Feyerabend's argument has been endorsed by several commentators who are critical of appeals to the importance of scientific method. However, it should be noted that Feyerabend's criticism strictly speaks against the fixity of methodological rules only. There is nothing in Feyerabend's writing that would counsel against the flexible use of a variety of different methodological rules that are revisable in the light of experience, reason, and other sources of justification.

None of the three criticisms just considered addresses contemporary issues in scientific methodology.

Four Theories of Scientific Method

Modern scientific methodology has given considerable attention to the following four general theories of scientific method: (1) inductive method, (2) hypothetico-deductive method, (3) Bayesian hypothesis testing, and (4) inference to the best explanation.

Inductive Method

The idea that scientific method involves inductive reasoning goes back at least to Aristotle, and was given a heavy emphasis by Francis Bacon and John Stuart Mill. Inductive reasoning takes different forms. For example, it is to be found in the fashioning of statistical generalizations, in the Bayesian assignment of probabilities to hypotheses, and in the reasoning involved in moving from data to hypotheses in the hypothetico-deductive method.

The most popular inductive approach to scientific method is sometimes called *naïve inductivism.* According to this account of method, science begins by securing observed facts, which are collected in a theory-free manner. These facts provide a firm base from which the scientist reasons upward to hypotheses, laws, or theories. The reasoning involved takes the form of enumerative induction and proceeds in accordance with some governing principle of inductive reasoning. As its name suggests, enumerative induction is a form of argument in which the premises enumerate several observed cases from which a conclusion is drawn, typically in the form of an empirical generalization. However, enumerative induction can also take the form of a prediction about something in the future or a retrodiction about something in the past. The governing principle for an enumerative induction to a generalization can be stated informally as follows: "If a proportion of As have been observed under appropriate conditions to possess property B, then infer the same proportion of all As have property B." This inductive principle can be taken to underwrite the establishment of statistical generalizations.

The naïve inductive method has been criticized in various ways, although the criticisms are mostly directed at extreme versions of the method—versions making the claim that observed facts can be known infallibly, that observations are made in an entirely theory-free manner, or that empirical generalizations can be secured through the use of a strongly justified principle of induction. However, the so-called naïve inductive method can be defended in a moderate form: Observed facts can be established reliably, if fallibly; theory has to be used to guide observations, and theoretical terms can be used to report observational statements without threatening the reliability of those statements; and principles of induction can be given an adequate justification on pragmatic grounds.

In the behavioral sciences, the radical behaviorism of Burrhus F. Skinner is a prominent example of a research tradition that makes use of a nonstatistical inductive conception of scientific method. The major goals of radical behaviorist research are first to detect empirical generalizations about learning, and then to systematize those empirical generalizations by assembling them into nonexplanatory theories. Murray Sidman's *Tactics of Scientific Research* is an instructive radical behaviorist account of the methodology of phenomena detection.

The Bayesian approach to hypothesis testing can be regarded as a sophisticated variant of inductive method. It is considered later as an account of scientific method in its own right.

Hypothetico-Deductive Method

The most popular account of method in science is the hypothetico-deductive method, which has been the method of choice in the natural sciences for more than 150 years. The method has come to assume hegemonic status in the behavioral sciences, which have often placed a heavy emphasis on testing hypotheses in terms of their predictive success. Relatedly, the use of traditional statistical significance test procedures is often embedded in a hypothetico-deductive structure.

The hypothetico-deductive method is characteristically described in one of two ways: On one account, the scientist takes a hypothesis or a theory and tests it indirectly by deriving from it one or more observational predictions, which are amenable to direct empirical test. If the predictions are borne out by the data, then that result is taken as a confirming instance of the theory in question. If the predictions fail to square with the data, then that fact counts as a disconfirming instance of the theory. The second account is from Karl Popper, who construes the hypothetico-deductive method in falsificationist terms. On this rendition, hypotheses are viewed as bold conjectures, which the scientist submits to strong criticism with a view to overthrowing or refuting them. Hypotheses that successfully withstand such criticism are said to be corroborated, which is a noninductive notion of support.

Even though the hypothetico-deductive method is used by many scientists and has been endorsed by prominent philosophers of science, it has received considerable criticism. Leaving aside Popper's less influential falsificationist account of the hypothetico-deductive method, the major criticism of the hypothetico-deductive method is that it is confirmationally lax. This laxity arises from the fact that any positive confirming instance of a hypothesis obtained through its use can confirm any hypothesis that is conjoined with the test hypothesis, irrespective of the plausibility of that conjunct. Another criticism of the hypothetico-deductive method is that it submits a single hypothesis to critical evaluation without regard for its performance in relation to possible competing hypotheses. Yet another criticism of the method is that it mistakenly maintains that hypotheses and theories arise through free use of the imagination, not by some rational, methodological, or logical means.

Criticisms such as these have led some methodologists to recommend that the hypothetico-deductive method should be abandoned. Although this might be a reasonable recommendation about the method as it is standardly conceived, it is possible to correct for these deficiencies and use the method to good effect in hypothesis testing research. For example, one might overcome the confirmational defects of the orthodox hypothetico-deductive method by employing a Bayesian approach to confirmation within a hypothetico-deductive framework. With or without a commitment to the Bayesian approach, one could use the hypothetico-deductive method to test two or more competing hypotheses deliberately in relation to the evidence, rather than one hypothesis in relation to the evidence. Furthermore, in testing two or more hypotheses, one might supplement the appeal to empirical adequacy by invoking criteria to do with explanatory goodness.

Bayesian Method

Although the Bayesian approach to evaluating scientific hypotheses and theories is looked on more favorably in philosophy of science than the hypothetico-deductive alternative is, it remains a minority practice in the behavioral sciences.

For the Bayesian approach, probabilities are considered central to scientific hypothesis and theory choice. It is claimed that they are best provided by probability theory, which is augmented by the allied philosophy of science known as *Bayesianism*. In using probability theory to characterize theory evaluation, Bayesians recommend the assignment of posterior probabilities to scientific hypotheses and theories in the light of relevant evidence. Bayesian hypothesis choice involves selecting from competing hypotheses the one with the highest posterior probability, given the evidence. The vehicle through which this process is conducted is Bayes' theorem. This theorem can be written in a simple form as: $Pr(H/D) = Pr(H) \times Pr(D/H) \div Pr(D)$. The theorem says that the posterior probability of the hypothesis is obtained by multiplying the prior probability of the hypothesis by the probability of the data, given the hypothesis (the likelihood), and dividing the product by the prior probability of the data.

Although Bayes' theorem is not controversial as a mathematical theorem, it is controversial as a guide to scientific inference. With respect to theory appraisal, one frequently mentioned problem for Bayesians is that the probabilistic information required for their calculations on many scientific hypotheses and theories cannot be obtained. It is difficult to know how one would obtain credible estimates of the prior probabilities of the various hypotheses and evidence statements that comprised, say, Charles Darwin's evolutionary theory. Not only are the required probabilistic estimates for such theories hard to come by, but also they do not seem to be particularly relevant when appraising such explanatory theories.

The problem for Bayesianism presented by scientific theory evaluation is that scientists naturally appeal to qualitative theoretical criteria rather than probabilities. It will be described in the next section that scientific theories are often evaluated qualitatively by employing explanatory reasoning rather than probabilistic reasoning.

Inference to the Best Explanation

In accordance with its name, inference to the best explanation (IBE) is founded on the belief that much of what we know about the world is based on considerations of explanatory worth. In contrast to the hypothetico-deductive method, IBE takes the relation between theory and evidence to be one of explanation, not logical entailment, and by contrast with the Bayesian approach, it takes theory evaluation to be a qualitative exercise that focuses explicitly on explanatory criteria, not a quantitative undertaking in which one assigns probabilities to theories. Given that a primary function of many theories in science is to explain, it stands to reason that the explanatory merits of explanatory theories should count in their favor, whereas their explanatory failings should detract from their worth as theories. The major point of IBE is that the theory judged to be the best explanation is taken as the theory most likely to be correct. There is, then, a two-fold justification for employing IBE when evaluating explanatory theories: It explicitly assesses such theories in terms of the important goal of explanatory power, and it provides some guide to the approximate truth of theories.

The cognitive scientist Paul Thagard has developed a detailed account of IBE as a scientific method—one that helps a researcher to appraise competing theories reliably through the coordinated use of several criteria. This method is known as the *theory of explanatory coherence.* The theory comprises an account of explanatory coherence in terms of many constituent principles, a computer program for implementing the principles, and various simulation studies that demonstrate its promise as a method of IBE.

According to the theory of explanatory coherence, IBE is centrally concerned with establishing relations of explanatory coherence. To infer that a theory is the best explanation is to judge it as more explanatorily coherent than its rivals. The theory of explanatory coherence is not a general theory of coherence that subsumes different forms of coherence such as logical and probabilistic coherence. Rather, it is a theory of *explanatory* coherence, where the propositions hold together because of their explanatory relations.

Relations of explanatory coherence are established through the operation of seven principles. These principles are symmetry, explanation, analogy, data priority, contradiction, competition, and acceptability. The determination of the explanatory coherence of a theory is made in terms of the three criteria. Within the theory of explanatory coherence, each of these criteria is embedded in one or more of the seven principles.

Thagard determined that explanatory breadth is the most important criterion for choosing the best explanation. This criterion captures the idea that a theory is more explanatorily powerful than its rivals if it explains a greater range of facts.

The notion of simplicity that Thagard deems most appropriate for theory choice is a pragmatic criterion that is closely related to explanation; it is captured by the idea that preference should be given to theories that make fewer special or ad hoc assumptions. Thagard regards simplicity as the most important constraint on explanatory breadth; one should not sacrifice simplicity through ad hoc adjustments to a theory to enhance its consilience.

Finally, Thagard found that analogy is an important criterion of IBE because it can improve the explanation offered by a theory. Explanations are judged more coherent if they are supported by analogy to theories that scientists already find credible.

The four theories of scientific method just considered are commonly regarded as the major theories of scientific method. Although all the methods have sometimes been proposed as the principal claimant for the title of *the* scientific method, they are better thought of as restrictive accounts of method that can be used to meet specific research goals, not broad accounts of method that pursue a range of research goals.

The Importance of Method

Even though methodological discussions of scientific method are not fashionable, they are of vital importance to the well-being of science. For it is to scientific methods that scientists naturally turn for the cognitive assistance they need to investigate their subject matters successfully. The evolution and understanding of scientific methods is to be found in the domain of scientific methodology; this fact makes this interdisciplinary sphere of learning of major practical and educational importance.

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See also Alternative Hypotheses; Bayes's Theorem; Falsifiability; Inference: Deductive and Inductive; *Logic of Scientific Discovery, The*

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