Once you have reconstructed the argument, so that you know how it is supposed to work, then you can appraise its success or failure. This step employs the criteria for evaluating different types of inferences, some of which are presented above.

Evaluating reasoning is a complex task, because human language is rich and fluid, and because we are able to see a large number of subtle connections among the facts we confront. While the task is difficult, the alternative is unacceptable. For if we give up trying to understand reasoning, then we must either naively accept the arguments of others, as if we were children, or play the cynic, and forswear the possibility of learning from the insights of others.

NOTE

1. "A Study in Scarlet," in Arthur Conan Doyle, *The Complete Sherlock Holmes* (Garden City, N.Y.: Doubleday, n.d.), p. 24.

Study Questions

1. Can a valid deductive argument have true premises and a false conclusion?
2. Can a valid deductive argument have false premises and a true conclusion?
3. Give your own example of hypothesis testing.
4. Give your own example of arguing by inference to the best explanation.

Scientific Inquiry

CARL G. HEMPEL

The scientific method of explanation involves formulating a hypothesis and testing it, then accepting, rejecting, or modifying it in light of the experimental results. But how do we test a hypothesis? That is the subject of the following selection by Carl G. Hempel (1905–1997), who was Professor of Philosophy at Princeton University.

As you read about hypothesis testing, you may wonder how hypotheses are developed. What is their source? No mechanical procedures are available; the answer lies in creative imagination. While giving free rein to ingenuity, however, scientific method requires that our intuitions be accepted only if they pass the rigors of careful testing.

1. A CASE HISTORY AS AN EXAMPLE

As a simple illustration of some important aspects of scientific inquiry let us consider Semmelweis' work on childbed fever. Ignaz Semmelweis, a physician of Hungarian birth, did this work during the years from 1844 to 1848 at the Vienna General Hospital. As a member of the medical staff of the First Maternity Division in the hospital, Semmelweis was distressed to find that a large proportion of the women who were delivered of their babies in that division contracted a serious and often fatal illness known as puerperal fever or childbed fever. In 1844, as many as 260 out of 3,157 mothers in the First Division, or 8.2 per cent, died of the disease; for 1845, the death rate was 6.8 per cent, and for 1846, it was 11.4 per cent. These figures were all the more alarming because in the adjacent Second Maternity Division of the same hospital, which accommodated almost as many women as the First, the death toll from childbed fever was much lower: 2.3, 2.0, and 2.7 per cent for the same years. In a book that he wrote later on the causation and the prevention of childbed fever, Semmelweis describes his efforts to resolve the dreadful puzzle.[1]

He began by considering various explanations that were current at the time; some of these he rejected out of hand as incompatible with well-established facts; others he subjected to specific tests.

One widely accepted view attributed the ravages of puerperal fever to "epidemic influences," which were vaguely described as "atmospheric-cosmic-telluric changes" spreading over whole districts and causing childbed fever in women in confinement. But how, Semmelweis reasons, could such influences have plagued the First Division for years and yet spared the Second? And how could this view be reconciled with the fact that while the fever was raging in the hospital, hardly a case occurred in the city of Vienna or in its surroundings: a genuine epidemic, such as cholera, would not be so selective. Finally, Semmelweis notes that some of the women admitted to the First Division, living far from the hospital, had been overcome by labor on their way and had given birth in the street: yet despite these adverse conditions, the death rate from childbed fever among these cases of "street birth" was lower than the average for the First Division.

On another view, overcrowding was a cause of mortality in the First Division. But Semmelweis points out that in fact the crowding was heavier in the Second Division, partly as a result of the desperate efforts of patients to avoid assignment to the notorious First Division. He also rejects two similar conjectures that were current, by noting that there were no differences between the two Divisions in regard to diet or general care of the patients.

In 1846, a commission that had been appointed to investigate the matter attributed the prevalence of illness in the First Division to injuries resulting from rough examination by the medical students, all of whom received their obstetrical training in the First Division. Semmelweis notes in refutation of this view that (*a*) the injuries resulting naturally from the process of birth are much more extensive than those that might be caused by rough examination; (*b*) the midwives who received their training in the Second Division examined their patients in much the same manner but without the same ill effects; (*c*) when, in response to the commission's report, the number of medical students was halved and their examinations of the women were reduced to a minimum, the mortality, after a brief decline, rose to higher levels than ever before.

Various psychological explanations were attempted. One of them noted that the First Division was so arranged that a priest bearing the last sacrament to a dying woman had to pass through five wards before reaching the sickroom beyond: the appearance of the priest, preceded by an attendant ringing a bell, was held to have a terrifying and debilitating effect upon the patients in the wards and thus to make them more likely victims of childbed fever. In the Second Division, this adverse factor was absent, since the priest had direct access to the sickroom. Semmelweis decided to test this conjecture. He persuaded the priest to come by a roundabout route and without ringing of the bell, in order to reach the sick chamber silently and unobserved. But the mortality in the First Division did not decrease.

A new idea was suggested to Semmelweis by the observation that in the First Division the women were delivered lying on their backs; in the Second Division, on their sides. Though he thought it unlikely, he decided "like a drowning man clutching at a straw," to test whether this difference in procedure was significant. He introduced the use of the lateral position in the

First Division, but again, the mortality remained unaffected.

At last, early in 1847, an accident gave Semmelweis the decisive clue for his solution of the problem. A colleague of his, Kolletschka, received a puncture wound in the finger, from the scalpel of a student with whom he was performing an autopsy, and died after an agonizing illness during which he displayed the same symptoms that Semmelweis had observed in the victims of childbed fever. Although the role of microorganisms in such infections had not yet been recognized at the time, Semmelweis realized that "cadaveric matter" which the student's scalpel had introduced into Kolletschka's blood stream had caused his colleague's fatal illness. And the similarities between the course of Kolletschka's disease and that of the women in his clinic led Semmelweis to the conclusion that his patients had died of the same kind of blood poisoning: he, his colleagues, and the medical students had been the carriers of the infectious material, for he and his associates used to come to the wards directly from performing dissections in the autopsy room, and examine the women in labor after only superficially washing their hands, which often retained a characteristic foul odor.

Again, Semmelweis put his idea to a test. He reasoned that if he were right, then childbed fever could be prevented by chemically destroying the infectious material adhering to the hands. He therefore issued an order requiring all medical students to wash their hands in a solution of chlorinated lime before making an examination. The mortality from childbed fever promptly began to decrease, and for the year 1848 it fell to 1.27 per cent in the First Division, compared to 1.33 in the Second.

In further support of his idea, or of his hypothesis, as we will also say, Semmelweis notes that it accounts for the fact that the mortality in the Second Division consistently was so much lower: the patients there were attended by midwives, whose training did not include anatomical instruction by dissection of cadavers.

The hypothesis also explained the lower mortality among "street births": women who arrived with babies in arms were rarely examined after admission and thus had a better chance of escaping infection.

Similarly, the hypothesis accounted for the fact that the victims of childbed fever among the newborn babies were all among those whose mothers had contracted the disease during labor; for then the infection could be transmitted to the baby before birth, through the common bloodstream of mother and child, whereas this was impossible when the mother remained healthy.

Further clinical experiences soon led Semmelweis to broaden his hypothesis. On one occasion, for example, he and his associates, having carefully disinfected their hands, examined first a woman in labor who was suffering from a festering cervical cancer; then they proceeded to examine twelve other women in the same room, after only routine washing without renewed disinfection. Eleven of the twelve patients died of puerperal fever. Semmelweis concluded that childbed fever can be caused not only by cadaveric material, but also by "putrid matter derived from living organisms."

2. BASIC STEPS IN TESTING A HYPOTHESIS

We have seen how, in his search for the cause of childbed fever, Semmelweis examined various hypotheses that had been suggested as possible answers. . . . [L]et us examine how a hypothesis, once proposed, is tested.

Sometimes, the procedure is quite direct. Consider the conjectures that differences in crowding, or in diet, or in general care account for the difference in mortality between the two divisions. As Semmelweis points out, these conflict with readily observable facts. There are no such differences between the divisions; the hypotheses are therefore rejected as false.

But usually the test will be less simple and straightforward. Take the hypothesis attributing the high mortality in the First Division to the dread evoked by the appearance of the priest with his attendant. The intensity of that dread, and especially its effect upon childbed fever, are not as directly ascertainable as are differences in crowding or in diet, and Semmelweis uses an indirect method of testing. He asks himself: Are there any readily observable effects that should occur if the hypothesis were true? And he reasons: *If* the hypothesis were true, ***then*** an appropriate change in the priest's procedure should be followed by a decline in fatalities. He checks this implication by a simple experiment and finds it false, and he therefore rejects the hypothesis.

Similarly, to test his conjecture about the position of the women during delivery, he reasons: *If* this conjecture should be true, ***then*** adoption of the lateral position in the First Division will reduce the mortality. Again, the implication is shown false by his experiment, and the conjecture is discarded.

In the last two cases, the test is based on an argument to the effect that *if* the contemplated hypothesis, say H, is true, ***then*** certain observable events (e.g., decline in mortality) should occur under specified circumstances (e.g., if the priest refrains from walking through the wards, or if the women are delivered in lateral position); or briefly, if H is true, then so is I, where I is a statement describing the observable occurrences to be expected. For convenience, let us say that I is inferred from, or implied by, H; and let us call I a ***test implication of the hypothesis*** H. . . .

In our last two examples, experiments show the test implication to be false, and the hypothesis is accordingly rejected. The reasoning that leads to the rejection may be schematized as follows:

2*a*] If H is true, then so is I.
But (as the evidence shows) I is not true.
H is not true.

Any argument of this form, called ***modus tollens*** in logic, is deductively valid; that is, if its premisses (the sentences above the horizontal line) are true, then its conclusion (the sentence below the horizontal line) is unfailingly true as well. Hence, if the premisses of (2*a*) are properly

established, the hypothesis H that is being tested must indeed be rejected.

Next, let us consider the case where observation or experiment bears out the test implication I. From his hypothesis that childbed fever is blood poisoning produced by cadaveric matter, Semmelweis infers that suitable antiseptic measures will reduce fatalities from the disease. This time, experiment shows the test implication to be true. But this favorable outcome does not conclusively prove the hypothesis true, for the underlying argument would have the form

2*b*] If H is true, then so is I.
(As the evidence shows) I is true.
H is true.

And this mode of reasoning, which is referred to as the ***fallacy of affirming the consequent***, is deductively invalid, that is, its conclusion may be false even if its premisses are true. This is in fact illustrated by Semmelweis' own experience. The initial version of his account of childbed fever as a form of blood poisoning presented infection with cadaveric matter essentially as the one and only source of the disease; and he was right in reasoning that if this hypothesis should be true, then destruction of cadaveric particles by antiseptic washing should reduce the mortality. Furthermore, his experiment did show the test implication to be true. Hence, in this case, the premisses of (2*b*) were both true. Yet, his hypothesis was false, for as he later discovered, putrid material from living organisms, too, could produce childbed fever.

Thus, the favorable outcome of a test, i.e., the fact that a test implication inferred from a hypothesis is found to be true, does not prove the hypothesis to be true. Even if many implications of a hypothesis have been borne out by careful tests, the hypothesis may still be false. The following argument still commits the fallacy of affirming the consequent:

2*c*] If H is true, then so are $I_1, I_2, \ldots, I_n$.
(As the evidence shows) $I_1, I_2, \ldots, I_n$ are all true.
H is true.

This, too, can be illustrated by reference to Semmelweis' final hypothesis in its first version. As we noted earlier, his hypothesis also yields the test implications that among cases of street births admitted to the First Division, mortality from puerperal fever should be below the average for the Division, and that infants of mothers who escape the illness do not contract childbed fever; and these implications, too, were borne out by the evidence—even though the first version of the final hypothesis was false.

But the observation that a favorable outcome of however many tests does not afford conclusive proof for a hypothesis should not lead us to think that if we have subjected a hypothesis to a number of tests and all of them have had a favorable outcome, we are no better off than if we had not tested the hypothesis at all. For each of our tests might conceivably have had an unfavorable outcome and might have led to the rejection of the hypothesis. A set of favorable results obtained by testing different test implications, $I_1, I_2, \ldots, I_n$, of a hypothesis, shows that as far as these particular implications are concerned, the hypothesis has been borne out; and while this result does not afford a complete proof of the hypothesis, it provides at least some support, some partial corroboration or confirmation for it.

Note

1. The story of Semmelweis' work and of the difficulties he encountered forms a fascinating page in the history of medicine. A detailed account, which includes translations and paraphrases of large portions of Semmelweis' writings, is given in W. J. Sinclair, *Semmelweis: His Life and His Doctrine* (Manchester, England: Manchester University Press, 1909). Brief quoted phrases in this chapter are taken from this work. The highlights of Semmelweis' career are recounted in the first chapter of P. de Kruif, *Men Against Death* (New York: Harcourt, Brace & World, Inc., 1932).

Study Questions

1. Give your own example of testing a hypothesis by use of scientific method.
2. Give your own example of an argument in the form of *modus tollens.*
3. If an implication inferred from a hypothesis is found to be true, is the hypothesis thereby proven to be true?
4. What is the value of a partial confirmation of a hypothesis?

Antiscientism

GILLIAN BARKER AND PHILIP KITCHER

Gillian Barker is Assistant Professor of Philosophy at Western University in Canada, and Philip Kitcher is Professor of Philosophy at Columbia University. They explore the reasons why hostility toward science is not uncommon.

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. . . [T]he world clearly contains genuinely anti-science sentiment: attitudes of hostility or contempt for science that have important effects on public decision making about science policy and hobble our ability to make good use of scientific knowledge. . . . Worries about the human implications of the scientific worldview and the scientific conception of knowledge go back to the early modern period when physics achieved its earliest successes.

The triumph of the "mechanical philosophy" in the eighteenth century provoked worries that science had given us a world that is soulless, meaningless, and devoid of all the things that matter to people. Before the Scientific Revolution, Europeans lived in a world that they understood to be filled with meaning and purpose, one in which the place of humankind was (in every sense) central. They were "at home" in the universe. The cosmos as they conceived it was of a reassuringly human scale, and its history stretched back only a few hundred human generations. Their knowledge about the world—about its structure and history—was at the same time knowledge about the meanings and purposes of their lives and actions, knowledge about how to live. Other traditional systems of belief have shared many of these features, although, of course, the details have varied widely. But the world revealed by the new sciences of the seventeenth century was quite different. The Earth was no longer the center of the universe, but just one planet among many. The universe was vast and impersonal, and devoid of the qualities most familiar to us; the homely world of our sensory and emotional experience came to be seen as an illusion laid over an austere reality—atoms moving through the void. Knowledge, as the new sciences came to conceive it, is a dispassionate knowledge of the facts of this austere world, and nothing more. It cannot help us to understand our place in the universe, the meaning or purpose of our actions or of larger events. Indeed, as the new sciences matured, they seemed more and more strongly to suggest that there are no meanings or purposes at all, except those that we invent; no truths about what we should do or how we should live, beyond our conflicting desires and opinions. In an image repeated again and again in writings by scientists and philosophers, we heirs of the Scientific Revolution found ourselves alone, in a "disenchanted" world, a world that cares nothing for us, a world unimaginably vast, empty, and cold.

The scientific developments of the ensuing centuries offer no new comfort. Quantum physics has given us a world that is far stranger and less comprehensible than that offered by the mechanical philosophy, but no more humane. And most important, evolutionary biology, cognitive science, and neuroscience have combined to bring the full force of the scientific worldview to bear on our understanding of ourselves. Descartes and the other mechanical philosophers abolished the idea of organisms as beings endowed with their own purposes and meaningful structure, but though they saw other organisms and human bodies as elaborate machines, they held that the machine that is a human body is connected to a soul. The new sciences of our era turn even the soul into part of the machine.

Defenders of science have little patience with these complaints. We should stand firm, they say, even if the truth is hard to face. If we give up the cozy illusions of the past, we may come to a different kind of fulfilling experience, one reported by scientists from Galileo to Richard Dawkins, achieving the thrilling sense of intellectual freedom science offers and appreciating the awe-inspiring beauty, order, and richness of the world it reveals. A clear-eyed vision of reality more than compensates us for the loss of our prescientific illusions. We should also remember that the sense of meaning and purpose inherent in the worldview of prescientific Europe was deeply involved in the justification of a social order marked by an oppressive class structure and dogmatic religious belief. Liberating people from the "purposes" of such a social order was a great achievement, one made possible by the emergence of modern science.