CHAPTER 7

ARGUMENT TO EXPLANATION

The sociologist Max Weber drew people's attention to an interesting correlation.

> A glance at the occupational statistics of any country of mixed religious composition brings to light with remarkable frequency a situation which has several times provoked discussion in the Catholic press and literature, and in Catholic congresses in Germany, namely, the fact that business leaders and owners of capital, as well as the higher grades of skilled labour, and even more the higher technically and commercially trained personnel of modern enterprises, are overwhelmingly Protestant. This is true not only in cases where the difference in religion coincides with one of nationality, and thus of cultural development, as in Eastern Germany between Germans and Poles. The same thing is shown in the figures of religious affiliation almost wherever capitalism, at the time of its great expansion, has had a free hand to alter the social distribution of the population in accordance with its needs, and to determine its occupational structure. [M. Weber, *The Protestant Ethic and the Spirit of Capitalism*]

Given this positive correlation between being Protestant and being capitalist, Weber then asked: "Why were the

districts of highest economic development at the same time particularly favourable to a revolution in the Church?"

In asking 'why' Weber was looking for an explanation of the correlation. Was it that cultures in which people were prepared to take economic initiatives more easily adopted the reformed faith? Was it that the Lutheran revolt encouraged people to venture boldly in the economic realm? Did capitalism cause the Protestantism, or Protestantism the capitalism? Or are both alternatives wrong? Was it a basic tendency towards personal independence and individualism that caused the adoption of both capitalism and Protestantism?

Notice that a correlation does not, of itself, imply any relationship or direction between the features correlated. It is simply a regular pattern. To find causes in correlations, or to claim some other reason for them, one needs to make further inferences—to an explanation.

In proposing his explanation, Weber went back to a particular idea introduced by Martin Luther in his interpretation of Christianity. That was the conception of labour or work as a calling, or vocation. This belief, Weber claimed, motivated the early Protestants to work with thorough conscientiousness, even though their rewards were meagre. The sense of labour being of value on its own provided in turn the foundation for capitalism.

In asking his question and proposing his answer, Weber was using a distinctive type of reasoning. Here he made no inductive generalization, going from sample to population. Nor did he simply notice a correlation. He was moving from a set of facts to an explanation of those facts. He was looking for an answer to the question: why are things just this way—why are capitalism and Protestantism correlated positively?

Causes are one form of explanation. Causes produce results. And if we know what produced a state of affairs, we

have some idea why things are the way they are. Indeed, many people equate explanation with cause. If you give a cause and show how something has been brought about, you have explained it.

But there are other kinds of explanations as well. A mathematician wonders why we can test additions, subtractions, multiplications and divisions by the method of nines.

According to this method, you take any number, no matter how long; you add the digits of the number; and whenever you come to nine, you start again. In addition, for example, when you do this with each number to be added and then use the same procedure in adding the results together, the figure remaining will be exactly the same as the number you get when you follow the method of nines with the calculated total of the original addition. This is the short way of checking additions that many of us learned at school.

The mathematician finds this fact about the number nine curious. When he asks for an explanation of it, he is not asking about a cause, but about the mathematical *principles* from which one could deduce, or logically infer, this phenomenon. And he finds it in the fact that our number system is decimal, based on multiples of ten.

In a similar way, in their monumental work *Principia Mathematica*, Bertrand Russell and Alfred North Whitehead endeavoured to explain all of mathematics by tracing it back to its ultimate first principles.

A third kind of explanation attempts to fit a number of different facts into a single, coherent picture. In Conan Doyle's classic detective story, "The Speckled Band," we are told how Sherlock Holmes notices a number of details: the second half of a return ticket in the palm of his visitor's left glove; the left arm of her jacket spattered with fresh mud in no less than seven places. He puts these facts together to reach the explanation that Miss Stoner had

started early to catch the train, and had a good drive in a dog-cart along heavy roads before reaching the station. He has explained why a set of curious facts are just the way they are.

A similar kind of inference occurs when Holmes puts the details of his client's story together with his investigations into her mother's will and his observations of the room where her sister died. Taking all the many details into account, he infers an explanation and anticipates the solution. Only then is he ready to set up the experiment that will establish its truth.

In each of these cases we have an argument to an explanation. Some set of facts attracts our curiosity. For Weber and the mathematician, there is an interesting regularity. For Sherlock Holmes and Miss Stoner there is something unusual and irregular. This provides the basis of the inference. And the conclusion is what we have called an explanation: a way of interpreting the facts so that they fit together, not only among themselves, but also with our wider experience and expectations.

The pattern for such reasoning looks like this:

Premise 1: Situation S has facts F^1, F^2, F^3...F^n.
Sub-conclusion: Explanation E would combine F^1, F^2, F^3...F^n into a single, integrated pattern. (In other words, they can be made to fit together.)
Conclusion: So E serves as an explanation for S.

The critical point in the argument is the move from premise 1 to the sub-conclusion. How do we arrive at E? For all that Sherlock Holmes calls his "deductions" elementary, this kind of reasoning is neither deductive nor obvious.

Those who have looked at this kind of reasoning in the past do not give us much help. Aristotle talks about quick wits, and C.S. Peirce calls it guessing.

The first thing to notice is the task which an explanation is meant to fulfill. It is to combine facts or observations into a single, integrated pattern. Once the concept of calling or vocation is introduced, for example, the correlation between Protestantism and capitalism makes sense. The decimal system of numbers removes the puzzle of the method of nines. And the hypothesis of a poisonous snake fitted with all the curiosities that Holmes had noticed.

It is not easy to spell out what we mean when we talk about a fit, or about a "single, integrated pattern". This is certainly not a question of correlation, of things being found next to each other in space, or simultaneous in time. For as we have seen, while correlations set the problems, they do not provide the explanations. Inferences to cause, to principle and to solution start from just those regularities (or irregularities) that generated the initial question. The explanation is to add something else. It is to arrange all the variety of facts in a single framework of meaning. It is to find a way of relating them. Each detail contributes to and acquires its significance from the total picture. The explanation is, in the first instance, not another fact, but a way of *understanding* facts, a way of *thinking about* them. And it relies on many different connections of meaning—on a network of relations.

For an explanation to work in the sub-conclusion, then, it must appeal to networks of meaning that are already familiar. Our experience offers a wide range of possibilities. The task in arguing to an explanation is to dredge up from our memory some possible relations that we might be able to transfer to our puzzling facts. Weber was already familiar with Luther's theology. If this were a totally new field, he could discover it by studying Luther's writing, and

the statements of the Lutheran churches. What was not part of his own experience could be found in the experience of the culture. In his explanation, he applied one part of this to the framework of capitalism. And we suspect he focused on this part because he knew committed individuals whose diligent work achieved material success. He drew an analogy from his experience to the problem with which he was faced.

Holmes' encyclopaedic knowledge about snakes and India, milk and whipcords, among other things, was transferred to his particular problem in a similar way. It provided links between the puzzling facts.

We have already noticed that we use analogy to identify relations. In these inferences the investigators are searching for appropriate analogies that might provide bridges to possible explanations. They are looking for a pattern of relations that will enable the various facts to fit together and make sense.

So we can add another line to the pattern for our reasoning:

> **Premise 1:** Situation S has facts F^1, F^2, F^3...F^n.
> **Premise 2:** Analogue A relates items I^1, I^2, I^3...I^n, and these are similar to the facts in S.
> **Sub-conclusion:** So explanation E (which is what A would look like in situation S) would combine F^1, F^2, F^3...F^n into a single, integrated pattern.

These features of an explanation do not make it any easier to reach a solution at the point where we are faced with an explanatory puzzle.[1] For in our experience and the

1 Although William J. McGuire, at the 1988 meeting of the Canadian Psychological Association, offered 49 tactics for generating hypotheses: "First catch your rabbit: Tactical heuristics for generating hypotheses in psychological research."

experience of our culture, we have many possible networks of relations upon which we could call. Many of them will turn out to be irrelevant and others will help only if they are considered from just the appropriate angle. The problem we face is how to find the needle in the haystack – the right explanation among all the possibilities.

However, the analysis we have provided so far does suggest some ways of assessing arguments to explanation. If we use these criteria of assessment to reject a number of possibilities, we can then focus on the few that should be taken seriously.

1. In the first place, an explanation needs to do justice to all the facts. It cannot ignore some, simply because they are inconvenient or difficult.

A great many explanations do not satisfy this requirement. Frequently reasoners do not find a solution to handle all the features of a puzzle, so they fall back on a proposal that fits only some of them and simply disregard the others, or ascribe them to unknown and perverse influences. It is not easy to find completely satisfactory explanations, and we often have to retreat to half-way measures of this sort. Nonetheless, whenever we do not integrate all the puzzling features into a single picture, we have not fully satisfied the requirements of an argument to explanation.

This criterion is regularly used for rejecting incomplete and inadequate proposals. This is illustrated in the way detectives in novels spell out the course of their investigations. Sherlock Holmes starts out being misled by the presence of gypsies and the murdered girl's cry of "speckled band". But he rejects the possibility of gypsies committing the crime once he sees that no gypsy could enter the room either through the window or through the door. His first explanation is set aside when it cannot fit all of the facts.

Many arguments for explanations concentrate on refuting alternative possibilities, using this criterion. They show that, in the proposal they are rejecting, some facts have not been sufficiently taken into account. By discarding options in this way, they make more plausible the theory they are advancing, since it alone does justice to the facts considered. However, they cannot establish it as the only possible explanation. For there may be some other way of combining the puzzling facts into a single picture that they have not yet considered.

(The application of this criterion is frequently complicated by the way in which people handle awkward facts. As we have seen, facts can be disregarded or ascribed to outside interference. In consequence, a debate between people with differing hypotheses may have difficulty finding common ground because one side takes seriously a set of facts dismissed by their opponents, while ignoring the facts they stress.)

2. The second criterion to take into account in assessing an argument of this sort is what people have called "simplicity." By that they mean that the explanation should appeal to analogues in our experience that relate items in a fairly straightforward way; that we must not create artificial and peculiar connections between ideas and features just to make the explanation work.

Julian Huxley makes this point about the battle over astronomy in the sixteenth century: "Even after Copernicus, the doctrine that the sun goes around the earth could still be logically maintained. But it demanded enormous complexity of epicycle upon epicycle. The rival theory that the earth goes around the sun was far simpler and more satisfying."

In one sense, the traditional theory was more familiar. Scholars had learned it when they were young, and the

rhythm of sunrise and sunset suggested that the earth was stable and the sun moved. But it was not simpler. To do justice to the facts astronomers progressively learned about the location of the sun and the planets, the theory that they revolved around the earth had to be made more and more intricate and complex.

Even though we may have to think hard before coming up with a good explanation, then, it should not be artificial. We find reaching an explanation difficult, not because the connections to be discovered are complicated, but because we have never associated some of the relations that turn out to be successful with this puzzling set of facts. We need to cast around in our accumulated experience to discover a pattern that we can then transfer to this new and different context.

The appeal to simplicity takes us back to analogy. For an analogy identifies relations quite apart from the particular things they relate. An explanation offers a simple relation because we recall an analogy from somewhere else in our experience. Testing explanations against the criterion of simplicity and the operation of drawing analogies are close cousins.

The two criteria for the assessment of an argument to explanation, then, are that it should explain all the facts in question, all of F^1, F^2, F^3...F^n; and that it should be simple in the sense that it draws on a fairly clearcut pattern of relations present in accumulated experience.

These two frequently come into conflict. A simple explanation may be achieved by being cavalier with facts; too scrupulous attention to facts can complicate a theory. Copernicus' view that the sun was the centre of circular planetary motion made it difficult to calculate the location of Mars and Jupiter. The simple theory of circular motion had to disregard facts, and it was not until Kepler replaced the circular orbits with elipses that the Copernican theory

satisfied our first criterion. On the other hand, the earth-centred theory had developed its complexity in an effort to cope with astronomical facts.

In some cases, then, simplicity, even though it does not explain everything, can justify a tentative explanation; at other times, the fact that an hypothesis cannot do justice to the facts is sufficient to reject it, no matter how simple it may be.

In other words, our two criteria cannot on their own establish an explanation as completely reliable. C.S. Peirce says that any particular set of facts may have an indefinite number of possible explanations; and of that indefinite set, there may be quite a few that satisfy our second criterion, of simplicity.

Because there is no certainty about any explanation, even when it does explain all the facts in a simple way, we should never assert one definitively. It is still subject to question. Rather than being a *thesis*, something proven, it is only an *hypothesis*, something supposed. Indeed, some people call this form of reasoning not "argument to explanation" but "hypothesis", because the conclusion is still uncertain.

The critical test of an hypothesis, or proposed explanation, comes when we try to apply it. Any good explanation should not only connect together the puzzling facts with which we started, but also anticipate other facts yet to be considered. From a proposed explanation, one should be able to make a prediction and then see whether the prediction comes to pass. So, for example, Sherlock Holmes entices his colleague, Dr. Watson, into the dark bedroom to wait for the arrival of the poisonous swamp adder. Only when he hears the hiss and, by the light of the candle, sees the snake retreat up the bell-pull does he know that his hypothesis has been confirmed.

In a similar way, Albert Einstein, puzzling about some curious results of experiments conducted by Michelson and Morley, developed the special theory of relativity, which hypothesized that light does not travel in a straight line. But his proposed explanation was confirmed only when the light of a star, known to be behind the sun, could be seen during a total eclipse.

Not all hypotheses can be so easily tested. Weber's theory that Luther's conception of calling or vocation made Protestantism into the seed-bed of capitalism does not offer predictions that can easily be investigated. The more facts about European and North American culture it can be shown to cover, the more adequate it is shown to be. But it is extremely difficult to take account of all social and cultural facts. And researchers are tempted to select for consideration those that most clearly conform to their expectations. In history and sociology, it is hard to keep separate the process of selecting the facts for observation and the predictions that follow from an hypothesis.

In addition, societies and cultures are highly complex, with many different networks of relations intersecting. So, the search for simplicity in explanatory hypotheses inevitably leads to dismissing a number of facts as insignificant – the result of interfering conditions. And making successful predictions becomes more difficult since, come what may, complications will frustrate their coming to pass.

Nonetheless, any proposed explanation should lead to some predictions about facts and documents not already considered. And it will become more likely to the extent that those predictions prove to be accurate. A prediction that fails calls into question the hypothesis, and may even prove it to be false. This appeal to prediction, and the readiness to surrender an hypothesis because the predictions are wrong, is the ultimate test of an argument to

explanation. It alone can provide some solid evidence that the reasoning is reliable.

One does, however, need to consider the kinds of predictions that are involved. The closer the predictions are to the original set of features that posed the puzzle, the more likely they are to be successful; so they provide weaker support for the theory. When the predictions concern a quite different kind of thing, and they nonetheless prove to be successful, they strengthen the explanation.

Thus, if Weber were to base his argument on Germany, Holland and Switzerland, and then draw some inferences to England and Scotland, which were also influenced by Lutheran and Calvinist ideas, the connection between the original information and the test would be too close to be very strong. Were he, however, to find a similar kind of connection with a sense of calling in Zoroastrian thought, leading to a greater tendency to capitalism among the Parsees (who practise that religion) than among their neighbouring Hindus or Muslims, his thesis would be stronger.

The observation of the star during the eclipse offered strong support for Einstein's theory of relativity because it was far removed from the area of Michelson and Morley's experiments, while still confirming the prediction.

In other words, we once again apply a pattern of similarity and difference. The greater the differences in successful predictions, the more reliable the inference to explanation. The greater the similarity in unsuccessful predictions, the less likely is the reasoning adequate. Because predictions use a relation between some facts as an analogy for others, they can be assessed using the criteria of analogical reasoning.

Once they can show evidence of successful prediction, reasoners may justifiably move from their sub-conclusion, 'explanation E would combine F^1, F^2, F^3...F^n into a single

integrated pattern,' to their final conclusion, 'E serves as an explanation for S.'

So our final representation of the pattern of this kind of reasoning looks like this:

Sub-premise 1: Situation S has facts F^1, F^2, F^3...F^n.
Sub-premise 2: Analogue A relates items I^1, I^2, I^3...I^n, and these are similar to the facts in S.
Sub-conclusion/Premise 1: So explanation E (which is what A would look like in situation S) would combine F^1, F^2, F^3...F^n into a single, integrated pattern.
Premise 2: On the basis of explanation E we have made predictions P^1, P^2, P^3...P^n and they have been successful.
Conclusion: So E serves as an explanation for S.

Because successful prediction is important in making the move from sub-conclusion to conclusion, it needs to be taken into account in our original assessment of the hypothesis. A good explanation is one that can in fact be easily tested using predictions.

One that would be true whatever happened does not take us very far. For example, some religious people believe that whatever happens is the will of God. Whenever good fortune dawns, the hypothesis is confirmed. If calamity occurs, that too establishes the explanation. But such a theory cannot really explain why things are the way they are; why they are not otherwise. For no matter what actually happens will be called God's will.

In a similar way some social theories are untestable. Committed capitalists will attribute all positive historical developments to free markets and a lack of government intervention. Events that on the surface do not support that thesis are made to fit by introducing sub-explanations and sub-hypotheses, or by appealing to complicating cir-

cumstances. Nothing is allowed that will disprove the theory. Once again we have an explanation that does not really explain.

In other words, a good explanation *should allow for some kind of testing that could in theory prove it false.* This then becomes our third criterion for assessing the sub-argument, even before we get to establishing our main conclusion.

An argument to an explanation takes as its first premise a set of puzzling facts. They may be more regular than one would normally expect, or they may offer an unexpected association of things. One looks for an analogy to serve as a second premise before concluding with a possible explanation that fits all the facts, is relatively simple, and can be tested. This hypothesis is then actually tested by making predictions and noting whether they are successful or not. Successful predictions warrant an inference to a final conclusion that the explanation is true of the original situation.

The sub-argument can be assessed by considering: first, whether the proposed explanation fits all the puzzling facts; second, whether it is "simple"— whether it appeals to networks of relations that are not artificially complicated; and third, whether the hypothesis allows testing by successful (or failed) predictions.

The final argument can be assessed by considering whether the predictions made concern things which are close to, or quite divergent from, the kinds of features already taken into account. The more divergent the successful predictions are, the more reliable the conclusion. On the other hand, where predictions fail, the closer they are to the original features, the more likely that the conclusion is wrong.

Sometimes investigators do not develop explanations in the framework of an argument. Instead of stating puzzling facts, proposing a hypothesis, and then looking for

confirmation, they simply offer a description of history or nature that ties a number of facts together into an ordered pattern.

Thus, in *The Communist Manifesto*, Marx and Engels start by simply asserting their hypothesis that "the history of all hitherto existing society is the history of class struggles." Then they provide an account of the past that ties together a number of events and movements under this explanatory rubric:

> In the earlier epochs of history we find almost everywhere a complicated arrangement of society into various orders, a manifold of gradation of social rank. In ancient Rome we have patricians, knights, plebians and slaves; in the Middle Ages, feudal lords, vassals, guildmasters, journeymen, apprentices, serfs; in almost all of these classes, again,subordinate gradations.
> The modern bourgeois society that has sprouted from the ruins of feudal society has not done away with class antagonisms. It has but established new classes, new conditions of oppression, new forms of struggle in place of the old ones.

In a similar way, Rachel Carson's *Silent Spring* explains why "the voices of spring" have been silenced in America by setting out details of biochemical research, descriptions of natural catastrophes, and anecdotes of initiatives taken. These facts fit together into a comprehensible and "simple" whole once the widespread, but unnecessary, use of chemical insecticides and weed killers is offered as the explanation.

It is easy to miss the argument to explanation in such texts. In the first place, they do not always distinguish the puzzling facts from the hypothesis proposed. *The Com-*

munist Manifesto combines them into a single story. *Silent Spring* regularly uses the explanatory language of cause in giving its account of what has happened.

In the second place, they are not presented tentatively, as possibilities subject to further testing; they are asserted as definitely true. The obviousness of the fit is supposed to be enough to establish credibility. Note the dogmatic confidence of Marx and Engels' first sentence, quoted above.

Nonetheless, in both cases we have an argument to explanation, the proposal of an hypothesis.

While it has been relatively easy to make and test predictions when dealing with Carson's thesis about chemicals, it becomes more difficult to do so when we turn to explanations of history and society, like those of Marx and Weber, where we do not have the possibility of setting up controlled experiments. There, our method of assessment may have to stop with the questions of fit and simplicity. But that means that we can justify only the sub-conclusion of their argument. We have no way of establishing the final conclusion: that E *does* in fact explain S – that class struggle *does* explain all previous history.

One needs to be on guard, then, when one encounters confident explanations that hide their inferential character. Be careful to distinguish between the account of facts known and experienced, and the explanation or interpretation that is to provide a network or pattern of meaning. Those explanations and interpretations need to be assessed with care. Do they fit *all* the facts? Or has the researcher selected only those facts that do in fact conform, conveniently ignoring all the others? Are they really simple, in that the analogies they draw are relatively uncomplicated? Are there any ways by which we can easily test the likelihood of the hypothesis? Whenever the answer to the last question is *no*, we need to apply the other assessments

especially carefully and well. Or else we may be led down the garden path.

EXERCISE:

For each of the following passages: (1) Identify (a) the facts that raised the initial question, asking for an explanation, as well as (b) the explanation that is proposed. (2) Assess the explanation in terms (a) of covering *all* the facts (including any you are aware of not explicitly mentioned), and (b) of being relatively simple. If appropriate, (3) suggest what kinds of predictions could be made to test the hypothesis. (4) List any alternative explanations that have been raised and rejected together with the criteria they do not satisfy.

> EXAMPLE: "Organs in a rudimentary condition plainly show that an early progenitor has the organ in a fully developed condition; and this in some cases implies an enormous amount of modification in the descendants. Throughout whole classes various structures are formed on the same pattern, and at a very early age the embryos closely resemble each other. Therefore I cannot doubt that the theory of descent with modification embraces all the members of the same great class or kingdom." C. Darwin, *The Origin of the Species*.

Facts to be explained: 1. Organs in a rudimentary condition; 2. throughout whole classes, various structures are formed on the same pattern and at a very early age the embryos closely resemble each other. (Notice that the

phrases "plainly show that" and "this... implies" suggest moves towards a conclusion, and therefore the phrases "an early progenitor has the organs in a fully developed condition," and "an enormous amount of modification in the descendants" are parts of the explanation, not parts of the facts to be explained.)

Explanation: All the members of a single great class or kingdom have descended with considerable modification from an early progenitor. (Here we have taken the two phrases mentioned above, together with the "therefore" clause at the end, and reworked it into a statement of what the "theory of descent with modification" involves.)

Assessment:

1. This explanation covers the facts mentioned. However, there is a lot of zoological data, and those of us who are not biologists are uncertain about how this explanation might handle other known facts.
2. The theory is simple and uncomplicated.
3. The theory can be tested by observing over time species placed in alien environments to see whether modifications do take place.

No alternative hypotheses are mentioned.

1. That man is wearing a dark pin-stripe suit; he is carrying a briefcase; and he has an expression of knowing what he is doing. I conclude that he is probably a business man.

2. "This hat is three years old. These flat brims curled at the edge came in then. It is a hat of the very best quality. Look at the band of ribbed silk and the excellent lining. If this man could afford to buy so expensive a hat three years ago, and has had no hat since, then he has assuredly gone down in the world." A Conan Doyle, "The Adventure of the Blue Carbuncle"

3. Mary is not eating the way she used to; she daydreams a lot; and she becomes really interested whenever she hears Jack's name mentioned. I would guess she is in love.

4. The 747 disappeared suddenly from the radar screen; on the radio transmissions and voice recorders there were no indications that the pilots were aware of difficulties. Several 747 planes have been grounded because of structural problems and indeed two have had weak sections blown off by pressure differential. Although parallel shards of metal were found perforating luggage from the tail section, it must remain most likely that the 747 suffered from acute metal fatigue which caused the crash.

5. During a 1989 conference on the environment held in London, Prime Minister Margaret Thatcher advocated taking prompt action against the future use of chlorofluorocarbons. Some commentators said that Thatcher, who began her working career as a chemist, didn't want to seem indifferent to this kind of threat to mankind. But she probably made her decision on the same basis she has used in the past—how it would benefit her politically in the future. Thatcher, already elected three times in a row, wants to be the first British prime minister to govern four terms in succession. The next British national election is not due until 1991. It will take that long to begin reducing the world manufacture of chlorofluorocarbons.

6. "How can A and not-A, being and non-being, reality and negation, be thought together without mutual elimination and destruction? We need not expect anyone to answer the question other than as follows: They mutually *limit* one another." J.G. Fichte, *Third Fundamental Principle of the Entire Science of Knowledge.*

7. "Archimedes made many wonderful discoveries of different kinds, but of all these that which I shall now explain seems to exhibit a boundless ingenuity. When Hiero was greatly exalted in the royal power at Syracuse, in return for the success of his policy he determined to set up in a certain shrine a golden crown as a votive offering to the immortal gods. He let out the work for a stipulated payment, and weighed out the exact amount of gold for the contractor. At the appointed time the contractor brought his work skilfully executed for the king's approval, and he seemed to have fulfilled exactly the requirement about the weight of the crown. Later information was given that gold had been removed and an equal weight of silver added in the making of the crown. Hiero was indignant at this disrespect for himself, and, being unable to discover any means by which he might unmask the fraud, he asked Archimedes to give it his attention. While Archimedes was turning the problem over, he chanced to come to the place of bathing, and there, as he was sitting down in the tub, he noticed that the amount of water which flowed over the tub was equal to the amount by which his body was immersed. This indicated to him a means of solving the problem, and he did not delay, but in his joy leapt out of the tub and, rushing naked towards his home, he cried out with a loud voice that he had found what he sought. For as he ran he repeatedly shouted in Greek, *heureka, heureka.*

"Then, following up his discovery, he is said to have made two masses of the same weight as the crown, the one of gold and the other of silver. When he had so done, he filled a large vessel right up to the brim with water, into which he dropped the silver mass. The amount by which it was immersed in the vessel was the amount of water which overflowed. Taking out the mass, he poured back the amount by which the water had been depleted, measuring it with a pint pot, so that as before the water was made level with the brim. In this way he found what weight of silver answered to a certain measure of water.

"When he had made this test, in like manner he dropped the golden mass into the full vessel. Taking it out again, for the same

reason he added a measured quantity of water, and found that the deficiency of water was not the same, but less; and the amount by which it was less corresponded with the excess of a mass of silver, having the same weight, over a mass of gold. After filling the vessel again, he then dropped the crown itself into the water, and found that more water overflowed in the case of the crown than in the case of the golden mass of identical weight; and so, from the fact that more water was needed to make up the deficiency in the case of the crown than in the case of the mass, he calculated and detected the mixture of silver with gold and the contractor's fraud stood revealed." Vitruvius, *On Architecture.*

8. "It has for some years been remarked that the remote spiral nebulae are, to all appearances, rushing away from the earth, and so presumably also from one another, at terrific speeds, which become greater and greater the farther they recede into space.... There is room for a good deal of doubt as to whether these huge speeds are real or not. They have not been obtained by any direct process of measurement, but are deduced by an application of what is known as Doppler's principle. It is a matter of common observation that the noise emitted by a motor-car horn sounds deeper in pitch when it is receding from us than when it is coming towards us. On the same principle the light emitted by a receding body appears redder in colour than that emitted by a body approaching us, colour in light corresponding to pitch in sound. By accurately measuring the colour of well-defined spectral lines, the astronomer is able to discover whether the body emitting them is approaching us or receding from us, and can estimate the speed of that motion. And the only reason for thinking that the distant nebulae are receding from us is that the light we receive from them appears redder than it ought normally to be." J. Jeans, *The Mysterious Universe.*

9. "After that I reflected upon the fact that I doubted, and that, in consequence, my spirit was not wholly perfect, for I saw clearly that it was a greater perfection to know than to doubt. I decided to ascertain from what source I had learned to think of something more perfect than myself, and it appeared evident that it must have been from some nature which was in fact more perfect. As for my ideas about many other things outside of me, as the sky, earth, light, heat, and thousands of other things, I was not so much troubled to discover where they came from, because I found nothing in them superior to my own nature. If they really existed, I could believe that whatever perfection they possessed might be derived from my own nature; if they did not exist, I could believe that they were derived from nothingness, that is, they were derived from my own defects. But this could not be the explanation of my idea of a being more perfect than my own. To derive it from nothingness was manifestly impossible, and it is no less repugnant to good sense to assume what is more perfect comes from and depends on the less perfect than it is to assume that something comes from nothing, so that I could not assume that it came from myself. Thus the only hypothesis left was that this idea was put in my mind by a nature that was more perfect than I was, which had all the perfections that I could imagine, and which was, in a word, God." R. Descartes, *Discourse on Method.*

10. An explanation for the Hindu prohibition against cattle slaughter:

"The practice arose to prevent the population from consuming the animal on which Indian agriculture depends. During the First Millenium B.C., the Ganges Valley became one of the most densely populated regions of the world.

"Where previously there had been only scattered villages, many towns and cities arose and peasants farmed every available acre of land. Kingsley Davis, a population expert at the University of California at Berkeley, estimates that by 300 B.C. between 50 million and 100 million people were living in India.

The forested Ganges valley became a windswept semidesert and signs of ecological collapse appeared; droughts and floods became commonplace, erosion took away the rich topsoil, farms shrank as population increased, and domesticated animals became harder and harder to maintain.

"It is probable that the elimination of meat eating came about in a slow, practical manner. The farmers who decided not to eat their cows, who saved them for procreation to produce oxen, were the ones who survived the natural disasters. Those who ate beef lost the tools with which to farm. Over a period of centuries, more and more farmers probably avoided beef until an unwritten taboo came into existence.

"Only later was the practice codified by the priesthood. While Indian peasants were probably aware of the role of cattle in their society, strong sanctions were necessary to protect zebus from a population faced with starvation. To remove temptation, the flesh of cattle became taboo and the cow became sacred." Marvin Harris, "India's Sacred Cow," *Human Nature*, 1978.

11. "'You see, Watson,' he explained in the early hours of the morning as we sat over a glass of whisky and soda in Baker Street, 'it was perfectly obvious from the first that the only possible object of this rather fantastic business of the advertisement of the League, and the copying of the Encyclopaedia, must be to get this not over-bright pawnbroker out of the way for a number of hours every day. It was a curious way of managing it, but, really, it would be difficult to suggest a better. The method was no doubt suggested to Clay's ingenious mind by the colour of his accomplice's hair. The four pounds a week was a lure which must draw him, and what was it to them, who were playing for thousands? They put in the advertisement, one rogue has the temporary office, the other rogue incites the man to apply for it, and together they manage to secure his absence every morning in the week. From the time that I heard of the

assistant having come for half wages, it was obvious to me that he had some strong motive for securing the situation.'

"'But how could you guess what the motive was?'

"'Had there been women in the house, I should have suspected a mere vulgar intrigue. That, however, was out of the question. The man's business was a small one, and there was nothing in his house which could account for such elaborate preparations, and such an expenditure as they were at. It must, then, be something out of the house. What could it be? I thought of the assistant's fondness for photography, and his trick of vanishing into the cellar. The cellar! There was the end of this tangled clue. Then I made enquiries as to this mysterious assistant and found that I had to deal with one of the coolest and most daring criminals in London. He was doing something in the cellar—something which took many hours a day for months on end. What could it be, once more? I could think of nothing save that he was running a tunnel to some other building.

"'So far I had got when we went to visit the scene of action. I surprised you by beating upon the pavement with my stick. I was ascertaining whether the cellar stretched out in front or behind. It was not in front. Then I rang the bell, and, as I hoped, the assistant answered it. We have had some skirmishes, but we had never set eyes upon each other before. I hardly looked at his face. His knees were what I wished to see. You must yourself have remarked how worn, wrinkled, and stained they were. They spoke of those hours of burrowing. The only remaining point was what they were burrowing for. I walked around the corner, saw the City and Suburban Bank abutted on our friend's premises, and felt that I had solved my problem. When you drove home after the concert I called upon Scotland Yard and upon the chairman of the bank directors, with the result that you have seen.'" A. Conan Doyle, "The Red-Headed League."

CHAPTER 8

REASONING FOR ACTION

In 1977, Mr. Justice Thomas R. Berger presented to the Canadian Minister of Indian Affairs and Northern Development the final report of his Inquiry into the Mackenzie Valley Pipeline proposed for the North. He summed up his report in these words:

> A Mackenzie Valley pipeline should be postponed for ten years. If it were built now, it would bring limited economic benefits, its social impact would be devastating, and it would frustrate the goals of native land claims. Postponement would allow sufficient time for native claims to be settled, and for new programs and new institutions to be established. This does not mean that we must renounce our northern gas and oil. But it does mean that we must allow sufficient time for an orderly, not hasty, program of exploration to determine the full extent of our oil and gas reserves in the Mackenzie Delta and the Beaufort Sea. Postponement will offer time for you and your colleagues to make a rational determination regarding the priorities to be adopted in relation to the exploitation of all our frontier oil and gas resources, at a time when the full extent of our frontier reserves has been ascertained. [xxvii, Reproduced with permission of the Minister of Supply and Services Canada, 1989.]

WITHIN REASON

A GUIDE TO NON-DEDUCTIVE REASONING