CHAPTER 2

# Facts

## WHAT ARE THEY?

In explaining scientific method, we will try to rely as much as possible on common experience and common sense. The reason for this is not that there is anything sacred about common sense—after all, the "common sense" of people living in modern, scientifically oriented societies has been shaped by the intellectual and cultural climate of these societies and is not the same as the common sense of fifteenth-century Europeans or that of natives of the Southern Sudan in the twentieth century. The appeal to common sense helps us to communicate better: to explain something that might be new and strange in terms of what is familiar.

However, there is one set of concepts in science that will arise time and again in the case studies that follow. They are so at variance with common sense and common understanding that we feel it is necessary to deal with them at the start. These concepts deal with *facts:* What are they? How do we know them when we see them? What is their role in science?

We are surrounded by facts—the things about us that we can see, feel, hear, and smell. We believe in their reality, and often go further and feel that nothing else is real. But the common view of these as the inescapable basic data of existence overlooks the strong component of training and experience in the simplest perceptions.

## FOOLING THE EYE

It is natural to believe what we see—it is hard to imagine doing anything else. But we don't usually realize that seeing is learned, that it





does not come automatically. We do not see with our eyes but with our minds. This can be brought sharply to our attention when we see something that isn't there or fail to see something that is, both of which happen often enough. We are aware that there are such things as "optical illusions," but we don't always recognize that their existence is of great significance. How can the eye be fooled? If it can, when should we trust it and when not?

When we examine optical illusions and why they work, we begin to understand that we see by *interpreting* a visual image, not just by *seeing* it. This can be demonstrated by pictures in which the "eye" is fooled, as in Figure 1. It might be brought home more clearly by reference to the picture of the cat in Figure 2. One sees at a glance that this is a picture of a cat. But a little thought about it will reveal that after all it has very little resemblance to the sense impressions we have when we see a real cat.

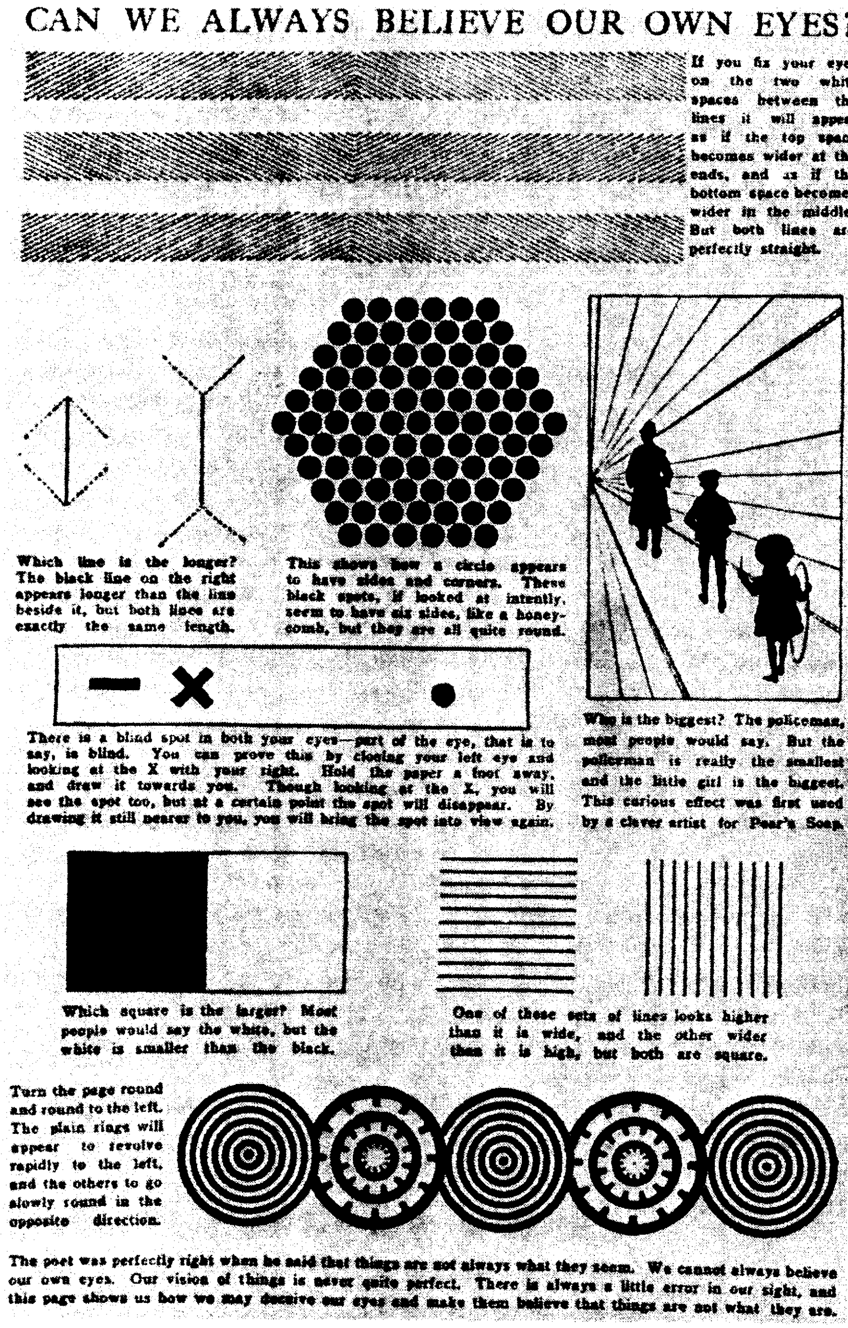
It doesn't have the color of a cat, or the three-dimensional character; it doesn't meow or climb trees; and the sensations one feels on patting it are not in the least like the real thing. It is in fact a highly stylized drawing that leaves out most of the details we see when we look at a real cat. We of Western culture have learned to recognize it as "cat," but it would not be recognized this way by people of other cultures who are not familiar with this mode of representation.

The point is that when we look at this picture we recognize it as representing a cat as rapidly and with as little reflection or analysis as we recognize a real cat as a cat. We recognize both in a flash, and in the same way. We see the cat as a fact, or as though it were a fact.

Figure 3 is a photograph of a cat. One might feel that recognizing this is a more objective and less culturally determined process than recognizing the drawing. But a photograph also differs from a real cat in important ways: it is much smaller, it is flat rather than three dimensional, it is in black and white rather than in color, and it is still rather than moving about. Recognizing it as a cat is again a culturally conditioned ability: we have been taught to see it as a cat. We don't "see"—we recognize patterns, with all the conditioning, practice, and training that that implies.

## SEEING AFTER BLINDNESS

The learned component of perception is demonstrated very strikingly by the experiences of people blind from birth who have undergone surgery that gives them vision in maturity. Surgery for removal of a cataract (a deterioration of the lens of the eye that makes it opaque) has been introduced in recent years. Infants are occasionally born with this



CAN WE ALWAYS BELIEVE OUR OWN EYES?

If you fix your eyes on the two white spaces between the lines it will appear as if the top space becomes wider at the ends, and as if the bottom space becomes wider in the middle. But both lines are perfectly straight.

Which line is the longer? The black line on the right appears longer than the line beside it, but both lines are exactly the same length.

This shows how a circle appears to have sides and corners. These black spots, if looked at intently, seem to have six sides, like a honeycomb, but they are all quite round.

Who is the biggest? The policeman, most people would say. But the policeman is really the smallest and the little girl is the biggest. This curious effect was first used by a clever artist for Pear's Soap.

There is a blind spot in both your eyes—part of the eye, that is to say, is blind. You can prove this by closing your left eye and looking at the X with your right. Hold the paper a foot away, and draw it towards you. Though looking at the X, you will see the spot too, but at a certain point the spot will disappear. By drawing it still nearer to you, you will bring the spot into view again.

Which square is the larger? Most people would say the white, but the white is smaller than the black.

One of these sets of lines looks higher than it is wide, and the other wider than it is high, but both are square.

Turn the page round and round to the left. The plain rings will appear to revolve rapidly to the left, and the others to go slowly round in the opposite direction.

The poet was perfectly right when he said that things are not always what they seem. We cannot always believe our own eyes. Our vision of things is never quite perfect. There is always a little error in our sight, and this page shows us how we may deceive our eyes and make them believe that things are not what they are.

**FIGURE 1.** "Can We Always Believe Our Own Eyes?" From *The Book of Knowledge,* 1922 (reproduced by permission of Grolier, Incorporated).



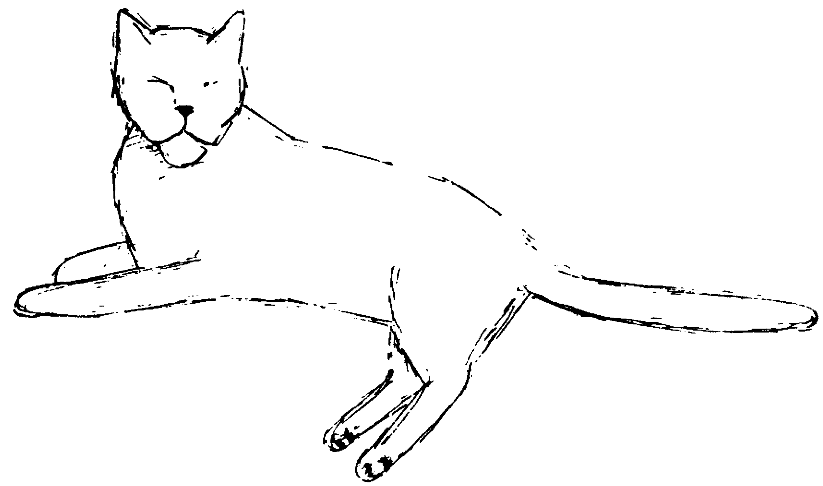


**FIGURE 2**

**FIGURE 3**

condition and grow up blind without the operation. When the technique was first developed, there were many adults who had been blind from birth due to this condition and on whom surgery to restore their vision was performed.

Their experiences on first seeing have been described by John Z. Young[1]:

> What would such a person see; what would he say, on first opening his eyes on a new world? During the present century the operation has been done often enough for systematic and accurate reports to be collected. The patient on opening his eyes for the first time gets little or no enjoyment; indeed, he finds the experience painful. He reports only a spinning mass of lights and colours. He proves to be quite unable to pick out objects by sight, to recognize what they are, or to name them. He has no conception of a space with objects in it, although he knows all about objects and their names by touch. "Of course," you will say, "he must take a little time to learn to recognize them by sight." Not a *little* time, but a very, very long time, in fact, years. His brain has not been trained in the rules of seeing. We are not conscious that there are any such rules; we think that we see, as we say, "naturally." But we have in fact learned a whole set of rules during childhood.
>
> If our blind man is to make use of his eyes he, too, must train his brain. How can this be done? Unless he is quite clever and very persistent he may never learn to make use of his eyes at all. At first he only experiences a mass of colour, but gradually he learns to distinguish shapes. When shown a patch of one colour placed on another he will quickly see that there is a difference between the patch and its surroundings. What he will not do is to recognize that he has seen that particular shape before, nor will he be able to give it its proper name. For example, one man when shown an orange a week after beginning to see said that it was gold. When asked, "What shape is it?" he said, "Let me touch it and I will tell you!" After doing so, he said that it was an orange. Then he looked long at it and said, "Yes, I can see that it is round." Shown next a blue square, he said it was blue and round. A triangle he also described as round. When the angles were pointed out to him he said, "Ah. Yes, I understand now, one can *see* how they feel." For many weeks and months after beginning to see, the person can only with great difficulty distinguish between the simplest shapes, such as a triangle and a square. If you ask him how he does it, he may say, "Of course if I look carefully I see that there are three sharp turns at the edge of the one patch of light, and four on the other." But he may add peevishly, "What on earth do you mean by saying that it would be useful to know this? The difference is only very slight and it takes me a long time to work it out. I can do it much better with my fingers." And if you show him the two next day he will be quite unable to say which is a triangle and which a square.
>
> The patient often finds that the new sense brings only a feeling of uncertainty and he may refuse to make any attempt to use it unless forced to do so. He does not spontaneously attend to the details of shapes. He has not learned the rules, does not know which features are significant and useful for naming objects and conducting life. Remember that for him previously shapes have been named only after feeling the disposition of their edges by touch. However, if you can convince him that it is worth while, then, after weeks of practice, he will name simple objects by sight. At first they must be seen always in the same colour and at the same angle. One man having learned to name an egg, a potato, and a cube of sugar when he saw them, could not do it when they were put in yellow light. The lump of sugar was named when on the table but not when hung up in the air with a thread. However, such people can gradually learn; if sufficiently encouraged they may after some years develop a full visual life and be able even to read. (pp. 61–63)



It is apparent that seeing—the sense we think of as most directly putting us in touch with facts—is learned rather than automatic. We see with our minds, not with our eyes, and we are subject to whatever unconscious biases and misconceptions are produced by the training that teaches us to see.

We are not arguing a case for disbelieving what we see. We have no choice, really. However, being aware that perception is not passive observation but rather a learned use of our intellectual faculties, however unconsciously it is done, should alert us to the possibility that things need not be what they seem, and that changes in our own thinking may change what we see.

## FACTS ARE "THEORY LADEN"

In addition to the unconscious cultural component in our perception of fact, most scientific facts contain a consciously chosen and analyzable component of prior knowledge and theory.

Consider the simple-sounding statement, "This stone weighs 3 pounds." There is implied here the acceptance of a whole body of scientific laws and agreed-on procedures. Briefly, we start with the subjective sensation of heaviness felt by the muscles when lifting something. Then we learn by experience that heaviness is an invariant property of most solid things: a stone that was heavy yesterday is heavy today. This is a primitive statement of an important scientific principle: the conservation of mass. Next we establish a criterion of equality of "heaviness" by constructing a balance to compare weights. We are now introducing the concept of the lever. We note that equally "heavy" things (as judged by our muscles) placed at equal distances from the central pivot of our lever tend to balance. Then we choose one object as a standard, and call it, say, 1 pound. Anything that balances it on our set of scales also weighs 1 pound. Then we *define* a weight of 2 pounds as anything that balances two 1-pound objects placed together on one side of the scale, and so forth. There is thus a lot of physics in the statement, "This stone weighs 3 pounds." That it really weighs 3 pounds is an objective fact, verifiable by any observer who wants to take the trouble to do so, but it would be misleading to call it a fact of nature: it is too man-made. It didn't exist until we invented it. This feature of facts is often described by saying that facts are "theory laden."

So we recognize that there is a difference between the commonsense view of "facts" as hard, inescapable, unchangeable things and the reality in science where the things we call facts are fuzzier. Facts have a culturally conditioned component and are partly created by the theories we hold, and thus are subject to change if the theories themselves are changed.

## HOW FACTS ARE USED

As an outgrowth of the commonsense view of "the facts" as being fixed and unchangeable, there have grown certain misconceptions of how facts are used in science. It is often said, for example, that theories must agree with *all* the facts; unless they do, they are wrong. This, as we will see, has very little relation to how science proceeds. This statement ignores the reality that the world is composed of an absolutely enormous number of facts: every grain of sand on a beach is different from every other; no two weigh exactly the same or have the same shape. Yet the weight and shape of each one are separate facts. No theory can be expected to explain such a multitude of things; we must be content with much less.

But suppose we modify the statement to mean that we select a group of facts out of the infinite variety the world presents us with—don't we demand that our theory at least explain all of these? The answer is no. The facts we select are in large part determined by some theory or preconception as to what facts are important and what facts are not. We will see in this book examples of conflicts between theories that lasted for long periods of time. If choosing between theories were a simple matter of finding which one agreed with a limited number of facts, the conflicts would have ended quickly. The reason they could drag on so long is that different scientists disagreed about which facts were the important ones to explain.

There is a common view of science that it consists of collections of experimentally verifiable facts arranged in some orderly manner. It has been pointed out that a telephone book or a railroad timetable is an orderly collection of facts but it is not science.[2] What we seek in science, as noted earlier, are general statements of explanatory power from which a multitude of verifiable facts can be deduced.



## HOW SCIENCE BEGINS

Science does not begin with facts; it begins with the perception of a problem and the belief in the possibility of an answer. Astronomy did not begin with the gathering of data on the motion of the sun, moon, and stars; it began with the belief that knowledge of such motions was worth having. Why the Babylonians of 5000 years ago wanted such information can be only a matter of conjecture, but it must have involved religious beliefs, astrological hypotheses about the influence of the stars on the course of history or the lives of men, or the idea that knowledge of the motion of the heavenly bodies had some practical predictive value here on earth. Certainly knowledge of the phases of the moon is useful; the position of stars and the sun in the sky correlates with the season of the year and therefore can be used to predict the timing of events that recur annually.

Once a problem is perceived and formulated, does the gathering of facts begin then? It was once believed that science could be reduced to a precise methodology that could be applied to the facts in a mechanical way by anyone wanting to determine the cause of a given phenomenon. This view was first expressed by Francis Bacon,[3] and formulated much later in a set of "Methods of Experimental Inquiry" by John Stuart Mill.[4] The procedure Mill proposed is to consider as many instances of the occurrence of a phenomenon as one wishes to explain, and examine all the circumstances or facts attending each occurrence. Those circumstances that are absent from some occurrence of the phenomenon cannot be the cause of it. Ultimately, if the phenomenon has a single cause, only that circumstance that is present every time it occurs and absent every time it does not can be the cause.

The above statement is perfectly plausible, but useless. It is useless because the number of circumstances attending a phenomenon is infinite and no criteria of relevance are provided. Relevance requires some prior hypothesis, and the method proposed offers no directions for forming hypotheses. Yet no science is possible otherwise.

## COLLECTING ALL THE FACTS

Let us take an example. It is desired to find the cause of lung cancer. One therefore locates as many people with lung cancer as possible and an equal number of people who do not have the disease, and starts to list the circumstances attending each case: age, sex, employment, ethnic origin, smoking history, dietary habits, income, the number, age, and sex of children, marital status, neighborhood lived in, type of house lived in, number of rooms, type of furniture, street, age of parents and cause of their death, details of education, model of car driven, likes and dislikes in books and music, etc. One sees very quickly that the list has no end. Further, under each category there are a tremendous number of individual details. If one objects that most of the details are irrelevant, the answer must be, "How do we know?" It is only because we already have some feeling, even if hazy, as to possible causes of cancer that we can rule out most of the detailed circumstances of the list. Needless to say, many of the great scientific discoveries resulted from recognizing the relevance of facts that were previously overlooked and putting aside facts previously considered important.

## THE FACTS ABOUT MOTION

Consider the facts about motion known to the ancient world. Here on earth motion tends to come to a stop unless some agent acts to keep it going. A stone rolling downhill comes to rest sometime after it has reached level ground. An arrow shot from a bow eventually falls to the earth. Living things die and cease moving. When the winds stop blowing, the ocean becomes calm. However, in the sky the heavenly bodies keep moving, most of them in regular paths, with no sign of slowing down. These facts clearly show that the heavenly bodies in their motion obey different laws than do things here on earth. And down here it is clear that motion occurs only if there is an agent to cause it; when the agent stops acting, the motion stops.

However, the laws that govern motion were found not by listing these facts and then drawing an obvious conclusion but rather by making an imaginative leap that went beyond the facts and was not contained in them. It consisted of looking at the facts in a new way—of guessing that motion on earth stops not because of the absence of an agent to produce it but rather because of the active presence of an agent to stop it—namely, the friction that is always present to resist motion taking place on earth. Once this step was taken, laws that apply equally to the heavenly bodies and to objects on earth could be discovered.



## WHICH FACTS ARE RELEVANT?

Let us consider another example. Suppose members of one family were all suddenly struck by a serious illness, followed by death within a day or two. What facts would we gather to explain this? In an earlier era the following might have been considered. Are there any people living in the neighborhood known as casters of spells whom this family might have offended? Are there any Jews, gypsies, or other strangers living nearby? Is any member of this family guilty of some serious sin such as adultery or sacrilege? Today we have other hypotheses about disease, and we look for other circumstances, but the hypotheses we start with still determine which facts we look for. Mill's Methods of Inquiry are useful only if we have rival hypotheses and must choose between them. The hypotheses come first.

This point can be made more concisely by some dialogue from a Sherlock Holmes story [(5)]:

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|---|---|
| [Colonel Ross:] | "Is there any other point to which you would wish to draw my attention?" |
| [Holmes:] | "To the curious incident of the dog in the night-time." |
| [Colonel Ross:] | "The dog did nothing in the night-time." |
| [Holmes:] | "That was the curious incident."(p. 25) |

The circumstance noted by Holmes was to Colonel Ross not a circumstance at all, yet this nonfact was the key to the solution: the crime was committed by someone known to the dog.

Thus, we conclude that, although facts indeed are stubborn things, they are inextricably interwoven with our prior hypotheses and our cultural prejudices. It is best to think of them as having a man-made component rather than being purely objective facets of an already existing nature, although they can be as tangible and inescapable as such other man-made objects as 10-ton trucks.

## SCIENCE AND PUBLIC FACTS

So facts are not really independent of the observer and his theories and preconceptions. However, at any one time, in any one culture, it is usually possible for most observers to agree on them. To put it better, *facts are what all observers agree on.*

This statement implies something crucial about those facts with which science is concerned: they must have more than one observer. There must be a group of observers that anyone can join—it can't be a private club. Of course, joining the club imposes duties. Often, one cannot judge the truth of some claimed observation without going to the trouble of learning a lot of things that most people do not automatically know. Is the sparkplug removed from the motor of this car burned out or not? This is a question of fact, but not everyone knows offhand how to verify it. One must be not only an observer but also an informed and interested observer.

This allows for the possibility that the informed and interested observers could all be wrong. It has happened in the past and will happen again. But it is the best we can do, and it is what makes science possible.

## REFERENCE NOTES

1. John Z. Young, *Doubt and Certainty in Science*, Oxford University Press, New York, 1960. Reprinted by permission of the publisher.
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4. E. Nagel, Ed., *John Stuart Mill's Philosophy of Scientific Method*, Hafner, New York, 1950.
5. A. Conan Doyle, Silver Blaze, in: *Sherlock Holmes. Selected stories by Sir Arthur Conan Doyle*, The World's Classics: Oxford University Press, London, 1951.

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PART II

# Case Histories