PART I

WHAT CAN WE KNOW AND HOW DO WE KNOW IT?

THE INTRODUCTORY SECTION OF THIS BOOK EXPLORES THE DIFFERENCE between scientific knowledge and religious knowledge. It introduces the particular use of language peculiar to each discipline and explores the methods of each. The role of philosophy in guiding the attitudes and presuppositions of both scientists and theologians will receive attention. This introduction will be designed to expose prejudices and to illustrate the limitations of each way of knowing while laying a foundation for developing an appreciation for the contributions of each.

Scientific texts begin with the assumption that the universe is knowable. One reason that this assumption developed in the West was the Christian concept of a knowable God who created a knowable universe. Since science deals with the physical, a person has to be careful not to assume that the physical universe is all that exists. The relationship between observation, models, theories, and laws will be examined. The philosophical contributions of Aristotle to ways of knowing will be explored.

People all over the world have religious experience that makes them aware of the reality of a spiritual realm they cannot see. More importantly, the tacit dimension of faith makes people aware of the personal nature of this spiritual realm. This section explores the difference between faith and other kinds of knowledge. This section also explores the philosophical contribution of Plato to the Western debate about the nature of reality.

How does our philosophy affect how we interpret our world? In many ways the conflicts of science and religion come not from the methodology of science or the pages of Scripture. Instead, the conflict tends to come from the philosophy of science and the philosophy of religion.

Chapter One

THE SCIENTIFIC WAY OF KNOWING

WHY SHOULD WE BE INTERESTED IN THE SCIENTIFIC WAY OF KNOWING? We live in a world that is greatly influenced by science. If we consider the world one hundred years ago, we see that science and technology have moderated the effects of disease, have affected how we work and play, have changed the way we travel, have made war much more destructive, and have expanded our views beyond our birth region to the world and beyond. In addition, science has changed how we view our relationship to the animals of our planet. The evolutionary concept of a common ancestor permeates the thinking of our culture. Thus, it is very important for an informed person to understand the philosophical underpinnings for the development of modern science in the West, to identify the limitations of the scientific way of knowing, and to examine what really happens when scientists carry out experiments. This chapter will provide you with the information needed to understand the scientific way of knowing.

Philosophical Basis

Let us consider a couple of recent events to get a feel for the scientific way of knowing. On August 7, 1996, scientists at NASA announced the results of an analysis of a meteorite (ALH84001) discovered in Antarctica. They announced that their analysis revealed that the meteorite was 3.6 billion years old, had structures that looked like fossilized bacteria, and was from Mars. Wait a minute! How come scientists assume that they have tools to deal with very old rocks or rocks from another planet? Science is based on an undergirding concept: that the universe is knowable, is regular, is predictable, and is uniform. It does not matter whether the rock is young or old, terrestrial or Martian; scientists assume that the same physical and chemical processes were and are at work. This undergirding concept is a philosophical concept that provides the framework within which science works. Scientists assume it, but it is a concept that cannot be analyzed by science.

How did this undergirding philosophical concept arise? Or put another way, why did modern science arise in the West during the Reformation and Renaissance? Alfred North Whitehead said it grew out of the biblical worldview that viewed the universe as a product of divine creation. As we consider Whitehead's proposal, let us consider some other worldviews. Ancient Greek culture provided a fertile ground for scientific ideas that resulted in a number of important concepts: Aristotle (observations), Plato (theory), Pythagoras (mathematics), Archimedes (technology), and Ptolemy (astronomy). Yet science as we know it today did not develop in ancient Greece. Why? Because behind every event, there were the gods and goddesses. Whether there was rain or drought depended upon the mood of the god or goddess, not upon observable natural phenomena. Thus, to the Greeks there was no regularity to study.

What about the Chinese? In 1983, at an exhibit at Chicago's Museum of Science and Industry entitled "China: 7000 Years of Discovery," Jimmy Davis observed these discoveries and achievements: compass, gunpowder, rockets, papermaking, printing, silk, accurate astronomy records, and ships much larger than Columbus's ships which had reached the tip of Africa by the 1430s. Yet institutional science did not develop in China. Why? The Chinese were never convinced that humans could understand the divine code that rules nature. To them true reality was behind the appearance of the physical world.

Why did the Christian view of a divine creator lead to institutional science during the Reformation and Renaissance? This concept of a divine creator led to several reasons to study nature. The Christian believes that nature is really there and has value because God created it; this view would be antithetical to other worldviews such as Zen Buddhism. The view that nature is a creation of God and not a god itself removed the fear of studying nature; it would be dangerous, maybe fatal, to probe or dissect a tree if it was divine. The view of God as a moral lawgiver encouraged the Christian scientist to look for natural laws. Also, the Christian view of God as eternal and omnipresent leads to the thought that these natural laws would be uniform through the universe; the same laws should apply on earth as well as in the heavens.

The Christian scientist's belief in a creator God also encouraged the development of experimental science. Their belief that humanity was created in the image of God led to the realization that humanity should have powers of observation and reasoning necessary to gain reliable information about the universe. A further support for experimention was the concept of *creatio ex nihilo*, which is that God created the universe out of nothing. The concept of *creatio ex nihilo* meant that God was not constrained in the creation by preexisting matter. Thus, details of the universe must be found by observation rather than by rational deduction.

The belief in a creator God also encouraged the Christian scientist to develop technology. They believed that the Fall of mankind in the Garden of Eden had a destructive effect upon the human condition. They hoped that applying their scientific discoveries through technology would improve the human condition and somewhat alleviate the destructive effects of the Fall. Thus, science was permeated with religious concerns for the poor and sick.

Finally, the concept of a creator God opened to the Christian scientist another avenue for discovering information about God. Romans 1:20 (NRSV) states, "Ever since the creation of the world his eternal power and divine nature, invisible though they are, have been understood and seen through the things he has made." This led to the concept of the two books: book of revelation (the Bible) and book of creation (nature). Since both were written by God, both books are in harmony and are knowable.

Limitations and Domain of the Scientific Way of Knowing

Does the scientific way of knowing have limitations? Let us consider another recent event: scientific announcements about the Shroud of Turin. The shroud is a linen cloth with a faint image of what appears to be a crucified man that some believe is Christ. From 1978 to 1988, the Roman Catholic Church allowed scientists to examine the shroud. Scientific tests used were photo- and electron-microscopy, X-ray spectroscopy, ultraviolet fluorescence spectroscopy, thermography, chemical analysis, and carbon-14 dating. What kind of information could this scientific analysis provide? It could tell us the type and age of the cloth from which the shroud was made, the chemical nature of the image, whether the shroud had come in direct contact with a body, whether there was blood on the cloth, and whether the image contained brush strokes. Could the scientific analysis tell us whether Jesus was the Son of God? No, that would be outside the realm of the scientific way of knowing. Why? Because science deals with the properties of physical objects, the physical behavior of physical systems, and the formative history of earth and its inhabitants and of the entire universe.[1] Let us examine each category of inquiry in more detail.

- *Properties of Physical Objects.* Questions here might be: What is the surface temperature of the sun? What is the mass of an electron? Or what is the structure of the insulin molecule?
- *Physical Behavior of Physical Systems.* Questions here might be: What process maintains the sun's temperature? What happens when acids and bases combine? Or what occurs in nuclear decay?
- *Formative History.* Questions here might be: What events and processes have contributed to the formation of the Great Lakes? What occurred on Mars to form its craters? What is the history of life forms on the earth? Or what is the life cycle of a star?

Thus, we are saying that science can give us information about the natural or physical world and that the nonphysical is not an object of study for science. The natural sciences in no way deny the existence of other realms of reality; they merely restrict their attention to the physical realm.[2] This restriction largely results from the methods science has of acquiring data. As we will shortly see, modern science uses an *empirical* approach. An empirical approach is based on observation or experience. Thus, to examine something, the scientist must somehow physically interact with the object. Ways of physically interacting range from directly using our senses, such as touching an object, to indirectly using our senses, such as examining how electromagnetic radiation (light) interacts with an object. Anything that cannot be physically interacted with is thus outside the realm of science.

Some scientists have a tendency to go from only studying the physical to assuming that the physical is all there is.[3] A classical example of this is the beginning of Carl Sagan's book *Cosmos:* "The Cosmos is all that is or ever was or ever will be." Another version of this is to assume that only those questions that science can answer are meaningful. These statements are examples of the philosophy of naturalism, which consider nature the whole of reality that can only be understood by scientific investigation.

There are many very important questions that fall outside the physical. What is beauty? What is love? Is there a God? Why am I here? Even with these questions, some scientists will attempt to explain the nonphysical in physical terms. In regard to beauty and love, a scientist might propose an explanation that reduces the totality of beauty and love to the reaction of chemicals in one's brain. In our scientific age, this *reductionism* is everywhere. (Reductionism refers to the attempt to explain all biological processes by the same physical processes that chemists and physicists use to interpret inanimate matter.) While chemical reactions are involved in our response to beauty and love, the scientist has no scientific basis to restrict the discussion to the empirical or deny the existence of the *metaphysical.* (Metaphysical refers to a reality beyond what is perceptible to the senses.)

In regard to God and purpose, again the scientist may say neither exists because he or she restricts his or her analysis to the physical realm and claims not to see any purpose in nature. When the scientist states that only empirical explanations are valid, the scientist has left science and moved to philosophy. This philosophy is called *naturalism.*

The Scientific Method

Now that we have examined the domains and limitations of the scientific way of knowing, let's examine how scientists explore the physical universe. The general procedure is the scientific method.

Traditional View

The traditional view that we will discuss in this section was the dominant view of science from the seventeenth century to the middle of the twentieth century. It is still adhered to in some circles. As long ago as the fourteenth century, it was realized that humans have tendencies that are not always trustworthy.[4] Our emotions, hunches, prejudices, and traditions are not always reasonable guides to understanding the universe. By the sixteenth and seventeenth centuries, thinkers believed that methods could be developed to exclude these human tendencies. Francis Bacon (1561–1626) in 1620 in *Novum Organum* made the most influential early statement of a method of scientific analysis. The method must be:

- *Objective*: Speculation, politics, emotion, bias, preconception, etc. should be removed.
- *Empirical*: Observation was to be purely neutral, purely objective, reproducible, and the same for all observers. Nature would dictate the data.
- *Rational*: Scientific processes must be rigorously logical and mathematical.

No conclusions were to be accepted unless they were logically implied, rigorously confirmed, and empirically proven. How did one do this? Bacon proposed *induction*. In logic, induction is reasoning from a few members to the whole, from the particular to the general. Bacon proposed that one began by assembling a substantial collection of empirical data from observations and from experimentation. The collected data was to be organized and classified to lay bare the basic, simple principles of nature. An example is to collect data on the pressure and volume of a gas. Robert Boyle (1627–91), an early proponent of the scientific method and a founder of modern chemistry, collected such data as shown in Figure 1.1.

Pressure	Volume	1/V
48	29	0.0345
44	32	0.0313
40	35	0.0286
36	39	0.0256
32	44	0.0227
28	50	0.0200
24	59	0.0169
20	71	0.0141
16	88	0.0114
14	100	0.0100

Fig. 1.1. Boyle's Law: Experimental Data.

A common way to organize data like that in Figure 1.1 is to graph (plot) the data to determine if there is a *linear relationship* between the *variables*. In this example the pressure and volume are the variables; they may assume any one of a set of values. A linear

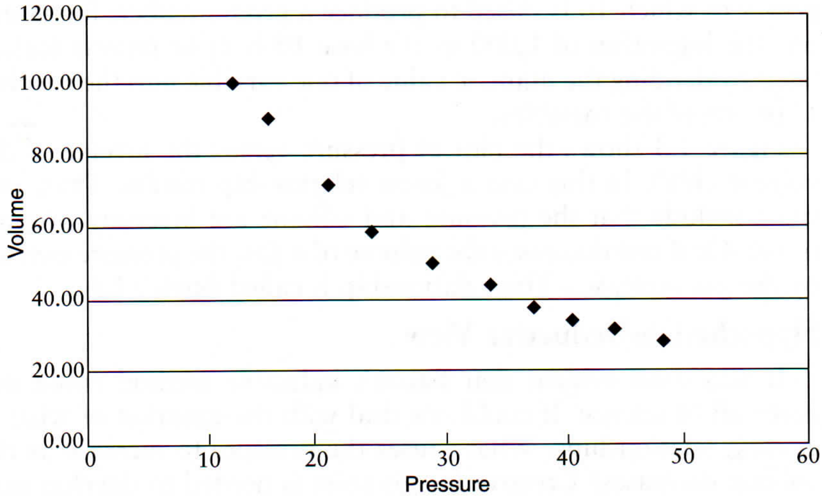

Fig. 1.2. Boyle's Law: Plot of Pressure versus Volume.

relationship results when an increase in one variable results in a corresponding increase in the other variable.

Figure 1.2 gives the plot of pressure versus volume; the result is a curve implying no linear relationship. If this simplest plot failed to give a linear relationship, then the scientist would try some mathematical transformation of one of the variables. The scientist might calculate the *logarithm* (the exponent that indicates the

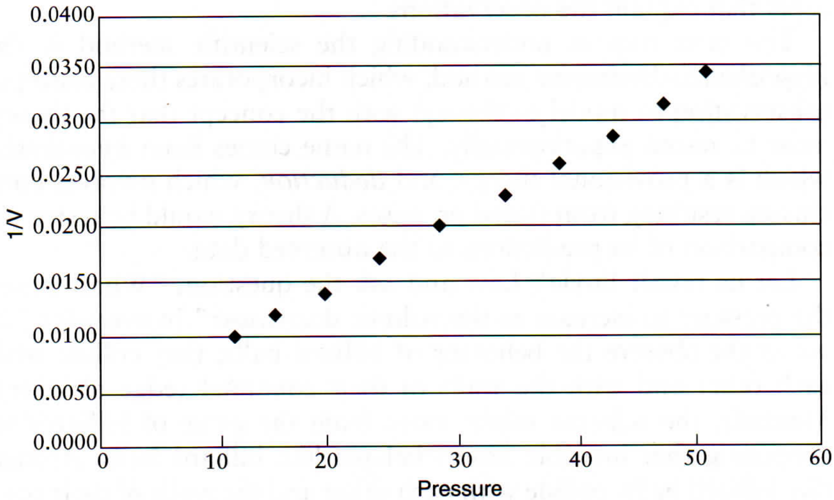

Fig. 1.3. Boyle's Law: Plot of Pressure versus Inverse of Volume.

power to which 10 is raised to produce a given number; for example, the logarithm of 1,000 to the base 10 is 3) or *inverse* (calculated by dividing the numeric value of one variable into the number 1) of one of the variables.

Figure 1.3 shows the plot of pressure versus the inverse of the volume (1/V). In this case a linear relationship results. Thus, one can conclude that the pressure and volume are inversely proportional. Or if one decreases the volume of a gas, the pressure exerted by the gas increases. This relationship is called Boyle's Law.

Hypothetico-Deductive View

It was soon evident that Bacon's inductive method could not cover all of science. It could not deal with the question of what is causing relationships. What causes the pressure to increase as the volume decreases? Creative imagination is needed to develop new concepts, often from *analogies* to everyday experiences.[5] An analogy is a resemblance in some particular property between things otherwise unlike, such as between a behavior of balls in a game of billiards and gas molecules. Bacon's inductive method does not guide the scientist in developing these explanatory concepts. These analogies develop into *models* that lead to generalized *theories.* Models are mental pictures for a system. Models are needed to help us visualize processes or objects that are too far away (planets), are too small (atoms), take too long to observe (coal formation), or contain too many particles (gases). Theories are overarching concepts that explain the observations.

The next step in understanding the scientific method is the *Hypothetico-Deductive* method, which incorporates these concepts (observation to model to theory) with the concept that the theory must be tested experimentally. The name comes from *hypothesis,* which is a provisional theory, and *deduction,* which involves conclusion resulting from stated premises. A theory would be tested by comparison of its predictions to the observed data.

Let us revisit Boyle's Law and ask the question, "What causes the pressure to increase as the volume decreases?" In everyday life we might observe the behavior of billiard balls; they collide with each other and with the walls of their container (edge of table). Mentally, the scientist might move from the game of billiards to proposing that invisible atoms behave like billiard balls. Atoms, like billiard balls, collide with each other and the walls of their container without sticking together; they collide and move on. This is the billiard-ball model of the atom. From this model of the atom came the Kinetic Theory of Gases which relates the *macroscopic* (visible) to the *microscopic* (invisible).

The macroscopic volume represents the amount of space within which the microscopic gas particles can move. The macroscopic pressure results from the average change in momentum experienced by the microscopic gas particles as they collide with and rebound from the walls of the container. (In the case of Boyle's Law, reducing the volume by half doubles the number of collisions and thus doubles the pressure. Daniel Bernoulli first explained this in 1738.) The macroscopic temperature is proportional to the average *kinetic energy* (energy associated with motion) of the microscopic particles. These relationships between macroscopic and microscopic events were used to determine all the empirical gas laws as well as the *thermal conductivity* (how fast an object increases in temperature), *diffusion* (how fast particles scatter), and *viscosity* (the property of resistance to flow in a fluid) of gases. This corroboration between the predictions of the theory and empirical data led to an acceptance of the Kinetic Theory of Gases.

Gradually, it came to be realized that empirical data can never prove a theory since there may be other theories that could agree with the data. Also, there is always the possibility that one more experiment could be run that might not turn out as expected. How then does a scientist assess a theory? The following discussion follows the arguments advanced by Ian Barbour.[6]

One criterion is still *agreement with data*. Agreement with data is the first criterion. If the theory does not agree with the data, then why continue to use it? A second criterion is *coherence* with other accepted theories. Interconnection of a proposed theory with other accepted theories increases the confidence of the scientific community. A third criterion is *elegance and simplicity*. These concepts go back to the ancient Greeks, who viewed nature as simple and elegant. Another label for this is *Occam's Razor,* formulated by the English scholastic William of Occam (1285–1349). Occum's Razor states that the simplest of competing theories is preferred to the more complex. Paul Dirac (1902–84), who made significant contributions to the development of quantum mechanics stated in the 1939 Scott Lecture to the Royal Society of Edinburgh that beauty is more important than simplicity. To Dirac, Newtonian mechanics represented simplicity while Einstein's special theory of relativity represented beauty. A fourth criterion is *scope*. How comprehensive is the theory? Does it unify diverse areas? A fifth criterion is *fruitfulness*. How well does it predict the outcomes of further experiments? Can it provide the road map for a research program? During a scientist's career, the scientist will use a combination of these criteria to assess a theory.

Once scientists recognized that empirical data cannot prove a theory, Karl Popper and others proposed that empirical data can only *falsify* a theory. Yet even disagreement of a theory with empirical data does not always lead to its abandonment. This does happen in some cases. A case of theory abandonment is the shift from the Ptolemy earth-centered theory of the universe to the Copernicus sun-centered theory of the universe. In other cases the theory may be modified. An example is Copernicus's sun-centered theory with circular orbits being changed to Kepler's sun-centered theory with elliptical orbits. Another example of this second case involves the Kinetic Theory of Gases. Real gases do not behave as the theory predicts in all cases; real gases become liquids or solids, which is not predicted by the Kinetic Theory and its billiard-ball atoms. The theory was modified by van der Waals to include the concept that gas particles interact with one another with attractive and repulsive forces. In some cases *ad hoc* auxiliary hypotheses are proposed. The Copernican theory should have resulted in a *parallax* (annual change in the apparent position of near stars relative to the stellar background). No parallax was observed in Copernicus's day. So Copernicus added a hypothesis that the stars are so far away that the parallax could not be seen with the instruments of his day. Copernicus had no empirical data on which to base his hypothesis.

Paradigm View

Through the work of Thomas Kuhn and others, we now realize that Bacon's desire for a totally objective science is impossible. We now know that theories influence observation. Theories guide the scientist in the selection of what to observe, the formulation of the type of questions to ask, and selection of the language to use to report the findings. In addition, we also realize that theories are *paradigm* dependent. A paradigm provides a framework or window that defines for a scientific discipline what kinds of questions to ask and the types of explanations to seek. Examples of paradigms are

Newtonian physics of the eighteenth century versus *relativity* and *quantum physics* of the twentieth century. In chemistry, examples would be that combustion is the liberation of *phlogiston* versus the view that the combustion is combination with oxygen.

Let's examine the two views of combustion to see how a paradigm and its theories directed scientific research. When one watches wood burn, one gets the impression that the wood loses something, leaving only an ash. Thus, combustion seems to result in the decomposition of a material with a loss of weight. The residue appears to be less compact than the starting material: wood and ash, iron and rust. In 1702, Johann Becher and Georg Stah of Germany proposed that combustible materials contain the substance phlogiston. Phlogiston escapes when a material burns. Air is necessary for combustion since the air absorbed the phlogiston that was released. The air does not get saturated with phlogiston because the plants remove phlogiston from the air. Thus, plants become saturated with phlogiston and burn when they are dry. Substances like coal must be composed almost entirely of phlogiston since they leave very little ash. Respiration is considered to be the removing of phlogiston from the organism.

The concept of phlogiston explains combustion and agrees with common-sense observations. The phlogiston idea directed the chemistry of its day. Chemists became interested in isolation and study of gases. Henry Cavendish discovered hydrogen (1766). Daniel Rutherford discovered nitrogen in 1772. Joseph Priestley (1733–1804) identified nitrous oxide, nitric oxide, carbon monoxide, sulfur dioxide, hydrogen chloride, ammonia, and oxygen. These discoveries were not expressed by the modern terms that we listed but in terms of phlogiston. Hydrogen was identified as phlogiston since it is light and very flammable. Oxygen was called dephlogisticated air (air without phlogiston) because wood burns stronger in it than air; this implied that it had more capacity to absorb more phlogiston than air.

Looking at combustion through the window (paradigm) of phlogiston did result in many important discoveries. However, the window caused chemists not to pursue certain questions. Questions concerning the relationship between masses of the materials before and after combustion were not pursued. Answers to these types of questions were not needed to understand combustion in the phlogiston paradigm. Once mass measurements were done, *anomalies* arose which ultimately challenged the phlogiston paradigm and led to its replacement by the concept that oxygen is needed for combustion.

The French chemist Antoine Lavoisier (1743–1794) repeated many of the gas experiments of earlier chemists. He collected weight (mass) data on the amounts of *reactants* and *products* involved in combustion. Lavoisier's most famous experiment involved repeating the experiment of Priestley, which had resulted in Priestley's discovery of dephlogisticated air (oxygen). Priestley had found that when he heated mercury calc (mercury oxide), mercury metal and a gas (dephlogisticated air) were produced. Lavoisier redesigned the experiment so he could determine the amounts of mercury calc, mercury, and gas involved in this process. He found that heating the mercury calc results in the production of mercury metal and a gas (which he called oxygen).

Lavoisier observed that the weight (mass) of the mercury calc equaled the weight of the products (mercury metal and oxygen). When the mercury metal produced by the previous reaction was heated with the oxygen, he found that mercury calc was produced. Lavoisier observed that the amount of oxygen required for this reaction equaled the amount of oxygen liberated by the original heating of the mercury calc. He further observed that the weight of the reactants (mercury metal and oxygen) equaled the weight of the product (mercury calc). On the basis of his careful measurements, Lavoisier concluded that combustion occurs by the addition of oxygen, thus increasing the mass. This discovery is today called the *Law of Conservation of Mass* (the mass of the products equals the mass of the reactants).

What allowed Lavoisier to approach this chemistry in a new light? Maybe it was the fact that Lavoisier was a businessman first, then a chemist. Could he have been applying the analogy of the balance sheet to the reaction of chemicals? Because of his work on the conservation of mass, Lavoisier is considered one of the founders of modern chemistry. But for his work as a tax collector he was guillotined by the French Revolution.

Lavoisier's experiments ultimately led to paradigm shifts: combustion is oxidation and chemical reactions involve the conservation of mass. However, many scientists could not make the shift to the new paradigm. Priestley spent the rest of his life fighting for phlogiston and against oxidation. This is an example of where the paradigm is so strong that one cannot see the data in any other way. In the case of Priestley and Lavoisier, they both had the same observations. Yet theories and paradigms colored how they saw these observations and the type of experiments they did to support their points of view. Bacon's hope for unbiased, objective, empirical science will always be constrained by the paradigm of the scientist.

Summary

Science is based on the philosophical concept that the universe is knowable, predictable, and uniform. Science cannot develop in a capricious universe. Historically, the worldview that supported the development of science was Christianity with its concept of a Creator and a knowable, created universe. This worldview also supported the development of technology to reduce the suffering of people. Science is empirical and thus limited to dealing with the physical universe. Scientists have to be careful not to assume that only the physical is important. Scientists also have to be careful not to give metaphysical statements in the guise of science. The modern scientific way of knowing began with a desire to be objective, empirical, and rational as the scientist organizes data using induction. Gradually, scientists realized that imagination, analogies, models, and theories were needed to develop explanatory concepts. A scientist's theories and paradigms influence the selection of what to observe, the type of questions to ask, and the language used to report findings.