FRAUDS, MYTHS, AND MYSTERIES:

Science and Pseudoscience in Archaeology

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Epistemology: How You Know What You Know

Knowing Things

The word *epistemology* means the study of knowledge—how you know what you know. Think about it. How does anybody know anything to be actual, truthful, or real? How do we differentiate the reasonable from the unreasonable, the meaningful from the meaningless—in archaeology or in any other field of knowledge? Everybody knows things, but how do we really know these things?

I know that there is a mountain in a place called Tibet. I know that the mountain is called Everest, and I know that it is the tallest land mountain in the world (there are some a bit taller under the ocean). I even know that it is precisely 29,028 feet high. But I have never measured it; I've never even been to Tibet. Beyond this, I have not measured all of the other mountains in the world to compare them to Everest. Yet I am quite confident that Everest is the world's tallest peak. But how do I know that?

On the subject of mountains, there is a run-down stone monument on the top of Bear Mountain in the northwestern corner of Connecticut. The monument was built toward the end of the nineteenth century and marks the "highest ground" in Connecticut (Figure 2.1). When the monument was built to memorialize this most lofty and auspicious of peaks—the mountain is all of 2,316 feet high—people knew that it was the highest point in the state and wanted to recognize this fact with the monument.

There is only one problem. In recent times, with more accurate, sophisticated measuring equipment, it has been determined that Bear Mountain is not the highest point in Connecticut. The slope of Frissell

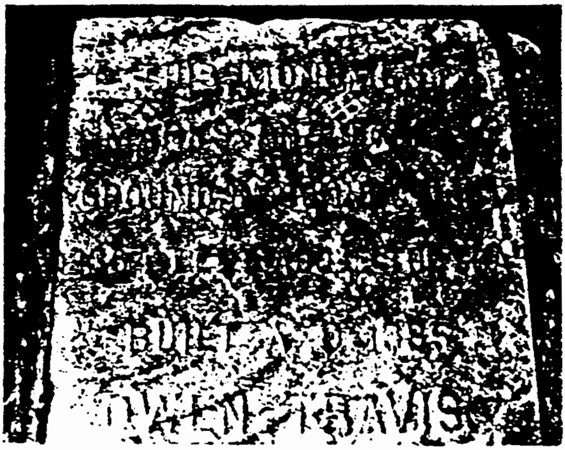

Figure 2.1 Plaque adorning a stone monument perched atop Bear Mountain in the northwest corner of Connecticut. Note that the height of the mountain is given as 2,354 feet (it actually is only 2,316 feet) and, in either case, though memorialized as "the highest ground" in the state, it is not.

Mountain, which actually peaks in Massachusetts, reaches a height of 2,380 feet on the Connecticut side of the border, eclipsing Bear Mountain by about 64 feet.

So, people in the late 1800s and early 1900s "knew" that Bear Mountain was the highest point in Connecticut. Today we *know* that they really did not "know" that, because it really was not true—even though they thought it was and built a monument saying so.

Now, suppose that I read in a newspaper, hear on the radio, or see on television a claim that another mountain has been found that is actually ten (or fifty, or ten thousand) feet higher than Mount Everest. Indeed, recently, new satellite data convinced a few, just for a while, that a peak neighboring Everest was, in actuality, slightly higher. You and I have never been to Tibet. How do we know if these reports are true? What criteria can we use to decide if the information is correct or not? It all comes back to epistemology. How indeed do we know what we think we "know"?

Collecting Information: Seeing Isn't Necessarily Believing

In general, people collect information in two ways:

1. Directly through their own experiences
2. Indirectly through specific information sources like friends, teachers, parents, books, TV, etc.

People tend to think that number 1—obtaining firsthand information, the stuff they see or experience themselves—is always the best way. This is unfortunately a false assumption because most people are poor observers.

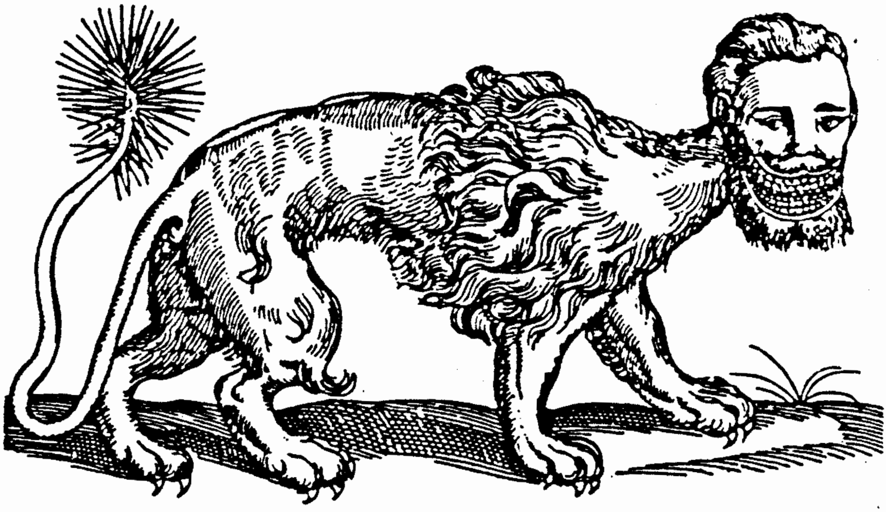

Figure 2.2 A seventeenth-century rendition of a clearly mythological beast—a *Mantichora.* The creature was considered to be real, described as being the size of a wild ass, as having quills on its tail that it could hurl at adversaries, and as having a fondness for human flesh.

For example, the list of animals alleged to have been observed by people that turn out to be figments of their imaginations is staggering. It is fascinating to read Pliny, a first-century thinker, or Topsell, who wrote in the seventeenth century, and see detailed accounts of the nature and habits of dragons, griffins, unicorns, mermaids, and so on (Byrne 1979). People claimed to have seen these animals, gave detailed descriptions, and even drew pictures of them (Figure 2.2). Many folks read their books and believed them.

Some of the first European explorers of Africa, Asia, and the New World could not decide if some of the native people they encountered were human beings or animals. They sometimes depicted them with hair all over their bodies and even as having tails (see Chapter 5).

Neither are untrained observers very good at identifying known, living animals. A red or "lesser" panda escaped from the zoo in Rotterdam, Holland, in December 1978. Red pandas are very rare animals and are indigenous to India, not Holland. They are distinctive in appearance and cannot be readily mistaken for any other sort of animal. The zoo informed the press that the panda was missing, hoping the publicity would alert people in the area of the zoo and aid in its return. Just when the newspapers came out with the panda story, it was found, quite dead, along some railroad tracks adjacent to the zoo. Nevertheless, over one hundred sightings of the panda *alive* were reported to the zoo from all over the Netherlands *after* the animal was obviously already dead. These reports did not stop until several days after the newspapers announced the discovery of the dead panda (van Kampen 1979). So much for the absolute reliability of firsthand observation.

Collecting Information: Relying on Others

When we explore the problems of secondhand information, we run into even more complications. Now we are not in place to observe something firsthand; we are forced to rely on the quality of someone else's observations, interpretations, and reports—as with the question of the height of Mount Everest. How do we know what to believe? This is a crucial question that all rational people must ask themselves, whether talking about medicine, religion, archaeology, or anything else. Again, it comes back around to epistemology; how do we know what we think we know, and how do we know what or whom to believe?

Science: Playing by the Rules

There are ways to knowledge that are both dependable and reliable. We might not be able to get to absolute truths about the meaning of existence, but we can figure out quite a bit about our world—about chemistry and biology, psychology and sociology, physics and history, and even prehistory. The techniques we are talking about to get at knowledge that we can feel confident in—knowledge that is reliable, truthful, and factual—are referred to as *science*.

In large part, science is a series of techniques used to maximize the probability that what we think we know really reflects the way things are, were, or will be. Science makes no claim to have all the answers or even to be right all of the time. On the contrary, during the process of the growth of knowledge and understanding, science is often wrong. The only claim that we do make in science is that if we honestly, consistently, and vigorously pursue knowledge using some basic techniques and principles, the truth will eventually surface and we can truly know things about the nature of the world in which we find ourselves.

The question then is, What exactly is science? If you believe Hollywood, science is a mysterious enterprise wherein old, white-haired, rather eccentric bearded gentlemen labor feverishly in white lab coats, mix assorted chemicals, invent mysterious compounds, and attempt to reanimate dead tissue. So much for Hollywood. Scientists don't have to look like anything in particular. We are just people trying to arrive at some truths about how the world and universe work. While the application of science can be a slow, frustrating, all-consuming enterprise, the basic assumptions we scientists hold are really very simple. Whether we are physicists, biologists, or archaeologists, we all work under four underlying principles. These principles are quite straightforward, but equally quite crucial.

1. There is a real and knowable universe.
2. The universe (which includes stars, planets, animals, and rocks, as well as people, their cultures, and their histories) operates according to certain understandable rules or laws.
3. These laws are immutable—that means they do not, in general, change depending on where you are or "when" you are.
4. These laws can be discerned, studied, and understood by people through careful observation, experimentation, and research.

Let's look at these assumptions one at a time.

There Is a Real and Knowable Universe

In science we have to agree that there is a real universe out there for us to study—a universe full of stars, animals, human history, and prehistory that exists whether we are happy with that reality or not.

The Universe Operates According to Understandable Laws

In essence, what this means is that there are rules by which the universe works: stars produce heat and light according to the laws of nuclear physics; nothing can go faster than the speed of light; all matter in the universe is attracted to all other matter (the law of gravity).

Even human history is not random but can be seen as following certain patterns of human cultural evolution. For example, the development of complex civilizations in Egypt, China, India/Pakistan, Mesopotamia, Mexico, and Peru was not based on random processes (Lamberg-Karlovsky and Sabloff 1979; Haas 1982). Their evolution seems to reflect similar general patterns. This is not to say that all of these civilizations were identical, any more than we would say that all stars are identical. On the contrary, they existed in different physical and cultural environments, and so we should expect that they be different. However, in each case the rise to civilization was preceded by the development of an agricultural economy. In each case, civilization was also preceded by some degree of overall population increase as well as increased population density in some areas (in other words, the development of cities). Again, in each case we find monumental works (pyramids, temples), evidence of long-distance trade, and the development of mathematics, astronomy, and methods of record keeping (usually, but not always, in the form of writing). The cultures in which civilization developed, though some were unrelated and independent, shared these factors because of the nonrandom patterns of cultural evolution.

The point is that everything operates according to rules. In science we believe that, by understanding these rules or laws, we can understand stars, organisms, and even ourselves.

The Laws Are Immutable

That the laws do not change under ordinary conditions is a crucial concept in science. A law that works here, works there. A law that worked in the past will work today and will work in the future.

For example, if I go to the top of the Leaning Tower of Pisa today and simultaneously drop two balls of unequal mass, they will fall at the same rate and reach the ground at the same time, just as they did when Galileo performed a similar experiment in the seventeenth century. If I do it today, they will. Tomorrow, the same. If I perform the same experiment countless times, the same thing will occur because the laws of the universe (in this case, the law of gravity) do not change through time. They also do not change depending on where you are. Go anywhere on the earth and perform the same experiment—you will get the same results (try not to hit any pedestrians or you will see some other "laws" in operation). This experiment was even performed by U.S. astronauts on the moon. A hammer and a feather were dropped from the same height, and they hit the surface at precisely the same instant (the only reason this will not work on earth is because the feather is caught by the air and the hammer, obviously, is not). We have no reason to believe that the results would be different anywhere, or "anywhen" else.

If this assumption of science, that the laws do not change through time, were false, many of the so-called historical sciences, including prehistoric archaeology, could not exist.

For example, a major principle in the field of historical geology is that of *uniformitarianism*. It can be summarized in the phrase, "the present is the key to the past." Historical geologists are interested in knowing how the various landforms we see today came into being. They recognize that they cannot go back in time to see how the Grand Canyon was formed. However, since the laws of geology that governed the development of the Grand Canyon have not changed through time, and since these laws are still in operation, they do not need to. Historical geologists can study the formation of geological features today and apply what they learn to the past. The same laws they can directly study operating in the present were operating in the past when geological features that interest them first formed.

The present that we can observe is indeed the "key" to the past that we cannot. This is true because the laws or rules that govern the universe are constant—those that operate today operated in the past. This is why science does not limit itself to the present, but makes inferences about the past and even predictions about the future (just listen to the weather report for an example of this). We can do so because we can study modern, ongoing phenomena that work under the same laws that existed in the past and will exist in the future.

This is where science and theology are often forced to part company and respectfully disagree. Remember, science depends on the constancy of the laws that we can discern. On the other hand, advocates of many religions, though they might believe that there are laws that govern things (and which, according to them, were established by a Creator), usually (but not always) believe that these laws can be changed at any time by their God. In other words, if God does not want the apple to fall to the ground, but instead, to hover, violating the law of gravity, that is precisely what will happen. As a more concrete example, scientists know that the heat and light given off by a fire results from the transformation of mass (of the wood) to energy. Physical laws control this process. A theologian, however, might agree with this ordinarily, but feel that if God wants to create a fire that does not consume any mass (like the "burning bush" of the Old Testament), then this is exactly what will occur. Most scientists simply do not accept this assertion. The rules are the rules. They do not change, even though we might sometimes wish that they would.

The Laws Can Be Understood

This may be the single most important principle in science. The universe is knowable. It may be complicated, and it may take years and years to understand even apparently simple phenomena. However, little by little, bit by bit, we expand our knowledge. Through careful observation and objective research and experimentation, we can indeed know things.

So, our assumptions are simple enough. We accept the existence of a reality independent of our own minds, and we accept that this reality works according to a series of unchanging laws or rules. We also claim that we can recognize and understand these laws or at least recognize the patterns that result from these universal rules. The question remains then: how do we do science—how do we explore the nature of the universe, whether our interest is planets, stars, atoms, or human prehistory?

The Workings of Science

We can know things by employing the rules of logic and rational thought. Scientists—archaeologists or otherwise—usually work through a combination of the logical processes known as *induction* and *deduction*. The dictionary definition of induction is "arguing from specifics to generalities," while deduction is defined as the reverse, arguing from generalities to specifics.

What is essential to good science is objective, unbiased observations—of planets, molecules, rock formations, archaeological sites, and so on. Often, on the basis of these specific observations, we induce explanations called *hypotheses* for how these things work.

For example, we may study the planets Mercury, Venus, Earth, and Mars (each one presents specific bits of information). We then induce general rules about how we think these inner planets in our solar system were formed. Or, we might study a whole series of different kinds of molecules and then induce general rules about how all molecules interact chemically. We may study different rock formations and make general conclusions about their origin. We can study a number of specific prehistoric sites and make generalizations about how cultures evolved.

Notice that we cannot directly observe planets forming, the rules of molecular interaction, rocks being made, or prehistoric cultures evolving. Instead, we are inducing general conclusions and principles concerning our data that seem to follow logically from what we have been able to observe.

This process of induction, though crucial to science, is not enough. We need to go beyond our induced hypotheses by testing them. If our induced hypotheses are indeed valid—that is, if they really represent the actual rules according to which some aspect of the universe (planets, molecules, rocks, ancient societies) works—they should be able to hold up under the rigors of scientific hypothesis testing.

Observation and suggestion of hypotheses, therefore, are only the first steps in a scientific investigation. In science we always need to go beyond observation and hypothesizing. We need to set up a series of "if . . . then" statements; "if" our hypothesis is true "then" the following deduced "facts" will also be true. Our results are not always precise and clear-cut, especially in a science like archaeology, but this much should be clear—scientists are not just out there collecting a bunch of interesting facts. Facts are always collected within the context of trying to explain something or in trying to test a hypothesis.

As an example of this logical process, consider the health effects of smoking. How can scientists be sure that smoking is bad for you? After all, it's pretty rare that someone takes a puff on a cigarette and immediately drops dead. The certainty comes from a combination of induction and deduction. Observers have noticed for about three hundred years that people who smoked seemed to be more likely than people who did not to get certain diseases. As long ago as the seventeenth century, people noticed that habitual pipe smokers were subject to tumor growths on their lips and in their mouths. From such observations we can reasonably, though tentatively, induce a hypothesis of the unhealthfulness of smoking, but we still need to test such a hypothesis. We need to set up "if . . . then" statements. If, in fact, smoking is a hazard to your health (the hypothesis we have induced based on our observations), then we should be able to deduce some predictions that must also be true. Sure enough, when we test specific, deduced predictions like

1. Smokers will have a higher incidence than nonsmokers of lung cancer
2. Smokers will have a higher incidence of emphysema
3. Smokers will take more sick days from work
4. Smokers will get more upper respiratory infections
5. Smokers will have diminished lung capacity
6. Smokers will have a shorter life expectancy

we see that our original, induced hypothesis—cigarette smoking is hazardous to your health—is upheld.

That was easy, but also obvious. How about an example with more mystery to it, one in which scientists acting in the way of detectives had to solve a puzzle in order to save lives? Carl Hempel (1966), a philosopher of science, provided the following example in his book *The Philosophy of Natural Science.*

The Case of Childbed Fever

In the 1840s things were not going well at the Vienna General Hospital, particularly in Ward 1 of the Maternity Division. In Ward 1 more than one in ten of the women brought in to give birth died soon after of a terrible disease called "childbed fever." This was a high death rate even for the 1840s. In one year 11.4 percent of the women who gave birth in Ward 1 died of this disease. It was a horrible situation and truly mystifying when you consider the fact that in Ward 2, another maternity division in the *same* hospital at the *same* time, only about one in fifty of the women (2 percent) died from this disease.

Plenty of people had tried their hand at inducing some possible explanations or hypotheses to explain these facts. It was suggested that more women were dying in Ward 1 due to "atmospheric disturbances," or perhaps it was "cosmic forces." However, no one had really sat down and considered the deductive implications of the various hypotheses—those things that would necessarily have been true if the proposed, induced explanation were in fact true. No one, that is, until a Hungarian doctor, Ignaz Semmelweis, attacked the problem in 1848.

Semmelweis made some observations in the maternity wards at the hospital. He noted some differences between Wards 1 and 2 and induced a series of possible explanations for the drastic difference in the mortality rates. Semmelweis suggested:

1. Ward 1 tended to be more crowded than Ward 2. The overcrowding in Ward 1 was the cause of the higher mortality rate there.
2. Women in Ward 1 were from a lower socioeconomic class and tended to give birth lying on their backs, while in Ward 2 the predominate position was on the side. Birth position was the cause of the higher mortality rate.
3. There was a psychological factor involved; the hospital priest had to walk through Ward 1 to administer the last rites to dying patients in other wards. This sight so upset some women already weakened by the ordeal of childbirth that it contributed to their deaths.
4. There were more student doctors in Ward 1. Students were rougher than experienced physicians in their treatment of the women, unintentionally harming them and contributing to their deaths.

These induced hypotheses all sounded good. Each marked a genuine difference between Wards 1 and 2 that might have caused the difference in the death rate. Semmelweis was doing what most scientists do in such a situation; he was relying on creativity and imagination in seeking out an explanation.

Creativity and imagination are just as important to science as good observation. But being creative and imaginative was not enough. It did not help the women who were still dying at an alarming rate. Semmelweis had to go beyond producing possible explanations; he had to test each one of them. So, he deduced the necessary implications of each:

1. If hypothesis 1 were correct, then cutting down the crowding in Ward 1 should cut down the mortality rate. Semmelweis tried precisely that. The result: no change. So the first hypothesis was rejected. It had failed the scientific test; it simply could not be correct.
2. Semmelweis went on to test hypothesis 2 by changing the birth positions of the women in Ward 1 to match those of the women in Ward 2. Again, there was no change, and another hypothesis was rejected.
3. Next, to test hypothesis 3, Semmelweis rerouted the priest. Again, women in Ward 1 continued to die of childbed fever at about five times the rate of those in Ward 2.

4. Finally, to test hypothesis 4 Semmelweis made a special effort to get the student doctors to be more gentle in their birth assistance to the women in Ward 1. The result was the same; 10 or 11 percent of the women in Ward 1 died compared to about 2 percent in Ward 2.

Then, as so often happens in science, Semmelweis had a stroke of luck. A doctor friend of his died, and the way he died provided Semmelweis with another possible explanation for the problem in Ward 1. Though Semmelweis's friend was not a woman who had recently given birth, he did have precisely the same symptoms as did the women who were dying of childbed fever. Most importantly, this doctor had died of a disease just like childbed fever soon after accidentally cutting himself during an autopsy.

Viruses and bacteria were unknown in the 1840s. Surgical instruments were not sterilized, no special effort was made to clean the hands, and doctors did not wear gloves during operations and autopsies. Semmelweis had another hypothesis; perhaps the greater number of medical students in Ward 1 was at the root of the mystery, but not because of their inexperience. Instead, these students, as part of their training, were much more likely than experienced doctors to be performing autopsies. Supposing that there was something bad in dead bodies and this something had entered Semmelweis's friend's system through his wound—could the same bad "stuff" (Semmelweis called it "cadaveric material") get onto the hands of the student doctors, who then might, without washing, go on to help a woman give birth? Then, if this "cadaveric material" were transmitted into the woman's body during the birth of her baby, this material might lead to her death. It was a simple enough hypothesis to test. Semmelweis simply had the student doctors carefully wash their hands after performing autopsies. The women stopped dying in Ward 1. Semmelweis had solved the mystery.

Science and Nonscience: The Essential Differences

Through objective observation and analysis, a scientist, whether a physicist, chemist, biologist, psychologist, or archaeologist, sees things that need explaining. Through creativity and imagination, the scientist suggests possible hypotheses to explain these "mysteries." The scientist then sets up a rigorous method through experimentation or subsequent research to deductively test the validity of a given hypothesis. If the implications of a hypothesis are shown not to be true, the hypothesis must be rejected and then it's back to the drawing board. If the implications are found to be true, we can uphold or support our hypothesis.

A number of other points should be made here. The first is that in order for a hypothesis, whether it turns out to be upheld or not, to be scientific in the first place, it must be testable. In other words, there must be clear, deduced implications that can be drawn from the hypothesis and then tested. Remember the hypotheses of "cosmic influences" and "atmospheric disturbances"? How can you test these? What are the necessary implications that can be deduced from the hypothesis, "More women died in Ward 1 due to atmospheric disturbances"? There really aren't any, and therefore such a hypothesis is not scientific—it cannot be tested. Remember, in the methodology of science, we ordinarily need to:

1. Observe
2. Induce general hypotheses or possible explanations for what we have observed
3. Deduce specific things that must also be true if our hypothesis is true
4. Test the hypothesis by checking out the deduced implications

If there are no specific implications of a hypothesis that can then be analyzed as a test of the validity or usefulness of that hypothesis, then you simply are not doing and cannot do "science."

For example, suppose you observe a person who appears to be able to "guess" the value of a playing card picked from a deck. Next, assume that someone hypothesizes that "psychic" ability is involved. Finally, suppose the claim is made that the "psychic" ability goes away as soon as you try to test it (actually named the "shyness effect" by some researchers of the paranormal). Such a claim is not itself testable and therefore not scientific.

Beyond the issue of testability, another lesson is involved in determining whether an approach to a problem is scientific. Semmelweis induced four different hypotheses to explain the difference in mortality rates between Wards 1 and 2. These "competing" explanations are called *multiple working hypotheses*. Notice that Semmelweis did not simply proceed by a process of elimination. He did not, for example, test the first three hypotheses and—after finding them invalid—declare that the fourth was necessarily correct since it was the only one left that he had thought of.

Some people try to work that way. A light is seen in the sky. Someone hypothesizes it was a meteor. We find out that it was not. Someone else hypothesizes that it was a military rocket. Again this turns out to be incorrect. Someone else suggests that it was the Goodyear Blimp, but that turns out to have been somewhere else. Finally, someone suggests that it was the spacecraft of people from another planet. Some will say that this must be correct, since none of the other explanations panned out. This is nonsense. There are plenty of other possible explanations. Eliminating all of the explanations *we* have been able to think of except one (which, perhaps, has no testable implications) in no way allows us to uphold that final hypothesis. We will see just such an error in logic when we discuss the Shroud of Turin artifact in Chapter 11.

It's like seeing a card trick. You are mystified by it. You have a few possible explanations: the magician did it with mirrors, there was a helper in the audience, the cards were marked. But when you approach the magician and ask which it was, he assures you that none of your hypotheses is correct. Do you then decide that what you saw was an example of genuine, supernatural magic? Of course not! Simply because you or I cannot come up with the right explanation does not mean that the trick has a supernatural explanation. We simply admit that we do not have the expertise to suggest a more reasonable hypothesis.

Finally, there is another rule to hypothesis making and testing. It is called *Occam's Razor* or *Occam's Rule*. In essence it says that when a number of hypotheses are proposed through induction to explain a given set of observations, the simplest hypothesis is probably the best.

Take this actual example. During the eighteenth and nineteenth centuries, huge, buried, fossilized bones were found throughout North America and Europe (Figure 2.3). One hypothesis, the simplest, was that the

Figure 2.3 An 1827 lithograph of a fossil quarry in the Tilgate Forest, Sussex, England. Workers are extracting a dinosaur bone from a large rock fragment. From Mantell's *Geology of Sussex*.

bones were the remains of animals that no longer existed. This hypothesis simply relied on the assumption that bones do not come into existence by themselves, but always serve as the skeletons of animals. Therefore, when you find bones, there must have been animals who used those bones. However, another hypothesis was suggested: the bones were deposited by the Devil to fool us into thinking that such animals existed (Howard 1975). This hypothesis demanded many more assumptions about the universe than did the first: there is a Devil, that Devil is interested in human affairs, he wants to fool us, he has the ability to make bones of animals that never existed, and he has the ability to hide them under the ground and inside solid rock. That is quite a number of unproven (and largely untestable) claims to swallow. Thus, Occam's Razor says the simpler hypothesis, that these great bones are evidence of the existence of animals that no longer exist—in other words, dinosaurs—is better. The other one simply raises more questions than it answers.

The Art of Science

Don't get the impression that science is a mechanical enterprise. Science is at least partially an art. It is much more than just observing the results of experiments.

It takes great creativity to recognize a "mystery" in the first place. In the apocryphal story, countless apples had fallen from countless trees and undoubtedly conked the noggins of multitudes of stunned individuals who never thought much about it. It took a fabulously creative individual, Isaac Newton, to even recognize that herein lay a mystery. Why did the apple fall? No one had ever articulated the possibility that the apple could have hovered in midair. It could have moved off in any of the cardinal directions. It could have gone straight up and out of sight. But it did not. It fell to the ground as it always had, in all places, and as it always would. It took great imagination to recognize that in this simple observation (and in a bump on the head) rested the eloquence of a fundamental law of the universe.

Further, it takes great skill and imagination to invent a hypothesis in this attempt to understand why things seem to work the way they do. Remember, Ward 1 at the Vienna General Hospital did not have written over its doors, OVERCROWDED WARD or WARD WITH STUDENT DOCTORS WHO DON'T WASH THEIR HANDS AFTER AUTOPSIES. It took imagination first to recognize that there were differences between the wards and, quite importantly, that some of the differences might logically be at the root of the mystery. After all, there were in all likelihood many, many differences between the wards: their compass orientations, the names of the nurses, the precise alignment of the windows, the astrological signs of the doctors who worked in the wards, and so on. If a scientist were to attempt to test all of these differences as hypothetical causes of a mystery, nothing would ever be solved. Occam's Razor must be applied. We need to focus our intellectual energies on those possible explanations that require few other assumptions. Only after all of these have been eliminated, can we legitimately consider others. As summarized by that great fictional detective, Sherlock Holmes:

> It is of the highest importance in the art of detection to be able to recognize, out of a number of facts, which are incidental and which are vital. Otherwise, your energy and attention must be dissipated instead of being concentrated.

Semmelweis concentrated his attention on first four, then a fifth possible explanation. Like all good scientists he had to use some amount of what we can call "intuition" to sort out the potentially vital from the probably incidental. Even in the initial sorting we may be wrong. Overcrowding seemed a very plausible explanation to Semmelweis, but it was wrong nonetheless.

Finally, it takes skill and inventiveness to suggest ways for testing the hypothesis in question. We must, out of our own heads, be able to invent the "then" part of our "if . . . then" statements. We need to be able to suggest those things that must be true if our hypothesis is to be supported. There really is an art to that. Anyone can claim there was a Lost Continent of Atlantis (Chapter 8), but often it takes a truly inventive mind to suggest precisely what archaeologists must find if the hypothesis of its existence were indeed to be valid.

Semmelweis tested his hypotheses and solved the mystery of childbed fever by changing conditions in Ward 1 to see if the death rate would change. In essence, the testing of each hypothesis was an experiment. In archaeology, the testing of hypotheses often must be done in a different manner. There is a branch of archaeology called, appropriately enough, "experimental archaeology" that involves the experimental replication and utilization of prehistoric artifacts in an attempt to figure out how they were made and used. In general, however, archaeology is largely not an experimental science. Archaeologists more often need to create "models" of some aspect of cultural adaptation and change. These models are simplified, manipulable versions of cultural phenomena.

For example, James Mosimann and Paul Martin (1975) created a computer program that simulated or modeled the first human migration into America some 12,000 years ago. By varying the size of the initial human population and their rate of growth and expansion, as well as the size of the big-game animal herds in the New World, Mosimann and Martin were able to test their hypothesis that these human settlers caused the extinction of many species of game animals. The implications of their mathematical modeling can be tested against actual archaeological and paleontological data.

Ultimately, whether a science is experimentally based or not makes little logical difference in the testing of hypotheses. Instead of predicting what the results of a given experiment must be if our induced hypothesis is useful or valid, we predict what new data we must be able to find if a given hypothesis is correct.

For instance, we may hypothesize that long-distance trade is a key element in the development of civilization based upon our analysis of the ancient Maya. We deduce that if this is correct—if this is, in fact, a general rule of cultural evolution—we must find large quantities of trade items in other parts of the world where civilization also developed. We might further deduce that these items should be found in contexts that denote their value and importance to the society (for example, in the burials of leaders). We must then determine the validity of our predictions and, indirectly, our hypothesis by going out and conducting more research. We need to excavate sites belonging to other ancient civilizations and see if they followed the same pattern as seen for the Maya relative to the importance of trade.

Testing a hypothesis certainly is not easy. Sometimes errors in testing can lead to incorrectly validating or rejecting a hypothesis. Some of you may have already caught a potential problem in Semmelweis's application of the scientific method. Remember hypothesis 4? It was initially suggested that the student doctors were at the root of the higher death rate in Ward 1, because they were not as gentle in assisting in birthing as were the more experienced doctors. This hypothesis was not borne out by testing. Retraining the students had no effect on the mortality rate in Ward 1. But suppose that Semmelweis had tested this hypothesis instead by removing the students altogether prior to their retraining. From what we now know, the death rate would have indeed declined, and Semmelweis would have concluded incorrectly that the hypothesis was correct. We can assume that once the retrained students were returned to the ward (gentler, perhaps, but with their hands still dirty) the death rate would have jumped up again since the students were indeed at the heart of the matter, but not because of their presumed rough handling of the maternity patients.

This should point out that our testing of hypotheses takes a great deal of thought and that we can be wrong. We must remember: we have a hypothesis, we have the deduced implications, and we have the test. We can make errors at any place within this process—the hypothesis may be incorrect, the implications may be wrong, or the way we test them may be incorrect. Certainty in science is a scarce commodity. There are always new hypotheses, alternative explanations, and more deductive implications to test. Nothing is ever finished, nothing is set in concrete, nothing is ever defined or raised to the level of religious truth.

Beyond this, it must be admitted that scientists are, after all, ordinary human beings. They are not isolated from the cultures and times in which they live. They share many of the same prejudices and biases of other members of their societies. Scientists learn from mentors at universities and often inherit their perspectives. It often is quite difficult to go against the scientific grain, to question accumulated wisdom, and to suggest a new approach or perspective.

For example, when German meteorologist Alfred Wegener hypothesized in 1912 that the present configuration of the continents resulted from the breakup of a single inclusive landmass and that the separate continents had "drifted" into their current positions (a process called *continental drift*), most rejected the suggestion outright. Yet today, Wegener's general perspective is accepted and incorporated into the general theory of *plate tectonics.*

Philosopher of science Thomas Kuhn (1970) has suggested that the growth of scientific knowledge is not neatly linear, with knowledge simply building on knowledge. He maintains that science remains relatively static for periods and that most thinkers work under the same set of assumptions—the same *paradigm*. New ideas or perspectives, like those of Wegener or Einstein, that challenge the existing orthodoxy, are usually initially rejected. Only once scientists get over the shock of the new ideas and start testing the new frameworks suggested by these new paradigms are great jumps in knowledge made.

That is why in science we propose, test, tentatively accept, but never prove a hypothesis. We keep only those hypotheses that cannot be disproved. As long as an hypothesis holds up under the scrutiny of additional testing through experiment and/or is not contradicted by new data, we accept it as the best explanation so far. Some hypotheses sound good, pass the rigors of initial testing, but are later shown to be inadequate or invalid. Others—for example, the hypothesis of biological evolution—have held up so well (all new data either were or could have been deduced from it) that they will probably always be upheld. We usually call these very well supported hypotheses *theories*. However, it is in the nature of science that no matter how well an explanation of some aspect of reality has held up, we must always be prepared to consider new tests and better explanations.

We are interested in knowledge and explanations of the universe that work. As long as these explanations work, we keep them. As soon as they cease being effective because new data and tests show them to be incomplete or misguided, we discard them and seek new ones. In one sense, Semmelweis was wrong after all, though his explanation worked at the time—he did save lives through its application. We now know that there is nothing inherently bad in "cadaveric material." Dead bodies are not the cause of childbed fever. Today we realize that it is a bacteria that can grow in the flesh of a dead body that can get on a doctor's hands, infect a pregnant woman, and cause her death. Semmelweis worked in a time before the existence of such things was known. Science in this way always grows, expands, and evolves.

Science and Archaeology

The study of the human past is a science and relies on the same general logical processes that all sciences do. Unfortunately, perhaps as a result of its popularity, the data of archaeology have often been used by people to attempt to prove some idea or claim. Too often, these attempts have been bereft of science.

Archaeology has attracted frauds and fakes. Myths about the human past have been created and popularized. Misunderstandings of how archaeologists go about their tasks and what we have discovered about the human story have too often been promulgated. As I stated in the first chapter of this book, my purpose is to describe the misuse of archaeology and the nonscientific application of the data from this field. In the chapters that follow, the perspective of science will be applied to frauds, myths, and mysteries concerning the human past.