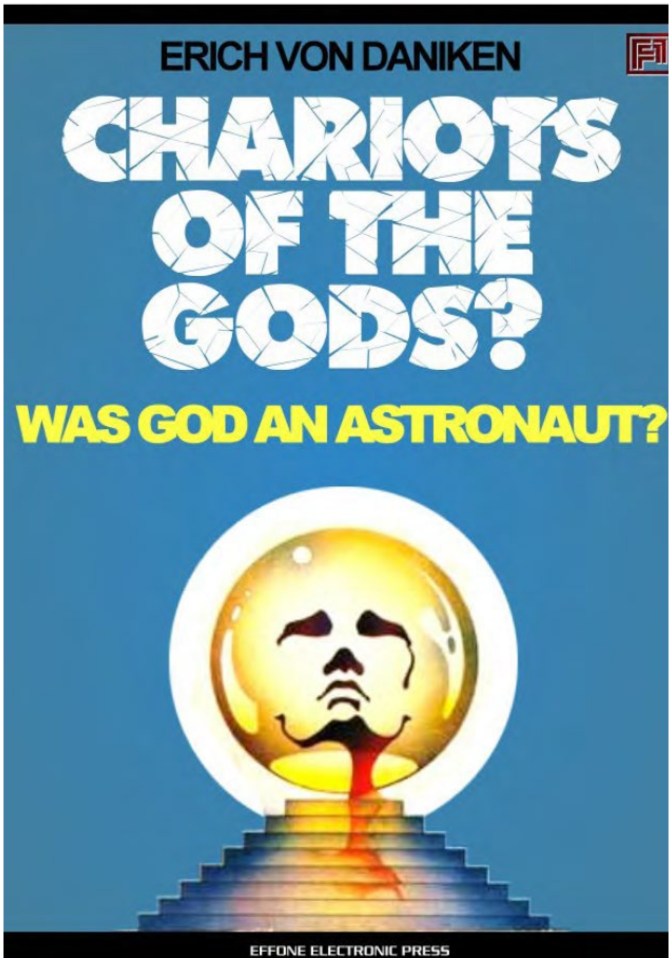


Chariots of the Gods (1968)

Introduction

It took courage to write this book, and it will take courage to read it. Because its theories and proofs do not fit into the mosaic of traditional archaeology, constructed so laboriously and firmly cemented down, scholars will call it nonsense and put it on the Index of those books which are "better left unmentioned." Laymen will withdraw into the snail-shell of their familiar world when faced with the probability that finding out about our past will be even more mysterious and adventurous than finding out about the future.

Nevertheless, one thing is certain. There is something inconsistent about our past, that past which lies thousands and millions of years behind us. The past teemed with unknown gods who visited the primeval earth in manned space-ships. Incredible technical achievements existed in the past. There is a mass of know-how which we have only partially rediscovered today.

There is something inconsistent about our archaeology! Because we find electric batteries many thousands of years old. Because we find strange beings in perfect space suits with platinum fasteners. Because we find numbers with fifteen digits - something not registered by any computer. But how did these early men acquire the ability to create these incredible things?

There is something inconsistent about our religion. A feature common to every religion is that it promises help and salvation to mankind. The primitive gods gave such promises, too. Why didn't they keep them? Why did they use ultra-modern weapons on primitive peoples? And why did they plan to destroy them?

Let us get used to the idea that the world of ideas which has grown up over the millennia is going to collapse. A few years of accurate research has already brought down the mental edifice in which we had made ourselves at home. Knowledge that was hidden in the libraries of secret societies is being rediscovered. The age of space travel is no longer an age of secrets. Space travel, which aspires to suns and stars, also plumbs the abysses of our past for us. Gods and priests, kings and heroes emerge from the dark chasms. We must challenge them to deliver up their secrets, for we have the means to find out all about our past, without leaving any gaps, if we really want to.

Modem laboratories must take over the work of archaeological research.

Archaeologists must visit the devastated sites of the past with ultrasensitive measuring apparatus.

Priests who seek the truth must again begin to doubt everything that is established.

The gods of the dim past have left countless traces which we can read and decipher today for the first time because the problem of space travel, so topical today, was not a problem, but a reality, to the men of thousands of years ago. For I claim that our forefathers received visits from the universe in the remote past. Even though I do not yet know who these extra-terrestrial intelligences were or from what planet they came, I nevertheless proclaim that these 'strangers' annihilated part of mankind existing at the time and produced a new, perhaps the first, homo sapiens.

This assertion is revolutionary. It shatters the base on which a mental edifice that seemed to be so perfect was constructed. It is my aim to try to provide proof of this assertion.

Erich Von Daniken

There Were Giants Upon the Earth

Gods, Demigods, and Human Ancestry: The Evidence of Alien DNA

ZECHARIA SITCHIN

2010

Bear & Company
Rochester, Vermont • Toronto, Canada

INTRODUCTION

And It Came to Pass

And it came to pass,
When men began to multiply on the face of the Earth
and daughters were born unto them,
that the sons of God saw the daughters of men
that they were fair, and they took them wives
of all which they chose.

There were giants upon the Earth
in those days and also thereafter too,
When the sons of God
came in unto the daughters of men
and they bare children to them the
same Mighty Men of old,
Men of Renown.

The reader, if familiar with the King James English version of the Bible, will recognize these verses in chapter 6 of Genesis as the preamble to the story of the Deluge, the Great Flood in which Noah, huddled in an ark, was saved to repopulate the Earth.

The reader, if familiar with my writings, will also recognize these verses as the reason why many decades ago, a schoolboy was prompted to ask his teacher why it is "giants" who are the subject of these verses, when the word in the original Hebrew text is *Nefilim* – which, stemming from the Hebrew verb NaFoL, means to fall down, to be downed, to come down-and in no way 'giants'.

The schoolboy was I. Instead of being congratulated on my linguistic acumen, I was harshly reprimanded. "Sitchin, sit down!" the teacher hissed with repressed anger; "you don't question the Bible!" I was deeply hurt that day, for I was not questioning the Bible-on the contrary, I was pointing out the need to understand it accurately. And that was what changed my life's direction to pursue the Nefilim. Who were they, and who were their "Mighty Men" descendants?

The search for answers started with linguistic questions. The Hebrew text does not speak of "Men" who began to multiply, but of Ha'A.dam-"The Adam," a generic term, a human species. It does not speak of the sons of "God," but uses the term Bnei Ha-Elohim-the sons (in the plural) of The Elohim, a plural term taken to mean "gods" but literally meaning "The Lofty Ones." The "Daughters of The Adam" were not "fair," but Tovoth-good, compatible ... And unavoidably we find ourselves confronting issues of origins. How did Mankind happen to be on this planet, and whose genetic code do we carry?

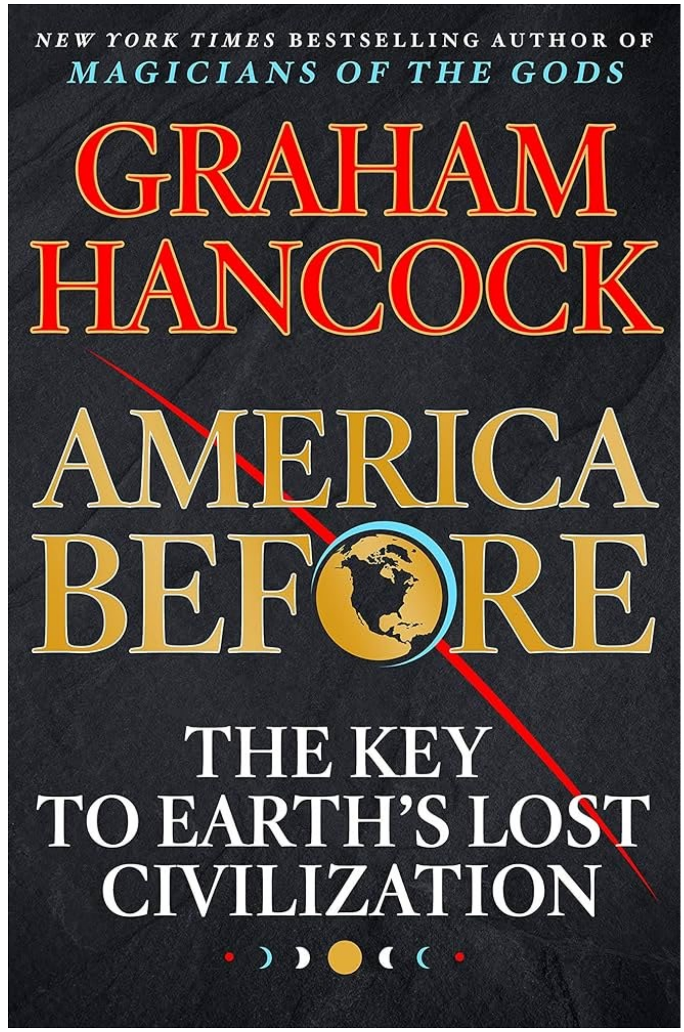
In just three verses and a few words-forty-nine words in the original Hebrew of Genesis-the Bible describes the creation of Heaven and Earth, then records an actual prehistoric time of early Mankind and a series of amazing events, including a global Flood, the presence on Earth of gods and their sons, inter-species intermarriage, and demigod offspring ...

And so, starting with one word (Nefilim), I told the tale of the Anunnaki, "Those who from Heaven to Earth came" -space travelers and interplanetary settlers who came from their troubled planet to Earth in need of gold, and ended up fashioning The Adam in their image. In doing so I brought them to life-recognizing them individually, unraveling their tangled relationships, describing their tasks, loves, ambitions, and wars-and identifying their inter-species offspring, the 'demigods'.

I have been asked at times where my interests would have taken me were the teacher to compliment rather than reprimand me. In truth, I have asked myself a different question: What if indeed "there were giants upon the Earth, in those days and thereafter too"? The cultural, scientific, and religious implications are awesome; they lead to the next unavoidable questions: Why did the compilers of the Hebrew Bible, which is totally devoted to monotheism, include the bombshell verses in the prehistoric record-and what were their sources?

I believe that I have found the answer. Deciphering the enigma of the demigods (the famed Gilgamesh among them), I conclude in this book-my crowning oeuvre-that compelling physical evidence for past alien presence on Earth has been buried in an ancient tomb. It is a tale that has immense implications for our genetic origins-a key to unlocking the secrets of health, longevity, life, and death; it is a mystery whose unraveling will take the reader on a unique adventure and finally reveal what was held back from Adam in the Garden of Eden.

ZECHARIA SITCHIN



I HAVE IN MY SHELVES a renowned and much respected book titled *History Begins at Sumer*. The reference, of course, is to the famous high civilization of the Sumerians that began to take shape in Mesopotamia-roughly modern Iraq between the Tigris and Euphrates rivers-around 6,000 years ago. Several centuries later, ancient Egypt, the very epitome of an elegant and sophisticated civilization of antiquity, became a unified state. Before bursting into full bloom, however, both Egypt and Sumer had long and mysterious prehistoric backgrounds in which many of the formative ideas of their historic periods were already present.

After the Sumerians and Egyptians followed an unbroken succession of Akkadians, Babylonians, Persians, Greeks, and Romans, and there were, moreover, the incredible achievements of ancient India and ancient China.

It therefore became second nature for us to think of civilization as an "Old World" invention and not to associate it with the "New World" at all.

Besides, it was standard teaching in the nineteenth and twentieth centuries that the Americas-North, Central, and South-were among the last great landmasses on earth to be inhabited by humans, that these humans were nomadic hunter-gatherers, that most of them subsequently remained hunter-gatherers, and that nothing much of great cultural significance began to happen there until relatively recently.

This teaching is deeply in error and as we near the end of the second decade of the twenty-first century, scholars are unanimous not only that it must be thrown out but also that an entirely new paradigm of the prehistory of the Americas is called for. Such momentous shifts in science don't occur without good reason and the reason in this case, very simply, is that a mass of compelling new evidence has come to light that completely contradicts and refutes the previous paradigm.

Everyone has and does their own "thing," and my own thing, over more than quarter of a century of travels and research, has been a quest for a lost civilization of remote prehistory-an advanced civilization utterly destroyed at the end of the Ice Age and somewhat akin to fabled Atlantis.

Plato, in the oldest-surviving written source of the Atlantis tradition, describes it as an island "larger than Libya and Asia put together" situated far to the west of Europe across the Atlantic Ocean. Hitherto I'd resisted that obvious clue which I knew had already been pursued with unconvincing results by a number of researchers during the past century. As the solid evidence that archaeologists had gotten America's Ice Age prehistory badly wrong began to accumulate in folders on my desktop, however, and with new research reports continuing to pour in, I couldn't help but reflect on the significance of the location favored by Plato. I had considered other possibilities, as readers of my previous books know, but I had to admit that an immense island lying far to the west of Europe across the Atlantic Ocean does sound a lot like America.

I therefore decided to reopen this cold case. I would begin by gathering together the most important strands of the new evidence from the Americas. I would set these strands in order. And then I would investigate them thoroughly to see if there might be a big picture hidden among the details scattered across thousands of scientific papers in fields varying from archaeology to genetics, astronomy to climatology, agronomy to ethnology, and geology to paleontology.

It was already clear that the prehistory of the Americas was going to have to be rewritten; even the mainstream scientists were in general agreement on that. But could there be more?

This book tells the story of what I found.

GRAHAM HANCOCK

EPISTEMOLOGY
How You Know What You Know

Condensed and adapted from *Frauds, Myths, and Mysteries,* by Ken Feder (2018)

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 fact from fantasy in archaeology or in any other field of knowledge? Everybody knows things, but how do we really know these things?

For example, suppose I were to ask you to name the "tallest mountain in the world." Most of you, I am pretty sure, would respond confidently with the answer "Mount Everest," giving the Western name for the mountain that the native people of Tibet call Chomolungma (Goddess of the Universe). Most people know that Everest is "the tallest mountain in the world;" and a few of you might even know that its height is about 29,035 feet (8,850 meters) above sea level. Did you also know, however, that though the peak of Everest represents the highest point on earth, it isn't really our planet's tallest mountain if, instead of "above sea level," you define a mountain's height as the distance from base to summit? That distinction belongs to Mauna Kea, a mountain in Hawaii whose summit is 33,476 feet (10,203 meters) higher than its base, which is located deep under water and, therefore, far below sea level. Mauna Kea is, in fact, an astonishing 4,441 feet (1,354 meters) taller than Everest.

You will find Mt. Everest's height of 29,035 in every published or online reference to the great peak – but only after November 1999. Until late in 1999, it was believed that the peak of Everest was "only" 29,028 feet (8,848 meters) above sea level.

That figure was determined in 1954 using the best technology available at the time. Our technology for doing such things as measuring elevations has improved dramatically in the intervening years. In a project sponsored by the National Geographic Society, a team of climbers ascended Everest in March 1999 to remeasure the "roof of the world." Using information gleaned from Global Positioning System satellites, it was determined that Everest is actually 7 feet higher, 29,035 feet high, and may be growing, if only by a small fraction of an inch each year, as a result of geological forces.

If asked to name the tallest mountain in the world, most people would respond "Mount Everest," and some might even know that it peaks at about 29,035 feet (8,850 meters) above sea level. But how many know that, if you measure the height of a mountain from base to summit, Mauna Kea, in Hawaii, is taller (33,476 feet [10,203 meters])? And how do we know any of this anyway?

One of the defining characteristics of science is its pursuit of ***modification and refinement*** *of what we know and how we explain things.* Scientists realize they have to be ever vigilant and, contrary to what some people seem to think, ever open to new information that enables us to tweak, polish, overhaul, or even overturn what we think we know. Science does not grudgingly admit the need for such refinement or reassessment but rather **embraces it as a fundamental part of the scientific method.**

But now back to epistemology. You and I have likely never personally assessed or verified the measurements of Everest, Mauna Kea, or any other mountain. So what criteria can we use to determine if any of what we think we know about these peaks is true or accurate? 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; and
2. Indirectly through specific information sources such as the internet, friends, teachers, parents, books, TV, and so forth.

People tend to think that obtaining information directly and personally by seeing it or experiencing it for themselves is always the best way. Think of the old expression, "Seeing is believing." In other words, you can believe something as long as you see it with your own eyes. But there's a problem here: our eyes aren't all that reliable. In fact, most people are pretty poor observers.

The "Lamia;' depicted here in a seventeenth-century woodcut, was supposedly a real creature, a hideous combination of mammal and fish and, apparently, male and female. People actually claimed to have seen the Lamia. They didn't: it's imaginary.

For example, the list of animals that people claim to have seen – and that turn out to be figments of their imagination – 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 encountered these animals, gave detailed descriptions, and even drew pictures of them (Figure 2.3). Many folks read their books and believed them.

Nor 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 and beautiful animals indigenous to China, Tibet, Nepal, and Burma – 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 the panda's return. About the time the newspapers came out with the panda story, it was found, sadly quite dead, along some railroad tracks adjacent to the zoo. Nevertheless, more than 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).

I can poke fun at myself on this very point. A couple of years ago I was driving in the early morning along a major artery in a highly developed part of the town of West Hartford, Connecticut. Off in the distance I saw an animal crossing the otherwise empty road. Its butt stuck up in the air and it moved with a strange, loping stride with each step it took punctuated by a hop.

I wracked my brain for what in the world the critter was and my initial identification was nonsensical. The animal crossing the road appeared to be a capybara, a giant South American cavy, an animal in the guinea pig family. I've never been to South America, but I have seen capybaras in zoos, and that was the identification I came up with, no matter how unlikely, after that brief and unexpected encounter.

The animal made it to the other side of the road and moved down an embankment, so I figured I'd never get a closer look and its identity would forever remain a mystery, but I got lucky. I slowed down as I crossed what had been the animal's path, looked down the hill and saw it. It wasn't a capybara. It was a raccoon missing one of its front legs. That explained the strange way it walked.

That's how our minds work. We see something off in the distance. Maybe it's an animal. Maybe it's an enigmatic light in the sky. Is this something we need to be concerned about? We search for an identification, and we come up with one based on incomplete data. After all, it's better to identify the movement in the grass in front of you as a crouching lion and respond carefully. As the old saying goes, "it's better to be safe than sorry." If you ignore that movement in the grass and it's a lion, you might get eaten. If you overreact to that movement in the grass and it's not a lion, you haven't lost anything.

So much for the absolute reliability of firsthand observation. Think about that the next time you read an eyewitness account of the sighting of a Bigfoot, a Sasquatch, the Loch Ness Monster, or a Chupacabra.

Red pandas are distinctive-looking animals and not readily mistaken for any other kind of creature. Nevertheless, the case of the missing red panda in Holland and the many false sightings of it long after it had been killed is a cautionary tale indicating we should be skeptical about accepting eyewitness accounts too literally.

Collecting Information: Relying on Others

In exploring the problems of secondhand information, we run into even more complications. When 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 reported heights of Mount Everest and Mauna Kea.

In assessing a report made by others, you need to ask yourself several questions: How did they obtain the information in the first place – revelation, intuition, science? What are their motives for providing this information? What agenda – religious, philosophical, nationalistic, or otherwise – do they have? What is their source of information, and how expert are they in the topic?

If you're interested in human antiquity, what can you do to understand what kinds of claims are reliable? Again, it comes back to epistemology: How do we know what to think we know, and how do we know what or whom to trust for information about the past?

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 used to get at knowledge 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 the time. On the contrary, during the process of the growth of knowledge and understanding, science is often wrong. Remember that even as seemingly fundamental a fact as the height of the tallest mountain on earth is subject to interpretation (how do you define "tallest"), reassessment, and correction. **The only claim that we do make in science is that if we conscientiously, consistently, explicitly, 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.**

Although the application of science can be a slow, frustrating, all-consuming enterprise, the basic assumptions we scientists hold are very simple. Whether we are physicists, biologists, or archaeologists, we all work from 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.

<u>1. There Is a Real and Knowable Universe</u>

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. My favorite quote on this topic comes from John Adams (1770), the second president of the United States: "Facts are stubborn things; and whatever may be our wishes, our inclinations, or the dictates of our passion, they cannot alter the state of facts and evidence." Science is based precisely on those stubborn facts.

Recently, it has become fashionable to deny this fundamental underpinning of science. A group of thinkers called deconstructionists, for example, insists that all science and history are merely artificial constructs, devoid of any objective reality or truth. To them, there are no "facts," stubborn or otherwise. Some deconstructionists go further and describe science itself as a Western "myth"; it is no more objective and no more "real" than nonscientific myths.

As Theodore Schick and Lewis Vaughn (2010) point out, however, if there is no such thing as objective truth, then no statements, including this one – or any of those made by the deconstructionists themselves – are objectively true. We could know nothing because there would be nothing to know. This is not a useful approach for human beings. Science simply is not the same as myth. Science demands rigorous testing and retesting, and it commonly rejects and discards previous conclusions about the world as a result of such testing. The same cannot be said for nonscientific explanations about how things work.

2. 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).

Though human societies are extremely complex systems and people do not operate according to rigid or unchanging rules of behavior, social scientists can nevertheless perceive patterns and regularities in how human groups react to changes in their environment and how their cultures evolve through time. For example, development of complex civilizations in Egypt, China, India/Pakistan, Mesopotamia, Mexico, and Peru was not the result of random processes. Their trajectories exhibit 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 would be different. However, in each case the rise of civilization was preceded by development of an agricultural economy and socially stratified societies. 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 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.

3. 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

By projecting back in time the physical, geological processes they can investigate operating in the present, geologists can reconstruct how ancient landforms, like the spectacular spires of Bryce Canyon, developed through time.

seventeenth century. 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. This experiment was even performed by U.S. astronauts on the moon during the Apollo 15 mission. 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 was false, many of the so-called historical sciences, including prehistoric archaeology, could not exist.

For example, 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, for example, Bryce Canyon, in Utah was formed. However, because the laws of geology that governed the development of Bryce Canyon have not changed through time and because these laws are still in operation, 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.

In the words of nineteenth-century geologist Charles Lyell, **the "present" we can observe is the "key" to understanding 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 (every weather report includes a prediction about the future). 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.

4. The Laws Can Be Understood

This may be the single most important principle in science. The universe is, theoretically at least, knowable. It may be complicated, and it may take many years to understand even apparently simple phenomena. Each attempt at understanding leads us to collect more data and to test, reevaluate, and refine our proposed explanations – for how planets formed; why a group of animals became extinct while another thrived; or how a group of ancient people responded to a change in their natural environment, contact with a group of foreigners, or adoption of a new technology. We rarely get it right the first time and are continually collecting new information, abandoning some interpretations while refining others.

We constantly rethink our explanations. In this way, little by little, bit by bit, we expand our knowledge and understanding. Through this kind of 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 patterns, rules, or laws. 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

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 propose *explanations called* ***hypotheses*** for how these things work. ***The process of suggesting general explanations based on specific observation is called INDUCTION.***

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 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 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 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 the 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 new "facts" should also be discovered. ***The process of figuring out what new, specific data should be observed based on our generalized hypotheses is called DEDUCTION.*** 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 of trying to test a hypothesis.**

THE CASE OF CHILDBED FEVER

Here's an example of how this process works. In nineteenth-century Europe, the hospital could be a very dangerous place for a woman about to give birth. Death rates in some so-called lying-in wards were horrifically high, the result of what became known as "childbed fever." A seemingly healthy young woman would arrive at the hospital with an unremarkable pregnancy, experience a normal labor, and give birth to a healthy baby. Over the course of the hours and days following birth, however, the mother might exhibit a rapid pulse, high fever, distended and painful abdomen, foul discharge, and delirium – and then would die.

Table 2.1 Number of Maternal Deaths Following the Birth of a Child. (Note the tragically high maternal death rates in hospitals of the nineteenth century.)

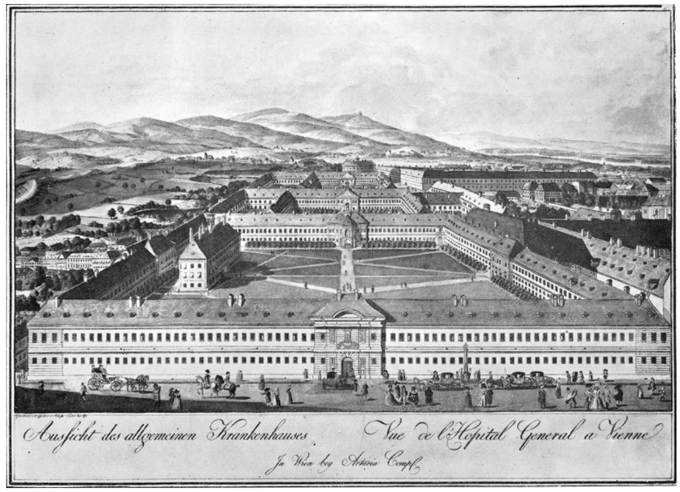
	HOME BIRTH	HOSPITAL
Modem United States	1 per 10,000	1 per 10,000
London mid-nineteenth century	10 per 10,000	600 per 10,000
Paris mid-nineteenth century	50 per 10,000	547–880 per 10,000
Dresden mid-nineteenth century	unknown	304 per 10,000

Oddly, *while childbed fever took a horrible toll in hospital deliveries, it was rare or absent in home births.* In fact, a woman was generally much safer if she gave birth on the street or in an alley on her way to the hospital than if she actually arrived there. Nineteenth-century hospital death rates (expressed as the number of maternal deaths per every 10,000 births) are astonishingly, frighteningly high – many times higher than home birth death rates in these same cities – and contrary to what many of us might have expected.

The situation was more complicated for Austria's Vienna General Hospital where there were two separate maternity divisions (Figure 2.6). Each year between 6,000 and 7,000 women arrived at the gates of the hospital to give birth, and about half ended up in each of the two divisions. In Division 2, in a given year, on average, about 60 women died soon after giving birth, a death rate of about 2 percent (which figures out to 200 per 10,000; see Table 2.2). Astonishingly, in Division 1, in the same hospital, the number of yearly deaths was more than ten times higher, with more than 600 (2,000 per 10,000 births) and as many as 800 dying in a given year, a terrifying death rate as high as 27 percent (Nuland 2003:97).

Physicians were, needless to say, appalled by such statistics and patients were, understandably, terrified. Many doctors performed autopsies on women who had died of childbed fever and found them ravaged by an aggressive infection and filled with an intensely foul-smelling whitish fluid. Many of these physicians were more than willing to propose hypotheses suggesting possible causes of the condition.

Table 2.3 Hypotheses Proposed to Explain Childbed Fever before Semmelweis
Atmospheric disturbances
Tight petticoats
Foul hospital air
Blocked milk ducts
Female modesty
Fear of childbed fever



This 1784 woodcut shows the Vienna General Hospital where, in 1848, a physician's experiment led to the solution of the mystery of childbed fever.

Some doctors proposed the ironic and circular explanation that childbed fever had a psychological origin. They suggested that the cause of childbed fever was the fear of getting childbed fever!

Back in Vienna at the General Hospital, Ignaz Semmelweis, a young Hungarian doctor who had been turned down for a couple of plum assignments, ended up, by default, in obstetrics. Determined to solve the childbed fever riddle, Semmelweis realized that the General Hospital, with its two divisions having very different mortality rates, presented a unique opportunity to experimentally test the various hypotheses proposed to explain childbed fever.

Semmelweis and some of his colleagues at the hospital recognized a handful of potentially important differences between the two obstetrical divisions in the hospital and induced a series of possible explanations for the drastic difference in their mortality rates. They suggested:

1. Division 1 tended to be more crowded than Division 2. The **overcrowding** in Division 1 was a possible cause of the higher mortality rate there.
2. Women in Division 2 were assisted by midwives who directed the women to deliver on their sides, while those in Division 1 were attended to by physicians and medical students who kept women on their backs during delivery. **Birth position** was a possible cause of the higher mortality rate.
3. There was a psychological factor involved; the **hospital priest** had to walk through Division 1 to administer the last rites to dying patients in other wards. Perhaps this sight so upset

some women already weakened by the ordeal of childbirth that it contributed to their deaths.

4. Unlike the women in Division 2, who were assisted by experienced midwives using far less invasive techniques, the women in Division 1 were attended to by medical students being trained in obstetrics. Perhaps all of the additional **poking and prodding** conducted during this training was harmful and contributed to the higher death rate of women in Division 1.

These induced hypotheses all sounded good. Each marked a genuine difference between Divisions 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** was correct, then alleviating the crowding in Division 1 should reduce the mortality rate. So they cut down on the crowding in Division 1. The result: no change. So the first hypothesis was rejected. It had failed the scientific test; it did not explain the difference in mortality rates, and it simply could not be correct.
2. Semmelweis went on to test **hypothesis 2** by changing the birth positions of the women in Division 1 to match those of the women in Division 2. Again, there was no change, and another hypothesis was rejected.
3. Next, to test **hypothesis 3,** the priest was rerouted. Women in Division 1 continued to die of childbed fever at about five times the rate of those in Division 2. This hypothesis was also rejected.
4. To test **hypothesis 4,** it was decided to limit the number of invasive procedures used on the women to train the students in their examination techniques. The statistics showed that this change had no impact on the death rate in Division l; 10 or 11 percent of the women continued to die even when fewer students were allowed to examine them internally.

Then, as so often happens in science, Semmelweis had a stroke of luck. Well, it was lucky for him but not for his friend. That friend – also a doctor – died, and the manner of his death provided Semmelweis with another possible explanation for the problem in Division 1. Though Semmelweis's friend was not a woman who had recently given birth, he did present precisely the same symptoms as did the women who were dying of childbed fever. Most important, this doctor had died of a disease similar to 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 by doctors to clean their hands, and doctors did not wear gloves during operations and 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 physicians and medical students, 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, it might lead to her death.

This possibility inspired Semmelweis's final hypothesis: The presence of physicians and medical students in Division 1 was at the root of the mystery after all. Students who attended the women in Division 1 regularly conducted autopsies as part of their training and so would be in contact with dead bodies on the same days they were assisting women giving birth. furthermore, physicians would frequently perform autopsies on the bodies of women who had already died of childbed fever, often going directly from the autopsy room to the birthing rooms to assist other women giving birth. Herein was a grimly ironic twist to this new hypothesis; if there was something bad in dead bodies, the attempt by physicians to solve the mystery of childbed fever by performing autopsies on its victims was one of the most important factors in transmitting the disease to additional women.

To test this hypothesis, Semmelweis instituted new policies in Division 1, including the requirement that all attending physicians and students cleanse their hands with chlorinated lime, a bleaching agent, before entering. The result: the death rates in both divisions dropped (see Table 2.2). Division 2, always the safer one, came down from a rate of 200 to a rate of 130 maternal deaths for every 10,000 births. Division l declined far more dramatically, from the previously cited maternal death rate of 2,000 to a rate of 120 per

10,000 births. Semmelweis had both solved a mystery and halted an epidemic.

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 induces 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 for a hypothesis, whether it turns out to be upheld or not, to be scientific, it must be testable. In other words, there must be clear, deduced implications that can be drawn from the hypothesis and then tested. Testing a hypothesis is crucial. **If there are no specific implications of a hypothesis that can 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). This assertion renders the claim of psychic power inherently untestable 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 Divisions I 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 because 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 a local advertising blimp, but that turns out to have been somewhere else. Finally, someone suggests that it was the spacecraft of beings from another planet. Some will say that this must be correct because 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.**

A Rule in Assessing Explanations

Finally, there is another rule to hypothesis making and testing. It is called **Occam's razor** or Occam's rule. In thinking, in trying to solve a problem, or in attempting to explain some phenomenon, "entities are not to be multiplied beyond necessity." In other words, the hypothesis that explains a series of observations with the fewest other assumptions or leaps – the hypothesis that does not multiply these "entities" beyond necessity – is the best explanation.

Another way of stating this fundamental rule of scientific reasoning was expressed by Dr. Theodore Woodward in the 1940s. Dr. Woodward noticed that his student doctors at the University of Maryland School of Medicine often suggested the least plausible and most exotic of diagnoses for patients presenting with rather mundane symptoms. Woodward's advice to his students: "When you hear hoof beats, think of horses, not zebras." In other words, go with the most likely diagnosis first. In the vast majority of cases, what looks like a cold, is actually a cold and not some rare tropical disease that has been clinically diagnosed in only a handful of people. Expressed most broadly, only when you've eliminated the most likely, should you consider more exotic explanations. That applies to lights in the sky, an animal seen at a distance, and a strange inscription on a cave wall.

Consider the case of the symmetrical, axe-shaped pieces of chipped stone found in the seventeenth century in apparently ancient soil layers in Europe (Figure 2.7). Today, anyone looking at these objects would immediately conclude that they were tools, the product of human ingenuity and labor, "Stone Age" artifacts made by our prehistoric ancestors.

Symmetrical, flaked stone objects like this hand axe were found in Europe at least as far back as the seventeenth century. Though they clearly are the result of human handiwork, ignoring Occam's razor, many thinkers disputed this and suggested that these objects had been made by fairies or bolts of lightning.

This commonsense interpretation that the objects had been made by a past people was problematic for many thinkers in past centuries. Based on a common interpretation of the Bible, there could have been no "Stone Age," no period in antiquity when people made tools of stone, so the objects in question, in this view, could not have been made by ancient human beings. Thinkers who denied that the stone axes had been made by ancient people had to come up with alternate explanations. Some were rather fanciful. Perhaps these "hand axes" were not the handiwork of ancient human beings but had been made recently by elves or fairies; some went so far as to call the stone tools "fairy stones." Other scientists disagreed, suggesting, instead, a more natural – but also implausible – explanation: Perhaps bolts of lightning struck the earth and produced such objects. These thinkers called the stone objects "thunderstones:' Of course, there was no evidence that elves or fairies actually existed, much less that they occupied their time making stone axes. Similarly, no researcher had found symmetrically chipped stone objects at the location of lightning strikes. Apply Occam's razor here: chipped stone objects that looked like tools should be assumed to be the product of human labor (think horses) unless and until substantial evidence in support of an alternative explanation (zebras) is forthcoming. Other explanations raised more questions – about elves, fairies, and lightning's capacity to make useful tools – than they answered.

Consider another example. While excavating a nearly 2,000-year-old village site in the town of Windsor, Connecticut, we found a 1950s vintage beer bottle at precisely the same depth that we had been finding ancient Native American pottery.

How could we explain this? Objects found at the same soil depth – in the same "stratigraphic level" – ordinarily date to about the same age. How could 2,000-year-old pottery and a 1950s glass bottle have ended up together in the soil? Was this evidence of time traveling beer guzzlers? Do we need to rewrite all of human history – a claim often made about ostensibly amazing discoveries regularly announced on the internet – and admit that American Indians were producing glass bottles thousands of years before we thought that technology existed? Well, no, don't tear up the history books quite yet. On careful examination of the soil, it became clear that the bottle was found at the same depth as the ancient artifacts because long after the site had been occupied it had fallen into an animal burrow. The animal, probably a woodchuck, had burrowed into the archaeological layer long after the site was abandoned and decades before we arrived to dig. That burrow had been filled in after someone, apparently, had thrown or dropped the beer bottle into the hole. It just took us a while to recognize that the bottle was intrusive to the archaeological layer. The history books are safe. As is most often the case, the far simpler explanation – in this instance littering as opposed to time travel – prevails.

THE ART OF SCIENCE

Don't get the impression that science is a mechanical enterprise. Science is at least partially an art. It takes great creativity to recognize a "mystery" in the first place. You've probably heard the story of how Sir Isaac Newton "discovered" gravity by watching an apple fall from a tree. Certainly, 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 to even recognize that herein lay a mystery. As recorded by his friend, William Stukeley in 1752, Newton wondered, "Why should the apple always descend perpendicularly to the ground ... why should it not go sideways, or upwards? but constantly to the earth's centre? assuredly, the reason is that the earth draws it. There must be a drawing power in matter" (Stukeley 1752). It took great imagination to recognize that in this simple observation of an apple falling to the ground rested the eloquence of a fundamental law of the universe.

Where Do Hypotheses Come From?

Coming up with hypotheses is not a simple or mechanical procedure. The scientific process requires creativity. Hypotheses arrive as often in flashes of insight as through plodding, methodical observation. Consider this example.

My field crew and I had just finished excavating the 2,000-year-old Loomis II archaeological site in Connecticut where a broad array of different kinds of stones had been used for making tools. Some of the "lithics" came from sources close to the site. Other sources were located at quite a distance, as much as a few hundred miles away. These non-native "exotic" lithics were universally superior; tools could be made more easily from the nonlocal materials, and the edges produced were much sharper.

At the time the site was being excavated, I noticed that there seemed to be a pattern in terms of the size of the individual tools we were recovering. Tools made from the locally available and generally inferior materials of quartz and basalt were relatively large, and the pieces of rock that showed no evidence of use – archaeologists call these discarded pieces *debitage* – were also relatively large. In contrast, the tools made from the superior materials – a black flint and two kinds of jasper – that originated at a great distance from the site were much smaller. Even inconsequential flakes of exotic stone – pieces you could barely hold between two fingers – showed evidence of use, and only the tiniest of flakes were discarded without either further modification for use or evidence of use, such as for scraping, cutting, or piercing.

I thought it was an interesting pattern but didn't think much of it until about a year later when I was cleaning up the floor of my lab after a class in experimental archaeology where students were replicating stone tools. We used a number of different raw materials in the class, and just as was the case for the 2,000-year-old site, stone of inferior quality was readily available a few miles away, whereas more desirable material was from more distant sources.

As I cleaned up, I noticed that the discarded stone chips left by the students included perfectly serviceable pieces of the locally available, easy-to-obtain stone, and only the tiniest fragments of flint and obsidian. We obtained flint in New York State from a source about 80 miles from campus, and we received obsidian from Wyoming from a source more than twenty times farther away (more than 1,600 miles). Suddenly it was clear to me that the pattern apparent at the archaeological site was repeating itself nearly two thousand years later among my students. More "valuable" stone – functionally superior and difficult to obtain – was used more efficiently, and there was far less waste than in stone that was easy to obtain and more difficult to work. I could now phrase this insight as a hypothesis and test it using the site data: More valuable lithic materials were used more efficiently at the Loomis II archaeological site (Feder 1981b). In fact, by a number of measurements, this turned out to be precisely the case. The hypothesis itself came to me when I wasn't thinking of anything in particular; I was simply sweeping the floor.

It may take great skill and imagination to invent a hypothesis in the attempt to understand why things seem to work the way they do. Remember, Division 1 at the Vienna General Hospital did not have written over its doors "Overcrowded Division" or "Division with Student Doctors Who Don't Wash Their Hands after Autopsies." It took imagination, first, to recognize that there were differences between the divisions and, second, to hypothesize that some of the differences might logically be at the root of the mystery. After all, there were many differences between the divisions: their compass orientations, the names of the nurses, the precise alignment of the windows, the astrological signs of the doctors who worked in the divisions, 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 in the story "The Reigate Puzzle":

> 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. (Doyle 1891-1902:275)

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, birth position, and psychological trauma seemed like very plausible explanations to Semmelweis, but they were wrong nonetheless.

Testing Hypotheses

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 were giant human beings in antiquity, a mysterious race of ancient "mound builders" in North America, or a Lost Continent of Atlantis, but often it takes a truly inventive mind to suggest precisely what archaeologists must find if the hypothesis of their existence is indeed to be validated.

It might seem obvious that medical researchers, physicists, or chemists working in labs can perform experiments, observe the results, and come to reasonable conclusions about what transpired. But how about the historical disciplines, including historical geology, history, and prehistoric archaeology? Researchers in these fields cannot go back in time to be there when the events they are attempting to describe and explain took place. Can they really know what happened in the past?

Yes, they can, by what historians Michael Shermer and Alex Grobman (2000:32) call a "convergence of evidence": For example, in their book *Denying History: Who Says the Holocaust Never Happened and Why Do They Say It?* they respond to those who deny that the Germans attempted to exterminate the Jewish population of Europe in the 1930s and 1940s. After all, even though that era isn't ancient history, we still can't return to observe it for ourselves, so how do we know what really happened? Shermer and Grobman marshal multiple sources of evidence, including documents like letters, speeches, blueprints, and articles where Germans discussed their plans; eyewitness accounts of individual atrocities; photographs showing the horror of the camps; the physical remains of the camps themselves; and inferential evidence like demographic data showing that approximately 6 million European Jews disappeared during this period. Though we cannot travel back in time to the 1940s, these different and independent lines of evidence converge, all pointing in the same direction, allowing us to conclude with absolute certainty that a particular historical event – in this case, the Holocaust – actually happened. Indeed, we can know what happened in history – and prehistory.

Ultimately, whether or not a science is experimentally based makes little logical difference in testing 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.**

Testing of hypotheses takes a great deal of thought, and we can make mistakes. We must remember: We have a hypothesis, we have the deduced implications, and we have the test. **We can make errors at any step in the 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, and nothing is ever defined or raised to the level of religious truth.

Skeptics, Not Cynics; Doubters, Not Deniers

You'll often see this claim in popular media reports about a groundbreaking scientific discovery: "The skeptics were wrong!" Like, "haha, all of you skeptics didn't know what you were talking about and now you have to eat crow." Or eat something else. But here's the deal. Skeptics are never really wrong in the sense that it's never wrong to be skeptical unless and until convincing, irrefutable evidence is forthcoming. Skeptics are not cynics, people who just don't accept anything; "skepticism" and "cynicism" are not synonyms. Skeptics express doubt, not denial about a new discovery or new claim or hypothesis because that's what science does until overwhelming evidence is presented. If you don't like skepticism, you can't be a scientist.

Let me give you an example, and forgive me if you're not into sports metaphors, but just go with it for a bit. Suppose you're a big fan. You love your team. Maybe it's your university's basketball squad, your city's major league baseball franchise, or your wizarding school's quidditch team. Now, a friend with the same team spirit says "We're going to go all the way this year – to the Final Four, the World Series, the Tri-Wizard Tournament" (take your pick).

You are skeptical. I mean, your three best players were seniors and just graduated and entered the WNBA draft. Or maybe your best pitcher last year signed a big money contract with another team, leaving the rotation up in the air. Or perhaps all of the other teams got Nimbus 2000s over summer break, and your team is stuck with old-school brooms. So, for very good reasons, you doubt that your team is going to be terribly successful this year. You're skeptical.

Now, suppose your team actually pulls it off and wins it all this year. Were you wrong doubting that they would? Of course not. Based on the evidence you had at the beginning of the season, based on the

The inscribed, standing stone found at the Crystal River archaeological site in Florida (left). Compare it to the Maya stelae (right). Did the Maya visit Florida in antiquity and teach the local native people to carve a stela? There isn't enough evidence to confirm that hypothesis. As a result, most archaeologists are skeptical but certainly willing to examine additional evidence if it is forthcoming.

conditions in play at the time, skepticism was absolutely sensible and correct.

Science is all about revision based on new information, especially when new data are revealed and/or conditions change. What you didn't know at the time you expressed your skepticism – what you could not have known – was that a couple of the sophomores on the basketball team would play in a summer league and really up their game. What you couldn't have known was that a pitcher currently in the minors would make a big leap to the majors and make you forget all about the guy who got away. And you had no way of predicting that the Nimbus 2000s would be affected by a safety recall – a problem with airbag deployment – and your wizarding school would be in great shape with their old equipment.

Now here's an archaeological example. In the 1940s, archaeologists excavated the Crystal River mound site on the west coast of Florida (Bullen 1966; see Figure 7.14). Two strange features were discovered at the site. Both included upright slabs of stone, one with an image of a human face etched onto it, and there appeared to be food and chipped stone offerings buried at the base of the inscribed stone (Figure 2.8, left). That kind of feature had never been seen before – or since – in North America, but it vaguely resembles the stelae of the Maya culture in Mexico, Belize, Guatemala, and Honduras (Figure 2.8, right). When the site was excavated and continuing to this very day, some suggested that Crystal River had some, maybe even direct, contact with the great Maya civilization to the south and that this contact inspired them to mimic those stelae.

It's an interesting possibility, but most archaeologists were and continue to be skeptical. No definitive evidence confirming the connection has ever been found – no artifacts made from raw materials sourced to the Maya homeland, no Maya hieroglyphs found at Crystal River or anywhere else in North America, no Maya burials, and so on. So, doubt, skepticism, that's the right move. For now. If future research reveals the kind of confirming proof I've just listed, then great – the skepticism will fade away. But that doesn't mean the skeptics would have been wrong when they expressed their skepticism because, after all, we're not psychic or clairvoyant and could not have known that supporting evidence would be found. And, anyway, I'm skeptical about psychic power in the first place, but that's another story.

The Human Enterprise of Science

Science is an imperfect human endeavor practiced by imperfect human beings. It can be difficult for a scientist not to "fall in love" with a hypothesis – because it seems interesting or clever, because it's new and exciting, and, mostly, because he or she came up with it – but it's a trap that must be avoided. Unfortunately, scientists do not always succeed in steering clear of this kind of attachment to an idea; in fact, they are sometimes unsuccessful to the point of ignoring contradictory data or even fudging results to better fit a preconceived notion. In a shocking survey of more than 3,200 American scientists, a remarkable 15.3 percent confessed that they had ignored specific pieces of data or observations "based on a gut feeling that they were inaccurate" (Martinson, Anderson, and de Vries 2005:737).

I think those scientists who revealed that they had omitted or ignored data that contradicted their previous work had fallen into the trap of being in love with their own ideas. People fall in love with other people and learn to overlook their imperfections and inconsistencies, and that's probably a good thing. But it's not so good with scientific explanations. We don't want to overlook the imperfections, inadequacies, and errors in a hypothesis; we want to explore them and, in this way, find ways toward better explanations. In essence, and to extend the analogy far beyond where I should, we need always to be ready to file for divorce from those mistakes, blunders, and dead ends, prepared to move on and not look back.

Beyond this, **scientists 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 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.

Of course, it isn't easy for any scientist to question the validity of claims made by well-respected authorities. For example, today we take it for granted that sometimes quite large, extraterrestrial, natural objects go streaking across the sky and sometimes even strike the ground (then they are called meteorites). Perhaps you have been lucky enough to see a major meteor or "bolide," an awesome example of nature's fireworks. But until about two hundred years ago the notion that solid stone or metallic objects originating in space regularly enter the earth's atmosphere and sometimes strike the ground was controversial and, in fact, rejected by most scientists. In 1704 Sir Isaac Newton categorically rejected the notion that there could be meteors because he did not believe there could be any cosmological source for them.

Anyone looking up at night can't help but notice that, occasionally, bright streaks of light cross the sky. Many scientific luminaries, including Sir Isaac Newton, rejected the hypothesis that this could be explained by bits of extraterrestrial stone and metal burning up in the earth's atmosphere. Today, we know that this is precisely what these flashes are, and we call them meteors.

The quality of an argument and the evidence marshalled in its support should be all that matters in science. The authority or reputation of the scientist should not matter, at least not much. Nevertheless, not many scientists were willing to go against the considered opinion of as bright a scientific luminary as Isaac Newton. Even so, a few brave thinkers risked their reputations by concluding that meteors really did originate in outer space. Their work was roundly criticized, at least for a time. **But science is "self-corrective": Hypotheses are constantly being refined and retested as new data are collected.**

In 1794, over the skies of Siena, Italy, there was a spectacular shower of about 3,000 meteors, seen by tens of thousands of people (Cowen 1995). Even then, a nonmeteoric explanation was suggested. By coincidence, Mount Vesuvius had erupted just eighteen hours before the shower, and some tried to blame the volcano for being the source of the objects flaming across the Italian skies.

Critics did what they could to dispel the "myth" of an extraterrestrial source for the streaks of light over Siena, but they could not succeed. Further investigation of subsequent major meteor falls in the late 1700s and early 1800s as well as examination of the chemical make-up of some of the objects that had actually fallen from the sky (an iron and nickel alloy not found on earth), convinced most by the early nineteenth century that meteors are what we now know them to be – extraterrestrial chunks of stone or metal that flame brightly when they enter our planet's atmosphere.

In science we propose, test, and tentatively accept but never prove a hypothesis. We keep only those hypotheses that cannot be disproved. As long as a hypothesis holds up under the scrutiny of additional testing through experiment and 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.

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. In the class you're taking now, the perspective of science will be applied to frauds, myths, and mysteries concerning the human past.

FREQUENTLY ASKED QUESTIONS

1. Can science answer all of our questions?

No, but it never promised to. **Science is a process,** a way to approach questions about the physical world (including people and their cultures), not the metaphysical world. Scientists endeavor to understand how the universe works. The search for meaning is valuable and we all do it: Why are we here in this universe? What is the point of our existence? How should we behave toward one another? How should we treat the planet on which we live? Though science can provide the framework for a worldview or philosophy, the answers to these philosophical questions are not discovered through science.

2. Doesn't scientific truth change in every generation?

In a sense, this is true. But our understanding of the world is not simply cyclical. We really do know more today about how the solar system formed, the constituents of atoms, earth history, the etiology of disease, and the evolution of our species than we knew a century, a decade, or even a year ago.

Here's an example. I began teaching in 1977 and one of my courses was a broad survey of human prehistory that began with the evolution of anatomically modern human beings, people whose skeletons look just like our own. At the time, I taught my students that the earliest appearance of those modern looking people could be traced back to no more than about 40,000 years ago in Europe. The oldest modern-looking human bones had been dated to about that period, so that's what the evidence available at the time suggested.

Today, nearly forty years later, when I cover the topic of the evolution of anatomically modern human beings, I tell students that the oldest evidence of modern looking bones dates to close to 200,000 years ago and the crucible of our species was Africa, not Europe. That's an enormous jump, and the date has changed for a simple reason; we actually know more than we used to. Science is a process in which we are continually making new discoveries, developing new analytical procedures, and rethinking what we thought we knew. And who knows – in the next forty years new discoveries may cause us to revise that date yet again. Sure, by that time I'll likely be a human fossil myself, but the never-ending search for more evidence and revising our interpretations is what makes science so exciting.