Chapter 3: INDUCTIVE REASONING AND RELIABLE BELIEFS

We should relish the thought that the sciences as well as the arts will always provide a spectacle of fierce competition between alternative theories, movements, and schools. The end of human activity is not rest, but rather richer and better human activity. Richard Rorty

Deduction and Induction

We must now be more specific on the claims made in Chapter 2 about reliable beliefs. How exactly does a belief acquire certain features of evidence such that it is likely to continue to be reliable in the future? How exactly do we establish long-term reliability?

Think of just some of the issues on which people disagree.

1. Many smokers live a long and healthy life, sometimes outliving their non-smoking peers, because smoking helps relieve stress and protect against Alzheimer's disease.

   Tobacco use is the leading preventable cause of death in the United States. Cigarette smoking causes an estimated 440,000 deaths, or about 1 of every 5 deaths, each year. An estimated 25 million Americans who are alive today will die prematurely from smoking-related illnesses, including 5 million people younger than 18.

2. Heavy use of smart phones leads to brain tumors.

   There is no evidence that heavy use of smart phones cause brain tumors.

3. A healthy diet consists in eating high protein, high fat foods, but low in carbohydrates.

   A healthy diet consists in eating low fat foods that are rich in complex

carbohydrates.

4. The universe is about 14 billion years old and human life is part of an evolutionary process that has been occurring on Earth for at least 4 billion years.

   The universe is about 6,000 years old and initially human life was created as part of a six day process. Evolution cannot be true, because there has not been enough time for it to happen on Earth.

5. The appearance of fossils of dead animals on Earth is due to a great flood that occurred at the time of Noah's Ark.

   Explaining fossils of dead animals by Noah's Ark is a joke; geologists and paleontologists know that the time line for the creation of fossils is spread over a period of millions and millions of years and fossils were not created by a single event.

6. Venereal disease and pregnancies in unmarried teenagers are caused by sex education classes in the public schools.

   Venereal disease and pregnancies in unmarried teenagers are caused by general lack of sex education.

7. Having same-sex parents is very bad for children.

   Generally, there are no adverse effects on children who are raised by same-sex couples.

8. The evidence is overwhelming that significant global warming is taking place due to human activities and emissions of huge increases in carbon dioxide into the atmosphere by those activities.

   There is no global warming due to human activities. Whatever temperature fluctuations there have been in recent year are due to natural cyclical temperature changes seen throughout the Earth's history.

9. The state-capitalist system of China is better for economic growth and prosperity than the casino capitalistic system of the United States.

   The free-market capitalist system of the United States is better for economic growth and prosperity than the government controlled system used in China.

10. Barry Bonds, former Major League baseball player and holder of the all-time Major League home run record, cheated by using illegal steroids.

    Barry Bonds did not knowingly use illegal steroids, because he was told he was being injected with vitamins.

Clearly what you believe is true mattes in terms of making many practical decisions for your life, public policy, judgments of fairness, and even for the fate of the Earth. Beliefs become statements or propositions in deductive arguments. To be maximally useful, we not only need valid deductive arguments but we also need to know the premises are true. How do we sort through all the competing claims above and so many more like them? How do we know which beliefs are more reliable?

Very often deductive arguments contain premises that are general statements of alleged fact. Here is an example:

Conclusion: Smoking should be banned from all public buildings.

Premise 1: Smoking is a principal cause of lung cancer and other serious illnesses, and second hand smoke kills 35,000 people a year.

Premise 2: No one has a right to infringe on the health rights of another in pursuit of what they deem their own happiness.

Premise 3: If premises 1 and 2 are true, then smoking should be banned from all public buildings.

With the premise of the moral principle that no one has a right to infringe on the health rights of another in the pursuit of what they deem their own happiness, the validity of this argument should not be in dispute. What is disputed by smokers' rights groups and cigarette manufacturers is the truth or reliability of the first premise and the assumption of the danger of secondhand smoke. How do we know these beliefs are true? When I ask my students this question, I sometimes hear, "Well, you know, '*they'* say these beliefs true." But who is being referred to and how does this group know these statements are true? The more informed student will respond that "they" are teams of specially trained biomedical researchers who have used scientific methodologies to study the link between cigarette smoking and illnesses such as lung cancer and emphysema for many years. True, but scientists often disagree. In fact, cigarette manufacturers have their own teams of scientists who claim that the link between secondhand cigarette smoke and serious illness has not been proven.

By the early 1990s, 36 percent of Japan's total population (almost 60 percent of the men) smoked cigarettes. At a time when U. S. government policy supported the belief that smoking cigarettes is very dangerous to health and the British government was putting "Smoking Kills" labels on packages of cigarettes, Japanese government policy asserted that the link between smoking and lung cancer had not been established and the Freedom Organization for the Right to Enjoy Smoking Tobacco called the studies on cigarette smoking "gross exaggerations."

At this time in China only 30% of the millions smokers believed that smoking was harmful and 10%-20% believed that smoking improved their health. While cigarette consumption in the United States has declined dramatically, it has risen 70% in the last

25 years in developing countries. Faced with this decline, American cigarette manufacturers market the specialness of their cigarettes in third world countries with slogans such as, “the way America tastes.” At the beginning of the twenty-first century, in some developing countries young women in cowgirl outfits handed out free Marlboro cigarettes to teenagers at rock concerts and discos and those who lit one up right away were given Marlboro sunglasses.

Could this be another Flat-Earth story? Are the relativists right? Can any belief be supported well by evidence? Is it possible that anything is made true simply by believing it is true or as long as it is part of a cultural tradition? Is objectivity a myth? If the Japanese government changed its policy, accepting the same policy as that of the United States and Great Britain, would this mean that the link between smoking and lung cancer was formerly false in Japan, but now it is true? Or, that smoking was always harmful, and it just took many years for the culture and government of Japan to "discover" this objective truth?[1] And speaking of history, even in the United States Camel cigarettes were once advertised as the cigarette of choice by doctors.

Skeptics will point out that many seemingly solid scientific ideas of the past were rejected by a later generation of scientists as false. Could this happen again? In Woody Allen's movie *Sleeper*, a former operator of a New York health food store has been put to sleep and cryogenically preserved for many decades and then brought back to life. He awakes to a relativist nightmare in which many of the beliefs and values that he took for granted in the 1970s are now seen as the myths of a more primitive time. One of the more startling beliefs of this new age for a former health food devotee is that smoking cigarettes is now thought to be good for people's lungs, like taking vitamins! How likely is it that this will happen? How do we know that what science is telling us about cigarette smoking is objectively reliable?

[1] Even if it is true that anything is made true simply by believing it true, is this not an objective discoverable truth?

Our task in this chapter is very important. Not only do we need to understand and be able to recognize the nature of different inferential claims (deductive v inductive), but also we need to provide a philosophical justification for the claim that in spite of life's uncertainty, some beliefs are better (more reasonable to accept as reliable) than others. Specifically, we need to show that some inductive inferential links are better or more probably true than others; that there are many beliefs that a reasonable person should accept ─ such as the link between cigarette smoking and serious illness, that the Earth is spherical and millions of miles from the Sun, that the Universe is enormous and very old, that life on Earth has evolved over many millions of years, and that the human species has a contingent historical past. We need to flush out and defend the claim that some ideas are more reasonable to accept than others, even though it is conceivable that we can still be wrong about future reliability when we accept a well-supported belief. In other words, we need to understand that there are many beliefs that are uncertain and at risk given the evidence in an imperfect world, but that some beliefs are much more probable and well-supported by evidence than others.[2]

Let's begin with some technical definitions and recognition exercises.

Deductive arguments:

Arguments where the goal (to achieve valid arguments) is to provide conclusive evidence for the conclusion; the nature of the inferential claim is such that it is impossible for the premises to be true and the conclusion false. (Valid or Invalid)

Inductive arguments:

Arguments where the goal (to achieve strong and reliable beliefs) is to provide the best available evidence for the conclusion; the nature of the inferential claim is such that it is unlikely that the premises are true and the conclusion false. (Strong or Weak)

Here are some examples:

Deductive argument:

All U.S.-manufactured cars built after 2004 were equipped with tire pressure warning lights at the factory.
John has a 2005 U.S.-manufactured Ford.
Thus, John's car was equipped with tire pressure warning lights at the factory.

Inductive argument

[2] Remember that the rational force of a valid argument is seriously compromised if we can't also establish in some way that the premises are reasonable. And many premises can be justified only inductively.

After careful observation we have not seen any hummingbirds all day in this forest. Therefore, probably there are not any hummingbirds in this forest.

Notice how each example fits the definition. In the deductive example the author is not claiming that John's car probably was equipped with tire pressure warning lights. The tone of the argument is such that we are sure that if the premises are true, the truth of the conclusion follows conclusively. John could possibly have a 2003 Ford, or the year when all cars had to be equipped with tire pressure warning lights might not be 2004. (Remember, valid deductive arguments can have false premises.) But if it were true that every U.S.-manufactured car built after 2004 was indeed equipped with tire pressure warning lights at the factory, and John has a car built in 2005, then there is no doubt that he has one of the cars equipped with tire pressure warning lights at the factory. Deductive arguments attempt to provide certainty for their conclusions. As you should recall from Chapter 1, when the reasoning or inferential part of this attempt is successful, as in the present example, we call such arguments valid. When the inferential attempt is unsuccessful, we call such arguments invalid.[3]

In the inductive example, the nature of the situation and the use of the indicator word *probably* in the conclusion show that the author's intent cannot be to prove beyond a shadow of a doubt that there are no hummingbirds in the forest. Other indicator words or phrases for inductive arguments would be *it is likely*, *it is plausible that*, and *it is reasonable to conclude*. **Inductive arguments can provide only "some" evidence for the conclusion; the conclusion always goes (generalizes) beyond the evidence provided in the premises to some extent**. **At best, good inductive arguments have conclusions that are probably true**. With inductive arguments we have to deal with levels of **probability**.

A probable belief or event, is one that is likely to be true or occur given the evidence; the evidence gives us high confidence that a belief is true or an event will likely happen, even though there is some risk. It is very probable that the sun will rise as it always has tomorrow, but there is no 100% guarantee because the sun has a life-time as does every object in the universe. (Our sun's life-time has about another 5 billion years!)

Clearly, in our hummingbird example it is possible for the premise to be true, while the conclusion is false. We could walk all day in a particular forest and examine a large part of it, and agree that we have not seen any hummingbirds. But because our conclusion is a generalization about the whole forest, including many parts we did not observe, to make the conclusion false would require only one human-avoiding, elusive hummingbird, which perhaps moves quickly from our sight every time we approach. Furthermore, notice that even if we supplemented our argument with more true premises, such as a year of daily observations of the forest by a team of trained ornithologists specializing in hummingbirds and who know the signs of hummingbird habitation ─ food supply consumption, use of particular nest material, fecal droppings ─ still something could have been missed, and the conclusion could still be false, although now very unlikely. Also

[3] Remember that to completely fulfill the goal of a deductive argument, the argument must be sound. The reasoning or inference must be valid, and the premises must be true.

notice, however, that these added premises would make the conclusion stronger and more likely to be true. Although an uncertain world, we can add supportive evidence and increase probability.

To state, "No hummingbirds exist in this forest" is to make what logicians call a **universal generalization**. Further examples would be, "All crows are black," "All presidents are wealthy," "No politicians are poor," and "No Buddhists are violent." All that is required to falsify a universal generalization is one contrary instance to the generalization. Any finding of a single hummingbird, a white crow, a poor president or politician, or a violent Buddhist would be a falsification of the above generalizations.

Technically, all inductive arguments are invalid. It is always possible for the conclusion to be false, and the premises to be extensive and all true. Many students will often draw an overly skeptical and cynical conclusion from this realization. (So have some great philosophers!) They reason that if most of our beliefs are based on inductive evidence, where our beliefs are conclusions of inductive arguments or premises in deductive arguments, and the conclusions of inductive arguments can always be false no matter how rigorous the effort put into substantiating our premises, then we really have no rational basis for believing anything as true or reasonable for acceptance! In other words, because the definition of a sound argument in Chapter 1 (deductive valid argument, plus true premises) is only an ideal case that is never realized in the real world ─ because we can never prove absolutely that the premises are true ─ some students become skeptical about accepting any belief as reliable.

The beliefs that many people have are based on very weak foundations and are *hasty* universal generalizations. Therefore, such initial skepticism is often healthy. But in the present case most students go too far. My own suspicion is that this is a "pendulum" effect. Because many students have been taught by their parents, culture, or subculture to think in very black-and-white terms ─ to divide up the world between true beliefs (theirs) and false beliefs (other people's beliefs that they disagree with) ─ they are initially puzzled or confused by the claim that a belief can have evidence for it and be reliable, but not known to be true in an absolute sense. Thus, in recognizing for the first time that beliefs cannot be supported absolutely, they often swing all the way over to the opinion that nothing must be true. This epistemological swing is a way of psychologically protecting their beliefs from criticism and themselves from confusion. If nothing is true, then all beliefs are equal and the amount of effort we put into substantiating our own beliefs is irrelevant and we can believe whatever we want. If beliefs require evidence, but still cannot be known with certainty to be true no matter how much effort is put into gathering evidence, then this seems like a lot of work for nothing. We might as well save the time for watching music videos, surfing the Internet, updating our Facebook pages, or playing video games.

As you should recall from Chapter 2, this is the philosophical position Protagoras developed many centuries ago. Sophisticated versions of relativism are still defended today. For instance, the late philosopher Paul Feyerabend at the University of California at Berkeley argued that we live in a culture dominated by a scientific "mythology." He

claimed that so-called scientific objectivity is a myth, that modern scientific beliefs are no better than primitive beliefs, that all beliefs can be equally supported and hence can be considered true. According to Feyerabend, a careful analysis of so-called rational evidence shows that all beliefs can be rationalized and that "anything goes." According to Feyerabend, this result is not just that of an ivory tower debate of no practical consequence. Substantial concerns are at stake, because our world is rapidly becoming a global culture dominated by science and technology, and hence a cultural imperialism is obliterating cultural diversity.[4] Views such as Feyerabend's are used to support postmodernist's claims that sexual discrimination, racial injustice, and culturally biased curricula at colleges are produced by an oppressive Eurocentric perspective.

Feyerabend and the postmodernists raise perennial issues of great importance, which should be debated carefully in a society that values an open exchange of ideas. If nothing else, these claims show how apparent abstract issues are intimately linked to those things that concern us the most. However, it should be apparent that relativism is not the position defended in this book. I will argue that realizing that induction is not deduction does not mean that we cannot be rational in using induction. **We can have good reasons for accepting some beliefs as reasonable, reliable, and probably true to use for practical decisions on courses of action in an uncertain world**. However, we do need different standards of appraisal to judge deductive and inductive arguments. As we will see, in using inductive arguments the judgment of the worth of the inferential claim must always be relative to alternatives, rather than against some ideal of absolute certainty. In the above example, clearly the evidence of bird specialists who observe the forest daily for more than a year is better than that of an untrained group of hikers meandering through the forest on only one day. If you were on a committee that needed to make an important decision on logging the forest based on whether or not a rare, endangered hummingbird species lived in this forest, which evidence would you use?

In the case of Iraq and weapons of mass destruction, during the Iraq war, which would be better? An extensive search by untrained military personnel or an extensive search by specialists trained in detecting signs of nuclear, biological, and chemical weapons? Furthermore, if you went shopping at a particular store and then lost your keys, how much of the store would you have to search before you concluded that the keys were probably not in this store? In Iraq, after almost a year and half of searching, specialists in weapons of mass destruction found no evidence of existing weapons. In the case of the hummingbirds, the store, and Iraq, the conclusions that there are no hummingbirds in the forest, the keys are not in the store, and Iraq had no weapons of mass destruction could still be wrong, because the evidence is inductive and we are

[4] See Feyerabend's ***Against Method*** (Verso, 1993), his ***Science and a Free Society*** (NLB, 1978), and his ***Farewell to Reason*** (Verso, 1988). In his later years, Feyerabend softened somewhat his views. He admitted that some beliefs will not "gain traction," but that his essential argument is that reality is abundant, that we attempt to shape it and pigeonhole it with beliefs, and all fall short of capturing the abundance, so no belief should be masqueraded as being "objective." See his ***Conquest of Abundance*** (University of Chicago Press, 1999).

generalizing. But these conclusions would be stronger than, and not be equal to, the alternatives as the relativists argue.

Also, recall our discussion on gravity from Chapter 2. What would you teach children about jumping off tall buildings? Would you teach them that the belief in levitation is equal in evidence to the belief in gravity and falling? Which belief has the most inductive evidence for it and hence is the most reliable? Because a belief is a generalization and hence could be false does not mean that it is false or that it is not well supported by inductive evidence.

Before we go any further examining the rational basis for inductive inference, let's get some practice recognizing and separating deductive and inductive inferential claims.

Decide if the following arguments are either inductive or deductive arguments.

EXAMPLE 3-1

All Republican presidents have been in favor of a strong military.
President Bush was a Republican president.
It follows that President Bush was in favor of a strong military.

EXAMPLE 3-2

John is on the softball team and has short hair. Dan is on the softball team and has short hair. Kenji is on the softball team and has short hair. It seems likely that all the members of the softball team have short hair.

EXAMPLE 3-3

All members of the terrorist organization Hamas are sympathetic to the Palestinian cause
Barack Obama is sympathetic to the Palestinian cause.
So, Barack Obama must be a member of the terrorist organization Hamas.

EXAMPLE 3-4

If Hansen is the serial murderer, then his fingerprints would be on the gun. His fingerprints were on the gun. Therefore, it is clear that Hansen is the serial murderer.

EXAMPLE 3-5

Most presidents of the United States did not die in office. Therefore, it is doubtful that the twelfth president of the United States died in office.

Here are the answers. Example **3-1** is a valid deductive argument. The author is not attempting to persuade us that it is only likely that Bush was in favor of a strong military, but rather that the conclusion follows conclusively from the premises. Example **3-2** is an

inductive generalization. From the particular cases of a few members having short hair and being on the softball team, the author generalizes that all the members of the softball team are likely to have short hair. Example **3-3** is an invalid deductive argument. Although the word "must" if often ambiguous, suggesting either high probability or conclusive necessity, it appears that the author of this argument is attempting to provide conclusive evidence for the conclusion, thinking that the premises are sufficient for deducing that Obama is a member of Hamas. If the author intended only something like "Obama is probably a member of Hamas" for the conclusion, then we would have to appraise this argument by inductive standards. But the tone of the argument appears to be deductive, even though the inferential claim fails from this perspective (invalid deductive argument).

Number **3-4** (invalid deductive) is a good example of how easy it is to turn an apparent deductive argument into an inductive argument. As the argument is presented, the phrase "it is clear that" indicates that the author thinks that the premises provide conclusive evidence for the conclusion. They don't. It is possible that the premises are true, but Hansen is not the serial murderer. This could be a classic case of circumstantial evidence. There are many ways Hansen's fingerprints could have been on the gun. He could have picked up the gun shortly after the shooting or touched the gun in some way prior to the actual murder in which the real murderer used gloves, leaving only Hansen's fingerprints on the gun. Suppose in discussing this situation with the author of the argument, after reminding him of these possibilities, he backs off from his initial claim. He tells us that he meant it is reasonable to tentatively suspect Hansen, to bring him in as a prime suspect for questioning. If so, we would then appraise the author's argument based on inductive standards. How strong is the evidence, his fingerprints on the gun, for the conclusion that Hansen is the serial murderer? What other kinds of evidence are needed to strengthen our confidence in the conclusion?

Finally, example **3-5** (inductive) shows it is a misconception to believe that deductive arguments always move from general premises to particular conclusions and that inductive arguments always move from particular premises to general conclusions. Although this is often the case -- **3-1**, **3-2**, and **3-3** fit this alleged rule -- it is not always the case. Although **3-5** has a general premise (a statement about most presidents) and a particular conclusion (a statement about the twelfth president), the nature of its inferential claim is inductive. Because the premise states only that "most" presidents have not died in office, it is impossible to conclude with certainty from this premise alone that the twelfth president of the United States did not also die in office and the author of this argument indicates as such with a reference to probability (“doubtful”) in the conclusion.

It is important to decide if arguments are deductive or inductive, because different standards of appraisal apply for judgments on the worth of the reasoning. The distinction between invalid and valid deductive arguments marks a sharp dichotomy between inferences that are on track and those that are not. Like deductive arguments, inductive arguments attempt to take us (through inference) from what we think we know is true (premises) to what else is true (a conclusion). But in appraising inductive arguments we will see that judgments of good reasoning involve a comparative matter of degree, more

of a sliding scale of bad to good, from very **weak** (improbable and unreliable) to very **strong** (probable and reliable). As a simple rule of thumb, look for tones of arguments such as,

(**Deductive**) "There is conclusive evidence that X is true, if the premises are accepted as true."

(**Inductive**) "There is good evidence (if the premises are accepted) that X is probably true, a reliable belief."

Separating deduction from induction is not always easy, and as in general communication, disagreements occur. But standards of appraisal cannot be applied until some decision is made, until some focus has been decided upon.

Induction and Reliable Beliefs

As a further example of inductive reasoning and the philosophical nuances that you need to master for a full understanding of inductive appraisals, consider the following.

Suppose we bring a barrel full of apples into a room. Suppose someone tells us that the barrel contains one hundred (100) apples. I reach into the barrel, and from the top, pull out one apple and place it on a desk. Upon inspection we can see that no one in his right mind would eat this apple. It is considerably overripe, being very soft and full of maggots. Although few people would purchase the barrel of apples for human consumption, suppose I gave you one thousand dollars to wager on the status of all the apples in the barrel. What I want to know is, at what point in gathering evidence (we are going to pull out more apples) would you be willing to bet your one thousand dollars on the conclusion "All the apples in the barrel are rotten."

Here is my offer: if after only one apple is observed you bet that all the apples are rotten and you are correct, then you will win one hundred thousand dollars. If you bet after five are observed and you are correct, you win ninety-five thousand dollars, and so on. However, if even one apple is not rotten, I take back the one thousand dollars.

Clearly, this is an inductive situation. I am essentially asking you to tell me at what point in gathering evidence you believe the evidence is sufficient to warrant the generalization (that all the apples are rotten) is reliable. At what stage in gathering evidence would the generalization be probable? In the first case, you have ninety-nine cases in which the conclusion could be shown to be wrong, even though the premise is true that one apple is rotten. Even after pulling out ninety-nine apples and (supposing) all were rotten, it is still possible that the last apple is not rotten,[5] that the conclusion (generalization) "All the apples in the barrel are rotten" is false.

[5] Notice that in order to avoid a disagreement we would need a stipulative definition before we start for what we mean by "not rotten." Perhaps we would agree beforehand to have a neutral observer in the room, and if this neutral observer would be willing to eat an apple, we would designate it as not rotten.

On the basis of only a single positive instance, would it be wise to conclude that all the apples are rotten? Wouldn't this be a very weak induction? Would you risk your one thousand dollars at this point? What if the thousand dollars were you own money?

Small amounts of evidence need not always be weak. A microbiologist, for instance, might be willing on the basis of this one apple to wager that all of the apples are likely to be rotten, if a few other pieces of information were provided. Given the general background knowledge of the existence of bacteria and their ability to reproduce rapidly given the right conditions, if it were known at what temperature the apples were stored, and for how long, a conclusion that all the apples are rotten might not be unreasonable. If we also noticed that a significant amount of fluid was oozing from the rotten apple and the microbiologist was allowed to examine this fluid microscopically, scientists trained in this field might be willing to bet their one thousand dollars -- reasoning that the fluid has (suppose) an extremely high bacterial count and must have been draining from the top of the barrel to the bottom (because of gravity) for some time.

Often in science a very small number of observations are made to do a lot of hypothetical work, especially when they are placed within a framework of a general consensus of belief of how other aspects of the world work. Around the world, physicists in huge laboratories the size of small cities accelerate subatomic particles and smash them into each other. With a very few key observations from these experiments, the theoreticians follow long excruciating mathematical trails until they arrive at statements about the first microseconds of the universe, approximately 14 billion years ago! Physicists believe that hidden within the depths of every atom is fossil-like evidence of how matter and energy were first formed to make our universe. By smashing subatomic pieces into each other they are attempting to mimic the first microseconds of our universe.

Similarly, our microbiologist could apply other general scientific beliefs (also based on induction) to make a judgment on the significance of the observation of one rotten apple. Plus, we could learn from apple farmers the general knowledge that apples in a barrel always spoil from the bottom up! These other beliefs are sometimes called **higher-order inductions**, **auxiliary hypotheses**, or **background knowledge**. They are also based on inductive reasoning, but if they have been tested and have a high degree of reliability, they strengthen and **corroborate** our belief in other generalizations. A web of well-supported generalizations all supporting another generalization considerably enhance reasonable confidence in an at-risk belief. When a number of beliefs “fit together” so to speak and each is independently supported by strong inductive evidence, there is less risk and higher probability. For instance, one reason of many that modern scientists overwhelmingly support the basic Darwinian theory of biological evolution is that it is supported by fundamental well-supported generalizations from astronomy, chemistry, physics, geology, paleontology, and genetics. Understanding evolution is also the foundation for modern biomedicine.

Much could go wrong in our apple example, however. The general beliefs could be wrong. Perhaps the laws thought to govern bacterial growth don't work in this particular barrel. Perhaps gravity stopped working in this barrel. Maybe an associate of mine placed

the rotten apple on top of the barrel just before the barrel was brought into the room. In judging the significance of one observation, our microbiologist would need to weigh the reasonableness of many other judgments. How likely would it be that gravity stopped working in just this barrel at just this time? How likely would it be that there is a conspiracy involved in this game; that the rotten apple was placed on top just before the barrel was brought into the room, or that one apple on the bottom was placed in a hermetically-sealed package? As we noted in the previous chapter, a single observation or belief is not neutral but is part of a web of belief, and we can alter our interpretation of this single case depending on how firmly we believe it is reasonable to hold on to other beliefs.

At least we should be able to say that a bet by an informed microbiologist with only one observation is better than a bet by someone with no knowledge of bacteria and the microbiological process of spoilage. Also, a bet based on a single case would be better if it was known that spoilage in similar barrels generally takes place from the bottom up, and better still if we had evidence that no conspiracy was involved ─ that we had good reasons to trust the person who brought the barrel into the room, that this person does not know me, that he retrieved the barrel from a warehouse that was secured from tampering, and so on.

However, without such background beliefs, without appeals to independent or higher-order inductions, concluding that all the apples are rotten from a single positive case is a very weak inductive inference. To make the inductive inference stronger more apples need to be sampled. If I pulled out four more from the top, for a total of five, and all of them were just like the first one, we would now have a better (stronger, more probable) basis for concluding that all the apples are rotten. This type of evidence is called **induction by enumeration ─ we gather or add up more positive premises or cases for our conclusion**. In general, the more positive cases in favor of the hypothesis, the stronger the hypothesis. Would you bet your one thousand dollars at this point? You could still win ninety-five thousand dollars. Suppose all five apples are the same ─ very rotten, maggots, fluid draining onto the table?

Suppose we select five more apples. If all five are again simply pulled off the top, it is still possible that the apples on the bottom are not rotten. Thus, a stronger case could be made by choosing a **randomized representative sample**, by selecting one from the top, one from the very bottom, one from each side of the barrel, and one from the middle of the barrel. If all five are rotten, this would strengthen the hypothesis considerably. A doctor does not need to examine a patient's entire blood supply to do a cholesterol test. A small sample of blood is used to generalize accurately the patient's general HDL and LDL cholesterol levels. Political pollsters use this technique. We have learned that it is much easier to determine the voting behavior of 50 million voters by examining a representative sample of twelve hundred voters (Democrats, Republicans, different races, income levels, ages, sexes, past voting behavior, and so on) distributed throughout the country, rather than one hundred thousand predominantly liberal people living in New York. A small representative sample is much stronger inductively than a large unrepresentative one. Some positive cases are stronger and offer better tests than others.

For this reason, philosophers of science, who study how inductive reasoning is used in science, distinguish between **mere positive cases** of support for a belief and **genuine confirming instances** for a belief.

As an example of a mere positive case that is not a genuine confirming case, suppose someone believes in UFOs, and he claims to have some startling evidence ─ pictures ─ that we have been visited. Suppose we ask to see the pictures and when he produces them, the pictures show blurred images of fast-moving lights that could be spaceships, but also could be images of the planet Venus or of airplanes taken by an inexperienced photographer. When we complain that the pictures don't prove anything he responds, "Don't you see? The UFOs emit a special radiation that makes any pictures taken of them blurry!" Given his hypothesis, he has made blurred photographs of fast-moving lights mere positive cases for his belief in UFOs. But no scientist would consider this evidence genuine confirming instances for a belief in UFOs. Similarly, in our hummingbird example above, suppose we simply looked on the ground within, say a ten-square-foot area and noted that within each square foot we have found no hummingbirds. Each observation of no hummingbirds within a square-foot area of the forest floor would be a positive case for the belief that there are no hummingbirds in this forest. But because we would not be looking in the places an expert would know are likely locations for hummingbirds, our observations would not be genuine confirming instances. A genuine confirming instance for a generalization pushes the generalization harder so to speak by honestly looking for a case that would prove a generalization false. So, it provides more credibility for the generalization when it supports the generalization.

So, five representative apples are better, more genuinely confirming, than ten just off the top. We are pushing the hypothesis more. We have sampled regions of the barrel looking harder for cases that would show the generalization false that all the apples are rotten. Would you bet on the generalization at this point, that all the apples in the barrel are rotten?

I would bet at this point, if I could be reasonably assured of the barrel's independence from human interference and bias, that the barrel of apples was not tampered with, and that only natural processes were involved in whatever took place within the barrel. The inductive evidence is relatively strong and the reward very high ─ I can still make ninety thousand dollars. My decision is based on relatively high **probability** and high **value**.

Keep mind we are not interested in a deductive guarantee for our conclusion. Not possible. Rather at what point is it **unlikely** that the conclusion is false, I would bet at this point, because pulling out more apples lowers my possible earnings and does not increase the likelihood of the conclusion being true that much.

Suppose then we continued to sample the apples by pulling out forty more. Suppose that we now have fifty rotten, maggot-infested apples sitting on a table with fluid running profusely off the table onto the floor. Suppose we pulled the apples from the barrel in a representative way, not just from the top down, but from all over the barrel. Would you bet now? Now we have both a lot of induction by enumeration and a greater

representative sample. Plus also relatively high value; you can make $50,000. Suppose we also had a reasonable assurance that the barrel was not tampered with, the authoritative testimony of a microbiologist, and appeals to independent, background inductions as to the nature of spoilage (bottom-up) in a barrel like this. Would it be wise not to bet? Most reasonable people (who have not had too much logic) would bet their "free" one thousand dollars at this point. But probably they would not bet their life savings or their cars. Even though it would be more likely now that all the apples are rotten, we know that it is still possible that some, even many, of the remaining apples are not rotten.

Suppose we pulled out forty-nine more. Suppose that all ninety-nine sampled are rotten. Would you bet now? You still have a chance of doubling your money, of making another one thousand dollars. Do we know that the last remaining apple is rotten? There would still be risk (and lots of anxiety if you bet your own money) as the last apple was pulled from the barrel, because it is still remotely possible that this last apple is not rotten, that just by chance the spoilage had not yet reached this apple. It is still conceivable that the hypothesis, "all the apples are rotten," is false, even though we have an overwhelming number of positive cases supporting it. It is still **conceivable, but no longer reasonable**, assuming all the other inductive support noted above is still in place, including reasonable assurance that there has been no tampering with the barrel. From an inductive point of view, it would be irrational to believe that the last apple is not rotten.[6]

There is much about the logic of induction and how it is used in everyday life and science that can be summarized with reference to this simple example.

First of all, the kinds of inductions that we often actually use are much weaker than the standards most people impose on themselves in betting their one thousand dollars. Generally people make decisions by jumping to conclusions from very little evidence on the issues discussed at the beginning of this chapter. During the first decade of the twenty-first century polls showed that only about 27% of the people in the United States believed in evolution. Yet, the vast majority of scientists, who we will see are trained to make use of the best inductive reasoning, accept the modern belief in evolution (called natural selection) as a reliable belief because it is overwhelmingly supported by evidence. Today most scientists have the attitude that not believing in evolution is like not believing in gravity in terms of the possible harm such non-belief could cause. (Many people are often confused on the choices here, believing that they have to believe in evolution or God. No, this choice is what logicians call a questionable or false dilemma. More on this below and on the fallacy of questionable dilemma in Chapter 5.)

Suppose you were given the task of entertaining a very important person and you decided to take this person to a good restaurant. How would you go about deciding what a "good" restaurant is? You could use your own personal **experience.** Perhaps you went to a particular restaurant before, and the service and food were excellent. But if you only went

[6] For further details on what scientists know about spoilage in a barrel of apples, see the entertaining, ***Why You Can Never Get to the End of the Rainbow and Other Moments of Science,*** Don Glass, ed. (Indiana Univ. Press, 1993).

once and tried only one offering from the menu, aren't you making a big inductive leap and generalization? Would this be much different than pulling one apple out of a barrel? How many times could you have gone to this restaurant? How many items could you have tried? Maybe the restaurant just had one particular good night when you were there. Suppose you didn't use your own experience, but called a friend instead. Suppose your friend endorsed a particular restaurant as excellent. Now you would be using the **testimony** of another person. But the same questions could be asked. How many times has your friend been to the restaurant? How many different items were tried? Suppose you called another friend who is restaurant critic for a local newspaper. Now presumably you would be appealing to an **authority**, to someone that makes a living sampling restaurants. But authorities often disagree and the same questions can be asked. How many times did this authority frequent the restaurant? How many items were tried? Was this authority there only one night? Was this test really an independent test? Did the operators of the restaurant treat this authority special knowing that this would be very important to their business? Suppose you read in the newspaper that a particular restaurant is the talk of the town and that it takes weeks to get a reservation. Now you would be appealing to **popularity**. Because so many people are going to this restaurant, you think it must be good. But how many times has each person gone to this restaurant? Are they really enjoying the food and service, or are they just assuming that they are because everyone is supposed to at such a popular restaurant?[7]

I am not suggesting with these examples that it is always unreasonable to use our own personal experience, the testimony of others, and appeals to authority and popularity. I am suggesting only that we make "bets" all the time apparently with a lot less evidence than the ideal standards of inductive reasoning. If you are sitting on a chair right now reading this book, how do you know that the chair will continue to support you? Your assumption that the chair will support you involves a generalization. You are generalizing from past experiences of successfully and safely sitting in chairs to the present moment. However, perhaps the chair will collapse soon, and you will suffer serious injury to your spinal column and be physically impaired for the rest of your life. Did you check the chair carefully before you sat down to make sure that it was not a fake chair like those used in the movies, that break easily when smashed over someone's head? Why not? You are inductively reasoning that, given your past experience, it is unlikely that someone has tricked you at this moment by replacing a normal chair with a fake chair. Perhaps you have sat in this chair before and everything has always been normal. But how many times have you sat in this particular chair compared to the number of times you could have sat in this chair? From one perspective, statistically speaking, no matter how many times you

[7] It might interest you to know that I was once somewhat famous among the employees of a particular prestigious Waikiki restaurant in Honolulu. Before deciding to be a college professor I worked as broiler chef at this restaurant. One night, this restaurant had a very bad night. Everything went wrong. We all were very nervous because a movie star had walked in unannounced with a lot of friends. This movie star was a very fussy prima donna, and we concentrated so hard making his dinner perfect that we not only made a mess of his dinner, but most of the others we served that night as well. For my part, I was fired for slightly undercooking his two-inch-thick lamb chop ─ I was trying to make sure that it was not overcooked ─ which I suppose is why I am writing this book rather than still working in restaurants! Anyone who ate there that night could have easily concluded that this restaurant was not all that it was advertised to be and would have been very disappointed if they brought special guests.

have sat in the chair, compared to the number of times you could have sat in the chair, the percentage is less than one apple out of a barrel of one hundred.

My point is not that you have been irrational by sitting in the chair. In fact, most people would think your action irrational if you started carefully checking every chair in the future for a hidden terrorist bomb (another possibility). The point is that we must and do use inductive reasoning rationally all the time, even though we lack certainty that our conclusions are true. If we waited until we had a situation comparable to ninety-nine out of one hundred apples, we would all be sitting in the corner of our rooms afraid to do anything. Lots of things could be true, but when the inductive evidence is overwhelming it is irrational not to believe or act.[8] **The point is not that we are unreasonable using induction or that we should always avoid generalizations (we can't), but how important is the conclusion we are considering and how can we make an inductive inference stronger when the conclusion is very important.**

A second point that should be understood from our barrel of apples example is that even though we may disagree about when it is reasonable to bet on the conclusion, we can at least agree that some levels of evidence and the inductive arguments based on them are objectively stronger than others. With deductive arguments we can have a crisp line between valid and invalid arguments. With inductive arguments there is no crisp line. Instead we have a sliding scale between very strong inductive arguments (99 rotten apples out of 100) and very weak inductive arguments (one rotten apple from the top out of 100). Five apples off the top are better than just one. A representative sample is a more genuine test and amounts to a stronger inductive argument than a simple accumulation (induction by enumeration) of positive cases. Lots of genuine positive cases are better than only a few. Genuine positive cases become stronger if they are consistent with other established background beliefs (higher-order inductions). Independent tests are better than tests that allow for the possibility of bias and tampering.

Many of my colleagues might disagree with me that it is reasonable to bet after ten apples, only five of which were the result of a representative sample. Instead, they may claim that given that we can still win fifty thousand dollars, betting after fifty have been observed in a representative manner is much wiser. But we would not disagree over what was the better case. Their inference would be stronger in the sense that the conclusion would be less likely to be false. However, they would also agree with me that some positive instances are better than others; that a test that involves a representative sample is a better or more genuine test than one that simply selects five off the top.

In the previous chapter we saw how vague statements can lead to unfair acts of persuasion. A similar situation applies to the testing of beliefs. It is easy to find mere positive cases for a belief if that belief is vague. For instance, suppose someone believes

[8] I once had a student who had a serious mental collapse. He called me from his home and said that he could not come to class anymore because he was convinced that the governor's wife liked the color red (she seemed to wear a lot of red dresses). And so he was convinced that the normal pattern of traffic signals had been changed in our state ─ red signaled "go" and green signaled "stop." He said we could not be sure if everyone had been informed of this change, so it was too dangerous to come to the college!

in astrology (many astrological predictions are very vague). As evidence for the value of astrology, he cites the dramatic instance of a man whose horoscope told him it was a bad day to fly. On that day there was a terrible plane crash killing everyone on board, but the man lived because he followed the horoscope's advice. Although this seems a very precise prediction and a dramatic positive instance for the reliability of astrology, the weight of this positive instance changes considerably when we find out that horoscopes frequently tell people it is a bad day for them to fly without plane crashes occurring. If this person responds to this by pointing out that "bad day" can mean a lot of things -- delays in departure or arrival, lost baggage, poor service, a rough and uncomfortable flight, or a baby crying throughout the flight, then we see how very easy it is to find mere positive cases for a belief and how much harder it is to distinguish between genuine confirming instances for a belief and mere positive cases if our belief is vague. Because "bad day" is so vague, almost any occurrence would be a positive case for the astrological prediction.

If I believe that taking massive doses of vitamin C will prevent colds, and for the past one hundred days (from May to August), after taking massive doses of vitamin C I have had no colds, I have a lot of mere positive support for my belief. But have I genuinely tested my belief by selectively not including the winter months? Even if a belief is not vague, selective testing can easily generate mere positive cases.

So, although we cannot have a nice, clean black-and-white line of separation between good and bad inductive arguments, as we can with the distinction between valid and invalid deductive arguments, we can have a sliding scale of reasonableness where some inductive arguments are objectively more convincing, more reasonable, and stronger than others. As we noted above, the issue is not whether we can ever be certain using induction -- we can't, induction is not deduction, and it is always conceivable that our conclusion could be false. Rather, the focus is on knowing when it is reasonable to accept an at-risk, probable conclusion given the alternatives. It is a hopeless, unrealistic, utopian task to have as the goal of life and reasoning the separation of absolutely true beliefs from all conceivable beliefs.

In 2009, polls showed that a slight majority of likely Republican voters believed that president Barack Obama was not born in the United States. Obama's father was from Kenya and some believed that Obama was born there and hence he was not legally the president of the United States. The so-called "birther" movement had gained a lot of traction and was discussed prominently in the media and by some potential Republican candidates for president. A Lieutenant Colonel (Terrence Lakin, lead Flight Surgeon charged with caring for Army Chief of Staff pilots and air crew) refused an order to deploy to Afghanistan because he believed Obama was born outside the United States and should not be commander in chief. However, the Hawaii State Department of Health had certified repeatedly that Obama was born in Hawaii. Obama had released an official short version of his birth certificate during the course of 2008 election. A story was published in the local paper about the doctor who had delivered Obama at Kapiolani Medical Center for Women and Children on Oahu, Hawaii, a block away from where Obama's grandparents lived and the famous high-school he would eventually attend. The

governor of Hawaii had publically stated many times that he was a personal friend of Obama's parents when they were all at the University of Hawaii in the early 1960s when the president was born. According to governor Abercrombie, "I was here when that baby was born." Finally in the spring of 2011, president Obama had a federal official fly to Hawaii and obtain a copy of the original long form of the president's birth certificate and had it released to the news media. But a hard core percentage of "afterbirthers" remained convinced, now more than ever they said. Proof that something was amiss – it took Obama two years to release the long form. Plus, Obama could have easily used the vast resources of the CIA to digitally alter the long form. Conceivable, but reasonable there was a grand conspiracy on the parts of countless people given the evidence? The evidence that Obama was born in the United States v not born in the United States was not equal.

We have to make decisions daily on the basis of comparing at-risk conclusions based on the evidence. We have to separate the reasonable from the merely conceivable. We are interested in good decisions, on actions based on the best possible evidence. Hence, given important inductive situations, especially those in the domain of science that deal with generalizations concerning human nature, health, and general welfare, the goal is not certainty but tentative acceptance, constant testing, and better inductions. The basic takeaway message so far about inductive reasoning is that **we can learn from experience how to make our generalizations less at-risk and more probable**. We use inductions to make inductions better.

A third point that emerges from our apple barrel example is that false ideas work (See example 3-6 below). We can use a general idea that is false to make a prediction that is true. This realization should both humble and encourage us. It should humble us, because it should caution us against being too confident and egocentric about our own beliefs. It should encourage us because the nature of induction is consistent with the notion that life will always be a game of self-correction, growth, and learning. An important illustration of this point is the use of induction in science.

Scientists often test their theories using a combination of deduction and induction. Once a theory is formulated, a prediction is deduced about what should be observed under particular conditions if the theory is true. If we propose a simple generalization that all the apples in the barrel are rotten, then we would predict that one selected from the middle should be rotten. If one selected from the middle is not rotten, we can deduce that our generalization is false.[9] The testing procedure is ultimately based on induction, however, because if an apple is pulled from the middle of the barrel and observed to be rotten, this confirms the hypothesis inductively, but it does not deductively prove it. Compare the following forms of reasoning:

[9] A simple falsification of this sort assumes that the generalization is simple. In science a complex theory will consist of many generalizations -- usually the main hypothesis along with auxiliaries and background assumptions. Hence, because we can deduce only that at least one of the premises is false of a valid argument with a false conclusion, given a false prediction from a complex theory, we can infer only that part of the theory (one of the generalizations) is false.

EXAMPLE 3-6

All the apples are rotten
Therefore, one from the middle is rotten. (Valid deductive argument)

EXAMPLE 3-7

If all the apples are rotten, then one from the middle is rotten.
One from the middle is rotten.
Therefore, all the apples are rotten. (Invalid deductive argument)

EXAMPLE 3-8

One apple from the middle is rotten.
So, all the apples are probably rotten. (Weak inductive argument)

EXAMPLE 3-9

Five apples sampled from different parts of the barrel are rotten.
So, all the apples are probably rotten. (Stronger inductive argument)

EXAMPLE 3-10

Fifty apples sampled from many different parts of the barrel are rotten.
Generally it is known that apples in a barrel rot from the bottom up.
All the rotten apples sampled show a very high bacterial content, indicating that they have been rotten for some time.
So, all the apples are probably rotten. (Very strong inductive argument)

The logic of this situation shows that we need more than simple confirmation (positive cases) to accept a belief as reliable. It is possible to deduce true conclusions (the apple will be rotten in the middle of the barrel) from a premise that may be false (all the apples are rotten) -- that an idea or belief "works" by simply making a correct prediction or having positive confirming instances in its favor is no guarantee of its truth or long-term reliability. Simple confirmation for a belief offers little assurance that the belief will continue to work and that a little critical investigation might not reveal a better-supported idea or belief, one that will work even better and have more long-term reliability. I might be a vice president for a tobacco company, have smoked two packs of cigarettes all my adult life, and have not been sick a day in my life. The belief in no proven link between smoking and serious illness works for me. So far. As Bertrand Russell, a British philosopher and logician, once remarked, "The man who has fed the chicken every day throughout its life at last wrings its neck instead." Our goal should be to make better use of inductive reasoning than a chicken.

All major scientific theories are based upon inductive reasoning. Scientists know that the fact that a theory works and has been reliable is no guarantee that it will continue to be

so. Because it is possible to deduce true predictions from a false theory, no matter how long a theory has been successful in making predictions, it cannot be known to be true absolutely. It could be found false tomorrow. In fact, in our relationship with nature the logical situation is much worse than our apple example. In nature, the situation is analogous to a barrel full of an infinite number of apples.

However, some things are very important to us and we have to place our bets in making important decisions as best we can. Because our health is very important to us and we began this section asking how science can reasonably advise us on a link between cigarette smoking and serious illness, let's draw out the scientific story on cigarette smoking a little. In the process you should be able to see how science attempts to make inductive inferences more reliable, and understand better the delicate balance between cautious methodology and boldness of inference necessary for self-correction in science.

Induction: A Case Study

In the 1970s, the warning label on a package of cigarettes changed from "Caution, smoking ***may be*** hazardous to your health" to "Caution, smoking ***is*** hazardous to your health." By 2011, the U. S. Food and Drug Administration released very graphic warning labels that it proposed go on cigarette packages by September 2012.

This change showed that within the scientific community a consensus had been reached that, among other health problems, cigarette smoking is a principal factor in causing lung cancer.[10]

To clarify terminology first, what does "principal factor" mean? It does not mean that every person who smokes cigarettes will probably get lung cancer. To say, as is believed today, that 80 percent of all lung cancer cases are caused by smoking is not the same as saying that 80 percent of the people who smoke will have, and eventually die of, lung cancer. Some smokers may die of other causes, such as other forms of cancer, accidents, or old age. However, it is now believed that cigarette smokers are many times more likely than nonsmokers to get lung cancer. This implies that it is possible to have lung cancer and not smoke, and not have lung cancer and smoke. The probability of dying from lung cancer is very low if you do not smoke, and the probability of dying from lung cancer is also somewhat low if you do smoke ─ 1%-16% within ten years depending on amount of smoking, age, and smoking history. But the probability of dying of lung cancer if you do not smoke is so low, that

[10] By 1992 in Great Britain the front of all cigarette packages displayed the message, "Tobacco Seriously Damages Health," and the back had one of the following: "Smoking Causes Cancer," "Smoking Causes Heart Disease," "Smoking Causes Fatal Diseases," and "Smoking Kills."

even though the probability of dying of lung cancer as a smoker is also somewhat low, it is many times higher. So, "principal factor" means "major" factor; that most lung cancer cases are caused by cigarette smoking. How has this been established? How has it been determined that this is a reliable belief?

Many decades ago public health officials began to notice a significant increase in the number of lung cancer cases at the same time cigarette smoking was increasing. In the 1930s there were about three lung cancer deaths per one hundred thousand persons per year. By 1955, this had increased to twenty-five deaths per one hundred thousand persons per year. At first this was primarily a male disease; many more men smoked than women. As more and more women began to smoke the death rate for women began to increase. At this point, cigarette smoking was strongly correlated with lung cancer. But **correlations** can be coincidental. Increased use of suntan lotion by teenagers in the 1960s and 1970s is strongly correlated with increased cases of teenage venereal diseases, but an increase in the number of teenagers is more likely the cause of both. In the case of cigarette smoking, factors such as air pollution, daily stress, and the pace of life had also increased. Thus, because science is interested in making inductive inferences as strong as possible, strong correlations are only a good place to start an investigation, not conclude one. At this point, the evidence linking smoking and lung cancer was only circumstantial. There were lots of positive cases, but there was no genuine test at that time.

Scientists have learned, often painfully, that nature can often trick us. They have learned that sometimes when on the surface two occurrences seemed to be linked in the sense of one causing the other, there is actually a third event causing the illusion of a link between the first two. The fact that cigarette smoking and lung cancer have been increasing together could be an illusory link, and the real cause of both could be the increased stress (both environmental and mental) of modern life. So, we learn to adopt methodologies of inquiry that will increase our chances of separating beliefs that reflect only nature's tricks from more reliable beliefs about nature's real processes. We learn to adopt methodologies that will submit our beliefs to genuine tests.

One such methodology is called a **randomized controlled trial**, study, or experiment. A controlled study is deliberately designed to reveal coincidental correlations by allowing possible hidden factors to reveal themselves and destroy the initial correlation. A controlled study controls the factors or **variables** that might be the hidden causes by keeping them the same and under observation in at least two groups, and then allowing only one variable to be different. To genuinely test the link between cigarette smoking and lung cancer, at least two groups of people would need to be examined in such a way that the people selected for both groups would not be significantly different overall in where they live, what they eat, and the stresses they experience. They would not all live in the same place, eat the same food, or have a similar life-style. Rather, overall there would be no significant difference in the two groups. For instance, some people might live in the country and some in the city, but the proportion of each should be the same in each group. Similar to the technique of using a representative sample in the barrel of apples example, each group would consist of a **randomized representative sample** of people in general with no bias towards ill health in either group. If all the people in a

smoking group lived in polluted cities, the objectivity of the controlled study would be seriously compromised. Ideally, the only difference overall would be that one group smokes cigarettes and the other does not. In this way, if a third factor is the real cause of lung cancer, because this cause will be in both groups, there will not be a higher incidence of lung cancer in the group that smokes and the correlation between the cigarette smoking and lung cancer will be destroyed.

One of the first systematic controlled studies on cigarette smoking was carried out by medical researchers E. C. Hammond and D. Horn.[11] More than 180,000 men in the United States between the ages of fifty and sixty-nine were interviewed, targeting their smoking habits, general health, and living environment. Each man was randomly assigned to an observation group in such a way that there was no apparent difference in the representation of major variables in each group other than in one group all the men smoked cigarettes and in the other group no one smoked cigarettes. At the beginning of the study none of the men had any serious illness. After a period of time, the doctors compared the death rate due to lung cancer between the two groups.

To simplify the results, the statistics can be presented from the point of view of the proportion of deaths per one hundred thousand men over a ten-year period. In the group of men who had never smoked, the study indicated that thirty-four cases of lung cancer resulted per one hundred thousand men over ten years. In the group of men who had smoked cigarettes, the study indicated that 4,719 cases of lung cancer resulted per one hundred thousand men over a decade (Figure 3-1). This was a significant difference (140 times more). Furthermore, the study showed that the more a man smoked ─ from less than one-half pack per day to more than two packs per day ─ the more likely he would be one of the 4,719 after ten years. Could the high percentage of lung cancer deaths among the men who smoked be a coincidence?

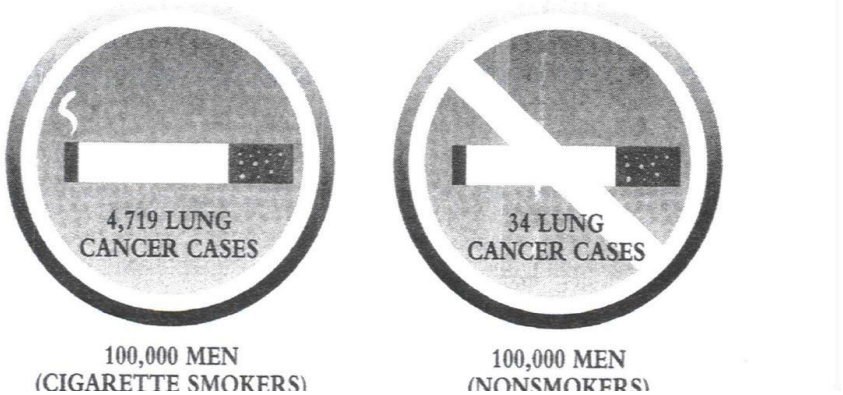
[11] Hammond, E. C. and D. Horn, "Smoking and Death Rates," ***Journal of the American Medical Association***, 166: 1159-72, March 8, 1958; 166: 1294-1308, March 15, 1958.

FIGURE 3-1 HAMMOND AND HORN CIGARETTE SMOKING STUDY

Ages: *50–69 at the beginning of the study.*

Health: *No apparent serious illness at the beginning of the study.*

Result: *Ten years later, 140 times more instances of lung cancer for men who smoked cigarettes.*



Compared to an ideal study, the Hammond and Horn study could be criticized on several points, which the tobacco companies were quick to do. Although a basic environmental variable was controlled in this study ─ no significant difference existed in each group in the number of men who lived in the city and those who lived in the country ─ several other important factors were not controlled. For instance, it was possible that all the men who died of lung cancer, including those who had never smoked, ate a diet significantly different from those who did not die of the disease. Or, they may have had unhealthy occupations, whether in the country or the city that placed unusual stress on the lungs. Perhaps all the men with cancer had stressful occupations involving a great deal of daily anxiety. Finally, and this has been a point the tobacco companies have used consistently, the variable of heredity was not controlled. That is, it is possible that all the men who had cancer were prone to some form of cancer genetically, and this would be revealed by finding other incidents of cancer in their family histories. Parents, grandparents, and relatives of the men who succumbed to lung cancer might have shown a high percentage of cancer, if this was investigated.

Such criticisms serve a very positive function. Critical examinations that reveal weaknesses serve as a basis to make the next study trial better. Since the Hammond and Horn study, thousands of similar studies have been conducted, each incorporating tighter and tighter controls based on possible oversights of the previous studies. By the early 1980s, studies included controls on all of the variables just mentioned. The results have not changed much. By 1985, more than 140,000 people a year died of lung cancer, an impressive majority smoked cigarettes, and for the first time lung cancer for women exceeded that of breast cancer. In the early 1990s, the results of a forty-year study of British doctors showed that only three of every two hundred men who smoked twenty-five cigarettes a day from the age of thirty-five onward lived to age ninety, whereas thirty of every two hundred nonsmokers survived to ninety. And for those who think that serious illness from smoking is only produced in one's later years, this same study

showed that in the forty-five to fifty-four age group, 1.14 percent of the smokers died each year (thirty times higher) compared to .0389 percent of the nonsmokers.[12] Other diverse corroborating generalizations have also been identified in other studies, ranging from the effects of secondhand smoke to analysis of cigarette smoke, which have revealed more than two hundred toxic substances and radioactivity. For instance, here is a partial list:

Acetic Acid (Corrosive to respiratory tract)
Acetone (used in nail polish removers)
Ammonia (Used in floor and toilet cleaners)
Arsenic (a poison)
Cadmium (Car battery Fluid)
Carbon Monoxide (interferes with the supply of oxygen in the blood to the rest of the body)
DDT/dielderon (Insecticides)
Ethanol (Alcohol)
Formalin (used in preserving human tissue and fabric)
Hexamine (used in explosive compounds)
Hydrogen Cyanide (Poison)
Methane (Petroleum Gas)
Naphthalene (used in moth balls)
Nicotine (Schedule 6 Poison)
Nitro Benzene (a petrol additive)
Phenols (used in disinfectants)
Stearic Acid (used in candle wax)
Toluene (Industrial solvent)
Vinyl Chloride (used in PVC).

Some of these ingredients (Formalin for instance) are deliberately added to "enhance" taste and Ammonia is added because it promotes the body's rapid absorption of nicotine. The Ammonia example shows, critics of the tobacco industry claim, that through product design as well as advertising, there has been a deliberate attempt to addict people to cigarettes. In 1999 the federal government filed a lawsuit against Philip Morris USA Inc. and its parent, Altria Group Inc., R.J. Reynolds Tobacco Co, Brown & Williamson Tobacco Co., British American Tobacco Ltd., Lorillard Tobacco Co., Liggett Group Inc., Counsel for Tobacco Research-U.S.A., and the Tobacco Institute. Because the evidence that smoking was harmful was so overwhelming and the tobacco industry had made a concerted effort to mislead the public for over 50 years, the government filed this multimillion dollar case under the Racketeer Influenced and Corrupt Organizations Act. The lawsuit claimed that the companies manipulated nicotine levels in cigarettes to make them more addictive, knew smoking was linked to cancer and other diseases, but conspired to set up research and public relations organizations to cast doubt on those scientific findings. Keep in mind that if it is true that smoking related deaths average over

[12] This study was conducted by Richard Doll of the Imperial Cancer Research Center at Oxford University. For a summary of Doll's work, see his "The Lessons of Life," ***Cancer Research: the Official Organ of the AME,*** Vol. 52, N7, April 1, 1992, 2024.

400,000 per year, then every couple of days more people die due to smoking than died from the 9/11 attacks of the World Trade Center. Imagine the political alarm bells that would go off if terrorists killed over 2,000 U.S. citizens every few days!

The history of genuinely testing the relationship between smoking and lung cancer reveals other factors that make inductive inferences stronger. One controlled study, no matter how thorough, is not enough. Such studies need to be criticized and repeated. **Replication of experiments** is a fundamental best practice in science. Experiments and trials also need to be repeated by **independent investigators.** If Hammond and Horn repeated their study themselves, they might be too interested in seeing their results replicated, and this could seriously bias the design of any new studies, including how interviews are conducted and results interpreted. Also, they received a large grant for their first study, and their reputations and futures as professional scientists would be at stake. Finally, as in our barrel-of-apples example where background knowledge of bacteria was used to strengthen an inductive inference, when independent investigators have worked in an entirely different area using techniques of inductive inference to establish beliefs that **corroborate** a particular belief, that belief is strengthened. In science, a web of corroborating beliefs is often used to support a main hypothesis. We have learned independently that toxic and radioactive substances are linked to cancer, and learning that these substances are in cigarette smoke strengthens the case that nature is not tricking us, but is showing us something about what happens when cigarette smoke is repeatedly put into human lungs.[13]

Does this prove that cigarette smoking is the principal cause of lung cancer? No. There is no such thing as a scientific proof, if "proof" means something that is known with absolute logical certainty. A controlled study can never be completely controlled. The number of ways people can differ, the number of possible variables, is infinite. In all the studies on cigarette smoking, it is possible that some obscure third factor was the real culprit. All of the people who had lung cancer could possibly have had some subtle factor in common that went unrecognized in every study. Perhaps the real cause was that all of the lung cancer victims were given bubble gum on their fifth birthday, and it just so happened that the gum contained a chemical that weakened their immune systems and left them susceptible to a particular virus later in their lives, which then led to lung cancer fifty or so years later! Worse, perhaps lung cancer is very slow in developing and some other factor starts it at an early age, and the developing cancer somehow causes most people to smoke! These and millions of other "off the wall" possibilities have never been tested.[14]

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[13] For another example of corroboration, consider that controlled studies have shown a link between cigarette smoking in women and cervical cancer. Also, when normal human skin cells are grown in a laboratory and then infected with human papillomarvirus (a virus associated with cervical cancer) and then doused with low doses of N-nitrosomethylurea (a cancer-causing chemical derived from the nicotine in tobacco smoke), when injected beneath the skin of mice these cells produce malignant tumors in most cases resembling those of cervical cancer. ***Science News***, March 18, 1989, page 166, and April 6, 1991, 215.

[14] A more likely and interesting possibility is the role of radioactive radon gas prevalent in some homes. Radon gas also is believed to cause lung cancer. It is emitted naturally from the Earth and collects in small amounts in some homes that are well-insulated from cold winters. Recently, however, scientists have

The link between smoking and lung cancer cannot be known in the sense of being known beyond any logical or conceivable doubt. But beware of arguments that claim that because we lack complete certainty, different beliefs about smoking are equal. They are not equal in probability of being true. Given the evidence, we can say that we know beyond a reasonable doubt that cigarette smoking is a principle cause of lung cancer. After decades of research, we possess a reliable belief that will likely stand up to further testing and upon which we can base a course of action. It is very unlikely that in the year 2020 we will discover that nature has been tricking us and that smoking is actually good for our lungs, like taking vitamins. People can continue to smoke for all kinds of reasons, but they should not fool themselves on the risk they are taking. Given the alternatives, it is clear what a reasonable person should believe: Long-term cigarette smoking is causally linked with serious illness, and it is irrational to believe that no evidence exists for this claim, or that we will someday find that smoking is good for our lungs.[15]

Relativists use the elements of risk and uncertainty inherent in inductive reasoning to claim that we can believe whatever we want to believe, that all beliefs are true and can be made reasonable with enough effort. As we have seen, however, though we cannot be absolutely certain, decades of careful research show that linking cigarette smoking with serious illness is a much more reliable belief than tobacco company claims that the link is only a coincidence.

Consider another example. Suppose we were on a jury charged to judge the case of a man suing the Adolph Coors Company because he claimed to have found a dead mouse in a can of Coors beer while drinking it. Independent scientific evidence is introduced by a coroner showing that the mouse died about a week before the man called a local TV station saying that he felt something against his mouth while drinking the beer, and three months after the can was sealed at the Coors brewery. Also, the mouse had external wounds consistent with being stuffed through the can's pop-top opening, and tests showed that the mouse died from a single blow to his neck and did not drown. Finally, testimony reveals that six months earlier the man making the charge had been in an accident with a Coors beer truck and he is bitter that his insurance claim is still unsettled.

Based on this testimony, it seems most likely that the man killed the mouse with an ordinary mousetrap and stuffed it through the opening in the beer can. Based upon this evidence, it would be irrational to believe that the man was telling the truth. Even though it is still conceivable that the date of death for the mouse is wrong, that the mouse received the wounds from the machinery at the brewery, that the man's bitterness toward

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conducted studies controlling for radon gas. The tentative conclusion at this stage in the research is that radon and smoking appear to "synergistically" increase the risk of lung cancer. See John S. Neuberger, "Residential Radon Exposure and Lung Cancer: An Overview of Published Studies," ***Cancer Detection and Prevention, 1991***, 15, no. 6: 435; and "Residential Radon Exposure and Lung Cancer: Evidence of an Urban Factor in Iowa," ***Health Physics***, 66, (March 1, 1994): 263. Exposure to asbestos and a diet low in fruit and vegetables have also been linked to lung cancer.

[15] Often people who smoke believe that "This can't happen to me." Perhaps objective facts need to be supplemented by subjective experiences. For a grim description of what it is actually like to experience lung cancer ─ the pain, surgery, and eventual death ─ see John A. Meyers, ***Lung Cancer Chronicles*** (New Brunswick: Rutgers University Press, 1990).

the Coors Company is just a coincidence, that all the testimony is part of an involved conspiracy to support the Coors Company, there are no reasonable grounds for believing these possibilities. With enough effort we can imagine how the man might be telling the truth and that all the evidence against him is either circumstantial or part of a conspiracy, but **imagining a conceivable scenario is not evidence**. The mere conceivable web of belief needs some evidence for each supporting part. What evidence is there that the date of the death of the mouse is wrong? What evidence is there that there is a vast conspiracy to support the Coors Company?

If we were on the jury, even though we could be wrong, we would need to select the most reasonable belief from the given alternatives. Based on the evidence, some beliefs can be judged more reliable than others. Even though we can be wrong, there are many situations in which it is irrational not to "bet," irrational not to choose the best and most probable alternative given the evidence.

Let's summarize. The claim that cigarette smoking is a principle cause of lung cancer is a vast generalization. Scientists are not just saying that this claim is true in the United States or for our time only. They are claiming that this is true in general for all human beings and in all cultures, and that large numbers of lung cancer cases were caused by smoking in the past and will be caused in the future as well for people who continue to smoke. Bring a person from Japan or China and push them off a tall building and they will fall. Gravity is an objective fact and universally true. Take any person from Japan or China who smokes cigarettes and we know that this person is at a much higher risk of lung cancer than a person who does not smoke. Harm from smoking is a universal fact and not a matter of cultural opinion.

Why do scientists claim that there is an overwhelming amount of evidence for the connection between cigarette smoking and lung cancer? Why is this claim a reliable belief?

Compared to alternative beliefs is the evidence for this belief far superior?	**YES**
Have researchers gone beyond finding mere positive cases for the connection (mere correlations between smoking and lung cancer)?	**YES**
Have the best techniques of inductive reasoning been applied to genuinely test the connection between cigarette smoking and lung cancer (controlled studies, randomized representative samples, and repeated tests by independent investigators)?	**YES**
Is the causal connection between cigarette smoking and lung cancer consistent with and corroborated by background knowledge and other higher-order inductions (toxic substances and cancer)?	**YES**

Case closed? No, but very high probability.

Compare the meticulous testing of this belief to the hysteria generated by an article in the front page of my daily newspaper, "Tofu Linked to Dementia" (***Honolulu Advertiser***, November 20, 1999). From a single study that was actually a retrospective analysis as part of a heart study (The Honolulu Heart Study), that lacked controls on many types of foods and possible life-styles, many people jumped to the conclusion that if they eat tofu they would suffer dementia and Alzheimer's disease in old age. (The study did show a strong correlation between tofu consumption in some ethnic Japanese men and later dementia and Alzheimer's.)

Notice the red flags compared to our list of the hallmarks of good inductive reasoning noted above. Single study, not repeated. Lack of rigorous controls. Plus, there was a major conflict with the hysterical generalization some derived from this study and background knowledge and other higher-order inductions. Soy consumption is generally high in Asian countries (is very high in Japan) and also amongst Seventh Day Adventists. Yet, cases of dementia are much lower in these groups.

Remember to beware of mere associations and correlations. In 2010 a single study reported a slight association between childhood cancer and test-tube babies. This relationship could be causal, but it would need much more study. Often parents who have to use in vitro fertilization already have genetic problems that make normal conception difficult if not impossible. Embryos with defective genes are most often aborted naturally. So, a third cause is surely possible—the genetics of the parents who opt for in vitro fertilization due to infertility.

Beware of getting a world view of beliefs from newspaper and Internet headlines or quick news from friends on Facebook. Always ask some simple critical questions. Was the study considered a good study by other scientists? What is the overall track record for the claim? Supported by other well-supported beliefs? Has the testing been repeated many times by independent investigators?

Logic and Creativity

An essential theme of this book is that logic is a tool that helps us stay on track when we want to test our beliefs for reliability. Do not infer from this that logic is some sort of way of life that differs from or interferes with the creative, artistic life; that logic is always to be used in isolation of, or in place of, creativity and imagination. In the hat example of Chapter 1, to begin the logical trail that led to the conclusion that the blind man must have on a white hat, out of all possible things to think about and out of all possible places to start, it was necessary to notice that the first man could not have seen two red hats, otherwise he would have known he had on a white hat and gone free. Once we see this premise, it seems trivial and it is hard to see how we could have seen anything else, how we could have thought about anything else and followed a much different trail. But the starting point of a trail of reasoning always seems easy after it is recognized.

How do we have insights into a perspective that allows us to start a trail of thinking? Have you not wondered at some time or another where the human race has gotten all its ideas? I remember as a small child watching an aunt make wheat bread. I remember bothering her with question after question about what she was doing: "How is it made? What are the ingredients? Wheat? What is wheat? A plant? From the seed of a plant?" How could human beings ever figure out such a thing? How did we connect up the seed of a common weed to make the bread for my peanut butter and jelly sandwich?

Jean-Paul Sartre, in his existentialist novel, **Nausea**, tells the story of a man who has decided, "Science! It is up to us." This man has decided to read every book in his city library so that he will know everything there is to know. He starts with the first book on the first shelf, and by the time Sartre's hero Antoine Roquentin meets up with this "self-taught man" he is into the L's and reading **Peat Mosses and Where to Find Them**, by Larbaletrier. According to Sartre,

> He has read everything; he has stored up in his head most of what anyone knows about parthenogenesis, and half the arguments against vivisection. There is a universe behind and before him. And the day is approaching when, closing the last book on the last shelf . . . he will say to himself, "Now what?"

He will know many facts, but will he have made any connections? Will he gain any perspectives from all this factual knowledge with which to follow some new interesting trails of thought?

As a final example for these introductory chapters, to tie together our discussions of deductive and inductive logic, truth and the attempt to find reliable beliefs, and as an example to prepare you for why logicians and mathematicians believe you should experience firsthand the beauty, the agony, and the ecstasy of following formal symbolic logic trails (as you will be doing in Chapters 9, 10, & 11), I would like to share with you an example of the use of the human mind at its best. This illustration contains some mathematics (geometry), but with a little effort and a few pictures you should be able to understand and appreciate some exemplary reasoning.

Sometime during the third century B.C., in the city of Alexandria, Egypt, another admirer of books by the name of Eratosthenes was reading about a curious fact. Eratosthenes was the head librarian of the famous library of Alexandria. The knowledge stored in this library was far ahead of its time, and he had access to many great thoughts and facts. The fact that preoccupied him this day was rather ordinary on the surface. He read that in the city of Syene, the site of modern-day Aswan, Egypt, on the day of the summer solstice, June 21, the longest day of the year, at exactly noon, the Sun shone directly over a particular water well and cast no shadow down the well. The average person would probably not even notice this and would surely consider anyone strange who made a big deal over shadows while everyone normal was just trying to go about the day's business. But for someone it was at least curious. Someone had to notice the event and connect it with the summer solstice. For the brilliant Eratosthenes, nature was taunting us with one of its secrets. Magic with which to begin trails of inquiry is everywhere, but usually we are too busy and too "practical" to notice. Perhaps you have to have the mind of a child

and see everything as fresh, new, and exciting. In this case, there was a very exciting connection between the shadowless well and a very big thought.

It is doubtful that it happened this way, but for dramatic effect imagine that Eratosthenes first came across this little item of knowledge a few minutes before noon, June 21. We can imagine him looking up from the book with a passionate, startled look and staring blankly into space. He then rushes outside to find a tall, straight pole and observes at exactly noon a shadow cast by the pole. He then jumps up and down in ecstasy at this great discovery: There was no shadow in Syene, but at exactly the same time there was a shadow in Alexandria. What is the connection?

Combining a few premises based on reasonable inductions with logical and mathematical deduction, Eratosthenes discovered, on the basis of this curious fact, not only that the Earth is spherical, but that its circumference is very large ─ approximately twenty-five thousand miles. It was an ordinary fact, but a very big fact when placed at the starting point of a deductive reasoning trail.

He had a great deal of help in making this discovery. Not only did he have help in obtaining all the premises ─ someone needed to measure the distance from Alexandria to Syene,[16] and someone had to observe and note the connection of a shadowless well at Syene with the date and time ─ but the intellectual environment in Alexandria that made possible the connection of these facts owed its existence to the ancient Greek philosophers who believed that a few facts could go a long way with a little deduction.

The city of Alexandria was founded by the Greek conqueror Alexander the Great. With him came the intellectual tradition of faith in reason, the passion to explore the physical and biological world of Alexander's tutor Aristotle, the belief in natural law of the pre-Socratics, and the triumph of the mathematical teachings of Pythagoras, Plato, and Euclid ─ particularly geometry. With the deductive science of geometry and a belief, fostered by the Greek philosophical rationalists, that with mathematics we possess a mystical power to transport our minds and "see" (like our blind man from Chapter 1) what our eyes may never see, Eratosthenes was able to create a plausible belief about the nature of our Earth that was far ahead of his time.

First of all, what could account for there being a shadow in one place, but not at another? For one possible logical trail, if the Earth was flat, the Sun could be relatively close to the Earth. When the Sun was directly over the well in Syene, it would be at an angle in relation to the pole in Alexandria, thus casting a significant shadow (Figure 3-2). A more likely possibility was that the Sun was very far away, so far that by the time its light reached the Earth, the light rays would be virtually parallel to each other.[17] If this were

[16] Supposedly, Eratosthenes had to hire people to walk off the distance. The distance is approximately five hundred miles, so Eratosthenes's premise had to be the result of an average or approximation, a type of inductive generalization, from the results obtained from individual measurements of the distance.

[17] This premise was also based on inductive and deductive reasoning. But by this time astronomers had already worked out a reasonable basis to believe that the Sun was very far away, even though the estimate of how far the Sun was from the Earth was far less than what we believe to be true today.

so, then another way to account for the shadow in one place, but not the other, would be to assume that the surface of the Earth was curved (Figure 3-3). And if it was curved, it was reasonable to assume that its curved surface met to form a sphere. This was not a new idea. Pythagoras had argued as early as the fifth century B.C. that the sphere was the most perfect shape for the Earth, and Aristotle and others had noted that during an eclipse of the Moon, the dark shape made on its face was that of a disk. (They reasoned that the eclipse was caused by the Earth's shadow moving across the Moon when the Earth was positioned between the Moon and the Sun. Search the Internet for “eclipse moon pictures” to see the curved shape of the Earth passing over the Moon.)

FIGURE 3-2

One way to explain why there was no shadow in Syene, yet at the same time a shadow in Alexandria, is that the Earth is flat and the sun is relatively close to the Earth.

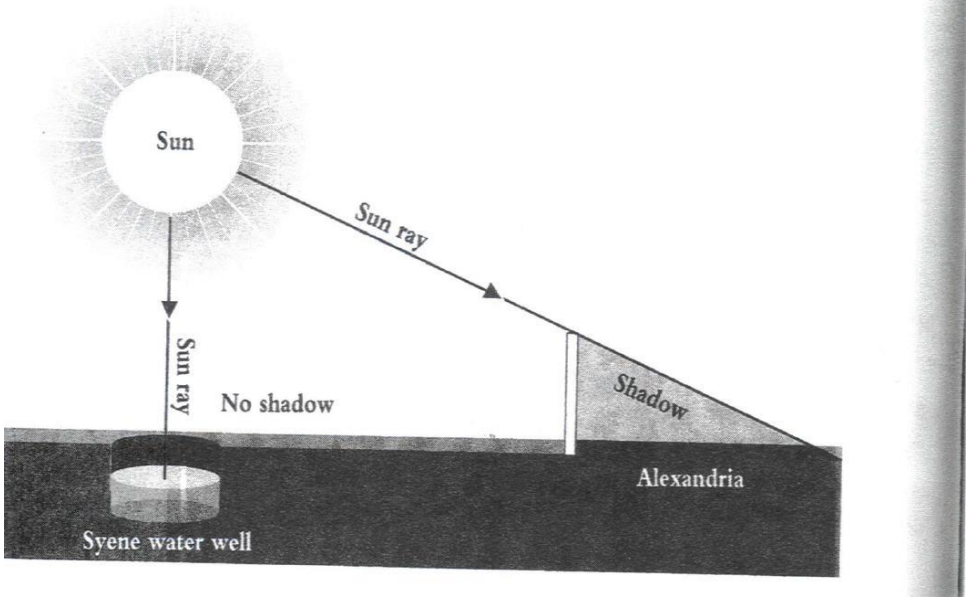
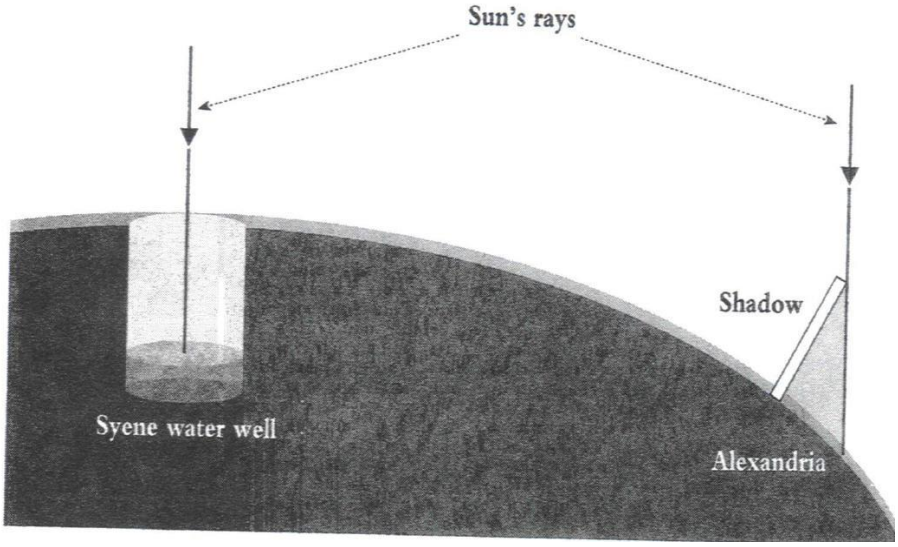


FIGURE 3-3

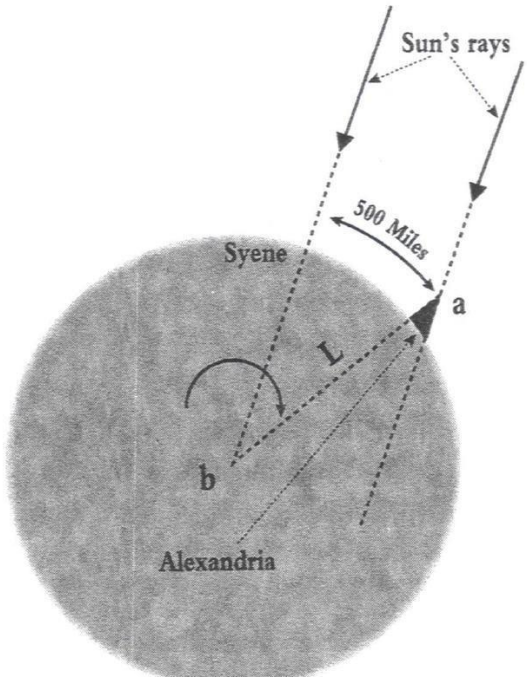
Another explanation why there was no shadow in Syene, yet at the same time a shadow in Alexandria, is that the sun is very far away from the Earth (so far that the rays of light are virtually parallel by the time they reach the Earth) and that the Earth has a curved surface, which implies that the Earth is a sphere.



As the master keeper of this tradition, Eratosthenes knew that circular objects can be measured and analyzed using a method of proportion. (For the purpose of illustration we will assume he knew about degrees. Actually he used fractions.) He also knew from the geometry of Euclid, the alternate angles formed by a line intersecting two parallel lines would be equal. Thus, he reasoned, by measuring the angle of the shadow in Alexandria, we would automatically know the angle made by drawing a line from Alexandria to the center of the Earth and another line from Syene to the center of the Earth (Figure 3-4). This angle would then deductively tell us not only the proportion of space taken up by the angle compared to the entire 360-degree circumference, but also the proportion of space taken up by the distance from Alexandria to Syene compared to the circumference of the entire Earth. Using a simple sundial, he measured the angle created by the shadow in Alexandria to be 7 degrees, approximately 1/50 of a circle. Thus, if the distance from Alexandria to Syene was 1/50 of the circumference of the entire Earth, then the distance around the entire Earth must be fifty times more than the distance between the two cities. Because he had ascertained that the distance from Alexandria to Syene was about five hundred miles, the Earth must be approximately twenty-five thousand miles in circumference (500 x 50 = 25,000).

FIGURE 3-4

By using basic geometry, a few facts, and a lot of insight, Eratosthenes was able to show that if the five hundred miles from Syene to Alexandria was 1/50 of the entire circumference of the Earth, then the Earth must be approximately twenty-five thousand miles in circumference (500 × 50 = 25,000). By measuring the angle a *of the cast shadow in Alexandria to be 7 degrees, he knew the angle* b *to be 7 degrees or about 1/50 (7/360) of a circle. Although the angles in this illustration are exaggerated, note that a crucial premise in Eratosthenes' conclusion is the geometric principle that a line* L *intersecting two parallel lines creates alternate angles that are equal (*a = b*).*



No one at the time could confirm this conclusion with direct experience. Also, Eratosthenes used induction to establish the probable truth of important premises: The Earth was probably a sphere; the Sun was so far away that the light rays were affectively parallel by the time they reached the Earth. Along with the factual knowledge that there was no shadow in Syene, but one in Alexandria that measure 7 degrees, and the distance from Syene to Alexandria was about 500 miles, he then used mathematical principle in geometry and arithmetic to deduce the Earth's probable size. Although the observation of a lunar eclipse supplied observational evidence supporting belief in a spherical Earth, and it was reasonable to assume at this early date that the Sun was very far away, no one possessed the means to circumnavigate the globe in the third century B.C. Nor were there pictures from space showing a beautiful blue sphere. The direct factual evidence for a large, spherical Earth was hardly overwhelming. At this time, whether one believed in the reasonableness of Eratosthenes' picture of the Earth depended more on one's faith in the power of following logical and mathematical trails than the facts. Like our blind man in

Chapter 1, Eratosthenes could not see the entire Earth. But if his premises were correct, he could see it in another way.[18]

A tradition that placed great faith in the following of deductive reasoning trails, curious facts noted by someone else, reasonable background assumptions based on inductive reasoning accepted at the time, accident and serendipity,[19] all of these supplied the ingredients for Eratosthenes' discovery. But they had to be connected by finding the right place to start. It is easy to see the connection after someone has made it. It is easy to see all the pieces after someone has laid them out. The number of potential pieces and trails, however, are always infinite, and one can possess all the facts in the world, like Sartre's self-taught man, and unless one can connect them, all that results is "Now what?"

Eratosthenes had many biases, but these biases helped him make connections. He accepted the rationalism of the ancient Greeks and the idea that mathematics and deduction granted us a special power to transport our understanding to invisible places. Today, physicists and astronomers continue this tradition. They tell us reasonable stories of incredible places trillions and trillions of miles away, of stars bigger than half our entire solar system, of billions of galaxies, some thousands of times larger than our Milky Way with its 300 billion stars, of neutron stars where the matter is so dense that a spoonful would weigh many tons, of black holes, places that seem to be "holes" in our three-dimensional reality, and of quasars that seem to have the brightness and energy of millions of galaxies put together.

For most of the people of Eratosthenes's time, it was hard to believe that the Earth was so large. The distances they were used to extended no more than a thousand miles. Eratosthenes's conclusion conflicted with what these people were familiar with, and no one could take a picture from space confirming that he was right. But the reasoning trail he followed gave him a reasonable basis even for his time to believe that the Earth was much larger than what was commonly believed. Today, astronomers follow similar reasoning trails and tell us a story about the size of our universe that is also hard for most people to believe. Relatively close to our fragile home, they tell us that our Sun is about 93 million miles away. If you could drive in a magic car at sixty miles per hour you would spend 175 years getting to the Sun. Yet the nearest star to us is three hundred thousand times further away than this. Astronomically speaking, the thousand or so stars that we can see at night with the naked eye are all relatively close to us. Most of them are part of a little section within the Milky Way galaxy. Stars on the other side of our galaxy are twenty thousand times farther away than the closest star to us. Our galaxy in turn is a swirling island home in a vast sea of similar island homes. The closest major galaxy to our Milky Way, the Andromeda galaxy, is more than 550,000 times further away than the

[18] Eratosthenes also had to assume that Syene and Alexandria were on the same meridian of longitude, on the same line that would connect these cities and connect the north and south poles. This assumption is not only necessary for an accurate measurement of the Earth's circumference, it is wrong. Hence, by today's standards of measurement, his result, although remarkable, is not accurate. Modern measurements give a 24,902 mile circumference.

[19] Luck has played a role in many scientific discoveries. Was Eratosthenes looking for facts about water wells and shadows? What if he had not read the particular book that described the shadowless well in Syene?

closest star. So, if it would take 175 years to get to the Sun traveling at sixty miles per hour, it would take 300,000 x 550,000 x 175 years to get to Andromeda! And yet Andromeda is a close neighbor in an immense astronomical neighborhood that extends billions of times further away than the distance to the closest star (see Figures 3-5 and 3-6). Like Eratosthenes, with some careful observation and by following logical and mathematical trails, we have continued to push our understanding to unimaginable places, places we will undoubtedly never visit.

Figure 3-5

Andromeda galaxy: like the galactic merry-go-round of our home galaxy, billions of stars swirl around the great galaxy of Andromeda. At more than 500,000 times farther away from Earth than the nearest star to us, massive stars, many trillions of miles apart, appear as packed-together white dust. (Lick Observatory)

Scientists who work in both astronomy and physics also tell us a reasonable historical story of how our existence on this fragile blue speck we call Earth is the result of billions of lucky physical accidents that have taken place over an incredibly long time -- about 14 billion years. To name but one, it is now believed that our Moon was formed by an accidental collision between the Earth and a large asteroid or a large chunk of debris left

over from the formation of our solar system. Without this collision, our atmosphere would be very different; there would be no tides, and most likely no life on Earth.[20]

Similarly, evolutionary biologists study life's history on Earth, carrying out the implications of Darwin's theory of natural selection, and describe for us the myriad, contingent trails involved in species development. To name but one important part of just one never-to-be-repeated trail, they tell us that if another asteroid or comet had not struck the Earth about 60 million years ago, leading to the extinction of the dinosaurs, the human species would never have evolved.

Figure 3-6

Just as Eratosthenes discovered the Earth was big, modern astronomers have discovered that the universe is very big. They believe billions of galaxies exist. This picture is a cluster of galaxies called the Coma cluster. It is relatively close to Earth, yet these galaxies are over a hundred times farther away from Earth than the Andromeda galaxy. (National Optical Astronomy Observatories)

Is Darwin's theory of natural selection true? Using the strong inductive argument check list noted above for the link between cigarette smoking and lung cancer, the acceptance of Darwin's basic theory of evolution (natural selection) is a slam dunk for

[20] See ***What If The Moon Didn't Exist? Voyages to Earths That Might Have Been***, Neil E Collins (Harper Collins, 1993).

scientists. There is an overwhelming amount of positive evidence for the theory (fossil evidence), and the theory is supported by the background knowledge from many sciences, such as astronomy, chemistry, geology, genetics, and physics. The theory has passed abundant genuine tests and fortunately or unfortunately scientists can now take evolution into human hands and accomplish artificially what nature takes millions of years to accomplish. Compared to its competition – creationism, Lamarckism, intelligent design – the theory is far superior in terms of the inductive support.

Putting these beliefs all together, modern science has constructed for us a humbling, but reasonable world view of where we are and where we have come from. Our Earth is a very small speck of fragile dust in a very old and large universe, and our importance is far from obvious. This world view could be wrong, but the quality and quantity of the evidence, and the rigor of the inductive methodologies used, are the same as with the cigarette-smoking example described above. Thus, like the cigarette example, the beliefs that make up this world view are some of the most reliable beliefs we have, at least in broad outline. Most contemporary philosophers of science believe that no matter how much logical deduction and mathematical analysis is used in science, at some point the world must be checked by observation for the confirmation of a belief. But many great scientific and technological discoveries are instituted by people sitting at desks, following the elegant trails of mathematical equations. Many times these trails lead to uninteresting conclusions.[21] Often they lead to a conclusion that is inconsistent with experience, and we must start over and examine new trails. But they are powerful tools that sometimes let us see very far.

Recognizing Inductive Arguments

Before you try the exercises keep in mind that in each chapter so far there have been two basic goals – a big picture understanding of concepts and their practical importance, and a down-to-earth practical task. In Chapter 1, although it is important to take seriously the big connection between the concept of validity and our computer technology and the testing of beliefs, the more down-to-earth focus was to begin to recognize deductive inferences (valid and invalid) and that some arguments have premises that lock us into their conclusions and some do not. In Chapter 2, although there was the important issue of truth and the concept of a reliable belief, the down-to-earth task was to just start getting some practice recognizing arguments and their parts (premises and conclusions).

In this chapter there is the very important connection between the concept of a reliable belief and inductive reasoning, and the identification of some major features of evidence that make some inductive arguments stronger than others. But the down-to-earth task is to continue to practice recognizing arguments and to be able to see that sometimes people present their arguments deductively and sometimes inductively. To help you with Exercises II and III, and in keeping with the formalization recognition techniques we

[21] Remember this when you study Chapters 9-11. You will need to think like Eratosthenes, but many of your trails will lead nowhere.

started in Chapter 1 (seeing the simple form or pattern behind the scenes), let's summarize formally typical argumentative situations that indicate inductive arguments.

In recognizing inductive arguments look for these situations. All of the following would be inductive situations.

Premises that talk about:	**Conclusion** that talks about:
One, Some, Most Xs --->	Most, All Xs
Past events --->	Present events
Past and Present events --->	Future events
Time sequence of events ---> (A happened, then B happened)	Causal Connection between events (A caused B)

Any argument that fits one of these situations will be inductive, because the conclusion is a generalization in some way that goes beyond the type of evidence offered in the premises. If someone generalizes from premises that talk about one, some, or most things being such and such, and then concludes that all these things must be such and such, the argument will be inductive. Similarly if someone concludes that the present will be like the past (premise), he or she would be generalizing beyond what is known. Also, a prediction about what the future will be like (conclusion) based on what the past was or present is like will always be an inductive inference.

The last example is a little more abstract, but very common. Consider this argument:

Example 3-11

Our economy was in a terrible recession prior to 1992. When Bill Clinton became president and radically changed basic economic policies from a cold war focus to a peace dividend focus we had eight years of economic boom and prosperity. So, Clinton's policies caused the economic boom and the prosperity we experienced in the eight years of his presidency.

We classify this argument as inductive because the time sequence (Clinton became president, followed by an economic boom) does not provide conclusive evidence for the conclusion that Clinton's policies caused that boom. All inductive arguments provide some evidence for their conclusions, and this time sequence does provide some evidence for the conclusion that Clinton's policies were responsible for the economic boom. But the premise is far from conclusive. The conjunction of Clinton being in office at a time of economic boom could have been a coincidence and a very lucky break for Clinton. Were Clinton and his team of economic advisors responsible for the build out of the Internet and the globalization of the economy? Is this a strong or weak inductive argument? We will discuss this type of argument again in Chapter 5.

For now, see if you can spot any of the above underlying forms in the arguments in Exercises II and III.

Key Terminology

Inductive arguments
Deductive arguments
Universal Generalization
Falsification
Relativism
Induction by enumeration
Higher-order inductions, background knowledge
Representative sample
Positive confirming instance
Genuine confirming instance
Probability
Evidence from personal experience
Appeals to testimony
Appeals to authority
Appeals to popularity
Correlation
Causation
Randomized controlled study, or experiment
Variables
Repeating experiments (Replication)
Corroboration within a web of beliefs
Eratosthenes
World view of modern science

Concept Summary

Logicians distinguish between deductive and inductive reasoning. Although both forms of reasoning attempt to take us by inference from what we think we know to be true to what else is true, unlike deductive reasoning, where in principle conclusive support can be given for conclusions, **inductive reasoning** can never provide conclusive evidence for inductive conclusions. **Technically all inductive arguments are invalid.** Rather than conclude from this that it is irrational to use induction ─ we don't really have this choice because we use induction all the time ─ we must recognize that different methods of appraisal apply to judging the worth of inductive and deductive inferences, and that the goal of induction should be to learn how to make this form of reasoning stronger and the conclusions more probable. Accordingly, the terms valid and invalid do not apply to inductive reasoning and we will refer to **strong** vs. **weak** inductive arguments. We are interested in high **probability** for conclusions ─ strong evidence that one belief is most likely true compared to alternatives.

Judgments of the worth of inductive inferential claims must always be relative to alternatives; some inductive arguments are better, more probable than others, even though there is no clear demarcation between strong and weak inductive arguments as there is between valid and invalid deductive arguments. Without any other supporting inductions, **induction by enumeration** ─ finding more positive cases for a belief ─ is better than having only one positive case for a belief. Using techniques of **representative sample** are better than simple induction by enumeration, and a distinction can be made between finding **genuine confirming instances** for a belief and **mere positive cases** for a belief. Beliefs based on inductive inference are also stronger if they are supported by

independent, **higher-order inductions** (background knowledge) and a **web of corroboration**.

It is important to have the proper attitude when appraising inductive claims. It is important to recognize that evidence can exist for a belief even though it is not known absolutely whether the belief is true. Because most people tend to think of belief acceptance as categorical ─ they either totally accept a belief or they don't ─ we must learn that it can be rational to tentatively accept a belief, even though we may find the belief false or unreliable someday. Rather than seek beliefs that give us rest, decisiveness, and closure, the goal of inductive reasoning is to constantly test and replicate, and correct if necessary, to constantly be open to learning how to make our inductive inferential claims better, to accept beliefs that, based on their support, are likely to be reliable guides to the future and for making practical decisions.

The distinguished human activity that incorporates the best techniques of inductive reasoning is science. After centuries of being tricked by nature, scientists have devised self-corrective inductive techniques to test beliefs and theories that will make these beliefs and theories likely to be reliable guides to the future. Using creativity, insight, observation, deduction, and these techniques of induction, science has not only created powerful technological tools and reliable beliefs related to our health, but also a startling world view about our evolution and place in the universe. By establishing probable theories and reasonable assumptions and then following long deductive reasoning trails, science allows us to "see" a reality that otherwise would forever remain hidden from us.

Exercises 

EXERCISE I: True or False

1. *With enough evidence, inductive arguments can be made as strong as valid deductive arguments.

2. The amount of evidence is so overwhelming that we now know with absolute certainty that cigarette smoking causes lung cancer.

3. The observation of a correlation between an increase in smoking cigarettes and increased rates of lung cancer (3/100,000 lung cancer rate in the 1930s and 25/100,000 by 1955) was a good place to start an investigation on the possible causal relationship between cigarette smoking and lung cancer, not conclude one.

4. Induction by enumeration is stronger inductive evidence than a representative sample.

5. In a controlled study, it is possible to control every single variable.

6. A conclusion based on a randomized controlled study that is repeated several times by independent investigators is better than one that is done only once.

7. *False beliefs can work in making true predictions, and it is almost always possible to find mere positive cases in support of a belief.

8. Inductive arguments always involve inferences from particular premises to general conclusions.

9. To be reasonable and logical means never to be imaginative, because logic and imagination are incompatible.

10. *Inductive arguments must always be judged relative to alternatives, and there is no definitive demarcation between good and bad inductive arguments as there is with valid and invalid deductive arguments.

11. Universal generalizations can be falsified by a single negative instance.

12. Because of the nature of inductive reasoning, we should always avoid believing in universal generalizations, and there is no rational basis for accepting any belief as reliable.

13. A major feature of weak inductive arguments is that they will conflict with well-supported background generalizations or higher-order inductions.

14. *Scientists believe that Darwin's theory is known to be absolutely true.

15. The major hallmark of inductive arguments is that no matter how well supported the conclusion is, the conclusion always generalizes in some way beyond the evidence given in the premises.

EXERCISE II:

Identify which of the following are deductions and which are inductive generalizations.

1. Harris has a Honda, and it is reliable. Nguyen has a Honda, and it is reliable. Kanishiro has a Honda, and it is reliable. Therefore, all Hondas must be reliable.

2. *All Fords are expensive. So, Tanya's Ford must be expensive.

3. All of the apples in the barrel are rotten. So, one in the middle must be rotten.

4. A principal cause of lung cancer is cigarette smoking. So, John's smoking is dangerous.

5. April smokes and has poor health. Bob smokes and is sick a lot. Yuriko smokes and has trouble breathing in the evening. So, smoking contributes to poor health.

6. *Julio smoked for forty-five years and then had lung cancer when he was sixty-five. So, his smoking must have caused his lung cancer.

7. Presidents of the United States are always wealthy. So, Barak Obama must be wealthy.

8. In the past, all governments that overspent on defense and neglected the welfare of their people eventually collapsed. Hence, any present or future government that overspends on defense and neglects the welfare of its people will collapse.

9. The Supreme Court is about to make euthanasia legal. Hence, it is inevitable that suicide clinics will begin to pop up next to abortion clinics.

10. Many women who have had abortions later regret it. So, we should prevent all women from having abortions for their own good.

11. Evolutionary biologists have shown that whales and dolphins evolved from extinct dog-like creatures. So, it is very likely that all animals alive today evolved from extinct ancestral creatures.

12. It is impossible for any animal species to turn into another animal species. So, dog-like creatures did not turn into whales and dolphins.

13. Alicia is a liberal and voted for John Kerry in the 2004 presidential election. Raul is a liberal and voted for John Kerry in the 2004 presidential election. Isabel is a liberal and voted for John Kerry in the 2004 presidential election. So, all liberals voted for John Kerry in the 2004 presidential election.

14. Most Victoria Secret models have led very stressful lives and many have battled drug addiction. For instance, Naomi Campbell was a Victoria Secret model, battled alcohol addiction and experimented with drugs. So, the new Victoria Secret model from Brazil, Adriana Lima, will probably soon be experimenting with drugs.

15. All U. S. soldiers serving in Afghanistan support the president for re-election. So, all the U. S. soldiers serving in Gardez, Afghanistan support the president for re-election.

EXERCISE III

Structure the argument into premises and conclusion. Interpret each as a deductive or inductive argument and then give a brief argument for your interpretation based on the presence of indicator words or the apparent nature or the inferential claim. For the inductive arguments, explain whether each argument is strong or weak and why.

1. *Because the United States and the Soviet Union have not been able to agree for the past forty years on how to significantly reduce their nuclear arsenals, it is unlikely that they will be able to do so in the near future.

2. All Republicans support the president's Supreme Court nominee, and John Eless supports the President's Supreme Court nominee. Hence, there is no doubt that John Eless must be a Republican.

3. My family has bought Chrysler cars since the first ones were made. These cars have always been reliable. Thus, U.S.-manufactured cars are better than Japanese-manufactured cars.

4. Most modern presidents of the United States have been rich. Therefore, the winner of the presidential election in the year 2020 will probably be rich.

5. *Iraq's acceptance of the United Nations agreement is a necessary condition for a cease-fire. A cease-fire is necessary to stop the bombing of Iraqi cities. So, unless Iraq accepts the United Nations agreement, the bombing will continue.

6. "John is having an affair with Jill," thought Deirdre. "When I called John this evening, his phone was busy. When I then called Jill her phone was also busy."

7. It is most likely that the murderer knew the victim. First, there were no signs of forced entry into the house. Second, according to the neighbors, the victim's dog always barked at strangers, and on the night of the murder no one heard the dog bark. Third, two half-empty glasses of wine were found in the living room where the victim's body was found.

8. If we pay our medical bills and car payment this month, we will not have enough money for basic necessities. We have to have enough money for basic necessities. So, if we pay our medical bills, we can't make the car payment this month.

9. At Kansas State University only females weighing more than 110 pounds are members of the softball team, and all members of the softball team must have at least a C grade point average. It must follow that any female at Kansas State either weighing less than 110 pounds or with a grade point average below a C is not on the softball team.

10. *People argue that sex education should be taught in public schools. Why is this necessary? The worn-out reason is that a lot of parents do not talk about it at home, so it must be taught in school. Yet, since this trend started in the 1970s, VD

and pregnancy among teenagers and even preteens has sharply gone up. Why? I thought sex education was supposed to reduce these problems, not increase them. The answer is that a sex education course is a "how-to-do-it" course, nothing else. Sex education is stupid.

11. Vietnam was a quagmire and killing zone for American troops because political circumstances interfered with military operations and most local people did not support our troops. In Iraq, political circumstances interfere with American military operations and most local people do not support our troops. So, it is likely that Iraq will turn into a quagmire and killing zone for American troops.

12. The war with Iraq was not illegal. This is clear, because if Iraq violated the terms of the cease-fire agreements that ended the 1991 Persian Gulf War, and if enforcement of articles 16 and 17 of the United Nations Security Council resolutions are lawful, then the war with Iraq was not illegal. Iraq did violate the terms of the cease-fire agreements and enforcement of articles 16 and 17 are lawful.

13. Unprotected sex in unmarried couples is a major cause in the spread of AIDS. Unprotected sex is now common again in actors and actresses in the adult film industry. So, in the near future we can expect incidences of AIDS to increase in the adult film industry.

14. The world learned a hard lesson from Munich in 1938 when the British Prime Minister Neville Chamberlain gave into the demands of Adolf Hitler ─ appeasement of brutal dictators does not work. It emboldens the dictator and makes the fight for liberation harder. So, with history as our guide we know the right thing to do in Iraq is to destroy the regime of Saddam Hussein.

15. If civilization itself is at stake, then if we have to kill a thousand innocent people to get one terrorist, it is worth it. Civilization itself is at stake. Hence, if we have to kill a thousand innocent people to get one terrorist, it is worth it.

EXERCISE IV

Essays. Appraise the following arguments from an inductive point of view by describing how you might investigate each claim such that genuine positive support could be separated from mere positive cases of support. Hint: First think of possible cases that would most seriously weaken each claim, and then devise a hypothetical experimental test or investigation that would force nature to reveal the negative case if it exists. (Remember that in the cigarette smoking example, if we found that of those who had lung cancer all lived in a polluted environment, this would seriously weaken the claim that smoking cigarettes caused the lung cancer.)

1. Homosexuality is obviously morally wrong and disapproved of by God. Why else would so many homosexuals have AIDS?

2. *A recent survey of women with college degrees showed that many of the husbands of these women have had heart attacks. So it seems that a higher price than expected must be paid for a college education for married women.

3. A recent survey at a major university showed that students who took large doses of vitamin C for one year found that they had fewer episodes of cold and flu compared to the year before when they took no extra vitamin C. Therefore, taking large doses of vitamin C must be effective in preventing cold and flu episodes.

4. In the 1970s an article appeared in ***Reader's Digest***, entitled "Why Marijuana is Your Enemy." It cited the work of government-sponsored scientist Robert Heath. Heath claimed to have done a controlled study using rhesus monkeys that demonstrated clear signs of a causal connection between marijuana use and brain damage. Six rhesus monkeys in one group were given daily doses of marijuana, and six rhesus monkeys in another group were not. After a specified period of time all the monkeys were killed and their brains were analyzed. All six monkeys in the marijuana group showed enlarged synapses -- a key part of brain function -- implying brain impairment.

   Note: A rhesus monkey weighs only about six pounds, and Heath administered the marijuana to the monkeys by injecting directly into the monkeys' lungs the equivalent of twenty-five human marijuana cigarettes per day of pure THC, the psychoactive ingredient in marijuana. Marijuana is now known to affect behavior by acting on brain receptors for naturally occurring neurotransmitters called endocannabinoids. In other words, the brain makes its own marijuana-like compounds. These compounds seem to be involved in regulating pain, anxiety, hunger, and vomiting. In the United States it has been relatively easy for scientists to obtain research money from the government to study the harmful effects of marijuana and very difficult to obtain funding for possible medicinal uses. See “The Brain’s Own Marijuana,” by Roger A. Nicoll and Bradley E. Alger, ***Scientific American***, December 2004.

5. Night-lights a factor in nearsightedness in children

   Young children who sleep with a light or night-light on have a substantially higher risk of developing nearsightedness as they get older, says a new study in the journal ***Nature***. The study found that 55 percent of children who slept with a room light on before age 2 had myopia, or nearsightedness, between ages 2 and 16. Of the children who slept with a night-light before age 2, 34 percent were myopic, while just 10 percent of children who slept in darkness were nearsighted. A study with developing chickens showed that the amount of light during a 24 hour period greatly affected eye growth. That study concluded that even low levels of light penetrate eyelids during sleep, keeping eyes working

when they could be at rest. (Hint: the single study on children did not control for heredity.)

6. Child-care study shows marked increase in aggression

   A recent scientific study showed that children who attended a large child care center in Florida, where untrained education "associates" where responsible for large number of children at a time, typically displayed higher levels of aggression to their peers compared to children who stayed at home with their mothers. According to Minister Ben Mathews of the New Hope Faith Church, who sponsored the study, "This demonstrates what we have been saying for decades. Young children belong at home with their mothers. Mothers take note. Your career is not more important than your child."

7. John Kerry should win the vote for the presidency easily this November. A recent survey of the readers of the New York Times showed that the readers of this newspaper favored Kerry over George W. Bush by a three to one margin.

8. Analyze exercise III, number 10 (the sex-education claim).

9. In February 2010, Washington D.C. had two feet of snow in just one night. It was the most severe snow storm in years in the D. C. area. Events like this surely contradict the hysterical concern over global warming. The global warming fanatics are wrong.

   Do research on global warming. Find out what supporters of global warming predict about increased severe weather events. Study all the higher-order induction related to the prediction of global warming.

10. Evolution is not true. My ancestors were not monkeys.

    Do research on Darwin's theory of natural selection. Study the competing views: Lamarckism; Creationism; Intelligent Design. Why do modern scientists believe that the evidence is overwhelming that Darwin's basic theory is true? In particular learn about fossil evidence and modern genetics and why the results strongly support Darwin's predictions

ANSWERS TO STARRED EXERCISES

I.

1. False.

Technically, all inductive arguments are invalid. With inductive arguments, no matter how much evidence we have in terms of true premises or positive support, it is always

possible that the conclusion could be false. Hence, we don't use the terms *valid* or *invalid* for induction; we use *strong* or *weak*.

7. True.

From a generalization such as "All the apples in the barrel are rotten" we can correctly predict that some in the middle are rotten, even if the generalization is false. This and other examples (the UFO example, for instance) show that we need techniques of analysis that demonstrate more than mere positive confirmation for a belief.

10. True.

Life is tough and uncertain, but we have to make decisions based on probability. The best we can do in most situations is choose the most reasonable alternative. The goal is to learn how to learn, how to make inductive claims stronger. We have good reasons to believe that gravity is universal, that cigarette smoking does harm lungs, and that biological evolution is true.

14. False.

No inductive generalization can be conclusive, but scientists do believe that the evidence for Darwin's theory is overwhelming.

II.

2. Deductive.

Deducing from a general statement: "All Fords are expensive," a particular instance: "Tanya's Ford must be expensive.

6. Inductive.

Concluding a causal connection (Julio's smoking caused his lung cancer) from the mere time sequence (he smoked, then got lung cancer) is a type of generalization.

III.

1.

Conclusion:

It is unlikely that the United States and the Soviet Union will be able to agree on how to reduce their nuclear arsenals in the near future.

Premise: They have been unable to do so for the past forty years.

Inductive argument. Using past experience, this argument is generalizing about the future. The indicator word unlikely helps us understand that an inductive claim is being made. Because the conclusion says "near" future, unless there were any developments at the time that indicated a possible trend away from the forty-year history, this argument would be rated as relatively strong. Notice though that without the "near" qualification, the argument would be considerably weaker.

5.

Conclusion: Unless Iraq accepts the United Nations agreement, the bombing will continue.

Premises:

Iraq's acceptance of the United Nation's agreement is a necessary condition for a cease-fire. A cease-fire is necessary to stop the bombing of Iraqi cities.

Valid deductive argument. If the two necessary conditions mentioned in the premises are true, then the conclusion is true. The indicator word 'so' helps identify the conclusion. The author is deductively carrying out the implications of the necessary conditions mentioned in the premises. If Iraq wants the bombing to stop, there must be a cease fire. If Iraq wants a cease-fire, then they must accept the agreement. So, if they want the bombing to stop, they must accept the agreement (Either they accept the agreement or the bombing does not stop.)

10.

Although there are other possible interpretations for this passage, one argument contained within it is the following.

Conclusion (implied):

Sex education courses taught at public schools have caused an increase in VD and pregnancy among teenagers. (Implied)

Premises:

Since sex education courses started at public schools, there has been an increase in VD and pregnancy among teenagers.

Inductive argument. Notice that interpreted this way, the argument fits the inductive form of time sequence in the premise and a causal connection in the conclusion. The author is generalizing that there must be a causal connection between sex education classes and teenage sex problems from the fact that sex education courses and an increase in teenage sex problems happened at the same time. The author may think that this is conclusive evidence, but because the argument generalizes from the information

contained in the premises, the argument is an inductive argument. In Chapter 5 we will see that this argument is a Questionable Cause fallacy, a type of very weak induction.

IV.

2.

First of all, we don't know if the percentage of husbands who had heart attacks is an unusual number. Because this passage is concluding that women with college degrees somehow cause their husbands to have heart attacks, we would first need to survey a control group population of married women without college degrees and compare the rate of heart attacks for their husbands. Then, even if the percentage of heart attacks for husbands of women with college degrees is high compared to the control group, we would need to design a survey to see if a third cause was not responsible for this result. In other words, the fact that women having college degrees is correlated with husbands with high heart-attack rates does not mean that the former caused the latter. For instance, it is possible that women with college degrees are attracted to men with certain characteristics, such as the desire and ability to have challenging but stressful careers. (It is also possible that men who have personalities or characteristics implicated in other studies as possible causes of heart attacks are attracted to educated women.) In short, various controlled experiments would need to be conducted in which different characteristics of the husbands of college-educated women are tested as the possible cause. For instance, two groups of college-educated women and their husbands could be compared. In one group would be women and husbands with stressful occupations, and in the other would be women with husbands with less stressful occupations. If a higher rate of heart attacks were found in the first group, this would confirm the hypothesis that stress is more likely a factor in heart attacks than just being married to a college-educated woman.