CHAPTER 14 Reasoning about Causes and Their Effects

An inductive argument can establish its conclusion with probability but not certainty. A previous chapter examined many types of inductive argumentation and introduced some of the methods of statistical reasoning. This chapter begins a systematic study of causal reasoning. Causal arguments are arguments in support of a causal explanation or causal claim. You know what a causal claim is. If I say it's raining, then my claim is not a causal claim. If I say God made it rain, then I'm making the causal claim that God caused the rain. A causal claim is a claim that an effect has a cause. All of us are interested in finding causes; without finding them we'd never understand why anything happens. In the beginning of the chapter, we will explore reasoning about correlations and conclude with reasoning about causes and effects. We will investigate how to recognize, create, justify, and improve these arguments. Cause-effect reasoning often involves arguing by analogy from the past to the present, but it also can involve appealing to scientific theories and to other aspects of logical reasoning, as we shall see in this and the next chapter.

Correlations

A correlation is a connection or association between two kinds of things. For example, scientists are interested not only in statistics about lung cancer, but also in how smoking is related to lung

cancer. This relationship is one of apparent connection, and it is described mathematically by saying that the values of the variable "number of smokers in a group" and the variable "number of lung cancer cases in that group" are **correlated**. The word *correlated* is a technical term. Finding a correlation in your data between two variables A and B is a clue that there may be some causal story for you to uncover, such as that A is causing B, or vice versa.

> One's heart leaps up when one beholds an unexplained correlation between familiar phenomena. — W. V. Quine

Suppose that a scientific article reports that smoking is positively correlated with lung cancer. What this means or implies is that groups of people with a high percentage of smokers usually also have a high percentage of lung cancer cases, and groups with a low percentage of smokers usually also have a low percentage of lung cancer cases.

Here is another way to make the same point. The two percentages tend to rise and fall together across many groups. If A = percent of smokers in any group and B = percent of lung cancer cases in the same group, then the scientific article is reporting that values of the variable A tend to go up and down as values of the variable B also go up and down.

Definition: If the values of the variable A tend to increase and decrease in synchrony (parallel) with the values of the variable B, then there is a *positive correlation* between the values of A and the values of B.

When the values of A and the values of B are positively correlated, we also say that the variables themselves are positively correlated.

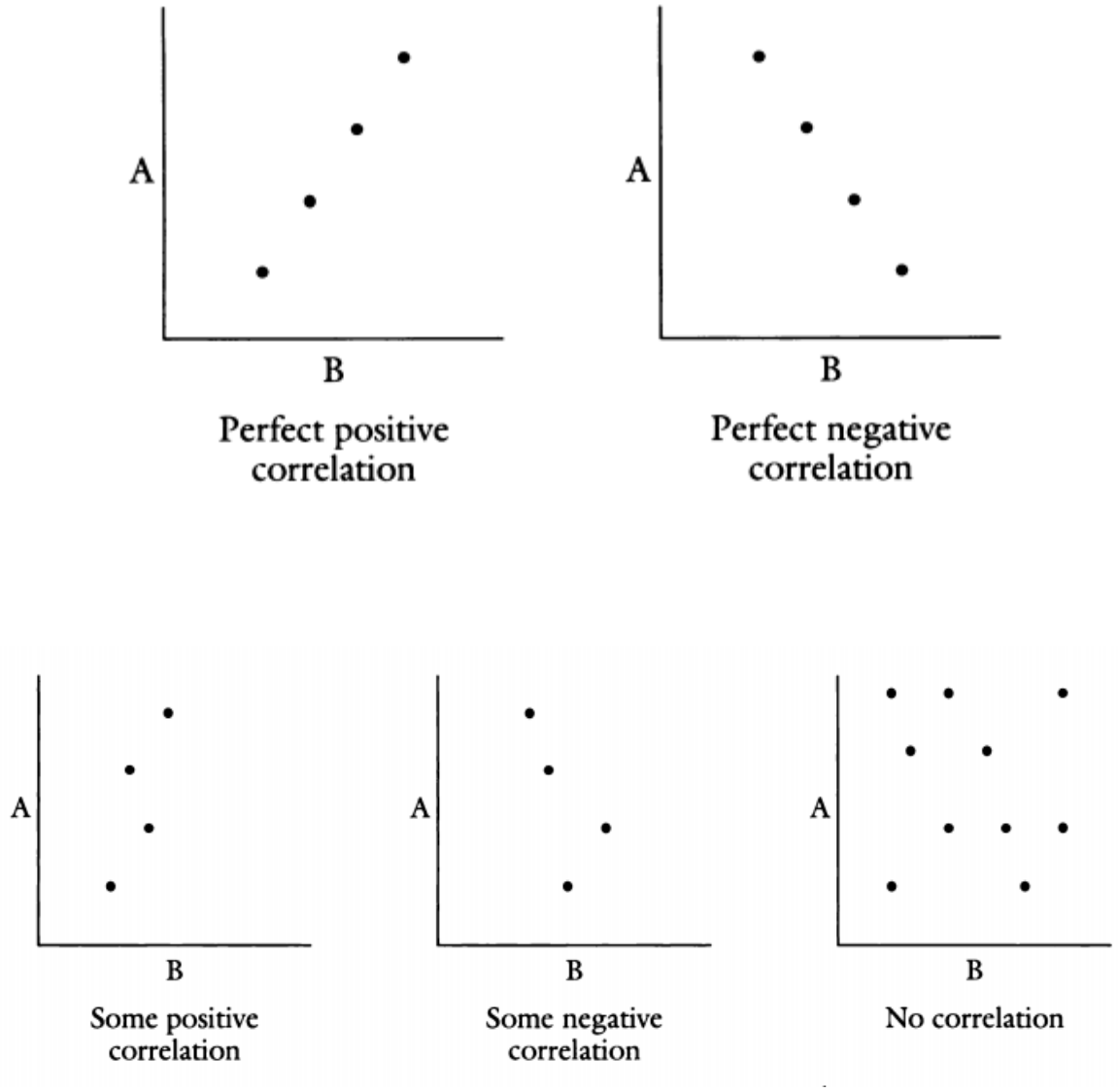
Pressure and volume of a contained gas are negatively correlated. When you increase the pressure, you usually notice a decrease in volume, and vice versa.

Definition: If A tends to increase when B decreases and vice versa, then there is *negative correlation* between A and B.

Definition: If A changes haphazardly as B changes, then there is *no correlation* between A and B.

Being correlated is a matter of degree. Also being correlated negatively or positively implies that the two variables are not independent of each other. If we were to delete the phrase *tends to* from the first two definitions, we would have *perfect correlations*. When A *always* increases with increases in B, and *always* decreases with decreases in B, then A and B are perfectly positively correlated. When scientists say two variables are *directly proportional*, they mean that a perfect positive straight-line correlation exists between them. A perfect negative correlation between two variables, such as the pressure and volume of an ideal gas, is often expressed by saying

they are *inversely proportional*. The accompanying graphs show some of these possible relationships between two variables A and B.



In the two top, straight-line graphs, we have evidence that A is directly proportional to B. In the second, we have evidence that A is inversely proportional to B. When A is correlated with B, it follows with certainty that B will be correlated with A, and vice versa. In other words, correlation is a symmetrical relationship.[337]

337 We've been using discrete, not continuous variables; that is, the points on the graphs are disconnected. Many variables are continuous rather than discrete — for example, time, altitude,

We've introduced correlations by talking about variables, but correlations can also occur among characteristics. For example, there's a correlation between the characteristic of being a Canadian and the characteristic of owning a warm, hooded coat. The characteristic "being a Canadian" can be thought of as a variable with two values "characteristic is present" and "characteristic is absent." In other words, the characteristic C can be thought of as a variable with the possible values of "present" and "absent" or the values C and Not-C. With this sort of variable, it doesn't make sense to talk about their values "changing in synchrony." Here are some new definitions of *correlation* that apply to these kinds of characteristics:

> Definition A is **positively correlated** with B in a given population whenever the percentage A's among B's is greater than the percentage of A's among the Non B's.
>
> Definition A is **negatively correlated** with B in a given population whenever the percentage oL4's among them is less than the percentage of A's among the Non B's.
>
> Definition A and B are **uncorrelated** if the percentages oL4's among the B\ is the same as among the Non-5's.

For example, being tall is positively correlated with being a professional basketball player because you'll find a higher percentage of tall people among the players than among the non-players. In applying the above definition of positive correlation, we would let

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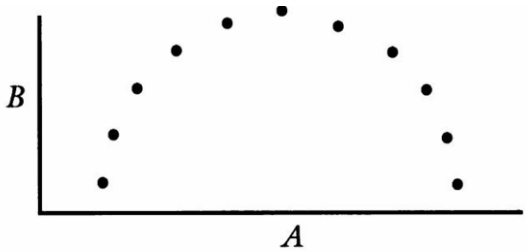
and degree of satisfaction with a politician. Continuous variables can always be turned into discrete variables by dividing the continuum into separate categories; for example, the continuous variable *time* could be replaced with the discrete variable *time-to-the-nearest-minute*. Correlation between two variables can actually be quantified. That is, a number can be assigned to the correlation. The number, called the **correlation coefficient**, can range from minus one for a negative correlation to plus one for a positive correlation. In this chapter, we will not investigate how to calculate these coefficients. The correlation coefficient is a measure of how well a straight line graph will represent the data. Consider a graph that looks like this:



This graph has a small correlation coefficient, so a straight line does not do a good job of representing this graph. Nevertheless, there is clearly some sort of correlation between A and B. It is a **nonlinear correlation**.

A = tall people

B = professional basketball players

Non-B = people who aren't professional basketball players

Is there any correlation between being Canadian and having a banana tree in one's backyard? Yes, definitely. Randomly examine groups of people. The higher the percentage of Canadians, the fewer people in the group who will have a banana tree in their backyard. There is a negative correlation.

———CONCEPT CHECK———

Given our common knowledge about horse racing and the jockeys who ride the horses, is there any correlation between a person's body weight and their being a professional jockey?

a. Yes, they are positively correlated.
b. Yes, they are negatively correlated.
c. No, they are uncorrelated.

———[338]

Correlation is a matter of degree. Some correlations are strong; some are weak. If the percentage of people with lung cancer were only slightly higher among smokers than nonsmokers, the correlation between lung cancer and smoking would be weak. In reality, however, the percentage of people with lung cancer is much higher among smokers than nonsmokers, so the correlation is strong.

Definition The **strength of the correlation** between characteristics A and B is proportional to the difference between the percentage of B's that are A and the percentage of Not-B's that are A.[339]

———CONCEPT CHECK———

338 Answer (b). In a group of jockeys, you'd expect the average weight to be less than the average weight of most people in society.

339 Statisticians prefer to use a somewhat more complicated measure of strength for correlations, but this definition can be quite helpful as a rule of thumb.

Are U.S. income taxes correlated with citizens' gross incomes? Positively or negatively? Strongly or weakly? Perfectly?

340

Some persons find correlations where others do not. Here is a dispute that occurred many years ago. The lobbyist for the Associated Anglers of the Colorado River claimed there is a correlation between the number of striped bass in the Colorado River and the amount of water taken out of the river by the State of Nevada. A housing developer in Las Vegas said he sees no correlation. Who is correct? Well, let's look at the data. The lobbyist and the housing developed do not disagree on the raw data. Here are some charts of this data from the previous century:

Water exports from the Colorado River to Nevada

Date	Water (mill. acre-feet)	Date	Water (mill. acre-feet)
1950	0.5	1975	4.5
1955	1.0	1980	5.0
1960	1.0	1985	4.5
1965	2.0	1990	5.9
1970	2.8		

Estimated Adult Striped Bass in the Colorado River

340 U.S. income taxes are positively correlated with citizens' gross incomes. The correlation is not perfect, but it is fairly strong. The correlation is weak in the highest income brackets, where those persons tend to pay proportionately a fairly small percentage of their income in taxes thanks to tax shelters.

Date	Fish (millions)
1969	1.6
1970	1.7
1971	1.6
1972	1.8
1973	1.6
1974	1.4
1975	1.8
1976	1.5
1977	0.9
1978	1.1
1979	1.1
1980	1.0

Date	Fish (millions)
1981	0.9
1982	0.8
1983	1.0
1984	1.0
1985	1.0
1986	1.0
1987	1.0
1988	1.0
1989	0.7
1990	0.5
1991	0.5

How can you look at these two sets of data and tell whether a correlation exists? If you look for trends in the data, you will notice that through time the exports of water have increased, while the number of fish have more or less decreased. As one goes up, the other comes down, which is a sign of a negative correlation. Only a statistician can tell how strong the correlation is, but you can tell from the trends that a correlation is present and that it is unlikely to be due to accidental fluctuations in the levels of water and fish.

Significant Correlations

Given an observed correlation, how can you tell whether it is significant rather than accidental? Well, the problem of telling when an association is significant is akin to the problem of telling when any statistic is significant. The point is that the correlation is significant if you can trust it in making your future predictions. Conversely, an observed correlation is not significant if there is a good chance that it is appearing by accident and thus wouldn't be a reliable sign of future events. However, you usually aren't in a position to perform this kind of calculation of the significance of the correlation. If you are faced with a set of data that show a correlation, you might never be able to figure out whether the correlation is significant unless you collect more data. If the correlation is just an accident, it will disappear in the bigger pool of data when more data are collected.

> Significant correlations are those that continue into the future. They are the correlations that occur because some real causal activity is at work.

If you cannot collect more data, and cannot ask a statistician to calculate the correlation coefficient for you, then the only other way to tell whether the correlation is significant is to see whether accepted scientific theories about how the world works enable you to predict that the correlation will hold. For example, suppose you have all the data available about Napoleon Bonaparte's childhood and you discover a positive correlation between his height as a child and his age as a child. Is the correlation significant? You cannot collect any more data about Napoleon's childhood; you have all there is to have. You cannot start his life over again and collect data about his childhood during his second lifetime. Nevertheless, you know that the correlation between his height and age is no accident, because you hold a well-justified theory about human biology implying that height in childhood increases with age. If this connection holds for everybody, then it holds for French emperors, too. So the correlation in the Napoleon data is significant. In summary, to decide whether a correlation is accidental, you might try to collect more data, or you might look to our theoretical knowledge for an indication of whether there ought to be a correlation.

———CONCEPT CHECK———

What is the story behind the correlation in the passage below?

Amid Wall Street's impenetrable jargon and stone-faced forecasts for the stock market in 1984 comes this nugget of foolishness: If the Washington Redskins win the Super Bowl this Sunday, the market is going up. Or, conversely, if you think the market is going up this year, you ought to put your money on the Redskins.

If this method of market forecasting sounds like nonsense, you're in good company. But consider this: The results of the Super Bowl have become a . . . signal of future market activity.

In the 17 Super Bowl games that have been played since 1967, every year [in which] the National Football Conference team won, the New York Stock Exchange composite index ended the year with a gain. And in every year in which the American Football Conference team won, the market sank.[341]

a. This correlation is caused by heavy betting on the Super Bowl results.

b. There is a correlation because game results caused stock market investments by football players.

c. The correlation is a coincidence (that is., not a significant association).

d. The correlation can be used as a reliable indicator that if the NFC won the Super Bowl last time, then the AFC will win next time.

———[342]

The stronger a correlation, the more likely that some causal connection or some causal story exists behind it. Investigators are usually interested in learning the details of this causal story; that is the central topic of the next section, but here's a word of caution: The rooster crows, then the sun comes up. He didn't cause it, did he?

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341 R. Foster Winans, "Wall Street Ponders If Bull Market in '84 Hinges on Redskins," *The Wall Street Journal*, January 18, 1984, p. 49.

342 Answer (c). The pattern will not continue in the future. It is an accident. Answer (a) is unlikely to be correct because bets are unlikely to affect the Stock Exchange so radically.

Causal Claims

Magic doesn't cause food to appear on your table at dinnertime. Someone has to put some effort into getting it to the table. Effort **causes** the effect, we say. Similarly, houses don't just "poof" into existence along the edge of the street of a new subdivision, except perhaps in Harry Potter books. It takes a great deal of physical labor to create these effects. Although effort causes some events, other events are caused with no effort at all. For example, the moon's gravity is the cause of tides on Earth, yet the moon is not making an effort. It just happens naturally.

Cause-effect claims don't always contain the word *cause*. You are stating a cause-effect relationship if you say that heating ice cubes *produces* liquid water, that eating chocolate *cures* skin rashes, that the sun's gravity *makes* the Earth travel in an ellipse, or that the pollen in the air *triggered* that allergic reaction. The terms *produces*, *cures*, *makes*, and *triggered* are **causal indicators**; they indicate that the connection is more than a mere accidental correlation. Not all causal claims are true, of course. Which one of the previous ones isn't?

———CONCEPT CHECK———

Here is a 1950s newspaper advertisement for cigarettes. The cause-effect claim is hidden between the lines. Identify it by rewriting it so it uses the word *causes* explicitly.

More Doctors Smoke Our Cigarette

Check for yourself — smoke our cigarette and see if you don't get less throat irritation.

———[343]

The causal claim about chocolate was false. If you want to cure a skin rash, try something other than chocolate.

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343 Smoking our cigarette causes less throat irritation than smoking other brands of cigarettes.

We need to be careful and not to take causal claims too literally. Here is a causal claim:

> I succumbed to nostalgia.

Literally, this is suggesting that there is something called "nostalgia" that caused me to succumb. But we know not to interpret it that way. Instead of making the abstract thing called "nostalgia" have these causal powers, it would be better to interpret the sentence this way:

> My mental state caused me to choose actions that would best be described as reflecting an unusual desire to return to some past period of my life.

———CONCEPT CHECK———

What is the best way to interpret this causal claim?

> Extreme blondness brings bad luck; it cries out to be pillaged.

344

Some scientific reports make causal claims, and some make only associational (correlational) claims. It's important to be able to distinguish the two in order not to misinterpret what is being reported. Unfortunately many claims are ambiguous and aren't clearly one or the other. The next concept check will help you learn to distinguish these kinds of claims.

———CONCEPT CHECK———

In the following three passages, one is claiming not only that A and B are associated but also that they are causally related. In another, the scientist is more cautiously claiming only that there is an association between A and B. In the third, the scientist is being ambiguous, and you cannot tell which kind of claim is intended. Which passage is which?

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344 Before concluding that blondness causes bad luck, namely being pillaged, it would be better to interpret the sentence [from the film White Material] along these lines:

> In our community, people who are very blond often have unpleasant events happen to them that other people describe by saying, "That was unlucky." Those so-called unlucky events are the result of a belief, held by me and other people in our community, that encourages us to pillage the homes, farms and businesses of very blond people.

i. Statistics reported by the Ugandan ministry of police establish a relationship between a person's age and whether he or she was a victim of violent crime in Uganda last year.

   a. causal b. only association c. ambiguous

ii. Our study has now uncovered a link between inflation and people's faith in the stability of their economy.

   a. causal b. only association c. ambiguous

iii. Eating too much licorice candy produces diarrhea.

   a. causal b. only association c. ambiguous

345

If you insert a cup of sugar into the gas tank of your gasoline-driven car this afternoon, its engine will become gummed up. This is a **specific causal claim**. More generally, if you put sugar into any engine's gas tank, the engine will get gummed up. This last causal claim is more general; it doesn't apply only to this sugar in your car, nor to this date. Because it mentions kinds of objects rather than specific ones, it is a general causal claim — a **causal generalization**. So causal claims come in two flavors, general and specific. Scientists seeking knowledge of the world prefer general claims to specific ones. You can imagine why.

An event can have more than one cause. If John intentionally shoots Eduardo, then one cause of Eduardo's bleeding is a bullet penetrating his body. Another cause is John's intention to kill him. Still another is John's action of pulling the trigger. All three are causes. We say they are **contributing causes** or **contributing factors** or **partial causes**.

Some contributing causes are more important to us than others, and very often we call the most important one *the* cause. What counts as the cause is affected by what we are interested in. If we want to cure Eduardo, we might say the bullet's penetrating the skin is *the* cause. If we are interested in justice, we might say that John's actions are *the* cause, and we would leave all the biology in the background.

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345 (i) b (ii) c (iii) a. The notorious word *link* is sometimes used to assert a causal connection and sometimes to assert only a correlation, so it is not a reliable causal indicator term. The claim about chocolate is false. The claim about pollen might or might not be true, depending on the circumstances. Because you don't know the circumstances, you are not in a position to call it false.

Causal claims come in two other flavors in addition to specific and general: those that say causes *always* produce a certain effect, and those that say causes only *tend* to produce the effect. Heating ice cubes in a pan on your stove will always cause them to melt, but smoking cigarettes only tends to cause lung cancer. Scientists express this point by saying heating is a *determinate cause* of ice melting, but smoking is not a determinate cause of lung cancer. Rather, smoking is a *probable cause* of cancer. The heating is a determinate cause because under known proper conditions its effect will happen every time; it doesn't just make the event happen occasionally or make its occurrence more likely, as is the case with smoking causing lung cancer. If our knowledge is merely of causes that tend to make the effect happen, we usually don't know the deep story of what causes the effect. We understand the causal story more completely when we have found the determinate cause.[346]

The verb *causes* can be ambiguous. Speakers often say "smoking causes cancer," when they don't mean determinate cause but only probable cause cause. We listeners must be alert so that we correctly interpret what is said.

346 In some systems, there are no determinate causes to be found. So-called "stochastic systems" behave this way. Quantum mechanics is a theory of nature that treats natural systems as being stochastic in the sense that the state of the system at one time merely makes other states probable; it does not determine which state will occur. Systems described by quantum mechanics are stochastic systems. So are the systems of inheritance of genes, which the Austrian monk Gregor Mendel first described back in the nineteenth century.

Eating peanuts tends to cause cancer, too. But for purposes of good decision making about whether to stop eating peanuts, we would like to know how strong the tendency is. How probable is it that eating peanuts will be a problem for us? If there is one chance in a million, then we are apt to say that the pleasure of peanut eating outweighs the danger; we will risk it. For practical decision making we would also like to overcome the imprecision in the original claim. How much cancer? How many peanuts? How does the risk go up with the amount? If we would have to eat a thousand peanuts every day for ten years in order to be in significant danger, then pass the peanuts, please.

Inferring from Correlation to Causation

Unfortunately, additional problems occur with the process of justifying causal claims. If we know that A causes B, we can confidently predict that A is correlated with B because causation logically implies correlation. But we cannot be so confident about the reverse — a correlation doesn't usually provide strong evidence for causation. Consider the correlation between having a runny nose and having watery eyes. We know neither causes the other. Instead, having a cold causes both. So in this case we say that the association between the runny nose and the watery eyes is **spurious**, because a third factor is at work causing the correlation.

In general, when events of kind A are associated (correlated) with events of kind B, three types of explanation might account for the association:

1. The association is accidental, a coincidence.
2. A is causing B, or B is causing A.
3. Something else C is lurking in the background and is causing A and B to be significantly associated. That is, the association is spurious because of lurking factor C.

CONCEPT CHECK

Why is the frequency of lightning flashes in Iowa in the summer positively correlated with popcorn production in Iowa in the summer? Hint: The association is spurious.

[347]

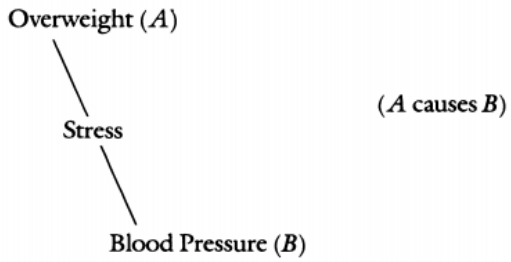
Given an observed correlation, how can you figure out how to explain it? How can you tell whether A is accidentally correlated with B, or A causes B, or B causes A, or some C is causing both? Here is where scientific sleuthing comes in. You have to think of all the reasonable explanations and then rule out everything until the truth remains. An explanation is ruled out when you collect data inconsistent with it. This entire process of searching out the right explanation is called the **scientific method** of justifying a causal claim. Let's see it in action.

There is a strong positive correlation between being overweight and having high blood pressure. The favored explanation of this association is that being overweight puts stress on the heart and makes it pump at a higher pressure. Such an explanation is of type 2 (from the above list). One alternative explanation of the association is that a person's inability to digest salt is to blame. This inability makes the person hungry, which in turn causes overeating. Meanwhile, the inability to digest salt also makes the heart pump faster and thereby helps distribute what little salt there is in the blood. This pumping requires a high blood pressure. This explanation, which is of type 3, is saying that the association is spurious and that a lurking factor, the inability to digest salt, is producing the association.

347 The real causal story behind the correlation is that storms cause both the lightning and the rain that helps the corn grow.

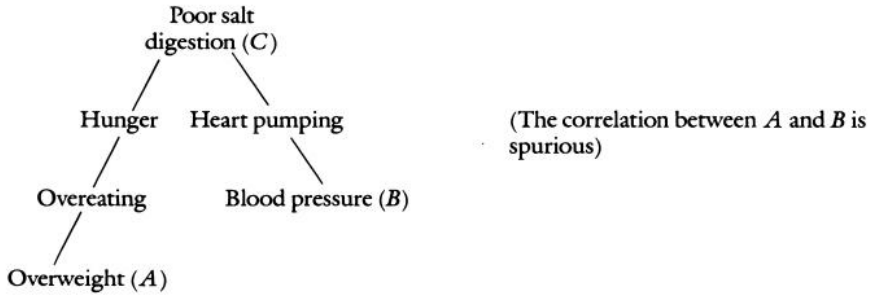
Diagramming Causal Relationships

Tree diagrams can be helpful in understanding the difference between the two explanations. Here is a diagram of the first explanation (each line descends from cause to effect):



This diagram indicates that the correlation is not spurious.

A diagram of our second explanation shows that the association is spurious because factor C is causing both A and B :



Here we are with two alternatives, two possible explanations of the correlation between being overweight and having high blood pressure. How do we find out whether either one is correct? We test them using the scientific method. To do so, we need a test that will rule out one or the other of the explanations. Let's see. How do we test whether poor salt digestion is to blame? We could look to see whether people with the problem also tend to be overweight and have high blood pressure. That is, we could see whether C is correlated with A and also with B. If not, we could throw out the second explanation. That would leave the first one, but it wouldn't establish that the first explanation is correct; it would only establish that the second is worse than the first. What we would then need is a second test. Perhaps we could pay people to overeat and see if their blood pressure goes up. If so, we would be on the road to confirming the suggestion that overeating is the cause of high blood pressure. And this is how science works. But let's stop and look at the bigger picture.

When someone suggests a possible explanation — that is, proposes a hypothesis — it should be tested. The test should look at some prediction that can be inferred from the explanation. If the actual findings don't agree with that prediction, then the explanation is refuted. On the other hand, if the prediction does come out as expected, we hold onto the hypothesis.

However, it is not always an easy matter to come up with a prediction that can be used to test the hypothesis. Good tests can be hard to find. Suppose, for example, my hypothesis is that the communist government of the U.S.S.R. (Russia, Ukraine, and so on) disintegrated in the early 1990s because it was fated to lose power then. How would you test that? You can't.

This process of guessing a possible explanation and then trying to refute it by testing is the dynamic that makes science succeed. The path to scientific knowledge is the path of conjecturing followed by tough testing. There is no other path. (Philosophers of science say that the path to scientific knowledge is more complicated than this, and they are correct, but what we've said here is accurate enough for our purposes.)

Notice the two sources of creativity in this scientific process. First, it takes creativity to think of possible explanations that are worth testing. Second, it takes creativity to figure out a good way to test a suggested explanation.

———CONCEPT CHECK———

A third explanation of the association between high blood pressure and being overweight is that stress is to blame for the correlation. Stress leads to anxiety, which promotes overeating and consequent weight gain. This extra weight causes not only a higher body temperature but also extra blood flow. That flow in turn requires the heart to pump faster and thus to increase the blood pressure. This explanation is of which of the following three types?

a. coincidence b. cause leads to effect c. spurious correlation

Draw the tree diagram of the causal relationship.

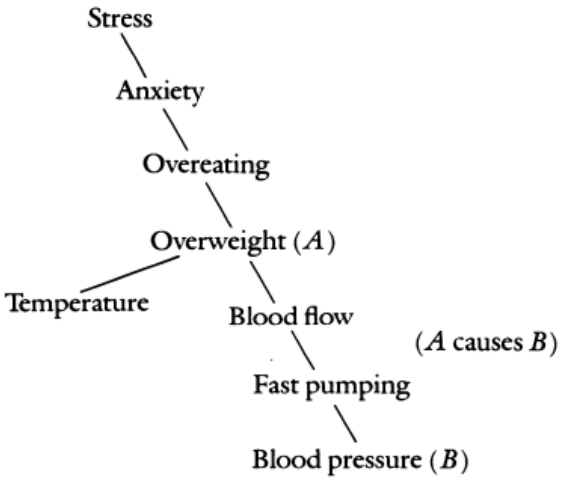
———348

348 Answer (b). The correlation is not spurious. The explanation is of type 2. Here is the diagram:

Criteria for a Causal Relationship

Suppose you get a lot of headaches and you are trying to figure out why. You note that you are unusual because you are the sort of person who often leaves the TV set on all day and night. You also note that whenever you sleep near a TV set that is on, you usually develop a headache. You suspect that being close to the TV is the cause of your headaches. If you were to immediately conclude that the closeness to the TV does cause the headaches, you'd be committing the *post hoc fallacy*. The fallacy lies in supposing that A caused B when the only evidence is that A has been followed by B a few times. I would commit the fallacy if I said that the sun regularly comes up after the rooster crows, so he's the cause of the sun coming up. If you aren't going to avoid the post hoc fallacy, then how should you proceed?

First you should ask someone with scientific expertise whether there's any scientific evidence that sleeping close to a TV set that is on should cause headaches. Let's assume that there is no convincing evidence one way or the other, although a few statistical studies have looked for a correlation between the two. If the data in those studies show no association between sleeping near the TV and getting headaches, you can conclude that your suspicions were wrong. But let's suppose such an association has been found. If so, you are not yet justified in claiming a causal connection between the TV and the headaches. You need to do more. Before making your main assault on the causal claim, you need to check the temporal relation, the regularity, the strength, and the coherence of the association. What does that mean?



1. *Temporal Relation*: To be justified in saying that A causes B, A should occur before, not after, B. The future never causes anything in the present. This temporal relation is important because effects never precede their causes. Fear of sleeping near a TV in the future might cause a headache, but the future sleeping itself cannot cause it now. That is one of the major metaphysical presuppositions of all the sciences. Our claim, or hypothesis, that sleeping close to a TV causes headaches does pass this first test.

2. *Regularity*: Suppose that three scientific studies have examined the relationship between sleeping near a TV and having headaches. In two of the studies an association has been found, but in one, none was found. Therefore, the association has not been so regular. Sometimes it appears; sometimes it doesn't. The greater the regularity, the more likely that the association is significant.

3. *Strength*: Even when an association is regular across several scientific studies, the strength of the association makes a difference. The weaker the association between sleeping near a TV and getting headaches, the less justified you can be in saying that sleeping near the TV causes headaches. If, after sleeping near the TV, you get a headache 98 percent of the time, that's a much stronger association than a 50 percent rate.

4. *Coherence*: The coherence of an association must also be taken into account when assessing whether a causal claim can be inferred from an association. Coherence is how well the causal claim fits with the standard scientific ideas of what is a possible cause of what. Suppose a researcher notices an association between color chosen by painters for the Chinese government's grain silos and the frequency of headaches among Canadian schoolchildren. On years when the percentage of blue silos in China goes up, so do the Canadian headaches. In green years the headaches go down. Suppose the researcher then speculates that the Chinese colors are causing the Canadian headaches and provides these data about the correlation to make the case. Other scientists would write this off as a crackpot suggestion. They would use their background knowledge about what could possibly cause what in order to deny the causal claim about the colors and the headaches. This odd causal claim does not cohere with the rest of science. It is too bizarre. It is inconsistent with more strongly held beliefs. The notion of coherence is quite fascinating. We will examine it in more detail in the next chapter when we discuss the paradigm of a science.

———CONCEPT CHECK———

Have you ever noticed that night is associated with day? First there's the night, then there's the daytime. Again and again, the same pattern. Regular as clockwork. A consistent, strong association. This would seem to establish the causal claim that night causes day. Or would it?

349

Criteria for Creating Good Explanations

We create explanations to show our listeners or readers how something works or how things got to be the way they are. If you're creating an explanation for why China has so many more people than Siberia, you may want to talk about history and the social, political, and geographical forces shaping those two areas of the world. In doing so, you take it for granted that your audience accepts the fact that China really does have more people than Siberia. If you have to get your audience to first accept this fact, you need to argue for it, not explain it.

To create a good explanation of something is not easy. In this section we will examine some of the faults in explanation construction and then introduce criteria for constructing good explanations. Explanations have many features in common with arguments, so many of these criteria apply to constructing good arguments as well.

The explanation should fit the facts to be explained and should not conflict with other facts. When you are explaining an event, you must show why the event should have occurred, and your explanation should not be inconsistent with any facts. For example, suppose you want to explain why your friend recovered from the flu after only four days of being ill. Here is an explanation of this event: Your friend drank five glasses of orange juice every day he was sick, and drinking orange juice in such heavy doses will knock out anybody's flu virus within four to six days. This explanation does imply that your friend's recovery is to be expected. That's a plus for the explanation. Unfortunately, a doctor can tell you that many, many flu victims who have been tested with orange juice this way have not recovered for several weeks. So your explanation is in conflict with the facts about these other people. Consequently, the explanation violates our rule and should be rejected.

An explanation should do more than merely describe the situation to be explained. For example, suppose we ask a psychic, "How do you successfully locate oil and gold with your mental powers?" and she answers, "Geologists conduct an initial survey of the area for me. Afterward I

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349 The correlation does support the claim somewhat, but the claim is ridiculous, as we now know from our knowledge of scientific theories. The correlation is spurious. Unlike the people of 3,000 years ago, we know what causes daylight, and it's not night. We can suggest a much better explanation of why there's an association between night and day. No doubt you are thinking about the rotation of the Earth under the sun's spotlight. If you had lived 3,000 years ago when everyone believed the world to be flat, you'd probably never have imagined the alternative suggestion that the correlation between daytime and nighttime is caused by rotation of the Earth.

fly over it, extend my hand, and sense the location of the underground deposit. Or I run my finger over a map and point out where to drill." This answer describes the sequence of events leading up to the event to be explained, but it is intellectually unsatisfying, since we wanted to find out more details about the cause of the psychic's supposed success. We hoped for a causal explanation that would show what makes the psychic's actions work for her when they won't work for us.

Good explanations are not circular. A good explanation doesn't just rephrase what it is trying to explain. A biologist makes this mistake if she tries to explain why humans have two feet by saying it is because they are bipeds. It is true that humans are bipeds, but the definition of *biped* is "two-footed animal," so the biologist's "explanation" merely names the phenomenon; it does not explain it. It does not give us what we want — either the causal mechanism that makes humans have two legs instead of some other number, or some evolutionary story of the genesis of two legs in humans. What would a noncircular explanation look like? Well, the causal explanation might say that our genes control growth and force humans to have two legs as they develop. A second kind of explanation could point out how, through evolution, a gradual change occurred in hip structure as our ancestors adapted to situations that favored walking on two legs. Whether either of these two explanations is correct is another matter; however, neither of them is circular.

Supernatural explanations should be avoided unless it is clear that more ordinary, natural explanations won't work. For example, suppose Inge says, "I got skin cancer because my number came up; evidently it was my time. She is explaining her cancer as being the consequence of some supernatural force that intervenes into the natural causal order of things and makes events happen; this is the supernatural force we call "fate." It's not impossible that she is correct, but her explanation is very weak. Here is a better explanation: Inge works in a manufacturing plant where she comes in daily contact with benzene fumes, and benzene is a well-known cause of skin cancer, so the benzene caused Inge's skin cancer. Until we rule out benzene, let's not pay much attention to fate.

Good explanations are relevant. A Toyota is a Japanese car. If I explain why Julie has never owned a Toyota by saying that she hates German cars, I can be accused of violating the need for relevancy. Her hating German cars might explain why she doesn't own a BMW, but it's not clearly relevant to why she doesn't own a Toyota. If there is some connection, it should have been stated as part of the explanation.

Explanations should be consistent with well-established results except in extraordinary cases. Suppose I explain why I have a headache almost every day at noontime by pointing out that at noon I'm the closest I am to the sun all day; because the sun's gravitational pull on me is strongest at noon, its pull must be the cause of my headaches. This would be an odd explanation. It is a well-established scientific fact that the sun does exert a gravitational pull on us and that this pull is strongest at noon. However, it is also well established that our bodies are

insensitive to these small gravitational changes. So, I should look elsewhere for the cause. The inconsistency of my explanation with well justified scientific theory detracts from the quality of my explanation. My explanation might still be correct, but for it to be convincing to the experts a revolution would have to occur in the field of biology. Extraordinary explanations are those that require big changes in the beliefs of the experts, and extraordinary explanations require extraordinarily good evidence. An ordinary explanation of the headaches, such as their being caused by my eating a half-pound of beets only on the days I get the headaches, would be a more promising explanation if it's true that I do eat beets that often.

> Extraordinary explanations require extraordinarily good evidence.

Explanations should be tailored to the audience whenever possible. Suppose we try to explain the red marks on Emilio's nose as being due to overexposure to sunlight. If our audience already knows that sunlight can cause skin cancer and that skin cancer can cause red marks, we may not need to add any more to the explanation beyond perhaps reminding the audience of these facts. However, if the audience doesn't know these facts, we are obliged to support the facts. Also, our explanation should be pitched at the proper level of difficulty for our audience; we cannot use technical terminology on an audience that won't understand the technical terms. Explanations are easier to understand if they explain something unfamiliar in terms of something familiar, even if being easy to understand is not a sign of being correct. Most of us are unfamiliar with the principles of electricity, such as the relationship between current and voltage, but we are familiar with how water flows through a pipe. So, a good explanation of electricity for us might be based on an analogy between electrical current and water flow:

> The amount of water flowing through a pipe per second is analogous to the amount of electrical charge flowing through a wire per second, and this amount is called the electrical "current." If you want to increase water flow, you've got to increase the water pressure. Similarly, if you want to increase the electrical current in a wire, you have to turn up the voltage.

OK, that helps explain the behavior of electricity to an audience untutored in physics, but it's not a correct explanation that would convince the scientific community. Correct explanations might be very difficult to understand, as you'd find out if you tried to read the paper of 1864 written by James Clerk Maxwell that really did explain electricity to the scientists.

The more precise the explanation, the better. Excessive vagueness weakens an explanation. The more precise a claim, the easier it is to test and thus to refute. If someone claims that eating five medium-sized dill pickles will bring on a headache within twelve minutes, you can test it on someone, perhaps yourself. However, if the person is vaguer and instead claims only that

eating pickles will produce headaches, you have a tougher time. What kind of pickles? What size? How many? Will eating them produce headaches in five minutes, five days, next year? The vague claim is too hard to test. The more precise claim is more easily refuted, if it is false, but it tells us so much more if it can't be refuted. This is why precise claims are said to be more "scientific" than vaguer ones.

Testable explanations are better than untestable ones. Saying "She wasted all her month's food money on lottery tickets because she was in the wrong place at the wrong time" would be an example of an untestable explanation. How do you test it?

———CONCEPT CHECK———

All the following statements are trying to explain why tigers eat meat but not plants. Which explanation is the best, and why?

a. Tigers are carnivores.

b. Professor DeMarco says so, and he is an expert on tigers.

c. Tigers are naturally meat eaters, because many years ago the most powerful witches on earth placed a spell on the tigers and forced them to be that way.

d. Tiger cells contain a gene that prevents their stomachs from digesting plant cells.

e. My science textbook says tigers eat meat but not plants.

350

Assessing Alternative Explanations

Suppose your TV-headache correlation has a proper temporal relation, regularity across several studies, strength, and coherence with your background knowledge. Despite this, a factor lurking in the background could be causing both the headaches and the TV to be on. For example, maybe family quarrels cause the headaches and also cause you to turn on the TV to escape the quarrels.

Unless you had thought of this possibility, or alternative hypothesis, and unless you had also thought of ways to test it and had then ruled it out successfully, your confidently asserting that sleeping next to the TV caused your headaches would be committing the post hoc fallacy.

Here is one test that would help confirm some of the hypotheses and rule out others. Suppose you were to hire several people to sleep in a laboratory near TV sets like yours. For half the subjects in this test, the TV would be on; for the other half, the set would be off. What would you predict about the results, given each of the alternative hypotheses? The prediction from your favored hypothesis is that there would be a lot more headaches among those people whose set is on and a lot fewer among those whose set is off. However, from the hypothesis that family quarrels are to blame, you would predict that the two groups of subjects would have the same frequency of headaches. Therefore, your test can produce results that will be consistent with one hypothesis while refuting the other. That ability to discriminate between two competing hypotheses is a sign of a good scientific test.

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350 Answer (d) is best. Although (d) is probably not a correct explanation of why tigers are carnivores, at least it is testable, consistent with well-justified biological theory, not circular, and doesn't appeal to the supernatural. Answer (a) is circular because carnivore just means "eater of flesh, not plants." Answer (b), like (e), is an argument, not an explanation; it provides a good argument for believing that tigers are meat eaters and not plant eaters, but it gives no explanation of why tigers are this way. Answer (c) is not acceptable because it violates the canon to be cautious about offering supernatural explanations until it is clear that more ordinary, natural explanations won't work.

Another point illustrated here is that the best way to infer from a correlation between C and E to the claim that C causes E is to do a **controlled experiment**. In a controlled experiment, you divide your subjects into two groups that are essentially equivalent with one major exception: the suspected cause C is present in one group but not the other. The latter group is called the **control group**. The group with the suspected cause is called the **experimental group**, or, in the case of a drug experiment, the **treatment group**. Run the test and see whether the effect E occurs much more in the experimental group than in the control group. If you notice a big difference, then it's likely that C really does cause E.

Let's suppose that you decide it is too expensive to do this sort of testing — you don't have the lab or the TV sets or the time it would take to run the experiment. Instead you decide to put an advertisement in a magazine asking readers to write if they have noticed headaches after sleeping near a TV set while it is on. You subsequently receive forty letters from people who have had experiences similar to yours. If you were to take these letters to be sufficient evidence that sleeping near the TV does cause headaches, you'd be jumping to conclusions. This second test isn't very good. All you've found are data consistent with your favorite hypothesis. You haven't actively tried to refute your hypothesis. So, you haven't really followed the scientific method. Your results don't qualify as a scientific proof.

This same point about experimental design can be made by considering whether it's true that every emerald is green. Let's say that, although you do suspect this hypothesis to be true, you want to test it to find out. Which would be the best test? (1) Try to find positive evidence by putting an ad in the paper asking people to let you know whether they own a green emerald. (2) Try to find negative evidence by putting an ad in the paper asking people to let you know whether they own an emerald that is not green. One response to the second ad would be much more informative than many responses to the first, wouldn't it? So strategy 2 is the best. This is the strategy of searching for inconsistent data rather than confirming data.

> Good scientists runs tests designed to disconfirm, not to confirm.

Probably the single greatest source of error in science is the natural human failing of trying to confirm one's own guess about the correct explanation of something while

failing to pay enough attention to trying to disconfirm that explanation. That is, we all have a tendency to latch onto a hypothesis and try to find data consistent with it without also actively searching for data that would show us to be wrong. We have this tendency because we really don't want to be shown wrong, because we are lazy about using our imagination to produce alternative explanations, and because it takes a lot of physical effort and expense to create tests that would show our suspicions to be wrong. In short, we have a natural tendency to look for a shortcut to the truth. Unfortunately, there is no effective substitute for the long, difficult path of conjectures and refutations. This is the path of guessing the reasonable alternative suggestions and systematically trying to refute them. The scientific method is this method of conjectures and refutations.

The Scientific Method

Let's now summarize the major points about the scientific process of finding our way to the truth. Scientific sleuths conjecture possible explanations — the so-called scientific hypotheses — then try to test them in order to rule them out. Testing is not normally a passive process of observation. Instead, it is an active attempt to create the data needed to rule out a hypothesis. When a hypothesis can stand up to many and varied attempts to rule it out, we have produced a scientific proof of the hypothesis. The key idea of the scientific method is that the true hypothesis cannot be ruled out; the truth will survive the ruling-out process. So if we were correct in suggesting that A really does cause B, then observing and testing will eventually produce data inconsistent with alternative suggestions. That is, we can then rule out the possibility that B causes A instead, and we can rule out the possibility that some C causes both A and B to be correlated.

This whole procedure of doing science might seem easy at first, but actually scientific proofs are not easy to come by. A major problem is lack of imagination. If you cannot imagine the possible lurking C's, how can you be expected to rule them out? To illustrate, consider why having lung cancer is associated with buying a copy of *The New York Times* newspaper on Tuesdays. The claim implies that the percentage of lung cancer cases is higher among those people who buy this newspaper on Tuesdays than among those people who don't buy it. Why? Although some associations are accidental, just statistical flukes, this one is not. So which causes which? Is buying the paper on Tuesday causing people to get lung cancer, or is having lung cancer causing the paper-

buying behavior? Finding the answer scientifically is much like solving a mystery. Can you solve it?

Here are some suggestions to pursue. What is special about the ink on Tuesday's newspaper? Could there be a cancer-causing agent in the ink? Or should we give up on showing that the buying causes the cancer and try to go the other direction? Maybe cancer victims have a good reason to buy the paper. Maybe Tuesday is the day the paper contains the most articles about cancer, so lung cancer patients are especially likely to buy the paper on that day.

Unfortunately for these suggestions, a little testing will refute them. Perhaps you spotted the error in the reasoning. You were being misled away from the real causal story behind the association between lung cancer and Tuesday *Times* buying. First, there's a significant association between lung cancer and *Times* buying on Friday, too. And Wednesday. The real story is that living in a city tends to cause both the lung cancer and the *Times* buying on Tuesday; it causes their association. Living in a city, any city, makes it more likely that a person will take in cancer-causing agents such as air pollution. Also, living in a city makes it more likely that a person will buy *The New York Times* on Tuesday, and Wednesday, and other days. Country folks are less likely to read big-city newspapers — on Tuesday or any other day. So, city living is the cause. By asking whether lung cancer causes the paper buying or vice versa, I was purposely committing the false dilemma fallacy. Pointing out that something else could be the cause of both is a way of going between the horns of this dilemma.

What this story demonstrates is that proving something scientifically can be quite difficult because of lack of imagination. Scientific proofs can't just be "ground out" by some mechanical process. Your leap from association to cause is successful to the degree that all the other explanations of the association can be shown to be less probable, and this can require a considerable amount of scientific imagination. This same point can be re-expressed by saying that if somebody can imagine an equally plausible explanation for the association, or a more probable one, then your original inductive leap from association to cause is weak.

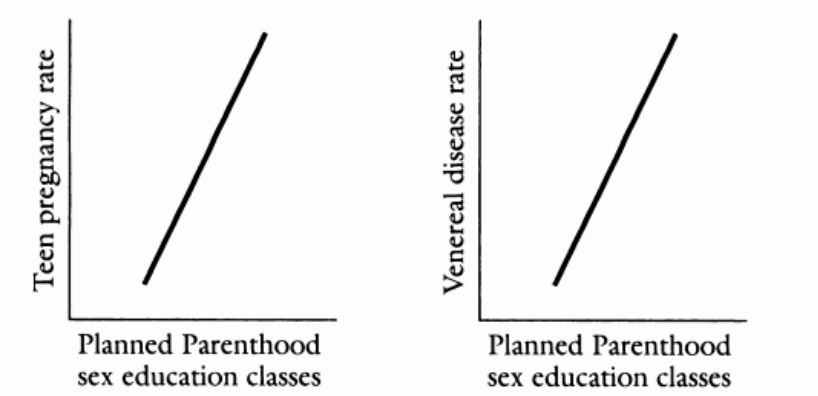
Some Case Studies

The following letter to the editor is fun to read, and analyzing it will demonstrate all the points we've made about using your creative abilities in justifying causal claims. For

background, the Planned Parenthood organization, which is attacked in the letter, is the largest dispenser of birth control information in the United States.

> **Dear Editor:**
>
> **The author of your letter to the editor last week claims we need Planned Parenthood. We need something—but it's not Planned Parenthood. Not if a tree is to be judged by its fruit.**
>
> **Hasn't it struck anyone a little bit strange that ever since Planned Parenthood has been "educating" teenagers, teenage pregnancy and venereal disease rates have shot through the roof? Doesn't it seem a little awkward that legal abortions, which are supposed to eliminate all but "wanted" children, have coincided directly with a rise in child abuse as well as symptoms of high stress and emotional disorders in women?**
>
> **Are we so far down the road to self-indulgence that we don't recognize simple cause and effect?**
>
> **I personally know three teenage girls who had their first sex because of the way sex education was presented in their high schools. They were led to think that sex was normal for teenagers and that if they maintained their virginity something was a little strange about them. Each episode followed a Planned Parenthood presentation!**
>
> **Planned Parenthood makes a lot of money from what it does. Chastity would put it out of business. Are our children only animals that we cannot expect the vast majority to control themselves?**
>
> **Ashley Pence**

The point of Pence's letter is primarily to state her beliefs and to give a few suggestive reasons; she is not trying to provide scientific proofs for her beliefs. Nevertheless, if she expects readers to change their own beliefs and adopt hers, as she appears to want, then she has the burden of proof and should offer some good reasons. What reasons does Pence offer? In her early sentence that begins "Hasn't it struck anyone a little bit strange . . .," she suggests there are positive associations of the following sort:



Pence implies a causal connection in these associations when she says, "Are we so far down the road to self-indulgence that we don't recognize simple cause and effect?" Assuming that the positive associations can be shown to exist (and a logical reasoner would like to be satisfied of this), the next step for the logical reasoner is to ask whether there are plausible alternative explanations for these associations. Maybe the associations are accidental. Or maybe the causal connection goes the other direction; for example, the rise in teenage pregnancy might be causing Planned Parenthood to be invited to offer more sex education classes in order to reduce the pregnancy rate. Thus, there are serious alternative explanations that the author apparently has not ruled out. That makes her causal claim weakly justified. However, caution is called for because:

> an unjustified claim isn't necessarily a false one.

In the next sentence of her letter, Pence implies, between the lines, that legal abortions are causing three problems: child abuse, symptoms of high stress in women, and symptoms of emotional disorders in women. Can you imagine other possible causes for these effects that she hasn't ruled out? For example, what else can cause high stress?

In short, there are serious problems with the causal reasoning in this letter. As a result of our analysis, it is clear that the letter is basically stating opinion, not fact.

———CONCEPT CHECK———

Pence has several suggestions for what should be done about all the problems mentioned in her letter to the editor. Which one of the following is definitely not one of her direct or indirect suggestions?

a. Children should stop acting like animals.

b. Stop sex education classes.

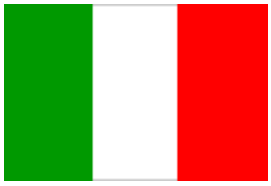
c. Stop funding Planned Parenthood.

d. Planned Parenthood should be stopped from performing its illegal abortions.

351

Here is a speech that might have been given to the County Sheriffs Association of the United States. It contains a report of a scientific study of crime. Be on the lookout for mistakes made by John Doe who misunderstands the report; he understands some things and misunderstands others.

> Slowly, science is figuring out crime. A reputable, independent, Italian social research organization found that 66 percent of criminals in U.S. jails did not have a high school degree. To me, this shows that lack of education is partly to blame for crime in our nation. Isn't it time to act on the causes, not just the symptoms of crime?



Suppose John Doe is asked to comment on the quality of the speaker's preceding argument, and he gives the following response.

> (1) The first problem with the study is that it was conducted on convicted criminals, which is not a representative sample of the U.S. (2) The study did not state the age of these criminals; maybe they were all seventeen and were not old enough to complete high school but were in the 11th grade. (3) They should also do a study on the people who had not finished high school but who were not convicted criminals. (4) They cannot say that lack of education is the cause of crime in other countries because some countries do not have the funds or desire to educate their population. (5) How do we know where this firm got its information? (6) Maybe they just got it from one prison. (7) And why should it be

351 Answer (d). The letter did not suggest that Planned Parenthood should be stopped from performing illegal abortions; the focus was on legal ones.

> an Italian firm? Italians don't live in the U.S. and do not understand us Americans. (8) Lack of money causes crime, not just lack of education.

John has missed some of the key things that should have been said about the report. There are other errors. What? Can you suggest any improvements in his answer? For our final activity in this chapter, let's dig deeply into this situation. The principal difficulty with John Doe's response to the report is its failure to mention the two main errors contained in the report. First, the 66 percent statistic by itself does not establish a correlation between lack of high school education and being convicted of crime in the U.S. Second, even if it did, there is no basis for jumping to the conclusion that lack of education is partly causing U.S. crime.

Why doesn't the 66 percent statistic make the case for the correlation? For it to do so, you'd need to know that 66 percent is unusual. Maybe 66 percent of all Americans don't have high school degrees. If so, there is no correlation. Assuming for a moment that there is a significant correlation, it still isn't a basis for saying that lack of education partly causes crime, because there are other reasonable explanations that haven't been ruled out. Perhaps poverty, greed, and bad genes cause both the crime and the lack of education. Or maybe becoming a criminal causes lack of education, not the other way around.

Let's now analyze John Doe's response sentence by sentence. Sentence (1) is mistaken in saying that the sample is not representative of the U.S. The real goal is to be representative not of the U.S. but of U.S. criminals. The target population of the statistical reasoning is convicted criminals in the U.S., not everybody in the U.S.

There is also a problem with sentence (2). Doe is complaining that he doesn't know the ages of the criminals whose education was examined. But he mistakenly implies that his lack of information is a sign of some error in the study. He may be thinking of the correct, but minor, point that the reader is not given enough information to tell whether the sample is representative of U.S. criminals. If the sample were only of seventeen-year-olds, undoubtedly it would be non-random and apt to be unrepresentative of U.S. convicted criminals. However, Doe shouldn't make too much of this. His answer would be better if it showed some awareness of the fact that there is no reason to believe the sample was of seventeen-year-olds because the study was done by a "reputable . . . research organization," which presumably means a competent one. Also, Doe gives no indication that this is in fact a minor point.

The point in sentence (3) is not made clearly. Yes, the study also should have included people who had not finished high school but who were not convicted criminals, but why should it have done so? The point would be to make sure that the figure of "66 percent" is unusual. A finding that significantly fewer than 66 percent of the unconvicted people had not finished high school would demonstrate the correlation that the speaker implies does exist — namely, that there's a negative correlation between crime and education. Doe should say all this explicitly, but he doesn't. In addition, if that is Doe's point in sentence (3), it is a major point and should have been emphasized, say by placing it first, not third.

Sentence (4) complains that some countries are too poor or are not as motivated as the U.S. to educate their citizens. That comment may be true, but it is irrelevant to whether the lack of education causes crime; it speaks only to why there is lack of education, which isn't the issue.

In sentence (5), Doe says we aren't told the source of the study's information. This would be a minor but correct statement by itself, but when (5) is accompanied by sentence (6), which says the study might have been done in only one prison, it makes the mistake of implying that the sample was too small. Doe's comments fail to recognize that the sample is probably large enough, simply because it is common knowledge to social researchers that the U.S. has many prisons, and a reputable research organization would not have obtained its data from just one prison. The reason that sentence (5) would be a minor point by itself is that there isn't much need for the reader to know where the organization got its information; what is more important is whether the organization is good at its research and whether it can be counted on to have made a good effort to get a representative sample of U.S. criminals.

Sentence (7) is mistaken because there is no good reason why Italians cannot do high-quality social research on Americans.

Sentence (8) states, "Lack of money causes crime, not just lack of education." This is probably true, but if off the mark. The speaker said only that lack of education is *partly* a cause of crime; the speaker didn't rule out poverty as another cause. Doe's answer mistakenly implies that the argument did rule out poverty.

In summary, Doe missed or didn't adequately express the main points, and most of his other points were mistaken, too. Note how this evaluation of Doe's evaluation addresses many topics of logical reasoning: sticking to the issue, arguments from

authority, vagueness, implication, identifying arguments, and distinguishing cause from correlation.

Review of Major Points

This chapter explored the difference between a causal claim and one that is merely correlational. Causality and correlation are intimately connected in three ways. First, if A does cause B, there will always be a correlation between A and B, but the reverse isn't true. Second, if you suspect that A causes B, then finding the predicted correlation between A and B will help justify the causal claim, whereas not finding the correlation will refute it. Third, a correlation between A and B is a reason to suspect that A does cause B. Of these three connections between causality and correlation, the first is about prediction, the second is about justification, and the third is about discovery. Prediction, justification, and discovery are three major elements of the scientific process.

The "scientific method" is the method of discovering possible causes, then testing them. The key idea in justifying a claim about what causes what is to actively test alternative causal stories (hypotheses) in an attempt to rule them out. Testing is active, whereas observation alone is more passive. That is one reason that the method of inductive generalization is not as powerful a tool as the scientific method.

Criteria for creating good explanations include the following: (1) The explanation should fit the facts to be explained and should not conflict with other facts. (2) An explanation should do more than merely describe the situation to be explained. (3) Good explanations are not circular. (4) Supernatural explanations should be avoided unless it is clear that more ordinary, natural explanations won't work. (5) Good explanations are relevant. (7) Explanations should be consistent with well-established results except in extraordinary cases. (8) Extraordinary explanations require extraordinarily good evidence. (9) Explanations should be tailored to the audience whenever possible. (10) The more precise the explanation, the better. (11) Explanations should be testable.

Glossary

causal claim A claim that asserts or denies the existence of a causal connection between two things, such as events, people, states, or between two types of things. A causal claim indicates that the connection is more than a mere accidental one. The standard form of a causal claim is: C causes E, where C is the cause and E is the effect. A causal claim is also called a *cause-effect claim* or a *causal statement*.

causal generalization A generalization that makes a causal claim. Causal generalizations assert causal connections between kinds of things rather than between specific things. The standard form is: (All, most, many) events of kind C cause events of kind E.

causal indicator A term that signals the presence of a causal claim. Examples: produces, cures, makes, triggers.

cause-effect claim A causal claim.

contributing cause One among many causes. The contributing cause that is most important for our present purposes we call *the* cause. A contributing cause is also called a *contributing factor* or *partial cause*.

control group In a controlled experiment, the group that does not receive the cause that is suspected of leading to the effect of interest.

correlation An association. Finding a correlation between two variables A and B is a clue that there may be some causal story to uncover, such as that A is causing B. Characteristics A and B are correlated if the percentages of A's among the B's is not the same as the percentages of A's among the not-B's.

determinate cause A cause that will make its effect happen every time under known proper conditions.

directly proportional A perfect positive straight-line correlation between two variables.

experimental group In a controlled experiment, the group that receives the suspected cause of the effect being studied. Sometimes called the "treatment group."

inversely proportional Characteristic of a perfect negative straight-line correlation between two variables.

negative correlation A relationship that exists when variable A tends to increase when B decreases, and vice versa. Characteristic A is negatively correlated with characteristic B in a given population whenever the percentage As among the Bs is less than the percentage of As among the not-Bs.

no correlation A lack of relation between two variables. Characteristics A and B are uncorrelated if the percentages of A's among the B's is the same as among the not-B's.

perfect correlation A relationship that exists when two variables always change together. That is, both may increase together or both may decrease together.

positive correlation A relationship between A and B that exists when variable A tends to increase when B increases and vice versa. Characteristic A is positively correlated with characteristic B in a given population whenever the percentage of A's among the B's is greater than the percentage A's among the not-B's.

post hoc fallacy The mistake of supposing that A caused B when the only evidence is that A is followed by B a few times.

probable cause A cause that will make the effect happen occasionally. When a probable cause occurs, the effect is probable but not certain.

specific causal claim A causal claim that asserts a specific claim rather than a general claim.

spurious association An association between A and B that results not because A is causing B or B is causing A but instead because some lurking factor C is causing A and B to be associated.

strength of the correlation A measure of how well two things are correlated. As a rule of thumb, the strength of the correlation between characteristics A and B is proportional to the difference between the percentage of B's that are A and the percentage of B's that are not-A.

treatment group The experimental group in an experiment involving treatment with a drug.

uncorrelated A lack of correlation between two variables.

Exercises

Correlations

■ 1. Refer to the exercise in an earlier chapter about Lady Theresa.

> Analyzing the data from the laboratory, you discover a statistically significant correlation between when Lady Theresa gets the right answer on the card tests and when she twitches her right hand. What do you recommend doing to determine, whether a statistically significant correlation holds the other way around—that is, between her right hand twitching and her getting the right answer on those card tests?[352]

■ 2. If increases in the percentage of citizens in jail is caused by decreases in income among the citizenry, among other things, what can you say about the correlation between the citizens' income and the citizens' criminal convictions.

a. It is positive. b. It is negative.[353]

3. Create an original, nontrivial multiple-choice question, with answer, that requires an understanding of the notion of correlation of two discrete variables.

■ 4. How strong is the correlation mentioned in this passage? Comment also on any causal inferences.

> The Surgeon General has determined that breathing is dangerous to our health. This conclusion was drawn from a survey of 100 prisoners in a New York prison who have

352 You need to do nothing. If A is correlated with B, then B must be correlated with A.

353 Answer (b).

died within the past five years. All were habitual breathers. A strong correlation; take heed and watch your breathing.[354]

5. Barometers measure air pressure. When the air pressure is low, air from farther away rushes in to restore the imbalance. This new air is likely to bring with it new weather, especially rain. So, the height of mercury in an outside barometer is

a. positively correlated

b. negatively correlated

c. not correlated

with the probability of rain (in the vicinity of the barometer).

6. State something that, in the summer in mountainous states, is positively correlated with the amount of the previous winter's snowfall.

Identifying Causal Claims

1. Which phrase below is least likely to be used to say that A causes B?

a. A leads to B.

b. B is caused by A.

c. A makes B happen.

d. A occurs with B.

e. A produces B.

f. B is affected by A

■ 2. Rewrite the following causal claim using the word *cause* or *causes* explicitly.

Whenever the sun sets, it gets dark.[355]

3. In an exercise in an earlier chapter, you are asked to analyze the conversation between Lesley and Rico about a measles vaccine. Identify the causal claim that they inferred from the finding

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354 Would you find less death if you looked at nonbreathers? There is no significant correlation. This passage is a variation on a joke by Howard Kahane, *Logic and Contemporary Rhetoric: The Use of Reason in Everyday Life*, 4th ed. (Wadsworth, 1984), p. 111.

355 The setting of the sun causes darkness.

that 1 out of 622 children receiving the vaccine had gotten measles within the next seven months.

■ 4. Which of the following sentences contain causal claims, and which contain merely correlational claims?

a. Money makes you happy.

b. Sniffing ragweed pollen triggers the creation of histamine in the blood of allergy sufferers.

c. It therefore is the case that lack of education is partly to blame for crime, at least in the United States if not necessarily elsewhere.

d. Putting an infant on a feeding schedule would probably make it cry until its feeding time.

e. The data on the height of corn are associated with the amount of water the corn gets during its growing season.

f. Adding water to corn plants usually leads to taller growth.

g. There are more smokers among Japanese-born Canadians than among other Canadians.[356]

■ 5. David claims that there is a link between smoking and sugar consumption. He says he has noticed that people who avoid the sugar jar when offered a cup of coffee also are more apt to be a smoker than someone who does dip into the jar. If so, Davis is likely to have uncovered

a. a positive correlation

b. a negative correlation

c. a non-standard transverse Kurzweil correlation[357]

■ 6. Following are three causal claims. Which claim is a specific, rather than general causal claim?

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356 a. causal b. causal c. causal d. causal e. correlational f. causal g. correlational

357 The more apt a person is to consume sugar the LESS apt the person is to be a coffee drinker. A group with many coffee drinkers would be a group with relatively fewer sugar consumers. So, this is a negative correlation.

a. John Jameson stabbed her with his own kitchen knife.

b. PEOPLE kill people; bullets don't.

c. Anyone who drinks a cup of gasoline will get very sick.[358]

7. Label the following passages:

i. Statistics reported by the Ugandan ministry of police establish that a person's age makes the person more susceptible to being mugged.

a. only an association b. causal c. ambiguous

ii. Our study has now uncovered a link between people's religion and their faith in the stability of their economy.

a. only an association b. causal c. ambiguous

iii. Medical doctors believe that high sugar consumption is associated with weight gain in rats and mice.

a. only an association b. causal c. ambiguous

iv. Medical doctors believe that having diarrhea is associated with eating too much licorice.

a. only an association b. causal c. ambiguous

v. Medical doctors now believe that eating too much licorice is associated with diarrhea.

a. only an association b. causal c. ambiguous

9. What causal claim is the speaker, Huckleberry Finn, making in the following quotation?

I've always reckoned that looking at the new moon over your left shoulder is one of the carelessest and foolishest things a body can do. Old Hank Bunker done it once, and bragged about it; and in less than two years he got drunk and fell off of the shot tower, and spread himself out so that he was just a kind of a layer, as you may say; and they slid him edgeways between two barn doors for a coffin,

358 Answer (a). It makes a specific causal claim rather than a general one.

and buried him so, so they say, but I didn't see it. Pap told me. But anyway it all come of looking at the moon that way, like a fool."

a. Looking at the new moon over your left shoulder causes most cases of drunkenness.

b. Drunkenness causes looking at the new moon.

c. Carelessness or drunkenness on the shot tower was stupid.

d. Looking at the new moon over his left shoulder caused Bunker to die.

Inferring from Correlation to Cause

■ 1. If scientific studies were to show that 80 percent of juvenile delinquents are from homes under the poverty line, could being from a home under the poverty line be a determinate cause of juvenile delinquency? Why?[359]

■ 2. If there is a causal connection between two variables, then there must be a positive correlation between them.

a. true

b. false[360]

3. Given that you have observed a correlation between A and B and have noticed that A doesn't occur after B, you then need to consider whether A causes B. Which one of the following would be the worst methodology to adopt to find out?

a. Look to see whether the causal connection between A and B can be deduced from other acceptable theories.

b. Try to eliminate alternative hypotheses about the connection between A and B by running tests on those hypotheses.

c. Consider whether some third factor C is causing A and also causing B.

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359 To be a determinate cause, the statistic would have to be 100%, not 80%.

360 Answer (b). Why couldn't it be negative?

d. Check to see whether the probability of A equals the probability of B.

■ 4. The following comment was made as a joke, but if it were made seriously, what would be wrong with it?

All muskrats walk single file; at least the only one I ever saw did.[361]

5. Explain why the correlation between monthly ice cream revenues in New York City and monthly revenues in Utah from snow ski rentals is spurious. Be specific; don't merely restate the definition of *spurious*.

■ 6. The stronger a correlation between two variables

a. the more likely there is

b. the less likely there is

c. still does not affect the probability of[362]

a causal connection between them

■ 7. The "scientific method" is the method of guessing possible explanations of interesting phenomena of nature and attempting to refute them by running experiments or making observations.

a. more or less true b. clearly false[363]

■ 8. Dr. Thomas Pyne has noticed a correlation between the color of the chairs in his college classrooms and the handedness of the chairs. The chairs for left-handers are

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361 First, by making a universal generalization from just one example, the speaker is committing the fallacy of hasty generalization. In addition, there is no file at all if there is just one member of the file. If you noticed that one muskrat cannot walk single file, then you realized that the generalization is an inconsistent remark. By the principle of charity, you might consider assuming that the one muskrat was walking single file with other non-muskrats; however, this assumption probably violates the principle of fidelity because it lessens the impact of the original joke and because there is no other indication that any other animals were observed. The joke was told to the author by Robert Garmston.

362 Answer (a).

363 Answer (a). This description of the scientific method as being the method of conjectures and refutations was first clearly stated by Karl Popper.

always black, never the bright colors of the other chairs. What is most likely to be correct about the situation?

a. The color of the chair is causing its handedness.

b. The handedness of the chair causes it to receive the paint color it does.

c. Decisions by chair manufacturers affect paint manufacturing, often causing paint supplies to run out of all colors except black.

d. The correlation does not cohere with our background knowledge.[364]

9. Write an essay about a significant piece of scientific research that uncovers a correlation and then tries to establish a causal connection. Begin by describing the research and its results in your own words. Use a footnote to indicate the source of your information. Then show how various points made in this chapter apply to the research. The essay should contain at least four of the terms from the glossary at the end of this chapter.

10. Write an essay that describes an experiment you yourself designed and ran in order to test the significance of a suspected correlation. The correlation need not have great social or scientific importance. Within your essay, argue for why your test does establish that the correlation is or is not significant.

Explanations

1. Write an essay explaining one of the following:

> How to torpedo a non-money bill in the state legislature before it reaches the floor for a vote. Audience: fellow lobbyists.
>
> How the game of basketball has changed since its creation. Audience: college physical education majors.
>
> How to build a fireplace in a new house. Audience: homeowners.

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364 Answer (b). Some manufacturer has probably decided to paint all the left-handed chairs black. The chair's being black is caused in part by its being left-handed and caused in part by the painter in the plant following the manufacturer's decision.

Why World War I was not won by the Germans. Audience: high school seniors in a history class.

How a refrigerator refrigerates. Audience: high school science class at the sophomore level.

How to get shelf space in U.S. supermarkets for the new cereal your company is planning to manufacture. Audience: your manager.

■ 2. Which comment below most accurately characterizes the following letter to the editor:

Dear Editor:

You smeared the public relations trade in your editorial when you said, "If Ollie North is lying to the U.S. Senate, he's lying very well, which would make him a highly excellent PR guy." This is a terrible indictment!

In my eighteen years as a public relations consultant, working on some very controversial issues, I have never found it necessary to lie on behalf of a client, nor have I ever been asked to. Lying is not an important criterion for becoming an "excellent PR guy."

a. The writer believes most public relations people do lie to help their clients.

b. The writer is appealing to anecdotal evidence.

c. The writer believes that lying for one's client usually causes bad public relations for that client.

d. The writer is committing the black-white fallacy.

e. The writer is committing the straw man fallacy.[365]

3. What is the main principle of good explanation construction that is violated in this explanation?

Reporter: Why do you suppose that National Football Conference teams always win the Super Bowl, and the American Football Conference teams always lose?

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365 Answer (b). The anecdotal evidence is his own experience. It is true that most PR people are not primarily liars, although they are experts at shaping a sentence so that it emphasizes the good aspects of the client's product and the bad aspects of the opponent's.

Coach: I think it has something to do with the caliber of the teams in each conference. The AFC teams such as the Buffalo Bills just aren't as good as the Redskins and Giants of the NFC.

a. The explanation is supposed to fit the facts to be explained and not conflict with other facts.

b. A good explanation doesn't just rephrase what it is trying to explain.

c. Good explanations will explain something in terms of something else that we can understand to be relevant.

d. Good explanations will explain something unfamiliar in terms of something familiar.

e. Explanations should be consistent with well-established results except in extraordinary cases.

4. Discuss the pros and cons of the explanation in this letter to the editor. Begin by clearly identifying the explanation — that is, by saying what is being used to explain what.

There is an evil current running throughout history. People haven't been nice to each other. Take a look most recently at Nazism in Germany and Stalinism in the Soviet Union. Look at all the cases of demon possession in the files of the Catholic Church. It's time for your readers to wake up to the fact that the Devil is at work.