11. It has recently been concluded that measurable levels of stress do not increase the likelihood of complications in pregnancy, based on a study correlating stress levels and the incidence of complications.
12. Fred's car went out of control and off the road because the roads were icy and, as we all know, ice on the road significantly reduces traction.
13. The fate that befell the Amerinds when they first came into contact with the European invaders is among the best-documented illustrations of the effects that epidemics in general and smallpox in particular have exerted on the course of wars. Shortly after the arrival of Cortez and his Conquistadores, smallpox spread like wildfire through the Indian population. As smallpox was then prevalent in Europe, the Spaniards had probably developed immunity to it through early exposure, whereas the Indians, who had no racial experience with it, proved very susceptible. By killing at least half the Indians and demoralizing them at a critical time, the epidemic certainly played a part as important as Spanish arms and valor in bringing about the conquest of the South American continent. (René Dubos, *The Mirage of Health*)
14. In light of the fact that Congress included significant increases in income tax in the new budget and that higher income tax results in decreased consumer spending and deepening recession, the likely result of the new budget will be to deepen the current recession.
15. According to *Newsweek,* "a new study headed by doctors from the University of Minnesota provided the strongest evidence yet that cholesterol does indeed contribute to heart disease. The 838 subjects of the study had survived a previous heart attack and had cholesterol levels above 220. Half were told to modify their diets; some of them were given drugs. The other half underwent a surgical procedure to reduce absorption of cholesterol into the bloodstream. In the surgery group, cholesterol levels dropped to an average of 196, compared with 241 in the control group. Over a 10-year period the combined rate of second heart attacks or death from heart disease was 35 percent lower in the treated patients—and they required less than half as many cardiac operations as the controls. The study also showed convincingly, for the first time, that the progression of heart disease could be accurately forecast by X-rays taken to monitor plaque buildup inside the arteries."

8.3D Mill's Methods

Of the four types of causal arguments, the causal conclusion is logically most important. Causal conclusions are intended to establish the causal generalizations that we use in making predictions, explanations, and prescriptions. Therefore, we need to know when a causal conclusion is strong and, thus, what kind of evidence to look for. That requires a theory of causal reasoning. Mill's Methods is such a theory. It purports to answer the question, *What kind of evidence is good evidence for a causal statement?*

Premises *Evidence of Mill's Method*

Causal conclusion *C causes E*

John Stuart Mill (1806–1873), in his *System of Logic,* describes five methods for identifying causes and effects. They are the methods of agreement, difference,

concomitant variation, residue, and the joint method of agreement and difference. We examine the first four and comment on the last. Philosophers do not agree about the adequacy of Mill's methods. Some think Mill claims too much for them. But our purpose is not to enter the debate; it is to adapt the methods as seems reasonable to the assessment of arguments that conclude with a causal statement.

1. The Method of Agreement According to the method of agreement, the cause of an event E is that circumstance common to all cases in which E occurs. Thus, to paraphrase Mill:

> method of agreement *If two or more instances of a phenomenon E have only one antecedent circumstance in common, then probably that antecedent circumstance is the cause or a partial cause of E.*

Reasoning that whenever a phenomenon occurs, the cause will be present, Mill's first method for identifying a cause tells us to look for an antecedent circumstance present in all those cases in which the phenomenon occurs.

Suppose, for example, five friends have lunch at a restaurant, and an hour later three get sick from food poisoning. The method of agreement suggests that we can identify the spoiled food causing the sickness by looking for the antecedent circumstance common to the three cases of illness.

Example 20

	ATE	GOT SICK
Denise	salad, roast beef, apple pie, tea	No
Amy	clam chowder, salad, apple pie, coffee	Yes
Beth	clam chowder, apple pie, cola	Yes
Ellen	hamburger, fries, cola	No
Clara	clam chowder, chicken, coffee	Yes

Following the method of agreement, we focus on those cases in which the illness occurred and look for a common element.

Case A Amy's illness has antecedents: *clam chowder,* salad, apple pie, coffee.

Case B Beth's illness has antecedents: *clam chowder,* apple pie, cola.

Case C Clara's illness has antecedents: *clam chowder,* chicken, coffee.

The three cases of illness have only one circumstance in common: clam chowder. On the principle that the cause is probably that circumstance common to otherwise different instances of a phenomenon, it is reasonable to conclude that the clam chowder is at least a causal factor in producing the illness.

The form of an argument using the method of agreement is:

1. *Case A of phenomenon E has antecedent circumstances* f, g, h, *and* i.
2. *Case B of phenomenon E has antecedent circumstances* f, h, *and* j.
3. *Case C of phenomenon E has antecedent circumstances* f, k, *and* i.

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4. *Therefore, circumstance* f *is probably the cause or a partial cause of E.*

Although the case of the food poisoning illustrates Mill's first method, it seems contrived. Isn't it fortunate that *only one* dish was common to the cases of illness? What if there had been two or three common items eaten by those who got sick? Furthermore, isn't it possible that there are other circumstances common to the three? In fact, looking at our example, there are others: All three are women and, let us suppose, all three are wearing red. On what grounds, then, do we single out food items as antecedent circumstances and not, say, color of clothing? These questions require some discussion of the adequacy of Mill's first method. (Indeed, Mill's other three methods raise similar problems, which, however, we will not stop to address. Let the present discussion suffice.)

Let's take the second problem above first. On what grounds do we single out food items as antecedent circumstances and not such things as wearing red? What is to count as an antecedent circumstance? In practice we distinguish between circumstances thought to be relevant to a phenomenon and those that are not. Wearing red, we say, is not relevant to getting sick after lunch. In other words, we form a *hypothesis,* a reasonable guess based on past experience, as to what circumstances are relevant candidates for the cause of a phenomenon. Using a hypothesis, we significantly narrow the field of antecedent circumstances and thus may apply a method like Mill's first method to isolate the cause. This qualification is required for the application of Mill's first method (and, with the appropriate changes, the others as well):

Given the hypothesis that antecedent circumstances f, g, h, i, *and so on are* causally relevant *to E, then, according to the method of agreement, if two or more instances of a phenomenon E have only one antecedent circumstance in common, probably that antecedent circumstance is the cause or a partial cause of E.*

Second, given two or more occurrences of a phenomenon E, how likely are they to have *only one relevant* antecedent circumstance in common? What do we do when two or more *relevant* antecedent circumstances are common to the otherwise different cases of E? In our example, we may imagine that, besides each woman having clam chowder, each also ate apple pie. The first thing to notice is that the antecedent of Mill's method of agreement does not obtain: We do not have two or more instances of E with only one circumstance in common. Thus, in such a case Mill's first method does not identify the cause of E. We must turn to Mill's second method. Nevertheless, the first method does allow us to eliminate from further consideration all those circumstances not present in instances of E. It provides, in other words, positive evidence that the

cause of E is, at least, among those antecedent circumstances common to E. We may state this as a modified version of Mill's first method:

> modified method of agreement *If two or more instances of a phenomenon E have antecedent circumstances* f *and* g *in common, then probably (*f *causes E) or (*g *causes E) or (*f *and* g *cause E).*

Naturally, this modified version can be rewritten to apply to cases in which there are more than two common antecedent circumstances. The essential point is that, while Mill's method of agreement may not be sufficient to identify *the* cause of a phenomenon, it does allow us to identify potential causes.

2. The Method of Difference Using Mill's second method, the method of difference, we can continue the investigation. According to this method, we compare cases in which the phenomenon occurs with those cases in which it does not occur to discover in what way they differ. If there is a single antecedent circumstance present when the phenomenon occurs but absent when it does not occur, that circumstance is causally involved in the phenomenon. For example, you may conclude that touching the TV antenna is the cause of the clear picture on your TV screen when you observe that it is clear when you touch it but not clear when you take your hand away. Or, to take another example, you may conclude that it is the ham that causes the salty taste in your stew when you notice that the salty-tasting batch has ham in it while the other batch does not.

> method of difference *If an instance of phenomenon E and an instance in which E does not occur differ only in the presence of one antecedent circumstance with the instance of E, then that antecedent circumstance is probably the cause or a partial cause of E.*

The form of an argument employing the method of difference is:

1. *Case A of phenomenon E has antecedent circumstances* f, g, h, *and* i.
2. *Case B without phenomenon E has antecedent circumstances* g, h, *and* i.

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3. *Therefore, circumstance* f *is probably the cause or a partial cause of E.*

By using the method of difference in conjunction with the method of agreement—actually what Mill calls the joint method of agreement and difference—we can handle the problem raised above: those cases in which two or more instances have *more than one* antecedent circumstance in common. Let's suppose that Amy, Beth, and Clara also have apple pie in common. By the method of agreement, we can say that the three cases of illness are caused by apple pie, clam chowder, or the combination of apple pie and clam chowder. Now we compare their cases with those in which one of the two antecedents is present yet the illness is not.

Example 21

Case A	Amy's illness has antecedents: *clam chowder,* salad, *apple pie,* coffee.
Case B	Beth's illness has antecedents: *clam chowder, apple pie,* cola.
Case C	Clara's illness has antecedents: *clam chowder,* chicken, *apple pie,* coffee.
Case D	Denise, no illness, has antecedents: salad, roast beef, *apple pie,* tea.

By using the method of difference, we see that the apple pie cannot be the cause of the illness because Denise had apple pie but did not get sick. Thus, of the two common antecedents, the apple pie may be eliminated as a cause.

When we use the method of agreement, we look for what is common to instances of a phenomenon we are investigating. Thus, we eliminate those antecedent factors not present in all cases in which the phenomenon occurs. When we use the method of difference, we look for some difference between instances of a phenomenon and instances without the phenomenon. Thus, we eliminate those antecedent factors present whenever the phenomenon fails to occur.

Below is the form of an argument employing both the method of agreement and the method of difference.

METHOD OF AGREEMENT AND METHOD OF DIFFERENCE

1. *If* f *and* g *are common to E, then probably (*f *causes E) or (*g *causes E).*	*(modified method of agreement)*
2. f *and* g *are common to E.*	*(by observation)*
3. *Therefore, probably (*f *causes E) or (*g *causes E).*	*(by 1 and 2, MP)*
4. *If circumstance* g *but not E, then probably not (*g *causes E).*	*(method of difference)*
5. g *and not E.*	*(by observation)*
6. *Therefore, probably not (*g *causes E).*	*(by 4 and 5, MP)*
7. *Therefore, probably* f *causes E.*	*(by 3 and 6, DS)*

3. The Method of Concomitant Variation Any number of things in our experience exhibit variations. Hot plates get hotter; people get physically stronger or weaker. Frequently, we observe that such variations coincide with (are concomitant with) variations in other circumstances.

Example 22

The more Smith exercises, the stronger he seems to get.

Example 23

The higher the humidity, the longer it takes the paint to dry.

The fact that instances of two different kinds of phenomena consistently vary together provides some evidence that they are causally related. To paraphrase Mill:

> method of concomitant variation *If variations in phenomenon E coincide with variations in phenomenon P, then it is probable that E and P are causally related.*

A virtue of the method of concomitant variation, Mill claims, is that it is particularly useful for those cases in which the method of difference cannot be applied. Mill's example is the phenomenon of the tides. Suppose we suspect that the moon's gravitational pull on Earth is the cause of the tides. In this case, there is no possibility of applying the method of difference because we cannot get rid of the moon (which is what we'd have to do to see what effect, if any, that had on the tides). But what is possible, Mill says, is to observe the variations in the position of the moon and look for concomitant variations in the tides. Hence, we see that the tide rises with the rising moon and ebbs with the latter's setting.

Now the fact that two phenomena vary consistently is evidence that they are causally related but not evidence about which is the cause and which the effect. Thus, for example, we should not conclude that the moon is causing the tides just because we observe a concomitant variation between the two. Odd as it may sound, perhaps the tides cause the moon to rotate! By itself the method of concomitant variation gives us only correlations of phenomena and, hence, evidence of a causal connection. To conclude which phenomenon is causing which, we need evidence beyond what the method of concomitant variation provides, evidence that is perhaps provided by the other methods.

In thinking about two phenomena that vary in relation to each other, it is useful to make a distinction. In some cases, a phenomenon varies *simultaneously* with some other circumstance. For example, variations in humidity and paint-drying time occur simultaneously. The moon's rotation occurs simultaneously with the changing of the tides. On the other hand, some phenomena vary *subsequent to* variations in some other circumstance. For example, one's muscles get bigger subsequent to increased exercise. Next year's crop of insects varies with the severity of this year's winter.

About the second kind of case above, we can conclude that the antecedent phenomenon is the cause of the subsequent because we know that what comes after cannot be the cause of what comes before. If we know, in other words, that some phenomenon E has circumstance *f as an antecedent,* then we could reason that variations in E are caused by variations in *f*. Letting the symbols + and – represent increases or decreases, we can express the form of the argument by the method of concomitant variation as follows:

> *Case A* *Phenomenon E has antecedent* f.
> *Case B* *Phenomenon E+ has antecedent* f+.
> *Case C* *Phenomenon E– has antecedent* f–.
>
> ---
>
> *Therefore, probably variations in antecedent* f *cause variations in E.*

Of course, for those cases in which phenomena vary inversely, the form of argument would differ accordingly. For example, phenomenon E+ has antecedent *f*–.

About those kinds of cases in which phenomena vary simultaneously, Mill suggests that, if possible, we try to produce variations in one phenomenon by controlling variations in the other. For example, in a tightly sealed room we vary the humidity and see whether that produces variations in drying time. Then we try the reverse. We speed drying time by thinning the paint, say, to see if that alters the room's humidity. Or, as another example, we observe that increasing the temperature of a gas increases its volume but increasing volume does not increase temperature. Such experiments enable us to say which of two simultaneously occurring events is varying because of which.

Example 24

Given a balloon filled with air to a volume of fifteen cubic inches at room temperature, say, 70°F, I then step outside into the cold, 20°F, and observe that the balloon nearly collapses. When I return to the warm house, the balloon resumes its previous volume.

Experiments in which we produce variations in some phenomenon by controlling others borrow from what we have learned with the method of difference. In effect, we try to produce a difference in one by making a difference in the other. In short:

Case A *Phenomenon P increases (or decreases); E increases (or decreases).*

Case B *Phenomenon E increases (or decreases); P neither increases nor decreases.*

Therefore, variations in P probably cause variations in E.

What finally entitles us to say that the moon causes the tides and not the reverse? We cannot experiment on the moon and the tides. However, in this kind of case, the method of difference provides a way of testing the hypothesis that the tides cause the moon's variations. Comparing our moon with planets having a moon but no oceans, we conclude that the tides cannot be the phenomenon causing variations in the moon; it must be the reverse.

4. The Method of Residue Suppose we are investigating some complex phenomenon such as the increased incidence of AIDS in our community. Let us say that we already know certain facts: (1) The AIDS virus is transmitted through exchange of body fluids, typically blood or semen; (2) in all the cases of AIDS we have observed, the antecedent circumstances have been either contaminated needles in IV drug use, unsafe sex, or blood transfusions; (3) we have established that IV drug use is a causal factor in 65 percent of the cases and unsafe sex is a causal factor in 25 percent of the cases. Thus, we can conclude that the remaining cases are caused by blood transfusion. Our argument is:

Example 25

1. *All observed instances of AIDS have as their antecedent circumstances IV drug use, unsafe sex, or blood transfusion.*

2. *IV drug use is a causal factor in 65 percent of cases of AIDS.*
3. *Unsafe sex is a causal factor in 25 percent of cases of AIDS.*

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4. *Therefore, blood transfusion is a causal factor in the remaining cases of AIDS.*

That argument illustrates Mill's method of residue, which he describes as follows:

> method of residue *Subtract from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.*

An example of the form of an argument using the method of residue is this:

1. *Phenomenon E consists of parts E1, E2, and E3.*
2. *E has antecedent circumstances* f, g, *and* h.
3. f *causes E1.*
4. g *causes E2.*

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5. *Therefore,* h *causes (the residue) E3.*

In short, if we know what part one antecedent plays in a complex phenomenon, we can infer the part played by the other. Suppose we want to clarify for ourselves what effect the strings are having in an orchestra, given that we can hear the horns well. Following the method of residue, we ask the horn section to sit out while the strings play.

The method of residue may be used to identify interfering causal factors as well. Suppose a patient is being given an antihypertensive drug that we know should have the effect of a reduction in blood pressure. Yet we observe that the patient is not responding as predicted. In searching for other antecedent circumstances, we discover that the patient has been taking epinephrine to control a cold. Assuming that we can rule out other factors and given that the antihypertensive normally dilates blood vessels, we can reasonably conclude that the epinephrine is interfering. Letting *f* refer to the antihypertensive drug, *g* the epinephrine drug, and E reduced blood pressure, we are reasoning as follows:

1. *Antecedent circumstance* f *is known to cause E—that is, all things being equal, in cases where* f *is present, E occurs.*
2. *Case A Antecedent circumstances* f *and* g, *E does not occur.*

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3. *Therefore, in Case A, probably* g *causally interferes with* f.

As the examples illustrate, the method of residue presupposes some causal knowledge of a phenomenon. Perhaps by means of the other methods, we have a partial understanding

of the phenomenon. This method allows us to identify at least one, perhaps other causal factors contributing to the phenomenon.

Summary: Mill's Methods Mill's methods provide four criteria for assessing the strength of arguments having a causal conclusion. In applying Mill's methods, the following points should be observed.

First, Mill's methods assume that relevant circumstances or factors have been identified. That is, the use of Mill's methods requires a hypothesis about which kinds of circumstances are to be considered. Thus, in assessing an argument in support of a causal statement, we should consider whether a premise asserting that, for example, "in all instances of E, only antecedent circumstance *f* is present" is true. Are there relevant circumstances that have not been considered?

Second, consider the methods as *providing evidence* in support of or contrary to a causal claim. That is, if a causal claim—X causes Y—is supported by premises based on one of the methods, we will say that that causal claim is strengthened. Let us say, further, that a causal claim is given additional strength by premises based on more than one method.

Below is a shorthand summary with simple explanations, not rigorously expressed, of the four methods we have studied. In examining a particular argument, use this general summary to direct you to the previous, more detailed discussions.

AGREEMENT

If a circumstance *f* is the only circumstance always present whenever E occurs, then we have supporting evidence for the conclusion that *f* is the cause of E.

Why? Because whatever is the cause of E will be present whenever E is present.

DIFFERENCE

If E occurs when *f* is present but not when *f* is absent, then we have supporting evidence for the conclusion that *f* causes E.

Why? Because the nonoccurrence of E is attributable to some difference in antecedent circumstances.

CONCOMITANT VARIATION

If one phenomenon varies consistently with another phenomenon, then we have supporting evidence that the two are causally related.

Why? Because if two variable phenomena are causally related, then they will exhibit concomitant variation.

1. Given two phenomena that vary consistently, if one precedes the other, then we have supporting evidence that the former causes the latter.
2. Given two phenomena that vary consistently, if by altering one we can produce concomitant variations in the other, then we have supporting evidence that the former causes the latter.

RESIDUE

If one or more parts of a phenomenon can be causally explained by one or more parts of the antecedent circumstances, then we have supporting evidence that the remaining part of the phenomenon can be causally explained by the remaining antecedent circumstance.

Why? Given a complex phenomenon represented as E1, E2, and E3 and antecedents *f*, *g*, and *h* and given that E1 is causally explained by *f*, and E2 is causally explained by *g*, then the only remaining factor to explain E3 is *h*.

Since these four methods provide evidence in support of a causal statement, we can say in summary that:

> *A causal conclusion is strong to the degree that it is supported by premises with evidence of one or more of Mill's methods.*

Exercise 8.3B Mill's Methods In the following exercises, (a) identify the causal statement that is asserted; then (b) explain which method or methods are employed or should be employed to support the causal statement.

Sample Exercise *Researchers reported in* Scientific American *recently that some species of frogs are able to survive the winter by existing in a frozen state. Ice on the skin of the frog causes the liver to excrete large amounts of glucose into the blood system. The glucose in the blood acts to control the formation of ice crystals in the body and to prevent cellular collapse.*

Answer (a) The causal connection asserted in the passage is that between the presence of glucose in the frog's blood system and effects of freezing. (b) Mill's methods of agreement and difference are appropriate in this example. First, researchers have identified the glucose in the blood as the causal factor inhibiting the effects of freezing. Second, it would strengthen the causal claim to observe those cases in which the frog is frozen but the liver is prevented from excreting glucose into the blood.

1. Leaning the mixture improves gas mileage, Chris Beitzel concludes. His reasons: when he leans, he gets better mileage than when he doesn't.
2. Ralph reasons that his grades are improving over last semester's because this semester he is sleeping an extra hour each night.
3. Alice suspects that she is allergic to Bud's cat because every time she visits his house the cat is there and she starts sneezing. But when he visits her house, the cat isn't and she doesn't. Does she have good evidence for her suspicion? If so, by what method? If not, by what method can she confirm or disconfirm her suspicion?
4. Smith needs some more lavender paint. Previously he mixed red, blue, and white to make the shade he wanted. He knows that red and blue make purple, so he reasons that adding white must produce lavender.
5. Kay-kay, a precocious three-year-old, reasoned that turning the knob on the stereo caused the music to get louder or softer because no matter how far or how fast she turned the knob, the sound changed along with it.
6. At the first weighing, the mother stepped onto the scale alone. Her weight caused the scale to show 150 lb. At the second weighing, the

mother stepped onto the scale holding her baby. Their combined weight registered 165 lb. Thus, the weight of the baby, being the cause of the difference, is 15 lb.

7. Comparing the cases in which women are employed in jobs involving a high degree of social interaction with cases in which women are not, we can conclude that, all things being equal, social interaction reduces the incidence of chronic ailment.
8. After watching the relationships between barometric pressure and fish activity, Ray Minard concludes that the higher the barometric pressure, the less likely the fish will bite.
9. Caffeine does not increase the risk of heart disease, for as a recent study shows, comparing caffeine users, users of decaffeinated products, and those who use neither, heart disease is as low for caffeine users as it is for those who use neither. The incidence of heart disease is slightly higher for those who use decaffeinated products.
10. Airplane crashes have a number of causes: equipment malfunction, weather conditions, pilot error, ground control error. Studies show that equipment malfunction, weather conditions, and pilot error account for 87 percent of airplane accidents examined in the past nineteen years. We conclude that 13 percent are due to ground control error.
11. If the cycle goes over a bump and the engine misfires, and then goes over another bump and the engine misfires, and then goes over another bump and the engine misfires, and then goes over a long smooth stretch of road and there is no misfiring, and then goes over a fourth bump and the engine misfires again, one can logically conclude that the misfiring is caused by the bumps. (Robert M. Pirsig, *Zen and the Art of Motorcycle Maintenance*)
12. Cigarette smoking and exposure to secondhand smoke both significantly hasten hardening of the arteries . . . [according to a study in the January 1998 *Journal of the American Medical Association*]. An estimated 30,000 to 60,000 deaths a year in the United States can be attributed to secondhand smoking, wrote the authors, led by epidemiologist George Howard. . . . Howard and colleagues used ultrasound to measure how much carotid-artery walls thickened over a three-year period in 10,914 adults age 45 to 65. Subjects who had smoked on average one pack a day for 33 years had a 50-percent increase in the progression of hardening of their arteries when compared to non-smokers. Among past smokers—who had previously smoked a pack daily for 25 years—a 25-percent increase in progression was found. Among non-smokers who reported exposure to secondhand smoke for an average of 18 to 20 hours weekly, there was a 20-percent increase . . . when compared with people without such exposure. (*New York Times*, January 14, 1998)
13. The following is an excerpt from a *New York Times* report on studies showing that "birds can calibrate their innate sense of magnetic north with the movement of celestial objects across the sky."

    In a study performed by Kenneth P. and Mary A. Able of the State University of New York at Albany, 20 Savannah sparrows were divided into four groups and exposed to a rotating disk with dim lights resembling stars.

    In the wild, young birds learn the location of true north by noting the axis of the rotation of the night sky.