Or how about this: the temperature is up, there are more cases of malaria in the East African highlands; therefore global warming is causing more malaria in the East African highlands. QED.

Convinced by these news stories from respectable broadcasters and newspapers? You shouldn't be; they are all causation/correlation errors, made harder to spot by plausibility (at least to some). Plausibility is often part of the problem, encouraging us to skip more rigorous proof and allowing the causation instinct to settle too quickly: it sounds plausible, so it must be right. Right? Wrong.

In all these cases, environmental campaigners noted that as one measurement—average global temperature—moved, so did another: the position of the coastline, the number of frogs, cases of malaria. They put these facts together and confidently assumed they had added two and two to make four and produce what they called compelling evidence, but we might prefer to call them classic cases of logical hopscotch, fit for, if not derision, at least serious skepticism. All these claims have been vigorously and credibly challenged, as we shall see.

It is worth saying here and now that this chapter is no exercise in climate change denial. We need to beware of another fallacy, namely that because campaigners sometimes make false claims about the effects that therefore no effects exist. That doesn't follow either. We can note in passing that some critics of global warming have been equally guilty of spectacular numerical sophistry. The point is that even with strong cases, perhaps especially with strong cases of which people are devoutly convinced, they get carried away, and are too quick to let causation rest wherever it helps them.

So this is a guide to a certain variety of failed reasoning, but it is a frequent failure in hard cases, given great impetus by numbers. If we state that a rare frog is dying out as a result of global warming, it sounds OK, but lacks beef; it would be more powerful if we could throw in some measurements and say that researchers believe the past decade of record temperatures has led to a 60 percent decline in the population of red-spotted tree frogs.

Put aside, if you can, your own convictions, and follow us to the point: we are concerned here only with how to avoid mistaking correlation for a causal relationship. Learn how and, whatever side you are on, you can get closer to something more important than this kind of conviction: understanding.

It is a peculiar hazard, this tendency to confuse causation and correlation, which is (A) well known and well warned against, yet (B) simultaneously repeated ad nauseam, making it tempting to say that A causes B. It is also a hazard far more widespread than debate about climate, if more easily spotted, it must be said, in examples like these:

> People with bigger hands have better reading ability; so we should introduce hand-stretching exercises in schools.

> In Scandinavia, storks are more likely to be seen on the rooftops where larger families live. Therefore storks cause babies.

Less obvious here:

> Children who come further down the birth order tend to do less well in school tests. Therefore birth order determines intelligence.

Downright controversial here:

> People with multiple sclerosis have lesions in the brain; so if we stop the lesions, we can stop the disease (i.e., the lesions cause the problem).

And here:

> Girls at single-sex schools do better than girls in mixed schools, therefore single-sex schools are better for girls.

What seems often to determine how easily we spot causation/correlation errors is how fast a better explanation comes to mind: thinking of decent alternatives slows conclusions and sows skepticism. Once again, imagination can take you far (though a thirst for more data also helps).

Good prompts to imagination are these straightforward questions: what else could be true of the group, the place, the numbers we are interested in? What other facets do they share, what else do we know that might help to explain the patterns we see? This is where the instinct for seeing causation can be put to good use, by stretching it further than the first answer at hand.

Where shall our imagination begin? With the most comical of our examples. The statement that hand size in children correlates with reading ability is true; but true because . . . ?

Because we tend to read better as we grow up, mostly through maturing intelligence and education, and as we grow older our hands grow bigger. Bigger hands are a correlate of better reading, but the cause lies elsewhere; no case, then, for a program of hand stretching in schools.

Next, storks and babies. This is harder, since the true explanation is less easy to guess, and there really are more storks on homes with larger families. But where does the causation truly lie? Perhaps because the house tends to be bigger as family size increases, and with more roof space . . .

In both cases there is a third factor that proves to be the genuine explanation: age in the first, house size in the second. That is one typical way for causation/correlation error to creep in. Two things change at the same time, but the reason lies in a third.

Now we begin to see how it works, what about the others, all of which have made the news?

Sufferers of multiple sclerosis have lesions in the brain. The more advanced the illness, the worse the lesions. But do the lesions cause the progressive disability characteristic of that illness? It is

plausible—for many years it was thought true—and when a drug called beta interferon, which seemed to arrest the lesions, was discovered it was used in the fervent hope that it would slow the disease.

There was only one way to verify the hypothesis, and that was by studying patients over many years to see how fast the illness progressed, relative to the number of lesions and the use of beta interferon. The results, when finally produced in 2005, were bitterly depressing: patients who have taken beta interferon do have fewer lesions, but are no better on average than others who have not. The progressive worsening of other symptoms seems to continue at the same rate in both groups. The lesions were found to be an effect, not a cause, of multiple sclerosis, and beta interferon was, said researchers, to use a mordant analogy, no more than a bandage that failed to treat the cause.

Birth order and intelligence is also tricky. It is, once again, true that the further along the birth order you are, the worse you tend to do in IQ tests: first-borns really do perform best, second-borns next best, and so on, not every time, but more often than not, and there is a plausible explanation (watch out!) that goes like this. The more children a family has, the less parental attention each receives: the first has lots, the second maybe half as much, and so on. This is believable, but does that make it true?

Let's try the imagination test: what else could be true as you pass along the birth order? At third or fourth, or even sixth or seventh, what is plainly true is that we are now looking at a big family. What do we know about big families? One thing we know is that they tend to be of lower socioeconomic status. Poorer people tend to have more children, and we also know that the children of poorer families tend, for various reasons, to do less well. So the further down the birth order you are, the more likely you are to come from a poorer family; not always, of course, but is this true often enough to be the explanation for what happens on average?

The evidence is not conclusive, but the answer is "probably," since it also turns out, when looking at the birth order of children from the same family, that no one has found a significantly consistent pattern of performance; the last born within the same family is, as far as we know, just as likely to do best in an IQ test as the first.

The causation/correlation mistake here has been to try to explain what happens across many families (richer, smaller ones tend to do better; larger, poorer ones not so well) and claim that it applies to birth order within any one family. It looks plausible (that word again) and it seems commonly believed, but it probably is wrong.

Next, gender and school performance. It is true that girls attending single-sex schools do better academically than girls who don't. Does this prove causation, i.e., does it prove that it's single-sex education that produces the better examination results? (We'll put aside the question of what it does to their social education, which is too normative a concept to measure.) Is it, in short, the lack of boys that did it?

Again, we must use our imaginations to ask what else is true of girls in single-sex schools. We must be restless in the search for causation and not settle on the obvious correlation as our culprit. The first thing that's true is that they have relatively wealthy parents; most of these schools are fee-paying. And what do we now know from the previous example about socioeconomic status and academic performance? Wealthier families tend to have, for whatever reason, academically higher performing children. Second, single-sex schools are more often selective, so that there will be a tendency to take the more able girls to begin with. So it is not surprising that single-sex schools do better: they take more able girls than other schools and these girls are usually from wealthier families. We have established that they ought to do better for all sorts of reasons, and this without taking into account any consideration of the effect of single-sex teaching.

Spare a thought for the statistician asked to settle this question who has to find a way of distilling school results to rid them of the effect of socioeconomic background or pupil selection by ability so as to isolate the gender effect. As far as they have been able to do that, the balance of statistical opinion, once they have made these allowances, is that there is no difference.

There *is* evidence that girls tend to make slightly less inhibited choices of subject in a single-sex school, and it will almost certainly suit some pupils—which may be reasons enough for wanting your daughter to attend—but it cannot be expected to secure better exam results in general than the girls would achieve had they attended a mixed school that took pupils of similar ability.

Perhaps now, if the sensitivity of these subjects hasn't created so much hostility that we've lost our readers, we can turn to one of the most sensitive of all: climate change.

First, malaria in East Africa. It has been known for some time that malaria in highland areas is hindered by low temperatures, which inhibit the growth of the parasites in the mosquito. The Tear Fund was one of several charities to produce evidence of an increased incidence of malaria in the East African highlands and to attribute it to climate change.

There were anecdotes: of the man from the highlands who had become landless and was living in poverty because he was bitten, got malaria, couldn't sustain work on the land, lost the land and was forced to work in bonded labor.

But when researchers looked closely at the records, they found no support for the argument. One of them, Dr. Simon Hay, a zoologist from Oxford University, said of the records for that specific area in contrast to global averages, that: "The climate hasn't changed, therefore it can't be responsible for changes in malaria." His colleague David Rogers, a professor of ecology, said that some groups responded to this by accepting that there was no change in average climate but arguing that there had been a change in variability of the

climate. That is an intelligent proposition, knowing, as we now do, that averages can conceal a lot of variation. So they looked—and found no significant change there either. The researchers concluded that an increase in drug resistance is a more likely explanation for the observed increase in malaria—in this instance. This was a case where there was not even a correlation at the local level but an assumed connection between what was happening to climate globally and disease locally.

Mary Douglas, an anthropologist, wrote that people are in the habit of blaming natural disasters on things they do not like. But the loose conjunction in the back of the mind of two things both labeled "bad" is not a sound basis for believing that one causes the other.

The so-called first victim of climate change was the South American golden toad. "It is likely," said one campaigner, "that the golden toad lives only in memory."

J. Alan Pounds, from the Golden Toad Laboratory for Conservation in Costa Rica, acknowledges that the toads have been badly affected by a disease called the chytrid fungus, but argues: "Disease is the bullet, climate change is the gun."

In fact, the fungus does not need high temperatures, and was deadly to the toads anywhere between 39°F and 73°F. Alan Pounds is not convinced: "We would not have proposed the hypothesis we did if there was not such a strong pattern," he said. It is quite likely, most scientists believe, that climate change will wipe out some species. It is not at all clear in this case that it has already done so.

Climate change is confidently expected to result in a rise in sea levels. Rising sea levels may well cause coastal erosion. The temptation is to observe coastal erosion and blame a climate-change effect on sea levels, as several TV news reports have done, accompanied by dramatic shots of houses teetering on clifftops.

But take a moment to note that even the environmental campaigning group Friends of the Earth is hesitant. Though deeply concerned about the future effects of climate change on coastal erosion, it says there has been erosion at the rate of about 3.3 feet a year for the last 400 years in parts of East England: "This erosion over the centuries is a result of natural processes and sea-level rise from land movements. However, in recent years the rate of erosion appears to have increased at some points along the coast. The causes are poorly understood, but in addition to natural processes and sea-level rise, the effects of hard coastal defenses are thought to play an important role. Ironically, our attempts to defend against sea-level rise may actually add to coastal erosion." When Friends of the Earth is cautious, reporters might also think twice.

Untangling climatic causation from correlation is fiendishly hard. And though climate change may raise sea levels and make coastal erosion seriously worse in the future, it is hard to claim it has made a difference yet. In fact, the rate of sea-level rise was faster in the first half of the twentieth century than in the second. (Though some argue that climate change has already affected the frequency and severity of storms and that these have caused coastal damage.)

When a tidbit of evidence seems to our taste, the temptation is to swallow it. For the noncommitted, too, this kind of deduction has an appeal—to laziness. It doesn't demand much thought, the nearest suspect saves time, the known villain might as well do. Even with intellectual rigor, mistakes happen, as with beta interferon and multiple sclerosis. During medical trials of new drugs, it used to be customary to record anything that happened to a patient taking an experimental drug and say the drug might have caused it: "side effects," they were called, as it was noted that someone had a headache or a runny nose and thereafter this "side effect" was printed forever on the side of the packet. Nowadays these are referred to as "adverse events," making it clear that the cause was unclear and they might have had nothing to do with the medication.

Restlessness for the true cause is a constructive habit, an insurance against gullibility. And though correlation does not prove

causation, it is often a good hint, but a hint to start asking questions, not to settle for easy answers.

There is one caveat. Here and there you will come across a tendency to dismiss almost all statistical findings as correlation-causation fallacy, a rhetorical cudgel, as one careful critic put it, to avoid believing *any* evidence. But we need to distinguish between casual associations often made for political ends and proper statistical studies. The latter come to their conclusions by trying to eliminate all the other possible causes through careful control of any trial, sample, or experiment, making sure if they can that there is no bias, that samples are random when possible. The proper response is not to trash every statistical relationship but to distinguish between those that have taken some thought and those that were a knee-jerk.

So what, finally, about the correlation at the beginning of this chapter, of being overweight and longevity? It is true that the data from the United States shows overweight people (overweight, not obese) living a little longer than thin people. So what other factors makes it hard to be sure if there is a direct causal link between putting on weight and adding years? One possibility is illness. Very ill people tend to be very thin. Put their fates into the mix and it has an effect on the results.

This argument is far from settled. A technical quarrel? Yes, but more importantly an imaginative and a human one. You don't need a course in statistics to be struck by the realization that sick people often get thinner. We can all make causation errors, and we are all capable of detecting them, if we think twice.

LAST WORD

Although this book has been about how numbers are used, it is best thought of as being not about numbers at all, but about life. That is another way of saying that what matters most is the practical point of it all, which is neither primarily to entertain, nor to ridicule, but to change. And the change we hope for is not only in people's enjoyment of, or facility with, numbers for their own sake. It is change in the way we understand experience, change to the way we are governed, to how we are informed, to the way we see and think. Numbers, at least the kind here, are how we often express hope and anxiety, the way we capture our well-being, often the way we assert political and moral values. The tiger might not be real, but the purpose is as real as they come.

Finally, to further the aim of simplicity, here—almost seriously—is simplicity simplified: a summary guide to seeing through the world of numbers, on one page.