The Process of Scientific Investigation. Review of *What Science Is and How It Really Works*. By James Zimring. Review by Stanley A. Rice. Email: SRice@se.edu.

James Zimring's book, *What Science Is and How It Really Works,* is a good introduction to the powerful but sometimes messy process of scientific investigation. I certainly wish I had read a book like Zimring's when I started my graduate studies; this would have helped me avoid many of the mistakes I made. Fortunately, none of my mistakes were major, and all were opportunities for learning. I recommend Zimring's book for students who contemplate a career in science. I see Zimring's book as an excellent counterpart to my book for citizen-scientists, *Scientifically Thinking: How to Liberate Your Mind, Solve the World's Problems, and Embrace the Beauty of Science.*

Zimring is a practicing scientist rather than a philosopher of science. The author presents many fascinating examples of how important scientific thinking is in understanding everyday concepts, and how everyday reasoning can be wrong. Many of these examples are disconcerting. What we experience is the product of what happens in our brains, which is almost never a direct and literal representation of what is in the environment. Our minds can and do trick us. One of the most important roles of science is to keep our minds from tricking us, as far as possible.

One of my favorite examples from Zimring's book was the story of the little 1950's cult, led by Dorothy Martin, that claimed that Sananda from the planet Clarion communicated to her through automatic writing. Sananda first told her that the Earth, except for his elect, would be destroyed on a certain date. Some cult members sold their worldly goods to await their salvation. The date came and went. We all recognize that this cult was utterly unscientific. But, Zimring points out, it was not as unscientific as we might have supposed. The cult used induction to draw a general conclusion, even though it was from the questionable (to us) data of automatic writing. Their line of thinking was not all that different from science. It is what they did next, when the world did not end, that was utterly unscientific. Rather than to go back and change their initial hypothesis (to reject Sananda, as a few cult members did), they tried to rationalize. Zimring indicated that Sananda's "ability...to capriciously change without any alteration in any other part of the web of belief" is the main reason the cult members were unscientific. Dorothy Martin said that Sananda had changed his mind and the world was not going to end. A hypothesis that cannot possibly be

wrong—such as that Sananda might destroy the Earth, or then again he might not—is unscientific. And it leads those who embrace the hypothesis into increasingly desperate rationalizations. In a way, all religion has this problem: if you pray for someone to be healed from an ailment, God might answer your prayer, and then again God might not. As a brilliant piece of research led by Herbert Benson demonstrated in 2006, supplementary intercessory prayer does not result in a greater degree of healing from heart disease. In fact, the patients who knew they were receiving supplementary prayer did worse, not better, in recovery. Today, the most famous example of rationalization is creationism. Creationists keep adding more and more miracles to their doctrine to make the evidence match their faith, as I am describing in a series of articles for *Skeptical Inquirer*. As Zimring says, you can explain anything as a "godwink," a term he did not make up.

Another good example is about a different Martin. Bill Martin was supposedly a British marine whose dead body washed up on shore in Spain during the Second World War. The body was actually that of someone who had died from ingesting rat poison. "Martin" carried papers that indicated, on very official-looking documents, that the Allied invasion of southern Europe would take place through Greece. It was actually planned to enter through Sicily, and the Germans suspected that this was the case. But they ended up believing the fake papers, and the Sicily invasion took them by surprise. The Nazi leaders, so brilliant in all the ways except where it mattered, did not take alternative (auxiliary) hypotheses into account seriously enough.

But scientists can make scientific mistakes also. One example, from Zimring's area of expertise, is the efficacy of disease screening. Some very rare diseases, such as some genetic disorders, can be detected in advance by tests. But these tests always have at least a small false-positive rate. If the disease is rare enough, the number of false positives will overwhelm the number of true positives, making the test appear ineffective. Zimring points out that we feel obligated to explain rare events; but in a large population, a rare event is almost certain to happen to someone. Pure guesswork can be right several times in a row if you have enough people doing it.

The human mind, evolved in prehistory, can be tricked by numbers. Zimring uses the example of a wealth management company that could claim, in a letter to several hundred potential clients,

that they accurately predicted the periods of growth and decline in the stock market eight times in a row. The odds against this happening would be 1,024 to 1. But this is what the company did. They sent out thousands of letters to potential customers. Half of the letters predicted market growth, half predicted market decline. So far, they probably didn't get many customers. But if the market grew, they would then send letters to the half that had received the prediction of market growth: see, we were right! This random half of customers was still thousands of people. To this second group, half received predictions of growth, half of decline. By chance, half of these customers—one-fourth of the original—would receive the correct prediction. See, we were right twice in a row! If you start with enough potential customers, even a rate of 1,024 to 1 would leave you with a lot of very impressed and insufficiently skeptical people who might have a lot of money to invest. If you start with just 50,000 people in your initial broadcast, you could get 3,125 people to believe that you were "right" five times in a row. The human brain, which evolved in conditions in which mathematical demands did not extend beyond the ability to count wildebeest or enemy soldiers, is unsuited for the modern marketplace.

One of the central ideas of Zimring's book is to emphasize the web of knowledge that the scientific community has formed by centuries of hypothesis-testing. Ideas that challenge the web of knowledge are treated skeptically by scientists at first.

Can one inconvenient fact destroy a beautiful theory? Not necessarily, says Zimring. It will, but only if that one inconvenient fact can be absolutely proven to be true, which it cannot. Nevertheless, there remains a major problem in scientific research: the replication crisis (see Chris Chambers, *The Seven Deadly Sins of Psychology,* reviewed in AJP, Spring 2018). Frequently, when a researcher replicates an experiment, the second researcher gets different results. As far back as 1970, N. C. Smith noted in *American Psychologist* that psychologists often ignored replication research. This is an ongoing problem but it appears to me, viewing psychology from the outside, that psychological researchers are now taking this problem seriously.

Zimring also discusses the discomfort that some scientists feel with the accepted structure of scientific papers. The introduction section of a paper makes it sound as if the hypothesis being

tested follows from previous knowledge in an uncomplicated fashion, and materials and methods section makes it sound like the researchers followed a completely logical process in reaching their conclusions. These things are seldom if ever true. But that does not matter. You do not necessarily want to drag your readers through the tortured pathways of thought that you had to go through.

Zimring shares my dislike of most fringe thinkers who hold onto the shirt-tails of science in order to get their ideas noticed. But it is sometimes the fringe thinkers who eventually lead us to a new understanding of the subject. Zimring says, “Science very much needs its fringe thinkers, although it often treats them badly.”

In conclusion, to paraphrase Winston Churchill, science is the worst way to understand the world except for all the other ways. *What Science Is and How It Really Works* gives lots of examples of how the scientific method has allowed the big brains of unpromising apes understand the world better than we had any right to expect.

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