CORNELIA DEAN

MAKING SENSE *of* SCIENCE

Separating Substance from Spin

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Cornelia Dean

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PREFACE

For thirty years I have been a science journalist at the *New York Times*; for almost seven years, I headed the newspaper's Science Department, supervising coverage of science, medicine, health, environment, and technical issues. From Day One, I have thought that covering these subjects for the *Times* was the best job in the world.

As science editor I dispatched correspondents to cover research in every continent. And I traveled myself, to places like the Dry Valleys of Antarctica, where researchers study what may be Earth's simplest food web, and Palomar Mountain, in California, where the 200-inch Hale Telescope gathers up the light of the universe.

We had the intellectual support of the editorial hierarchy in a newsroom that in those days was flush with money. For example, I once took it upon myself to dispatch a reporter to the Chilean Andes when astronomers there observed a newborn supernova. Coming from a newspaper where long-distance telephone calls were subjects of budgetary debate, I found this kind of thing thrilling.

Today, the money situation is not so good. The business model of the mainstream "legacy" news media is broken, and we do not know what will fix it. Though there are bright spots—like the *Times,* where support for science coverage is still strong—news outlets generally are cutting back on science and environmental reports. Across the country reporters on science and environment beats have been reassigned or fired outright. Medical coverage too often focuses on "news you can use" clickbait rather than advances in understanding human biology.

Internet sites take up some of the slack. But while the web can be a valuable source of information, it propagates bad information and even deliberately fake news along with the good. And the toxic quality of many comment threads online can actually turn people away from high-quality science news. At least, that's what researchers from the University of Wisconsin found in 2013. The finding was one of the reasons the magazine *Popular Science* ended the practice of allowing readers to comment online on its articles, as its online content director noted on September 24, 2013.

So while I continue to write for the *Times,* I have been spending more and more of my time talking to scientists and engineers about the need for them to communicate with the public. I teach seminars for graduate students and postdoctoral researchers to help them develop the skills they need to conduct that kind of engagement successfully. I participate in training programs for young researchers seeking to engage more fully in the debates of the day. This engagement, I tell them, is (or should be) part of what it means to be a researcher.

In 2009 I distilled some of this thinking into a book, *Am I Making Myself Clear?,* aimed at encouraging researchers in these efforts. The book you are reading now is aimed at the other important part of the equation: the public, citizens, *us*—the people who struggle to make sense of what we hear when scientists and engineers talk to us and—especially—when others try to shape or spin those messages to their own advantage.

Of course, this book is written by a journalist, not a researcher. Even worse, it is the book of one journalist—me—and I have no scientific or other technical training of any kind. I was first transferred into the *Times*'s science department, on what was supposed to have been a temporary assignment, because someone (true story) had seen me in the newsroom carrying a copy of *Scientific American.*

So my goals are relatively modest. I hope to show my readers the kinds of thinking we do in the newsroom when we try to decide whether a given finding is newsworthy, trustworthy, and important. I will illustrate the book with examples from my experiences as a science journalist. Inevitably, I will leave things out or, I fear, ascribe undue importance to things just because I experienced them. Still, I hope the material I have collected here will help people assess the scientific and technical claims and counterclaims they increasingly encounter in public debates and in their private lives.

Chapter 1 will describe the problems we ordinary folk bring to this table—our ignorance, irrational patterns of thinking, inability to think probabilistically, and erroneous ideas about risk. Chapter 2 will discuss the research enterprise—what science is (and isn't), how the scientific method works today, the use of computer models in research, and the sometimes problem-plagued process of peer review. Chapter 3 will talk about what happens when things in this world go wrong, either because researchers have misbehaved or because they find themselves in unfamiliar arenas, in courtrooms or quoted in the media.

The second part of the book will describe how all these factors play out. Chapter 4 will discuss how the research enterprise is financed, and how money influences things like our health care and what we eat. Chapter 5 will discuss the influence of politics on the conduct of science, particularly when it comes to the environment and arguments over religion.

The Appendix offers nuts-and-bolts advice on assessing who is an "expert," reading research papers, and deciding whether to believe polls and surveys.

This book cannot possibly be a comprehensive guide. It will not provide all the answers, or even many answers. It will, however, provide some interesting and (I hope) useful questions.

Making Sense of Science

INTRODUCTION

We live in an age of science. Daily, we learn more and more about the biological and physical world. But ignorance and untruth are hallmarks of our times as well. People with economic, electoral, or ideological agendas capitalize on our intellectual or emotional weaknesses to grind their own axes. Too often, they get away with it.

Examples of distortion or outright deception are numerous and come from all sides of the political spectrum. Industries persuade government agencies to write regulations that suit their needs rather than the needs of the public or the environment. Industry lobbyists may even write them. And politicians hungry for campaign contributions go along with it. Advocacy organizations, hoping to attract new members and contributions, may fight these industries with loud but exaggerated or even invalid warnings about supposed dangers to public health or the environment.

Science can be misused by doctors, who may prescribe drugs or order tests without proven benefit; by religious leaders, who spread misinformation to support their doctrines; and by politicians and lobbying groups, among others, who court voters aligned to their goals.

How can all this happen? The answer is simple. Politicians, lobbyists, business interests, and activists make their cases in the public arena, back their arguments with science or engineering "facts," and rely on the rest of us to leave them unchallenged. Most of us don't have the knowledge or the time to assess scientific and technical claims. It may not even occur to us that assessing such claims is something we ought to try to do.

The issues we face today are important and complex, but they will pale before the technical, ethical, and even moral questions we will confront in the not-too-distant future. Should scientists inject chemicals into the atmosphere or the ocean to counter global warming by "tuning" Earth's climate? Should people be able to design their own children? Should engineers design battlefield robots that decide, on their own, when to fire their weapons, and at whom? Work on these and other similarly game-changing technologies is already underway. Some of these technologies may be beneficial, even vital. But all should be debated and discussed by a knowledgeable public.

Are we up to it? It's hard to say confidently that we are. Science in the United States is taught poorly; knowledge of statistics is hardly taught at all. As a result, many of us are ignorant not just of scientific and engineering facts but also of the ways the research enterprise gathers its facts. Without the necessary skills to assess the data, we struggle with statistics and embrace downright irrational ideas about risk.

Nevertheless, we admire the research enterprise—a lot. In survey after survey, scientists, engineers, and physicians rank among those earning the highest respect from Americans. That is why people wishing to advance their own ends often seek to clothe their arguments in the garments of research, asserting "the science is on my side." We may accept these arguments simply because they sound credible to our untutored ears and, more importantly, because they mesh with our political or economic views or resonate with some fear or prejudice we may not even realize we hold.

Of course, a certain amount of irrationality is nothing new in the nation's political and economic life. But when the question is raising local property taxes or cutting Medicare benefits, most people have some intuition or life experience to guide them. While there is much that is arcane in economics, for example, most people know, more or less, whether their job is secure, if they have enough money to get by, or if people in their town are doing better or worse than they were a year ago.

That is not the case with science. Often its findings are counterintuitive or downright bizarre—as when researchers tell us hairspray aerosols erode the protective ozone layer over the South Pole, or that reducing acid rain by clearing the air of sulfur dioxide pollution can make the planet warmer. The intuitions we have about science often point us in wrong directions.

Meanwhile, as the federal government starts to step back as a backer of scientific research, the profit motive increasingly determines what is studied, how studies are designed—and whose findings become widely known and whose results are buried. All of these trends seem likely to worsen in a Trump presidency.

Two groups of people could help us separate fact from hype: researchers and the journalists who report on their work. But the culture of science still inveighs against researchers' participation in public debates. With rare exceptions, scientists and engineers are absent from the nation's legislatures, city councils, or other elective offices. Their training tells them to stay out of the public eye even when they have much to say that could inform public debates. In effect, they turn the microphones over to those who are unqualified to speak. Though I keep hearing that this institutional reserve is cracking, I do not believe it has cracked enough. And mainstream journalism, the kind of reporting that aims to give people the best possible approximation of the truth, "without fear or favor" (a credo of journalists at the *New York Times*), is struggling. Until we figure out how to fix it, journalists will often lack the financial resources they need to do a good job with complex technical subjects.

The result is a world in which researchers gather data; politicians, business executives, or activists spin it; journalists misinterpret or hype it, and the rest of us don't get it. Whoever has the most money, the juiciest allegation, or the most outrageous claim speaks with the loudest voice. The internet, newspapers, the airwaves, the public discourse generally are all too often brimming with junk science, corrupt science, pseudoscience, and nonscience.

More than fifty years ago, the British chemist and novelist C. P. Snow gave a speech at Cambridge University, in England. His subject was what seemed to him to be the greatest intellectual challenge of his age, a vast gulf of mutual incomprehension widening between scientific and literary elites, between science and the humanities. "In our society (that is, advanced Western society), we have lost even the pretence of a common culture," he said. "Persons educated with the greatest intensity we know can no longer communicate with each other on the plane of their major intellectual concern. This is serious for our creative, intellectual and, above all, our normal life. It is leading us to interpret the past wrongly, to misjudge the present, and to deny our hopes of the future. It is making it difficult or impossible for us to take good action."[1] His speech electrified his audience and set off a long, loud public debate on both sides of the Atlantic.

As he saw it, scientists did not know enough or care enough about the arts and literature of their own societies. And the literary elites knew so little about science and technology that they could not recognize genuinely stunning changes in our understanding of the natural world. Each group scorned the other as a bunch of ignorant specialists. In a kind of Luddism that persists today, literary intellectuals dismissed many of the benefits of science and technology, and longed for a more primitive and supposedly "genuine" age when people lived natural lives, closer to the land. For Snow, this kind of reasoning was idiotic. "It is all very well for us, sitting pretty, to think material standards of living don't matter all that much," he wrote.[2] But they do, and he had the parish records, ancient census reports, and other data to prove it: when people could choose to remain in technologically backward rural Edens or take jobs in factories, the dark satanic mills won out every time.

Much has changed in the decades since Snow's speech. Today, the gulf is not so much between scientific and literary elites as between scientific and engineering elites and everyone else. Few speeches by any scientist (or novelist) at any university electrify anyone nowadays. In itself, that can be read as evidence of the way academics have abandoned the public arena or even the ordinary world of everyday life.

True, science is in our culture today to a much greater extent than it was in 1959. To cite just two examples, computer science and medical research have transformed our lives, and everyone knows it. But though we may know how to surf the internet (even if we don't know how the information travels to our screen), and we may demand that every twinge be explored with an MRI (even if we don't know how the imaging machine works), the conduct of research, the scientific method, the *process* of discovery—is as mysterious to most of us as it was when Snow spoke.

In addition, as a society we seem much more willing than we once were to simply ignore or dismiss inconvenient scientific facts. Whether the issue is energy policy, stem cell research, cancer testing, or missile defense, scientific and engineering progress seems paradoxically to have left us more, not less, vulnerable to spin. If anything, the nonscientists of today are even more ignorant of science than were the literary intellectuals of five decades ago. Perhaps Snow could see this trend coming. In his original speech, when he wanted to illustrate their great ignorance, he said many of them could not even describe the second law of thermodynamics. Perhaps because too many of his readers proved his point, he changed the reference in a later version, saying merely that too many people are unfamiliar with the ins and outs of microbiology.

Our ignorance of basic scientific principles is troublesome, but much worse is our frequent inability to distinguish between science, pseudoscience, and outright hoaxes. Robert Park, then a physics professor at the University of Maryland, experienced the phenomenon when he served as the representative of the American Physical Society in Washington, D.C.—in effect, the lobbyist for the nation's physicists. "Of the major problems confronting society—problems involving the environment, national security, health, and the economy—there are few that can be sensibly addressed without input from science," he wrote a few years ago.[3] "As I sought to make the case for science, however, I kept bumping up against scientific ideas and claims that are totally, indisputably, extravagantly wrong, but which nevertheless attract a large following of passionate, and sometimes powerful, proponents. I came to realize that many people choose scientific beliefs the same way they choose to be Methodists, or Democrats, or Chicago Cubs fans. They judge science by how well it agrees with the way they want the world to be." This phenomenon is called "cultural cognition" or "motivated reasoning," and it is a subject of lively research and debate. It has a lot to say about how we respond to issues as diverse as climate change and gun control.

Meanwhile, many people positively flaunt their ignorance of science. When I was the science editor at the *New York Times,* it was not unusual to hear even senior colleagues proclaim proudly that they could not fathom mathematics, biology, physics, or any number of other technical subjects. That is not the kind of admission any of them would ordinarily make about politics, economics, bicycle racing, wine, military strategy, or poetry, regardless of the depths of their ignorance. Pride in technical ignorance is not something we can afford as a society.

Distrust of all major public institutions is on the rise. Since the Reagan administration, the phrase "public service" has become a contradiction in terms. Congress, state legislatures, and other governing bodies are scandal-ridden and so riven by politics that they are hardly able to function. In the wake of clergy sex scandals, even religious groups are losing influence.

We might, in theory, fall back on ourselves, on the so-called "wisdom of crowds." But though crowds may do better than individuals in estimating the number of jellybeans in a jar or the weight of an ox, crowd-sourcing on an issue less specific works best (or maybe only) when there is wide agreement in the crowd. When people disagree, all too often they attempt to shut opposing views out. That's why Wikipedia is most reliable on matters on which there is little to argue about—and why, if there are arguments, the site sometimes has to shut down a topic page.

Where does all this leave us? On our own. We can cross our fingers, hope for the best and declare, like climate-dodging politicians, "I am not a scientist!" Or we can try to understand the issues that confront us, as deeply—and as usefully—as we can.

— I —

WE THE PEOPLE

What We Know, and What We Don't Know

My *New York Times* colleague Claudia Dreifus regularly interviews researchers; edited versions of her "Conversations" have been running in the weekly Science Times section since 1998. I recruited Claudia for this job because I admired her interviews with other kinds of people—political figures, for example—and because I was eager to let readers of the science section hear scientists speak in their own voices, not just in a sound bite here and there but in an extended back-and-forth.

Claudia's interviews were a great success, and in 2002 the *Times* collected them in a book.[1] Soon after, Claudia gave a reading to promote the book, and I was in the audience. She described her initial worries about whether, given her lack of science training, she would be able to do a good job interviewing scientists. She learned, she said, that "science is very interesting if you get over the idea that you can't get it."[2]

She's right, but too many people don't realize it. Many of us don't know much about science, and we assume—probably because of bad experiences in high school or college science classes—that we "can't get it," that we will never know much about science or engineering, that the subjects are just too complex for us.

As a result, we don't engage. As a result of that, we are ignorant of the facts, we don't know how to think about what we *do* know, and we develop irrational ideas about all kinds of things, including risk. So our first task in assessing scientific or technical claims is to take inventory of our own mental defects and consider how they get in our way and how we can work around them.

One of our problems is ignorance. As a group, we Americans don't know a great deal about science. Jon Miller, a researcher at the University of Michigan who for decades has been surveying people in the United States and abroad on their knowledge of and attitudes toward science, once told me he estimates that only about a quarter of Americans are, as he put it, "scientifically literate"—able to read and understand the Science Times section of the *New York Times.* I don't think he is setting the bar very high. (His assessment also disappointed me because the writers and editors of that section strive to produce copy that almost any curious nonexpert reader can understand.)

Be that as it may, in many surveys we Americans don't show up too well. For example, periodic surveys assessed by the National Science Foundation show many of us don't know that atoms are smaller than molecules or even that Earth moves around the Sun and takes a year to do it. Only a minority of Americans accept the theory of evolution, the most abundantly supported idea in all of science.[3]

On the other hand, we are remarkably ready to accept utter nonsense. The survey finds widespread belief in the occult—about a third of us believe astrology is at least "somewhat" scientific. That's probably because we are far more likely to remember predictions that come true than the ones that don't. Perhaps it's also because far more newspapers run daily astrology columns than run any science columns at all. And it explains why, in most bookstores, titles on flying saucers far outnumber books about flying machines.

For years, people in and out of the STEM (science, technology, engineering, and math) community have bemoaned what they call the poor quality of science education in the United States. In 1983, in "an open letter to the American people," the National Commission on Excellence in Education spoke with alarm about the deficiencies in the nation's elementary and high school educational system.[4] In 1985, the American Association for the Advancement of Science began Project 2061, an effort to improve science education, including periodic assessments of what students actually know.[5] And in 2010 the President's Council of Advisors on Science and Technology (PCAST) issued a report: "Prepare and Inspire: K–12 Education in Science, Technology, Engineering and Math (STEM)."

As others had in the past, PCAST cited the importance of scientific and technical proficiency for people entering the job market, and for the nation's economic growth. The report called for five steps—training additional accomplished STEM teachers; rewarding effective teachers with extra "merit" pay and other benefits (an idea long unpopular among unionized teachers); establishing a new federal agency to develop instructional materials (an idea sure to encounter opposition from creationists and others on the religious right); supporting state efforts to establish STEM-focused schools; and taking steps to establish after-school STEM-related programs.

Has anyone heard these messages? Not enough of us, apparently. In January 2011, the Department of Education reported that only a fifth of the nation's high school seniors were what the department called "proficient" in science, the second-lowest level of any subject area covered by the National Assessment of Educational Progress, a test administered to a sample of 11,000 twelfth graders in 2009.[6] (Their performance in history was even worse.) Only one or two percent demonstrated enough mastery of science to be called "advanced."

What is the problem? For one thing, people with math, engineering, and science degrees are, even in a down economy, highly employable, usually at above-average salaries. Though there are exceptions, of course, persuading these people to take jobs in the nation's math and science classrooms can be a hard sell. Many technically proficient people also don't want to jump through the requisite teaching certification hoops.

In far too many high schools, science and mathematics are taught not as fascinating fields filled with important problems to be solved, but rather as collections of facts to be memorized and regurgitated. Science labs are not places where the quest for knowledge is carried out but rather places where students are given a set of materials and instructions to conduct "experiments" whose results are known in advance. They are told ahead of time what their lab work will produce. This cookbook approach is the antithesis of science. And it is not much fun.

According to an expert panel convened by the National Research Council to assess the situation, American high school students don't ordinarily ask their own questions, figure out their own experiments to answer them, or consider what their results have to say about natural phenomena. Plus, the report said, teachers are rarely trained to teach labs, class schedules are not conducive to lab work, and the pressure to adhere to testing guidelines means labs often get short shrift.[7] "Even the most artfully designed inquiry-based lab . . . must compete for time in a crowded academic schedule," the journal *Science* wrote in assessing the panel's report.[8] So many students emerge from high school or even college viewing science classes as alternately humiliating or boring.

Another problem is the typical high school science curriculum: biology followed by chemistry and then physics. This pattern of instruction came into wide use at the beginning of the twentieth century, just as more and more young people started continuing their education beyond the eighth grade. At that time, biology was regarded as the easiest science to learn. It was thought of as a largely "descriptive" activity. So it came first. Physics, regarded as the most complex, came last. Today, many experts agree this approach is backwards.

Now, there is growing recognition that biology is the most complex scientific field. Understanding biology depends on having an understanding of chemistry, which in turn depends on having an understanding of physics. In an ideal world, advocates of change say, high school students would routinely learn physics first, then chemistry, then biology. (Optimists in this crowd envision a day when students would learn physics in ninth grade, then chemistry, then biology, and then, as seniors, would take a more complex physics course.)

But there is one immediate problem: teaching ninth or tenth graders physics means teaching younger students enough math to make the experience worthwhile. Inspired middle school math teachers are not exactly thick on the ground.

In 2002, I thought beliefs and attitudes might be changing, at least as far as evolution was concerned. That year, the NSF reported, for the first time, that a majority of Americans—a bare majority, 53 percent—accepted the theory of evolution. The agency announced this finding with a celebratory press release. At last, evolution had won over a majority of Americans!

But when I asked Miller about the survey results, he dismissed them. He said they were an artifact, the result of news accounts of an uproar then underway in Kansas over the state school board's decision to add creationism to the state's high school biology curriculum.

Sure enough, within a couple of years, the survey responses dropped back down to a mere 45 percent accepting evolution. Eventually, the NSF stopped considering evolution in asking questions about scientific literacy, calling the issue too charged.

The teaching of evolution continues to be contentious. Usually, we hear about it when someone sues school authorities somewhere over the issue. Meanwhile, though, in school districts all over the country, evolution is quietly dropped or glossed over in biology instruction, perhaps because, according to the National Science Teachers' Association, about a third of the nation's science teachers are creationists themselves.[9]

But evolution is the foundation upon which the modern edifice of biology and medicine is built. If students need to emerge from high school with a decent understanding of biology, they must understand evolution—and they must understand why creationism is a religious idea, not a competing scientific theory.

Education about the environment is another area in which curriculum standards are under attack. Private industry groups advocate for the addition or omission of information within state curricula. For example, the coal industry produces its own curricular materials emphasizing coal's usefulness and downplaying its many negative environmental effects.

A 2008 survey of college students about climate change found widespread ignorance, whether or not they believed the change is real. They attributed it to a hole in the ozone layer (the phenomena are unrelated), were disinclined to believe human activity is the main culprit (it is) and worried that melting sea ice would cause coastal flooding (melting of floating ice will not raise sea levels, though melting of glaciers and inland ice sheets will).

"Student misconceptions about . . . climate change have been documented at all educational levels," a geologist at the University of St. Thomas in St. Paul, Minnesota wrote in *EOS,* the transactions of the American Geophysical Union.[10] In large part, he attributed their wrong ideas to "climate myths and misinformation that are perpetuated by a small but vocal group of politicians and climate change skeptics."

Meanwhile, another survey points to the nation's science teachers as possible sources of misinformation on climate. "Notably, 30 percent of teachers emphasize that recent global warming 'is likely due to natural causes' and 12% do not emphasize human activity" as a cause of climate change.[11] Sometimes, the researchers said, the teachers adopt this stance because of political pressure in their communities. But sometimes they don't know very much about the subject, particularly the overwhelming degree to which the world's climate scientists agree that human activity, chiefly the burning of fossil fuels, is behind the problem. Of course, science and engineering issues are not the only centers of ignorance among American youth. Surveys show that many cannot name the three branches of government, don't know why Abraham Lincoln was an important figure, and cannot find the Pacific Ocean on a map.

Although, as a group, American students do not perform well when they are compared with students from other countries in tests or competitions in math or science, results on these tests depend a lot on factors, such as the size of a nation's student body, or what percentage of its students are eligible to enroll in science or engineering courses, even in high school.

Also it is hard to ignore the fact that when the world faces a scientific or technical problem—everything from the Ebola virus to tsunami detection—eyes turn to the United States. We lead the world in research science and engineering. Unfortunately, scientific and technical elites performing superbly will only take you so far in a democracy. And improving science education alone is not enough to meet our democracy's need for an informed citizenry. Many of the issues we confront now as voters are entirely new to us. Stem cell research, carbon cap and trade, artificial life—were these topics covered in your high school science classes? Probably not, even if you are under thirty. But they are issues you will confront as a voter. So the issue is not increasing the number of scientific or engineering "facts" stored in students' heads by the time they leave high school. Rather, it is a matter of teaching them how to assess new claims and findings.

And while widespread ignorance is bad, what is worse in a democracy is the positive embrace of ignorance we see in some political circles. Far from seeking knowledge about pressing questions like climate change, the safety of the food supply, or the utility of gun control laws, some of us form fixed opinions *before* doing the research, and are unwilling to seek information that might contradict those opinions. Still worse, some even characterize scientists who study these questions as out of touch with ordinary people.

So improving science education in the schools may be necessary, but it will never be sufficient. There are always going to be things we will need to learn as adults. We need practice how to learn, and we need to acquire patterns of thinking that allow us to consider all sides of an argument dispassionately. Unfortunately, those are traits many of us lack.

The Belief Engine

A few years ago, researchers reported that hurricanes with female names were deadlier than storms with male names.[12] Is that possible? No, even though two of the most destructive storms in recent years were named Katrina and Sandy. In surveys, the researchers found, the participants were more likely to say they would evacuate a coastal area in advance of a storm with a male name than one with a female name. The female names seemed less frightening. Between 1950 and 2012, the researchers noted, storms with female names caused on average forty-five deaths; storms with male names caused on average twenty-three deaths. (The National Hurricane Center did not start giving storms male names, alternating with female, until 1979, by which time the coast was much more heavily developed, and therefore more vulnerable.)

This study points to something important: people don't necessarily judge scientific information—like meteorological reports on approaching storms—according to the facts. While ignorance of scientific or engineering reality is a central problem, it is only one of the factors that lead us to bad decisions—like staying put in a dangerous place when a storm approaches. Many other factors come into play: shortcuts in thinking we use to navigate the world, often with undesirable results; our unwillingness to accept information not in accord with opinions we already hold; wild misunderstandings about statistics and downright irrational ideas about risk. These patterns of thought are so persistent and so widespread that they seem to be hard-wired in us, to the point that the ordinary human brain is not a sharp analytical instrument but rather a credulous receptacle for erroneous ideas—what the physicist Robert Park calls "a belief engine."[13]

The idea that people are, on the whole, so out-to-lunch they cannot be good citizens is not new. It was a theme of the political commentator and theorist Walter Lippmann who made the point in his 1922 essay "Public Opinion." He said the habit of clinging tenaciously to irrational ideas hindered people's ability to make rational decisions. Did Lippmann really mean to issue so sweeping an indictment? It's hard to say. But there is no doubt that the human mind is a sink of irrationality.

Over the years, many researchers have attempted to plumb its depths. Two of the most successful were the psychologists Daniel Kahneman and Amos Tversky, who collaborated for years to discern ways our human brains go off the rails when we have to make judgments, especially in uncertain times. Tversky and Kahneman called these thought patterns heuristics (roughly, rules of thumb) and biases. They described them in 1974 in a paper now regarded as a landmark of science.[14]

Kahneman, who won the Nobel Prize for this work in 2002, elaborated on the work in his 2011 book *Thinking, Fast and Slow.*[15] Kahneman, Tversky, and other researchers have identified a long list of irrational patterns of thought that plague us as a species. Here are some examples. Some are almost amusing. Others have serious consequences. Think about the degree to which you fall into these patterns. For me, the answer is: often.

Priming

If you ask people to name an animal, roughly 1 percent will say "zebra." If you ask people first where Kenya is and then what are the opposing colors in a game of chess, and *then* to name an animal, roughly 20 percent (including me) will say "zebra."[16] We are responding to what experts call *priming.*

Anchoring

Researchers have also found that if you ask people to write down the first three digits of their telephone number, and then ask them to guess when Genghis Khan died, they will be more likely to say he died before the year 1000—in a three-digit year—than if you don't make the phone request before you ask the question. (He died in the 1200s, possibly in 1227.)

Generalizing from Examples

We accept large conclusions drawn from small amounts of data. Journalists, in particular, must be wary of this habit—it is surprising how often researchers will make sweeping claims about the action of a drug, the effects of an environmental pollutant, or some other phenomenon on the basis of only a few good data points. Kahneman and Tversky called this "insensitivity to sample size." Often people get away with these generalizations. Few people look deeply (or even superficially) into the data and anyway, for most of us, a good story means more than a barrel of evidence. If someone offers us a good story, we don't necessarily even look for the evidence.

Illusory Correlation

The "belief engine" is always seeking to derive meaning from the information it absorbs. It regularly sees patterns or connections in what are really random occurrences or bits of data, a phenomenon known in psychology as *apophenia*. Sometimes, for example, the brain assumes that if A happens and then B happens, A must have caused B. Once the brain has constructed a belief like that, it begins looking for support for it, often blinding itself to evidence that contradicts it.

Lawyers (and logicians) call this thinking *post hoc ergo propter hoc,* from the Latin for "after that, therefore because of that." Stated in such bald terms, the reasoning is obviously faulty, but it is stunning how often people infer causality from patterns of correlation.[17]

One of the most flamboyant examples of this thinking was the litigation that erupted over silicone breast implants. By the early 1990s, thousands of American women had received these breast implants, some for reconstruction after cancer surgery but the majority for cosmetic reasons. Doctors had known for some time that the implants could produce localized problems, like scarring, and that they could even rupture inside the body. Now, though, they were hearing far more alarming reports. Women with silicone implants were suffering systemic diseases like multiple sclerosis or lupus that were leaving them permanently disabled. Soon, there were lawsuits all over the country. Merrill-Dow, the leading silicone implant maker, was under siege. Eventually, a class action lawsuit resulted in the creation of a $3.4 billion trust fund to compensate the women who had been disabled by their implants.

There was only one problem. There was never any evidence that the implants or the silicone they contained caused the women's disabilities. There were plenty of doctors prepared to testify about how sick their patients were—they *were* sick. Scientists hired by the plaintiffs and their lawyers produced studies linking their ailments to their implants. But the women with implants had diseases thousands of American women contract every year, and at rates no higher than average. Implant manufacturers, who had repeatedly made this point in litigation, were finally vindicated when a scientific panel, appointed by the judge hearing the class action suit, declared emphatically that there was no reason to believe the implants were at fault.

By then Merrill Dow was bankrupt, and the $3.4 billion had flowed from implant makers to plaintiffs and their lawyers. New regulations had barred the use of silicone not only in breast implants but also in a host of other useful medical devices.

Education and high income do not necessarily protect us against this kind of irrationality. Compared to the national average, people in the San Francisco Bay Area are wealthier and better educated, yet the Bay Area is a center of opposition to childhood vaccination, motivated by the erroneous belief that vaccines have been linked to autism.

Initially, the idea was that mercury, a vaccine preservative, must somehow kill nerve cells in susceptible children. There has never been any evidence for this idea, but because autistic children typically receive the diagnosis in early childhood, after rounds of routine vaccinations, it has taken hold. It persists despite the fact that autism rates continued to climb after mercury was removed from vaccines, and also despite the accumulating evidence that children with autism suffer not because of brain cell death but because their brains do *not* undergo a kind of cellular pruning process that normally occurs at about age two. Parents who refuse to vaccinate their children in a timely manner have created conditions that fuel outbreaks of illnesses like whooping cough and measles.[18]

Post hoc ergo propter hoc may be a notoriously erroneous concept, but it is hard to fight. A story that taps into our emotions is much more likely to be remembered than a demographic study. But some irrational mental glitches are far less obvious.

Availability

We put a lot of emphasis on things we have seen and experienced or observed ourselves. For example, we may choose a particular medical treatment because a relative had it, or even buy a stock because someone we know has made money with it.

In their landmark paper, Kahneman and Tversky speculated that this pattern of thought may be an evolutionary holdover from the days when there was hardly any such thing as "data." What happened to people who lived in your immediate surroundings was almost certainly more relevant to you than what happened to people elsewhere.

Framing

Suppose a deadly epidemic has broken out and the disease is expected to kill 600 people. Which drug is better: Drug A, which will save 200 people for sure, but only 200 people; or Drug B, which has a 1/3 probability of curing everyone and a 2/3 probability of saving no one? Given this choice, most people will choose Drug A, the drug that will certainly save 200 people. Yet if Drug A is described as dooming 400 people for sure, most people choose Drug B. Other surveys have shown that if doctors present a surgical procedure as having a 10 percent mortality rate, most people will reject it. If they say it has a 90 percent survival rate, most people will accept it. These two scenarios illustrate something psychologists call *framing effects*; that is, the degree to which the way a question is framed determines how we will answer it.

Here's another example: obesity in the United States. Is it a problem of individual appetites out of control? Maybe it is a result of misguided agricultural subsidy policies that have produced vast corn surpluses that in turn produce vast supplies of high-fructose corn syrup, a staple of inexpensive (and fattening) processed food products. Or maybe, as some activist groups tell us, obesity is nothing like the health menace we have been told it is, and the constant drumbeat about it is little more than bigotry.

Framing effects have always been important in policy making but today they are more important than ever, especially with science- or engineering-related issues whose details may be unfamiliar, complex, or otherwise hard to grasp. In situations like this, people rely on trusted advisers or opinion leaders who in turn rely on trusted advisors to frame the situation for them. Their advice can make one approach seem to be not just the best bet, but a moral imperative.

Bias of Optimism

Overall, we have a greater willingness to accept findings that would be welcome, if they were true. This pattern of thinking leads us to overestimate the chances that one thing or another will work out well for us. For example, people's ideas about what the stock market will do are typically rosier than past experience would suggest. The same goes for real estate prices.

According to Kahneman, three factors underlie erroneous optimism: we exaggerate our own skill; we overestimate the amount of control we have over the future, and we neglect to consider the possibly superior skills of others.[19]

We also habitually underestimate the odds of failure in complex systems. Years ago, I was stunned when my colleague William J. Broad reported that engineers had concluded the odds of catastrophic failure in any given mission of the Space Shuttle were about 1 in 70. The number seemed way too high. But in 135 shuttle launchings there have been two catastrophic failures—the explosion on launching of *Challenger* in 1986 and disintegration on descent of the *Columbia* in 2003. In other words, about 1 in 70.

Aversion to Loss

We fear loss much more than we desire gain. Kahneman and Tversky attributed this to our Paleolithic past, when survival was hardly a sure thing. In that kind of subsistence existence, they reasoned, a benefit is nice, but a loss can be catastrophic. Perhaps this is one reason why people who are asked to choose between $100 now and $120 a month from now will almost always take the money and run.

Aversion to loss also encourages us in the so-called *sunk cost fallacy,* in which we persist in unprofitable or even obviously doomed endeavors because of the time, effort, and money we have already put into them. (My family calls this practice "pouring good money after bad.") A reasonable person would look ahead, calculate the costs and benefits going forward and make a decision on that basis. As for the rest of us . . .

Inattentional Blindness

A few years ago, I attended a presentation by Max Bazerman, a professor at Harvard Business School. He was talking about what he calls "predictable surprises"—bad news we have every reason to anticipate but, for various reasons, do not. To begin his presentation, he showed his audience a short film. He told us the film would show a group of young people, some in white shirts and some in black, passing basketballs to each other. He asked us to count the number of times someone in a white shirt threw the ball.[20] (If you want to view the film before you read the spoiler, read no further and search on "selective attention test" on YouTube.)

Though the counting task was harder than it seemed, many of us got it right. But then Bazerman asked if any of us had noticed anything unusual in the film. In his audience of about 200 people, no one raised a hand. So he ran the film again. What none of us had noticed was that in the middle of the ball-tossing a "gorilla" walked through the players, stopped in the middle of the room, turned to face the camera, and thumped its chest.

It seems incredible that none of us had seen the person in the gorilla suit, but since then I have shown the film often, and not a single person has seen the gorilla. (In another version, a woman carrying an open umbrella walks through the players. No one notices her either.)

Researchers call this phenomenon *inattentional blindness*—our failure to see something that is right in front of us because our atmiss it. That is why many climate dissidents presented with yet more evidence that the problem is real dismiss it as yet more proof that the conspiracy is larger than they had thought.

I first heard these ideas discussed in detail in the summer of 2010, when I was asked to address leaders of the National Academy of Sciences on the public's understanding of science. Kahan and Anthony Leiserowitz, director of the Yale Project on Climate Change, were on the program.[24] The examples they used then were attitudes toward climate, gun control, nuclear power, and nanotechnology.

Kahan said his interest in this research began with his assumption that people might have opinions, but if new information became available, "they would take in new information and if necessary adjust their views in light of it." But then, he said, he realized that "if things actually worked like this, there would be a progression to universal enlightenment"—something we have yet to witness.

In fact, he and Dr. Leiserowitz told the group, people assess new information in light of their prior perceptions. And they look for conforming information, dismissing facts that don't fit their views.

Social scientists have recognized this thinking pattern for decades, at least, but it is drawing new attention now, in particular, because of the widespread inability of climate scientists to understand why so many Americans are so resistant to their message about the threat of greenhouse gas emissions.

Kahan and Leiserowitz group people they study on two scales: egalitarian-hierarchical and communitarian-individualistic. They found that people with a communitarian/egalitarian frame of mind are prepared to accept information about environmental risks like climate change. The concerted action needed to avert it is not uncongenial to these people. But people who are hierarchical and who are individualistic rather than communitarian are much more likely to be skeptical.

Leiserowitz and Kahan found these factors were good predictors of people's views not just on climate but also on topics as varied as gun control, use of the vaccine against human papilloma virus (a major cause of cervical cancer), storage of nuclear waste, and the carrying of concealed weapons.

What does this tell us? Among other things, it suggests that merely exposing people to more information is not necessarily going to lead them to good decisions. As a journalist, I hate this idea, but the evidence for it is pretty convincing.

And it means that when you find yourself reflexively accepting or rejecting some assertion or other, it might be wise to examine your own patterns of thinking. Try this thought experiment: when you assess Donald Trump as a political leader, does his lurid personal life tell against him? How about Bill Clinton? Depending on your politics, you are probably readier to excuse one than the other.

Statistical Incompetence

Meanwhile, there's another problem, in some ways the biggest of all. Americans, in aggregate, have a very poor understanding of statistics. And even if, like me, you know a little about the field, your intuitions can still lead you astray. I experienced this phenomenon a few years ago, when I was one of a hundred or more science journalists who participated in a workshop on medical evidence. It was organized by the Knight Center at the Massachusetts Institute of Technology, which supports efforts to improve science journalism.

One of the presenters was Josh Tenenbaum, a professor of cognitive science at the university. He began his presentation by announcing that he was going to determine who in his audience had extrasensory perception. He had a fair coin—a perfectly balanced coin—and he would flip it five times. Then he would transmit mind rays to us, telling us how it landed. We would absorb his mind rays, if we could, and write down whether each flip was heads or tails.

There are thirty-two possible combinations, but about a third of us, including me, wrote down HHTHT. Another quarter of us wrote the obverse, TTHTH. No one wrote down HHHHH, though the odds are identical to the odds of HHTHT—if a coin is evenly balanced it ought to turn up five heads in a row, or five tails, about 3 percent of the time.

This and similar tests tell us that most people know what randomness looks like. Even among "sophisticated populations," as Tenenbaum called them—and probably he would have classed a room full of science journalists as a sophisticated population—people gravitate toward the same guesses. Why should we care about this little bit of cognitive arcana? Because it comes into play whenever anyone talks about cancer clusters or "outbreaks" of autism or the like.

Five heads in a row does not *feel* random. The sequence does not match our intuitive sense of what randomness looks like. We don't understand that if something—like cancer—is widespread and distributed more or less randomly over a large population, there will inevitably be clusters of it here and there. If there are no clusters, a statistician could tell us, then the distribution is too even to be random.

But three cancer cases in the same neighborhood or three children with autism in the same school look alarming. "Aha," we think, there must be "something in the water." And sometimes there is. But usually there is not. There is only the reality of statistics.

Regression to the Mean

Imagine you are the boss and you have two employees. One of them does a task unusually well and you praise her. But then her spectacularly good day is followed by days of ordinary performance. Meanwhile, the other employee does a task unusually badly and you berate her. Her bad day is followed by ordinary—i.e., better—work.

As a boss, you may conclude that praise is an ineffective management tool, that punishment works much better. Is that right? No. What you have just experienced is called regression to the mean, the tendency of whatever it is you are measuring to return after an extraordinary episode to ordinary levels.

According to Kahneman and Tversky (and many others), we do not expect to see this regression even when it is bound to occur, and when we see it occurring we invent spurious reasons to explain it—for example, that praise encourages workers to slack off.

The Wisdom of Bayes

Few people have ever heard of Thomas Bayes, an eighteenth-century English statistician and Presbyterian minister who wrote, among other things, "An Essay towards Solving a Problem in the Doctrine of Chances." The work relates to something statisticians call *conditional probability*; that is, the probability of something, given something else. For example, what is the probability that a card is a king, given that it is a face card? Since there are twelve face cards in a deck and four of them are kings, the probability that a card is a king, given that it is a face card, is 4/12 or one-third.

Conditional probability arises more commonly than you might expect. For example, assume there is a test that will tell you, with 98 percent accuracy, if you have cancer. That is, if you have cancer, the test will be positive 98 percent of the time, and if you don't have cancer, it will be negative 98 percent of the time.

Then imagine that you have had the test and the result was positive. Should you worry? You might if you did not consider this important question: how common is cancer? In other words, you must be sensitive to what statisticians call the "prior probability" of outcomes.

In this example, suppose we know that at any given time .5 percent of people—one half of one percent—actually have cancer (the prior probability). Then imagine 10,000 people take the test.

Given cancer's prevalence in this example, fifty of them will have cancer. If the test is 98 percent accurate, forty-nine of them will receive a positive result, a cancer diagnosis.

Meanwhile, the other 9,950 people are also getting their test results. These people don't have cancer, but because the test is only 98 percent accurate, 2 percent of them—199 people—will receive a positive diagnosis.

In other words, of the 248 positive results, 199 are false positives—people receiving a diagnosis of a disease they do not have. In this example, only about 20 percent of the people who receive a positive cancer test result actually have the disease.

This example was offered by John Allen Paulos, a mathematician at Temple University, who writes about it in his book *Innumeracy*.[25] "This unexpected figure for a test that we assume to be

98 percent accurate should give legislators pause when they contemplate instituting mandatory or widespread testing for drugs or AIDS or whatever," he wrote. And, as he notes, many tests in wide use are even less reliable.

How Do You Know?

Sometimes our most erroneous thinking arises because of ideas we don't think to question because they are so obviously correct.

Though some of my neighbors disagree with me, I think an example of this kind of thing played out recently where I live, on Chappaquiddick Island, off Martha's Vineyard, in Massachusetts. The island has only one paved road, and in July and August many people bike along it, including many children. A number of people thought it was obvious that things would be safer if we had a bike path. Until I looked into it, I thought so too.

But it turned out to be far from clear that the proposed remedy—a two-way bike path along one side of the road—would make things better. In fact, some evidence suggests that this kind of bike path actually makes things worse. The problem occurs when another street or even a driveway meets the road/path. Drivers typically look to the left for an oncoming car; they forget that a bicycle might be coming from the right.

Another proposed remedy, creating a bike lane and marking it with a white line along the side of the road, also sounded good to me, until I discovered evidence that when bikers and drivers share the road, drivers tend to slow and give bikers lots of room. Where there is a white line, motorists drive as if every inch of macadam up to the line belongs to them. Result? Cars drive much closer to bikes than they would otherwise.

I don't know what research will ultimately tell us about this question, but the idea that a bike path could make things more dangerous, not safer, is highly counterintuitive. Still, it is frustrating when people who assert something is necessary cannot say why, except that "it's obvious."

Donald E. Shelton, a judge in Ann Arbor, Michigan, encountered something similar when he began looking into the idea that manufactured or applied them in bulk, not for people who might consume residues on their produce. What was alarming the scientists? Global warming, habitat loss, and loss of biological diversity.

In general, the scientists had chosen the more significant concerns. Alarmist reports notwithstanding, pesticide residues in the food supply are not a threat to public health. People who eat fruits and vegetables, even those labeled "organic," consume far more pesticides than they realize, in the form of natural compounds plants make to protect themselves from insects and other threats. Many of these "natural" pesticides work just the way the synthetics do. And there is no doubt eating your vegetables is good for you.

Oil spills do not constitute a major global hazard, either. Even the Deepwater Horizon disaster in the Gulf of Mexico does not seem to have left the lasting damage some had predicted. Anyway, if you worry about oil in the ocean, worry about ordinary day-to-day leakage from ships. Far more oil seeps into the oceans that way than through attention-getting spills.

That is not to say we should soak our fields in pesticides or spill oil. Chemical pesticides interfere with the environment, and organic farming methods are undoubtedly better for the land and possibly even more productive—even if they aren't better for our health than conventional crops. And oil spills help no one except the companies hired to clean them up and the environmental groups that draw new members and donations when one of them occurs. But how prominent should these problems be when we set our environmental priorities? The question is important because while we can afford to spend money to protect the environment, our budget for the task is not infinite. We must spend it wisely to thwart threats that could change our environment for the worse, permanently. Instead, we tend to go by the public's list, spending vast amounts of money on situations that pose little hazard and neglecting issues whose threat is vast.

People in industrialized countries live safer lives than ever before, yet we worry more about risk. Researchers who study risk and people's perception of risk offer several explanations.

First, the hazards we face are quite different from those our ancestors confronted. Technology has greatly increased humanity's ability to control our environment, and we are far more dependent on technology than people were even a generation ago. But the powerful, complex technologies on which we depend have powerful, complex—and sometimes unwelcome—effects.

Second, we have more information about the risks confronting us. Some of this information is imperfect, specious, or even fraudulent, but that does not make it any less worrying.

And so, we worry more. We are a loss-averse species and we have more to lose.

Finally, we have lost trust in government, religious authorities, business leaders, and social institutions which once might have been able to reassure us. Trust in Congress is at a low ebb—but trust in almost everyone seems to be at a low ebb as well.

Meanwhile, the debate over what is risky and what is not has become thoroughly politicized. Experts on risk perception say that is the inevitable consequence of government efforts to regulate our exposure to hazards. They say that once you establish a regulatory agency, give it a jurisdiction, and tell it to make rules, it will start doing research on what and how to regulate. In doing so, it will uncover new situations demanding their own new rules, leading to more findings, more rules, and so on.

This rule-making does not occur in a vacuum. Regulation becomes a forum for competing interests. Scientific arguments become proxies for political or economic or philosophical or even religious disagreements. In the end, even what looks like a purely scientific decision for policy makers eventually turns out to hang on the answer to this value-laden inquiry: How do we want the world to be?

Over the years, a whole field of social science research has grown up around figuring out what we are afraid of, and why. Today there is wide agreement on a number of points.

- We fear the uncontrollable more than things we can control. This is why we fear flying far more than driving, though driving is far more dangerous.

- We fear things imbued with dread. Although cancer is not always the unremitting horror it was in the days before adequate pain relief, we still dread it far more than we fear diseases like heart failure, which in many ways can be at least as miserable and kills more of us than cancer does.
- We fear the catastrophe more than the chronic condition, even if the chronic condition carries the same risk or worse.
- We fear things imposed on us—water pollution, say—more than things we expose ourselves to voluntarily, like fatty foods or cigarettes. If we cannot tell whether or not we have been exposed, we are even more afraid.
- Things with delayed effects are more frightening than things whose effects are immediate.
- New risks are scarier than old risks.
- If we don't trust the person or agency telling us about the risk, we are more afraid.
- A hazard with identifiable victims is more frightening than one whose risk is spread over a large population. That is why mad cow disease is more frightening than a diet rich in red meat, even though mad cow disease has killed practically nobody and heart disease—worsened by a beefy diet—is a leading cause of death.
- We worry more about things that affect future generations than threats to ourselves alone.
- We fear things we cannot see, like radiation, more than things we can see, like sooty pollution from coal-fired power plants. So we fear nuclear power plants, which in the United States have killed no one, far more than we fear pollution from coal-fired power plants, which causes lung problems that send tens of thousands of people to the hospital every year in the United States and, by some estimates, kills 5,000 of them or more annually.
- We are more afraid of things that are artificial, synthetic, or otherwise human-made than we are of things that

> occur naturally. For example, some people worry a lot about the presence in the environment of synthetic chemicals that mimic the actions of hormones like estrogen. They don't worry at all about the estrogenic effects of a diet rich in soy.

In fact, a good way to make people afraid of something is to identify it as "chemical." For example, if I offered you a glass of dihydrogen monoxide, would you drink it? Maybe not, unless you knew (or deduced) that dihydrogen (H_2) monoxide (O) is H_2O—water. The natural world is made of chemicals—they are the stuff of life.

Politicians, corporations, or others with an axe to grind capitalize on our widespread inability to react sensibly to risk. As a result, we may waste money or issue needless regulations to protect ourselves against trivial or even nonexistent threats. Or they may pose a problem, but not for the reasons we think. Or they may be problems whose cure may make matters worse.

Problems That Don't Exist

In 1997, a study appeared in the journal *Pediatrics* with an alarming finding. More than 225 clinicians who evaluated more than 17,000 girls aged 3 to 12 in the course of normal physical exams found that many were displaying signs of puberty "at younger ages than currently used norms."[28] The researchers suggested that chemicals in the environment, particularly chemicals that mimic the action of the female hormone estrogen, should be investigated as a possible cause of the situation.

The study received abundant attention in the press. Within months, many people knew that this change in puberty had occurred among American girls and believed that synthetic chemicals in the environment were almost certainly the cause. But few people read the actual study. If they had, they might have asked whether its data were powerful enough to support its frightening conclusion.

Later, critics of the study noted that the clinicians in the study were asked to assess how many of their preteen girl patients were developing budding breasts, a characteristic the researchers had defined as their marker of puberty. But because the clinicians did not actually touch the girls, it was difficult for them to differentiate between fatty tissue and breast tissue. What they were observing was almost certainly that more of their preteen girl patients were overweight.

Anyway, while it is difficult to tell exactly when a young girl has entered puberty, one part of the process is easily detectable and has been tracked for decades: age of first menstruation. And, according to many medical authorities, the age of menstruation in the United States is unchanged since the 1950s at least.[29] American girls begin menstruating at younger ages, overall, than they did in the nineteenth century, and sooner than girls in many poor countries of the world, but those differences are the result of better nutrition. Overweight girls may begin menstruating somewhat earlier. As the Committee on Adolescence of the American Academy of Pediatrics put it, a higher gain in body mass index (BMI) during childhood is related to earlier menstruation. Even so, the academy said, American girls "are not gaining reproductive potential earlier than in the past."[30]

Since then there have been a number of other reports, and new evidence may change expert opinion. But so far the best—some would say the only—hard evidence we have about the onset of puberty among American girls suggests that nothing much has changed—except that American girls are getting fatter.

Of course, there is such a thing as abnormally early puberty, which can be caused by conditions like brain tumors. Many experts worry now that wide acceptance of the idea that chemicals in the environment are causing girls to enter puberty earlier may cause some of these cases to be ignored.

Activists making the puberty-chemical link cited the decline of amphibian populations around the world as more evidence for their case. The amphibians—frogs, toads, salamanders, and other creatures—are declining all over, and in many places researchers were reporting the appearance of amphibians with ambiguous sexual or-