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TWO
THE BELIEF GENE
In Which Science Offers a Strategy for Sorting Out the Truth

THE MOST COMMON OF ALL FOLLIES

IN 1995 THE NATURAL LAW PARTY succeeded in getting its presidential candidate, John Hagelin, on the ballot in all fifty states—a goal that had eluded other third-party hopefuls, even Ross Perot four years earlier. The platform of the Natural Law Party offered an "action plan to revitalize America," based on "scientifically proven solutions." The centerpiece of the scientific proof was an experiment conducted in Washington, D.C., in the summer of 1993.

More than five thousand experts in Transcendental Meditation (TM) from around the United States and eighty countries worldwide spent two-week shifts in the nation's capital as part of the National Demonstration Project to Reduce Violent Crime in Washington, D.C. Mostly young white professionals, they began arriving on June 5. Their objective in the coming

weeks would be to meditate in unison, creating a "coherent consciousness field" that would produce a calming effect, not just among the meditators but throughout the city. Organizers of the $6 million project predicted that violent crime in the city would be reduced by 20 percent.

The head of the project was John Hagelin, a thirty-nine-year-old physicist with a receding hairline and a perpetual cherubic smile. His high forehead was unfurrowed by negative thoughts. A summa cum laude graduate of Dartmouth, Hagelin had gone on to complete a Ph.D. in physics at Harvard. In 1983 he was regarded as a competent theoretical physicist and had a postdoctoral research appointment at the Stanford Linear Accelerator; then, in the midst of personal problems, he simply vanished, reappearing a year later as chairman of the Physics Department at Maharishi International University in Fairfield, Iowa. The university was founded by the Maharishi Mahesh Yogi, the Indian guru who vaulted to fame after becoming the spiritual advisor to the Beatles.

Hagelin held a press conference in the District Building to announce the violence-reduction project. Once a beautiful example of a classic white-marble municipal building, the crumbling structure seemed to symbolize the inability of the District of Columbia to govern itself. The formerly broad halls had been narrowed by ramshackle partitions erected to create more offices for political appointees. In a conference room with paint peeling from the walls, Hagelin explained that the Project to Reduce Violent Crime was a "scientific demonstration that will provide proof of a unified superstring field." Superstring theory is an abstract and highly speculative physical theory that attempts to connect all the forces of nature. According to Hagelin, one such force is a collective consciousness that can be accessed by TM. A superstring field, generated by many minds meditating in unison, would radiate throughout the community, reducing stress and spreading tranquility.

The weeks that followed seemed like something out of an old mad-scientist movie—an experiment that had gone horribly wrong. Each Monday morning, the *Washington Post* would tally the gruesome weekend slayings in the city. Participants in the project seemed serenely unaware of the mounting carnage around them as they sat cross-legged in groups throughout the city, eyes closed, peacefully repeating their mantras. The murder rate for those two months reached a level unmatched before or since.

At the end of the demonstration period, Hagelin, smiling his unworldly smile, acknowledged that murders were indeed up "due to the unusually high temperatures," but "brutal crime" was down. One could only imagine that the murders were being committed more humanely—perhaps a clean shot between the eyes rather than a bludgeoning. Over the coming year, Hagelin promised, the results would be carefully analyzed according to strict scientific standards.

As promised, Hagelin was back a year later with a fifty-five-page report of the results of the project. It was a clinic in data distortion. A beaming Hagelin announced at a press conference that, during the period of the experiment, violent crime had been reduced by a remarkable 18 percent. "An eighteen-percent reduction compared to what?" a puzzled reporter for the *Washington Post* asked, recalling the dreadful murder rampage of the summer of '93. Compared to what it would have been if the meditators had not been meditating, Hagelin explained patiently. "But how could you know what the rate would have been?" the reporter persisted. That had been arrived at, Hagelin responded with just a trace of irritation, by means of a "scientifically rigorous time-series analysis" that included not only crime data but such factors as weather and fluctuations in Earth's magnetic field.

According to Hagelin, their analysis showed a significant reduction in psychiatric emergency calls, fewer complaints against the police, and an increase in public approval of President Clinton during the period of the experiment—all consistent with the hypothesis that a coherence-creating group of TM experts can relieve communal stress and reverse negative social trends. All of this had been carefully scrutinized by an "independent scientific review board," several of whose members were present at the press conference. Hagelin was clearly irritated when I asked how many of the "independent" review board members practiced TM. "Some members of the review board have had previous experience with TM," he replied, struggling to retain some trace of his smile. He lost the

struggle when I insisted on polling the members of the scientific review board. They were all followers of the Maharishi.

"The most common of all follies," wrote H. L. Mencken, "is to believe passionately in the palpably untrue." The belief of the Maharishi's followers in the power of TM was not influenced in the slightest by the outcome of the "experiment." This was pseudoscience: all the talk of "string theory" and "consciousness fields" and "time-series analysis," was meant to give the appearance of science. Which is not to say that those involved were not sincere in their belief. They may have believed so fervently that they felt a responsibility to *make* the facts support their belief. People will work every bit as hard to fool themselves as they will to fool others—which makes it very difficult to tell just where the line between foolishness and fraud is located.

The vast majority of scientific research, of course, is far removed from either foolishness or fraud. But to what extent are the interpretations given to scientific evidence shaped by the worldview of the scientist? A good place to examine this question is the current controversy over global warming.

THE GREAT GLOBAL WARMING DEBATE

André Gide, the great French moralist, wrote in his journal a half century ago: "Man's responsibility increases as that of the gods decreases." Every step taken by science claims territory once occupied by the supernatural. Where once we accepted storms and drought as divine will, there is now overwhelming scientific evidence that we ourselves can affect Earth's climate. It is a measure of how far science has come that scientists have been given responsibility for telling us whether our planet is headed for some climate catastrophe of our own making, and if so, what steps we can take to avoid it.

The evidence comes from a revolution in climate research over the past decade, brought about by new observational techniques, including satellites, and a prodigious increase in computational and data-storage capabilities made possible by microelectronics. It now seems undeniable that surface temperatures are warmer than they were a hundred years ago. There is also no doubt that the burning of fossil fuels since the beginning of the industrial revolution has resulted in a significant increase in atmospheric carbon dioxide.

What is in dispute is what the long-term consequences of continued carbon dioxide increases will be for Earth's climate and the quality of life. Carbon dioxide, or CO_2, is called a "greenhouse gas," because like a greenhouse, or your car when it's parked in the sun with the windows closed, it traps heat. Some fraction of the sunlight that strikes the Earth is absorbed, warming the planet, which then reradiates energy. But because it is not nearly as hot as the sun, whose light is most intense in the yellow-green region of the visible spectrum, the Earth radiates at much longer wavelengths, peaking in the invisible infrared region of the spectrum. CO_2, like glass, is transparent to the rays of visible sunlight that warm the Earth but blocks heat from radiating back into space. The presence of CO_2 and other greenhouse gases in the atmosphere helps to keep our planet warm. CO_2 is also the raw material for plant growth. Using the energy of sunlight, plants draw CO_2 from the air to make hydrocarbons, releasing oxygen into the atmosphere as a by-product. When the plant dies and decays, or is burned, or is eaten by an animal, the carbon is recombined with oxygen and returned to the atmosphere as carbon dioxide, completing the cycle.

Before the industrial revolution, the concentration of carbon dioxide represented a natural balance, but in a little more than a century, humans have disrupted that balance by burning fossil fuels that were built up in underground deposits over a period of hundreds of millions of years. If this release of carbon dioxide into the atmosphere continues, climatologists warn, there could be disastrous consequences in the next century: many of the world's great cities will be submerged by rising sea levels as the polar ice caps melt, and drastic changes in rainfall patterns could wreak havoc on food production.

The average temperature of the Earth has risen by perhaps one degree Fahrenheit in this century, and it would be more if we had not also polluted the atmosphere with soot, blocking out some of the Sun's rays. The greatest concern is that there are feedback mechanisms that might cause this gradual warming to accelerate. Thawing tundra, for example, would release trapped methane, another greenhouse gas, causing still more warming. Warming would also reduce the amount of sea ice. A large fraction of the sunlight that falls on ice is reflected back into space, but water absorbs sunlight rather efficiently. If the area of the Earth covered by sea ice shrinks, the warming will accelerate further. There is evidence of such rapid warming in prehistoric times. The nations of the world, many scientists argue, should take immediate steps to control the burning of fossil fuels, at least until we can better predict the consequences. We have no right, they declare, to place future generations in jeopardy.

Not all scientists agree. A number of prominent scientists point out that there were periods of global warming long before humans began burning fossil fuels, and CO_2 is a relatively minor greenhouse constituent in the atmosphere. They contend that any rise in global temperature since 1850 may simply be the result of natural solar variations. Some go further, describing the increase in carbon dioxide as "a wonderful and unexpected gift of the industrial revolution." The increase in atmospheric CO_2 has stimulated plant growth, making this a lusher, more productive world, capable of sustaining a much larger population. Besides, if there is some greenhouse effect, it may be just what Earth needs to stave off another ice age. The more industrial growth we have, including increased burning of fossil fuels, they argue, the better off we will be. They stop just short of telling us we have a moral obligation to burn more hydrocarbons.

If scientists all claim to believe in the scientific method, and if they all have access to the same data, how can there be such deep disagreements among them? If the climate debate was just about the laws of physics, there would be little disagreement. What separates the two sides in the climate controversy, however, is not so much an argument over the scientific facts, scientific laws, or even the scientific method. The climate is the most complicated system scientists have ever dared to tackle. There are huge gaps in the data for the distant past, which, combined with uncertainties in the computer models, means that even small changes in the assumptions result in very different projections far down the road. Neither side disagrees with that. Both sides also agree that CO_2 levels in the atmosphere are increasing. What separates them are profoundly different political and religious worldviews. In short, they want different things for the world.

The great global warming debate, then, is more an argument about values than it is about science. It sounds like science, with numbers and equations and projections tossed back and forth, and the antagonists believe sincerely that they are engaged in a purely scientific debate. Most scientists, however, were exposed to political and religious worldviews long before they were exposed in a serious way to science. They may later adopt a firm scientific worldview, but earlier worldviews "learned at their mother's knee" tend to occupy any gaps in scientific understanding, and there are gaps aplenty in the climate debate.

This sort of dispute is seized upon by postmodern critics of science as proof that science is merely a reflection of cultural bias, not a means of reaching objective truth. They portray scientific consensus as scientists voting on the truth. That scientists are influenced by their beliefs is undeniable, but to the frustration of its postmodern critics, science is enormously successful. Science works.

We will come back to our example of the climate war later in this chapter, but to understand how science can rise above the beliefs of its practitioners, we must first understand something of the process by which beliefs are generated.

PLEISTOCENE PARK

To borrow from the premise of the movie *Jurassic Park*, suppose a mosquito gorged on one of our Cro-Magnon ancestors thirty thousand years ago and then became trapped in amber, providing science with ancient human DNA. Would a Cro-Magnon clone, raised in today's society, be some dangerous brute that might escape and terrorize society? The movie *Pleistocene Park* would not be that exciting. A Cro-Magnon would most likely be indistinguishable from the rest of us. Far too little time has passed for any genetic adaptation to the modern world. All of recorded history covers a mere five thousand years—the industrial revolution just two hundred—the space age barely four decades. So here we are,

saddled with stagnant genes that were selected for life as Pleistocene hunter-gatherers, trying to cope with a world of jet travel and computers. What provided a survival advantage in a Pleistocene wilderness, does not necessarily do so today.

Behavioral traits are as much a part of our genetic inheritance as physical characteristics. We respond to external stimuli in ways that conferred some sort of survival advantage on our distant human and prehuman ancestors. Psychologist James Alcock describes our brains as "belief engines," constantly processing information that comes in from our senses and generating new beliefs about the world around us. These new beliefs are selected by the brain to be consistent with beliefs already held, but they are generated without any particular regard for what is true and what is not.

A belief begins when the brain makes an association between two events of the form: *B* follows *A*. The next time *A* occurs, the brain is primed to expect *B* to again follow. The survival advantage of such a strategy for our primitive ancestors is obvious. They had scant means for separating causal connections from mere coincidence—better to take heed of every connection and be safe. We avoid some food, for example, because we once got sick after eating it. Our illness may have had nothing to do with the food, but unless we're facing starvation, there's not much to be lost by avoiding it.

Information gathered by the senses is normally routed through the thalamus, a small subsection deep within the brain, to the sensory cortex, which analyzes it in detail to decide how much weight it should be given. An exception is olfactory input, which apparently follows more evolutionarily ancient pathways to reach the cortex. Sensory information processed by the cortex finally reaches the amygdala, almond-shaped structures in the temporal lobes. The amygdalas contribute the emotional portion of our response to sensory stimuli. Parts of the amygdala, for example, are involved in fear. Animals with damage to these parts are no longer perturbed by stimuli they previously learned to fear.

Whether a belief is retained depends on how significant *B* is—how frightened we were, for example—and whether the association with *A* gets reinforced. Without reinforcement, the expectation that *B* will follow *A* will usually fade in time. If *B* again follows

A, however, it may still be a coincidence, but it will now be far harder to persuade us of that.

The belief may also be permanent if the information entering the thalamus coincides with a high state of emotional arousal, such as fear or the thrill of victory. The chemical messengers of emotion cause the thalamus to bypass the sensory cortex and route the information directly to the amygdala. This is often the origin of what might be called personal superstitions—the golfer who won't play without his lucky hat, for example. People develop elaborate rituals in an effort to re-create the conditions that surrounded some rewarding experience or to avoid conditions their brains associate with fear or pain. We often find ourselves almost compelled to go through these rituals, even when the cerebral cortex is telling us that a causal connection is highly implausible.

This kind of belief generation was going on long before our ancestors began to resemble humans, of course, but the advent of language opened a powerful new channel, both for the formation of beliefs and for their reinforcement. Speech exposes us to the generation of shared beliefs—beliefs based not on personal experience but on experiences related to us by others. This has the potential to spare us a lot of unpleasantness. Everyone, for example, need not discover the hard way that a particular plant is poisonous. The shared beliefs of a family or tribe are also a powerful force of social cohesion and are reinforced throughout our lives. Language makes vicarious experience the dominant source of belief in humans, overwhelming personal experience. The power of language was enormously amplified by the invention of writing and continues to be amplified by every new advance in communication from the printing press to the World Wide Web. Beliefs can now spread around the world in the twinkling of a computer chip. That which allows us to learn from others, unfortunately, also exposes us to manipulation by them.

Small children are particularly open to new beliefs, accepting without question whatever they are told by adults. Their belief engine runs freely, finding few previous beliefs to contradict what they are told. For a small child who must quickly learn that stoves burn and strange dogs bite, this sort of credulity is important to survival. Because a child's beliefs are not enmeshed in a network of

related beliefs, however, children seem able to cast them off almost as easily as they adopt them. Fantastic stories about Santa Claus and tooth fairies, which are accepted uncritically, are dropped just as uncritically when someone, often a playmate, explains that it isn't really so. Nor do children appear to develop doubts about other things they've been taught, just because the Santa Claus story was taken back.

As the store of beliefs grows, conflicts with existing beliefs become more likely, and doubt begins to manifest itself. By the time the child reaches adolescence, beliefs tend to be enmeshed in an insulating matrix of related beliefs. The belief process becomes decidedly asymmetric: the belief engine is generating beliefs far more easily than it erases them. Once people become convinced that a rain dance produces rain, they do not lose their belief in years the drought persists. They are more likely to conclude that they have fallen out of favor with the Rain God, and perhaps add a human sacrifice to the ritual.

The result is that most of us wind up with beliefs that closely resemble those of our parents and community. Society, in fact, often holds it to be a virtue to adhere to certain beliefs in spite of evidence to the contrary. Belief in that which reason denies is associated with steadfastness and courage, while skepticism is often identified with cynicism and weak character. The more persuasive the evidence against a belief, the more virtuous it is deemed to persist in it. We honor faith. Faith can be a positive force, enabling people to persevere in the face of daunting odds, but the line between perseverance and fanaticism is perilously thin. Carried to extremes, faith becomes destructive—the residents of Jonestown for example, or the Heaven's Gate cult. In both cases, the faith of the believers was tested; in both cases, they passed the test.

The wonder is not that we can be easily fooled but that we function as well as we do on what would seem to be, as far as our genes are concerned, an alien planet that does not at all resemble the wild planet on which our genes were selected. If this sounds hopelessly gloomy, be patient, we are coming to the good news: we are not condemned to suffer the tyranny of the belief engine. The primitive machinery of the belief engine is still in place, but evolution didn't stop there. It provided us with an antidote.

WHAT IS SCIENCE?

How can it be that brains designed for finding food and avoiding predators in a Pleistocene forest enable us to write sonnets and do integral calculus? We invent poetry and higher mathematics because our brains hunger for patterns. The wonderful pattern recognition equipment residing in the higher centers of the human brain allowed our ancestors to adapt to changing conditions with remarkable ease, by quickly picking up the patterns that are characteristic of the new environment.

Animals with much smaller brains than ours also rely on pattern recognition, of course. The desert *Cataglyphis* ant, for example, whose brain contains perhaps a hundred thousand brain cells, compared to a million times that many for a human, forages over enormous expanses of seemingly featureless terrain, wandering to and fro in search of food. When these ants finally encounter some windblown seed, they return with it at once to their nest in an almost straight line. They navigate by the position of the Sun—even if the Sun is obscured by clouds—using patterns of polarized light. But the ability of *Cataglyphis* to recognize patterns, as marvelous as it is, is very specialized. Transplanted to a different environment, such as the forest floor, where landmarks abound but where the sky cannot be seen, *Cataglyphis* would be lost.

In humans, the ability to discern patterns is astonishingly general. Indeed, we are driven to seek patterns in everything our senses respond to. So far, we are better at it than the most powerful computer, and we derive enormous pleasure from it. Pattern recognition is the basis of all esthetic enjoyment, whether it is music or poetry or chess or physics. As we become more sophisticated, we seek out ever more subtle patterns. So intent are we on finding patterns, however, that we often insist on seeing them even when they aren't there, like constructing familiar shapes from Rorschach blots. The same brain that recognizes that tides are linked to phases of the moon may associate the positions of the stars with impending famine or victory in battle.

That is again the belief engine at work. But once we recognize how easily we can be fooled by the workings of the belief engine, we can use the higher centers of the brain to consciously construct a more refined strategy that combines our aptitude for recognizing patterns with the accumulation of observations about nature made possible by language. Such a strategy is called science.

> Science is the systematic enterprise of gathering knowledge about the world and organizing and condensing that knowledge into testable laws and theories.

This elegant description, borrowed from biologist E. O. Wilson's *Consilience*, provides a template that can be held up against claims to see if they belong in the realm of science. How well the template fits comes down to two questions: Is it possible to devise an experimental test? Does it make the world more predictable? If the answer to either question is no, it isn't science.

The success and credibility of science are anchored in the willingness of scientists to obey two rules:

1. Expose new ideas and results to independent testing and replication by other scientists.
2. Abandon or modify accepted facts or theories in the light of more complete or reliable experimental evidence.

Adherence to these principles provides a mechanism for self-correction that sets science apart from "other ways of knowing," to use a fashionable euphemism. When better information is available, science textbooks are rewritten with hardly a backward glance. Many people are uneasy standing on such loose soil; they seek a certainty that science cannot offer. For these people the unchanging dictates of ancient religious beliefs, or the absolute assurances of zealots, have a more powerful appeal. Paradoxically, however, their yearning for certainty is often mixed with respect for science. They long to be told that modern science validates the teachings of some ancient scripture or New Age guru. The purveyors of pseudoscience have been quick to exploit their ambivalence.

Scientists generally believe the cure for pseudoscience is to increase science literacy. We must ask, however, what it is we would want a scientifically literate society to know. There are a few basic concepts—Darwinian evolution, conservation of energy, the periodic table—that all educated people should know something about, but the explosive growth of scientific knowledge in the last half of the twentieth century has left the scientists themselves struggling to keep up with developments in their own narrow specialties. It is not so much knowledge of science that the public needs as a scientific worldview—an understanding that we live in an orderly universe, governed by physical laws that cannot be circumvented.

Although the old belief-generating machinery of the brain is still in place, habits of critical thinking can be adopted that subject each fledgling belief to skeptical analysis before continued reinforcement renders the belief hopelessly resistant. The first question that must be asked about a fledgling belief is whether *B* really follows *A* any more frequently than we would expect from chance. The belief engine, of course, knows nothing of the laws of probability. Any such analysis must be consciously imposed by the higher centers of the brain.

Most people, for example, will grant that a coin toss will come up heads or tails with equal probability. They will even concede that this must be true every time the coin is tossed. And yet, if the coin comes up heads four times in a row (which it has one chance in sixteen of doing), it takes a certain amount of mental discipline not to believe that the fifth toss is more likely to be tails. The part of our brain that understands that heads and tails are equally likely expects the tails to start catching up. This is known as the "gambler's fallacy." Heads and tails will tend to even out over the long run, but this says nothing about the next toss.

We must also ask if there is a plausible mechanism by which *A* could cause *B*. Even if we are satisfied that the connection between *A* and *B* is more than a coincidence, it still does not mean that *A* causes *B*. They could, for example, have a common cause. Ideally, we might know some physical principle that would help us decide, but more generally we have to decide whether that's the way other things seem to behave.

In 1934 the great chemist Irving Langmuir, who won the 1932 Nobel Prize for his studies of molecular films, read about the work of Duke University psychologist J. B. Rhine on extrasensory perception (ESP). Langmuir was fascinated by what he called "pathological science—the science of things that aren't so." Its practitioners, he argued, are not dishonest; they simply manage to fool themselves. To Langmuir, ESP appeared to be a classic example of pathological science.

Among the symptoms that Langmuir associated with pathological science was that the evidence always seems to be at the very limit of detectability. In our cocktail party analogy it would mean you could just barely make out what was being said over the din of background noise. Under these conditions it's easy to be mistaken about what was said.

If the claim is that the mind can influence the toss of a coin, for example, the reported success rate might be 51 percent rather than the 50 percent you would predict. Thus a great many trials would be needed to be reasonably sure that such a small deviation from pure chance is anything but expected random variation. But now there is a new problem: if there is some systematic flaw in the design of the experiment—perhaps some slight asymmetry in the two sides of the coin that influences which side is more likely to come up—it would produce a noticeable result only after a large number of trials. One experimentalist measuring a 51 percent success rate after a very large number of trials might therefore conclude that the result reveals the existence of an unidentified flaw in the experimental design and seek to identify the flaw. Another might conclude that the subject was able to mentally influence the coin and not look for flaws. Scientific claims that are based on small statistical differences, therefore, always carry less weight.

Another common characteristic of pathological science, Langmuir observed, is that there seems to be no way to increase the magnitude of the effect. To hear a sound more clearly, as in our discussion of conversations at cocktail parties in the last chapter, you move closer to the source, but neither distance nor time seemed to affect ESP. It didn't matter if the coin was tossed in some other city; the success rate would be the same. That, Langmuir pointed out, is certainly contrary to the way everything else in the world seems to work.

If the success rate was truly greater than chance, however, no matter how slight the advantage, it would be a profoundly important result, forcing a complete reexamination of all our assumptions about the way the world works. Langmuir visited Rhine and explained his reservations. To his surprise, Rhine seemed unperturbed and even urged Langmuir to publish his views. The result, Rhine predicted, would be that his ESP research would attract more graduate students and more funding. Moreover, Rhine was quite open about showing Langmuir how he conducted and analyzed his experiments.

Rhine had carried out hundreds of thousands of trials over the years involving the ability of people to guess the identity of cards dealt face down. He used a deck with five different cards, and in each trial the subject would be asked to guess the identity of twenty-five cards. On average you would expect people to guess correctly 20 percent of the time, thus getting five of the twenty-five right. Sometimes, of course, the subject would score better than five, other times worse. But out of a huge numbers of trials, Rhine found, the average was somewhat greater than you would predict by chance.

To his amazement, however, Langmuir discovered that in calculating his averages Rhine left out the scores of those he suspected of deliberately guessing wrong. Rhine believed that persons who disliked him guessed wrong to spite him. Therefore, he felt it would be misleading to include their scores. How did he know they deliberately guessed wrong? Because their scores were too low to have been due to chance. Indeed, he was convinced that abnormally low scores were as significant as abnormally high scores in proving the existence of ESP.

When Langmuir attempted to explain the flaw in Rhine's reasoning to a reporter, the reporter was unable to follow Langmuir's statistical arguments. What he wrote was that a famous Nobel laureate was looking into ESP. Rhine was overwhelmed with new graduate students and offers of financial support. As Rhine had expected, Langmuir had given ESP credibility simply by taking notice of it.

This creates a troubling dilemma for scientists. Joe Newman's challenge to scientists to debate him may have been rhetorical, but had some prominent physicist taken up his challenge, it would almost certainly have worked to Newman's advantage. Simplistic arguments and homespun humor are more effective in such a debate than citing the laws of thermodynamics. Debate has a way of seeming to elevate a controversy into an argument between scientific equals. It is an arena made for voodoo science.

The final step in applying a scientific worldview is to put a fledgling belief to the test. When I was young boy interested in nature, I read in one of my books that raccoons always wash their food before eating. I had in fact been told the same thing by my father, and I had even seen raccoons swishing their food in the edge of a stream, so there was not much reason to doubt it. The book explained that this behavior was not actually meant to cleanse the food but only to moisten it, because raccoons have no salivary glands. It seemed to be a reasonable explanation, and I carried this bit of lore around in my head for most of my life, eventually passing it on to my own children.

One summer, however, during a period of prolonged drought, a family of hungry raccoons began coming up to our house every evening at dusk to beg for food. They were impossible to resist, and we began buying dry dog biscuits for them, which we kept in a shed behind the house. Because the poor raccoons had no salivary glands, I would put out a pan of water first so they could moisten the food. They would crowd around me as I opened the shed and took out the paper bag of dog biscuits. Very soon, however, I noticed that at the first rattling of the paper bag, the raccoons would start salivating—saliva literally dripped from their jaws. No salivary glands indeed! After that, I tried feeding them without the pan of water. It didn't seem to bother them; they ate anyway. If the water was there, they used it. If it wasn't, they went right ahead and ate. I still don't know why raccoons like to swish their food in the water. My guess is they're washing it. The lesson is that no matter how plausible a theory seems to be, experiment gets the final word.

BACK TO THE CARBON DIOXIDE WAR

Which brings us back to the global climate-change debate. The special responsibility of scientists is to inform the world of its choices. During some three and a half billion years of evolution, the environment shaped our genes. Our genes are now shaping the environment. But it may be years before anthropogenic effects on climate are well enough understood to make those choices clear. On one side, there are scientists who warn that we can't afford to wait. These Malthusian pessimists argue for the "precautionary principle." Changing human behavior takes time, they contend, and if we don't start now it may be too late to prevent a catastrophe.

On the other side are the technological optimists, who insist that to make policy before we understand the problem, if indeed a problem exists, is to to invite failure. To have followed such a policy in the past, they argue, would have denied the world the unquestioned benefits of industrialization. They remind us that science has always found solutions to the problems generated by population growth and industrialization.

In the spring of 1998, a research group (group A) analyzing data from weather satellites concluded that over a twenty-year period there has been a slight cooling of the upper atmosphere, rather than the slight warming inferred from surface measurements. However, a second group (group B) reexamined the data and pointed out that the analysis failed to take atmospheric drag into account. That would put the satellite trajectory fifteen kilometers closer to Earth, which had the effect of turning slight cooling into slight warming. Group A thanked group B for pointing out the correction but were led thereby to reexamine the data themselves. They found that two further corrections, for orbital precession of the satellites and calibration drift in the radiometer, largely offset the effect of atmospheric drag. Group B appreciated this latest refinement but felt these effects were too small to change the conclusion that the troposphere is warming.

The most significant lesson from the satellite data may be that the ideological passion of Malthusian pessimists at one extreme and technological optimists at the other—so long as both sides adhere to the scientific process—actually serves as a powerful motivation for better climate science. Each side knows that every flaw in their data or oversight in their analysis will be seized upon by their opponents. Both sides strive to produce better data and better analysis in the conviction that the truth will favor their prejudice. The numbers, when science finally learns them, will ultimately decide the winner. In the end, the result will be a better understanding of global climate.

Of the multitude of problems that daily vex modern society, few, it seems, can be sensibly resolved without recourse to the knowledge of science. There are times, however, when society cannot wait for the scientists to get it right. The courts must resolve disputes, Congress must enact legislation, government agencies must impose regulations, doctors must treat the ill, all on the basis of the best scientific evidence available at the time. There no longer seems to be any reasonable doubt that human activity is affecting Earth's climate. Governments must initiate some precautionary measures, even though the precise consequences are still unclear.

The need to make decisions involving scientific questions that are as yet unresolved creates an inevitable tension between those who mistrust technology and those who trust it too much. At these two extremes, the scientific process is sometimes circumvented, giving rise to voodoo science, as we will see in the next two chapters.