27

Christopher

The EMF problem had continued to heat up. Scientists at the Environmental Protection Agency had written a report saying EMFs were carcinogens, and someone leaked a draft copy. The president's Science Advisor had rejected the report, nevertheless people still complained about EMFs to their representatives in Washington, some of whom contacted me. A senate staffer who was investigating the matter had told me, "Cancer is a terrible thing, but I don't see how anybody can link it with powerlines. Every time there's a study that says one thing, there's another study that says something different." I had learned from an assistant to another congressman that he had looked into the possibility of burying powerlines and learned it would cost billions. The assistant said his boss didn't want to be known in his district as the man who was responsible for doubling everyone's electric bill. A policy advisor for a California congressman had told me he considered holding public hearings but decided against it after he received complaints about the possible impact on property values near powerlines. I had heard directly from a Massachusetts congressman about a delegation of homeowners that visited him. They were concerned about a cluster of cancers in children in their neighborhood, and told him they didn't think the cluster just happened because everything happens for a reason; they suspected the powerline that passed through their neighborhood. All these inquiries had led to much harrumphing in Congress concerning the EMF issue, particularly among the Democrats. A committee chairman had said in a speech, "The occurrence of even a single case of cancer is a great tragedy. We are faced with a public-health hazard of unknown proportions. The people have a right to know the facts. If something they live with or that is present in their neighborhood is killing them, they ought to be told. We have to find the facts."

Shortly thereafter Congress had passed a law that gave $40 million to Kenneth Olden, the director of one of the institutes of NIH, and directed him to find the facts about EMFs and cancer. The program, which he called RAPID, had sent shock waves through the NIH because, consistent with

its motto "science by scientists for the sake of science," NIH despised the involvement of laymen in its activities, and was especially fearful of open politics. Olden surely had felt revulsion at the idea the power companies might be causing cancer simply because not burying the powerlines was economical. Just as surely, as a black physician he must have been sickened by the failure of physicians at his agency to treat the poor black syphilitics from Tuskegee in a manner consistent with their Hippocratic oath, and this must have motivated him to insure that he did not commit the same sin, neglect of one's highest duty. Olden had said: "The best scientific minds in the world will resolve the EMF issue, and the process will be open, transparent, objective, scholarly, and timely under Congress's mandate." Only later did I learn how Olden had coped with the impossible task Congress had given him; his strategy had been the same as that Andy Bassett had used with Bernard Baruch, and I had used when I advised Dennis Thibodeaux concerning his legal problems.

Olden had appointed John Christopher to run RAPID. When I had first met him he told me, "I promised Dr. Olden I would solve the problem with no lingering concerns, and that is what I intend to do." Three years later, after spending all of the money he got from Congress on experiments he thought meritorious, including mine on the immune system of mice, Christopher was ready to fulfill his promise. He hand-picked a panel of experts and organized a meeting to debate the meaning of all the results that had been obtained in the RAPID studies. I was one of those whom he invited to participate.

When Erica, my graduate student, learned of the meeting, she was anxious to attend. Some of the other invitees told me they planned to bring students or other guests to observe the debate, so I agreed to bring her.

We went down to Dallas for the meeting. A little before dawn the phone rang and woke me up. It was Erica. I expected bad news, but she was excited because the circus was in town and asked me to go with her to watch the unloading of the animals.

First we saw tigers skulking in their cages as a boom-crane lifted them off flatcars and onto wagons. Then a troop of chattering chimpanzees were led down a gangplank to join the parade. Next we saw the elephants lumber out of their boxcars and organize themselves into a line, all in response to sharp raps from the long slender sticks of their handlers. Each

elephant wrapped its trunk around the tail of the elephant it followed, except for the first elephant which raised its trunk high over its head, as if the air there smelled better. The crowd stared, but the animals seemed to take no notice of them.

"It seems like a sad life," Erica said as we watched the spectacle.

"Perhaps not," I said. "The animals are well fed and all their needs are met."

We walked back to the hotel slowly, to pass the time until it got light and the meeting started. To test Erica's mettle I began to question her about her ambitions.

"You could be back in the laboratory doing experiments, but instead you came here. What do you expect to learn?"

"Well, Professor Marino, I suppose that the best science is done at the NIH, and I would like to meet the people who work there, and learn what I can from them."

"Do you mean that you would like to make connections so that when you apply for a grant the people at the NIH will know who you are and perhaps look favorably on your application?"

As a streak of daylight betrayed her blush, she said, "What interests me most is learning how science can be used to prevent disease."

"Is that what you think the NIH does?" I asked.

"That's what they say," she replied.

"So you think that 'preventing disease' is a precise subject that can be taught?" I asked.

"Yes, I have no reason to think otherwise."

"Before you began working in my laboratory, we corresponded for almost a year. Then we had several long discussions. After all that you decided to devote yourself to conducting EMF experiments because you had an understanding of the person from whom you expected to learn. But you don't know anyone at the NIH, so why do you think you can believe what they say?" I asked.

"I just presume that what they say is trustworthy," she said.

"But how do you know that you can trust what you hear at the meeting?"

She had no answer so I suggested that she give the matter some thought, and I promised to introduce her to Christopher at the first opportunity.

At the hotel where the meeting was to be held, our path was blocked

by picketers who were protesting cruelty to the circus animals. I told them we were scientists and had no connection with the circus. Reluctantly they stood aside and let us pass.

When we entered the meeting room we saw Christopher. He was walking in the front, and walking with him in two lines were many experts whom I recognized. On one side I saw Neil Chernoff of the Environmental Protection Agency, Imre Gyuk of the Department of Energy, and Phu Phant of the Food and Drug Administration. On the other side I saw John Morrison of the Electric Power Research Institute and Russel Reiter of the University of Texas. Those who followed behind listening to their conversation seemed mostly to be some of the foreigners that Christopher had drawn into his EMF program, but I also saw some Americans in the troop. When Christopher turned around, the troop divided perfectly and circled to the rear.

After that I recognized Martin Ruhig, who was Christopher's deputy; he was sitting at the opposite end of the room, and seated around him were men and women not much older than Erica. I supposed they were asking him questions on strategies for obtaining grants from the NIH.

Then I spied Don Justesen, or at least someone who looked like him, sitting on his suitcase and looking even more glum than usual; he had arrived too late the previous evening, and so had lost his room. Sitting on a couch was Charles Pick, a physicist from Rhode Island; he appeared to be with the woman who sat next to him. There was Asher Sheppard, owner of the Asher Sheppard Consulting Company, talking with Monica Lugner and her sister Eva Stum, both of the Electric Power Research Institute. I would have loved to know what they were discussing. James Barnes of Wyoming sipped coffee and stared into space, looking very much like the pensive college professor he was. He asked a young man, whom he took to be a caterer, for a doughnut, but the man turned out to be Paul Afelis from the Department of Energy, who had become involved with EMFs so recently that Barnes didn't know him.

Just after we had come in, Nancy Wertheimer, the woman from Colorado who wrote the first papers about EMFs and childhood cancer, entered immediately behind us, accompanied by David Savitz from the University of North Carolina. They spoke cordially and I saw no signs of resentment, even though she had paid for her studies out of her own pocket and Savitz had received millions from the Electric Power Research Institute and the

NIH to repeat her work.

In the hallway outside the room I saw the enigmatic Ross Adey, from California, pacing back and forth along a straight line taking care not to veer to either side, like a funambulist.

After taking in the scene we went up to Christopher and I said, "Dr. Christopher, this is Erica. She has the feeling that you can teach her something, though she doesn't know exactly what that might be."

He said to her, "Each day you're here you will learn more about science, and when you go home, you'll be better than when you came."

"Better at what?" I asked.

"Not in measuring enzyme levels, cloning a gene, or designing an experiment" – here he looked directly at Erica – "but in your ability to evaluate scientific evidence to predict the circumstances and conditions that will or will not cause disease. We will determine whether powerline EMFs threaten human health, but the principles that will guide our decision are applicable to any agent that is thought to cause disease."

"Isn't a threat something immediate," I asked, "and therefore shouldn't the answer be obvious?"

"Special skill is needed to assess the truth of the claim that EMFs cause cancer," he replied.

"Some questions can be answered exactly, some approximately, and some not at all. What kind of a question is the safety of powerlines?" I asked.

He replied quickly, "The kind that can be answered exactly, because it's a scientific question."

I did not want to impose any further on Christopher, who I could see was anxious to start the meeting, so I ended our conversation by thanking him for his kindness in speaking to Erica. As she and I walked away, she told me how excited she was at the prospect of learning what Christopher had promised he would teach her.

"It's the most important thing anyone could teach," I said, "because everyone wants to avoid getting sick. The question of whether anyone can know or teach that is something I have thought about a lot."

She had no idea what I meant, so I explained.

"Many well-known persons advise the public about health matters. For instance, Pat Boone says that a particular drug will cure acne, or Larry King says that garlic will promote health. People who accept their opinions haven't really been taught anything because Boone and King have no spe-

cial expertise. If we consider the fate of experts, we reach the conclusion that they did not know what made people sick. No one knew more about biochemistry than Philip Handler or more about medicine than Andrew Bassett, yet both died of cancer. I could mention many other experts who were also unable to save themselves. So I don't believe that the health or disease of human beings can be predicted with certainty. There are no equations for that, and I don't imagine that there are fortune-tellers who really possess such knowledge. Still, I suppose we must wait and listen to Christopher. If he can demonstrate that the ability to predict disease is something that can be known and taught, you and I will both be wiser."

We then walked to our seats, Erica to the place designated for observers, me to a chair at the square of tables designated for the experts. Christopher began the meeting by explaining that he had been trained as a statistician and immunotoxicologist, but subsequently had become a specialist in the subject of discovering the overall meaning of a group of scientific studies. Then he explained what was at issue. "Our task is to determine with scientific certainty whether EMFs from high-voltage powerlines cause leukemia or brain cancer. There have been thousands of scientific reports, and they have confused the public and the decision-makers. Our government needs to know the truth, which we can find by ascertaining whether laboratory studies have convincingly shown that EMFs can damage cells in a way that is harmful to human health, or whether EMFs common in homes can cause health problems."

The experts murmured when they heard that weighty responsibility described with such clarity; even the foreigners looked somber. Christopher continued: "Foremost among the principles that must guide your judgment is that of the plausibility of a relationship between EMFs and either damaged cells or health problems. Does it make sense? Is there a mechanism by which it can occur? If we understand how an agent affects the body, we can more readily accept that it might lead to disease. For example, we know from laboratory studies that chemicals in cigarette smoke can form DNA adducts; adducts, of course, lead to altered gene activity, and ultimately cancer. So we can see the means by which smoking leads to cancer. Do laboratory studies similarly disclose plausible mechanisms that might explain how EMFs could cause cancer?

"A related principle is that of proportionality between dose and effect. The reality of a causal relationship between an environmental agent and

its effect is more readily acceptable if more serious consequences follow from higher levels of the agent. For example, the cancer rate is far greater among those who smoked for many years compared with those who smoked for only a few years. Are the effects attributed to EMFs proportional to EMF dose?

"A third principle is that of coherence. If similar experiments produce opposite results, then we can be confident that the effects of EMFs are not real. All properly done studies of the link between smoking and cancer point to a link between them. Do the EMF reports similarly agree with one another?

"Your successful competition for NIH grants is evidence that you have mastered these three great principles. My role is to guide you in their application to the EMF studies during open scholarly debate."

When he finished, Christopher asked Rose Mandel of the University of Toronto to give her opinion of the EMF immunology studies, and to state whether they showed that EMFs had the power to alter the immune system. She described her studies, those of Jacob Juko from the University of Kupio, James Morrison from Battelle Institute, Meike Mevissen from the University of Berlin, and Thomas Tenforde of the Bonneville Power Authority, along with the reports from about a dozen other investigators. She did not mention my studies except to say that my methodology was novel and had not yet been generally accepted. She concluded, "The studies evaluated a wide variety of immune-function endpoints in mice, rats, baboons, sheep, and humans, including immune-system structure, cell- and humoral-mediated immunity, and innate immunity. Limitations of the studies have included a lack of consistency in study design and exposure parameters, and a failure to repeat the experiments to insure that the results were correct. For these reasons the studies do not sum to anything, and give no indication of a possible mechanism by which EMFs could alter the immune system. It is therefore not possible to draw firm conclusions regarding the potential effects of EMF exposure on the immune system, and further studies should be conducted."

Christopher expressed satisfaction with Mandel's evaluation, and others echoed his view, especially Pick and Morrison, who each made strong speeches. Pick said, "Unsubstantiated claims have generated fears of powerlines in some communities, leading to expensive mitigation efforts, and, in some cases, to lengthy and divisive court proceedings. The costs of mitiga-

tion and litigation relative to the powerline–cancer connection have risen into the billions of dollars and threaten to go much higher. The diversion of these resources to eliminate a threat which has no persuasive scientific basis is disturbing."

Morrison played the same tune: "More serious environmental problems are neglected for lack of funding and public attention, and the burden of cost placed on the American public is incommensurate with the risk, if any."

When the views from that side had been completely aired I spoke for the first time, directly addressing Mandel. "Suppose you had come to the opposite conclusion, namely that a particular mechanism was the means by which EMFs alter the immune system. Could that be a complete explanation, or would it still be necessary to understand the mechanism of that mechanism?" I asked.

"I don't understand your question."

"For example, accepting that DNA adducts are part of the mechanism for lung cancer, would you agree there must be a mechanism by which adducts play their specific role?"

"Of course."

Christopher interrupted the discussion and said, "I don't see where this is leading."

I acted as if I hadn't heard him and continued to address Mandel. "Then there is something that happens after the formation of the adduct but before the development of the cancer, and whatever that process is, it can more accurately be called the true mechanism because it is more basic."

"Yes," she said.

"Wouldn't there always be an even deeper mechanism, so that it is impossible to conceive of any specific structure that could truly be called the mechanism by which the EMF altered the immune system?"

"The hope," she said, "would be that we might come sufficiently close to understanding what mediates the effects of EMFs that we could, for all practical purposes, declare an end to our quest."

"Well, if even in principle there is no unique mechanism, the requirement that a mechanism must be identified before the causal impact of EMFs on cancer can be accepted would seem to make acceptance impossible."

That remark was too much for Pick who confidently observed that "the NIH obviously doesn't agree that the process is an infinite regress as you seem to suggest. It spends billions of dollars every year to find biological

mechanisms."

"Why do they seek knowledge of mechanisms?" I asked.

"Because it is good science," he replied.

"But the pursuit of mechanisms is not the hallmark of good science. What, for example, is the mechanism by which gravity works? Or, if you prefer, explain the mechanism of Ohm's law."

"They are forces," he replied. "It is meaningless to ask what the mechanism is of a force. Forces are governed by laws, so knowledge of mechanisms is unnecessary. It is precisely because there are no such laws in biology that it is necessary to identify mechanisms before we can believe what we see, and accept it as real."

"If there are no laws in biology," I said, "why do living things show patterns of behavior and response? Are these patterns chance events?"

"Of course not," he replied. "Living things obey laws, it's simply the case they don't obey mathematical laws, as in physics."

"I find that shocking! Do you say that living things don't obey the laws of physics?"

"Insofar as living things are objects they obey the laws," he said. "A living thing will be attracted by gravity in exactly the same way as a nonliving thing. If I apply a voltage to something that is alive, the current that flows will be exactly the same as when the voltage is applied to something that is not alive but has the same electrical resistance. The point is that living things don't obey any other general law that we know about."

"Do you think they obey general laws that we don't know about?" I asked.

"I didn't say that. You're putting words in my mouth," he replied.

I told Pick that was not my intention, and he settled down. Then I looked away from Christopher and asked no one in particular, "Why is it necessary to identify a mechanism before the ability of EMFs to alter the immune system is accepted as plausible? Shouldn't any attempt to identify mechanisms, if that is possible, be taken after the ability to affect the immune system has been established, for the reason that only real effects can have mechanisms?"

The room became silent, as if I had been rude to our host, but Christopher's thoughtful reply put me at ease. "Then you suggest that the principle of biological plausibility puts the cart before the horse?"

"It seems that way to me," I replied.

At this point, several committee members who had previously been silent spoke up and expressed one degree or another of criticism of this or that aspect of the point I had raised, and tempers flared. When this happened the observers sitting with Erica perked up, as if a show was about to begin. The situation was skillfully rescued by Christopher, however, who calmed the committee by thanking its members for their deep interest in the issues. I took advantage of the calm to ask Mandel, "If the laboratory evidence explains how EMFs could cause cancer, would it then follow that powerlines are unsafe?"

"Not necessarily. Just as it does not follow that low levels of mercury in drinking water are unsafe even though mercury is toxic."

"Because toxicity always depends on dose?" I asked.

She agreed.

"For example," I said, "someone might need to drink as much water as an elephant before the mercury levels could cause harm."

She agreed.

"Suppose we conclude that the laboratory evidence does not explain how EMFs cause leukemia or brain cancer. Would it then follow that powerlines are safe?"

"It would certainly seem so. From a scientific point of view, if a thing is not unsafe, it is safe."

"Then the principle is the same as in algebra: a negative multiplied by a negative is a positive."

She agreed.

At this point several committee members called for a vote because, they said, the discussion had become tiresome and it was time to move on to a new topic. Christopher acquiesced and put to the vote the question, "Do the laboratory studies of the effects of EMFs on the immune system of animals convincingly demonstrate that EMFs can affect the immune system?" The final vote was no, 16, yes, 8, and 3 abstentions.

After lunch, when a sense of comity had returned, Christopher asked Juko to summarize the studies of the effects of EMFs on the brain, to assess whether there were such effects and, if so, whether they could be responsible for physiological changes leading to brain cancer.

In his speech Juko said that the studies involving the effects of EMFs on the brain had reported every kind of result imaginable. To the amusement of many on the committee, he said, "Whatever your favorite result

is, I can point to someone who found it and someone else who didn't," and he proceeded to give examples.

"There are reports that EMFs affected the electrical activity of the brain," he said, "but other reports concluded that no such effects existed. Among those who report effects, some said that the energy in the brain waves increased but others said that it decreased. The story is the same for studies involving intracellular levels of calcium ions. Some said it went up, others that it went down, and still others that it never changed."

He said that because the studies were "incoherent" he had to conclude that EMFs alone can't affect the brain, at least not to the extent that they could cause cancer. He said his own research, though, had shown that EMFs "may act as a co-carcinogen."

Barnes, recognizing that Juko was a foreigner and perhaps not knowledgeable regarding the nuances of English, asked him, "In English, 'may' could be 'I just don't know,' or 'Definitely yes, but only in particular circumstances.' Which is your meaning?" Juko replied that he had both meanings in mind.

Justesen asked Juko whether he had meant to say that the EMF research was "incoherent" or "inconsistent." When pressed to explain what he understood the difference to be, Justesen said that "incoherent" meant that two things did not rise and fall together in a fixed relationship, like two waves spreading on a pond, and that "inconsistent" meant that two things could not both be true, because the truth of one thing opposed the truth of the other thing. For example, it would be inconsistent to claim that a clown was happy and sad because being one precluded being the other. Juko confessed to not recognizing any distinction between the words, and after a long discussion a consensus developed that while a distinction might exist between the terms in some contexts, there was none in the case of the EMF studies.

I then asked Juko, "Is the evidence 'incoherent' or 'inconsistent' because, for example, one study claims that EMFs increased the energy of brain waves in people whereas a similar study claims EMFs decreased it and a third study claims there was no effect?"

"Yes, that's a fair summary of the pattern of results," he replied.

"Then the evidence is incoherent because, according to what you believe, if a phenomenon were real it would be verifiable."

"Not only according to what I believe," he said, "but according

to science."

"And verification was absent because in one case the energy increased, in the second case it decreased, and in the third case it was unchanged. Is that right?" I said.

"Yes," he said.

"What exactly must be verified?" I asked.

"If the reality were that EMFs increased the energy, then that phenomenon would have to be verified before it could be accepted. If EMFs actually decreased the energy, then that would have to be verified."

"By 'reality' you mean what is objectively true?" I asked.

"Of course," he replied.

"Couldn't it be the case that the phenomenon to be verified was exactly what was observed – that sometimes the energy increased, sometimes it decreased, and sometimes it was unaffected?"

"That would be a strange state of affairs," he said. "There must be a law that determines whether the energy is to increase or decrease because, according to science, everything that happens does so by necessity. It is law that requires one alternative or the other. If we observe both kinds of changes, and also neither, the plain meaning is that there is no law. Wouldn't you agree that is a proper scientific explanation?"

"Undoubtedly, at least for gravity and alchemy," I said, "because that explanation makes it clear why one is useful and the other isn't. Still, I wonder whether your explanation is no more than an opinion, or perhaps only a special rule. Would it not be permissible for a scientist to believe that the rule applied in only some cases, and not in others, and that EMFs were an example of the kinds of cases in which the rule did not apply?"

"I don't know what you mean," he said.

"Suppose two theories claimed to explain something but one of them was more in tune with the observations. Would you agree that it would be more preferable?"

"Of course."

"Doesn't my theory – which is that EMFs can affect the energy in human brain waves, either increasing it or decreasing it, but that the occurrence and the direction of the effect in specific human beings is unknowable – fit the data better than your theory that the body of research has no meaning because it resembles a sequence of positive and negative numbers that add up to zero?"

"Why on earth would you say that the occurrence of an effect in a particular case, or its direction, is unknowable?" he asked.

"Why would you say it must always be otherwise?" I said.

"All of our scientific laws require consistency. When the conditions are the same, the results must be the same."

"I would not deny that our laws require consistency. But isn't that because they were made that way?"

"Wait. That's another error on your part. Our general laws were not made by man – they were made by nature and discovered by man."

"But as Dr. Pick pointed out this morning, living things don't obey general laws. There is no force that descends on human beings and requires a particular response in each individual. This being true, I think there is no reason to suppose that the consistency built into the laws that describe nonliving things should be imputed to the behavior of living things, for which there are only particular laws."

As I suspected would happen, Pick chimed in.

"Dr. Marino, is it necessary for you to use such vague language?" Before I could reply Christopher said, "Andy, could you make your point using clearer language?"

I asked Christopher whether I should do so by continuing the argument, or by means of a story, and he replied that the choice was mine. Several dozing committee members suddenly awoke and said it would be more interesting if I were to tell a story, and so that's what I did.

"In the beginning, God made an infinite number of equations that governed everything that happened in the world. But He was dissatisfied because the world was only a machine, and therefore had no capacity to love and honor Him, so He created human beings and gave each one a unique equation that was not controlled by an outside force. To the humblest and most self-effacing human beings God gave superior intellects so that they could eventually come to understand His handiwork. Those so favored, who became known as physicists, eventually learned to understand the equations that controlled the part of the world that was a machine, and progressively distilled them into smaller and fewer classes of greater generality. After a long time the physicists finally intuited the perfect equation, the one that completely governed the machine.

"It had been God's plan that the humble physicists would also learn that there was no single universal equation that governed life, because He

had intended that human beings would not be machines, and hence not perfectly predictable. Now there was an angel named Grun, who was one of those who had disobeyed God and was banished from heaven. In retribution, Grun went among human beings attempting to implant in their minds the belief that they were only machines, like the rest of the world. He hoped to thwart God's plan and drive people to despair, because machines have no purpose.

"Grun was rebuffed by most human beings who immediately saw that his message was preposterous on its face. The physicists, however, who were always receptive to ideas that benefited all human beings, became victims of their own open-mindedness; they embraced Grun's message and became its proselytizers among other scientists, who profoundly respected what physicists had accomplished and therefore believed in the truth of everything they said. As a consequence, scientists came to believe they could know everything, as God knows it. This explains why Juko believes as he does."

When I finished, animated discussions broke out among the committee members. On one side, there were those who were anxious to show their support for Dr. Pick, who had announced that he hadn't come to listen to myths aimed at rehabilitating worthless studies, and that it was now time to vote and move on. There was also a group that seemed to think my theory made sense. Most of the action was in the center ring, where a shouting match occurred regarding the basis for choosing between Juko's theory and mine.

Christopher saw that no one was winning any converts so he said, "Let us put aside for now the discussion of what the proper underlying view is. We can return to it later." Then he began to question me directly, something he had not done to anyone else on the committee. "If EMFs affect brain waves and lead to brain cancer in some cases, as you say, then the evidence that we have on the large scale would seemingly be inexplicable. Since high-voltage powerlines were first built in the United States, consumption of electrical energy has increased each year, but death from brain cancer has not risen at the same rate. This shows that powerline EMFs pose no significant hazard to the average person."

I thought about Christopher's argument for a few moments and then said: "Even if one believes that the cancer rate has lagged behind the rate of powerline growth, the difference might have meanings other

than the one you suggested."

"What are you getting at?" he said.

"Suppose we asked what it means when an animal wags its tail," I said. For a cat the act is a manifestation of discontent. For a dog, tail-wagging indicates health because a sick dog never wags its tail. Some say that a cow wagging its tail manifests contentment, and the same may be true for a deer, which is known to indicate fear when it freezes its tail in an upright position. So the fact of tail-wagging can have many different meanings."

"You'll have to do better," Christopher said, "wagging tails are different than brain cancer."

"Dr. Philip Handler," I said, "when he was president of the National Academy of Sciences, appointed three different blue-ribbon committees to study the question of health risks due to powerline EMFs. These experts examined all sides of the issue, yet none concluded that EMFs were safe because of a mismatch between the rates of powerline construction and cancer death. The possibility should therefore be considered that your argument has a hidden defect that is not presently apparent to you."

Christopher had no ready reply, so I continued. "It is unprofitable for us to spend our time debating the meaning of expert committees whom we cannot question directly. Rather we should try to get at the truth by the direct interplay of our own thoughts."

He nodded in agreement.

"I would therefore like to suggest an alternative to your interpretation of the facts."

"Please do," he said.

"EMFs affect the brain waves in each exposed subject," I said, "but the consequences of that detection process are different in different people, like two adjacent raindrops released from a cloud and striking the earth at widely separated points. The claim is not that EMFs can cause only brain cancer, but rather that they can cause all cancers, indeed all diseases, in the sense that their presence always raises the probability for disease in an individual, compared with their absence. This capability is not unique to EMFs – it is probably manifested by all stressors. One reason, therefore, that the incidence of brain cancer has not increased in proportion to the levels of EMF in the environment could be that EMFs are killing people in other ways."

The fractious nature of the issues under discussion again led the com-

mittee to boil over. Christopher responded by adjourning the meeting for the day, but not until he promised me that we would return to the discussion of the two theories.

As Erica and I were passing through the lobby on our way to dinner, we came across a young girl and her father who were arguing with a woman who wore bright red cheek-rouge. Her name-tag identified her as the superintendent of the local school district. We listened, and learned that the girl had been a contestant in a high-school science fair being held at the hotel, and that her project had been judged the best but the superintendent had refused to award her the trophy. When the girl's father pressed for an explanation the superintendent told him, "The project basically encourages sex, and our philosophy is abstinence." When Erica and I went over to where the projects were on display, we saw that the girl had tested six different brands of condoms and found that one brand was stronger than the others.

After dinner, on our way back to our hotel we were delayed because traffic was stopped to allow rescue vehicles and police cars to come and go. Later that evening I learned that an aerial performer at the circus had been twirling from a long piece of chiffon, which had snapped. There was no safety net and she was not wearing a harness, so she fell thirty feet onto the concrete floor and died.

The next morning, Christopher and Ruhig joined Erica and me at breakfast. Soon after he sat down Christopher said, "If, as you speculated yesterday, the consequences of EMFs differ from person to person, how is it possible to decide whether EMFs cause cancer? Wouldn't we be left with only mysticism or some kind of teleology?"

"Would you agree," I said, "that what makes something scientific is that it can be described by a rule that allows predictions?"

"Yes."

"And that it would still be scientific even if the predictions were not perfect, like predictions about whether a medicine or a treatment for a disease will be successful?"

"Yes," he replied. Then he asked, "What method is there to make reliable predictions?"

"The same method that was used to discover the general laws of physics," I replied.

"Induction?"

"Yes. The method of induction. It's not possible to answer our question about EMFs using the method of proof, because there is no underlying law that governs everything by necessity. Instead, every human being is a self-enclosed whole, governed by a unique law. But it would be reasonable to search for a pattern in how human beings react to living in a sea of EMFs. That pattern would be the answer to the question whether people who live or work in high EMFs have a higher rate of brain cancer or leukemia compared with people who live in low EMFs or no EMFs."

Christopher nodded, and then left the table to prepare for the next session of the committee, which was to be devoted to the human studies. When he was well out of earshot, Erica said, "He seems troubled."

"He has good reason," I said, "because he has a heavy responsibility."

In his opening remarks to the committee on the last day of the meeting, Christopher said only, "Today we will consider whether the EMFs in homes or industry can cause health problems. Do people who live or work in EMFs have a higher than expected cancer rate?" Before he called on anybody to summarize the evidence, I said, "Who has the burden of proof, those who would say 'yes,' or those who would say 'no,' and by what standard of certainty?"

Pick couldn't let this pass. He said, "There is only one standard in science, truth, so it makes no difference who has the burden of proof. In science, at least, the search for truth is not an adversarial process. We are not lawyers, at least not most of us."

When the buzzing at the table and in the audience seated behind us had ceased, I said, "But we are human beings and therefore prone to error. If you think about the consequences of error, you can see why the choice of a standard is crucial. We could err by accepting that EMFs don't cause cancer when in reality they do, or by accepting that they do when they don't. The two errors do not have equally bad consequences. Either the people who live near powerlines will be injured by loss of health, or the power companies will be forced to needlessly bear the costs of undergrounding the powerlines. If you believe the people have at stake the interest of greater importance, you will not conclude there is no risk when there is a reasonable doubt about the truth of that claim."

Pick's reply illuminated his value system. "It would be far better for the overall stability of society," he said, "to advise the public that powerlines

were safe, at least until we were certain that this is not the case, because a definite answer is preferable to vague allusions of potential problems."

Barnes then gave his point of view, saying, "I think it is better to be safe than sorry. So it would be prudent to make worst-case assumptions about the human studies and build in a margin of safety to avoid risk." Pick then accused Barnes of denying that there was an identifiable standard for assessing what is or is not a fact in science.

I said to Pick, "Regarding the health risks of EMFs at least, it looks as if the facts are whatever those in authority say they are by the expedient of choosing and assigning the burden of proof, like setting the bar so high only a few jumpers can clear it. So the facts are the choices they make."

"Who are 'they?'" he asked.

"We should have a discussion about that," I replied.

Christopher diverted attention from that suggestion by turning to Monica Lugner and Eva Stum, two sisters who represented the largest stakeholder in the EMF dispute, the Electric Power Research Institute. They had formerly worked as experts regarding the health implications of depleted uranium and the hole in the ozone layer, and had recently moved into the EMF area and begun to opine that high-voltage powerlines were completely and absolutely safe, with no ifs, ands, or buts. Many businessmen and housewives had been swayed by the sisters' view. He said to them, "Obviously you cannot discuss comprehensively the human studies in the short time available, but tell us this. Besides satisfying those who are already convinced that the human studies show powerlines are safe, do you think you can appeal to someone who is not yet convinced?"

"Definitely," Lugner answered. "But rather than simply giving a lecture for which we might be criticized for picking and choosing the evidence that we considered, I would like to ask for someone on the committee to volunteer to respond to our questions concerning the basic principles of human studies. If you have no objection." Christopher nodded his approval.

At this point Afelis spoke up and said, "I would be happy to respond to questions, so that we can quickly get to the bottom of the matter."

"Tell me, do powerlines cause cancer?" Lugner asked.

"If we believed the Wertheimer study, and several others, we would say yes. But if we accepted your studies we would say no," Afelis replied.

"Did Wertheimer claim that children who lived beside powerlines got cancer more often than children who lived elsewhere?"

"Yes."

"Because of EMFs?"

"Yes."

"But the children who didn't live near powerlines also got EMFs from other sources. Isn't that true?" Lugner asked.

"Surely," Afelis replied.

"Then if EMFs were present in both groups, isn't it illogical to claim that they caused more cancer in one group than the other?"

"Perhaps there were more EMFs along the powerline?" he said.

"Did Wertheimer measure the EMFs along the powerline?" she asked.

"No," he replied.

"Then she would have no way of knowing whether there were more of them at that location, correct?"

"Well, I suppose it's reasonable to assume that EMFs are higher near powerlines," Afelis replied nervously.

"But it's not established as a fact in her study, is it? It's just speculation."

"Yes."

"Suppose we studied cancer among men who worked as stockbrokers and insurance salesmen," she said. "We would not expect to find exactly the same number of cancers in the two groups, but rather that the number would be greater in one of them, correct?"

"It would be quite extraordinary if the numbers were exactly the same," he said.

"Suppose it was higher among the stockbrokers. Could we conclude that selling stocks caused cancer?"

"That would be foolish."

"Suppose we conducted the same study among women who were either nurses or teachers, and we found that the number of cancers was higher among the teachers. Could we conclude that teaching causes cancer?"

"No."

"If children who drank white milk got more cancers than children who drank chocolate milk, would it be fair to say that white milk causes cancer in children?"

"Of course not."

"Isn't comparing children who live beside powerlines with those who don't the same as these cases, so that there is no reason to claim that powerlines cause cancer."

Before Afelis could answer, Stum piped up and said, "Actually, powerlines cure cancer."

"I never heard anything like that," Afelis said, with a surprised look on his face.

The pair's admirers on the committee cheered, while others were speechless with amazement. I suppose to astound us even more, Lugner kept on relentlessly questioning Afelis with the same method.

"You know, don't you," she said, "that EMFs are used by physicians to treat disease?"

"Yes."

"And that the government has said they are effective?"

"Yes, for treating bone diseases."

"Do you agree that a thing cannot at the same time be itself and its opposite?"

"I don't know what you mean."

"If something is hot, it cannot at the same time be cold. If a thing is good, it cannot at the same time be bad."

"Yes," he said, "but…"

"Then if EMFs cure disease," Stum interrupted, "they cannot cause disease, and since cancer is a disease, EMFs cannot cause cancer."

"I can't argue with you," Afelis said.

The sisters were winding up to throw Afelis still another curve ball, but I had had enough, so I jumped in and said to him, "It would have been appropriate to make a distinction between the conditions under which EMFs are applied. Their successful use under the careful control of a physician does not imply that good results would occur when EMFs are applied to everyone by the power company. Things are not good or bad in themselves. And earlier, when the probative weakness of questionnaire studies was pointed out, you didn't seem to appreciate that the trick being played was to deny the usefulness of questionnaire studies simply because they do not yield clear and unambiguous results, like making the perfect the enemy of the good."

Then I said to the sisters, "Enough of these games. Any more would be superfluous. Please begin to try to convince us that EMFs are safe, as you say."

I watched to see if Christopher would take up my theme and encourage the sisters to present more substantial arguments. He said nothing, however,

and they launched into more, similar arguments, which neither I nor anyone else on the committee was willing to address. Near the end of their performance, Stum addressed the committee as a whole and said, "The studies that purport to link powerlines with cancer of the brain or blood all suffer from statistical uncertainties, so it is a fallacy to suggest that the results mean anyone's chances of getting cancer are increased by EMFs."

Christopher shifted the focus of the conversation by asking, "Dr. Lugner, some experts have written about what has been called 'the precautionary principle.' Would you tell us how you think it ought to be applied in evaluating the human studies about EMFs?"

"There is no evidence in the human studies that can rationalize the need for any precautions insofar as EMFs are concerned," she replied.

That was too much for some of the members of the committee and shouting matches developed, leading to a loss of decorum that prevented Christopher from taking a vote regarding the significance of the human studies on EMFs. The next morning he folded his tent and took his show on the road to two other cities.

On the way home I asked Erica whether Christopher had lived up to her expectations. "Not in the way I expected," she said. "I think preventing disease is a subject that can be learned and taught, but not by means of his three great principles. His approach reminds me of the way someone might train a dog."

"Then how?" I asked.

"I think your way is better."

Christopher finally returned to the NIH and began to ponder his decision. What happened during those crucial months, according to a source within the NIH who was present at almost all the important meetings, shaped both Christopher's fate and the fate of the public. The story began at the Dallas meeting, which had been where Christopher came to believe that there was a realistic possibility that EMFs from powerlines caused cancer, and even that EMFs might have other effects on health that were largely unknown because they were largely unstudied. He had expected the representatives of the Electric Power Research Institute to act like barkers at a carnival, and had included them in the meetings only because he was required to do so by Olden. But Christopher had believed he still could orchestrate a give-and-take among the other participants that would lead inexorably to the identification of the presence or absence of good science

capable of resolving the EMF issue. That idea died in Dallas, and his view of science fell into disequilibrium. Ultimately, he concluded that the best answer to the question posed by Congress was that the issue of EMF safety was very complicated and could not be resolved on purely scientific grounds in the absence of rules regarding the meaning of uncertainty.

Christopher sought Ruhig's support and found him sympathetic. He too felt that Olden's order to "resolve the issue" couldn't be implemented in light of what had taken place at the meetings. Nevertheless, Ruhig reminded Christopher that they both worked for Olden, who was attempting to obey a direct congressional mandate, and that he had told them that he would accept one of only two possible outcomes: either there is strong, certain evidence that EMFs cause cancer, or EMFs are safe. Ruhig told Christopher there was nothing they could do about Olden's order, as much as they would like to, and he advised Christopher to obey it.

Christopher, however, resolved to follow his conscience. He told Olden that the question put by Congress could not be answered on the basis of scientific principles alone, and that the moral force of science, and the respect and confidence that people have in it should not be weakened by asserting scientific certitude where none existed. Olden again reminded Christopher that the only permissible outcomes of the inquiry were that there is strong, certain evidence that EMFs cause cancer, or that EMFs are safe. And that if the NIH were to proclaim that EMFs caused cancer, Christopher needed to be as certain of that fact as a human being could be. When Christopher held his ground Olden removed him from the adjudicatory process and ordered Ruhig to draft a report that concluded EMFs were safe.

Ruhig asked his staff to prepare a statistical estimate of the number of deaths due to brain cancer and leukemia that could be attributed to powerline EMFs. He had thought that the number would be minuscule, and thus that the estimate could serve to support Olden's decision. According to the analysis, between six and six hundred cancer deaths would occur annually for each one million people in the population. When Olden learned of this estimate, he began to have doubts about his course of action, and particularly about whether the oath he had sworn as a physician to do no harm would permit him to issue a judgment that could result in such severe harm to so many people. He knew that the EMF research program would be ended if he concluded that EMFs were safe, and thus that his conclusion would not be challenged. His doubts deepened; he became depressed,

and he began to complain about not feeling well.

In the meantime, Ruhig produced a draft final report that concluded EMFs were safe, as he had been instructed to do; the statistical estimate was not included because it pointed in the wrong direction.

As Olden agonized about what he would do, the whole affair rapidly came to a conclusion by means of forces he could not control. The end began when someone leaked the draft final report to congressmen who had been instrumental in the creation of the EMF program. They immediately went on CNN and took credit for solving the problem of EMFs, and the story appeared in all the major newspapers. In the face of this publicity, Olden decided that the only course open to him was to release the report, which he did. It was lavishly praised by the Electric Power Research Institute, which said that the process NIH had followed to evaluate powerline EMFs should also be used to evaluate the supposed problems with nuclear waste.