Take the World From Another Point of View

This is a Yorkshire Television interview with Richard Feynman, which was shown in Great Britain in 1973. Our article is an abridged—but otherwise unedited—transcript of the sound track, with the comments and questions of the interviewer in italics.

Take any crazy idea. It is hard to make up a very crazy idea—witches, for instance. And you talk about what people used to believe about witches, and you say, "How could they believe in witches?" And you turn around and you say, "What witches do we believe in now?"

What ceremonies do we believe in? Every morning we brush our teeth. What is the evidence that brushing our teeth does any good against cavities? And you start wondering. Are we all imagining that, as the earth turns and the orbit has an edge between light and dark, that along that edge all the people are doing the same ritual—brush, brush, brush—for no good reason? Have you tried to picture this perpetual line of toothbrushes going around the earth?

Take the world from another point of view. Now it may well be that brushing the teeth is a very good thing because it gets rid of cavities, but you can try to find out whether it does or doesn't. You ask your dentist. He says, "Of course." And you say, "What about evidence?" I have not found the evidence from dentists, because they just learned it in school. Now I am not trying to argue whether it is good or bad to brush teeth. What I am trying to argue for is to *think* about it. Think about it from a new point of view.

You see—I have had in my life a number of pleasant experiences. One of the earliest ones was when I was a kid and I invented a problem for myself—the sum of the powers of the integers—and in trying to get the formula for it I developed a certain set of numbers, the formula for which I couldn't get, and I discovered later that those were known as the Bernoulli numbers and they were discovered in 1739. So I was up to 1739 when I was about 14.

Then a little later I'd discover something, and I would find out that I just may have invented a thing which we now call operator calculus. That was invented in 1890 something.

Gradually I was inventing things that came later and later. But the moment when I began to realize that I was now working on something *new* was when I read about quantum electrodynamics. I read a book, and I learned about it. For example, I read Dirac's book, and he had these problems that nobody knew how to solve. I couldn't understand the book very well because I really wasn't up to it. But there in the last paragraph at the end of the book it said, "Some new ideas are here needed." And so there I was. Some new ideas were needed. OK—so I started to think of some new ideas.

Richard Feynman, Nobel Prizewinner, and his son Carl step gingerly down the wet cobbles of Millback, high in the Yorkshire Pennines. Feynman, professor of physics at the California Institute of Technology, retreats to this remote village near his wife's home for a special purpose. It is here he finds the time and solitude to sift the ideas that have made him the most feared and original mind in modern physics. Feynman is in the forefront of one of the oldest and most intriguing games of hide and seek in science—finding the ultimate constituents of the world. In this search Feynman is a celebrated maverick who was encouraged by his father, who was a New York clothing salesman, to confront conventional wisdom.

One Sunday all the kids were walking in little parties with their fathers in the woods. The next Monday we were playing in a field, and a kid said to me, "What's that bird? Do *you* know the name of that bird?"

I said, "I haven't the slightest idea."

He said, "Well, it is a brown-throated thrush." He said, "*Your* father doesn't teach you *anything*."

But my father had already taught me about the names of birds. Once we walked, and he said, "That is a brown-throated thrush. In German it is called the *Pfleegel-flügel.* In Chinese it is called *Keewontong.* In Japanese a *Towhatowharra*, and so on. And when you know all the names of that bird in every language, you know *nothing*, but absolutely *nothing*, about the bird."

So I had learned already that names don't constitute knowledge. Of course that has caused me a certain amount of trouble since because I refuse to learn the name of anything. So when someone comes in and says, "Have you got any explanation for the Fitch-Cronin experiment?" I say, "What's that?"

And he says, "You know—that long-lived k meson that disintegrates into two pi's."

"Oh, yes, *now* I know."

I never know the names of things.

What my father forgot to tell me was that knowing the names of things was useful if you want to talk to somebody else—so you can tell them what you are talking about.

The basic principle of knowing about something rather than just knowing its name is something that you have stuck to, isn't it?

Yes, of course. We have to learn that these are the kinds of disciplines in the field of science that you have to learn—to know when you know and when you don't know, and what it is you know and what it is you don't know. You've go to be very careful not to confuse yourself.

How else did he try to mold your methods of thinking—the way you looked at the world?

Well, we had a lot of little games. Like at the dinner table he would pick up some little problem, and he would say, "Supposing we were Martians, and we came down from Mars to this Earth, and we would look at it from the outside." I can't explain exactly what he meant, but there is a way of looking at something anew, as if you were seeing it for the first time, and asking questions about it as if you were different. For instance, suppose you were a Martian who never slept. (They don't have to sleep, say.) And you come down to this Earth and you saw these people who have this funny property that every day for a certain amount of time they have to lie down and they're unconscious. Then the natural questions would be: How does it feel to get unconscious? What happens to you? Do ideas run along and suddenly they stop? Or do they just run more and more slowly? Or what *happens* to your ideas?

So I tried to answer the question: What happens when you become unconscious?

Do you find that these days when you are faced with a particularly difficult problem, when you are absolutely stuck, you still tend to say, "Let's look at it like a Martian would look at it?"

Sometimes. But there are a lot of things that people have done.

For example, Faraday described electricity by inventing a model (field lines). Maxwell formulated the equations mathematically with some model in his head, and Dirac got his answer by just writing and guessing an equation. Other people, like in relativity, got their ideas by looking at the principles of symmetry—and Heisenberg got his quantum mechanics by only thinking and talking about the things he could measure. Now take all these ideas: Try to define things only in terms of what we can measure. Let's formulate the equation mathematically, or let's guess the equation—all these things are tried all the time. All that stuff—when we are going against the problem, we do all that. It is very useful, but we all know that. That is what we learn in physics classes—how to do that.

But the *new* problem is where we are stuck. We are stuck because all those methods don't work. If any of those methods would work, we would have gone through them. So when we get stuck in a certain place, it is a place where history will not repeat itself. And that even makes it more exciting. Because whatever we are going to see—the method, the trick, or the way it's going to look—it's going

When you know the name of a bird in every language, you know nothing— but absolutely nothing— about the bird

to be very different from the way we have seen before, because we have used all the methods from before. So therefore a thing like the history of the idea is an accident of how things actually happen. And if I want to turn history around to try to get a new way of looking at it, it doesn't make any difference; the only real test in physics is experiment, and history is fundamentally irrelevant.

The most enduring legacy from his father was not just learning to question the physical world, but an enthusiasm for the inquiry, which—at 54—Feynman shares today.

It has to do with curiosity. It has to do with people wondering what makes something do something. And then to discover, if you try to get answers, that they are related to each other—that things that make the wind make the waves, that the motion of water is like the motion of air is like the motion of sand. The fact that things have common features. It turns out more and more universal. What we are looking for is how everything works. What makes *everything* work.

What happens first in history is that we discover the things that are on the face of it obvious. And then gradually we ask small questions, and then we dig in a little deeper into things that we need to do a little more complicated experiment to find out about. But it is curiosity as to where we are, what we are. It is *very* much more exciting to discover that we are on a ball, half of us sticking upside down and spinning around in space. It is a mysterious force which holds us on. It's going around a great big glob of gas that is fed by a fire that is completely different from any fire that we can make (but now we *can* make that fire—nuclear fire.)

That is a much more exciting story to many people than the tales that other people used to make up about the universe—that we were living on the back of a turtle or something like that. They were wonderful stories, but the truth is so much more remarkable. So what's the pleasure in physics for me is that it is revealed that the truth is so remarkable, so amazing, and I have this disease—like many other people who have studied far enough to begin to understand a little of how things work. They are fascinated by it, and this fascination drives them on to such an extent that they have been able to convince governments and so on to keep supporting them in this investigation.

As a theoretical physicist, Feynman in recent years has been concerned with the long-asked, almost childish question, "What are things REALLY made of?" "What makes up the world we see around us?" "Have we at last come to the foundation stone from which we can make anything—a tree, a human being—or must we go on looking at smaller and smaller pieces and going deeper and deeper into a bottomless pit?" Feynman is trying to knit together our scattered knowledge of the smallest pieces of matter to see whether they fit a pattern. The problem, although fundamentally important to all branches of science, seems far removed from everyday reality.

The world is strange. The whole universe is very strange, but you see when you look at the details that the rules of the game are very simple—the mechanical rules by which you can figure out exactly what is going to happen when the situation is simple. It is like a chess game. If you are in a corner with only a few pieces involved, you can work out exactly what is going to happen, and you can always do

that when there are only a few pieces. And yet in the real game there are *so* many pieces that you can't figure out what is going to happen—so there is a kind of hierarchy of different complexities. It is hard to believe. It is incredible! In fact, most people don't believe that the behavior of, say, me is the result of lots and lots of atoms all obeying very simple rules and evolving into such a creature that a billion years of life has produced.

There is such a lot in the world. There is so much distance

continued on page 22

Take the World from Another Point of View...

continued from page 13

between the fundamental rules and the final phenomena that it is almost *unbelievable* that the final variety of phenomena can come from such a steady operation of such simple rules.

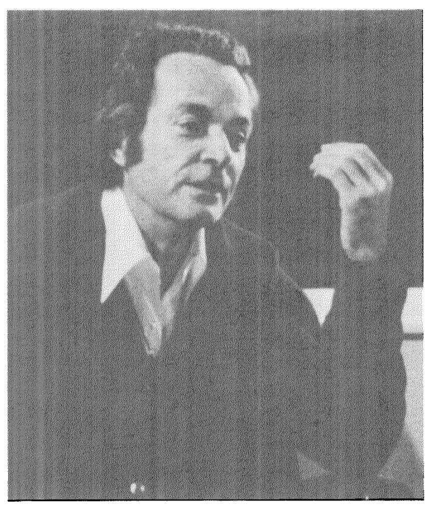
Do you have to build the most complex scaffolding to find out the simple rules?

But it is not complicated. It is just a lot of it. And if you start at the beginninng, which nobody wants to do—I mean, you come in to me now for an interview, and you ask me about the latest discoveries that are made. Nobody ever asks about a simple, ordinary phenomenon in the street. What about those colors? We could have a nice interview, and I could explain all about the colors, butterfly wings, the whole big deal. But you don't care about that. You want the big final result, and it is going to be complicated because I am at the end of 400 years of a very effective method of finding things out about the world.

In the search for the ground rules of the physical world, John Dalton worked out a complicated explanation over a hundred and fifty years ago. He assumed that everything we see is made out of tiny atoms, that they are immutable and indestructible, and that atoms of different chemical elements—like lead or copper—have different weights. Too small to be observed, the atoms combine with each other to form complicated molecules, and vast collections of these molecules are recognizable to us as tables, trees, or whatever. But in the final analysis atoms were to be the smallest constituents of matter, ultimate and unchangeable.

At the turn of the century we evolved our present picture of the atom—light electrons surrounding a heavy central core or nucleus. Once the atom was shown to be destructible, attention turned to the nucleus, and during the thirties it was found that bombarding one nucleus with another led to a release of energy and the breaking up of the nuclei. This process, which takes place in nuclear accelerators, is photographed in a liquid bubble chamber.

Take a liquid—liquid hydrogen or some other liquid—and expand it so it is ready to boil at low temperature and it has to boil and it has to form bubbles some way, and any little piece of dirt or any little disturbance in it will form a bubble. In that condition, if a particle comes flying through from some machine, it leaves a track, it tears up the atoms along its track. We can't see that, but when the liquid tries to boil, the bubbles form around these charged particles which are left, and we can take a picture of the bubbles. So the simplest picture would be of a string of bubbles. But if the particle on the way through hit the nucleus of another atom, then



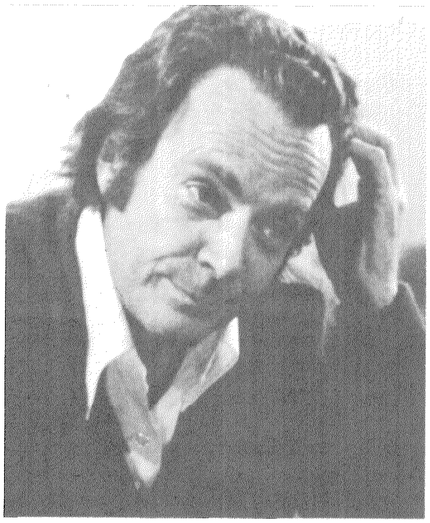
you see a string of bubbles in a kind of a Y. Or instead of a Y you may see an even more complicated track—three or four coming along and then one of them going into two—and you know that some particle went along and disintegrated. Now these things are going nearly at the speed of light, so a short distance of a few centimeters corresponds to a tenth of a billionth of a second. That is, if a track comes out and goes along and then bifurcates into two, you know you made a particle disintegrate into two in less than ten-billionths of a second. So you see it is not very difficult to find out about these things with clever techniques.

Since the war, with evidence from bubble-chamber photographs, physicists have explored the nucleus of the atom. The results have been spectacular and confusing. The harder the nuclei were bombarded against each other, the more they disintegrated into even tinier particles until literally hundreds were known. In the last ten years some order has been made out of seeming chaos by arranging the particles into patterns. Each pattern has 8 or 10 members related by nuclear properties like spin and mass. To the physicist, these patterns imply the possibility of even smaller particles not yet identified but already named. The key to the question of what makes up the physical world, then, lies in the understanding of the nature of these nuclear patterns.

We are getting close because we have a number of little theories by which we can understand these patterns. One picture, which describes what particles you are going to find rather well, is that all these particles are made up of something else which we happen to call quarks. Now a quark is an object which comes in three varieties. It is either an A type, a B type, or a C type of quark. The particles that we find are two big classes, and one class we can understand as being made out of three quarks. And depending on the different proportions —how many A, B, and C's—and how they are moving around each other, we *count* how many states we would get from putting three objects together that can be made in so many ways—27 different ways, each one being three. We find groups of particles in groups of 27 analogously and so on.

It is a little more complicated and a little more subtle, but it is *like* that. And then when we allow for their motion *around* each other, we find the higher energy states. And even semiquantitatively there seems to be a relation between the states and the rates with which one turns into another, and so it looks like they are made out of just three quarks.

Then there is this other class of particles which we call mesons. The first class is called baryons (the words aren't going to do you any good), but the other class, the mesons, we have to understand as being made of one quark and one antiquark. An antiquark is a negative particle, with all the charge properties the exact opposite of a quark.



We make a quark and an antiquark, put those together, and we understand the meson state. Put three quarks together, and we understand all the others. So we have made really great progress in analyzing these patterns. So much so it looks very much as if, to me at least, that we are very close to understanding *this* part of physics—this strongly interacting system.

But what is the main barrier, still?

The main barrier is that we don't understand it quantitatively. We do not exactly understand the laws. I mean, we do things like I'm talking to you about, but a little more carefully, counting how many states we should get, and so on; but we don't know exactly how they move and exactly what holds them together, and so on and so on. Also, there are little paradoxes with this quark picture. It helps to give us the behavior at lower energies of what kinds of particles to expect. So you would expect that a particle would be made out of only three parts. But we have done some experiments at very high energy, hitting a proton with an electron —which can only be interpreted by supposing that the number of particles inside is really infinite—if there *are* particles inside. It can't be done with just three. You can calculate, and it doesn't come out right. So *there* is a difficulty.

Furthermore, the idea that there are just three particles is contradictory to the ideas of relativity and so on, which imply the existence of particles and antiparticles. And when there are three, it should be possible for the forces to produce pairs of particle and antiparticle in various numbers so there should not just be three but many more. So the infinity is not a paradox, by itself. The *three* is more of the paradox. Why is it so *simple*? Why can we get away and understand so much when there are just three—when there should be an infinite number, probably, in there, both theoretically and experimentally?

Another thing (it is a little technical but very paradoxical) is that we once had a rule for atoms that no two electrons can occupy the same state. It is called the exclusion principle. And we thought that we understood that that was necessary according to quantum mechanics, and relativity—it has to be. But with the quarks we find the exact opposite rule. Two particles *tend* to occupy the same state. The exact opposite seems to be contradictory with the principle.

There are ways of escaping this all the time, but only by complicating the picture. But the simplest picture of just three, which explains everything, is self-contradictory. Furthermore, some people suppose that maybe these quarks can come apart. That would mean the prediction of new states which would consist of only one quark, say. If there were such a state, it would have to have a charge of ⅓ the normal charges of our objects, for example—or ⅔. We don't find experimentally any such particles. Now everybody is looking for them, but it looks as if—if they exist at all—they have to be extremely heavy. Then the problem is, if they are extremely heavy, compared to a proton, say, how is it when you put three of them together you get a light object— one that is *not* heavy like a proton?

There are technical ways of arranging it, but they are always complicated. The situation is—as it always is when we are near the answer—it looks much simpler than it has any *right* to be; and we have to understand that simplicity and why we think it must be more complicated. Our minds are complicated, somehow. Just like the orbits of the planets, which were supposed to be circles, which looked simple. Then they found experimentally they weren't circles, so they made circles on circles on circles and got more and more complicated, and it turned out that it was really much simpler. It was a force varying inversely as the square of the distance which made ellipses and so forth. It was a different way of formulating rules entirely, which was beautiful. So now we have our wheels within wheels. It looks simple, and nature is no doubt simpler than all our thoughts about it now. And the question is, what way do we have to think about it so that we understand its simplicity? That is where we stand now.

On holiday, Richard Feynman is paid a neighborly visit by Yorkshireman Sir Fred Hoyle, the astronomer, cosmologist, and science fiction writer. At first sight there seems little in common between the study of galaxies and nebulae billions of miles in diameter and millions of light years old and nuclear physics where particles exist for only a million-millionths of a second. But the formation of stars and galaxies is determined on a massive scale by the behavior of the very nuclear particles Feynman studies. Hoyle and Feynman share an interest in the foundations of physics, and exchanging ideas in the

continued on page 24

Take the World from Another Point of View . . .
continued from page 23

local pub is always as profitable as it is enjoyable.

FEYNMAN: You agree that the quasars are in real trouble. That the very big redshifts—
HOYLE: I think so. I have had this uneasy feeling now for about five years. It looked crazy for a while, but evidence is piling up all the time.
FEYNMAN: Every piece of evidence is the same problem; each one makes a new problem. If there were any cause for a redshift as big as that, other than recession, we would be all right.
HOYLE: That's right.
FEYNMAN: But in the present physical laws there doesn't seem to be any place for such a redshift. And at the same time the same kind of laws predict the kind of peculiar phenomenon of black holes, which is really confusing. And it could be that either the gravity is wrong or one of the physical laws is wrong too.
HOYLE: I am not arguing at the moment that the physical laws are wrong. But you would agree that one has to push it through along these lines.
FEYNMAN: The best way to progress I would think is maybe to try to be as conservative as we can. Try to be as conservative about the physical laws as possible in explaining the phenomenon. If you continuously *fail*, then you gradually realize that you have got to change something. But if we start out saying we've got to change something, there are so many ways of changing. Most often you don't have to change anything. Most of the time we succeed in ultimately explaining these damn things in terms of the known laws—but the cases that fail are the interesting ones.
HOYLE: Yes. It's like the story of the chap under the single lamp in the street, where a passerby says, "What are you looking for?" and he says, "I am looking for my key," and they search for it for a few minutes and at the end of these few minutes the passerby says, "Are you sure you lost it here?" and the man says, "Not at all. But unless I lost it here, I'll never find it."
FEYNMAN: It is interesting that in many other sciences there is a historical question, like in geology—the question of how did the earth evolve to the present condition. In biology—how did the various species evolve to get to be the way they are? But the one field which has not admitted any evolutionary question is physics. Here are the laws, we say. Here are the laws today. How did they get that way?—we don't even think of it that way. We think: It has *always* been like that, the same laws—and we try to explain the universe that way. So it might turn out that they are *not* the same all the time and that there *is* a historical, evolutionary question.

HOYLE: But how do you see it going? It is hard to speculate.
FEYNMAN: You're the speculator. You and I think differently. I think of the possibilities, but I am afraid to put things in. When I see the dark, I always think of the dark as too *big* for me to guess at. It is not much use in guessing. But you are different, and I would like to discuss with you sometime how you do that, because I am really a little afraid to make specific guesses. I am afraid to make specific guesses because the moment I make that guess I can see seven other alternatives—so, since I see these other alternatives, I don't know which one to piddle with.
HOYLE: My choice is very simple. I don't set any requirement that the answer be right. It is just what I am interested in. That's the difference.
FEYNMAN: That's the difference. I am not trying to find out how nature *could be* but how nature *is*. See what's right.
HOYLE: Well, I don't think you'll ever find it, you see. I—
FEYNMAN: Your idea is to find out what nature *could be*.
HOYLE: No, no—what I think is *interesting*.
FEYNMAN: Even if it's wrong?!

Common ground is enthusiastically explored. But is it only shared experience and knowledge that form a bond between working scientists and separates them from us, the interested layman, or even the artist? . . . Are you really saying, Dr. Feynman, that you have more in common with, say, a paleontologist or someone in a branch of science very far removed from yours than you would with a playwright or a poet?

Absolutely. Especially if he is a good paleontologist. Because if he is a good paleontologist, he is not just looking at old rocks. He is looking into the history of the earth. He is looking when he is standing and looking at his own hand, and he is thinking of how it evolved with five prongs and so on.

Or the size of the brain? I can talk about stuff like dolphins have bigger brains than we have and they have a signaling system. And we start to discuss all that they know about dolphins, and we complain about the way that the United States Navy has been doing its experiments, and it's not right, and we ought to find out more about dolphins—and we could just go on and on.

When I talk to a playwright or something, I find—because I don't go to plays, or something—I don't find it easy

to talk to them. I don't get much out of it.

I was going to say that you can talk to scientists of other fields, presumably, because you both read the scientific magazines and hear the scientific gossip.

No, because we don't have to have magazines or gossip. We think originally. We think of a new idea. We talk to each other, and we try to look at something from a new point of view, and we delight each other in a new point of view. And when you are talking to somebody else who is trying to think of something new, different—and he has thought about the whales or the dolphins and he has some little thing that he has thought of that is a little different than the thing that you thought of—and so when you are talking back and forth, he is excited about your point of view and you are excited about the observations that he has made. And our backgrounds give us a slightly different point of view. Like I specialize in physics, and he specializes in paleontology; and so his information on, say, dreams might be deeper, more evolutionary. For example, he might know about animals. He might have thought about what other animals dream and what the signs are and a lot of things that I haven't thought of. I can't make it up now because I am not a paleontologist, but I believe, yes, I find always that a good man—I take it all back.

I take it all back. A *good* man—I have talked to good men in other fields. There are certain kinds of men in *every* field that I can talk to as well as I can talk to a good scientist. I met a historian, a writer of history from France once, and I had a marvelous conversation with him. Maurois, his name was. André Maurois. And then I met an artist, Robert Irwin, who is a very important artist, and I could talk to him at the same depth of excitement.

So I take it all back. If you give me the right man in any field, I can talk to him. I know what the condition is. That he did whatever he did as *far* as he can go. That he studied every aspect of it as far as he could stretch himself. He is not a dilettante in any way. And so he talked deep, as far as he can go, and therefore he is up against mysteries

all the way around the edge, and awe. And we can talk about mystery and awe. That is what we have in common.

After discussing working problems, it is natural that Feynman and Hoyle would savor that most thrilling pleasure of all, the moment of revelation.

HOYLE: You *try* all sorts of things, and you are hopeful about trying it—and you have a moment in a complicated problem when quite suddenly the thing comes into your head and you are almost sure that you have got to be right.
FEYNMAN: Yes. And then you try to figure out what the conditions were at that moment so you can do it again. For example, I worked out the theory of helium once and suddenly saw everything. I had been struggling and struggling for two years and suddenly saw everything. I can remember everything about it, by the way. It's psychologically funny—you can remember the color of the paper you were writing on and the room and everything else, and then you wonder what was the psychological condition. Well, I know that at that particular time I simply looked up and I said, "Wait a minute—it can't be quite that difficult. It must be very easy. I'll just stand back, and I'll treat it very lightly. I'll just *tap* it, boomp-boomp." And there it *was*. So how many times since then I am walking on the beach and I say, "Now look, it *can't* be so complicated." And I'll tap-tap—and nothing happens. The delights *are* great, but the secret way—what the conditions are—
HOYLE: It's that missing bit in the brain, isn't it, that suddenly lights up and—
FEYNMAN: Yes. And I have *no* idea. I've thought about it. Some man suggested I think about it once because if I could only figure out the formula for what condition to be in to get good ideas, I'd be much more efficient and more happy. So I've often paid attention to what the condition is, and I've never found any correlations with *anything*. By the way, it's the delight that is *ab*solute ecstasy. You just go absolutely wild.
HOYLE: How long does it last for, really?
FEYNMAN: It's not very short. It's a very big moment—
HOYLE: Three days?
FEYNMAN: Yes. About. It's a very big moment—and then there are lesser pleasures as you work out more things and more people *notice* it and—
HOYLE: But the high peak—you're on the high peak for about three days.
FEYNMAN: That's right. Like the supernova, I suppose—no, that's *four* days; that's better. But I was going to say that it is the *hope* of that kind of goal—
HOYLE: That keeps you going.
FEYNMAN: That keeps you going through the doldrums.
HOYLE: Keeps you going to the end.
FEYNMAN: I think that what I learned from my father as a child was that, if you did work a little bit at these things, there would be the time that one should get this. And I had to learn that first, or I would never have been able to do it.
HOYLE: And then afterwards you wonder, now why the devil was I so stupid that I didn't *see* this.
FEYNMAN: Yes. That's not only true of you, it's true of the history of the sciences. You can always look at a particular moment in history and wonder why they hadn't thought of it earlier. It's because we're dumb, somehow.
HOYLE: It's most mysterious. It just means that however good you may get comparatively, compared to—
FEYNMAN: Apes.
HOYLE: Apes, that's right—that you're still very *bad* at it.
FEYNMAN: Absolutely. We're doing the best we can.
HOYLE: In a kind of stumbling way.
FEYNMAN: Yeah.
HOYLE: And with this depressing and sobering thought—
FEYNMAN: Well, it's been fun. □