preserved being." Be sure to examine the work carefully for other statements by Darwin that add strength, clarity, and meaning to this one. You may also employ the Darwinian device of presenting imaginary instances in your essay.

4. A controversy exists concerning the Darwinian theory of evolution. Explore your local or college library and the Internet for up-to-date information on the creationist-evolutionist conflict in schools. Look up either or both terms to see what articles you can find. Define the controversy and take a stand on it. Use your knowledge of natural selection gained from this piece. Remember, too, that Darwin was trained as a minister of the church and was concerned about religious opinion.

5. When Darwin wrote this piece, he believed that sexual selection was of great importance in evolutionary changes in species. Assuming that this belief is true, establish the similarities between sexual selection in plants and animals and sexual selection, as you have observed it in people. Paragraphs 10–12 discuss this issue. Darwin does not discuss selection in human beings, but it is clear that physical and stylistic distinctions between the sexes have some bearing on selection. Assuming that to be true, what qualities in people (physical and mental) are likely to survive? Why?

6. **CONNECTIONS** Which of Francis Bacon's four idols (p. 591) would have made it most difficult for Darwin's contemporaries to accept the theory of evolution, despite the mass of evidence he presented? Do the idols interfere with people's ability to evaluate evidence?

7. **CONNECTIONS** To what extent are Darwin's theories a threat to public morality? Consider Iris Murdoch's "Morality and Religion" (p. 757), and examine Darwin for his awareness of the concepts of morality that Murdoch discusses. Would Murdoch find it difficult to accept Darwin's views of evolution? What moral conflicts would Murdoch be likely to find in his theories? If she were to accept Darwin's theories, how would she connect the ideals of religion with the process of natural selection in nature? Write an essay that connects Murdoch's concerns for morality with Darwin's interpretations of the actions of nature.

8. **CONNECTIONS** In his essay, Darwin discusses natural selection, the way in which genes may alter the biology of individuals in a natural setting. Compare what he has to say about biological change with what Philip Kitcher (p. 656) has to say about artificial selection in which people decide how to change genes to satisfy their own needs or desires. Both processes treat the same issue: how change happens to biological individuals. What might Darwin have said to Kitcher, given Darwin's own comments on the artificial selection of breeders of animals in his own time? What's the difference between the natural selection of a child's genetic gifts and the selection by parents (or politicians) of a child's genetic gifts? Who alarms you more, Darwin or Kitcher?

RICHARD P. FEYNMAN

The Value of Science


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RICHARD PHILLIPS FEYNMAN (1918–1988), one of the most impressive and colorful physicists of his age, was generally acknowledged as a genius among geniuses. His research and mathematical formulas thoroughly revised the modern theories of quantum electrodynamics. In fact, he was granted the Nobel Prize in Physics in 1965 for his work in this field.

Born and raised in Far Rockaway, New York, Feynman received his bachelor's degree at the Massachusetts Institute of Technology in 1939 and his doctorate in theoretical physics at Princeton University in 1942. His work on quantum mechanics at both universities was far-reaching and influential on other researchers. During World War II, Feynman worked on the Manhattan Project, which developed the atomic bomb, and was present at the detonation of the first bomb on July 16, 1945, at Alamogordo, New Mexico. His reaction was mixed; he was thrilled to see that his theories actually worked, but at the same time, he was fearful about the bomb's ultimate use.

After the war, Feynman worked at Cornell University as associate professor and then moved to the California Institute of Technology in 1950. He remained at Caltech for the rest of his career. Because he was a charismatic man with a great sense of adventure and humor, stories of Feynman's brilliance and wit entertained many scientists for years. He wrote two books of interesting personal experiences, *"Surely You're Joking, Mr. Feynman": Adventures of a Curious Character* (1985) and *"What Do You Care What Other People Think?": Further Adventures of a Curious Character* (1988), which both became best-sellers. Another best-seller, *The Pleasure of Finding Things Out* (1999), is a collection of his talks and essays that were originally published in magazines. Some of these pieces, especially his essay on miniaturization, "There's Plenty of Room at the Bottom," have proved prophetic.

One of Feynman's most impressive moments came during the investigation of the space shuttle *Challenger*'s explosion in 1986. The *Challenger* was launched in Florida on an unusually cold morning. It exploded moments after liftoff, killing all the astronauts on board. During hearings about the *Challenger* tragedy, Feynman took a piece of the

from the O-ring that sealed one of the stages of the booster rocket and dipped it into his ice water. With a flourish, he removed it and showed that sudden temperature change caused the O-ring to crack and fail. By this means, he uncovered the cause of the disaster.

"The Value of Science" is an unusual essay for Feynman. Most of his popular writing centers on his adventures and his experiences with very colorful scientists and friends. He speaks here to an audience with a general interest in science. Feynman is careful to make no absolute claims in the essay. Part of his point is that a good scientist is by nature first curious and second skeptical. Skeptics doubt not only what they are told but also what they see. Doubt is at the center of all scientific inquiry, according to Feynman.

FEYNMAN'S RHETORIC

This selection, "The Value of Science," was originally published in a book called *What Do You Care What Other People Think?*, which was published in the year of Feynman's death. It is a relaxed piece, clearly written as if he were chatting with someone interested in science. As a result, the paragraphs are often short and the language direct. Furthermore, he approaches the piece with a simple idea in mind: How does one answer the question, "What is the value of science?" With this question in mind, he begins with one of the most obvious issues with which the general public is concerned — the responsibility of the scientist to deal with social issues. His approach is to explain that scientists are experts in science, but "a scientist looking at nonscientific problems is just as dumb as the next guy" (para. 3). So, by the third paragraph of the essay, we can see that Feynman's strategy is to raise questions and give only partial answers. This approach is acceptable to him because the entire essay tells us not to be too sure about anything. He wants us to understand the value of doubt and to avoid any authoritarian certainty that might hobble us in the future.

Feynman uses examples to make his points as he moves from one idea to the next. The Buddhist temple provides him with an example of how an idea can clarify a difficult moral concept. Science is a key, not a solution, to problems. His example of how the atoms in our brains change and replace each other at regular intervals cautions us that life is a form of mystery. As an example of how imagination informs him, he places himself on an imaginary seashore reflecting on the creation of the earth and all living things, presenting his thoughts as if in poetic reveries (paras. 13–18). These examples help him convey the sense of awe that science helps us comprehend.

Feynman also uses the convenient rhetorical strategy of subtitles to segment the essay. After the first eighteen paragraphs devoted to a personal experience in a Buddhist temple in Hawaii and a beginning effort to establish the value of science, Feynman relies on subtitles to guide the reader:

- The Grand Adventure
- The Remarkable Idea
- Education, for Good and Evil

In such a short essay, this approach helps in clarifying the ideas he wishes to impart. For example, the last section concerning the responsibility of scientists actually picks up from the first few paragraphs that discuss the popular view that scientists have a responsibility to solve social problems. Ending an essay with a consideration of the opening concerns of the essay is a time-honored approach. Each of the other subtitles treats a specific issue, and all are part of the question of what the value of science is for a society.

Feynman also uses another important rhetorical strategy when he enumerates the values he wishes to emphasize. The first value is identified in paragraph 4 when he says, "The way in which science is of value is . . . that scientific knowledge enables us to do all kinds of things." He develops this idea by introducing a "moral choice" that tells us science can be used for good or evil. His example, another rhetorical strategy, of the metaphoric key to heaven that "opens the gates of hell" (para. 6) implies that science, like a key, is an instrument. We use the instrument for our own purposes.

The second value of science is "called intellectual enjoyment" (para. 9), a concept he goes on to examine. The third value of science is the experience with "ignorance and doubt and uncertainty" (para. 26), which he equates with freedom because doubt helps us avoid making the mistake of thinking we know something with absolute certainty when such certainty is what science aims at but can never achieve. Thus, we avoid being locked in by potentially false ideas.

PREREADING QUESTIONS: WHAT TO READ FOR

The following prereading questions may help you anticipate key issues in the discussion of Richard Feynman's "The Value of Science." Keeping them in mind during your first reading of the selection should help focus your attention.

1. What is the responsibility of scientists to solve social problems?
2. What is the relationship of scientific knowledge to certainty?
3. How is science of value to society?

The Value of Science

From time to time, people suggest to me that scientists ought to give more consideration to social problems — especially that they should be more responsible in considering the impact of science upon society. This same suggestion must be made to many other scientists, and it seems to be gen- believed that if the scientists would

It seems to me that we do think about these problems from time to time, but we don't put full-time effort into them—the reason being that we know we don't have any magic formula for solving problems, that social problems are very much harder than scientific ones, and that we usually don't get anywhere when we do think about them. 2

I believe that a scientist looking at nonscientific problems is just as dumb as the next guy—and when he talks about a nonscientific matter, he will sound as naive as anyone untrained in the matter. Since the question of the value of science is not a scientific subject, this discussion is dedicated to proving my point—by example. 3

The first way in which science is of value is familiar to everyone. It is that scientific knowledge enables us to do all kinds of things and to make all kinds of things. Of course if we make good things, it is not only to the credit of science; it is also to the credit of the moral choice which led us to good work. Scientific knowledge is an enabling power to do either good or bad—but it does not carry instructions on how to use it. Such power has evident value—even though the power may be negated by what one does. 4

I learned a way of expressing this common human problem on a trip to Honolulu. In a Buddhist temple there, the man in charge explained a little bit about the Buddhist religion for tourists, and then ended his talk by telling them he had something to say to them that they would *never* forget—and I have never forgotten it. It was a proverb of the Buddhist religion: 5

"To every man is given the key to the gates of heaven; the same key opens the gates of hell." 6

What, then, is the value of the key to heaven? It is true that if we lack clear instructions that determine which is the gate to heaven and which the gate to hell, the key may be a dangerous object to use, but it obviously has value. How can we enter heaven without it? 7

The instructions, also, would be of no value without the key. So it is evident that, in spite of the fact that science could produce enormous horror in the world, it is of value because it *can* produce *something.* 8

Another value of science is the fun called intellectual enjoyment which some people get from reading and learning and thinking about it, and which others get from working in it. This is a very real and important point and one which is not considered enough by those who tell us it is our social responsibility to reflect on the impact of science on society. 9

Is this mere personal enjoyment of value to society as a whole? No! But it is also a responsibility to consider the value of society itself. Is it, in the last analysis, to arrange things so that people can enjoy things? If so, the enjoyment of science is as important as anything else. 10

But I would like *not* to underestimate the value of the worldview which is the result of scientific effort. We have been led to imagine all sorts of things 11

past. It shows that the imagination of nature is far, far greater than the imagination of man. For instance, how much more remarkable it is for us all to be stuck—half of us upside down—by a mysterious attraction, to a spinning ball that has been swinging in space for billions of years, than to be carried on the back of an elephant supported on a tortoise swimming in a bottomless sea.

I have thought about these things so many times alone that I hope you will excuse me if I remind you of some thoughts that I am sure you have all had—or this type of thought—which no one could ever have had in the past, because people then didn't have the information we have about the world today. 12

For instance, I stand at the seashore, alone, and start to think. There are the rushing waves . . . mountains of molecules, each stupidly minding its own business . . . trillions apart . . . yet forming white surf in unison. 13

Ages on ages . . . before any eyes could see . . . year after year . . . thunderously pounding the shore as now. For whom, for what? . . . on a dead planet, with no life to entertain. 14

Never at rest . . . tortured by energy . . . wasted prodigiously by the sun . . . poured into space. A mite makes the sea roar. 15

Deep in the sea, all molecules repeat the patterns of one another till complex new ones are formed. They make others like themselves . . . and a new dance starts. 16

Growing in size and complexity . . . living things, masses of atoms, DNA, protein . . . dancing a pattern ever more intricate. 17

Out of the cradle onto the dry land . . . here it is standing . . . atoms with consciousness . . . matter with curiosity. 18

Stands at the sea . . . wonders at wondering . . . I . . . a universe of atoms . . . an atom in the universe. 19

The Grand Adventure

The same thrill, the same awe and mystery, come again and again when we look at any problem deeply enough. With more knowledge comes deeper, more wonderful mystery, luring one on to penetrate deeper still. Never concerned that the answer may prove disappointing, but with pleasure and confidence we turn over each new stone to find unimagined strangeness leading on to more wonderful questions and mysteries—certainly a grand adventure! 20

It is true that few unscientific people have this particular type of religious experience. Our poets do not write about it; our artists do not try to portray this remarkable thing. I don't know why. Is nobody inspired by our present picture of the universe? The value of science remains unsung by poets, partly because it is reduced to how- 21

Perhaps one of the reasons is that you have to know how to read the music. For instance, the scientific article says, perhaps, something like this: "The radioactive phosphorus content of the cerebrum of the rat decreases to one-half in a period of two weeks." Now, what does that mean? 22

It means that phosphorus that is in the brain of a rat (and also in mine, and yours) is not the same phosphorus as it was two weeks ago, but that all of the atoms that are in the brain are being replaced, and the ones that were there before have gone away. 23

So what is this mind, what are these atoms with consciousness? Last week's potatoes! That is what now can *remember* what was going on in my mind a year ago—a mind which has long ago been replaced. 24

That is what it means when one discovers how long it takes for the atoms of the brain to be replaced by other atoms, to note that the thing which I call my individuality is only a pattern or dance. The atoms come into my brain, dance a dance, then go out; always new atoms but always doing the same dance, remembering what the dance was yesterday. 25

The Remarkable Idea

When we read about this in the newspaper, it says, "The scientist says that this discovery may have importance in the cure of cancer." The paper is only interested in the use of the idea, not the idea itself. Hardly anyone can understand the importance of an idea, it is so remarkable. Except that, possibly, some children catch on. And when a child catches on to an idea like that, we have a scientist. These ideas do filter down (in spite of all the conversation about TV replacing thinking), and lots of kids get the spirit—and when they have the spirit when they are in our universities, so we must attempt to explain these ideas to children. 26

I would now like to turn to a third value that science has. It is a little more indirect, but not much. The scientist has a lot of experience with ignorance and doubt and uncertainty, and this experience is of very great importance, I think. When a scientist doesn't know the answer to a problem, he is ignorant. When he has a hunch as to what the result is, he is uncertain. And when he is pretty darn sure of what the result is going to be, he is in some doubt. We have found it of paramount importance that in order to progress we must recognize the ignorance and leave room for doubt. Scientific knowledge is a body of statements of varying degrees of certainty—some most unsure, some nearly sure, none *absolutely* certain. 27

Now, we scientists are used to this, and we take it for granted that it is perfectly consistent to be unsure—that it is possible to live and *not* know. But I don't know whether everyone realizes that this is true. Our freedom to doubt 28

was born of a struggle against authority in the early days of science. It was a very deep and strong struggle. Permit us to question—to doubt, that's all—not to be sure. And I think it is important that we do not forget the importance of this struggle and thus perhaps lose what we have gained. Here lies a responsibility to society.

We are all sad when we think of the wondrous potentialities human beings seem to have, as contrasted with their small accomplishments. Again and again people have thought that we could do much better. They of the past saw in the nightmare of their times a dream for the future. We, of their future, see that their dreams, in certain ways surpassed, have in many ways remained dreams. The hopes for the future today are, in good share, those of yesterday. 29

Education, for Good and Evil

Once some thought that the possibilities people had were not developed because most of those people were ignorant. With education universal, could all men be Voltaires?[1] Bad can be taught at least as efficiently as good. Education is a strong force, but for either good or evil. 30

Communications between nations must promote understanding: So went another dream. But the machines of communication can be channeled or choked. What is communicated can be truth or lie. Communication is a strong force also, but for either good or bad. 31

The applied sciences should free men of material problems at least. Medicine controls diseases. And the record here seems all to the good. Yet there are men patiently working to create great plagues and poisons. They are to be used in warfare tomorrow. 32

Nearly everybody dislikes war. Our dream today is peace. In peace, man can develop best the enormous possibilities he seems to have. But maybe future men will find that peace, too, can be good and bad. Perhaps peaceful men will drink out of boredom. Then perhaps drink will become the great problem which seems to keep man from getting all he thinks he should out of his abilities. 33

Clearly, peace is a great force, as is sobriety, as are material power, communication, education, honesty, and the ideals of many dreamers. 34

We have more of these forces to control than did the ancients. And maybe we are doing a little better than most of them could do. But what we ought to be able to do seems gigantic compared with our confused accomplishments. 35

Why is this? Why can't we conquer ourselves? 36

[1] **Voltaire** *Nom de plume* of François-Marie Arouet (1694–1778), author of *Candide*. He was one of France's greatest philosophers and writers of the French Enlightenment

Because we find that even great forces and abilities do not seem to carry with them clear instructions on how to use them. As an example, the great accumulation of understanding as to how the physical world behaves only convinces one that this behavior seems to have a kind of meaninglessness. The sciences do not directly teach good and bad. 37

Through all ages men have tried to fathom the meaning of life. They have realized that if some direction or meaning could be given to our actions, great human forces would be unleashed. So, very many answers must have been given to the question of the meaning of it all. But they have been of all different sorts, and the proponents of one answer have looked with horror at the actions of the believers in another. Horror, because from a disagreeing point of view all the great potentialities of the race were being channeled into a false and confining blind alley. In fact, it is from the history of the enormous monstrosities created by false belief that philosophers have realized the apparently infinite and wondrous capacities of human beings. The dream is to find the open channel. 38

What, then, is the meaning of it all? What can we say to dispel the mystery of existence? 39

If we take everything into account, not only what the ancients knew, but all of what we know today that they didn't know, then I think that we must frankly admit that *we do not know*. 40

But, in admitting this, we have probably found the open channel. 41

This is not a new idea; this is the idea of the age of reason. This is the philosophy that guided the men who made the democracy that we live under. The idea that no one really knew how to run a government led to the idea that we should arrange a system by which new ideas could be developed, tried out, tossed out, more new ideas brought in; a trial and error system. This method was a result of the fact that science was already showing itself to be a successful venture at the end of the 18th century. Even then it was clear to socially minded people that the openness of the possibilities was an opportunity, and that doubt and discussion were essential to progress into the unknown. If we want to solve a problem that we have never solved before, we must leave the door to the unknown ajar. 42

Our Responsibility as Scientists

We are at the very beginning of time for the human race. It is not unreasonable that we grapple with problems. There are tens of thousands of years in the future. Our responsibility is to do what we can, learn what we can, improve the solutions and pass them on. It is our responsibility to leave the men of the future a free hand. In the impetuous youth of humanity, we can make grave errors that can stunt our growth for a long time. This we will do if we say we have the answers now, so young and ignorant; if we suppress all discussion, all criticism, saying, 43

"This is it, boys, man is saved!" and thus doom man for a long time to the chains of authority, confined to the limits of our present imagination. It has been done so many times before.

It is our responsibility as scientists, knowing the great progress and great value of a satisfactory philosophy of ignorance, the great progress that is the fruit of freedom of thought, to proclaim the value of this freedom, to teach how doubt is not to be feared but welcomed and discussed, and to demand this freedom as our duty to all coming generations. 44

QUESTIONS FOR CRITICAL READING

1. How do modern scientists treat the question of certainty?
2. Why would people expect scientists to address social problems?
3. Why is it important to know that the atoms of the brain replace themselves?
4. What is the difference between the use of an idea and the idea itself (para. 25)?
5. What is the point of Feynman's experience in the Buddhist temple?
6. What does Feynman mean by "Education, for Good and Evil"?
7. What is the responsibility of scientists?

SUGGESTIONS FOR CRITICAL WRITING

1. What seems to be the popular view of the obligations of scientists to help solve social problems? Are the issues primarily associated with the problems that are created by scientific discoveries, such as television, computers, smartphones, wireless surveillance, advanced weaponry, and interplanetary exploration? If not, then what does society mean when it asks scientists to be socially responsible?
2. Do some research, particularly in recent newspaper and magazine articles, on the question of how contemporary society regards the achievements of science. Is there a wave of antiscientific attitudes on the part of the general public today? Are contemporary American politicians generally pro-science or antiscience What would move them to one position or the other? What is your position regarding the value of science in your world? Are you pro-science or antiscience?
3. Feynman's writing in paragraphs 13–18 is unusual in that it includes many fragments instead of sentences, and it seems to be very indirect in conveying something that he feels is important. Write a brief essay explaining what Feynman is doing in these paragraphs and what the implications for our scientific understanding of the world are in light of what he is saying. How do you connect these paragraphs with his previous