# Freedom in Research

Like food, we should have it in sufficient measure, but we should not need to assure ourselves by gluttony.

J. R. Pierce

In these days, freedom is mentioned so often in connection with research that a naive person might come to believe that freedom is, if not an end in itself, at least a sovereign ingredient which ensures success.

Whatever freedom may be, we sometimes feel that we want it above all things; we long for freedom, not only from the tyranny of people and events but from the weaknesses of flesh and spirit, from our appetites and our aspirations alike. This freedom, which I believe we shall eventually have in full measure, is very different from freedom as it appears to a willful child—having his own way from moment to moment, regardless of consequences to himself or others.

If there are indeed many sorts of freedom, then many sorts of freedom may be important in research. However, we will merely become confused by trying to identify freedom with the course and aim of research. The course of research is intelligent, creative, and enthusiastic work toward an end. The aim of research is new understanding or new accomplishment. Freedom will be important to research insofar as it contributes to the wise choice of problems and to the enthusiastic and successful pursuit of solutions.

It seems clear that the research worker must be free to work on a problem which challenges and interests him and which is yet within his capabilities, rather than a problem which he finds dull or which is beyond his abilities. He must be free to equip himself adequately to tackle his problem, with physical apparatus, of course, and also intellectually, through study or through contact with others, near or far. Without a good measure of such freedom, successful research just can't be carried out.

However, freedom should be like the food we eat. We should have a sufficient measure of freedom at hand when we need it. It should not be necessary for us to reassure ourselves about our freedom by engaging in ostentatious discussions or acts of freedom any more than it is for us to assure ourselves of continued sustenance by ostentatious gluttony. Indeed, a mania for freedom may be just as destructive to research as a lack of it.

We all know people who come around with a wonderful new idea every month, week, or day (maybe it just seems like once a day). I don't believe that even a great genius has that many ideas worthy of his serious effort. The man with an idea a day is unlikely to do anything substantial about any idea. He may become disgruntled because he cannot force others to work on his ideas, or he may unhappily work on one idea and bemoan the tyranny of the world in general. In no case is he apt either to make himself happy or to enrich the world.

Freedom does not even require that a man work on his own ideas. To do so is fine if the ideas are the best ones at hand. But, above all, a man needs to work on good, well-chosen ideas. Eminent and creative mathematicians have worked on Hilbert's problems of their own free will ever since Hilbert propounded them. First-rate scientists have traveled halfway around the world to work under a particular person or with a particular group and have worked gladly on problems suggested by the person or pursued by the group. Many a first-rate man has thanked his lucky stars that someone suggested that he do this or that. The idea may come from a colleague near or far, or from a "boss" who is older, wiser, or cleverer than the man himself.

Still, one does need freedom in choosing problems. It is deadly when a man feels that a problem is forced upon him, and even more deadly when he feels that it is a bad problem, either because the problem is just no good or because the problem is beneath or beyond his capabilities.

A man certainly doesn't need to exercise his freedom every day just to prove that it is still there, but it is a terrible thing to lose freedom, especially if it is lost little by little, so that he does not miss it until it is too late, or, even worse, does not realize that it is gone.

What, then, are the enemies of freedom? What can make a research worker unfree? I believe that several rather different things can do this.

## Demands of Responsibility

It seems to me that freedom is an empty word unless it implies *real* alternatives among which there is some uncertainty about what one's choice will be. If this is so, responsibility is certainly one of the greatest enemies of freedom. The trouble is, however, that responsibility has its good features, too, so that everyone must arrive at some compromise between responsibility and freedom.

Most of us would find it easier to spend six months here and a year there or to change jobs entirely if it weren't for our wives and children. Some men solve this problem by not marrying. Some leave their wives and children to shift for themselves, and thereby gain in freedom.

Brain children, too, fetter some of us. The idea-a-day man is apt to be irresponsible concerning his ideas. He hopes, of course, that someone else will nurture them from bare existence into viability in a world of ruthless competition. Indeed, the chronic begetter of ideas may become angry when no one else gives his offspring the attention he is unwilling to lavish on them.

More responsible researchers pick a promising idea and spend endless time and effort helping it to find its place in the world. Some, indeed, unwisely go so far as to want to monopolize the idea after it has become self-supporting and has found its way into the lives of others.

Whenever we assume responsibility for an idea or a project, whenever we espouse it as our own, whenever we hold ourselves responsible for its fate, we have

The author is director of research-communications principles at Bell Telephone Laboratories, Murray Hill, N.J.

lost a part of our freedom. However, such a loss is necessary if we are to accomplish anything.

Some people get themselves saddled with other sorts of responsibility. They have to decide or help decide who should be hired, who should be fired, how big a raise a man should get. They have to worry and fight about budgets, space, and rules and regulations. All this isn't so bad, but what really takes their time is the work of others.

I may be wrong, but I think that, by and large, research workers, even good ones, suffer more frequently from lack of help than from lack of freedom. It isn't merely that they need help in coping with nontechnical problems. They need help in choosing problems wisely, help in overcoming difficulties in their work, help in judging whether what they are doing is good or bad, help in getting rid of old projects which are really done, and help in getting into new things which will really be important and attractive. They also need not only encouragement for themselves but help in seeing that their work receives the recognition which it deserves. Only very rarely is a man completely self-sufficient. I know that I have benefited from and appreciated tremendously the ideas and help I have got from others.

Responsibility, both responsibility with respect to our own life and ideas and responsibility with respect to the ideas and lives of others, is sure to cost us a great deal of our freedom. However, we just can't get on without responsibility, and we must put up with the loss. We should, however, particularly realize that the more responsibility we assume for ourselves, the less anyone else has to or will assume for us.

Another thing that we can't do without is apparatus. Some ideas, some projects call for lots of expensive equipment. If a man has acquired a large-scale accelerator, a big radio telescope, or a large-scale computer, or if he has set to work on a large-scale experimental system of some sort, he is not likely to walk out on it because an attractive idea in some other field occurs to him. If a systems experiment is shackling him, he can abandon it if it is bad or complete it if it is good, but if he has an accelerator, a radio telescope, or a computer around his neck, he may be stuck in a field for life. This isn't fatal, of course; he can direct his thoughts to the field in question and have and pursue ideas in that field only. But he has lost freedom in that there is little chance that he will actually do something else, however much he may daydream about it. If he wants to recover his freedom, he can perhaps find a substitute, put him in charge, and leave him holding the bag.

## Specialization Has Its Drawbacks

Another way we can lose freedom is through excessive and unwise specialization, which can eventually leave us no alternatives to choose among. At any moment any man should be better able to cope with the problems he is currently working on than with others. However, the problems in a field can be made to last forever, but the real need for and value of research in a narrow field may dry up and vanish. Or, a man may be a fine pioneer in a field but may not be suited to do the refined and mathematically difficult work which becomes necessary as time passes. Wisdom and good sense may dictate that he stop what he is doing and turn to something else. But he is scarcely free if he has lost the ability to do so.

A man can lose the freedom to change his work by allowing himself to become intellectually incompetent to deal effectively with anything outside of his current narrow field of specialization, or he can lose this freedom of choice by becoming so emotionally involved in his field that he cannot bear to leave it. He can also lose any real freedom of choice by convincing himself that he has some commercial and social stake in a field, a stake he cannot afford to lose; he can convince himself that he is valuable only because of his expert knowledge, or is looked up to only because of it.

Still, just as we must have responsibility and apparatus, so too we must have some degree of specialization, even if this does cut into our freedom. There is one curtailer of freedom, however, with which I think we could well dispense. That is snobbishness.

A college president once described to me a sort of pecking order of the sciences. According to him, the mathematicians look down on the physicists, the physicists on the chemists, the chemists on the biologists, and the biologists on the psychologists.

One sure and utterly frivolous and destructive way for a man to lose his freedom is for him to feel overwhelmingly impelled to choose his work, not on the basis of its suitability to his talents, not on the basis of its interest to him, not on the basis of its urgency or importance, but rather on the basis of its status in the eyes of some person, group, society, journal, or what not.

Finally, what might be called management (though it includes institutional policies of long standing as well as people) can affect the researcher's freedom.

## On Changing Jobs

Sometimes a research worker may not have adequate funds for travel or for telephone calls, or he may find it difficult to get adequate apparatus or to get it promptly. These matters are frequently mentioned in connection with government laboratories. It is clear, however, that in these days of competition for engineers and scientists, a good man doesn't have to put up with such handicaps. He can go elsewhere to escape them, and he will.

Sometimes a man may feel that the scope of research in the institution where he works does not coincide with or include his interests. While an exceptional man may drastically alter the place at which he works (and this is desirable from time to time), a good man generally goes to a particular place because he is interested in the field and impressed by the quality of work done there.

A single man, even a very competent one, is bound to have much more freedom in changing his job than he is in changing what his associates are doing. This doesn't mean that he shouldn't try the latter, but a broad change in the nature or direction of the work of an institution involves other people's freedom as well as his own.

Finally, there can be a very real personal threat to a man's freedom; the tyranny of a boss. For research, it is absolutely essential that a man work on problems that he believes to be good problems for him and that he tackle them in a way in which he has confidence. We have noted that a man doesn't necessarily have to invent the problem or the general approach toward its solution himself.

Further, it is essential that if he does have a good idea, he should feel free to explore it (we have seen that he will not necessarily do so). He must further be convinced that his colleagues, including colleagues who may be bosses, welcome new ideas and are anxious to see them pursued and exploited. A free—indeed,

a cutthroat—competition among ideas is essential to research. It seems to me that a researcher should have no freedom to make other able people work on his ideas rather than on their own, beyond what he can make them want to do through persuasion based on the merits of his ideas.

Fortunately, today good people don't have to work under any other conditions. There is tremendous competition for good workers with good ideas. A man who really suffers from the tyranny of the boss can go to some other department or to some other company. And, if a boss is so tyrannous that good men leave him, he won't last forever.

Still, men do complain about the tyranny of jobs and bosses. It is my observation that these are seldom the best men. In fact, often they are men who have amply demonstrated their inability to do research when left completely to themselves, and sometimes they are men who should not try to do research under any circumstances.

Clearly, freedom is vitally important to research, but other somewhat inconsistent things are important, too. Responsibilities of one sort or another keep us from following up every idea or inclination we have. Apparatus ties us down. Concentration on one subject lessens our ability to tackle another. Then too, we may lose our freedom foolishly. Snobbishness may dictate our course of action. Or we may work in a poor environment, inadequately provided for, or with a tyrannous boss to browbeat us. But, in this day and age we are foolish if we put up with such things, unless we really aren't good enough to find another environment—or unless conditions aren't as bad as we think they are after all.

# Stratospheric Carbon-14, Carbon Dioxide, and Tritium

## The program of high-altitude balloon sampling reveals new information about the stratosphere.

French Hagemann, James Gray, Jr., Lester Machta, Anthony Turkevich

This article reports the results of measurements made in recent years of the carbon-14, carbon dioxide, and tritium in the stratosphere. The purpose of the measurements was to obtain information on the stratospheric concentrations of carbon-14 and tritium produced by the explosion of nuclear devices and to study the changes in these concentrations with time. Such data can be expected to furnish new insight into the circulation of the stratosphere, as well as to contribute to the evaluation of the hazards from nuclear explosions in the atmosphere.

The sampling program for carbon-14 was started in late 1953 at Minneapolis, Minn., and extended in 1955 to three other locations in the Western Hemisphere: San Angelo, Tex.; Canal Zone, Panama; and São Paulo, Brazil. The Minneapolis collection was shifted in June 1958 to Sioux City, Iowa. Carbon-14 was determined by measuring the specific activity of the carbon dioxide from air collected at altitudes between 45,000 and about 100,000 feet. Air samples were collected on a monthly schedule at four altitudes at each location unless operational difficulties prevented collection. The tritium measurements were performed only on samples collected at Minneapolis, primarily in the period 1957–58.

This article presents all of the significant original data and discusses the experimental errors which lead to correction of some of the values and rejection of others. Many of the technical details are omitted (*1*).

### Sampling System

*Basic equipment.* A balloon-borne system was developed by General Mills (*2*) to collect samples of whole air from the stratosphere. The collection system (Figs. 1 and 2) consisted of four major components: a lift balloon, a collection bag, an armored vessel, and a control unit.

The lift balloon was a nonextensible plastic film (2-mil polyethylene) balloon of the "Skyhook" type. When the lift balloon reached its full size, excess helium was vented through a duct system so that the balloon would float at a predetermined altitude during the collection period. After collection of the sample, an electrically operated trap-door-type valve in the duct released the exact amount of lift gas necessary to insure a controlled, safe descent of the system. A parachute was suspended directly beneath the balloon to help smooth the rate of descent and to prevent free fall of the equipment in case of failure of the balloon.

The collection bag was a large balloon fabricated of the same material as the lift balloon. Two sizes of bags were used, depending on the collection altitude: a bag 47.5 feet in diameter was used at altitudes above 80,000 feet, and a bag 34.6 feet in diameter was used at lower altitudes. A collection blower of the centrifugal type, powered by a 24-volt direct-current motor, was located below the collection bag.

When measurements were to be made of tritium, a measured amount of deuterium tracer, in the form of heavy water, was introduced into the collection bag at the time of sampling. To accomplish this, a dispenser containing the tracer was located between the blower and the collection bag. The dispenser was kept at a constant temperature of 95°C. A fine orifice in the dispenser was opened during the time the blower was in operation so that the water vapor was introduced uniformly throughout the collection period. The amount of tracer introduced, 2 to 5

Dr. Hagemann and Dr. Gray are staff members at Argonne National Laboratory, Lemont, Ill. Dr. Machta is on the staff of the U.S. Weather Bureau, Washington, D.C. Dr. Turkevich is on the staff of the Enrico Fermi Institute for Nuclear Studies, University of Chicago, Chicago, Ill.