sponsive to their own needs and expectations. But when teaching begins to lose its proper rewards for the teacher (whether or not he is aware of the loss or frustration), the teacher will flee and the fabric of the system will decay. The rewards of the teacher compose the warp of this social fabric, while the intermeshed rewards of the student make up its web. The system which best provides appropriate conditions is the tutorial arrangement, the next best things being the group tutorial, the seminar, and the small class. The more our arrangements depart from these ideals, the greater is the strain on the system and the less is it effective and satisfactory. I see the current excessive flight into graduate education in considerable part as an attempt to realize certain human conditions missing at the undergraduate level. Yet as graduate education becomes more impersonal, new arrangements such as postdoctoral programs and institutes evolve to meet persistent needs for satisfactory communication. I recognize that advances in knowledge also demand the prolongation of education, but that factor does not fully explain the changing state of affairs, even coupled with the factor of increasing social and economic demand for higher degrees. The fostering of graduate education reflects in part an implicit need to teach in a certain way, as well as a need to be taught in a corresponding way. If professors become aware of the attainable sources of their vocational satisfactions, they may become capable of designing both undergraduate and graduate systems of education which are purposeful, effective, rewarding, and therefore viable.

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. . . Unlike the editor of *Science*, I believe that the most neglected person on a university campus is not the undergraduate; it is the graduate student. The biggest gap today in American higher education is in thinking about graduate education—as distinct from finding bookkeeping devices to add more federal graduate "traineeships." . . . It is a remarkable tribute to the herd-instinct that in the Niagara of tears spilt over the neglected undergraduate and the horrible influences of federal money on his education, few have wept a tear over the more immediate victim of the research-orientation in universities—graduate education, into which universities put relatively little of their own money, thereby often making their graduate programs subsidiaries of the federal research structure.

What keeps us from making any progress is the belief that undergraduate teaching and research are, or should always be, connected in some way—that only the man who is active in research in his field can "challenge" the undergraduate. There is very obvious empirical evidence against this. We are all fully aware of the excellent undergraduate student produced for decades in the small liberal arts college, where "research" was barely present. You do not need to conduct research yourself in order to infect the young men in your classes (or your home) with the "vision" of science. Indeed, most of the good scientists I know are too busy to have much personal contact with students. Many have a narrow view of science rather than the catholic view that undergraduates need. It is unsound to point to the occasional brilliant exception like Linus Pauling, who has done both research and undergraduate teaching so well, and suggest that he be the pattern for modern teachers. In fact, I doubt seriously whether a 30-year old Pauling today would develop the way the original did. More likely than not, he would be deeply immersed in his research and in the federal science enterprise, and find his teaching outlet in graduate students.

A university really consists of a federation of two types of institutions—one a collection of undergraduate colleges, and the other a graduate-education-and-research enterprise. The radical restructuring of the latter complex would do a great deal to improve graduate education. It would also bring universities into a more defensible position vis-à-vis the public purse, which provides most of its money. The eventual abolition or substantial weakening of the ironclad departmental structure and the introduction of interdisciplinary research-and-teaching groups are virtually certain. Such groups can become the communities of learning where some of the personal interaction can take place, if only at the graduate level. I am sure that the creation and operation of such groups would be much more effective if they were recognized as having a perfectly legitimate teaching function, alongside of but administratively separate from the undergraduate programs. Such an administrative innovation would not exclude the exceptional Nobel Laureate from teaching freshman chemistry, but it would relieve undergraduate teachers of the ridiculous pressure of having to pose as researchers in order to be advanced.

The answer to the question "What are professors for?" can also be stated: To teach undergraduates, to teach graduates, to do research. My thesis is that there are two distinct though overlapping functions here with the division after the first comma, and that the sooner the universities recognize this division, the sooner we will be able to help professors be what they are supposed to be: Type-I professors inspiring undergraduates by their enthusiasm and desire to communicate the fundamentals and the overview of the field, and by a human relatedness which the earlier formative years demand; and Type-II professors functioning in the new communities of science (groups of professors and their postdoctoral and graduate students), where there is a thorough involvement in the real world of science (including government and industry and contracting and consulting). Not only should this break the traditional isolation of the academic community from society; it should encourage the adventure of tangling with the complexities of our modern world. If Type-II professors can teach this to the graduate students who will become the teachers of undergraduate scientists and the powerful science-administrators of tomorrow, who will claim that this is somehow less important than the personal factor in undergraduate education?

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Project Orion

Freeman Dyson's article on the demise of Project Orion ("Death of a project," 9 July, p. 141) is useful and interesting. One must, however, question his conclusion that "this is the first time in modern history that a major expansion of human technology has been suppressed for political reasons."

There has been no "suppression," but only a government determination that public funds will not be expended

at this particular time on this particular scientific effort. Such determinations, like almost any government decision, are always based, in part at least, on political considerations.

Dyson's conclusion seems to rest on the premise that it is natural, if not imperative, that government normally support any scientific effort which is soundly conceived, is useful from the standpoint of government objectives, and advances science. Although the government's commitment to science is a relatively new phenomenon, many leading members of the science-government community have come to speak and act as though this premise were an axiom of government. It should, however, be obvious that in our form of government science activities must compete at the political level for limited government resources with many other activities, and that particular science projects must likewise compete with other science projects for the share of public resources allocated to science programs.

It is indeed distressing that Dyson's view of the science-government relationship is such that he would view the "murder" of Orion, even for political reasons, as a "suppression" or as unique.

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It is important for scientists to point out, as Dyson does, that when political factors are used as bases for supporting or discontinuing support of scientific experiments or technological projects, it is likely that decisions which are scientifically wrong will be made. I agree that choices between alternative approaches to a technical problem should be made solely on the basis of scientific merit—as long as such a choice is not clearly inconsistent with human welfare.

The success of the Orion project, culminating as it would in the explosion of a number of nuclear bombs in outer space, would have a disastrous impact on people and governments throughout the world. The fact that the project was secret and sponsored by a U.S. military agency would certainly increase the likelihood of a violent negative reaction. Given the delicate balance of international relations today, and given the precarious instability in the magnitude of nuclear military preparations in the U.S.S.R. and in the U.S., the reaction to such an experiment might well cause increased distrust among nations. It is almost irrelevant, considering the lack of scientific sophistication on the part of most people in the world, to state that such nuclear explosions would cause no damage to the earth or to the people on it. The world public reaction would unquestionably remain violently opposed.

That the Orion project is "sweet" should not blind its scientists and engineers to the realization that larger issues of human welfare must take precedence over pursuance of the best techno'ogical approach to the problem of space propulsion. That scientific efforts in general, in an ideal world, should be independent of political considerations should not blind us to recognition of the negative effects of particular experiments in the real world of today.

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I wonder if Dyson is not underestimating the technical problems associated with an Orion-type vehicle. While the project may have been killed because of political issues, there are also good reasons for its elimination based solely on technical considerations. Although theoretical analysis and laboratory tests have substantiated the propulsion concept, the major problems associated with the complete system, including those of materials, structures, and operational characteristics, have not been considered in the detail necessary for establishment of an engineering design. Since the system is only as reliable as its weakest component, the demise of Project Orion can also be attributed to the unrealistic objectives expected of a first-generation plant and to the concentration of the entire effort on proving out the propulsion concept while important engineering and safety problems are essentially neglected.

Dyson believes that it is of vital significance to use nuclear weapons directly for peaceful applications and thereby remove some of the moral stigma associated with their use during the war. He goes so far as to blame the scientific community for not lifting a finger to save Project Orion, which is grossly unfair since the majority of scientists have never heard of the program. However, I for one was very happy to see it canceled at the present time. A vehicle containing a very large number of nuclear bombs to be lifted into space by a ground-based booster represents a potential hazard that we can do without. The radiation environment and fission-product release associated with normal operation of Orion are not desirable.

We have recently had an example of the SNAP 10A power reactor which, although thoroughly tested on the ground and launched successfully into orbit, shut itself down for an unexplained reason. A SNAP reactor is a toy compared to the complex machinery of a proposed Orion vehicle. Where could sufficient tests be carried out to provide the engineering information for successful design and operation of Orion? The number of nuclear tests required to achieve the reliability necessary for such flights as the manned Mercury and Gemini flights, for example, could give rise to an atmospheric pollution problem which in itself is sufficient reason for terminating the project. It would appear that when bases are established on the moon, a site would be available for testing the Orion concept without posing a direct hazard to people on earth, although the consequences of large-scale nuclear detonations upon the space environment would have to be evaluated.

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Endorsement of H.R. 5191

On 2 July, the board of directors of the National Society for Medical Research adopted statements of policy in three areas. Two of the statements—referring to state laws and student study of animals—reaffirm long-standing policies. The third—dealing with national legislation affecting animal research—announces endorsement of legislation for the first time. This statement follows a unanimous vote by the representatives of association members of NSMR for endorsement of H.R. 5191 (see Letters, 23 July). The NSMR believes that in this bill a way is pointed out to the Congress in which laboratory animal care can be improved without impeding the health progress on which human welfare depends.

The NSMR has thus adopted a pol-