amplify and reinforce Waddington's account. While Waddington was head of the Operational Research Section, Coastal Command, Royal Air Force (RAF), I was a member of Britain's Army Operational Research Group (AORG). I was able to see a diversified range of OR activity, because all the British Army's OR sections were centered in a single establishment (unlike the RAF, where they were dispersed by Commands). I worked in the section devoted to antiaircraft fire control but had frequent contacts with several other sections.

The reduction in status of OR today has been paralleled by a drastic change in content, so that the phrase "operations (or operational in English usage) research" hardly means the same thing as it did. A World War II OR worker recognizes little in contemporary OR literature. The proliferation of models derived from game theory is one new element, but on the whole the change that has occurred is best described as a great reduction in scope.

Waddington emphasizes that World War II OR had a strongly empirical approach, the first step being the acquisition of valid facts and data. This step was sometimes difficult, but it often happened that valid observations, once obtained, immediately provided a direct and obvious solution. On occasion, sophisticated mathematical analysis of model-making were indeed used, but in a great many important cases such techniques were not called for. If mathematical models were constructed, they had a close relation to observations. The adjective "valid" is applied to data to convey the meaning that they are to the point and unbiased, rather than necessarily precise numerically. It is presumably for this reason that many biologists were successful in OR: they were familiar with small-sample statistics and precautions against bias in collecting data. They certainly had no superior skill in constructing mathematical models. I remember being interviewed by Brigadier General B. J. F. Schonland (later Sir Basil Schonland), the head of AORG, before I joined the establishment. He said, "As a scientist you have been trained to observe. This is what we want you for, and it is in this that you differ from an engineer." Acquisition of data and nonnumerical information remained a dominant activity until the war ended. Quite often this involved design and construction of sophisticated instrumentation, and probably more ingenuity was used in this than in making abstract models.

A most important element in the success of World War II OR was the choice of problems. While they were obviously suggested by military needs, problems were not merely imposed from above, but were subjects of constant discussion between military and scientific personnel at all levels. In this way, problems that could reasonably be solved were selected, and hopeless undertakings were avoided. This resulted in a high proportion of success, but had the effect that the amount of research done was by no means proportional to military importance. Thus the sections dealing with radar and antiaircraft fire control remained the largest until the end of the war, while the section devoted to infantry was fairly small. Past success and personalities may have played a part, but the chief reason is that the areas of radar and antiaircraft fire control had many problems that scientists could successfully attack; it was much more difficult to find such problems in infantry.

J. A. Stockfisch has called attention to the need for much more empirical operational testing of military equipment in the style of World War II OR (*1*).

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1. J. A. Stockfisch, in hearings before the U.S. Congress, Joint Economic Committee, Subcommittee on Economy in Government, *Changing National Priorities* (Government Printing Office, Washington, D.C., 1970), part 2, appendix, pp. 721–729.

Support for Williams & Wilkins

In his report "Journals: Photocopying is not the only problem" (News and Comment, 29 Mar., p. 1274), John Walsh notes that Williams & Wilkins is asking for financial help in appealing to the Supreme Court its suit against the U.S. government for copyright infringement. He then adds that it "remains to be seen how many publishers will ante up."

As chairman of the ad hoc Committee for Copyright Protection, which is being organized to help Williams & Wilkins, I can report that publishers, and professional societies as well, are responding immediately and liberally.

In advance of any formal solicitation, nine publishers have volunteered contributions ranging from $500 to $5000. Many others have said they will make substantial contributions now that the Williams & Wilkins appeal has been accepted. I confidently predict that 50 to 100 publishers will contribute to this cause.

Further, six professional societies have already pledged contributions ranging from $100 to $5000. They are the American Chemical Society, American Society of Microbiology, American Society for Testing Materials, Society for Applied Spectroscopy, American Society of Civil Engineers, and the Institute of Electrical and Electronics Engineers. We are told that several other societies will contribute when a formal appeal for contributions is made.

This evidence of professional society concern exposes an odd conflict of interest that needs to be pondered thoughtfully by all scientists. While many individual scientists, along with many librarians and other information specialists, are pushing hard for exempted privileges of photocopying for scientific and educational uses, the officers of their professional organizations (and especially their publications officers) are drawing back from the sure prospect of resulting losses of subscription and advertising income to their already straitened journals. And, strangely enough, many members of the societies that are supporting the Williams & Wilkins appeal are also supporting the National Education Association's Ad Hoc Committee of Educational Organizations and Institutions on Copyright Law Revision, a group that has made the loudest and most persistent demands for the broad special exemptions.

Scientists should not confuse the rhetoric of "free flow of information" with the economics of "flow of free information." There is no such thing as free information; somebody has to pay the cost of any system for the organization and dissemination of science information. The privilege of "free" photocopying simply is not compatible with the economics of book and journal publishing. Why, then, do so many scientists seem to think they can have their cake and eat it too?

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Science Management Training

In his editorial "Managers of science" (15 Feb., p. 599) Dael Wolfle comments on the mid-career "training" of managers in mission-oriented and industrial sciences. While I believe that mid-career management training is an important way to correct deficiencies in science management, a more fundamental problem is the lack of management training of scientists during their doctoral programs.

As one who has twice been in middle management positions (as manager of operations and data systems for a small corporation and as chairman of a biology department in a university), I have found that when this topic was raised with upper management, in either industry or academe, only rarely was there any concern about either the correction of lower or middle management deficiencies or about the development of training programs.

After years of frustrated self-education in management technology, with a correlated lack of career productivity, I have decided that the only solution for me is to return to teaching and research activities.

Deficiencies in science management in both academe and industry (and I suspect the problem exists in government as well) can only be corrected by a basic change in attitudes early in the educational process. We are now seeing the conversion of certain traditional Ph.D. requirements (such as foreign languages) to more contemporary options (such as statistics, computer technologies, teaching and evaluation skills, and communication skills). Managerial skills should also be included as an optional Ph.D. requirement, since a smaller and smaller proportion of current and future Ph.D.'s will probably be retained in purely nonmanagerial positions, such as teaching.

There are two excellent reasons why the solution must come during the Ph.D. program and not at mid-career: (i) mid-career training is inefficient, as stresses of family, shifting career objectives, and peer pressure inhibit concentrated efforts; and (ii) middle management training (as we now know it) is too "expensive" in terms of bad management decisions made during on-the-job training.

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