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Can There Be Too Much Research?

With competing demands on scarce resources, more applied research may curtail education and progress.

Fritz Machlup

This article deals with an important question arising from the recent growth of research and development and the loud cheers that have accompanied this growth. Several kinds of research will be touched upon, but my chief subject will be industrial research and development. This four-word phrase will be referred to often, and the use of "IRAD" as a code word for it will save space.

Phenomenal Growth of IRAD

It has been estimated that the expenditures for IRAD in 1930 were less than $120 million; in 1953 they were $3700 million, and in 1956 they were $6500 million. One might make two reservations concerning the legitimacy of measuring the growth of IRAD by dollar outlays: that the data for the earlier years are not reliable and that the value of the dollar has diminished over the period. Yet neither of these considerations can throw any doubt on the order of magnitude of the figures in question.

The figures for recent years include large amounts of public funds spent by industry under government contracts; in 1956 no less than 49 percent came from the Federal Government. In addition there were direct expenditures of the Government for research and development performed by its own agencies ($1400 million) and expenditures for research, basic and applied, in universities and other nonprofit institutions. Some expenditures for *basic* scientific research are included in the figures for IRAD, but this is only a small portion—about 5 percent in 1953—of the activities of industrial organizations. Hence, when we speak of IRAD we mean primarily *applied* research and development, designed to produce new or improved technology—some of it in the form of inventions, patentable or unpatentable; some of it concerned with the application or adaptation of inventions and the acquisition of know-how; but all of it useful in industrial production involving new products, new devices, new processes.

Much of the phenomenal growth of IRAD has been connected with the war and defense effort of the nation, either directly, as in the execution of "crash programs" for the development of weapons and other defense materiel, or indirectly through the transfer of the "research-mindedness" of defense production to industry in general. Some of the increase in IRAD expenditures has probably been connected with the tax laws, especially the combination of high corporate income tax rates (and still higher excess-profits tax rates after the war) with the deductibility of IRAD payrolls from taxable income. In any case, industrial research has become very popular, not only among industrialists but also with the consuming public, as one can infer from the public-relations emphasis upon industrial research. In the main, the new research-mindedness of industry has probably proved profitable as well as productive, and everybody is satisfied that the increase in industrial research has been a splendid thing all around.

The More the Better?

If this past increase has been such a desirable development, should we be content with the level attained or should we press for more? Should we devote an ever-increasing portion of our resources (chiefly human resources) to industrial research, or is there perhaps some limit beyond which we should not go? It is easy to see that an economy might fail to allocate enough of its resources to IRAD. But can there ever be too much? Is not more research and development always better than less?

For most noneconomists the answer looks simple: More IRAD will produce more invention of better products and of better production techniques; this, in turn, will raise our standard of living; hence, we should always encourage industrial research, by allotting more government funds, by further liberalizing the tax laws, by strengthening the patent system, by employing whatever methods seem appropriate. "Let us have more IRAD, the more the better."

This view fails to recognize the existence of an economic problem—that is, a problem of choosing among alternatives. Economics comes in where more of one thing means less of another. To be sure, it would be nice to have more of a good thing, but if this implies that there will be less of something else, one should compare and choose. It is the

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economist's task to analyze what alternatives society will have to forego when it does what seems so desirable to many or to all. The social cost of what *is* done is the value of what *might* be done instead. In technical terms, the social cost of any action is equal to the value of the most valuable alternative opportunity that has to be foregone.

Many highly sophisticated economists will likewise incline to the view that there should be more inventive activity, not because it would be without social cost, but because the social cost is apt to be much smaller than the social benefit from the increased activity. They are convinced that society stands to gain from a shift of resources toward "inventing." By and large, economists in the free world are willing to rely on the price mechanism to guide or steer resources into the most wanted uses. But they recognize that there are certain situations or areas in which market prices and business profits will not adequately reflect the social benefits derived from particular goods or services. The private benefits that can be derived from inventive work are, as a rule, less than the potential social benefits. To express it in the economists' lingo: Since the "external benefits" of inventions—"external" because they accrue to individuals other than their producers and users—are substantial, the "social marginal product" of inventive activity is greater than the "private marginal product"; this implies that without government intervention not enough resources are allocated to the business of inventing, and that the total social product—the flow of real output—could be increased by shifting additional resources to IRAD.

Whence the Manpower

From what sectors of the economy can one withdraw the productive resources that are to be transferred to IRAD? Let us list all conceivable "sectors" that might be raided for manpower and then ask how likely each of them is to give up the human resources wanted for increased IRAD. (There are also IRAD expenditures for resources other than human, but the problems of finding buildings, apparatus, and materials needed for IRAD are not so serious.) "Inventive personnel" may be recruited by getting qualified persons away from (i) involuntary leisure, (ii) voluntary leisure, (iii) the production of security from invasion and revolution (including the production of military goods), (iv) the production of consumers' goods, (v) the production of capital goods, (vi) basic research, or (vii) education.

A shift of qualified persons from "involuntary leisure" to inventive activities would surely be the best of all possibilities, since the diminution of involuntary idleness would be a boon rather than a sacrifice. It would mean that there have been unemployed talents waiting to be used—talented individuals anxious to give up the leisure that had been imposed on them. This possibility, however, must be written off as an illusion if we are engaged in serious economic analysis. "Depression economics," based on the assumption that there are pools of unemployed resources ready to be put to work, has its uses, but only for what has been called an "upside-down economy" (*1*). Economic theory and economic policy for the "right-side-up economy" would be badly vitiated by the assumption that there are ever-ready pools of productive resources that can be drawn upon at any time, to any extent, for any use.

A shift from "voluntary leisure" would be the next best possibility. It would mean that some qualified people are ready, with some inducements, to devote more time to inventive activity, not at the expense of any other productive activity but at the expense of some of their leisure time. These people may be professionals or amateurs. The former are the scientists and engineers already in IRAD and possibly willing to work overtime. This pool of potential resources may be of great importance for the implementation of "crash programs" of research and development in a national emergency. But long-run programs, not directed toward specific goals (like winning a war or an international race for accomplishment of a particular technical feat) but designed for "progress in general," cannot successfully be based on the continuous and continual supply of overtime labor. The other source of volunteer labor—amateur researchers and tinkerers, busy with other jobs during their regular hours but glad to use their free evenings and weekends for inventive activity—can probably be drawn upon regularly. (Mobilization of these "individual inventors" was perhaps one of the achievements of the patent system in times past.) But this is a very limited source of supply, perhaps already fully utilized; in addition, the role of the "evening-and-Sunday inventors" has become quite insignificant in our age of organized research and development. Thus, the possible sacrifice of leisure cannot be counted on to provide the labor for additional inventive activity.

One must assume that society has allocated to national defense the resources that its experts consider indispensable. If the threat of invasion or revolution increases, resources will have to be withdrawn from other uses; if that threat is reduced, resources can be transferred and larger allocations can be made elsewhere. But one cannot reasonably assume that civilian industry, when it wants to increase its IRAD staff, will be able to raid the defense establishment or defense production for large numbers of engineers, even if one could find there the men qualified to do inventive work.

Alternative or Complementary Growth?

Having disposed of—as illusory—the first three hypothetical pools of manpower for additions to the IRAD staff, we may find it expedient to stop a moment for reorientation. The sectors left for consideration are the production of consumers' goods, the production of capital goods, basic research, and education. Let us now combine basic research, education, and applied research and development (including IRAD) into one sector, called "production of knowledge," and examine its relation to the other two. Is it really correct to regard these three sectors of production as alternatives? Since they actually have grown together, should they not rather be considered as complementary? Has not every increase in the production of capital goods helped, rather than hindered, the growth in the production of consumers' goods? Has not every increase in the production of knowledge accelerated, rather than retarded, the growth in the production of both capital goods and consumers' goods? Evidently, here is a conflict in economic interpretation that must be resolved before we can proceed.

Historically, production has increased simultaneously in all three areas; looking back over long periods, one does not find any absolute reduction in the production of consumers' goods when more resources were allocated to the production of capital equipment and of knowledge. Simultaneous increases in all areas have been possible because of the increase in the

total labor force and because of the advance of productivity. As more manpower became available, absolutely larger numbers could be allocated to all lines of endeavor; an increased allocation to one sector did not presuppose an absolute curtailment of others. But in percentage terms the allocation was still a matter of alternatives. And it is in these terms, and in terms of output per head, that the problem of resource allocation in an economy with rising population must be analyzed. Clearly, a relative increase in the allocation of resources to any one line of endeavor implies relative curtailments of others. (In a permissible simplification of the argument, teachers of economics often make the assumption, in the theory of resource allocation, that population and labor force remain constant. This permits them to present in terms of absolute quantities what for a growing population holds only in terms of relatives.)

Even with a constant labor force it is possible for production in all areas to increase if productivity—output per worker—increases. And productivity will almost certainly increase as more capital equipment and more technical knowledge are accumulated. Hence, with the advance of productivity it becomes possible to reduce the allocation of resources to the production of consumers' goods, and to increase the allocation to other areas, without causing any decline in final output. Indeed, this gradual reallocation of resources from consumers' goods production to the accumulation of capital and of knowledge will cause the output of consumers' goods, in the long run, to increase even faster.

This does not contradict the truth about the fundamental "alternativeness" of production of consumers' goods, capital equipment, and knowledge. At any moment of time, the three "departments of production" compete for the available resources, and increases in the allocations to the production of capital and knowledge at a rate faster than the rate of growth of manpower and of productivity will reduce the per capita output of consumers' goods in the near future.

Competition for Scarce Resources

The notion that an increase in the production of capital goods or in the production of knowledge should, if only temporarily, hold back the production of consumers' goods is so contrary to widespread preconceptions that we must not expect it to be easily accepted. Some slightly more thorough elaboration, or even a repetitive reformulation, may therefore be appropriate, or at least forgivable.

An increase in the stock of knowledge may lead to a rise in productivity and thus to increases in the output of consumers' goods and capital goods. Similarly, an increase in the stock of capital goods may raise productivity and thus permit increases in production. This may suggest that the most rapid accumulation of capital goods and knowledge will permit the fastest increase in consumption. But, alas, such accumulation presupposes the availability of resources. If resources are being fully used, increased appropriations for investment in capital and knowledge must imply reduced appropriations to the production of consumers' goods. There is, therefore, a dilemma: The way to increase consumption is first to reduce it. Only by reducing the production of consumers' goods can society transfer resources to the production of capital goods and useful knowledge, and only subsequently can the increased stocks of capital and knowledge raise productivity enough to enable the diminished resources that are allotted to consumers' goods production to bring their output back to the former level and above it.

These fundamental principles are sometimes forgotten, especially in rich economies or in economies with large pools of unemployed resources of some sort; yet they are essential to our understanding of economic development. It is very difficult for an undeveloped economy to advance to higher levels because poor people would starve to death before they could accumulate enough capital equipment and useful knowledge to raise their productivity sufficiently to permit a substantial increase in their consumption. The same principles work also in highly developed countries, though usually by affecting relative rather than absolute magnitudes: Consumption can still increase absolutely, thanks to accumulation from preceding periods, even when productive resources are shifted to the production of equipment and knowledge. What happens there is that a large part of the potential increase in the output of consumers' goods is "seized" when the consumption sector must give up resources to the other sectors. That the expansion in one sector encroaches on the others is sometimes forgotten, with unpleasant consequences. The drive to increase investment and consumption at the same time, and by more than the "inherited" increase in productivity would permit, results in price inflation. Increases in money outlays, bidding for a supply of goods which is not increased in the same proportion, are apt to show up in price increases (or shortages, where prices are not sufficiently increased); thus, the "effective demand" is partially frustrated. In other words, pushing forward more vigorously on one of the three fronts may force an unwanted pullback on one or both of the others. Such a forced retrenchment may have especially harmful consequences in the long run if it occurs in the area of "reproduction of knowledge"—that is, in education.

Increased research and development in order to increase the stock of knowledge is a splendid thing for society; so is increased production of productive equipment, and both are so highly valued because they eventually allow increased consumption. Yet, these three—more knowledge, more equipment, and more consumption—are alternatives in the sense that, even though all three can increase when productivity increases, a greater increase of one must mean, for the time being, smaller increases of the others. At any one moment, an increase in the production of knowledge means less equipment or less consumption than might otherwise be available, or less of both. A choice by society to increase research and teaching implies a choice, though usually unconscious, to have in the next years less productive equipment or less consumption, or less of both, than they might have had. Should a relative cutback of consumption prove impracticable, the choice is between "knowledge" and "equipment."

Replacement and Expansion

As a matter of fact, things are much more complicated than this simple set of alternatives may suggest. Capital equipment is produced partly to maintain the stock and partly to increase it. One might conclude, as the statistician does, that "net investment" is simply the excess of total production of capital goods over depreciation—over the used-up part of the stock. But it is possible to increase the production of one kind of equipment and neglect the replacement of another. For example, one may push the production of hydroelectric and atomic power plants and neglect the maintenance of the highways and of the

roadbeds and rolling stock of the railways. On balance, there might still be "net investment" or "accumulation of capital," and yet the failure to replace transport facilities may one day cause so serious a bottleneck that the total production may fall catastrophically. (In a competitive free-enterprise economy the danger of such an occurrence, in my opinion, is minimal, but it may be very real in a war economy or in a centrally directed economy.)

In an economy with increasing population and labor force, some "net investment," or net increase in capital stock, is needed merely to keep output per head from falling: Tools, machines, buildings are required to equip the additional labor force and maintain the average productivity of labor. Customarily, all new capital equipment above that needed to offset depreciation is called "accumulation" or "net capital formation." Yet, the part of it that merely serves to maintain capital per worker at the level previously attained, and thus does not contribute to an increase in output per head, had better be set apart from "accumulation in a narrower sense"—namely, in the sense of "production that increases capital per worker."

Similar questions and difficulties exist in the analysis of "production of knowledge." Here, too, necessary replacement may be neglected while "new knowledge" is produced, and the concept of "reproduction of knowledge" is highly problematical. The teaching of established knowledge to the young who are to take the places of those who retire or die is clearly replacement, or reproduction. But what about the education and training of the rising generation in an increasing population? If the number of people taught exceeds the number of the skilled that are lost to the labor force through death or retirement, this "volume of teaching" accomplishes more than "reproduction of knowledge" in a strict sense. On the other hand, if the percentage of people that are educated and trained were falling off, "knowledge per head" in the growing society would be reduced and productivity per worker might suffer. Thus, in order to maintain average knowledge and average productivity, it is necessary to educate increasing numbers of young people. Matters are complicated, however, by the possibility that opposite changes may occur in the percentage of people educated and in the level of education attained. Where the former is raised but the latter is lowered, it may be impossible to measure whether "knowledge per head" is maintained, increased, or reduced; but whether it can be measured or not, the possibility of a reduction cannot be denied.

The problem becomes even messier if there are opposite movements in the acquisition of new knowledge, in the dissemination of new knowledge to the few that are immediately concerned, and in the dissemination of established knowledge—education and training—to the rising generation. If resources are shifted from education to IRAD, the accumulation of new technical knowledge may be accelerated at the expense of the dissemination of established general knowledge. It is possible for industry, by providing more attractive job opportunities (for IRAD as well as for other kinds of qualified work), to drain schools of the teachers needed for the instruction of the new generation. No statistical technique is available to indicate whether the "net increase in knowledge" is positive or negative when a high rate of output of new technical knowledge, inclusive of inventions, is accompanied by a decline in the performance of the schools. The time may come when a lack of adequately trained graduates of the schools creates a bottleneck, obstructing not only further progress in the arts but also the maintenance of the general productivity of the people.

As in the formation and reproduction of capital, the problem is one of timing. Pushing IRAD *now,* in order to increase the production of new technical knowledge, may be at the expense of the reproduction of established knowledge and may result in an eventual decrease of general productivity with a forced reduction of IRAD *later,* perhaps even with a net loss in the production of technical knowledge in the long run.

Basic and Applied Research

It has been customary to divide knowledge, teaching, and research into two main categories, one of which is characterized as general, fundamental, liberal, basic; the other, as applied, practical, vocational, technical. The distinction is a useful one, even if blurred in many instances. The difference between basic and applied research happens to be significant for our present inquiry: whether there can be too much research.

We have stated that IRAD competes for the kind of human resources that are required for educating the young. Schoolteaching and applied research are largely alternative occupations; where both are full-time jobs, the qualified college graduate or the young M.A. or Ph.D. will accept either an IRAD job or a teaching job. The instances in which a man in IRAD work also teaches an evening class, or in which a teacher also serves as an industrial consultant, are merely exceptions which confirm the rule that applied research and teaching are alternatives. This is not the case with basic research, which to some extent is a complementary activity of teachers at advanced levels.

The essential complementarity between teaching (especially postgraduate) and basic research has always been recognized by institutions of higher education. The performance of university professors is judged, as a rule, by their research work, and it is from the great research scholars that advanced students have received their most lasting inspirations. The respected teachers in the best universities devote much less than one-half of their time to teaching and much more to basic research. By and large, the more research they do, the better they will be as teachers. Of course, teaching and research cannot be complementary where heavy teaching loads make it impossible for college teachers to carry on any significant research. Perhaps, if the amount of teaching is measured by the hours of classroom work, all research must be considered an alternative to teaching; only when the amount of teaching is measured by the results achieved—in terms of the intellectual capacities developed—will basic research be recognized as complementary to teaching on the highest levels.

The combined activity of teaching and basic research is not necessarily confined to the classrooms and laboratories of colleges and universities. Also outside academic institutions, in research organizations of all kinds, including the rare but outstanding basic-research teams maintained by industry, basic research may have teaching as a by-product when young research assistants, attached to a great scientist, can, under his guidance, informally continue their education no less effectively than on a campus.

The social benefits of basic research are invaluable, and its social cost is probably not too high. For apparently only a relatively small number of people can qualify as workers in basic research, and, hence, the promotion of basic research will not encroach heavily on other pursuits. If those who do basic research are

engaged in higher education, their usefulness as teachers may be increased, not diminished. And when the funds for basic research go to institutions of higher education, such outlays stimulate the employment not only of better but also of *more* academic teachers by enabling universities to meet more successfully the attractive salaries industry offers to qualified scholars in administrative posts and IRAD positions. In other words, increased public outlays for basic research are not likely to encroach on education. On the contrary, they may aid education by allowing universities to hold on to scholars who might otherwise be lured into industry, by allowing scholars to improve their qualifications as teachers, and by attracting more qualified young people into careers of scholarship. On these grounds one may say that there is little danger of there being "too much basic research."

IRAD and Adequate Education

However, IRAD and education—the acquisition of new applied knowledge and the dissemination of established basic knowledge—may be in serious competition with each other, especially if the teaching profession serves as a recruitment pool for IRAD personnel and if IRAD job opportunities attract promising college graduates away from schoolteaching.

Since the production and reproduction of knowledge nowadays is almost completely a government concern, an imbalance cannot be corrected by free enterprise. Schools are maintained chiefly by local government with the help of state government; more than 50 percent of research and development is financed directly by the central government; and a substantial part of industry-financed IRAD is indirectly paid for by the government when it allows the IRAD payrolls to be deducted from the corporations' taxable incomes. Even the part of IRAD that is not paid for by the Government is—according to many authorities—largely dependent on incentives held out by the governmental system of patent protection for inventions. Thus, whatever imbalance develops within the area of the production and reproduction of knowledge, as well as between the production of knowledge and the production of investment goods and consumers' goods, is not to be blamed on the competitive economic order but on the inadequacies of governmental planning.

These are not just academic speculations but very real problems of urgent concern to our democratic process. The high taxes needed to finance education and research cannot but impinge on the production of other things, and industry feels the pinch not a little (as does every taxpayer). On the other hand, the neglect of education is becoming increasingly notorious and is to a large extent attributable to the inflationary increases of wages and salaries in industry, which have made the financial rewards to teachers and scholars inadequate for the maintenance of the required supply.

It is contended, in some quarters, that technical improvements in teaching will make it possible for more students to be taught by fewer teachers. Experiments in the use of television methods of teaching are receiving conflicting evaluations. Some find television classes most promising, others are more than critical. Even without quantitative evidence it seems safe to hold that a good television lecture by an excellent teacher will be more effective than a poor classroom performance by an inferior teacher. It seems equally safe, however, to hold that passive observation of a television screen is a very imperfect substitute for active student participation in discussion in small groups. Perhaps the eventual introduction of mass-production methods in high-school and college instruction is inevitable; and perhaps, when this comes to pass, the demand for manpower for IRAD will encroach less on the supply of qualified teachers than it seems to do at present and may do even more seriously in the next few years.

Rational Resource Allocation

With the pressure of competing demands on the productive resources of the nation that exists today, the problem of allocation of resources deserves more thought than it has been given. According to their special interests, or often out of sheer enthusiasm, different groups try to promote increased outlays for capital investment, increased expenditures for education, increased disbursements for IRAD, and increased consumer spending, all at once—not just in times of depression (when it would make sense) but all the time. Of course, every one of these increases would be fine to have, but since they compete with one another we should first make up our collective minds regarding the comparative advantages. No matter whether an increase in industrial research is financed by the Government or by private industry (under the patent system or with some other stimulus), the decision to increase inventive activities is fully rational only when it seems likely that productivity can be raised faster and maintained more securely through more new technical knowledge than through more capital equipment, more basic research, or more education. If the total amount of productive resources that can be withheld from the production of consumers' goods is limited (as it must be), how much should be allocated to the production of capital goods, how much to the reproduction of established knowledge, how much to the acquisition of new basic knowledge, and how much to the production of increased technical knowledge? This is a matter for economic judgment, tempered by important political and moral considerations. It would surely be foolish to allot to IRAD *all* the resources that can be spared from the consumption sector; it would be stupid to allot *none* of the available resources to IRAD. Even very far within these extremes there may be too much promotion or too little promotion of IRAD.

It has become fashionable among students of economic growth and development to acclaim technological progress as the number-one factor in the process. This may be perfectly justified, but it does not imply that IRAD should be singled out as the most important of all pursuits. Some of those who stress IRAD in order to reduce the emphasis upon capital investment forget that the increase in the stock of capital goods may have been a necessary condition of all technological development. Others who play up IRAD at the expense of liberal education and of basic research forget the dependence of technological research upon advances in basic knowledge and upon an adequate supply of highly educated people. If one puts education, training, research, and development all into one category and sets it against investment in industrial plant and equipment, then one might possibly find evidence for the contention that—in some countries and over some periods of time—the investment in knowledge has contributed more per dollar to the increase in labor productivity than the investment in physical industrial facilities. The

bracketing of research with education is necessary for this statement to be tenable; for, among other things, the researchers and developers must have been previously educated and trained, and the utilization of new technical knowledge often requires degrees of dissemination and comprehension that cannot be attained without broad and general education.

If it should be possible to find statistical criteria for the identification of the specific contributions which "investment in knowledge" and investment in physical facilities have made to the increase in productivity, and thereby to obtain evidence for claiming "major credit" for the former, one would have to guard against the mistakes of regarding these findings as pertinent for other places, other times, and other allocations of resources. Particularly one would have to guard against the fallacy of confusing "total utility" and "average utility" with "incremental (marginal) utility." It is perfectly possible for technological research to deserve first prize in the distribution of merits for economic growth and, nevertheless, not to deserve first claim on additional resources.

Lest these remarks be understood as an attack on IRAD, or as a plea for drastic curtailments of IRAD expenditures, be it noted that such has not been my intention. I have intended to show that there *can* be too much IRAD work, not that there *has* been too much of it. Whether the present rate of IRAD expenditures is too high, too low, or just right, I do not know—though I am impressed with the present plight of education and cannot help looking askance at any so clearly identified rival bidder for potential teachers. In any case, a warning is in order against the position of the IRAD enthusiasts who champion the idea of "the more the better."

Note

1. This colorful expression was used by Abba P. Lerner [*Economics of Employment* (1951), pp. 141–150]. An "upside-down economy" is characterized by unemployment of all the productive resources that would be needed to produce increased amounts of goods and services. "Topsy-turvy economics is appropriate for an upside-down economy" (*ibid.*, p. 142). Such an economy is upside down because it would not be benefited by the things which contribute to the welfare of a normal economy—namely, economy, efficiency, and thrift—but, rather, would be benefited by their opposites—wastefulness, inefficiency, and prodigality (*ibid.*, p. 146). The prescription for upside-down economies is to print money and spend it. But when this prescription cannot lift the economy beyond a certain level of employment and activity, this level should be regarded as normal, and topsy-turvy economics should be shelved in favor of "ordinary economics," "concerned with the economical use" of scarce resources.

Literature in a Technological Age

Attitudes and values involved in a possible symbiosis between arts and science students are discussed.

T. R. Henn

This article is, of necessity, concerned with some problems in English education; but my experience of American and Canadian universities suggests that the problems may not be different there. For I have seen Plato issued as "mandatory" reading for the first-year students at the Royal Military Training College of Canada, and Sir Richard Livingstone was invited to lecture on that writer at Massachusetts Institute of Technology. I have listened to discussions of poetry at West Point, and by physicists and engineers at a dozen universities, and was struck in every instance by the eagerness, tact, good taste, and intolerance of nonsense that was apparent everywhere. Indeed, many of my best students of English have been trained in other disciplines—mathematics and natural sciences as well as classics or modern languages—and there is much to be said for these preludes to literary criticism.

But we are told that the gap between sciences and arts is steadily widening; that in a few years' time our society will be predominantly technological, and that this is because the whole cultural pattern of the world is changing. The study of literature and particularly of poetry thus becomes an interesting, perhaps pleasant, but wholly useless, anomaly, belonging (as Peacock saw it a hundred and fifty years ago) to a heroic age, and out of place in this age of iron. Our educators feel, vaguely, that this negation is "a bad thing." Here and in North America there have been countless experiments in "integrated courses." I have seen large classes of engineering students sprayed, as it were, with the warm Eau de Cologne of "Eng. Lit.," or dragged unwillingly through courses in "creative writing," their mentors hoping, rather despondently, that some of them would acquire a veneer of "culture." (Should not we still reach for our revolvers at that word?) We must examine the complaints a little more closely.

There is, in the first place, a fairly steady outcry against the relative illiteracy of many advanced students of science. Often this comes in the form of criticism of the shapelessness, inaccurate English, and lack of formal control in scientific writing, particularly at the postgraduate stage, with a consequent waste of time by those who direct such studies. Parallel to this, yet of quite another order, is the complaint, both from teachers and employers of scientists, of the lack of what Shelley called "the creative imagination." By that he meant, I think, no more than the ability of the mind that has been trained to think *synthetically*; to make, from time to time, "leaps in the dark"; to meditate profoundly on resemblances and analogies between things; and so to lead the way to creative thinking, which is apt—so I am told—to atrophy under the sheer weight of factual knowledge that the student of any of the great sciences must master today.

There are other complaints. Great in-

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