adopted promptly and that the designation as "specialized facilities" be removed from animal resource programs. Requiring institutions to allocate animal care costs comparably would create a level playing field; institutions could bench mark their costs and identify areas to improve efficiency based on local conditions. To further enhance animal welfare, we recommend that increasing funds be allocated to support animal health infrastructure especially for specialized animal populations.

We know of no national forum to exchange views or seek workable and timely solutions. A workshop planned by the NCRR is an important step in this direction. However, we believe that it is important that the scientific community be aware of the obstacles to continued productive animal-based research and join in overcoming them.

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Life-Sciences R&D, National Prosperity, and Industrial Competitiveness

R. Fears, M. W. J. Ferguson, W. Stewart, G. Poste

The importance of science and technology (S&T) as a catalyst in promoting national prosperity, improved health, and quality of life has long been cited as justification for investment in basic research and industrial R&D (*1*). Despite the dramatic economic and social benefits generated by S&T over two centuries of the industrial era, Vannevar Bush's vision of the endless frontier for research (*2*) has not yet yielded endless solutions for many in society.

Throughout the industrialized nations of the Organization for Economic Cooperation and Development (OECD), the relationship between science and society is in flux, with increasing political demands to forge closer ties between basic research and industrial applications to address societal needs. A recent paper in *Science* (*3*) referred to this trend as the "changing ecology of science" in which the principal challenge facing those responsible for science policy is how to prioritize S&T investments to optimize technology transfer, while maintaining a competitive science base in the face of constrained funding and escalating costs. We describe developments in science policy in the United Kingdom over the past 4 years that have imposed a major restructuring of the governmental policy apparatus for the review and funding of academic research and its linkage to the industrial sector.

We do not share the view (*4*) that a strategic policy for S&T is incompatible with excellence in life sciences and biomedical research or will inevitably lead to "short-termism" to meet the perceived avarice of financial and commercial constituencies. On the contrary, we believe that the denial that basic research can be assessed is counterproductive and unnecessarily alienates political constituencies involved in funding decisions.

The policy trends documented here are relatively recent, and it is too early to measure tangible achievements in terms of national goals. Nonetheless, the importance of developing innovative strategies and frameworks to capitalize on S&T and to develop coherence in public policy cannot be overstated (*5*).

Contestable Generalizations

It has become almost de rigueur in the United Kingdom, and elsewhere, to comment that the major impediment to industrial exploitation of science is the short-termism of industry and inadequacies in the management and comprehension of technology within executive boardrooms. These generalizations are questionable and dangerous. Excellence and mediocrity exist in both industry and academia, and national competitiveness demands excellence in both. In some sectors, industry scientists are world leaders. The pharmaceutical sector, for example, is outstandingly successful in the global marketplace. R&D expenditure by U.K. pharmaceutical companies accounts for 34% of national industrial R&D (*6*) and exceeds the life-sciences research funding provided by government and the medical charities. Pharmaceutical companies have also become leaders in life-sciences basic research such as genomics.

The assumption that the short-termist views of U.K. shareholders take precedence over patient investment for innovation can also be challenged (*7*). The United Kingdom has lagged behind the United States in the launch of new life-sciences companies with venture capital, but is ahead of continental Europe in the vitality of this sector (*8*). Whereas much remains to be done to infuse S&T into business degrees and the syllabi of other professions (such as law, accountancy, banking, and insurance) routinely involved in S&T activities (*8*), the United Kingdom also leads Europe in this regard.

In some parts of academia, there has been a delusional belief that every institute of higher education must become an international center of research excellence. Yet the expansion in the number of universities, following the recent U.K. reclassification of higher education centers, means that relatively few will achieve this status. Moreover, the capital investment for world-class competitiveness is daunting. The long-term effect of passive neglect of the science base infrastructure will be an inability to compete in the next century, when innovative technology products will be at a global premium. Neglect of an underpinning academic infrastructure implies a lack of appreciation by politicians of the importance of modern science in industrial competitiveness, or a decision that science is a low-priority national issue, or worse still, both.

Linking Research Outcomes to Socioeconomic Progress

It cannot be assumed that greater public awareness of S&T will necessarily promote public support for research (*9*). The potential to apply genetics research to improve human health will be influenced as much by the social environment in which scientific advances occur, and in which they are to be applied, as by research progress per se (*10*). Enabling the public at large to participate in the debate on S&T goals will remain a major challenge as citizens become increasingly cocooned from risk, expecting simple answers to complex problems and obtaining information from sensationalist media accounts that promise instant breakthroughs or impending catastrophe.

The economic and social dislocations created by new technologies can also pose troubling problems for all governments. New technology may create unemployment in

R. Fears is Director of Science Policy and G. Poste is Chairman of R&D, SmithKline Beecham Pharmaceuticals, New Frontiers Science Park, Harlow, Essex CM19 5AW, UK.
M. W. J. Ferguson is Professor and Dean of biological sciences, University of Manchester, Manchester M13 9PT, UK.
W. Stewart is President of The BioIndustry Association, Belgrave Square, London SW1X 8PS, UK.

traditional industries, often with devastating impacts on local communities overly dependent on firms founded in a previous era of industrial evolution and ill adapted to respond. It is imperative, however, that policies to sustain employment (a legitimate social goal) should not masquerade as S&T policy.

The perceived need to better link basic research to industrial application carries major implications for academic R&D. A "trust us" strategy from academia will no longer suffice when governments are faced with the unenviable task of allocating inadequate resources across a broad spectrum of social demand, much of which possesses greater leverage than the science base. All scientists must be prepared to accept and, more usefully, propose productivity measures for invention and for innovation (*11*). Without such willingness, the scientific community will come to be seen by politicians and the public as wanting to escape public accountability. Performance needs to be defined in terms of the quality of ideas generated and selected, the scope and scale of eventual industrial adoption, and success of industry in a global market. Interest in measuring the return of R&D investment is exemplified by the increasing emphasis on evidence-based medicine (outcomes research in the United States) in optimizing health care services (*12*, *13*).

The United Kingdom Technology Foresight Programme

The Office of Science and Technology (OST), established by the U.K. government in 1990, set out to better harness R&D across government departments and to develop new approaches for supporting academic research. The Technology Foresight Programme (TFP) (*14*) represents the most comprehensive inventory of national S&T assets in three decades, involving both academic and industrial constituencies. The TFP is influencing government decisions on future funding policies and regulations. Importantly, this activity does not signify an end to a pluralistic R&D system. In the United Kingdom, as in other countries, there has been a transformation in the mode of production of fundamental knowledge. It is no longer the sole preserve of universities and the funding research councils, but now involves a diversity of funding agencies and a broad spectrum of researchers in industry, government, charities, and academia (*15*).

The TFP recommendations on health and life sciences provide a clear profile of the size, scale, and complexity of U.K. research in biology and medicine (*16*); emphasize the need for greater interdisciplinary activities; and stress the vital importance of modern infrastructure and advanced computing. To ensure that S&T continues to occupy a place on the national agenda and to attract the attention of government and society at large, several challenges must be addressed.

First, in terms of scientific issues, creation of multidisciplinary support for integrative biology must be accorded high priority. Integrative biology encompasses a range of approaches—from faster identification of gene functions obtained from gene sequence to a more complete understanding of neurobiology, immunology, aging at a molecular, cellular, and whole organism level. Tools for defining and communicating risk-benefit issues to the public also merit greater attention. In addition, health policy must move from the present operation of a "sickness service" to the construction of a genuine "health" service in which disease prediction and prevention are accorded higher priority.

Second, at the educational level, world-class health care R&D cannot be sustained without an adequate university infrastructure and appropriately trained people. For example, clinical research requires new entrants trained at the interfaces such as doctor/scientist, doctor/information technology specialist, and doctor/economist, among others. Similarly, the dramatic change that will be imposed by molecular medicine, and genomics in particular, will pose substantive challenges for future professional competency and will require radical shifts in the medical curriculum.

Third, there is an urgent need to stimulate formation of new wealth-generating companies. Policy options range from the introduction of fiscal incentives for encouraging R&D to facilitating transfer across the academic-industry interface. We emphasize that commercial opportunities must not be interpreted solely in terms of new start-up companies emerging from the universities, important though these are. Imaginative ways of linking larger companies with leading academic researchers and spinning out new companies from larger parents offer new approaches for which we see considerable potential.

The Need for Consistency in European Union Policies

Europe, as a political union, is a formidable entity linked by a complex legislative framework. Yet at the national level, public ambivalence abounds concerning the correct balance between national sovereignty and autonomy versus subjugation to pan-European policies. It is clear, however, that European Parliamentary rulings affect all member nations. Coherence and consistency in science policy is essential if the full intellectual capital of Europe is to be harnessed for societal benefit. Such requirements are far from guaranteed, however, as evidenced by the difficulties encountered in reaching legislative consensus with respect to European Union regulations for genetically modified organisms, biotechnology products, and the patenting of genomic inventions, and with the Council of Europe Bioethics Convention. We believe that the TFP experience in the United Kingdom offers a wider lesson for Europe as a way of linking S&T "push" with societal "pull" and, in so doing, will reverse current fragmented policies and harness the formidable resources of intellectual capital that exist in Europe to the advantage of member nations and for global health care.

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