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Some critical episodes in the progress of medical innovation: An Anglo-American perspective

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ABSTRACT

The central concern of this paper is to show that medical innovations have depended heavily on breaking down barriers that have long prevailed in the academic world, in the form of disciplinary boundaries that have coalesced into separate departments; to be specific, some of the biggest breakthroughs for the Life Sciences have come from the realm of the Physical Sciences. The present study is confined mainly to molecular biology and to diagnostic technologies (as well as to the therapeutic technologies that have frequently flowed from them); both owed a great deal to institutional innovations that emerged in the Anglo-American medical research world. Opportunities for transfers of instrumentation and techniques across disciplinary boundaries have been considerably strengthened as medical schools have been located, geographically and organizationally, closer to the universities. The American Medical Centers and the Stanford Program provide many examples. These achieved more than counterparts in the UK like the Cavendish Laboratories at Cambridge, which had pioneered in such fields.

1. The emergence of the Life Sciences

The central concern of this paper is to show that medical innovations have depended heavily on breaking down barriers that have long prevailed in the academic world, in the form of disciplinary boundaries that have coalesced into separate departments. In the longer run, this sharp distinction between Life Sciences and Physical Sciences may be the basis for excessively narrow and inappropriate policy recommendations. The reason is that so many of the fundamental breakthroughs have come from outside of what we now call the Life Sciences; to be specific, some of the biggest breakthroughs for the Life Sciences have come from the realm of the Physical Sciences.

In making this argument, I do not reject the view that the 21st century is likely to be dominated by the Life Sciences. The growth in medical science, beginning in the last third of the 19th century with Pasteur's brilliant creation of the science of bacteriology, led to a vastly increasing degree of specialization in the medical world, both in medical research and in medical practice. Although this specialization generated huge benefits, it also imposed some severe constraints due to the obvious difficulties in dealing with problems that required a convergence of information from several separate disciplines. Pasteur contributed heavily to the need for more interdisciplinary research by the very growth of new specialized disciplines to which his research findings gave rise.

Fig. 1 sets out data on funding for basic and applied research from federal sources by the US government since 1970, distinguishing the NIH support for biomedical research from other agencies' support for Life Sciences, and shows impressively how the growth in total spending over these years has been dominated by the former, especially over the two decades from 1984 onwards.

One of the most powerful components of medical progress in the past 50 years has been the introduction of diagnostic technologies that have drastically transformed numerous sectors of medical care. Twenty-five or thirty years ago it was frequently said, often by prominent figures in the medical world, that such diagnostic technologies, however fascinating, were not leading to genuinely useful forms of therapy. This has (happily) turned out to be seriously incorrect, because they were looking for short-term benefits, and the benefits, as we now know, were generated only over much longer stretches of time. A similar statement can be made with respect to the breakthroughs flowing from molecular biology. The present study is confined mainly to molecular biology and to diagnostic technologies (as well as to the therapeutic technologies that have frequently flowed from them); both owed a great deal to institutional innovations that emerged in the Anglo-American medical research world.

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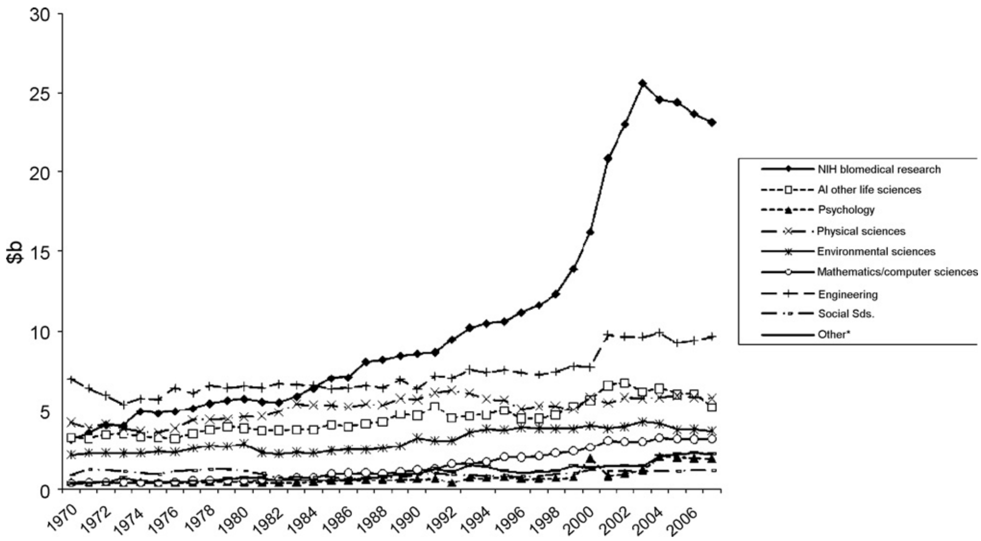

Fig. 1. Trends in federal research by discipline, 1970–2007 (constant $b). Notes: Basic and applied research only (Development and R&D facilities are not classified by discipline). Life Sciences are split into NIH support for biomedical research and all other agencies' support for Life Sciences (thanks to Scott Stern in preparing this breakdown). (*) includes research not elsewhere classified. FY 2006 and 2007 are preliminary data. Constant-dollar conversions based on GDP deflators from Budget of the US Government, FY 2009. Source: AAAS R&D Budget and Policy Program, Guide to R&D Funding; chart of Historical Data. Source data: National Science Foundation, Federal Funds for Research and Development, by FY.

Note also that the great achievements in medical research instrumentation have been powerfully complemented by the impacts of other innovations that have taken place well outside the medical world: information, computer and communication technologies that have, in turn, transformed the nature of research itself in the past quarter century.[1]

Instrumentation and techniques have moved from one scientific discipline to another in ways that have been full of consequences for the progress of science. In fact, it can be argued that an understanding of the progress of individual disciplines is generally unattainable in the absence of an examination of how different areas of science have influenced one another through technology transfer. This understanding is frequently tied directly to the timing, and the mode of transfer, of scientific instruments as well as useful new knowledge. What is obviously true is that opportunities for such transfers have been considerably strengthened as medical schools have been located, geographically and organizationally, closer to the universities.

2. X-ray crystallography: a powerful new instrument for medical research

The great breakthrough in the emergence of the Life Sciences was intimately connected with new instrumentations and methodologies that made it possible to examine the structure of very large protein molecules. Such examinations were at the center of the new science of molecular biology. What was involved was the crossing of certain disciplinary boundaries in the scientific world – or at least in the academic world – that were widely regarded as impenetrable. In much of the academic world, boundaries have frequently been barriers.

Erwin Schrodinger, an Austrian physicist, threw down the gauntlet in a book published in 1944, called "What is Life?" Moreover, in the early 1930s, Niels Bohr had suggested that physicists undertake an "epistemological transfer" in order ". . . to try to see how the new vision of the physical world changed perceptions of the biological world" (Morange, 2000: p. 72). By "changed perceptions", Bohr was of course referring to Quantum Theory.

[1] Physics Review Committee (1986), pp. 16–18, 21 and chapter 13.

Table 1
Growth of US academic medicine, 1960–1992 (1992 $).

	1960	1970	1980	1992
Support from NIH (millions of $)	1,320	3,028	5,419	8,407
Average Medical School budget (millions of $)	24.1	64.6	91.9	200.4
Full-time Medical School faculty (no.)				
Basic	4,023	8,283	12,816	15,579
Clinical	7,201	19,256	37,716	65,913
Matriculated Medical Students (no.)	30,288	40,487	65,189	66,142

Source: Iglehart (1994).

In the new physics, "A given object, such as a photon could, indeed, should, be studied both as a wave and as a particle" (ibid.: 72).[2] Donald Fleming has said of Leo Szilard: "Szilard was palpably mistaken when he said that conventional biologists were not interested in explanations. He was perfectly correct in sensing that they were seldom driven by the same passion as himself for ultimate explanations. It was this alien impulse that he and other physicists brought to the new 'molecular' biology—to strike for the ultimate secrets of life, and nothing less" (Fleming and Bailyn, 1969: p. 162). Table 1.

Although the origins of the new science of molecular biology are, with good reason, associated with Cambridge (England), the more specific institutional location in Cambridge was quite remarkable, i.e. the Cavendish Labs. What made the location remarkable is that, at the time, the Cavendish Labs were regarded as the world's most distinguished center for research in the realm of physics.

In looking upon the growth of the Life Sciences through the longer course of the 20th century, we should no longer be surprised to find that the Life Sciences had their critical beginnings in the realm of physics. In fact, such dependency goes as far back in time as the beginning of the X-ray machine in the middle of the 1890s. It should be recalled that X-rays were (serendipitously) discovered by Roentgen, who was a professor of physics at Wurzburg at the

[2] For insightful treatments of some of the leading figures of the 'new physics', see Fleming and Bailyn (1969); in particular, Leo Szilard, "Reminiscences" (Chapter 2), and Donald Fleming, "Émigré Physicists and the Biological Revolution" (Chapter 3).