

Resuscitating industrial research without monopoly money

The award of the 2009 Nobel Prize in Physics to Charles Kao, Willard Boyle, and George E. Smith underscores again the importance of industrial research, the subject of Joe Anderson and Orv Butler's article, "Industrial R&D in Transition" (PHYSICS TODAY, July 2009, page 36). I have a few comments to add about companies involved in semiconductor research, with which I am most familiar.

At Bell Labs from the postwar period through the mid-1960s, an "enlightened management philosophy" espoused by President Mervin Kelly attracted some of the best scientists and engineers, allowing them substantial latitude to follow their instincts in pursuit of basic research. But their research had to be on topics that might help its parent company AT&T improve its communications products and services. That mission-oriented approach helped Bell Labs attract such first-rate physicists as William Shockley, John Bardeen, Charles Townes, and Philip Anderson, who would otherwise have gone right into academia (which they all did eventually). Kelly realized that scientists of such high caliber could not be told exactly what research avenues to pursue but instead needed the freedom to find their own paths. By setting an overarching mission of improving communications, however, Kelly got what he had bargained for.

Thus when Bardeen came on board in early 1946, Shockley asked him to examine why the group's attempts to make a field-effect semiconductor amplifier had failed so miserably. Bardeen soon suggested his hypothesis of "surface

states"—that electrons trapped on the semiconductor surface were blocking electric fields from penetrating it. He and Walter Brattain were then encouraged to pursue basic research on the nature of those states. More than a year later, in November 1947, they made a serendipitous discovery that enabled them to invent the point-contact transistor. The mission-oriented focus of industrial research at Bell Labs meant that the fruits of basic research could be applied almost immediately to fabricating a useful electronic device. Today, more than 60 years later, the transistor is among the most useful devices ever created.

Bell Labs could afford to grant its best scientists that freedom because AT&T enjoyed a regulated monopoly on US telephone service. A few pennies of every dollar that we paid for toll calls in those days went to support the R&D efforts of Bell Labs and Western Electric. Given such a stable, assured funding stream, managers like Kelly could take a long-range view and support risky research projects that might not contribute to the company's bottom line for decades, if ever. Other industrial labs that did basic research—for example, General Electric and IBM—also enjoyed lucrative monopolies or near-monopolies on important goods and services. They, too, could and did take the long view.

After its 1984 breakup, however, AT&T had to compete head-to-head with its regional offspring and other companies such as MCI. Bell Labs no longer enjoyed the stable funding guaranteed by government regulation. Although its managers strove to maintain a commitment to basic research, the financial odds were stacked against them. Research that might not contribute to the bottom line within several years became increasingly difficult to justify.

Similar influences contributed to the decline of the central research labs that Anderson and Butler discuss, many of which had been established during the 1950s and 1960s in emulation of Bell Labs. Another problem was getting the fruits of research out of the labs and into product development in their manufacturing arms. Here Kelly tried another management innovation, setting up satellite units of Bell Labs engineers in

certain Western Electric plants—for example, the plant in Allentown, Pennsylvania, that fabricated high-tech semiconductor devices. Similar difficulties occurred at Fairchild Semiconductor Corp, which marketed the first commercial silicon microchips in 1961. Thus when Robert Noyce and Gordon Moore quit Fairchild and founded Intel seven years later, they intentionally avoided setting up a separate research lab; instead they incorporated R&D (predominantly D) functions directly in Intel's production units.

The 1950s and 1960s truly marked the industrial research labs' golden age, driven in part by the Cold War and ample military funding, and Bell Labs was its great exemplar. Doing basic research in a practical, industrial context and focusing it on improving goods and services has clearly had an enormous impact on modern life. We need to find ways to resuscitate that kind of activity in our laboratories today.

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Many of the points made in the article "Industrial R&D in Transition" are excellent, informative, and timely. In the section headed "Decentralizing research," the authors expressed some skepticism about the effectiveness of joint research involving industry, academia, and the government. We believe such collaboration can be extremely effective. The Semiconductor Research Corp, of which the Micro Electronics Advanced Research Corp and the Nanoelectronics Research Corp are subsidiaries, is an industrial consortium that sponsors precompetitive and targeted university research on behalf of the semiconductor industry. Since its founding in 1982, the SRC has helped to enable the continuation of an exponential rate of growth in performance per unit cost (Moore's law) for semiconductors and has provided support for more than 7500 graduates with advanced degrees in semiconductor technologies and related areas.

The SRC was gratified to receive the 2005 US National Medal of Technology for its contributions to the advancement of semiconductor technologies. Our

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experience has been that joint sponsorship of university research by industry and government agencies works well and can satisfy the missions of all three entities. Indeed, it is not difficult to find common ground between the research-program focus of our consortium and that of government research agencies.

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Butler replies: Michael Riordan correctly points out that AT&T could, as a monopoly, justify funding basic research at Bell Labs, something it could no longer do after its breakup. Although the results of that research did have enormous impact on modern life, Stephen Adams and I discovered, while writing *Manufacturing the Future: A History of Western Electric* (Cambridge University Press, 1998), that the impact was frequently delayed. Monopolies could fund basic research as good corporate citizens, in part because they could spread out the deployment of results to ensure adequate returns on disruptive innovations. As a monopoly, AT&T often waited to introduce the innovations created at Bell Labs. In the 1950s the average product life cycle at AT&T was on the order of 20 years. Under competitive pressures after 1984, that life cycle, we were told, shrank by 1996 to about six months and sometimes pushed to three months.

After 1996 Bell Labs, as a part of Lucent Technologies, might immediately develop innovations it created, but it lacked the funds to maintain the level of research it had under the AT&T monopoly. After the loss of monopoly status, competition pushed innovations into the marketplace at a far faster rate, but those innovations became increasingly incremental rather than transforming the technology.

Larry Sumney and Ralph Cavin reflect the views of the one industry that our study found to have successfully resolved the tensions in the research nexus involving industry, government, and academia. Research sponsored by microchip industry consortia is industry driven rather than government or university driven and is largely limited to “precompetitive” research—that is, research to improve the products of the industry as a whole without giving advantage to any single corporation or group of corporations. Microchip industry consortia have resolved the intellectual-property tensions between corporate interests and universities by

requiring a royalty-free license to members for any research funded by the consortium. A university, however, retains the right to sell that intellectual property to those outside the consortium. Whether or not industry-wide, consortium-led research would work in all high-tech industries remains to be seen. However, Semiconductor Research Corp and other microchip industry consortia provide a good model for one way to resolve the tensions frequently underlying government-driven university and industry collaborations.

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Newcomb looked to astronomy's future

Among the comments we received in response to our article “Simon Newcomb, America's First Great Astronomer” (PHYSICS TODAY, February 2009, page 46) are a number of inquiries about an often repeated quotation attributed to Simon Newcomb: “As far as astronomy is concerned, it must be confessed that we do appear to be fast reaching the limits of our knowledge.” An internet search brings up hundreds of sites that present this quotation as an example of how short-sighted, and wrong, even the most renowned scientists, inventors, and other learned people can be. But few sites include a proper reference to the quotation, let alone put it into context.

Newcomb first made the comment as part of a speech titled “The Place of Astronomy Among the Sciences,”¹ which he presented at the dedication of a new astronomical observatory at Syracuse University in New York on 18 November 1887. A more complete quotation is, “It would be too much to say with confidence that the age of great discoveries in any branch of science has passed by: yet, so far as astronomy is concerned, it must be confessed that we do appear to be fast reaching the limits of our knowledge. True, there is still a great deal to learn.”

Newcomb was talking about the “old astronomy” that focused almost entirely on cataloging celestial objects—stars, planets, moons, asteroids, comets—and computing their motions. In the same talk he also said that “all the geometry and astronomy, all the phenomena of the motions of the heavenly bodies are already reduced to one gen-

eral law.” He was referring to Newton's universal law of gravitation, which he then accepted without reservation. As we pointed out in our article, and in more detail in our book,² Newcomb later began to question Newtonian physics as he struggled with the discrepancies in the motions of Mercury. Ultimately, his findings provided an immediate test of Einstein's theory of general relativity.

It is important to realize that Newcomb was not including “new astronomy,” generally referred to today as astrophysics, in his assessment of the outlook for future discoveries about the universe. Just two paragraphs later in the printed version of his talk, he explicitly refers to the “new science of physical astronomy,” states that “the study of the stellar spectrum is a worthy one,” and mentions his curiosity about whether the spectrum of Sirius will change as the star goes through various stages of its life.

Newcomb's interest in learning about the universe never waned, and he argued strongly for the pure pursuit of knowledge, saying that it seemed almost as if the secrets of nature would be revealed “only to those who investigate from a love of nature herself.”

References

1. S. Newcomb, pts. 1 and 2, *Sidereal Messenger* 7, 14 (January 1888); 7, 65 (February 1888).
2. W. E. Carter, M. S. Carter, *Simon Newcomb: America's Unofficial Astronomer Royal*, Mantanzas, St. Augustine, FL (2006).

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