genetics may be, they do not seem adequate to the task of understanding the intricacies of the central nervous system. As Crick points out, these tools tend to furnish a "linear" understanding of problems, in the sense that the genetic code is linear. Whether they can furnish a deeper understanding of the brain—or, for that matter, of other puzzles such as differentiation and development—is another question altogether.

Like it or not, this doubt touches virtually all of the most intractable problems in biology, but is seldom considered anymore because the molecular biologists have enjoyed so many successes. For example, technicians now can sequence virtually any gene with ease, and the rush to popularize the appropriate techniques and cash in on them tends to obscure the inscrutability of the information often thereby produced. Undeniably, gene sequences often are, and will continue to be, useful. But, too often, simply knowing them is unenlightening.

"I want to dispel the impression that we know all there is to know," said Sidney Brenner, who is head of the Medical Research Council Laboratory for Molecular Biology in Cambridge, England, in one of the rare moments during the 3-day meeting when the current state of molecular biology was genuinely criticized. According to Brenner, there remains "a lot to find out" in the science of biology, which is not at a point where merely "applying things" can possibly solve all of the interesting problems. Properly understood, Brenner's message ought to discomfit some otherwise successful molecular biologists, many of whom now have jobs in the new biotechnology industry where the rush to find applications often replaces the search for understanding. Genetic engineering, upon which this industry depends, often seems to lack "the essence of design," Brenner, added. "Perhaps we're only 'genetic mechanics' today."

"Because experts are burdened with too much knowledge, they have done poorly at predicting the future in science," said Harvard molecular biologist Paul Doty during the Boston meeting. Though framed in a somewhat different context, his remark can be interpreted as a warning to those who have become too enthralled with the powerful tools now available to molecular biologists. Thus, even the best and the brightest of these scientists may be running the risk of stagnation by burdening themselves with too much of but one kind of data.

—JEFFREY L. FOX

Jeffrey Fox

Thirty years on

"The last opportunity to see [us] as we were."

Bell Labs—New Focus on the Bottom Line

Accustomed to a regulated life, how will the Labs do in the knock-down, drag-out world of competition?

The impending court-ordered breakup of the Bell system has stirred misgivings about the future of fundamental research at Bell Laboratories and the prospects for innovation in the U.S. telecommunications industry (*Science*, 23 September, p. 1267). But the Labs' product development and software engineering activities will have greater immediate influence on how AT&T fares as it moves from monopoly to the marketplace.

The hurly-burly of competition will force major changes both in the way that Bell Labs does its applied work and in its overall mission. When divestiture goes into effect separating the local telephone operating companies from AT&T, Bell Labs will lose its end-to-end responsibility for both technological innovation and network planning in the Bell system. Although Bell Labs' public image has been shaped primarily by its achievements in fundamental research, almost 90 percent of its technical staff has been occupied in providing a wide range of services—notably design and development of equipment, software engineering, and network planning—required to keep the huge and complex Bell system operating. After the breakup scheduled for 1 January, Bell Labs will serve as the R & D arm and Western Electric as the manufacturing arm, of the remaining AT&T companies.*

The traditional mission of Bell Labs and Western Electric was described by Bell Labs president Ian M. Ross in 1981 court testimony as "reducing operating costs and improving service" for the Bell system at large. Ross said that after the breakup, Western's mission would, perforce, be to maximize its profits.

To maximize profits, Bell Labs and Western Electric will have to compete successfully head to head with so-called general trade companies which have had to be nimble in the marketplace to survive. Past experience has not provided the Bell Labs–Western partnership strong preparation for the encounter. The partnership has been a unique one in which the R & D arm, Bell Labs, retained control for life over a product it had designed and developed. If problems arose, Bell Labs dealt with them. And with its responsibility for standard setting and network planning Bell Labs exercised unusual influence on the adoption of new technology and the pace of innovation over the whole system.

For all its merits, the Bell system has often been faulted for being slow to introduce new technology. Critics attribute this at least in part to AT&T's status as a regulated enterprise whose income has been tied to the rate base. What the company owns—plant and equipment—and its operating costs all figure into the rate base. Telephone equipment is traditionally amortized over a long period—regulatory agencies don't like quick write-offs. The Bell design strategy, so the argument goes, was influenced by the depreciation schedule and the fact that cost of expensive equipment could be recovered in the rate base. It was to the company's advantage, therefore, to design and manufacture reliable, long-lived equipment. This Bell Labs and Western Electric have done,

*Other AT&T subsidiaries will be AT&T Communications (long distance service), AT&T International (overseas operations), and AT&T Information Services (ATTIS, marketing equipment and services to business).

perhaps to a fault, considering the conditions they now face.

Critics say that to cope with the demands of cost-based pricing, AT&T will have to control its penchant for "gold-plating" in product development, speed up the development process, and get its high-production costs down. Bell Labs executives concede that their product strategy will have to be amended to come to terms with the industry trend toward shorter design life and with lower costs of production spurred by the rapid advance of chip technology. Perhaps most significant, Western Electric rather than Bell Labs is expected increasingly to call the tune in decisions on product development.

A case often cited to show that AT&T can err as an innovator is that of the PBX (private branch exchange) in the 1970's. AT&T is said to have lagged in exploiting new market opportunities created by advancing electronics technology as the conventional switchboard became a highly versatile piece of electronic equipment. At the time, the Federal Communications Commission (FCC) had begun to allow the connection of non-Bell terminal equipment to the telephone system, a development which AT&T had always opposed. A new report from the Organization for Economic Cooperation and Development "Telecommunications: Pressures and Policies for Change," notes that the number of PBX manufacturers in the United States rose from four in 1969 to 30 by 1980 and that over 1000 companies registered with the FCC to sell terminal equipment. The report says that the use of standard integrated circuits and system software reduced engineering development costs and lowered PBX manufacturing start-up costs from millions to hundreds of thousands of dollars. Companies with backgrounds in integrated circuits, computers, or software design entered the PBX market. AT&T suffered heavy losses of market share but responded with unaccustomed alacrity by announcing in 1979 that it would develop a full line of digital PBX's in 2 years.

One veteran of the PBX wars with a double perspective is a former Bell Labs' staff member, Ivan Cermak, who is now director of the ITT Advanced Technology Center in Connecticut. Cermak's last job with Bell Labs was in the organization's push to regain the initiative for Western Electric in the PBX market. He left 4 years later over what he recalls was a disagreement on product strategy. The main challenge to Western in the market for medium sized PBX's came from a Rolm digital PBX based on a military processor which was introduced in the middle 1970's. It was expensive but found a strong market. The Rolm PBX and others with sophisticated features cut into AT&T's market share. When work on the Western Electric answer went slower than anticipated, Cermak says he felt that the company should introduce an interim design to meet the competition. The difficulty of getting a corporate decision left him feeling that "there was nobody in charge," he says. The "troika" that traditionally made such decisions—Bell Labs representing development, Western Electric, manufacturing, and AT&T, marketing—in this case simply proved to be "too cumbersome."

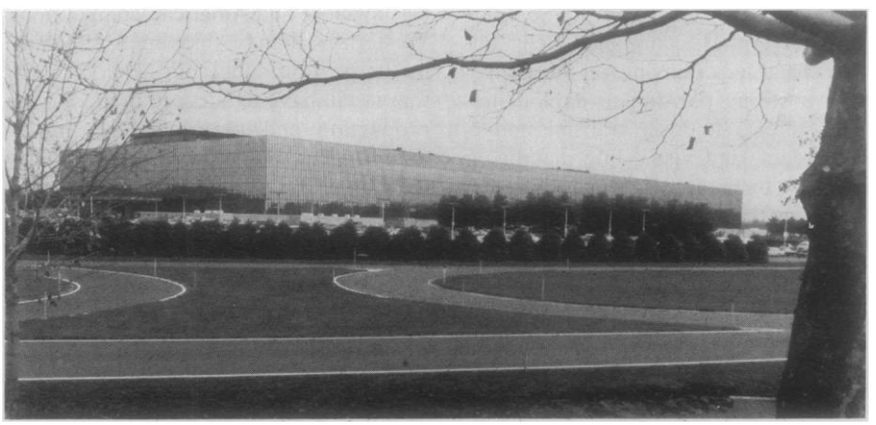
AT&T's new circumstances will require a different organization, says Cermak. The company will also have to reform its sales force, he says, repeating a frequently voiced criticism that AT&T sales force is made up of "order takers," whose habits were formed by monopoly conditions.

Cermak says he is convinced that divestiture will bring solid opportunities for ITT and other telecommunications and electronics companies to provide both products and R & D for the newly independent Bell operating companies. He notes that ITT already has a contract for R & D work with Southern New England Telephone, in which AT&T has a minority holding. He expects the ability of ITT and other firms to respond to the special needs of individual Bell companies to stand them in good stead in a competitive market.

It is certainly premature to conclude that past conditioning will cripple the Bell Labs–Western combination in the competitive arena. One Bell Labs insider notes that a new generation of top managers has taken over in the last decade, and they are "more hardnosed and concerned with the bottom line." It is regarded as significant that Bell Labs president Ian Ross is an engineer while his predecessors were trained in the physical sciences.

Despite the reductions in staff brought by divestiture, Bell Labs with 17,000 employees remains a very large industrial laboratory with what are widely admired as unparalleled resources. And the resolution of the AT&T antitrust case unleashes Bell Labs and Western Electric to pursue commercial opportunities with technology it was prohibited from exploiting in the past.

In its venture into what Ross calls "a new environment," he says Bell Labs expects to emphasize four key technologies—microelectronics, software systems, digital systems, and photonics or lightwave technology, which are already Bell Labs strong suits.



Bell Labs' Holmdel facility

The labs will lose some control over the pace of innovation in AT&T.

Bell Labs products, as one Labs executive put it, has been knowledge and technology. In late years, a lot of effort has gone into software to make the technology work. In a recent speech, Bell Labs vice president for computer technology and military systems, Eric Sumner, noted that in 1974 about 15 percent of the Labs technical staff was engaged in software development and software support. By last year, roughly half of the same group were concerned with software. Bell Labs prowess in software is exemplified by the saga of the UNIX operating system developed by Bell Labs staff in 1969 to facilitate computer time-sharing. An operating system is a program that acts as a sort of traffic manager to enable a computer to perform instructions efficiently. This year four major semiconductor companies—Intel, Motorola, National Semiconductor, and Zilog—signed agreements that will allow them to adopt the updated UNIX System V operating system for

use in their microprocessor products. The UNIX system is known for its "portability" which permits it to be used in the full range of computers from personal computers to mainframes. The agreement was interpreted in the trade press as a move by AT&T to have the system become standard in the industry.

Companies that adopt the UNIX system for their products pay licensing fees to AT&T. Perhaps more significant, Bell Labs and Western Electric have developed a broad range of software products based on the UNIX system that the company will be free to sell after divestiture.

AT&T has already made an aggressive move to capitalize on lightwave technology developed at Bell Labs and Western. The company, for example, is optimistic about its bid in the competition for the contract to lay the first Atlantic cable using fiber optics technology. Bell Labs also is regarded as having put the company in a strong position to exploit new developments in laser transmission of voice, data, and visual information via lightwave technology and is rumored to be nearing the commercial application of the technology to computers and memories.

AT&T is also regarded as capable of emerging full armed into the savagely competitive semiconductor industry. Western Electric is already among the dozen largest manufacturers of integrated circuits, although its products have been made only for internal consumption.

ITT's Cermak appears to express a view widely held in the industry with his appraisal that Western will be "a major force in semiconductors in a couple of areas. Their design capability is very good and they've invested a lot of money in tools," particularly for semiconductor applications in semicustom products. Such products are based on standard chips whose design can be varied to suit customer specifications.

Western will plunge into the vortex of semiconductor competition by vying for a share of the market for the 256K random access memory chip, the prospective big seller among integrated circuits. This will pit Western against the toughest Japanese and American competition. Western is already shipping 256K chips for its own products, but observers say that it will have to succeed in increasing production and lowering costs in its unionized factories in order to establish itself as a front runner.

Western is the developer of admired microprocessors used in its switching equipment and in fact is the source of many advances in computer science and design. Much speculation has centered on the question of what strategy AT&T will be following in venturing into the computer business. Company sources are noncommital about the rumor that Western will produce a personal computer and make a bold challenge to IBM on its own ground.

For Bell Labs and its AT&T parent, divestiture obviously brings risks and opportunities. Bell Labs officers jest wryly that since they managed the chaos of reorganization they should be able to survive mere competition. The restructuring, in fact, is not yet complete. Appeals about some details are still pending. Furthermore, Bell Labs and AT&T will have to live with vestiges of regulation. To satisfy the antitrust lawyers' aversion of cross subsidies, for example, Bell Labs is required to deal at arms length in various ways with AT&T's marketing subsidiary, AT&T Information Services (ATTIS), so that competitors are not put at unfair advantage. And other difficulties could arise. The move to cost-based pricing has upset the system of subsidies designed to promote universal telephone service by keeping local telephone service inexpensive. The cost of local service will rise with divestiture and a backlash is already building in Congress. An attempt by Congress to revise the overall settlement is seen as highly possible. And despite divestiture, the shock of political intervention could still be transmitted along the network to Bell Labs.—JOHN WALSH

EPA, Utilities Grapple with PCB Problems

PCB's in transformers may be a thing of the past sooner than expected

The Environmental Protection Agency (EPA) and a few utility companies seem ready to accede to demands that steps be taken quickly to replace electrical equipment containing polychlorinated biphenyls or PCB's. This appears to be a reversal, at least on the part of EPA, of a longstanding view that PCB's in electrical equipment pose no significant health hazard. The utility companies, however, have responded as a result of recent PCB accidents and the lawsuits that followed.

In 1976, when Congress banned the manufacturing of PCB's, it presumably thought that problems with this pervasive and toxic chemical were for the most part solved. But a loophole in the law allowed the continued use of PCB's in electrical transformers and capacitors as insulation. A year ago, the utility industry successfully argued before EPA that transformers filled with PCB's should only be replaced as the equipment wore out. At this rate, transformers would be replaced in 20 years. The cost to proceed any faster would be prohibitive, the industry contended.

Now EPA is moving to close the loophole. Because accidents involving the release of PCB's are occurring much more frequently than previously believed, EPA is considering a costly proposal that would ban PCB transformers in public buildings. But in the past 6 months, two utility companies say they have decided to speed up the replacement program not because they believe there are serious health hazards linked with PCB's but because they say they are weary of trying to counter the public perception that PCB's are extremely toxic. Public concerns were heightened after transformer accidents in Binghamton, New York, and San Francisco resulted in the contamination of commercial buildings, costing millions of dollars to clean up.

Other companies are campaigning to calm public fears about PCB's. General Electric and Monsanto, for example, have been active in disseminating information claiming that the health effects of PCB's have been overblown. Although there is good evidence that PCB's are toxic at high dose levels, the companies maintain that the data on low-dose effects are far less clear cut.

Last May, the Pacific Gas and Electric Company decided to replace its large transformers shortly after one of them