women in the San Antonio data bank who had positive lymph nodes and for whom relapse and survival information was available. Without knowing anything about the patients' clinical status, Slamon and his associates did DNA analyses, looking for oncogene amplification. The oncogene was amplified in 40% of the patients.

When the group then looked at the clinical data, it found that the more the oncogene was amplified, the more likely the woman was to relapse and the shorter her survival time. "Oncogene amplification was a better indicator than hormone receptor status, age of the patient, and size of the tumor. And it was independent of the number of positive nodes," Slamon says. Statistician Clark remarks that oncogene amplification is "the first prognostic factor that I've seen that, by itself, is that powerful." The more the oncogene is amplified, the worse the prognosis.

The clinical implications, if the result is confirmed, can be important, particularly in women whose cancer has not spread to the lymph nodes. Physicians now classify breast cancer patients as being in stage I through stage IV of the disease. Stage IV is the most advanced. But these stages are not foolproof, and oncologists would like to break down the classification still further. They are particularly interested in getting better prognostic information on stage I women who have negative lymph nodes and who generally have such a good prognosis that they are not given radiation or chemotherapy after their breast cancer is removed. Yet, according to Clark, breast cancer will recur in 25 to 30% of these women with negative nodes.

A consensus conference on breast cancer held at the National Institutes of Health in September of 1985 debated the question of whether women with negative lymph nodes should receive chemotherapy or radiation and concluded that there were not enough data to decide. If the oncogene finding holds up in node-negative women, it could provide a means of deciding.

In addition, the oncogene finding could be important in deciding on therapy for postmenopausal women with positive lymph nodes. Most of these women, according to McGuire, do no better when they receive chemotherapy than when they do not. But, says McGuire, "we would like to know which postmenopausal, node-positive women will have an early recurrence of their cancer. Then we would treat them very aggressively."

The oncogene that is amplified in breast cancer cells also could be telling researchers what causes the disease in the first place and how to devise a molecularly targeted treatment. The gene codes for a protein kinase, an enzyme that adds phosphate to tyrosines of certain proteins. "It is most closely related to the EGF [epidermal growth factor] receptor, but it is not the EGF receptor," Slamon notes. No one knows what binds to this receptor protein, but if the EGF receptor plays a role in the development or progress of breast cancer, blocking it could possibly arrest or cure the disease.

Slamon, McGuire, and their associates are now expanding their study, looking particularly at node-negative women from the tissue bank in San Antonio for whom long-term relapse rate and survival are known. There are more than 9000 breast cancers stored in the data bank at San Antonio, so the investigators are optimistic that they will be able to do a definitive study. ■

GINA KOLATA

Materials Scientists Seek a Unified Voice

The rise of materials science as a recognizable discipline paralleled the growth of the Materials Research Laboratories now run by NSF, but funding and identity problems remain

LAST year was the 25th anniversary of the interdisciplinary Materials Research Laboratories, established by the Defense Advanced Research Projects Agency (DARPA) but administered by the National Science Foundation (NSF) since 1972. The just published proceedings of a symposium that was held a year ago at the National Academy of Sciences to celebrate the occasion contain another of what is becoming an increasingly frequent call for the broad and diverse materials science community to organize itself more formally.*

The hope expressed in contributions by C. Peter Flynn of the University of Illinois and William Nix of Stanford University is that, with an appropriate mechanism for arriving at a community consensus, funding decisions can be made in the context of an overall national program and the field can present its needs effectively in the national arena.

At the moment, the primary means for arriving at anything like a consensus are the committees assembled when the academy or some other body sets out to study a materials-related issue. Two years ago, for example, the academy turned out a report for the Office of Science and Technology Policy titled "Major Facilities for Materials Research and Related Disciplines."

Now under way is a massive academy study involving five subpanels and a steering committee, all under the direction of Praveen Chaudhari of IBM's Yorktown Heights laboratory and Merton Flemings of the Massachusetts Institute of Technology (MIT). The report, not due to be published for another 2 years, will be an attempt to present a unified view of materials science and engineering in the spirit of the recent academy overviews "Opportunities in Chemistry" and "Physics through the 1990's."

As valuable as these ad hoc efforts are, they cannot provide the kind of continuous guidance that, for example, the High Energy Physics Advisory Panel has given for about two decades. This group, which was chartered to advise the Department of Energy on the needs and wants of high-energy physicists, has become an oft-mentioned model for how a relatively homogeneous scientific community that has its act together can express itself to the federal agency that funds its operations.

Whether materials science, which is a far less homogeneous and a much newer discipline, can adapt this or some other model has become a frequently debated question as the field has matured, the cost of facilities grown, and the competition for funds increased. In particular, while providing state-of-the-art instrumentation is a problem across the board, the expanding role of so-called "big science" facilities, such as synchrotron light sources, has generated much tension in the community. Beyond the admonishment that major facilities must not come at the expense of individual and small-group research, the academy's study on the subject did not address the issue of how to

Advancing Materials Research is available from the National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418, for $47.50. Also see *Science* editorial, 2 January, p. 9.

balance the demands of the two kinds of science.

The diversity that characterizes the inherently interdisciplinary field of materials science is what makes arriving at a consensus so difficult. To take a few examples from the wide ranging frontiers of materials research presented in the symposium proceedings, consider the art and science of making things small.

■ Metallurgist Morris Cohen of MIT discussed what he called "nanocrystalline metals" in which the average diameter of the crystalline grains is about 5 nanometers. The relative volumes of the grains and the intergranular regions or grain boundaries are comparable. Both the structure and the composition in the grain-boundary region can be unlike that permitted in the crystalline areas, so that overall the material has an altered and sometimes substantially improved set of physical properties, including in one case a tenfold increase in the stress required to fracture a sample.

■ Physicist Bertrand Halperin of Harvard University outlined several unusual electrical and magnetic behaviors in very small structures that arise because of interference between electron waves that take different paths in the sample. The interference occurs even though the electron trajectories are interrupted by many scattering events. For example, the electrical resistance of a field effect transistor whose active area (channel) is only 200 nanometers long by 50 nanometers wide varies randomly with the value of the voltage applied to the gate electrode that turns the transistor on and off.

■ Chemist George Whitesides of Harvard mentioned the possibility of self-assembling composite materials at the molecular level. Composites consist of a fiber reinforcement imbedded in a matrix, thereby combining the desirable properties of both phases, such as strength and ductility. With a self-assembling system, the material could be processed while in an easy-to-handle homogeneous phase, after which it would spontaneously separate into microscopically heterogeneous domains. One method for accomplishing this that is under study involves a mixture of polymers (either a blend or block copolymer) that would separate into reinforcement and matrix phases when cured.

Materials research emerged as a discipline in its own right in the early 1960s. Its interdisciplinary science and engineering character is reflected in the philosophy that mathematics, physics, chemistry, metallurgy, ceramics, geology, and so on were the "tools" from which materials scientists drew as necessary in learning how to optimize the beneficial properties of materials by manipulating their structures. Typifying this outlook were the Materials Research Laboratories (MRLs), which in fact were initially called simply Interdisciplinary Laboratories.

As recalled in the symposium proceedings by Robert Sproull of the University of Rochester, several factors converged around 1959 to result in the formation of the MRLs. One was the frustration at the Atomic Energy Commission (AEC) as it gradually realized that materials limitations were negatively influencing the development of nuclear power and that there were few university facilities for training materials researchers. An academy study recommended the establishment of a National Materials Laboratory. And the President's Scientific Advisory Committee, organized in the post-Sputnik atmosphere, quickly identified materials research and training as top-priority items.

The lack of an organization that can speak with authority for the field must be addressed.

The Department of Defense (DOD) had also expressed interest in materials, and, partly because the AEC's 1-year contracts were incompatible with the long-term commitments needed to induce universities to make available space, facilities, and faculty slots, DARPA was given primary responsibility for setting up the Interdisciplinary Laboratory program. Between 1960 and 1962, laboratories were established at 12 universities by DARPA and at two by the AEC. A trailblazing feature of the laboratories was the then almost unique umbrella contract to the university that provided block funding for facilities, equipment, and some research support.

A decade later, when DOD dropped its support of nonmission-oriented research at universities, NSF took over the program and renamed the laboratories MRLs. By this time, there were also about 30 explicitly named materials departments in universities. In his review of the history of the MRLs in the symposium proceedings, Lyle Schwartz of the National Bureau of Standards noted that, under NSF's administration, some of the original MRLs were phased out and others added, but the most significant change was the development of the "thrust group" concept.

It turns out that despite the participation of researchers from many disciplines in the MRLs, truly collaborative research was rare. With thrust groups, NSF in effect encouraged research on complex problems requiring effort on the part of cross-disciplinary teams of investigators by making funding available at the expense of individual research support. In the last 2 years, NSF has also begun establishing Materials Research Groups at universities with the aim of creating opportunities for thrust groups at institutions without MRLs.

Even the universities that have MRLs face the common problem of providing instrumentation and research support services to faculty and students. Over the last decade, funding for instrumentation and support seems to have fallen in the cracks. As reported by J. David Litster of MIT, about 70% of all university science (not just materials) departments contend that lack of equipment has been preventing crucial experiments. Litster concluded that people have been supported but instrumentation has not.

Not all kinds of equipment have suffered at the expense of people, however. The Department of Energy and NSF fund most of the university materials research. Flynn noted that in these agencies the fraction of the materials budgets committed to equipment that is expensive and shared by many researchers or that is specialized and often operated by one institution partly for the benefit of outside users, as well as to large, collaborative research centers, such as synchrotron light sources, has risen to almost 30%.

Nix argued that the combined effects of the growing cost of instrumentation, the increasing complexity of materials research problems, and a growing tendency for the agencies to want immediate results to applications-oriented materials problems have conspired to push researchers away from the traditional university "small-science" mode that has served so well in training creative new people. In particular, it appears that support for small-scale science is being continually eroded in favor of "big science," partly because of the decentralized nature of "small science." Nix concluded that the materials community must address the lack of a widely acknowledged organization that can speak with authority for the field.

To materials scientists, if not to federal budget analysts, the problem should primarily be one of equitably dividing not a fixed pie but a growing one. Wrote Flynn, "$600 million annually is much too small a national investment in this ubiquitous and still youthful branch of science. Materials scientists need to organize so that this viewpoint becomes recognized and accepted in the national debate." ■

ARTHUR L. ROBINSON