abilities have wide ranges, but 20-year probabilities for segments adjacent to Anza range from 4 to 86 percent for magnitude 6.0 to 6.7 events, according to Sykes and Nishenko. Similar earthquakes have comparable chances of striking as far north as the Riverside–San Bernadino area.

Summing up NEPEC's conclusions for Dallas Peck, director of the USGS, Sykes finds that "The probability is moderate to high that a large to great (magnitude 7.5 to 8) earthquake will occur in southern California during the next 30 years." Thus, although the likely sources of the earthquake threat have shifted, the seismic hazard remains the same. Still, it does not justify a hazard warning, as recently redefined by the USGS. NEPEC recommended that the earthquake hazard watch instituted in 1980 should not be replaced by a hazard warning, the only formal notice remaining in the USGS procedures.

While informal communications are substituted for a formal watch, the USGS is studying where on these segments of the southern San Andreas and the San Jacinto detailed earthquake prediction studies such as that under way at Parkfield (*3*) might be located. Such an effort, if undertaken, would be a considerable one. The Parkfield segment of the central San Andreas, where a magnitude 5.5 earthquake is expected between now and 1992, is the most intensely monitored site in the United States, but many researchers feel that the effort there is still insufficient and should be augmented before new sites for instrument clusters are chosen.

Even as attention is being focused on a few areas in southern California, Sykes cautions that "a few other major faults" besides the San Andreas and San Jacinto could produce major earthquakes "during the next few decades." None of the three large southern California earthquakes since 1857 were on the San Andreas. And even a moderate event in the densely populated Los Angeles basin, say a magnitude 6.5 event on the Newport-Inglewood fault system, could be as destructive as a magnitude 8 on the more distant Mojave segment of the San Andreas.—**RICHARD A. KERR**

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Chemists Seek a Higher Profile

A new National Academy of Sciences report explores the intellectual frontiers of chemistry and recommends some changes in funding

In its first full-scale survey of the chemical sciences since 1965, the National Academy of Sciences finds the field in intellectual ferment—and in danger of being taken for granted.

"Opportunities in Chemistry," is the product of 3 years' work by the 26-member Committee to Survey the Chemical Sciences, chaired by George C. Pimentel of the University of California, Berkeley.* It takes issue with a number of common perceptions of the field, starting with the idea that chemistry is a mature, stable science in which little of importance remains to be discovered. In part this perception is fostered by the existence of a mature, stable chemical industry, which carries on an immensely profitable business in petrochemicals, synthetic fibers, agricultural chemicals, and plastics. But it also arises because chemistry is the foundation for so many other disciplines: some of the most exciting work is being done in areas such as molecular genetics, immunology, and materials science, which are now regarded as independent fields by scientists and funding agencies alike.

At the same time, the report points out that chemistry has evolved considerably beyond the one lone experimenter stage. While hardly big science in the same sense as physics or astronomy, modern chemistry does qualify as a kind of "intermediate" science, in which researchers need major instruments such as picosecond lasers or even supercomputers to make progress. As a result, the survey committee concludes that the federal funding of basic chemical research needs to be improved in a number of ways.

In its first recommendation, the committee points to five areas on the intellectual frontiers of chemistry that it says deserve special attention and support:

- Understanding chemical reactivity. Using ultrafast laser spectroscopy, chemists have been able to dissect individual reactions and to follow the detailed flow of energy within molecules as they approach, interact, and move apart again. In addition, theorists using high-speed supercomputers have begun to understand these reaction dynamics from first principles. In the long run this work could pay off in new ways of controlling reactions and in the creation of whole new classes of materials.
- Chemical catalysis. Instrumentation is developing to the point where chemists can "see" molecules as they react on catalytic surfaces. Theorists are approaching a unified understanding of catalysis in all its forms. And synthetic chemists are improving their ability to tailor artificial enzymes and organometallic compounds with the desired reactivity and stereospecificity.
- Chemistry of life processes. On a molecular level, obviously, life *is* chemistry. Specifically, chemists have become deeply involved in molecular biology with the synthesis of tailored molecules such as natural product analogs, chemotherapeutic agents, and proteins altered to provide new functions.
- Chemistry around us. Analytical chemistry and reaction dynamics continue to be crucial to understanding the processes that couple the atmosphere, the oceans, the earth, and the biosphere. A famous example from the recent past is the ozone controversy, which hinged on interplay of ozone, chlorofluorocarbons, and sunlight in the earth's stratosphere.
- Chemistry under extreme conditions. In the normal course of events, a chemistry laboratory offers only a limited range of environments. In nature, however, chemical reactions take place over much wider range of conditions: extreme pressures (the interior of the earth and other planets); extreme temperatures (a reentry vehicle heat shield); in gaseous plasmas (the walls of a fusion reactor); and at superconducting temperatures.

To help pay for all this, the committee

*"Opportunities in Chemistry" (National Academy Press, Washington, D.C., 1985).

recommends, not surprisingly, that the chemical industry should strengthen its ties to academe, perhaps with the help of new federal tax incentives.

But then the committee moves on to its major finding, which is that the federal investment in chemistry is meager compared to the more glamorous big science disciplines such as physics and astronomy, and clearly incommensurate with the practical importance of the field. Unfortunately, as some committee members privately agree, this assertion is perhaps the weakest part of the whole report. As an example, consider one measure used to demonstrate the discrepancy: the number of federal basic research dollars invested in a given field in a given year, divided by the number of Ph.D.'s granted in that year. The discrepancy is indeed as much as an order of magnitude—$205,000 per chemistry Ph.D. in 1983 versus $1.09 million per physics Ph.D. and $3.8 million per astronomy Ph.D. And yet, only one page later, the report goes on to point with pride to the fact that chemistry is still a relatively small-scale, individualistic science—without ever trying to analyze how the aforementioned funding figures might reflect the different costs of doing physics or astronomy.

In any case, the committee recommends that the National Science Foundation (NSF) boost its support for chemistry—which currently stands at roughly $350 million per year—by 25 percent per year for the next 3 years. These additional funds should go toward increasing the average size of individual grants to reflect the fact that research projects now tend to involve more people, and toward increasing the federal support of advanced instrumentation—the latter being an item that has absorbed virtually all of the growth in the federal funding of chemistry during the last decade.

The committee likewise urges the various mission agencies to recognize the importance of chemistry to their own program and to increase their support accordingly. The National Institutes of Health, for example, should increase its grants for chemical research related to biomedicine, and should raise its support for chemical instrumentation in much the same way as recommended for the NSF. The Department of Energy, meanwhile, should plan a major initiative in those areas of chemistry relevant to energy technologies, with support for chemistry increasing by a factor of 2.5 over the next 5 years. Examples might include detergents to be injected into oil-bearing strata to aid tertiary oil recovery, or improvements in the utilization of low-grade fuels.

Similar increases were recommended for the Departments of Defense and Agriculture, the National Aeronautics and Space Administration, and the Environmental Protection Agency.

It is anyone's guess whether this increase in support will actually materialize, especially given the size of the federal deficit and the competition for the federal research budget by other disciplines. Even if it does not, however, the committee can still hope that the report will change the current pattern of funding chemistry.—**M. Mitchell Waldrop**

On the Origin of Insect Wings

Experimental data on thermoregulation and aerodynamics give the first quantitative test of a popular hypothesis for the evolution of flight in insects

The evolution of insect wings, like the origin of flight in vertebrates, has long been a challenge to the explanatory powers of evolutionary biologists. Both cases present essentially the same problem: how do you pass from a wingless ancestor to a flying descendant, when intermediate forms would be incapable of flight? Natural selection cannot work on structures that are as yet functionally incompetent.

This conundrum has spurred the elaboration of many imaginative and ingenious suggestions in the case of insects, including the initial evolution of "proto-wings" for gliding, for courtship display, for gill ventilation and aquatic locomotion, and for thermoregulation, but direct experimental tests of hypotheses have been few. In an elegant series of studies Joel Kingsolver, at Brown University, and M. A. R. Koehl, at the University of California, Berkeley, have obtained data that should allow a more secure assessment of certain insect flight hypotheses than has previously been possible (*1*).

Kingsolver and Koehl's experiments focused on the proposal, first developed in detail in the late 1970's (*2*), that insect wings derived from thermoregulatory structures that projected laterally from the body. The proposal was that natural selection worked first on the heat exchange benefits endowed by "proto-wings" (*3*) and then, when aerodynamic effects began to be felt, on the benefits of flight. There was, in other words, a shift of function, an exaptation (*4*), that allowed the development of fully fledged flight from structures that readily served as wings but had initially evolved for other purposes.

The idea sounded attractive enough in principle, and, judging from Kingsolver and Koehl's quantitative data, it turns out to be feasible too. Of particular interest in these results is the potential evolutionary importance of a simple increase in body size as compared with a modification in body geometry.

One reason why Kingsolver and Koehl addressed the plausibility of the thermoregulation and aerodynamic hypotheses is, simply, that they are amenable to experimental test. By contrast, it is very difficult to see how one might critically examine the idea that "proto-wings" might have functioned initially in courtship display.

By building various models of putative ancestral insect bodies, Kingsolver and Koehl were able to ask the following questions: What size of wing is effective in thermoregulation? At what size do "proto-wings" become aerodynamically effective at particular body sizes? And how do these two relate to each other, particularly to a potential transition from one function to the other?

Some modern insects (such as bumble bees) generate body heat by muscular contraction while others (including butterflies) use their wings to soak up the sun's warmth. In both cases a high body temperature is important for fast, powered flight. The investigators made the assumption that heat uptake was the principal function of "proto-wings." Measurements with the models show that increasing the size of the "proto-wing" increased the amount of heat that could be transmitted from the wings to the body by conduction, but an upper limit was quickly reached. The reason is