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Structure of a hypothetical protein with four helices (purple cylinders) modeled by the computer program Sculpt, a tool for guessing the structure of existing proteins or for designing new ones. In this special issue, other aspects of computing in science are discussed in News stories, Perspectives, and Articles beginning on page 841. [Sculpt was developed by Mark Surles, University of California San Diego Supercomputer Center; Jane and Dave Richardson, Duke University; and Fred Brooks, University of North Carolina, Chapel Hill]
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Computing in Science

Computers have changed our lives; their effect on science has been profound. They enable us to analyze and solve problems too complex to be treated analytically; they allow us to examine and process huge amounts of data; they make it possible to control complicated instruments; they facilitate communication. In this issue of Science we explore some of the continuing excitement and developments in computers and computing. We present four news articles, three perspectives, and three general articles. Because the field has so much depth and changes so fast, we can only taste a little, but we have tried to choose some aspects of the field that will have a rapid impact on the practice of science and will affect many of us. Computers and computing represent a wonderful integration of fundamental science and technology with almost instantaneous application to important problems in the real world. While this is not a good model for all of scientific activity, it certainly is impressive, to say nothing of being fun to watch.

Baskett and Hennessy analyze microprocessor technology and its impact on computing. They point out three major challenges in creation of high-performance, cost-effective computers: microprocessor performance, parallel computer architecture, and software that can take advantage of these advances. They discuss the first two of these areas. Their analysis also addresses economic issues of microprocessor-based computing and the economic impact of rapid technology improvement.

Hillis and Bogdhan discus an issue which for many of us appeared to be a major problem—programming parallel computers for scientific computation. Their analysis shows that many problems lend themselves naturally to parallel computing and that ultra-specialized algorithms and software are not required. For example, many scientific problems are naturally parallel by virtue of the physical laws that govern them. Interestingly, apparently sequential problems can be made parallel by use of a different algorithm. Thus, taking advantage of improvements in hardware and architecture will be easier than expected.

Forrest discusses genetic algorithms—computer programs that evolve solutions through natural selection. That is, they are modified by some random process (equivalent to mutation or crossover), and then those programs that are most fit are selected or reproduced whereas the least fit ones are discarded. Intriguing intellectually and potentially powerful computationally, this approach is clearly well adapted to take advantage of new technology and seems likely to have a significant impact on the solutions to a variety of important problems.

Our three perspectives address some of these same issues of performance, architecture, and software. Thordyke and Riganati discuss packaging and integration in massively parallel systems. Buie discusses workstation clusters and their use in scientific computing. Wulf deals with networking and our ability to take advantage of advances in computation and communication between scientists in different locations so we can benefit from collaborations.

The news articles address important applications of computing in the scientific arena. One of the major intellectual changes in science has been the ability to accumulate, access, and utilize large databases. This challenge has changed to a substantial extent the kinds of problems that we can solve and the ways we have of thinking about them. Pool, Freedman, Marshall, and Clery address various aspects of these critical problems from electronic databases, to analysis of the database, to dealing with overloads of information. As computing becomes faster and more powerful, the complexity of problems we can solve increases. Object-oriented programming is revolutionizing the way computer codes are written; Waldrop tells us about the area, what is new, and what some of the future is likely to bring.

As much of science grows and matures, it becomes progressively arcane and daunting, both financially and intellectually to its practitioners. Computing, interestingly enough, continues to become less expensive and more user friendly. It is hard to imagine where science would be without computers. It may be even harder to imagine where it’s going to be in the future.

John I. Brauman
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LETTERS

Disposing of Weapons-Grade Plutonium

The optimistic scenario for disposing of the stockpiles of separated weapons-grade plutonium in the United States and the Commonwealth of Independent States (CIS) proposed in the letter “Converting weapons to fuel” by Stanley G. Prusin et al. (30 Apr., p. 607) is impractical and uneconomical. The letter suggests that irradiating the material in the form of mixed plutonium-uranium oxide (MOX) fuel in all the nuclear power plants in the United States could “effectively eliminate” the entire inventory of roughly 200 metric tons (MT) of weapons-grade plutonium in “about 2 years.”

Processing 100 MT of weapons-grade plutonium per year in all U.S. light-water reactors (LWRs), which have a total generating capacity of about 100 gigawatts, would require operating them with full cores of MOX fuel enriched with nearly 5% fissile plutonium, if an average capacity factor of 70% is assumed. In order for a conventional LWR to burn a full core of MOX fuel, it must undergo structural modifications (1). To retrofit all U.S. reactors for this purpose would be a major and costly undertaking and would probably be unwise for older reactors. A less ambitious alternative would be to fuel LWRs with 30% MOX cores. In this case structural changes to the reactor would not be necessary. This strategy would reduce the plutonium throughput to 30 MT per year, increasing the time required to process the entire inventory accordingly. However, this option too is problematic.

Because the United States at present has no MOX fuel fabrication capability, it would have to construct an industrial-scale MOX plant. In order to absorb 30 MT of plutonium per year, its throughput would have to be 600 MT of heavy metal (MTHM) per year, which is about five times more than that of the largest currently proposed MOX plant. In a more modest plan, a single plant with a throughput of 100 MTHM would require 40 years of operation to process the U.S. and CIS plutonium inventories.

Moreover, it is doubtful that the MOX fuel would be commercially competitive with uranium fuel. Thus, MOX-generated electricity, rather than being a “benefit to mankind,” would instead mean higher bills for U.S. electricity consumers.

The wisdom of any proposal to disperse weapons-grade fissile material must also be questioned. Sending MOX fuel enriched with weapons-grade plutonium to all U.S. power reactors would enormously complicate the task of safeguarding the material against diversion and theft. Furthermore, a U.S. MOX program would be deleterious to nonproliferation efforts worldwide by legitimizing civil plutonium use.

Finally, one may wonder what would be the actual return for this investment. From a nonproliferation standpoint, reactor processing reduces the attractiveness of the material for weapons use by generating a radiation barrier and by degrading the isotopic content of the plutonium. However, weapons-grade plutonium can also be rendered highly diversion-resistant, at a lower cost, by diluting it with liquid high-level radioactive wastes now awaiting glassification or by adding high concentrations of chemical “spoilers” (such as neutron-poisoning lanthanides). Use of these methods could effect a swift conversion of fissile material inventories into a more secure form. The addition of spoilers would not preclude implementation of a MOX option in the future should the many difficulties be resolved.

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References

Fisheries Management

The Policy Forum “Uncertainty, resource exploitation, and conservation: Lessons from history” by Donald Ludwig et al. (2 Apr., p. 17) raises important questions about the ability of fisheries management to sustain harvests of fish stocks in complex biological and social environments. The impression left is that fisheries managers are incapable of estimating a sustainable yield for fish stocks and, even if they could, the demands of the fishing industry would block implementation of suitable exploitation regimes. In our view, the focus on failure ignores the substantial evidence of success.

Information for Contributors appears on pages 46–42 of the 1 January 1993 issue. Editorial correspondence, including requests for permission to reprint and reprint orders, should be sent to 1303 H Street, NW, Washington, DC 20005.
The fisheries of the northeastern Pacific are, for the most part, healthy because of conservative management. Scientists’ advice has been heeded and has been conservative in the face of the uncertainty noted by Ludwig et al. Management regimes are enforcing strict quotas in heavily overcapitalized fisheries and result in significant constraints on a multibillion-dollar industry. Seasonal and area restrictions are imposed for the protection of marine mammals and to account for uncertainties associated with species interactions and overall ecosystem health.

Specific examples illustrate this success. In the Bering Sea, the weight of total acceptable biological catch is about 2.5 million tons, but the fishery is restricted to no more than 2 million tons. Professionals in the fields of population dynamics, marine mammals, oceanography, economics, anthropology, and ecology participate in setting the level of harvest. Political pressures on management derive largely from economic pressures related to the allocation of quotas and not in quota setting.

Cooperative Canadian and U.S. research and management since 1937 have restored the sockeye and pink salmon stocks of the Fraser River in British Columbia. These fisheries were decimated by rockslides that blocked fish passage early in this century. Construction of fishways eliminated the major obstacles to rebuilding fish runs. Harvests have risen from about 1.5 million sockeye (1918–1921) to 12.9 million (1987–1990). This occurred despite tremendous pressure from an overcapitalized fishery to harvest more. The task of restoring runs of salmon in Washington, Oregon, and California demands serious scientific attention. The roles of habitat destruction, overfishing, hatchery production, and interdecadal shifts in ocean environment (1) present daunting challenges.

When halibut stocks were reduced by fishing in the 1920s, the West Coast halibut fishing industry called on Canada and the United States to initiate scientific studies of the causes and to recommend measures for conservation. Over the course of 70 years as a managed fishery, stocks of halibut have fluctuated with environmental changes and the effects of direct or indirect fishing, but they have never been in a state of distress or in danger of irreversible overexploitation. The highest yield ever from that fishery occurred in 1989 after 100 years of commercial harvests.

We may never know the precise relationships between environmental conditions and fishing pressure that led to the collapse of the Peruvian anchovy fishery or the California sardine fishery. However, there is broad scientific agreement that stocks of small pelagics fluctuate massively through time independent of fishing pressure. These fisheries pose complex problems of prediction, and management strategies have been designed and implemented that attempt to take these characteristics into account.

There is much more to learn about the management of these and other fisheries in the North Pacific, and funding for research is hardly lavish. Better databases are needed, and annual fisheries cannot wait for scientific consensus to be achieved. However, current fisheries management in this area contradicts the conclusions of Ludwig et al. that fisheries scientists cannot determine harvest levels to sustain stocks at abundant levels and that management institutions are incapable of resisting industry pressures.

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References

Determining Carcinogenicity

We write in reference to the letter "Pesticides and the Delaney amendment" by Philippe Shubik (4 June, p. 1409). For those who may be unfamiliar with the International Agency for Research on Cancer (IARC) Monographs on the Evaluation
of Carcinogenic Risks to Humans, we would like to make the following points.
1) The IARC does not "certify" that agents are (or are not) carcinogenic. It reviews all the evidence relevant to carcinogenicity and classifies agents according to the strength of the evidence for (or against) their carcinogenicity. The IARC monographs are composed in a way that expressly permits the reader to follow the reasoning of the IARC working groups that made the evaluations. Readers may therefore make their own decisions to accept or reject them.
2) The IARC monographs and their associated evaluations and classifications are prepared by scientists actively working in the different areas of cancer research, spanning human and experimental pathology, epidemiology, genetics, molecular biology, and toxicology. These scientists are invited to participate on the basis of their expertise and their ability to make objective evaluations of evidence relevant to carcinogenicity. The scientists who participate in the preparation of any particular monographs are listed in the front of the relevant volume of monographs so that anyone can see who has done the work.
3) For the sake of consistency in evaluation and classification, comprehensive descriptions are given of the approach used by each IARC working group in both evaluating the evidence and arriving at a classification. These descriptions, prepared by a working group of scientists expert in the study of carcinogenesis, are not rigid rules, but rather guidelines for use by each working group. The evaluations as well as the assignment of an agent or exposure to one of the IARC classification groups is, and will remain, a matter of scientific judgment.
4) As of this date, no agent has been described in an IARC monograph as "carcinogenic to humans" without there being sufficient evidence of its carcinogenicity in epidemiological studies in exposed humans.
5) Since October 1991, the IARC monographs have presented data on the possible mechanisms of action of potentially carcinogenic agents. Where this evidence is of itself adequate, it may be used to either strengthen or weaken inferences about the carcinogenicity of the agent to humans.

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Choose Your Poison
Philip H. Abelson recently provided an insightful response (Letters, 4 June, p. 1410) to criticism of his 26 February edito-
rial, “Pesticides and food” (p. 1235). In their comments on the editorial, David and Marcia Pimentel (Letters, 4 June, p. 1409) state that pesticides “cause serious health and environmental problems” and that “[m]ore than 67,000 human pesticide poisonings occur annually in the United States.” Abelson’s refutation of the spurious statistic on the number of pesticide poisonings is especially important because D. Pimentel published the same statement in Science several years ago without being challenged (Letters, 19 Apr. 1991, p. 358).

Abelson correctly identifies some of the fallacies in the way the Pimentels used data from the 1989 annual report of the American Association of Poison Control Centers (1). He could also have added that the same report shows that more than 56% of the potential exposures to pesticides in 1989 involved children less than 6 years old. Large numbers of young children are unlikely to be exposed to pesticides in the workplace, so one must assume that most of these potential exposures involved accidental exposures in noncommercial arenas (probably at home). Pesticide applicators in most commercial and agricultural settings receive extensive safety training and must be licensed. Homeowners, by comparison, are often unaware of the dangers posed by the pesticides they purchase at their local garden stores. Much of the human exposure to and misuse of pesticides could be avoided if pesticides were unavailable to homeowners and could be purchased only by licensed applicators. Of course, human welfare could also be improved if sales of all household cleaners and personal cosmetics were also limited to licensed applicators: More than 200,000 children under 6 years old were reportedly exposed to poisoning by household cleaners and personal cosmetics in 1989 (1).

I wish I could suggest an equally simple solution for reducing exposure to the intellectual “poisoning” that occurs when statistical information is misapplied by scientists in their efforts to generate support for their personal viewpoints on controversial subjects.

David Rosenberger
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References
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showing the thickness of the lithosphere. We should recall that wave-velocity cross sections are the sole basis for models of the nature and distribution of the different deep crustal materials. An attempt to construct such models is made in the next chapter in light of gravity measurements as well as heat flow and electric conductivity data.

The chapter dedicated to recent tectonic activity is no less interesting. We learn that the Baltic Shield is not very stable and is the locus of many earthquakes, albeit of small magnitude. Seismic activity can be compared with a generalized stress map and recent volcanic areas, but no seismotectonic data are reported here, even for the Mediterranean area, where many studies have recently been carried out.

Although *A Continent Revealed* inconclusively tries to demonstrate our knowledge of the European continent, it has some frustrating flaws. The data and their interpretation are not well integrated. For example, the cross sections showing the geophysical models are presented as several small pieces, and no clue is given to the crucial role of these data in the development of ideas about the structure, tectonic evolution, and geodynamics of the European basement. Although an EGT Atlas (as well as a CD-ROM that contains some of the Atlas data) is available separately, the problems related to the coordination of material could have been alleviated by the presentation of the maps and cross sections as fold-out documents.

While the EGT was being carried out, other groups were collaborating in studies of the structure of the European crust by deep seismic reflection profiling (for example, the Etude de la Crûte Continentale et œcânique par Reflection Sismique [ECORS] in France and Spain, the South West Approach-Transact [SWAT] in England), and it is frustrating that the results of these other projects are not sufficiently incorporated. For instance, a complete deep crustal transect from South England and Belgium to Spain through the Hercynian and Alpine domain is also available, and a comparison of its data with the EGT section results would have been fruitful.

Finally, it is unfortunate that a separate bibliography of the publications arising directly out of the workshops and retreats organized for the EGT project is not provided. Such a reference list would have helped to justify the considerable financial support that the program enjoyed as well as enhancing the value of the book itself, which can serve as a general introduction to the more specialized literature.

**Pierre Choukroune**

**Institut de Géologie, Université de Rennes 1, 35042 Rennes Cedex, France**

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**Reprints of Books Previously Reviewed**


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**Cities and Environments.** Hugh M. French and Olav Staver, Eds. McGill-Queen’s University Press, Montreal, 1993. xii, 340 pp., illus. $45. Canadian Association of Geographers Series in Canadian Geography.


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