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This Week in Science

Editorial

Technology for America's Future

Letters


ScienceScope

Sweeping overhead rates under the rug; gambling with Poker Flat science; etc.

News & Comment

Baltimore Throws in the Towel ■ David Baltimore's Mea Culpa

Science Under Wraps in Prince William Sound

Science Academy Elects New Members

Briefings: Hidden Costs of the Space Station ■ A Big Gift from Big Oil ■ A Billion Bucks for Materials ■ Congressional Day ■ Ten Years for the Brain ■ Cuban AIDS Control ■ Biotechnology Execs Earn More ■ Correction

Research News

Engineering Dogma Gives Way to Chaos ■ Flying High with Chaos Control

A New Ball Game in Nuclear Physics

How Peptide Hormones Get Ready for Work

Praying Mantises Play Top Gun

Sex and the Single Gene

Deep Rocks Stir the Mantle Pot

Articles

Reproductive Behavior and Health in Consanguineous Marriages: A. H. Bittles, W. M. Mason, J. Greene, N. A. Rao

Neutron Scattering: Progress and Prospects: J. D. Axe

Diversity of G Proteins in Signal Transduction: M. I. Simon, M. P. Strathmann, N. Gautam

Research Articles

Zinc Finger–DNA Recognition: Crystal Structure of a Zif268-DNA Complex at 2.1 Å: N. P. Pavletich and C. O. Pabo

A New Cofactor in a Prokaryotic Enzyme: Tryptophan Tryptophylquinone as the Redox Prosthetic Group in Methylamine Dehydrogenase: W. S. McIntire, D. E. Wemmer, A. Chistoserdov, M. E. Lidstrom

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COVER  Crystal structure of a zinc finger–DNA complex from the mouse protein Zif268. The view is down the axis of the double-helical DNA and emphasizes the symmetry of the complex. The DNA is blue; individual zinc finger domains are red, yellow, and purple; and zinc atoms are light blue. Similar DNA-binding domains occur in a large family of eukaryotic regulatory proteins. See page 809. [Photograph by N. P. Pavletich and C. O. Pabo]

Reports

825 Geometry, Topology, and Universality of Random Surfaces: J. R. Banavar, A. Maritan, A. Stella
827 Ultradeep (>300 Kilometers) Ultramafic Xenoliths: Petrological Evidence from the Transition Zone: V. Sautter, S. E. Haggerty, S. Field
830 In Situ Biodegradation: Microbiological Patterns in a Contaminated Aquifer: E. L. Madsen, J. L. Sinclair, W. C. Ghiors
833 Control of doublesex Alternative Splicing by transformer and transformer-2 in Drosophila: K. Hoshijima, K. Inoue, I. Higuchi, H. Sakamoto, Y. Shimura
836 Solution Structure of FKBP, a Rotamase Enzyme and Receptor for FK506 and Rapamycin: S. W. Michnick, M. K. Rosen, T. J. Wandless, M. Karplus, S. L. Schreiber
842 HBV X Protein Alters the DNA Binding Specificity of CREB and ATF-2 by Protein-Protein Interactions: H. F. Maguire, J. P. Hoeffler, A. Siddiqui
844 Inhibition of PDGF ß Receptor Signal Transduction by Coexpression of a Truncated Receptor: H. Ueno, H. Colbert, J. A. Escobedo, L. T. Williams
848 FTZ-F1, a Steroid Hormone Receptor-Like Protein Implicated in the Activation of fushi tarazu: G. Lavorgna, H. Ueda, J. Clos, C. Wu
851 Ca²⁺ Permeability of KA-AMP A-Gated Glutamate Receptor Channels Depends on Subunit Composition: M. Hollmann, M. Hartley, S. Heinemann
856 Identification of a Peptide Specific for Aplysia Sensory Neurons by PCR-Based Differential Screening: J.-F. Brunet, E. Shapiro, S. A. Foster, E. R. Kandel, Y. Ino

Technical Comment

860 Land Plants and Weathering: J. M. Robinson; R. A. Berner

Book Reviews

863 Physical Chemistry from Ostwald to Pauling, reviewed by R. Fiedel. Meteorology in America, 1800–1870, by B. Sinclair. Fundamentals of Molecular Evolution, by M. T. Clegg. Books Received

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Technology for America’s Future

Erosion of the competitive position of U.S. industry is well known to U.S. scientists and engineers. Until recently the federal government has paid little heed. Now there are signs that both the White House (see Science, 5 April, p. 20) and influential industrialists are devoting serious attention to the matter. A report issued by the Council on Competitiveness has been followed by a similar document from the Office of Science and Technology Policy. These provide information on our strengths and failures in the many areas of high technology. In what follows are comments based on the council’s report.*

In the era immediately following World War II, the United States had a virtual monopoly on new technology. This was fostered by spin-offs from defense R&D. The computer, the electronics components, the machine tool, and the aircraft industries were beneficiaries. Defense R&D gradually ceased to be a stimulus to the civilian economy. Global competition in high technology emerged. In both Japan and Germany the governments identified and fostered new targets for R&D. The pace of development in those countries accelerated. Recent comparative figures on the percentage of total government R&D budget devoted to various functions are as follows: for industrial development, U.S., 0.2; Japan, 4.8; Germany (figures for West Germany), 14.5; for defense, U.S., 65.6; Japan, 4.8; and Germany, 12.5; for health, U.S., 12.8; Japan, 2.6; Germany, 3.6; for energy, U.S., 3.9; Japan, 22.8; and Germany, 7.8.

These numbers show that the United States is not fostering industrial development directly while competitors are. The realities of today’s global markets militate against defense technology being useful in civilian markets. Defense industry is not geared to compete in commercial markets. The council’s report states:

Cost-plus contracts, quality control based on inspection rather than process improvement, highly specialized products, limited production runs and restricted markets are the dominant features of defense technology management. By contrast, flexibility, high quality at low cost, volume manufacturing expertise and access to many different markets are the primary concerns of managers in the private sector. . .

Today’s leading-edge technologies in microelectronics, computers and telecommunications are found, not in Defense Department laboratories, but in private industry. Moreover, consumer products are frequently driving state-of-the-art technology . . . Instead of industry adapting defense technology break-throughs to commercial markets, the Defense Department is increasingly adapting commercial technology to its needs.

Because foreign competitors have practically eliminated U.S. competition in some areas, the Defense Department finds itself dependent on foreign suppliers for many strategic technologies, including machine tools, electronic components, and integrated circuit fabrication equipment. For national security, to preserve our standard of living, and to create jobs, it is necessary to establish a national goal of fostering civilian high technology. The council’s report suggests that this might be accomplished if government, industry, and universities worked together. A key objective pointed to is generic technologies. These often underlie broad classes of products and can be worked on cooperatively ahead of the development of proprietary knowledge.

One of the most valuable features of the report is identification of 21 critical technologies. Critical technologies include electronic and photonics materials, process equipment, microelectronics, software, and computers. Under each of the 21 critical technologies are listed two to ten components and the status of the United States in each. For example, the United States is strong in various aspects of biotechnology and software. It is losing badly, or has lost position, in memory chips and robotics.

A substantial portion of the report is devoted to recommendations for actions by government, industry, and research universities. Perhaps the most important is a request for presidential leadership:

Presidential leadership is . . . essential to success. The President is uniquely positioned to set national priorities, communicate to them to the American public and directly involve key federal agencies in the effort to address them. Therefore, the full involvement and support of the White House is a key part of the effort to raise technology and competitiveness to a national priority.

—Philip H. Abelson


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49. We thank J. Leary for measuring the exact [M+H+] mass of the bis(tripeptidyl) cofactor. J. Sanders-Loehr for prepublication copies of their manuscripts, and L. Chen, V. L. Davidson, H. Duine, W. Hol, F. S. Mathews, E. G. Huizinga, and F. M. D. Villieux for their input and cooperation in the preparation of this manuscript. We also thank J. P. Klinman, C. Hartmann, and D. M. Dooley for support, discussions, and suggestions throughout the research.

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Chemistry Regenerated

Servos's aim is hinted in this book's title, for "the making of a science in America" begins with the reform program of Europeans Wilhelm Ostwald, Jacobus van't Hoff, and Svante Arrhenius. These chemists attempted to shift the focus of their field from substances to processes. Instead of asking simply what the products of a reaction would be, the new chemistry asked how much, how fast, and under what conditions these products appeared. In addressing such questions, new tools and new conceptual approaches were applied. Perhaps the most important of these was thermodynamics, with its mathematical techniques and its emphasis on the conditions for change and equilibria. With the new tools, however, came not only new powers, but also new demands. Mathematical sophistication, measuring minute changes in physical properties, discoursing in such abstractions as affinity, dissociation, and free energy, made traditional chemists acutely uncomfortable, to say the least. It is not surprising, therefore, that the new physical chemistry appealed most to a new generation.

That this new generation of chemists should flourish in the ambitious, rapidly expanding universities of the United States is also not surprising, but Servos makes clear that the particular experiences—and great success—of physical chemistry in America were not simply the product of environment but of individuals. The heart of his narrative is a rich and compelling description of the intellectual and institutional experiences of the men who brought the new discipline to America and who built the laboratories and departments, raised the funds, edited the journals, and taught the students that constituted a science's flesh and bone. G. N. Lewis, Wilder D. Bancroft, and, above all, Arthur A. Noyes put their stamp on physical chemistry in very different ways. In sensitively describing these differences, Servos gives us a tale that neatly balances the resolution of intellectual problems, the dynamics of institution-building, and the influence of personalities. The success of this balancing act is perhaps the greatest achievement of this work, and Servos's most important contribution to his field's own "reform."

At the center of all this is Noyes, whose extraordinary achievement was to build not one but two great programs in the new chemistry, first at M.I.T. from the 1890s until World War I, and then at Caltech in the 1920s and early '30s. The epitome of the successful academic entrepreneur, Noyes was driven by a dogged faith in the importance and ultimate success of making a new field at the boundary between physics and chemistry. His own contributions to theory and technique were modest, but he was able to gather around him students and co-workers who collectively were to provide the theoretical heart of physical chemistry. At M.I.T., G. N. Lewis established the groundwork for modern theories of the chemical bond, contributions that continued when Lewis left for Berkeley in 1912. At Caltech, "Noyes's greatest discovery" was Linus Pauling, whose work in bringing the new physics of quantum and wave mechanics to bear on chemistry was to mark a kind of culmination of the reform advocated by Ostwald and company.

A dramatic counterpoint to this theme of fulfilled ambitions and expanding horizons is provided by the story of Cornell's Wilder Bancroft. The founder and for more than 35 years editor of the Journal of Physical Chemistry, Bancroft played a quixotic role in the field's development. His journal provided a useful and important outlet for the new chemistry and helped to proclaim widely the important American role in the field. But Bancroft's vision of physical chemistry was never the same as that of Noyes and others. His devotion to applications of the phase rule is used by Servos as a symbol of Bancroft's limitations and intellectual perversity. As useful as the phase rule might be in certain situations (particularly in applied chemistry and metallurgy), it was quickly relegated by most physical chemists to the status of an occasionally useful rule of thumb, not, as Bancroft would have it, an important point of departure for chemical theory. Bancroft persisted in his unorthodox views, however, even late in his career, when he becameentranced by the importance of colloids. Servos gives a dramatic and poignant picture of the results of this iconoclasm, culminating in Bancroft's loss of his journal in 1932. Servos does not belabor the point, but his account of Bancroft, placed in such conspicuous contrast to the triumphs of Noyes, Lewis, and Pauling, is a kind of parable, meant to illustrate the fact that
numbers of gene substitutions and calculating genetic distances from gene sequence data are derived from population-genetic arguments. The molecular clock hypothesis, based on a population-genetic theorem, post-its that neutral gene substitutions should occur at a rate equal to the mutation rate, which may be a linear function of time. This result provides a basis for the estimation of divergence times among major lineages in the absence of an adequate fossil record. Moreover, times of duplication of major gene functions (for instance, divergence times of members of the globin gene superfamily) can be estimated from sequence data.

The fifth chapter of the book develops the estimation of organismic relationships from molecular data. If genetic distance increases as a monotonic function of time then it should be possible to estimate the pattern (topology) of relationships from gene-sequence data (molecular phylogenies). This application of molecular data has given rise to a number of computational algorithms that can seem complicated and confusing to the novice. While molecular phylogenetics has reinvigorated the study of systematics in recent years, it has also yielded several contentious ways of thought on computational methodology. Molecular phylogenies are also providing an independent basis for the analysis of morphological evolution and for testing major issues like the hypothesis that mitochondria and chloroplasts had an endosymbiotic origin.

The remaining chapters deal with what might be called molecular phenomenology. For example, during the past quarter-century we have learned that eukaryotic genomes contain vast numbers of repeated DNA sequences whose functions are obscure; introns were discovered, as were overlapping genes; the molecular structure of transposable elements was documented; and these genetic entities were found to be ubiquitous in nature. In addition, retroviruses and their associated retrotransposons were described and their occasional horizontal transfer among species was documented. This wealth of empirical information has produced a kind of natural history of the genome. As with classical natural history, the natural history of the genome must be accounted for within a unified theoretical framework. The theory of evolution provides that framework. It is a testament to the power of evolutionary theory that it can easily accommodate observations that were not imagined a quarter of a century ago.

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