Book Reviews

Technological Change

Patterns of Technological Innovation. DEVENDRA SAHAL. Addison-Wesley Advanced Book Program, Reading, Mass., 1981. xviii, 382 pp., illus. $34.50.

Economic analysis of technological innovation has followed two main approaches. The first, represented by the work of Edwin Mansfield, Zvi Griliches, and Edward Denison, relates macro-level dimensions of technological change (contribution to growth of output or interindustry productivity differences, rate of diffusion) to sets of economic variables (profitability, costs of an innovation). The second, a micro-level approach, represented by the work of Nathan Rosenberg, Bela Gold, and Richard Nelson, uses the evolution of a given technology or the behavior of specific firms as a unit of analysis to identify the factors and processes that affect the changing economic environment of a firm or industry and the changing characteristics of a technological innovation. Devendra Sahal's *Patterns of Technological Innovation* is an ambitious and impressive, but not always convincing, attempt to integrate these two research traditions.

The book involves a search for regularities in the origin, diffusion, and development of new techniques. Reflecting its genesis in a series of previously published articles, it covers such a wide variety of topics—relationships between science and technology, diffusion of innovation, technological cycles—that its many striking propositions cannot possibly be examined in a single review. The central theme of the book, however, is the diffusion of innovation; likewise the focus of this review.

Sahal combines several themes in the literature to advance two principal propositions concerning the diffusion of innovation. The first, a "diffusion via learning" hypothesis of technological change, suggests that innovations seldom remain unchanged during their adoption. Increased use of a technique often hinges upon improving its functional aspects and discovering new uses for it. In turn, both forms of learning are related to the accumulation of production experience. One of the major themes advanced by Sahal is that diffusion of technology is inherently a multidimensional phenomenon: during the time a new technology substitutes for the old, it usually undergoes numerous changes. This is an idea reminiscent of George Terborgh's concept of "functional displacement" (expounded in his *Dynamic Equipment Policy*, McGraw-Hill, 1949), which finds restatements and evidence in the studies by Gold and Rosenberg. Sahal further supports this multidimensionality argument by presenting case studies of the diffusion of the farm tractor, digital computers, transportation equipment, and means of generating electrical power.

In conjunction with this first proposition Sahal argues that the process of technological innovation is object-specific, that is, the development of every technology involves a learning process that is at least partly unique. Because technological learning is context-dependent, interindustry transmission of technical know-how is minimal.

Sahal's second proposition relates to the influence of scale on the characteristics of innovations: "The evolution of a technology often proceeds along more than one pathway so as to meet the requirements of its task environment. This is reflected in the fact that there exist many different types of the same technology, at least during the initial stages of its evolution" (p. 116). As evidence, Sahal points to the emergence of different locomotive technologies, yard switching, road freight, and road passenger service; and different farm tractors, the track type, the wheel type, and the garden variety. A converse proposition is also advanced: the process of development is often retarded because of the lack of adaptation between a technology and the larger system in which it will be used. The diffusion of an innovation (and the relative presence of competing technologies) thus depends on whether the scale of the large environment and the characteristics of the innovation are appropriately matched during evolutionary changes. Sahal combines these influences to contend that "innovative activity involves as many instances of deadlock as of progress," and further, "many seemingly instantaneous advances in technology are in fact based on prolonged development effort" (pp. 110–111). These are not new findings; however, they are given a new force because Sahal has rooted them in the intricacies and constraints of engineering design, such as the influence of rules of thumb on the design of steam locomotive engines.

Sahal underpins his arguments in two different ways: econometric testing of hypotheses and formulation of "lawlike relationships" akin to Boyle's law. Sahal's econometric tests provide passing support for his proposals, being subject, however, to many reservations concerning model specification, quality of data, and levels of significance. The case studies themselves are of uneven quality. The strongest of the studies is that of the diffusion of farm tractors, but even it falls short of the quality of single case diffusion studies such as Moses Musoke's study of the diffusion of tractors for cotton production (*Explorations in Economic History* **18**, 347 [1981]). I found the search for lawlike relationships disquieting and most often unconvincing, representing truncation of the complex processes that Sahal so astutely analyzes into simple relationships and receiving scant support in the empirical tests.

Overall, the book is a mixture, at times impressive, at times overreaching, of fresh insights, potentially important restatements of propositions that have failed to sufficiently influence theoretical or policy thinking, and underdeveloped theoretical or empirical arguments for strongly presented generalizations. It is a book to be read for the freshness and profuseness of its ideas, not for the convincing quality of its findings.

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Water Stress in Plants

The Physiology and Biochemistry of Drought Resistance in Plants. L. G. PALEG and D. ASPINALL, Eds. Academic Press, New York, 1981. xvi, 492 pp., illus. $70.

After many years of being able to do little more than document the degree of plant growth reduction or damage in response to "water stress," plant scientists have had two decades of tremendous progress in stress physiology research. In the '60's significant improvements and advances were made in methods of measuring plant water relations parameters, which resulted in greater precision in specifying the degree of stress and in quantifying the components of plant water potential. In the '70's specific behavioral and metabolic responses of plants to known levels of water, osmotic, and turgor potentials were elucidated and quantified. Though reviews of some of these responses have been published periodically, a general compilation of reviews of the subject has not been adequately accomplished heretofore.

This volume is intended to provide such a comprehensive treatment of the metabolic consequences of water stress on plants, and it is remarkably successful. Most of the authors are the very people who have been primarily responsible for the advances in the field, and they have synthesized and presented the information in a readable fashion in most cases.

The most important general response of plants to water deficits that has been clearly demonstrated within the past decade is osmotic adjustment, and this topic is extensively treated. The physicochemical aspects of solute accumulation as a response to water deficit are discussed by L. J. Borowitzka in the best general treatment of the roles and requirements of compatible solutes that I have seen. Borowitzka draws on her extensive experience with *Dunaliella*, which is one of the most intensively studied model systems for osmoregulatory behavior, and she gives fair treatment to proposed roles for accumulated solutes such as glycerol and proline in addition to their presumed role as compatible solutes. A pair of chapters on proline accumulation (physiological aspects by Aspinall and Paleg and biochemical aspects by C. R. Stewart) present a clear, synthetic picture of the importance of this solute in plant response to water deficits. There probably has been more research conducted on this amino acid, and more debate concerning its role, within the past decade than is the case for any other metabolite, and the abundant literature is effectively summarized in these two chapters. Especially valuable is a seven-page table listing all known examples of proline accumulation organized by taxon and type of stress. The solute next in importance in this context is betaine, which is covered by R. G. Wyn Jones and R. Storey. All known examples of betaine accumulation are summarized in a ten-page table.

The hormone that has received the most attention in the past decade is abscisic acid (ABA). Its physiological aspects are discussed by M. C. Pitman (ion uptake) and T. A. Mansfield and W. J. Davies (stomatal behavior), its biochemical aspects by B. V. Milborrow. Unfortunately, the notion that ABA increase should, and does, increase root permeability to water in stressed plants still has currency with these authors.

Two important suggestions are made in the book. Wyn Jones and Storey recommend a unified terminology, reserving the name "betaine" to indicate the class of compounds and naming individual betaines by reference to their parent amino acid (glycinebetaine, alaninebetaine, and so on). Up until now the term has been used to refer to the specific metabolite glycinebetaine as well as to the entire class of compounds. M. M. Jones, N. C. Turner, and C. B. Osmond attempt to straighten out use of "drought resistance" and related terms. They suggest a classification that uses "drought" as a meteorological term and avoids the confusion that results when "drought" and "plant water deficit" are equated. The proposed terminology makes sense, although their new term, "drought tolerance at high tissue water potential," probably should be "drought tolerance at high turgor potential."

A paper by S. K. Sinha and D. J. D. Nicholas on nitrate reductase contains far too many "unpublished results" by the senior author. That is inappropriate for a review, and it is inconsistent with all the other chapters in the book. In spite of that notable discrepancy, the chapters of the book fit together so nicely that it almost seems like a single-authored book. There are virtually no major contradictions on significant points among the contributors. I am sure this will be the most important general reference on drought resistance for the next few years.

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A Prominent Enzyme

Cytochrome Oxidase. A Synthesis. MÅRTEN WIKSTRÖM, KLASS KRAB, and MATTI SARASTE. Academic Press, New York, 1981. xii, 198 pp., illus. $30.

Cytochrome oxidase is a key enzyme of energy generation: in most respiring cells it catalyzes the transfer of electrons from the respiratory chain to oxygen gas. It is also one of the most complicated enzymes known; its four redox centers (two heme *a* groups and two copper atoms) have made it a favorite playground for physical chemists, and its many nonidentical subunits (up to a dozen, depending on the source) offer unusual opportunities for enzymologists and structural biologists. The eukaryotic enzyme is controlled by two distinct genetic systems: the three largest subunits are coded by mitochondrial DNA and made inside the mitochondria, whereas the remaining subunits are coded by nuclear DNA and made outside the mitochondria and imported into the organelles. Since the mitochondrial genes coding for cytochrome oxidase have been sequenced, the enzyme can now be studied and manipulated by the vast array of present-day genetic methods. Finally, by proper treatment with detergents, the enzyme can be persuaded to form crystalline sheets; analysis of these sheets by electron diffraction has already yielded first glimpses of the shape of individual cytochrome oxidase molecules.

Cytochrome oxidase, no doubt, richly merits a monograph, and the present volume comes close to what I regard as the ideal one. It is written by three young scientists who, working in the same Finnish laboratory, have discovered that cytochrome oxidase not only transfers electrons but also pumps protons. The style of the book is highly readable, the illustrations simple and well done, and the length just right. Most important, the different areas of research on cytochrome oxidase are presented in a competent and well-balanced fashion. The book begins with a chapter on "general orientation" and goes on to discuss structure and topography; physical properties, configuration, and topography of the redox centers; oxidoreduction properties of the redox centers; kinetics and catalytic machanism; and electron transfer and energy transduction. It is perhaps unfortunate that the manuscript was completed just as the genes for the mitochondrially made subunits were being sequenced; this important development is therefore only mentioned. As a teacher, I would also have welcomed at least a brief table summarizing the key historical developments. But these are minor points compared to the merits of the book. It will be a key reference for workers in the field for years to come, and I expect to see its brightly colored cover (green, of course) on the bookshelves of most of my colleagues. The authors have done a difficult job well.

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