interesting problems in science policy concerned with R & D in society, including management of innovation, technology and program assessment, and the scale and direction of R & D investment related to national goals, but economics holds a potentially integrative role in its present swing back to seeing itself as a policy science rather than a positive science. Nowhere, Freeman concludes, could such a trend be "more welcome and more fruitful than in the area of science policy."

This pressure for integration is exerted from another standpoint by Sardar and Rosser-Owen from London's Muslim Institute, whose chapter "Science policy and developing countries" calls attention to the narrowness of the economic base of the research so far conducted on developing countries and underscores the need for wider cultural interpretations of science policy and technology transfer. Such criticism questions the "occidentalizing dynamics of development and development policies"—which finds expression, for example, in the prestigious aerospace and atomic programs of a country like India—and presses the need for science policy in developing countries to provide systematic analysis of "actual domestic development needs." The real problem, the authors sum up, would appear to be "not so much inappropriate development programmes as inappropriate decision-makers."

The chapters contributed by the political scientists, Lakoff, Nelkin, and Sapolsky, which deal with aspects of the political experience of scientists, the advisory and adversary systems, the role of expertise and its relations to government, and the part played by scientists at all levels in military science, bring us closer to the user audience for this volume. It is perhaps on these subjects that the literature and scholarship are the most diffuse. The bias is substantially American. The discussion, however, and the recommendations for further case studies of conflicts among scientists and between scientists and government agencies, of the social and political conflicts involving science, and of the decision-making process concerning domestic and military policy are as relevant for Australia, Israel, Japan, India, Canada, Brazil, or Nigeria as for Britain, Europe, and the United States.

This work stands as a landmark that no student of the social relations of science and technology can afford to ignore. Additionally the editors see it as bridging a gap between researchers and policy-makers. As Salomon of the Organization for Economic Co-operation and Development points out, "There exists a real gap between decision-making and the studies devoted to science policies," a point amply borne out by the book's own referenced case studies of decision-making. In the past, communication, as the editors admit, has not been good. It is to be hoped that this compilation will both influence researchers to think about the practical implications and applications of their work and encourage policy-makers and administrators to make increasing use of the scholarship that is available.

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Photobiology

Primary Processes of Photosynthesis. J. BARBER, Ed. Elsevier, New York, 1977. x, 516 pp., illus. $71.50. Topics in Photosynthesis, vol. 2.

About 15 years ago, Martin Kamen wrote a small book called *Primary Processes in Photosynthesis*. Softbound, Kamen's book cost only $2.45, but it was a treasure chest of insight and humor. To appreciate the sweep and grandeur of photosynthesis, Kamen said, one must think of time in exponential units, so that the interval of time between, say, 10^{-15} and 10^{-14} second is just as significant as the interval between 1 and 10 seconds. From the absorption of a quantum of light, which takes about 10^{-15} second, to the growth of a field of beans, there are more than 20 orders of magnitude of time—a greater span than the age of the universe measured in years. Kamen argued that the really interesting intervals of time, however, were the ones between 10^{-9} and 10^{-4} second. He called this the era of photochemistry, the time when photosynthetic systems capture the energy of the quantum in the first, fleeting products of a chemical reaction. The earlier era of photophysics and the later eras of biochemistry and physiology seemed reasonably well understood, but of the initial photochemical reactions of photosynthesis very little was known. As Kamen put it, the photochemical era marked a strong maximum in the spectrum of our ignorance.

The photochemical reactions of photosynthesis have increasingly provided a meeting point for scientists with widely different interests, from physicists to biologists and from theoreticians to gadgeteers. This collection of articles edited by J. Barber illustrates the outcome of this convergence. The topics included range from theories of exciton migration through details of instrumentation to the effects of *p*H gradients.

Most of the chlorophyll or bacteriochlorophyll in the membranes of photosynthetic organisms is not involved directly in photochemical reactions. Instead it acts as an antenna that absorbs light and funnels the energy in about 10^{-10} second to special sites called reaction centers, where the photochemistry begins. A small fraction of the excitations fail to be trapped and are emitted as fluorescence. A polished chapter by J. Lavorel and A.-L. Etienne discusses measurements of the fluorescence yields and lifetimes, covering recent work employing picosecond excitation techniques as well as measurements of the fluorescence yield during continuous illumination.

The question of how energy can move to the reaction centers so rapidly has intrigued theoreticians for many years. R. S. Knox discusses recent theoretical work on this subject in a chapter that will be heavy going for more biologically inclined readers. He concludes that exciton motion in the antenna becomes incoherent within about 10^{-14} second after excitation and that a diffusive, random-walk process describes the movement of excitons to the traps adequately after this point.

The primary chemical process that occurs in the reaction center is the oxidation of a special complex of chlorophyll or bacteriochlorophyll molecules. In photosynthetic bacteria, the initial electron transfer occurs in about 10^{-11} second. An account of recent picosecond and nanosecond spectrophotometric studies of the primary reactions is given by P. Mathis in a chapter on fast absorption spectroscopy. Mathis's chapter is rich in technical details on photomultipliers, light sources, signal averaging, and related topics.

Photooxidations of chlorophylls also can occur in solution. Photooxidation in vitro, however, almost invariably proceeds by way of a triplet state, whereas the primary reactions in vivo appear to involve excited singlet states. Electron transfer occurs from excited singlet states in vitro, but it generally is followed by a rapid back reaction that returns the system to the ground state. The spectroscopy and photochemistry of chlorophyll in vitro are discussed authoritatively by G. R. Seely.

The photosynthetic systems of chloroplasts and algae contain two types of re-

action centers linked in series. Photosystem 2 generates a relatively mild reductant and an oxidant that is strong enough to oxidize H_2O to O_2. Photosystem 1 generates a relatively mild oxidant and a reductant that is strong enough to reduce ferredoxin and ultimately nicotinamide adenine dinucleotide phosphate. In both cases, the initial photochemical reaction appears to be the removal of an electron from a chlorophyll complex. The nature of the primary electron acceptor in system 1 has been controversial. Optical absorbance changes and electron spin resonance (ESR) signals that occur under certain conditions suggest that the initial acceptor is a nonheme iron complex called bound ferredoxin. Other experiments implicate another acceptor, "X." It is not yet clear whether X is in the normal sequence of carriers or on a side path. M. C. W. Evans gives a well-balanced account of the experimental observations, in a chapter that emphasizes ESR studies. He favors the view that X is the primary acceptor, but concludes that more work will be needed to settle the question.

Two chapters on photosystem 2 are both extremely well written, detailed but highly readable. In one, R. Radmer and G. Cheniae focus on the mechanism of O_2 evolution. A component "S" appears to become successively more oxidized by the removal of one electron on each turnover of the photochemical apparatus. When S has accumulated four oxidizing equivalents, it reacts with H_2O, generating O_2. Radmer and Cheniae review the evidence that S involves manganese. J. Amesz and L. N. M. Duysens discuss spectrophotometric studies of the primary and secondary electron carriers on both sides of system 2. The electron acceptors appear to be plastoquinones.

The distribution of excitations from the antenna to the two photosystems is treated by W. P. Williams. He considers how the initial distribution of excitations and "spillover" of excitations from one photosystem to the other are regulated so that each can work as rapidly as possible.

Other chapters include discussions of photosystem 1 by J. R. Bolton, of delayed luminescence by S. Malkin, and of linear and circular dichroism by R. P. F. Gregory. All of these contain material of interest, although Bolton's short chapter seems superfluous in view of Evans's more extensive discussion. The chapter on delayed luminescence seems too long in relation to the importance of the topic; that on dichroism is a bit heavy on technical details about commercially available apparatus and thin on experimental results.

Overall, the book provides an up-to-date account of a rapidly moving field. It is well indexed and the chapters are thoroughly cross-referenced. It should be of considerable interest to those beginning work in photosynthesis, to seasoned investigators in the field, and to many more general readers.

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Dormant Bodies

Spore Research 1976. Papers from a meeting, Leeds, Dec. 1975. A. N. BARKER, J. WOLF, D. J. ELLAR, G. J. DRING, AND G. W. GOULD, Eds. In two volumes. Vol. 1, xviii + pp. 1–420, illus. + index. $27.35. Vol. 2, xviii + pp. 421–916, illus. + index. $31.25. Academic Press, New York, 1977.

One would think that a book summarizing research presented at a meeting in December 1975 would by now be so out of date as to be useless. In the case of *Spore Research 1976*, however, the value of the two volumes is not to be searched for in their timeliness, but rather in their breadth and in the depth in which subjects of wide interest are treated. The British Spore Group has been meeting nearly every two years since 1963. This most recent collection of papers reflects the ongoing interests of the major British and Australian spore research groups. The emphasis is on the mechanism of heat and radiation resistance, the genetics of sporulation and germination, spore structure, dormancy, and germination. Few papers deal with molecular biological approaches to understanding sporulation.

A particular strength of these volumes is that they present well-written, detailed research papers containing data of tremendous practical importance. The properties of spores that are most relevant to industrial, pharmaceutical, food, and soil microbiologists are discussed here. Moreover, toxicologists and specialists in infectious diseases will find a wealth of information concerning the production and excretion of toxic substances by a variety of *Bacillus* and *Clostridium* species, as well as analyses of the relationship of toxin production to sporulation. It is interesting to note that only a small minority of the papers describe work with the *B. subtilis* species so much favored by geneticists and molecular biologists.

Some contributions deserve special mention. In the opening chapter E. Freese argues clearly and forcefully that sporulation is not induced by starvation but rather by nutrient limitation leading to metabolic imbalance and slow growth. Freese debunks some commonly held misconceptions about sporulation and recounts the many futile efforts to identify the "repressor" of sporulation. He offers the interesting hypothesis that asymmetric septation triggered by slowness of growth is the key to the onset of sporulation-specific events.

P. Setlow's summary of his elegant work on degradation during germination of spore core proteins is well worth reading, even though the author's more recent studies, some of which have now been published, leave this account somewhat dated.

G. J. Dring and G. W. Gould, two of the editors of the volumes, present a notably lucid description of their theory of the role of water content in determining heat resistance. They have reduced a potentially confusing subject to a form understandable by the uninitiated.

Many contributions should be of interest to readers outside the spore field. Ion transport, membrane proteins, peptidoglycan biochemistry, and gene regulation are all dealt with in ways that have general applicability.

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Pheromones

Chemical Control of Insect Behavior. Theory and Application. H. H. SHOREY and JOHN J. MCKELVEY, JR., Eds. Wiley-Interscience, New York, 1977. xiv, 414 pp., illus. $19.50. Environmental Science and Technology.

Research on chemical communication in insects has reached a state where even the insider has difficulty keeping up with the subject. Since the coining of the term "pheromone" in 1959, more than 100 such substances and related natural products have been chemically characterized and additional signal compounds have been found that more or less mimic natural products. In 1975 a group of specialists in such research met at the Rockefeller Foundation conference center in Bellagio, Italy, to discuss their findings on sensory functions and behavior as well as on matters of application such as "improvements in the traditional ways of managing insect populations."