aware of any connection between the thermodynamic properties of initial and final states and the mechanisms involved in the change from one to the other.

A very valuable feature of this monograph is its extensive tabulation of premelting and prefreezing phenomena near the solid-liquid transition. However meager, these slim clues may offer our best hope of eventually understanding the phenomena of melting and freezing.

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Bacterial Photosynthesis

The Photosynthetic Bacteria. RODERICK K. CLAYTON and WILLIAM R. SISTROM, Eds. Plenum, New York, 1978. xxii, 946 pp., illus. $85.

Two ideas have profoundly influenced modern thinking about photosynthesis. One of them goes back 50 years to C. B. van Niel, who, working with anoxygenic photosynthetic bacteria, suggested that the primary reaction in photosynthesis results in the production of a reducing component and an oxidizing component. Today this is known as a charge separation.

The other idea is more general and originated outside of this field. It is the chemosmotic coupling hypothesis of P. Mitchell. According to this hypothesis, the transfer of electrons down a redox gradient in a unit membrane occurs in such a manner as to produce a proton gradient over the membrane. This latter gradient serves to drive phosphorylation of adenosine diphosphate and other energy-demanding processes in the membrane.

These ideas are central to the subject of photosynthesis, and, accordingly, they form the basis for the largest section in this book, entitled Photometabolism. The section is built up around the reaction center, the isolation of which, by Clayton and co-workers, is one of the more recent landmarks in photosynthesis research. The sequence of events beginning with the transfer of excitation energy from antenna pigments to reaction center, and the conversion of this energy into a proton gradient, are described and discussed in 15 chapters.

The redundancy that the editors mention in their preface is most apparent in this section. Whether or not this is a disadvantage is a question for the individual reader to decide. I found it slightly irritating.

Organisms that carry out the processes described above are structurally very specialized. Therefore, the section on structure is an important one. Most of the chapters in the section are concerned with membranes or membrane components. The membranes of purple bacteria are much better understood than those of the other groups, and hence the long, well-written chapter on them by Niederman and Gibson dominates the section.

The structure of the photosynthetic apparatus of the green bacteria is unique. One of the light-harvesting components of these bacteria is a water-soluble bacteriochlorophyll a–protein complex that has been purified. Its structure and properties are described in a pithy paper by Olson.

Over the years a large number of data on many of the chemical constituents of photosynthetic bacteria have accumulated. Much of this information has been collected, ordered, and evaluated in the section on chemical composition. Carotenoids, cytochromes, and complex lipids are treated here. Methods of isolation and identification are also included, and these chapters will serve as invaluable sources of reference for years to come.

Apart from these sections and the balanced introductory chapter by Pfennig, the book presents a disconnected picture. Everybody would agree that the ability to convert light energy to chemical energy only under anaerobic conditions must have profound physiological (and ecological) consequences for the organism concerned. It follows that the ways in which the cell's physiological and biosynthetic machinery interacts with this special type of energy metabolism are very important. An awareness of this is cardinal in any attempt to properly describe the photosynthetic bacteria. But the sections on phosphorylation, peripheral oxidations and reductions, biosynthesis, and physiology seem to have been compiled without this in mind. As the chapters in these sections show, there are plenty of data and ideas. What is needed is coordination and a more imaginative disposition of the subject matter so as to integrate the various aspects, as is accomplished in the section on photometabolism.

Nevertheless many of the individual papers in these sections are very good. One of the most exciting is that by Kaplan on the control and kinetics of photosynthetic membrane development. Although it is established that at least some of the intracellular photosynthetic membrane is continuous with the peripheral, cytoplasmic membrane, it is still uncertain whether the intracellular membrane originates by invagination of the peripheral membrane. Kaplan's group has attempted to answer this type of question by the use of the technique of density shift, in which "heavy" membranes produced during growth in heavy water may be separated from those produced after a period of growth in ordinary water.

A sense of up-to-dateness is given here, as it is in many of the other chapters, by the inclusion of a note added in proof. Kaplan's addition describes an extraordinary finding with synchronous cultures of *Rhodopseudomonas spheroides*. In these cultures the rate of synthesis and incorporation of membrane proteins and photosynthetic pigments was shown to be constant throughout the cell cycle. However, synthesis and incorporation of the phospholipids was limited to a short period just prior to cell division. These results raise questions of great significance with respect to membrane synthesis, not only in photosynthetic bacteria, but in every kind of cell.

In summing up, I would say that the book's strength lies in its up-to-date treatment of the photochemical and closely associated metabolic and structural aspects of the anoxygenic photosynthetic bacteria (the blue-green photosynthetic bacteria are scarcely mentioned in the book), and it should be available to every research worker in the field of photosynthesis, oxygenic and anoxygenic alike. Those looking for a coherent picture of the biochemistry and biology of the photosynthetic bacteria will not find it here.

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Commonalities

On Aesthetics in Science. JUDITH WECHSLER, Ed. MIT Press, Cambridge, Mass., 1978. xii, 180 pp., illus. $12.50.

In his essay on "Darwin's tree of nature" in this volume, Howard E. Gruber comments on the existence of different esthetic moods in science. The prevailing mood in the present volume is one of reaction against the cold formality of the idealized model and admission of the subjectivity of science.

This subjectivity was imposed on physics early in the present century

"Wintry Mountains" by the early Ch'ing painter Kung Hsein (ca. 1620–1698). "There is a kind of phase rule relating the number of distinguishable types of features in a painting to the number of kinds of just-visible units with which the artist works and the manner and density of their packing. . . . It is [the] interplay [of atoms and lines] that gives unity and character to the assembly even when the parts are invisible, and the assembly on one level—whether in matter or in the perception that underlies art—itself becomes a part in a larger aggregate with its own pattern of interplay. . . . As in a physical aggregate, areas in the Kung Hsien painting can be distinguished not only by the nature of the individual brush strokes (=atoms) but also by the density and orientation of their arrangements. The trees . . . are separable from each other by the orientation of their leaves, just as individual microcrystals in a pure polycrystalline material are distinguished by lattice orientation alone." [From C. S. Smith's paper in *On Aesthetics in Science*; painting from the collection of John M. Crawford, Jr.]

when the interaction of the observer with the system observed was shown to affect both: the quantum of action couples the two, and an observation necessarily changes the observed system. Seymour Papert, in his essay "The mathematical unconscious," starts with Poincaré's premise that the distinguishing feature of the mathematical mind is not logical but esthetic. He contrasts this point of view with theories of the psychology of development, such as that of Piaget, that ignore the esthetic or even the intuitive. Papert's experiments in "loud thinking" at MIT have demonstrated that "mathematical work does not proceed along the narrow logical path of truth to truth to truth but bravely or gropingly follows deviations through the surrounding marshland of propositions which are neither simply and wholly true nor simply and wholly false."

Gruber, in the essay referred to above, uses Charles Darwin's notebook and early drafts to study Darwin's likes and dislikes, starting with Erasmus Darwin's evolutionary theories and the influence of his poetic account of nature on his grandson Charles. Both Papert and Gruber thus stress the importance of personal style and characteristics in the choice of a scientist's field of study and the way in which he or she solves the problems.

Poincaré is also the starting point, historically, in Arthur Miller's essay on the importance of visualization in the genesis of the quantum theory in the period 1913–1927. Poincaré had surveyed the famous Solvay Congress of 1911; he placed a high premium on visual thinking but was loath to abandon determinism, as one would have to in order to accept the discontinuities implied by Planck's radiation law. Miller traces the subsequent incompatibility of Bohr's visual and Heisenberg's nonvisual modes of thinking, introducing in turn Max Born and Erwin Schroedinger, analyzing the personal expressions of concern in the publications of each of the protagonists (Heisenberg at one point criticized Schroedinger's wave mechanics as "disgusting" and was enraged at Born's desertion of the cause of quantum mechanics). Miller correlates Bohr's discovery that visual thinking precedes verbal thinking with his lifelong interest in art, especially Cubism, and shows that Heisenberg eventually acknowledged the importance of intuition if not of visualization.

The essays of Gruber, Papert, and Miller undermining the myth of scientific objectivity are capped off by Geoffrey Vickers's "Rationality and intuition."

Essays by Cyril S. Smith and Philip Morrison deal with the perturbations of perfectly symmetrical structures. In his essay, "Structural hierarchy in science, art and history," Smith stresses the inherent connection between deviations from perfection and hierarchy in structure; the imperfections at one level constitute the structural elements of the next. Smith has made these observations earlier and elsewhere, but this particular essay abounds in quotable gems of wisdom; this reviewer must confine himself to the following examples: "Most human misunderstanding arises less from differing points of view than from perceptions of differing levels of significance"; "One cannot overemphasize the fact that everything—meaning and value as well as appropriateness of individual human conduct or the energy state of an atom—depends upon the interaction of the thing itself and its environment."

Morrison picks up the theme of perfection and imperfection in his essay on broken symmetries. He starts with Leibniz's principle of the indiscernibility of differences, pointing out the relationship between symmetry and modularity. Considering that perfect translational symmetry is in effect a kind of nightmare, the beginning and the end constitute welcome perturbations, whose existence would, however, be meaningless without the existence of the symmetry. Morrison's discussion of Lee and Yang's realization of our universe's handedness is not as clear as his welcome explication of the second law of thermodynamics, namely that if you create order you must pay for it in energy. His exposition of this possibility effectively dispels the myth that the world necessarily tends to disorder.

This collection of essays excels through unity in diversity, an apt application of what it preaches. Many such collections suffer from a lack of consistency in style or level of significance. It is to the credit of the editor, Judith Wechsler, that here the contribution is greater than the sum of its parts. If fault be found with the book, it is perhaps the excessive reticence of its editor.

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