the extent to which men collectively have gained such control. But the will to power is self-limiting, according to Stent, for when it achieves the security and affluence which are its end, the drive to know and to control is abated. Hence the end of progress, and for Stent this is in sight. Is Jacob's guarded optimism or Stent's determined pessimism justified? For me the concept of increasing levels of integration has provided an answer. If, as I believe it is, the progress of science is indeed measurable by the control it offers man of his environment, then there is a different way in which science is self-limiting. Man is related to his environment in a higher order of integration, such that a harmonious interplay must exist between them: man depends upon his environment, and the environment is shaped to a certain extent by man. These relationships must be regulated: there are constraints on man's control of his environment as there are constraints on the extent to which the environment can modify the plan of organization of man. Thus science itself is regulated in a feedback manner: the environmental changes it causes through technology come back to affect the evolution of man and all living things, thereby creating new challenges to the will to power. In this way science may be limited in its rate without being ground to a halt. The future may bring an entirely new way of looking at the integration of reproducible patterns of organization. And such a transformation will depend in turn on an evolution, of man, life, and their environment, along paths we cannot predict.

If Jacob's book helps to dispel the gloom of a projected end to progress, it leaves one with serious questions about the writing of histories of science. The picture I have of science is that of an evolving system: its direction is not strictly determined; what it is at any given time depends, of course, on what has preceded; it is contingent upon events that cannot be predicted but that assure still further transformation. In hindsight, the appearance of successive transformations, of new Russian dolls, may be hard to resist. The virtue of hindsight is that it permits one to order the events of history in a manner that fits some *post hoc* rational construction, no matter how disordered and unrelated the events may have seemed to the contemporary observer. As Jacob points out with respect to evolutionary theory, the gravest difficulty with history is its inaccessibility to direct verification. The historian might as easily see in our intellectual past the successive emergence of Russian dolls or a more continuous flow of ideas, or perhaps even share the Kuhnian vision of logically unrelated revolutions, depending on some theoretical conception or philosophical commitment (itself the product of evolution) that is consciously or unconsciously directing the vision.

It is interesting that in Jacob's book little is said about the personal lives of the scientists whose work he discusses with care, of the social and economic milieus of their lives and thought. Jacob comprehends their work after the fact, seizes upon it and synthesizes it in an esthetically satisfying plan. But have we really succeeded in knowing how the transformations have taken place? Was Mendel really imbued with a statistical approach to the study of heredity? If so, how did it come about? Was Boltzmann's statistical conception "in the air"? If so, in what manner did it take root in another mind? Are the receptivities of individuals to new ideas "in the air" a function of psychological factors, of the social milieu, of the "accidents" of their lives? The complete answers to such questions may require a degree of historical detail that is unattainable. But is this not the classic problem of historiography? Does one write a history or a likely story, an interpretation based on current views? These thoughts are not meant to depreciate Jacob's lucid account of man's changing ideas about heredity. Like a truly great intellectual history, it seizes and stimulates the imagination. It will stimulate biologists and philosophers of biology for a long time to come.

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Rich Material

Insect Ultrastructure. Royal Entomological Society of London Symposium No. 5, Sept. 1969. A. C. NEVILLE, Ed. Published for the Society by Blackwell, Oxford, 1970. viii, 188 pp., illus. $15.

At the 1860 soiree of the Entomological Society in St. Petersburg, Karl Ernst von Baer said that scientific studies involved an apprehension of general plans through the observation of detail and that for this pursuit no group of animals offered richer material than the insects. In the first contribution to this symposium on insect ultrastructure, D. S. Smith sets the stage for a modern justification of the claim. The book is the best evidence in print to support chauvinistic insect physiologists in their contention that insects provide uniquely suitable systems for tackling fundamental problems. Almost any of the ten chapters has ideas of general interest and makes an unspoken plea for studies on animals other than rats.

A. C. Neville considers the structure and mechanical properties of cuticle as a two-phase system of fibers and matrix. The fibers are oriented parallel to one another in laminae which may be arranged orthogonally, in preferred layers with a clockwise rotation, or helicoidally. The direction of rotation is the same on both sides of the whole animal so that insects are asymmetrical at the microfibrillar level. This finding perhaps supports the notion that cuticle architecture is determined by a process akin to crystallization. T. Weis-Fogh reviews some of the information on cuticle formation and contributes several new observations suggesting that microfiber orientation is determined by the intrinsic properties of chitin rather than through an orienting force exerted by the cells. The scanning electron microscope has given a new lease on life to insect morphologists, and H. E. Hinton contributes some beautiful pictures of insect surfaces, particularly cuticular diffraction gratings and interommatidial setae. The primitive surface microsculpture is a pattern of polygons reflecting the distribution of epidermal cells. W. H. Telfer and D. S. Smith discuss the problems posed by blood precursors being taken up and transformed into the intricately structured egg. The simplicity of insect organization in epithelial sheets and cylinders makes them particularly favorable for studies on transport and absorption. M. J. Berridge illustrates the role of extracellular compartments in the absorption of organic molecules, which may be linked to active transport of ions and water by the intestine. His model may also explain water uptake against an osmotic gradient. C. T. Lewis describes chemoreceptors that may be excited by a single molecule and mechanoreceptors that respond to distortions of 30 to 100 angstroms. The latter respond only when the neural membrane is stretched in a particular direction, a fact suggesting that an oriented, discriminatory molecular organizaation is involved. Neuromuscular junctions and stretch receptors are reviewed by M. P. Osborne and neurosecretion is reviewed by S. H. P. Maddrell. J. E. Treherne sums up the symposium and contributes on the central nervous system.

The book is illustrated with many good electron micrographs and some not so good. The conveners are to be congratulated for their selection of participants, but the presentations follow no particular order in the volume.

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Carbohydrates

Polysaccharides. GERALD O. ASPINALL. Pergamon, New York, 1970. xviii, 228 pp., illus. $8.75. Commonwealth and International Library: A Course in Organic Chemistry.

In the preface, the author of this concise and well-written treatise states that "polysaccharides seem at the moment to be less spectacular substances than proteins and nucleic acids [but] significant developments throwing light on structure-function relations will surely emerge in the near future."

The role of carbohydrates in nature is certainly an important one: cellulose, in number and in distribution, is by far the most prominent organic molecule in nature, and recent work on the biological processes occurring at the surface of animal cells has strongly implicated carbohydrate structures. Nevertheless, after reading this book one has a lingering doubt that any part of the material described in it will ultimately shed light on the relationship of structure to function. Aspinall's interest in the structure elucidation of complex polysaccharides isolated from plants, such as gum exudates and pectins, has strongly influenced his selection of material. The first 42 pages of the treatise concern methods of isolation and structure determination and offer an excellent summary to any chemist entering this very specialized field; of the remaining 180 pages, about 11 give a brief description of the biosynthesis of polysaccharides, sufficient for the chemist who is interested in the principles of biosynthesis mechanisms, but they do not do justice to the fascinating correlations recently established between changes in chemical structure of the connective tissue polysaccharides and the aging process or between the antigenic properties of bacterial polysaccharides and virus infection. The largest part of the remaining text concerns polysaccharides of plants and microorganisms, less than 15 percent being reserved for polysaccharides of animal origin.

The variety of the chemical structures devised by nature to protect plants from physical injury caused by such external forces as wind, weight of snow, frost, and heat or from microorganism attack is certainly astonishing. No correlation, however, has been established as yet between the structure of polysaccharides and their possible biological role, and consequently the reading of these numerous complex structures is rather tedious. This is unfortunate, because the selection of the references is judicious and the material well presented.

In the few pages devoted to the subject, Aspinall attempts a brief survey of the complex field of carbohydrates in animals. The progress of immunochemistry gives us hope that in this field the structure-to-function relationship will be understood earlier than in plant polysaccharides. The chemistry of the polysaccharides of connective tissues is extensively discussed, but a correlation of the structures with clinical problems would certainly have aroused the interest of the medical scientist. The treatment of the remaining carbohydrate structures of animal origin is much less effective, probably because of the preoccupation of the plant chemist with "purifying" polysaccharides until they are devoid of all "extraneous" material. Aspinall is not stressing the fact that all carbohydrate structures found in animal tissue (including the polysaccharides of connective tissue but with the possible exceptions of glycogen and hyaluronic acid) are glycoproteins having various carbohydrate chain lengths. To discuss blood group substances, which are glycoproteins having relatively short oligosaccharide side-chains, in the chapter on aminopolysaccharides, separately from other glycoproteins, is misleading; their structure is not different from that of other glycoproteins except at times for the terminal carbohydrate residue. Some of the structures discussed at length have not gained general acceptance, and other glycoproteins extensively studied by various groups are not mentioned.

The author has attempted a classification of his material based on chemical structure instead of the more usual classification based on origin. This more logical, new distribution presents as many problems as the old one: for example, chondroitin 4-sulfate, which contains an acid component (D-glucuronic acid), a sulfate group, and an amino sugar (D-galactosamine), and is, in the native state, a component of a glycoprotein (proteoglycan), is classified neither with the glycuronans nor with the complex acidic polysaccharides, sulfated polysaccharides, or glycoproteins, but with the aminopolysaccharides.

Because of its clear presentation and excellent, but restricted, selection of references (with the exception of the glycoprotein part), this small treatise would be most helpful for the reading of a course on the chemistry of plant and microorganism polysaccharides. But who, except perhaps the members of a few departments of agricultural chemistry and microbiology, still has the interest to teach such a course?

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Strengtheners

Whisker Technology. ALBERT P. LEVITT, Ed. Wiley-Interscience, New York, 1970. xiv, 478 pp., illus. $24.50.

Whiskers are metallic and nonmetallic filamentary single crystals that have ultrahigh strength, and many also have very high elastic moduli, low densities, and high melting points. Whiskers are potentially the most effective reinforcing agents for advanced structural composites, but their utilization is just beginning. The editor states that the purpose of this book is to present a "timely" summary of the progress since 1952, when Herring and Galt found that the strength of tin whiskers was an order of magnitude greater than that of ordinary tin.

After a brief historical introduction by the editor, the book proceeds from the growth, testing, and properties of whiskers to the mechanics of whisker strengthening in composites, and then to the fabrication of whisker composites and their properties. The 11 chapters, each by different authors, cover the