doubtful that their treatment of these alternative arguments and opposing observations will convert the proponents and sympathizers of the selectionist view.

It is my feeling that Kimura and Ohta's book presents a very strong argument that random frequency drift *may* serve to explain much of protein evolution and a major proportion of the observed protein polymorphisms. Clearly, what proportion of these observations *will* be explained by this mechanism remains an entirely empirical question. Existing in their theory are many testable hypotheses. Kimura and Ohta's book is an important contribution to evolutionary biology.

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Pest Control Strategy

Microbial Control of Insects and Mites. H. D. BURGES and N. W. HUSSEY, Eds. Academic Press, New York, 1971. xxii, 862 pp., illus. $33.

The first attempts to use microorganisms for the control of insect pests were made about a century ago, and since then the study of insect diseases and their development as control agents has progressed at an increasing pace. With the recent concern about purely chemical means of pest control, and the attendant reexamination of pest control strategies with greater emphasis on the integration of biological agents within control programs, there has been renewed interest in microbial control and an expansion of research effort in this field by industry and government agencies. Because of the specificity of many of the microorganisms causing insect disease and their apparent harmlessness for nontarget organisms, microbial control offers a means of selective suppression of many insect pests without the disruptive effects of broad-spectrum chemicals.

In this new book, the editors have brought together the expertise of over 40 contributors to provide an authoritative assessment of the present and future potential of microbial control of insects and mites. With 33 chapters by different authors, some unevenness of treatment is inevitable, but the central theme of practicality, together with careful editing, has minimized the disjointedness.

Early chapters provide a guide for the identification of the more common insect diseases and are followed by appraisals of the main groups of pathogens with respect to their status and use as control agents. Readers unfamiliar with the field are thus able to obtain essential background information otherwise widely scattered in the literature. *Bacillus thuringiensis*, the commercially produced pathogen most widely used in microbial control, is the subject of more detailed treatment, a reflection of the greater body of knowledge available concerning its structure, biochemistry, and host specificity. The main body of the book consists of reviews of the many factors affecting the potential of microbial control in pest management programs. Attention is given to the safety of microbial control agents for vertebrates and to the interactions of these agents with other insect pathogens, environmental factors, and chemical insecticides. The editors' declared intent to point out areas where further research is required is well fulfilled by the discussion of the possibilities of pest resistance to microbial control agents and of the safety of pest-insect pathogens for beneficial insects, concerning which the paucity of information is such that any appraisal of long-term effects in the field must be largely speculative. Clearly, the reactions of both pest and beneficial insect populations to repeated exposure to microbial control agents should be investigated as a matter of urgency.

The closing chapters of the book are concerned mainly with the economics and production of microbial control agents, and are of more interest to the specialist. Although formulations are discussed, there is, regrettably, relatively little information given on field application techniques, which are often of critical importance to the success of microbial control schemes. There are seven useful appendices giving sources of information and materials of particular relevance to microbial control. As a whole, the book provides the most authoritative and thorough coverage of microbial control in the English language, presented in such a manner as to be comprehensible to students and workers unfamiliar with this field. It is probable that it will become the standard reference work on the subject for some years to come.

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The Sciences of Heat

From Watt to Clausius. The Rise of Thermodynamics in the Early Industrial Age. D. S. L. CARDWELL. Cornell University Press, Ithaca, N.Y, 1971. xvi, 336 pp., illus. $11.50.

Bicentenary of the James Watt Patent for a Separate Condenser for the Steam Engine. A symposium, Glasgow, Sept. 1969. ROBERT DONALDSON, Ed. Published for the James Watt Bicentenary Committee by the University of Glasgow, Glasgow, 1971. 224 pp., illus. £2.

From Watt to Clausius is detailed, explaining unfruitful as well as fruitful ideas leading to the engineering sciences of heat transfer and thermodynamics, and it follows a chronological pattern. It thus emphasizes rather than suppresses the confusion of diverging and converging chains of ideas and indicates the distance that lies between a logical textbook exposition of a science and the tortured path that its development actually followed. The book is intended for teachers of thermodynamics as an antidote to the arbitrary and sterile treatment usually found in the textbooks they use. It would be a pity, however, if other readers were not also attracted to the book, for Cardwell, a historian of science at Manchester University, has much to offer even those who will not follow all of his arguments to their conclusions. His insights speak not only to the sciences of heat but also to the nature of scientific thought and understanding.

He points out, for example, that most engineers acquire from textbooks not only their knowledge of the substance of the sciences they use but their ideas of the very nature of science. The notion that engineers think only in logical fashion, often asserted as a fact by engineers, certainly derives in part from the assumption that a textbook reflects the logical (and thus the only possible) development of a science.

Cardwell also describes some of the distortions that result from the chauvinistic tendencies in textbooks of thermodynamics. In the pioneering textbook of P. G. Tait, for example, British contributions are stressed at the expense of others. It was Tait who claimed that Newton was responsible for the doctrine leading to the mechanical theory of heat. Actually, the concept of caloric, an imponderable fluid flowing from a higher to a lower temperature, being absorbed by a body as it was heated and squeezed out of a body by abrasion or compression, owed nothing to Newton, but it provided an entirely satisfactory explanation of virtually all observed phenomena. It was not until a full 50 years after Count Rumford's cannon-boring demonstrations that the dynamical aspects of heat began to be explainable. More seriously misleading to the student, however, was Tait's distortion of the important insights of Clausius regarding entropy. Many of us who grew up in the textbook tradition will learn for the first time that Clausius had a much clearer conception of entropy than Tait and his copiers have led us to believe. Except in esoteric studies, nobody until Cardwell has taken the trouble to pass on to readers what Clausius thought he was doing. He did not invent the index of unavailability, nor did he invent a pure mathematical function, unexplainable except symbolically. His explanation of entropy is not reducible to a phrase, but it can provide a classroom teacher or a student with more than the conventional and unsatisfactory bare-bones definition.

Cardwell shows clearly that the steam engine had to exist, and that it had to be in the form given to it by James Watt, before a satisfactory doctrine of thermodynamics could develop. It would be unthinkable, for example, for Sadi Carnot to have devised in 1824 a cycle that required a high-temperature source and a low-temperature sink if the Watt engine, with a separate condenser, had not provided the underlying pattern, if not the immediate model. Neither the Newcomen steam engine, in which condensation occurred in the steam cylinder, nor the high pressure noncondensing engine, whose condenser was the atmosphere, could reasonably have suggested the Carnot cycle. Of course, those who view science as merely the discovery of a preexisting coherent and logical system of relationships will disagree, but the evidence adduced by Cardwell is convincing to me.

On the other hand, the development of a theory of heat transfer, which was largely the work of French graduates of École Polytechnique, had no corresponding model in practice—for example, there was no developed technology of heat exchangers to suggest to Fourier that the mechanisms of heat transfer could be separately analyzed as conduction, convection, and radiation. Yet the definitive theory appeared, nevertheless, in Fourier's book of 1822. Neither is there a clear connection between practice and science during the period of intense activity in thermodynamics from 1845 to 1865. The work of Mayer, Joule, Kelvin, and Clausius all appears to have been impelled by intellectual, not practical, interests.

The narrative supports the idea that direct cause-effect contacts of science and technology occur sometimes but not always. To be convinced that technology must always "be there" in order for a science to develop still requires a leap of faith, but the leap is made a little shorter, I think, by this book.

Some readers may be irritated, as I was, by the author's occasional impatience with a scientist who "failed" to draw a nearly obvious conclusion or with one who "might have been successful if" he had just been a bit more perceptive. It is difficult to avoid the superior wisdom of hindsight, of course, but it should be more carefully guarded against. I disagree also on a few matters of fact, but no change that I should want to make would damage Cardwell's arguments. The text references to plates are hopelessly confused; otherwise, the publisher has produced a well-made book.

The *Bicentenary of the James Watt Patent* records the proceedings of a two-day symposium, in which a knowledgeable historian gave a lecture on Watt's genius, the James Watt Professor of Mechanical Engineering in Glasgow University traced the engineering development of the separate condenser from 1769 to the present and supplied a useful bibliography, and four technical papers were presented on current aspects of condensers. Two of the papers review recent research in film condensation and "dropwise" condensation, respectively. Because the book is such a mixed bag, the contributions will be effectively lost to readers who might in the future be interested. Better, it seems to me, to issue a commemorative brochure for ceremonial purposes, then publish the substantial contributions in the journals where they belong.

The symposium may have made a long-term contribution, however, by placing a large rock to mark approximately the spot on the "Green of Glasgow" where James Watt was walking on "a fine Sabbath afternoon" in 1765 when the idea struck him of the separate condenser.

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Cosmology

Relativistic Astrophysics. Vol. 1, Stars and Relativity. YA. B. ZELDOVICH and I. D. NOVIKOV. Translated from the Russian edition (Moscow, 1967; revised by the authors) by Eli Arlock. Kip S. Thorne and W. David Arnett, Eds. University of Chicago Press, Chicago, 1971. xviii, 522 pp., illus. $24.

Relativistic astrophysics was born prematurely in December 1963 at the first of the well-known Texas conferences of that name. The purpose of that conference was to explore the idea of Fowler and Hoyle that radio galaxies arise from an explosion associated with the gravitational collapse of super-massive stars. Such collapsing stars would rapidly enter the regime where general relativity is important. The discovery of quasars in 1963 suggested a further field of application of this idea. The birth was premature, however, because even today we do not know whether radio galaxies or quasars have anything to do with super-massive stars. The real beginning of relativistic astrophysics was in 1968 when Hewish and his colleagues discovered pulsars and Gold suggested that they are rotating neutron stars, a suggestion that is now generally accepted. The gravitational potential at the surface of a neutron star is as large as about one-tenth in units of the square of the velocity of light, which means that general relativity has important effects on its structure and stability. A dramatic example of a relativistic effect would be the behavior of a Foucault pendulum placed at one of the poles of the neutron star in the Crab nebula. Such a pendulum would define a local inertial frame, but in that frame the system of stars would be seen to rotate about three times per second.

The book under review is the first comprehensive discussion of relativistic astrophysics as it stood in late 1969. It is based on a Russian original completed in 1967 by the distinguished physicists Zeldovich and Novikov, revised by them in 1969, and further edited by the American astrophysicists Thorne and Arnett on the basis of an excellent translation by Arlock. Despite the complexities of this collaboration the book maintains a unified tone, the one we have come to associate over the years with the senior author. That means emphasis on the physics rather than on the formal mathematical structure of general relativity. In that spirit the book contains an interesting ac-