view it might be objected that as far as the *S*-matrix theory goes, the dispersion relations are pure conjecture not particularly well supported by later approximate calculations. For the student's sake it might be better to show how the analyticity suggested by the properties of the *S*-matrix actually follows from the unassailable principles of quantum field theory.

The least satisfying part of the book is the description of attempts to use analyticity and unitarity to make approximate calculations of strong-interaction processes, such as pion-pion and pion-nucleon scattering. This is through no fault of the author, who valiantly develops in a limited space the mass of necessary formulas, but is more a function of the highly unsatisfactory state of strong-interaction calculations. Here, as in many other places in physics, the approximations necessary to achieve tractable equations are so violent that the results are not really credible. Nonetheless, there are many useful and suggestive ideas, such as that of the bootstrap, which are adequately discussed.

The final chapters are in the nature of a morale-builder and reward to the persevering reader. It is shown how the ideas and machinery built up for strong-interaction physics, with not much in the way of final results, work beautifully for electrodynamics, allowing one to make calculations without ever encountering infinities. It is hoped that this tantalizing success will encourage people to persevere in the line of work reviewed by this excellent book.

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The Possibility of Perfecting Our Knowledge

Completeness in Science. RICHARD SCHLEGEL. Appleton, Century, Crofts, New York, 1967. xvi + 280 pp., illus. $7.50.

There are many fascinating problems associated with the question of how far science can describe and explain the universe, so it is very interesting to see a book that attempts to tackle them. Unfortunately this book is guided by a conception of the problem that makes it far from satisfactory.

A book with such a title must naturally cover a wide range of issues, and if it is not to deal with them in a superficial fashion it will make large demands upon its author. If he decides to deal with the subject matter of science in order to discuss the possibility of its completion, his task is all the more enormous. Schlegel in fact spends more than half the book describing, in what is usually a straightforward way, the substance of the sciences he chooses to deal with—cosmology and quantum theory. It is in terms of these extremes of science, the very large and the very small, that most of his discussion is formulated. Schlegel is a physicist with a special interest in the philosophy of physics, and with the simple confidence in his field of which only a physicist is capable he sets aside every other scientific field as being of only peripheral importance. Perhaps without such an extreme manner of bringing the problem of completeness down to size a book like this could never have been written.

Because he is so much concerned with presenting the results of modern physics, Schlegel does not realize how much he is taking for granted in his subject. He seems unaware of the relevance of the history of science to a general discussion of how complete science can be. Invariably the passage of time has shown that the science of a given period was less complete and less certain than its advocates thought it to be. Cosmology is likely to have changed radically within a decade, and it would be an unscientific prediction to claim that quantum physics is now in its final form. One wonders why Schlegel spends so much of his book presenting the results of studies that the next generation may well dismiss as misdirected.

In addition to ignoring the historical perspectives of his problem, Schlegel slides over the epistemological aspects. To think that science can be completed one must have a very special conception of the relationship of language, sensory experience, and the natural world. Different theories of knowledge will give different conceptions of what science can and cannot do. Perhaps because he is so prepared to accept as permanent the results that physics now claims, Schlegel neglects the epistemological underpinnings for such claims. He briefly develops the theory of knowledge he has adopted, but without consideration of alternatives or of the traditional objections to what can count as knowledge.

Schlegel mentions the better-known arguments against the possibility of completing any description (especially if it involves describing the descriptive records being made), but he does not make it clear why one should discuss the problem of completeness further than this. He offers few arguments to show that science can be completed, and in fact the possibility arises for him only in the context of a particular science that has solved all the problems that can be raised in terms of its concepts. He does not take into account the fact that sciences can do this only by so limiting and idealizing their concepts that any new phenomena discovered will be irrelevant to them, just as the complexities of diffraction and interference are irrelevant to geometric optics. This sort of completeness is like the conceptual framework of a prescientific culture in which all the questions that may be asked may also be answered without any need to observe phenomena any more carefully, so that the whole system can never be found to be wrong. Indeed it might be suspected that if a science could be considered complete there would be something seriously wrong with it. It is the openness of science which gives it its special and valuable characteristics.

In spite of its avowed theme then, this book is primarily about contemporary cosmology and quantum theory and what it would be like to complete science on the basis they provide. The result is an adequate and stimulating introduction to some interesting issues in the philosophy of physics, but nothing to satisfy anyone who has wondered at all about the problem of completeness in science.

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Birds

Ornithology. An Introduction. AUSTIN L. RAND. Norton, New York, 1967. 311 pp., illus. $8.50. World Naturalist series.

This is a concise, but comprehensive, survey of the birds of the world from the standpoint of their various relationships to their environment, to their ancestry, and to each other as illustrated

by their activities, needs, and reactions both in life histories and in morphological adjustments. The book is written for the nonspecialist, but is not written down to him, with the result that the technical ornithologist will also find it interesting and rewarding to read. The author interjects his own reactions to discussions about many uncertain topics, and as his personal experience has been worldwide and prolonged these are of interest to his professional colleagues as well-reasoned and balanced statements.

Thus, in his preface, the author writes that the basic problems that birds have had to face, those of reproducing themselves and of occupying and utilizing as fully as possible the space and the diverse habitats of the world, have been met in many ways and it is the diversity of these solutions that makes the study of birds as living organisms so endlessly fascinating. The book is arranged by topics into some two dozen chapters. To take but a few of these headings, we may mention the senses of birds; patterns of diversity; activity and rest; migration and hibernation; behavior, instinctive and learned; and the nature of species. This type of "breakdown" constitutes a new and welcome departure from the usual, prosaic type of textbook presentation.

The illustrations, by E. J. Pfiffner, are all black-and-white drawings with no attempt at a high degree of finish, but they are effective as visualizations of points made in the text. The book closes with five useful appendices containing information on such topics as classification and field-study techniques, a list of suggested reading, and the scientific names of all birds mentioned in the text. The book is adequately indexed, and should be a most useful as well as a reliable volume for the layman interested in knowing about birds, not just the birds in his immediate locality but birds in general.

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The Technological Awakening and Its Sources

Engineers of the Renaissance. BERTRAND GILLE. M.I.T. Press, Cambridge, Mass., 1966. 256 pp., illus. $12.

For all they may teach and inform, relatively few in the scholarly world produce books that carry their message with grace and style. But Bertrand Gille bears the burden of his extensive knowledge with deceptive lightness, conveying to the reader a history so well told that we unconsciously assume it to be already familiar. Considering that he provides us with an essential historical narrative, missing from the normal annals of civilization, this is a fine accomplishment indeed.

Engineers of the Renaissance deals to a large extent with the makers of the material environment—or rather the leaders of technological development—at a time when the Western world was undergoing enormous change. By an act of formidable original scholarship, Gille has transformed the primary material of this development—its artifacts (fortifications, bridges, houses, dikes, canals, and the like), its aspirations and its dreams (the drawings and diagrams of industrial machines, automata, and the mechanisms of war), and its rationale (the rare treatises, texts, and apologia, most of them in manuscript, of the nascent engineering professions)—into a historical narrative that gives us a balanced view of technological history. That assessment demonstrates the roots of the technological movement in the past, above all in the booming, expansionist atmosphere of the Hellenistic world. Its continuity through the succeeding medieval period is stressed, and though the new "awakening of technological thought" is revealed to be a 14th-century German phenomenon with considerable emphasis upon military technology (as revealed by such frequently imitated treatises as Konrad Kyeser's *Bellifortis*), the narrowness of the German school is also made clear. Limited by their concern mainly for military hardware, satisfied too soon with single solutions to engineering problems, their curiosity fixed by early success, the Germans were soon left behind by the Italians, whose daring and grace and boundless disposition to inquire brought them simultaneously to the pinnacle and the center of Renaissance technology, even as it did in the science of the period.

If the technicians of northern Europe emerged from a military matrix, those of Italy rose from a softer clime, with different ambitions and larger hopes. "They were true humanists," Gille tells us, "artists or scholars, who, beyond their particular problems . . . looked for general solutions . . . and the means for completely dominating the new world which was opening out. It was almost by accident that, as they proceeded, they encountered the military problems which were simultaneously engaging the attentions—but in this case almost to the exclusion of everything else—of their contemporaries north of the Alps" (p. 79).

The case for the Italians, and it is essentially one made for their imaginative fertility, is measurable in this general study of Renaissance engineering by a crude quantification. Of the ten chapters in the book, five are devoted to their accomplishments. In the course of his Italian tale, Gille also finally lays to rest the panegyric mythology of Leonardo da Vinci's alleged accomplishments in science and technology. If Leonardo's achievements are less than the obvious merit of the great drawings we have come to know, if originality is only an occasional ingredient in a welter of derivative ideas, there are a methodology and a conceptual aspiration that are truly his, and these Gille rescues and explains. In the problems of designing gears and of determining the elasticity of beams, in the studies of eddy currents, and in an occasional capacity to generalize (as is exhibited, for example, in his theory of water pumps) he showed remarkable powers, but even though he experimented from time to time he was not systematic or logical in his research. He "tried to define technical truths by the setbacks, mistakes, and catastrophes he experienced, just as doctors have acquired their knowledge of men through the expedients of their illnesses. . . . A scientist . . . would have been aware of the enormous gaps that existed and would have tried to build up a scientific whole. Leonardo was an engineer who was concerned only with efficiency and whose efforts brought him no more than a means of acquiring power over the material world" (p. 190).

In the last analysis, Gille shows us how the Renaissance engineers, for all the novelty of the world in which they lived, were bound by their own traditions. But though these may have led them into places which closed down upon them because the real stuff of the world would not respond to their theories, their aims nevertheless embraced the continuing technological