book is a greatly simplified system of nomenclature for the principal metamorphic facies. The complex system of subfacies found in Turner's earlier works is here abandoned with the recognition, following Miyashiro and others, that each sequence of facies, and possibly each facies, is unique. A facies can, in this view, be fully characterized only by the total array of mineral assemblages found in it. Under such circumstances the possibilities for subdivision are virtually endless, and this reviewer agrees with Turner that any useful generalized nomenclature must be a simple one.

The last three chapters of the book will perhaps be the most valuable part to most readers. They contain an updated summary of naturally occurring metamorphic facies as found in various parts of the world, followed in the last chapter by a discussion of the temperatures and pressures required for their development, and of their geologic setting both in time and space. Turner concludes here (and this reviewer agrees) that the ultimate source of the energy needed to produce metamorphism on a regional scale must be in the deep crust or upper mantle. In this view the granitic plutons characteristic of most metamorphic terranes are to be regarded as the ultimate end products of the metamorphic process rather than as its cause.

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Craniology

The Human Face. An Account of the Postnatal Growth and Development of the Craniofacial Skeleton. DONALD H. ENLOW. Illustrations by William L. Brudon. Harper and Row, New York, 1968. xvi + 304 pp., illus. $20.

In this interesting book the author sets out "to describe and illustrate a particular, fundamental mode of approach to the study of cranio-facial growth." This method, based extensively on the interpretation of variations of osseous histology, has been described previously by Enlow in some detail, and the present work is a compilation and an extension rather than a presentation of new concepts. Abundantly and clearly illustrated, the text provides a vivid description of the author's thoughts and deserves to be widely read by all students of craniology. Indeed, the clarity of the exposition tends to conceal certain hazards to those readers who have an empirical, clinical need to know but who may be less than firmly grounded in the totality of current craniofacial theory.

The decisive point of Enlow's argument derives from his definition of growth: "Overall enlargement in the size of any bone involves two basic processes: growth and remodeling. Growth itself represents the sum of actual increases in size," while remodeling is a process of "sequential, progressive adjustment that functions to maintain the shape and proportions of the bone. . . ." The text specifically states that combinations of osseous deposition and resorption are the only processes involved in growth according to this restrictive definition. The author goes on to establish a dichotomy between "displacement" and "growth." This is precisely the issue of criticism. Although Enlow acknowledges that "virtually all changes that a bone undergoes during growth are brought about by the various soft tissues associated with the core," it is evident that these same soft tissues are conceived of as operating only by means of their effect on osseous depositions and resorption. The thesis of this book is that changes in the size and shape of bones are brought about by the functional activity of soft tissues, but that changes in the spatial position ("displacement") of these same bones are only a secondary result of these same osseous processes. Other current theories of cranial growth present a more comprehensive definition of growth which includes not only changes in size and shape brought about by periosteal activity but also changes in spatial position. Further, these same theories emphasize that such "displacements" of bones occur passively, being brought about by the volumetric expansion of the functioning neural, orbital, oral, nasal, and pharyngeal spaces. When Enlow's description of direct, active periosteal transformations is added to the concepts of indirect, passive spatial displacements of these same bones, a unified and essentially correct picture of cranial growth is obtained.

Although the secondary, compensatory nature of sutural area growth is correctly recognized, as is the current devaluation of the concept of cranial "growth centers," there is still an equivocation in Enlow's account of the role of the cranial cartilages in facial growth. Admittedly this is a subject of active investigation and contention, but here again the "particular approach" of the author leads to a less than complete discussion of the available data.

This important book should be widely read. It is regrettable that it is not more comprehensive in its outlook. Recognition of its self-imposed limitations will do much to increase its usefulness as the clearest presentation to date of one half of the story of cranial growth.

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Refractory Materials

High-Temperature Materials and Technology. IVOR E. CAMPBELL and EDWIN M. SHERWOOD, Eds. Wiley, New York, 1967. xii + 1022 pp., illus. $27.50. Electrochemical Society Series.

Advances in important areas of technology such as power generation, aerospace propulsion, and materials production depend critically upon the behavior of materials at high temperatures. This book, a revision of the earlier *High-Temperature Technology* (Wiley, 1956), attempts to cover the properties, phenomena, and techniques characteristic of temperatures so high that many room-temperature solids would be molten, but below the point where only gases or gases and liquids remain (melting point of hafnium carbide, 4160°K; boiling point of tungsten, 6200°K). Beginning with a section on the fundamental thermodynamics and chemistry, the text proceeds to a series of chapters on the important classes of refractory materials, a series on various aspects of technique such as attainment of high temperatures, containment of hot matter, and fabrication, and a final series on measurement of temperature and of mechanical and other properties at high temperature.

The two editors have assembled 27 chapters prepared by two colleagues at Westinghouse, eleven at Battelle, and other contributors at the Air Force Materials Laboratory (three), General Electric (three), five universities, and eight other corporations. The book must be viewed as a committee product, in the knowledge that systems designed by committees are sometimes deficient in virtue. The consequent catechism elicits moderately favorable responses: Is the content complete, accurate, and up-to-date? Reasonably so;

most chapters are very competent reviews, and in the nine chapter bibliographies sampled the latest dates were 1958, 1960 (three chapters), 1963, 1964 (two chapters), 1966, 1967. Did the editors adequately define and limit the field to be covered? Yes; the inclusion of fiber-glass-plastic composites, which might be questioned because these substances melt so readily, is justified by emphasis on their ablation properties. Did they subdivide logically, and avoid overlapping? Yes and no; the subdivision of the major sections (Chemistry, Materials, Methods, and Measurements) is reasonable, but overlapping and repetition between some chapters (for example, "High-temperature thermodynamics" and "High-temperature reactions," "Selection of materials," and "Oxide ceramics") is slightly annoying. Did they standardize in editorial matters such as form, units, and terminology? No; I found it particularly disconcerting to jump from °C to °F and back, or from cal/(sec cm²)(°C/cm) to "BTU/(hr/ft²)(°F/in)." Did they require definitions or references for esoteric terms? Not always; "Refrasil," which has at least two commercial meanings, went unexplained, and that old misnomer "quartz" for a type of vitreous silica went uncorrected. Were the bibliography and indexes well done? No; the duplication inherent in chapter-by-chapter bibliographies could surely be avoided in this day of clerical automation; the author index is undependable; and the subject index should be much improved for the uninitiated, to whom the book is addressed in the preface.

The editors disclaim the intention of providing a handbook, and state their judgment that further revision of the individual authors' contributions was not necessary or desirable. To argue that judgment might be unfair, but it is true that the lack of unification and the imperfect indexing make for a poor reference work. On the other hand, an individual chapter may thereby have more value when used textbook-fashion, to orient a stranger in the field or compensate for past neglect of the journals and the meetings. The editors deserve thanks for assembling a well-organized collection of reviews of the important aspects of high-temperature materials technology. Most workers in this field would find profit at some point in its reading.

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History of a Machine

American Locomotives. An Engineering History, 1830–1880. JOHN H. WHITE, JR. Johns Hopkins Press, Baltimore, 1968. xxiv + 504 pp., illus. $20.

The steam locomotive enjoyed an active life, in Europe and America, of 125 years: it appeared as a useful and reliable machine between 1825 and 1830; its manufacture in the United States ceased in 1949, and it disappeared from productive service in the following decade. Its development during this long period was remarkably stable, perhaps to a degree unparalleled for machines invented in the modern industrial period. All the essential elements persisted in form and in working relations throughout its history: firebox, boiler, smokebox, cylinders, driving and truck wheels, driving mechanism, and valve gear appeared in their fundamental character at the beginning and remained to the end. This orthogenetic evolution offers the historian a built-in conceptual and organizational scheme, but mechanical and thermodynamic complexities, as well as the scanty source material, have discouraged him from trying his hand.

White's impressive work takes off from the second level, so to speak, and makes few concessions to the uninitiated. He assumes an understanding of the basic processes, uses the technical vocabulary of locomotive design and operation, and offers little explanation of the more complex thermal and mechanical elements. His treatment is analytical to an extreme degree, not only in the care with which he examines the requirements, the solutions, their successes and failures, but also in his method of splitting the subject into its separate aspects, pursuing each one through its entire chronological development before turning to the next. The result is that the major components of the locomotive are exhaustively described with respect to their function, design, changing form, and operating relation to other working elements, the descriptions set forth in a series of parallel subdivisions. This approach makes it possible to organize a mass of details into a logical pattern, but it places a burden on the reader, who must try to keep an image of the whole machine in mind as he moves from firebox, boiler, and smokebox to driving wheels, trucks, running gear, suspension systems, and the like, until he finally reaches the tender. In this respect, of course, he is helped by the generous illustrative material, but nothing is quite so helpful as a previous knowledge of how locomotives look and how they operate.

American Locomotives is divided into three main parts followed by eight appendices, of which the last is a chronological table summarizing the history of rail motive power to 1875. Part 1, Era of Fundamental Locomotive Design, is introductory, concerned with the first British imports and the British background to American design, native builders, materials, performance characteristics (treatment of which is particularly valuable, being rare in books on the subject), and locomotive types classified according to the familiar system of wheel arrangement invented by Fredric Whyte. With respect to the last subdivision, it is surprising to learn that for nearly the first half of its active life the locomotive was restricted to only eight different types, of which three were truckless engines (0-4-0, 0-6-0, and 0-8-0), whereas its subsequent development revealed a wide-ranging adaptive radiation into an additional 16 reciprocating types, a figure that I have arrived at by placing all Mallet articulated locomotives (of which there are 12 wheel arrangements alone), the Pennsylvania Railroad's late oddities, Forney tank engines, and steam turbine forms in only four separate categories.

Part 2 of White's volume, designated simply as Components, is the heart of the work and reveals the author's unparalleled mastery of his subject. He examines in detail 41 major parts, described in separate sections running from 3 to 15 pages in length. These subdivisions are grouped into three broad categories respectively designated "Boilers and boiler accessories," "Running gears," and "Miscellaneous" (cowcatchers, headlights, bells, whistles, and other components not essential to the operation of the machine). Here the analytical method reaches its fullest development. For each component White begins with the initial invention, which he takes as the fundamental form or standard and which serves as the basis for the analysis of the mechanical or thermal problem, and continues with the variation on the standard, the mode of operation of each one, the successes and the failures, all presented with numerous concrete examples. He is particularly effective in analyzing failure and inadequate operation, as in the cases, for example, of feed-water pumps and steam pressure gages, which offered peculiar problems because of the con-