discuss critically criteria by which one decides in favor of or against a typological classification rather than a continuous solution is a serious omission.

Bailey's hope that the book will be used as a text in both undergraduate and graduate courses seems unlikely to be fulfilled. The book may be useful, though, in several respects. For a research investigator who has access to the BC TRY system, it provides helpful illustrations of the application of this computational package. Results from the study of social areas are intrinsically interesting, and also serve as a good example of the apparent power of Tryon's object clustering methods. Finally, for the many who were so fortunate as to know Robert Tryon as a teacher and friend, it is rewarding to be given access to this comprehensive survey of his methodological and substantive work on cluster analysis.

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Revolutionary Mechanician

Lazare Carnot, Savant. CHARLES COULSTON GILLISPIE. Princeton University Press, Princeton, N.J., 1971. xii, 360 pp., illus. $17.50.

The impetus behind much of the work done in mechanics during the 18th century was the prize competitions held by the scientific academies of Europe. One frequent but unsuccessful competitor toward the end of the century was the young French engineer Lazare Carnot. Carnot was never victorious in his quest for a prize, but he was eminently successful in prosecuting the wars of revolution for France. It is his part in the Revolution that has attracted previous biographers. A product of the engineering school at Mézières, he was elected to the National Assembly in 1791 and became one of the most important members of the powerful Committee of Public Safety, in which capacity he vigorously defended the Revolution through the Terror. He was the only member of the Committee to hold an important government position after the Terror, and he continued in the Directory until September 1797, thereby earning the distinction of having survived longer in office than any other Revolutionary statesman until Bonaparte. It was not Carnot's talent as a politician but his organizational skill that gave him such endurance. A tough-minded and eminently practical engineer, he made himself indispensable to the prosecution of the war and earned the well-deserved title of the "Organizer of Victory."

In this monograph Gillispie describes the little-known scientific part of Carnot's career and shows the relationship between his ideas in mechanics and those of his son Sadi Carnot, a founder of thermodynamics. Lazare Carnot also wrote on the logical foundations of the infinitesimal calculus, and this work is described in an essay by A. P. Youschkevitch joined to Gillispie's monograph.

Carnot's *Essai sur les machines en général* (1783) and his *Réflexions sur la métaphysique du calcul infinitésimal* (1797) grew from the earlier papers submitted to the scientific academies of Paris and Berlin for prize competitions, and the discovery by Gillispie and Youschkevitch of these essays in manuscript in the academy archives has made it possible for them to follow the development of Carnot's ideas through successive stages. Half of the book consists of appendices containing photographic reproductions of pertinent parts of these manuscript essays. The book therefore serves a double purpose. It supplies a missing dimension to the biography of an important Revolutionary figure. It also details a somewhat inconspicuous but very important part of the history of mechanics—the development of engineering mechanics in the late 18th and early 19th century.

The rapid growth of rational mechanics in the 18th century was in large part the accomplishment of French mathematicians. Carnot shared in this tradition, but as an engineer he directed his attention specifically to the operation of machines. His work was highly abstract, but, as the title of his first book indicates, it was "machines in general" that formed the subject of his mechanical investigations. He was therefore interested in the transmission of power and in improving the efficiency of machines. It is here that Gillispie sees the greatest affinity between Lazare Carnot and his son Sadi, whose famous *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance* (1824) also treated "machines in general" with a special application to heat engines.

Gillispie devotes a great deal of space to a technical description of Carnot's mechanics. It is not easy reading, even for one trained in mechanics, because Carnot approached the problems of mechanics with the assumption that the basic mechanical interaction in machines was the collision of perfectly hard parts. "Living force" (kinetic energy) would inevitably be lost in such an interaction unless it took place by "insensible degrees." This assumption of hard-body impact, and not any mathematical complexity, is what makes his writing seem foreign to a modern reader, and one might wish that Gillispie had explained more clearly the basic ideas in this tradition of hard-body impact. An example is Carnot's theory of "geometrical motions." Any motion, finite or infinitesimal, which is perpendicular to the direction of the force of impact does not transfer any momentum and is therefore "geometrical," since it does not influence the interaction between the parts. Gillispie sees in the notion of geometrical motions the first idea of reversible processes. The notion is therefore important, and yet his description is far from clear. What Gillispie does show very well is that the "Carnot approach" as exemplified by Lazare and Sadi was important in establishing the concept of work (a term first used in a scientific sense by Coriolis in 1829) and in the general development of engineering mechanics.

Carnot's studies in geometry and in the foundations of the calculus continued his characteristic treatment of elementary considerations from a novel point of view. In the *Géométrie de position* (1803) he attempted to extend the notion of geometrical motions to create a new science "the theory of which is the transition from geometry to mechanics." One is struck by the fact that Carnot, who eschewed rational mechanics and limited himself to the essentially practical theory of machines, also wished to pursue his researches in a highly abstract manner, even questioning the validity of such notions as negative numbers. His most popular work, the *Réflexions sur la métaphysique du calcul infinitésimal* (1797), was an attempt to lay a logical foundation for the calculus in the theory of compensating errors. In his excellent essay Youschkevitch describes the development of Carnot's ideas and places his work in the history of other criticisms of the calculus.

The authors have given us a new

picture of Carnot, an engineer deeply involved in the political events of his time, who nevertheless retained a constant and productive interest in mechanics and mathematics. The book is handsomely printed, and Gillispie closes it with a very useful bibliographical essay.

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Harvey as Inductivist

William Harvey and the Circulation of the Blood. GWENETH WHITTERIDGE. Macdonald, London, and Elsevier, New York, 1971. xvi, 270 pp. + plates. $12.75.

Historians of modern science have offered few instances of radically conflicting interpretation firmly based on sound research and developed through cogent argument. The case of Harvey now becomes a notable exception. In question is Harvey the discoverer and at issue, to state it bluntly, are facts versus ideas. Gweneth Whitteridge favors facts and discounts ideas. Her study presents a forceful, ample, and often persuasive portrayal of the English physiologist as a "rational, unemotional" Aristotelian and the quintessential empiricist. By means of meticulous exposition and occasional general discussion, she seeks principally to create a chronology of Harvey's physiological studies. Her purpose and achievement are, however, anything but a mere precise dating of research and discovery. She stalks bigger game, and thus nicely transforms an extremely valuable assessment of Harvey's debt to his predecessors (notably Realdus Columbus) and a record of his own masterly anatomical investigations into a stern but fascinating polemic against the philosophical school of Harvey interpretation.

Whitteridge denies the famous doctrine of circles or its advocates any innovative influence on Harvey's consideration of the circulation of the blood. That discovery in her account is rendered the product of indefatigable and imaginative observation and experiment. Harvey loses all semblance of speculative philosopher and, above all, Neoplatonic metaphysician and becomes physiology's preeminent inductivist, moving from more or less randomly accumulated evidence and preliminary hypothesis to later testing and confirmation, or rejection, of that hypothesis. Unfortunately, this hackneyed methodological sequence is of uncertain validity. It is also of dubious value in interpreting Harvey and raises some question, because of unsure terminology, regarding the true objective of Whitteridge's analysis.

The reader of *William Harvey and the Circulation of the Blood* will be uncertain whether its author really intends to relate the "history of a discovery" or whether she hopes, following Harvey's own words, "to confirm it by sense and experience" (p. xi). At issue is the ambiguous delimitation of "discovery" and "confirmation," the treasured innovation being, of course, Harvey's total view of the motion of the heart and circulation of the blood. Whitteridge's great knowledge of the available evidence lends credence to her claim that, for the present, the precise date of Harvey's discovery is unattainable. She also asserts (p. 111) that Harvey's vigorous collection of data by means of comparative anatomy, vivisection, and astute observation indeed bore fruit: "At some stage these observations ceased to be random." Yet this is not to resolve but to restate crucial questions. Why did his observations cease to be random? Had Harvey found his hypothesis? How had he done so? Or, as is not unlikely, had his investigations never really been "random"? Had he, even before his Lumleian lectures of 1616, a hypothesis by which to work? In either case, what are the terms of the hypothesis or hypotheses which entered Harvey's mind?

It is at this point that the philosophical and certainly more audacious interpreters of Harvey, preeminent among them being Walter Pagel (*William Harvey's Biological Ideas*, 1967), make their contribution. Acknowledging the paramount role of vivisection and comparison in the confirmation of Harvey's discovery, they focus on the act of discovery or, at the very least, the conceptual preoccupations informing it. Here are emphasized Harvey's various allusions to heart and hearth, solar influences and meteorological cycles, allusions which Whitteridge is willing to dismiss as after-the-fact appeals to authority. (In this alone, she believes, Harvey acted as a traditionalist.) Whitteridge implicitly accepts Harvey's presentation throughout *De motu cordis* as not only the obvious logical exposition of a new doctrine but a virtual record of a great discovery. This is a perilous assumption and one which probably necessitates an inductivist interpretation of Harvey's achievement.

Elsewhere Whitteridge offers an uncommonly useful chapter on Harvey's views on the physiological primacy of heart or blood (the former holding sway over the mature body but the latter, because of its qualities and action in embryological development, being the truest basis of life in general). In appendix 1 appears, for the first time since the 17th century and in both Latin and in English translation, the most complete extant version of Caspar Hofmann's letter to Harvey of 19 May 1636 setting forth a Galenist's objections to the new doctrine of the circulation of the blood.

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Boron Compounds

Carboranes. RUSSELL N. GRIMES. Academic Press, New York, 1970. xiv, 272 pp., illus. $14. Organometallic Chemistry series.

The term "carborane" refers to a relatively new family of organoboron compounds which may be thought of as boron hydrides or polyhedral borane anions in which one or more boron atoms have been replaced by carbon atoms. We therefore find very stable carboranes which have closed polyhedral structures and some degree of electron-delocalization stabilization and relatively reactive open-framework carboranes containing more hydrogen atoms than carbon and boron atoms. Those of the former series (termed *closo*) are amenable to electrophilic substitution reactions and derivative formation with a vast variety of organic functional groups. Those of the latter, generally more unstable, series (termed *nido*) are less amenable to derivative formation and sometimes serve as precursors to *closo*-carboranes. Finally, recent work has provided a third general class of carboranes in which the basic framework structure contains atoms other than carbon and boron. Examples of this type of structural modification are known in which elements of groups II, III, IV, V and the transition metals are incorporated as framework members. Thus, the car-