Book Reviews

Ballistics in the Seventeenth Century. A study in the relations of science and war with reference principally to England. A. R. Hall. New York: Cambridge Univ. Press, 1952. 186 pp. Illus. $4.00.

It is easy to see why the seventeenth century, the age of the revolution in thought that first shaped our modern tendencies in science, has a special interest for historians and scientists. To what extent the new science—more especially the new dynamics of Galileo, Huygens, and Newton—can be explained in terms of the social and economic forces of the time, and how far it resulted from the internal laws of scientific progress, are questions on which students of the period are sharply divided. There have been staunch adherents of both extreme positions. A. R. Hall, assistant lecturer in the history of science at Cambridge University, makes an important contribution to our understanding of this broader question by examining closely the special case of ballistical investigations during the sixteenth and seventeenth centuries.

At first glance the influence of military technology on early science seems undeniable. It is well known that it was for the ostensible purpose of determining the ideal trajectory of a projectile that Galileo made his studies of falling bodies, developed his theory of inertia, and overthrew the structure of Aristotelian dynamics. This example has been repeatedly cited to illustrate the influence of military problems upon science. But Dr. Hall makes it clear that we have no right to infer from this an intimate collaboration between scientist and technologist; still less an immediate application of these discoveries to the useful arts. Although he would probably be the last to deny the interest of the seventeenth-century scientist in the world of practical affairs, yet he strongly insists that "men were led to discoveries in mechanics less by their practical usefulness than by the logic of historical development." The seventeenth-century contributions to ballistical science grew gradually out of the earlier tradition of scholastic speculations on motion, as modified by the impetus theory of the later Middle Ages and by the work of sixteenth-century theorists like Tartaglia. As we follow the progress of ballistical studies from Galileo through the time of Huygens and Newton, Hall demonstrates with great persuasiveness that the immediate purpose of these studies was scientific and mathematical; and that the results, since they assumed ideal conditions not encountered in nature, were not applicable to the needs of the practical artillerist. His examination of the manuals intended for the guidance of the soldier shows that, when they were not merely practical handbooks, they clung to the obsolete doctrines of the later scholastic physics long after the new dynamics had been universally accepted by men of science. No serious attempt to popularize the new parabolic ballistics was made until the last third of the century.

Dr. Hall has provided a useful corrective to some of our current notions by stressing the *de facto* independence of dynamical science from the fields of military technology and invention. But our author does less than justice to the ideology of utility that prevailed in the seventeenth century. The failure of the "new experimental learning" to find useful applications in this and that field of technology does not in itself justify treating its spokesmen as mere propagandists indulging in wishful thinking when they stress its social utility. Apart from the question whether men like Tartaglia and Galileo believed—as Hall's own evidence showed that they did—that they were making important contributions to the art of war, the fact remains that *immediate* utility and application were not what the apologists of the new learning habitually stressed. The new learning was defended as useful knowledge, first and foremost because it was the *kind* of knowledge that could be applied to the real world. Unlike scholastic natural philosophy, with which they were constantly comparing it, its concepts and theories were rooted in experience, and capable of verification by quantitative experiment. From Bacon onwards, with a vision and perception we can but admire, the apologists of this early modern science stressed not its immediate application to useful ends, but its eventual and long-term applicability. Bacon repeatedly warned against the "overhasty and unseasonable eagerness to practice" in the pursuit of this new approach to nature. This ideological position, carefully stated by the defenders of the Royal Society—we may perhaps describe it as the doctrine of the presumptive utility of abstract science—served to clothe even the most technical and abstract investigations with a mantle of social respectability.

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Origins of American Scientists. A study made under the direction of a faculty committee of Wesleyan University. R. H. Knapp and H. B. Goodrich. Chicago: Univ. Chicago Press, 1952. (For Wesleyan University.) 450 pp. $7.50.

A brief article in SCIENCE (113, 543 [1951]) has already acquainted its readers with one of the principal findings of this study: the tremendous differences in the percentage of male graduates of different colleges who later become scientists. From 1924 through 1934, the period which Knapp and Goodrich studied most intensively, the leading college in the United States was Reed College in Portland, Ore., which sent 13% of its male graduates on to scientific careers and later listing in *American Men of Science* with Ph.D. degrees, stars, or both. California Institute of Technology was next, with 7%. Then the list went down, through the University of Chicago, which was 16th with 4%, Rochester in 38th place with 3, and on down through a total of 489 institutions, some of which had none of their graduates included in *American Men of Science.*

Origins of American Scientists is a study of the factors associated with or responsible for the great differences in productivity. Geography was important; the Midwest and Far West did better than other parts of the country. Size and character of the institutions were also important; the percentage of male graduates who become scientists was higher for liberal arts colleges than for universities and was greatest for colleges which graduate from 40 to 150 men a year. Institutions of relatively high and those of relatively low cost were less productive of scientists than were those of intermediate cost. Catholic institutions, engineering colleges, colleges in which fraternities are strong and influential, and "big name" institutions were more or less unproductive of future scientists.

In an effort to explain these and similar findings, detailed statistical analyses were made of student-teacher ratios, library facilities, and a number of other items of information; questionnaires were sent to former graduates; and Knapp spent a year in visiting a selected list of 22 colleges.

The intellectual quality of the student body helped to explain some of the differences; schools that admit freshmen who average high on aptitude tests turned out more graduates who became scientists than did other schools, but still the geographic and other differences remained. A background of middle-class, Protestant, agrarian or semiagrarian, frontier pragmatism seemed to provide a particularly congenial atmosphere for the development of scientific interests. Students from such backgrounds are particularly likely to be found in the West and in the 1924–34 period were most likely to attend nearby institutions. Those who entered schools that had become rather secularized from the strict Protestantism of their earlier years became scientists in somewhat larger numbers than did those who entered other types of colleges. So did those who attended colleges that offered a liberal education—as distinct from colleges with a more pronounced vocational emphasis. In contrast, the famous and the high-cost institutions turned out fewer scientists, partly because the students who were able to afford their higher costs were more likely to enter fields that promised greater financial rewards than a scientist can expect. A later study (see following review) indicates that the cost aspect has been greatly changed since the end of World War II.

One of the most interesting portions of the book describes the teacher and the academic standards that favor the development of scientific interests. The successful teacher is not distinguished by his intellectual competence—above, of course, some necessary minimum—or by his professional eminence, or his mastery of particular pedagogic methods, but rather by the possession of two important personal qualities: "the first seemingly related to masterfulness, demandingness, vitality, and energy; the second, to human warmth and social accessibility." The authors summarize these traits by pointing out that this description fits what in psychological jargon could be called a strong father figure. Between the student and the teacher who inspires him there exists more than a purely intellectual relationship; the inspiring teacher is admired, he exercises some coercion over his students, but he is also an understanding confidant and a source of rewards for work well done. Interesting confirmation of this picture came from analyses of undergraduate departments which had started a fairly high number of students along the road to scientific careers. Relatively severe requirements for the major and relatively severe grading standards, on the one hand, and a relatively keen sense of social cohesion within the department, on the other, were all associated with high productivity. The teacher, and his department, are likely to inspire students to become scientists if the standards are high enough to weed out the poor prospects, and if, after that is done, there is a friendly and rewarding acceptance of those who show promise.

For teachers who take pleasure in starting young scientists on their careers and for educational administrators who are interested in an analysis of how academic standards, practices, and atmospheres influence students, there is much of thought-provoking interest in this book. As a more casual reason for wanting to read *Origins of American Scientists,* it includes a fascinating amount of detailed statistics on hundreds of famous and not so famous American colleges and universities.

The Younger American Scholar: His Collegiate Origins. Robert H. Knapp and Joseph J. Greenbaum. Chicago: Univ. Chicago Press; London: Cambridge Univ. Press, 1953. (For Wesleyan University.) 122 pp. Illus. $3.00.

This study differed in two major ways from the work described in *Origins of American Scientists*: the time period was more recent—since the end of World War II—and the subjects investigated were young scholars of promise instead of the mature scientists who constituted the population of the earlier book. "Young scholars of promise" are men and women who received their bachelor's degrees since 1946 and who have since received their doctor's degrees or have been given important graduate fellowships or scholarships by universities, private foundations, or the federal government.

The two studies are similar in that both sought information on the undergraduate institutions that have been most productive of students who have gone on to work for the doctor's degree. The institutions which, since 1946, have turned out a high proportion of students who have gone on to graduate work in the sciences differ considerably from those which had the highest productivity indexes twenty to thirty years ago. The top 20 institutions of the recent period include 7 that were among the top 20 in the earlier period and 13 that have come up from somewhat lower ranks. More important than the changes in relative position of individual institutions are the changes in characteristics of the institutions that are most productive. Since 1946, liberal arts colleges, universities, and technological institutes of comparatively high cost have trained relatively more students who continued into graduate work in the sciences than have those of lesser cost. Twenty to thirty years ago schools of moderate cost were more productive than either the cheapest or the most expensive ones. Since 1946 schools in New England and the East North Central region have been the most productive ones. In the earlier period those in the Middle West and Far West were the most productive. A feature which stands out as characteristically in the recent period as it did earlier is the higher productivity of private nondenominational colleges and universities over public and denominationally controlled ones.

The GI Bill, the establishment of much broader scholarship programs by some of the older and wealthier (and incidentally Eastern and more expensive) institutions, and the higher general income level, the authors suggest, have probably been responsible for the shift in the center of gravity from Midwestern and Western institutions of moderate cost to Eastern institutions of higher cost.

Unlike the earlier book, this one also considers the undergraduate origins of young scholars in the humanities and social sciences. In general, the trends in these two areas are similar to those that have been mentioned for science students. Inclusion of information on all three areas, however, permits some interesting comparisons. Some of the schools which are most productive of future scientists also rank high in the undergraduate preparation of future social scientists and humanists. In fact, there are 8 institutions that rank among the top 20 in productivity in all three areas: Swarthmore, Reed, Chicago, Harvard, Oberlin, Antioch, Carleton, and Princeton.

One of the most challenging problems posed by the findings of this study is the relatively small number of undergraduate institutions which send significant numbers of their students into graduate work in the scientific and scholarly fields. Writing of the young natural scientists, Knapp and Greenbaum report that only some 60 institutions show "significant and impressive rates of production, while among the remainder the dedicated young scholar is a rare exception among their graduates." Students who have gained distinction in graduate work in the social sciences come from a somewhat smaller undergraduate base, and those in the humanities from a still smaller base and one that is sharply concentrated in the northeastern section of the country. It is good that there are institutions which stand out well above the level of intellectual stimulation of the average American college, but how far is it desirable to concentrate the source of graduate students in a small number of undergraduate institutions and to have those as geographically concentrated as has been the case since 1946?

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Astronomy

The Expansion of the Universe. Paul Couderc; trans. by J. B. Sidgwick. New York: Macmillan, 1952. 231 pp. + plates. $6.00.

This highly readable book gives both the professional astronomer and the interested layman an account of the various data which led to the conception of an expanding universe. The book was awarded the Paul Pelliot Prize and the Henri de Parville Prize of the Académie des Sciences in 1950 and is excellently translated by J. B. Sidgwick.

After three introductory chapters dealing, respectively, with the observational data of our universe, the measurement of astronomical distances, and the distances and recession of galaxies, the author discusses in Chapter 4 the non-Euclidean space-time of general relativity. In Chapter 5 he treats the cosmological problem, in Chapter 6 the static universe of Einstein and the pseudo-static universe of de Sitter, and in Chapter 7 the expanding universe. Chapter 8 is devoted to a discussion of indications of a singular state of affairs about 4–5 billion years ago.

The book is very well written and can be read with profit by the interested layman—provided he is willing to read thinkingly—and it can be highly recommended.

There are a few minor points where, in my opinion, the book could be improved. The source of none of the excellent photos of galaxies is given. The Hertzsprung-Russell diagram is referred to as the Russell diagram (p. 39). The light deflection during an eclipse is *not* in accordance with the present predictions of general relativity and can scarcely be taken as a support for the theory of general relativity (p. 120).

Couderc goes to great length to prove that Lemaître's model fits the observational data, and he presents a strong case in favor of this. It is therefore to be regretted that the way in which he attacks other explanations is so often unnecessarily pugnacious, and even sometimes slightly malicious. This is the more surprising as Couderc mentions Omer's results of calculations regarding a nonhomogeneous model of the universe. From Omer's calculations one sees that the introduction of even a slight inhomogeneity can alter various results very considerably, and it seems to me that one must be extremely careful in adhering too rigidly to results obtained from a homogeneous model.

The case for the existence of a hyperdense state of the universe about 4 billion years ago has, to my mind, not been made. I agree immediately that all the evidence of Couderc's Chapter 8 points to a short time