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Twentieth-Century Classic Books and Benchmark Publications in Biology

GARY W. BARRETT AND KAREN E. MABRY

There is a rich body of scientific books and articles that have contributed to the education and training of biologists during the past century. Academics and other contributors to science journals have attempted—with mixed success—to identify the works that have enhanced the understanding and enjoyment of students majoring in biology throughout their undergraduate academic training. Efforts to classify publications in terms of their value to biology students and the public at large have been hindered by the lack of input from those who actually read and use the materials, as well as by the sometimes subjective views of the authors who compile such lists.

For example, in 1988 J. L. Carter and W. V. Mayer published an article in *BioScience* entitled "Reading beyond the Textbook: Great Books of Biology," which highlighted books that students majoring in biology should be encouraged to read. However, the sample size used to compile their list was limited, and there was no attempt to sample biologists in a comprehensive manner. Almost a decade later, R. L. DiSilvestro's (1997) article, "Books to Remember: A Look at a Few of the Twentieth Century's Classic Mainstream Biology Texts," catalogued his personal list of recommendations, but it too lacked input from the AIBS membership. Then, in 1999, *Scientific American* published an article by Philip and Phyllis Morrison, "100 or So Books that Shaped a Century of Science," based on input handed down over time from readers, reviewers, and the editorial staff at the magazine. They attempted to round out this legacy of about 80 titles to provide readers with a compilation of 100 books that had had an impact on scientific discovery and understanding in all branches of science during the past century. This was a step in the right direction, but the Morrisons' effort also was based on a small sample; moreover, their article did not focus on the books that were noted for having the greatest impact on career training or publications in professional journals that had most profoundly guided the careers of scientists from diverse fields within the biological sciences.

In an attempt to quantify the impact and influence of these publications on career training, we surveyed the AIBS membership (N = 4137) during the second half of 1999. Each of the 191 respondents was asked to list the three books and three articles that had the greatest influence on their careers.

Classic books

Based on membership data provided by Burk & Associates for the year 2000, about 87% of AIBS members identify biology, botany, or zoology as their major interest. Further, 70% of them identify themselves with the following fields of interest: ecology (27%, 1832 members); evolution (12%, 816 members); physiology (9%, 568 members); systematics (8%, 506 members); conservation (8%, 505 members); and genetics (6%, 390 members). A majority of the 70 affiliate member societies also focus mainly on organismal biology and ecological science. Thus, as expected, the selected classic books and benchmark publications reflected these interests. If another federation type of organization, such as the Federation of American Societies for Experimental Biology, had conducted a similar survey, the results probably would have shown a greater frequency of listings of classic books and publications in the fields of biomedical, molecular, or cellular biology. It should also be noted that 71% of the respondents were over 50 years old; this probably influenced the results, since these were the books and scientific publications that were published and discussed during their graduate studies or postdoctoral training period.

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Table 1. Top books that biologists consider to have made the greatest impact on their career training, arranged in rank order according to the number of times each was listed.

	Author	Title	Date of first publication	Number of listings
1.	Eugene P. Odum	*Fundamentals of Ecology*	1953	23
2.	Rachel Carson	*Silent Spring*	1962	22
3.	Charles Darwin	*On the Origin of Species*	1859	19
4.	Aldo Leopold	*A Sand County Almanac*	1949	16
5.	James D. Watson	*The Double Helix*	1968	10
6.	G. Ledyard Stebbins	*Variation and Evolution in Plants*	1950	9
7.	Robert H. MacArthur and Edward O. Wilson	*The Theory of Island Biogeography*	1967	8
8.	Richard Dawkins	*The Selfish Gene*	1976	7
9.	Charles S. Elton	*Animal Ecology*	1927	6
10.	Ernst Mayr	*Systematics and the Origin of Species*	1942	6
11.	John L. Harper	*Population Biology of Plants*	1977	6
12.	Edward O. Wilson	*Sociobiology*	1975	5
13.	George G. Simpson	*Tempo and Mode in Evolution*	1944	4
14.	Herbert G. Andrewartha and L. Charles Birch	*The Distribution and Abundance of Animals*	1954	4

Note: Full publication information is in "References cited."

Table 1 lists in rank order the books considered most significant by participants with respect to their impact on career training. Only books receiving four or more votes are included in this tabular summary. Clearly, the works listed in Table 1 have withstood the test of time in terms of their recognized excellence, literary value, impact on career training, and contributing to the protection and maintenance of a quality environment.

Three of the four most frequently mentioned books deal with ecology and the need to protect or preserve our natural wealth in keeping with a holistic, ecosystem-based philosophy. These books also represent the emergence of ecology and conservation biology during the second half of the 20th century. For example, books such as *A Sand County Almanac* (Leopold 1949), *Fundamentals of Ecology* (Odum 1953), and *Silent Spring* (Carson 1962) provided, respectively, the foundation for a land ethic and proper stewardship of the natural environment, an ecosystem-based textbook for students, and a book that awakened citizens to the harmful effects of pesticide (especially DDT) contamination. Each helped to set the stage for—and indeed became part of—the environmental movement of the 1960s and 1970s.

Books such as *On the Origin of Species* (Darwin 1859), *Systematics and the Origin of Species* (Mayr 1942), *Tempo and Mode in Evolution* (Simpson 1944), and *Variation and Evolution in Plants* (Stebbins 1950) provided the basis for and a deeper understanding of evolutionary biology, including a demonstration of how natural selection provides the framework for understanding the distribution and abundance of plants and animals. Ernst Mayr's *Animal Species and Evolution* (1963) and *Growth of Biological Thought* (1982) also received three votes each. Indeed, several books that were selected as classics, such as *Animal Ecology* (Elton 1927), *The Distribution and Abundance of Animals* (Andrewartha and Birch 1954), and *Population Biology of Plants* (Harper 1977), built upon this earlier knowledge of natural selection, thus providing a richer understanding of species abundance and their distribution on a global basis. Classic books in the fields of molecular and cellular biology included *The Double Helix* (Watson 1968) and *The Selfish Gene* (Dawkins 1976), which described the exact mechanisms of natural selection—an understanding that led to an explosion of research in fields such as population genetics and biotechnology. Finally, E. O. Wilson's *Sociobiology* (1975) began to integrate humankind with the natural world, thus providing a biological basis for the study of social behavior. It is notable that although only one of Wilson's books ranked on the most frequently cited list (Table 1), he is the author of the greatest number of books (six) that were cited in the survey. These included *Biodiversity* (1988), *The Diversity of Life* (1992), *Naturalist* (1995), *Biodiversity II* (with M. L. Reaka-Kudla and D. E. Wilson, 1997), and *Consilience* (1998). It is interesting to note that two books—*On Human Nature* (Wilson 1978) and *The Ants* (Hölldobler and Wilson 1990)—that received the Pulitzer Prize for general nonfiction in 1979 and 1991, respectively, were not mentioned. Clearly, Wilson has had a significant impact during the past several decades on citizens with respect to generating their interest in and understanding of biology and natural history.

Table 2. Top journal articles that biologists considered to have had the greatest impact with respect to their career training, listed in rank order according to the number of times each citation was listed.

	Author	Title	Date of publication	Number of listings
1.	Garrett Hardin	The tragedy of the commons	1968	12
2.	Eugene P. Odum	The strategy of ecosystem development	1969	9
3.	Raymond L. Lindeman	The trophic–dynamic aspect of ecology	1942	8
4.	G. Evelyn Hutchinson	Homage to Santa Rosalia, or why are there so many kinds of animals?	1959	7
5.	James D. Watson and Francis H. C. Crick	Molecular structure of nucleic acids: A structure for deoxyribonucleic acid	1953	6
6.	Lynn White	The historical roots of our ecologic crisis	1967	5
7.	Nelson G. Hairston, Frederick E. Smith, and Lawrence B. Slobodkin	Community structure, population control, and competition	1960	4
8.	Henry A. Gleason	The individualistic concept of the plant association	1926	3
9.	Robert H. MacArthur	Fluctuations of animal populations, and a measure of community stability	1955	3
10.	Ramon Margalef	On certain unifying principles in ecology	1963	3
11.	J. Philip Grime	Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory	1977	3

Note: Full publication information is in "References cited."

Benchmark scientific publications

The request on the survey to list three scientific publications that each respondent felt had had the greatest impact on his or her professional career elicited mixed responses. Comments from the respondents ranged from "Too many to attempt to list" to "Although I could easily select scientists whose publications have influenced me, it was very difficult to decide which papers best represented their work." Indeed, nearly 50 questionnaires left this item blank, probably because of respondents' difficulty in identifying a favorite author's most significant or influential work. However, responses to the questionnaires made clear that a select group of articles, published primarily in *Science, American Naturalist, Ecology,* and *Nature,* have influenced scientific thought and career training over the past century. Table 2 provides a summary of these articles; only those cited three or more times are listed.

Most of the articles listed in Table 2 represent major scientific breakthroughs or paradigm shifts in scientific thought. For example, as was the case with classic books, several articles in the 1960s, such as "The Tragedy of the Commons" (Hardin 1968) and "The Historical Roots of Our Ecologic Crisis" (White 1967), helped to set the stage for the environmental movement by questioning the role of public impact and religious beliefs on environmental degradation. The science of ecology came of age during the latter half of the 20th century; Lindeman's 1942 paper, "The Trophic–Dynamic Aspect of Ecology," not only set the stage for both Odum's classic text noted earlier but also provided a functional (energetic) basis for this emerging science. One must remember that the term *ecosystem* was not defined until Tansley did so in 1935. Consequently, several works focused on this new functional, rather than descriptive, approach to the study of the natural world.

Another example of research development is the classic paper by H. A. Gleason (1926) that provided an explanation of plant community composition and ecological succession based on the individualistic concept. E. P. Odum expanded this understanding of plant ecology by providing an ecosystem (energy-based) explanation of succession which he termed *ecosystem development* (Odum 1969). J. P. Grime (1977) outlined three more strategies to further explain community dynamics in terms of both evolutionary biology and systems' theory.

Likewise, earlier works such as G. E. Hutchinson's benchmark article, "Homage to Santa Rosalia" (1959), questioned why there are so many kinds of animals. Topics such as population control and community stability had their origin in the classic articles of Robert MacArthur (1955) and Hairston and colleagues (1960). Ramon Margalef (1963), among others, attempted to integrate these concepts into unifying principles of ecology.

Molecular biology also matured during the past half-century. Perhaps no other article played a greater role in this emergence than Watson and Crick's (1953) "Molecular Structure of Nucleic Acids: A Structure for Deoxyribonucleic Acid," published in *Nature.* This benchmark article led to revolutionary changes in fields such as Mendelian genetics, developmental biology, evolutionary biology, and biotechnology,

among others. Unfortunately, the emergence of ecology and molecular biology during the 1950s and 1960s tended to split biology into two camps frequently referred to as "holistic" science and "reductionist" science. A major challenge of the 21st century will be to integrate the biological and ecological sciences into a new field of investigation and understanding frequently referred to as *integrative science* (Barrett and Odum 1998, Barrett 2001).

Conclusions

We recognize that these lists of classic books and scientific publications are not exhaustive, and it is not our intent to detract from the significant influence that omitted works have had on contemporary biologists. We trust that these listings will enhance interest, reading, and understanding among undergraduate and graduate students majoring in the biological sciences, as well as nurture a better informed citizenry. Indeed, these publications have influenced scientific thought, resource policy and legislation, medical and applied science, and our understanding of systems (cells, organisms, ecosystems, and global-level systems), resulting in a higher standard of living, an improvement of the natural environment, and an expanded practice of preventative medicine for society as a whole. Equally important, these scholars have provided an infrastructure for even more scientific breakthroughs during the 21st century.

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Further Thoughts on Classic Books and Benchmark Publications in Biology

For a historian of biology, the list of classic books and benchmark publications generated by Barrett and Mabry's questionnaire is so striking that it deserves further comment. What is noteworthy is not just what is included but what is not included; moreover, several works are given a ranking that is inconsistent with our understanding of the recent history of biology. Since many of the books on the list reveal a commitment to evolutionary biology or to organismal biology in its many incarnations, one would have expected to see Theodosius Dobzhansky's *Genetics and the Origin of Species* (1937) ranked high on the list, or at least to make an appearance somewhere on it. This is the book that historians generally regard as the single most influential book on 20th-century evolutionary biology. Its absence is noteworthy, especially because it fueled the books by Stebbins, Mayr, and Simpson, which do make the list. That Stebbins's book ranked sixth is noteworthy too, given that animals generally eclipse plants in popularity. The prominent position of Stebbins in the classic book list, combined with the inclusion of Harper's *Population Biology of Plants* in the number 11 position on the list—and the strong presence of plant ecology generally—suggests that the respondents were well represented by plant population biologists.

Other books that are absent are James Watson's classic *Molecular Biology of the Gene* (1965); the textbook of comparative animal physiology by Knut Schmidt-Nielsen, *Animal Physiology* (1960); and Richard C. Lewontin's *The Genetic Basis of Evolutionary Change* (1974), which many consider the updated version of Dobzhansky's 1937 book. Given the absence of genetics, molecular biology (not counting the personal account of *The Double Helix*), and physiology, the list is not representative of biology generally; it does, however, represent the interests of the respondents. It is instructive here to evoke Ernst Mayr's most useful distinction, to which Barrett and Mabry allude, between the proximate and ultimate halves of biology to explain the selections (Mayr 1961). Proximate causes generally seek to answer the "how" questions in biology, whereas ultimate causes generally answer the "why" questions. The list heavily represents those biological sciences that seek ultimate causes, sciences like evolutionary biology, rather than those that seek proximate causes, like most of genetics, physiology, and molecular biology. The membership breakdown discussed by Barrett and Mabry shows that AIBS is heavily dominated by the "ultimate" half of biology.

It is also striking that not a single general textbook of biology is included—that is, books that were intentionally written for instructive purposes to serve the interests of general biology. Considering the age cohort represented by the respondents, one might have expected to see *Life: An Introduction to Biology* (1957), by G. G. Simpson, Colin S. Pittendrigh, and Lewis H. Tiffany. The widely adopted high school biology textbook series known as the BSCS (Biological Sciences Curriculum Study) series and William Keeton's (1967) widely used textbook of introductory biology at the college and university level would also have shaped the careers of biologists. A considerable number of biologists would not have entered the field without the BSCS series in the 1960s and 1970s (Mayer 1986). The absence of any general biology textbook may be attributable to the fact that general biology textbooks are not generally thought of as "shaping careers" in provocative ways, although they of course do so by transmitting the received wisdom of the field. Moreover, because the Keeton and BSCS textbooks were adopted only in the 1960s and 1970s, the respondents' age cohort may not have used them during their education.

What is represented accurately for the whole of biology (or all biologists and scientists generally) is the fact that biologists recognize that different kinds of books shape their careers. Thus we find some books, such as textbooks that organize new fields (Odum's *Fundamentals of Ecology*, for example) that are expected, but also personal or autobiographical accounts like Watson's *The Double Helix* that capture the thrill of scientific discovery, and works that are even classed as literary or inspirational accounts, such as Leopold's *A Sand County Almanac*. Then there are books that define an entire generation, like Rachel Carson's *Silent Spring*. Following the heady optimism of the atomic age, *Silent Spring* forced people to rethink science and technology, effectively putting the brakes on the unbridled, irresponsible use of both. Then, too, there are books on the list that influenced people not necessarily because of technical accuracy, but because they served as provocative or stimulating syntheses. These include Wilson's *Sociobiology* and Dawkins's *The Selfish Gene*. Given the inclusion of some of these, one might have also expected to see Paul Ehrlich's most provocative wake-up call, *The Population Bomb* (1968).

Also noteworthy is that there are no books or articles published after 1977. This is not surprising, however, given that the respondents selected books that shaped their careers, and for that age cohort, career-shaping works probably were read before the mid-1970s. Few respondents, probably, changed their outlook after this formative period.

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