NATIONAL ACADEMY OF SCIENCES

JOHN ALEXANDER MOORE
1915–2002

A Biographical Memoir by
BRUCE ALBERTS

Biographical Memoir

John A. Moore

JOHN ALEXANDER MOORE

June 27, 1915–May 26, 2002

BY BRUCE ALBERTS

FOR A PERSON WHO WOULD become a leading scientist, John Alexander Moore had a very unusual upbringing. Born on June 27, 1915, in Charles Town, West Virginia, he was raised by a devoted mother, twice married and divorced, who had few resources and no college education. John describes Markham, Virginia, where he lived through his first two years in high school, as "so small you wouldn't even call it a village." Everyone in the town—in a depressed rural area of northern Virginia about 70 miles southwest of Washington, D.C.—was poor. He was taught in a one-room schoolhouse until he became old enough to commute to the small town of Hume for high school. Early on, he developed his lifelong interest in collecting and classifying animals. An early accomplishment, fondly recalled by John, was his successfully stuffing a squirrel, for which he was awarded a certificate by a correspondence taxidermy school. Surrounded by nature and with very little in the way of other distractions, He became especially fascinated by birds. His first publication, at age 15, is a very brief note reporting that he had "secured a Short-eared Owl (*Asio flammeus*), which had been wounded and caught at Markham, Virginia."[1] How John managed to connect to a scientific journal is not known. But in his teens he boasted to a professor whom he needed to impress that he was "probably the world's authority on the birds of West Virginia," an incident John recalled later with considerable embarrassment. (Unless otherwise noted, quotes are derived from a 1998 oral interview.)[2]

John's educational opportunities were vastly expanded after his mother moved to New York City seeking employment. He spent his senior year of high school in the Hell's Kitchen region of Manhattan. During that time, he became a volunteer at the American Museum of Natural History, where he helped to compile specimen lists and references for a book on North American hawks and owls. More than a decade later, in 1942, he would become a lifelong research associate for that museum.

John's unique knowledge of birds must have made a strong impression during his college interview, likely explaining why he was accepted as an undergraduate at Columbia University, despite what he claimed to be his "very, very poor" academic preparation. Thus, for example, he said that in applying to college, "I didn't know whether Beethoven was a fruit or a person, or what."

With broad intellectual interests and a profound gift for making sense of complexity, John prospered at Columbia, where he would remain for 37 years. Columbia had long had the most outstanding Department of Zoology in the nation. The distinguished scholar Edmund Beacher Wilson, author of the monumental *The Cell in Development and Heredity* (3rd ed., 1925), served as the founding department chair in the late 19th century, and the chromosome theory of heredity was developed there by T. H. Morgan and associates between 1910 and 1928. In John's words,

> In a sense, modern biology began there. There were two outstanding scholars: one was E. B. Wilson, he was a cytologist; and the other was Thomas Hunt Morgan, the geneticist. …(And) that combination of cell biology and genetics, which is the basis of modern biology—it all started there. It was fascinating

and very exciting. …The people who were our teachers, at least the dominant ones, had been students of Morgan and Wilson in the teens.

John quickly befriended several graduate students and professors in Columbia's Department of Zoology, prospering in the intensely intellectual environment. Among the leading biologists he interacted with there were National Academy of Sciences members E. B. Wilson, Th. Dobzhansky, and L. C. Dunn.

John would graduate from Columbia College in 1936 and receive his Ph.D. from Columbia University in 1940. The direction for most of his future research was set in his second college year, when he obtained a job as a dishwasher in the laboratory of Professor Lester Barth, an embryologist. He included John in a field trip collecting salamanders and frogs, and John became entranced with the subject, choosing to remain with Barth for his Ph.D.

John published nine papers during his time as an undergraduate and graduate student at Columbia. Most of these publications were studies of the embryonic development of frogs, with John as the sole author. One was coauthored with a fellow student, Betty Clark, who entered graduate school at Columbia in the fall of 1936 after graduating from Radcliffe. John and Betty married in 1938, and their daughter Sally (now Sally Moore Gall) was born in 1941. Betty Clark Moore would also earn her Ph.D. in Barth's laboratory, and she and John remained close partners for 64 years—until his death in 2002.

By a long-standing tradition, graduate students enjoyed nearly complete independence in the zoology department. In discussing his memories of a fellow student in Barth's lab, John wrote that "Both of us were being 'supervised' by Lester Barth, but that wonderful person left us alone but always supported us if there was a need to do so."[3] Perhaps for this reason, Barth never appeared as a coauthor on the research that John published as a student—a tradition that would continue when John's own Ph.D. students published their research results.

Even before he completed his degree, John was offered a position at Brooklyn College, serving as a tutor in biology there for two years beginning in 1939. After a further two years as an instructor of biology at Queens College, John moved to Barnard College, the women's division of Columbia University. At Barnard he quickly moved through the assistant- and associate-professor ranks, becoming a full professor in 1950. John's leadership skills were quickly recognized, and in 1949 (at age 34), he was appointed chair of the prestigious Department of Zoology at Columbia, from which he had received his Ph.D. degree only nine years earlier. John did not enjoy chairing that "very contentious" department, which "consisted of a bevy of birds of paradise that could hardly stand each other." To terminate this unpleasant period in his career, where "keeping all these birds of paradise happy…stunted my growth," he arranged for a yearlong sabbatical as a Fulbright research scholar in Sydney, Australia (1952-1953). Relieved of administrative duties, John and Betty spent a very happy and productive year in Australia, engaging in extensive fieldwork, describing new frog species, and greatly stimulating their type of science in that region, as eventually summarized in a highly influential 338-page monograph (1961).

Although John's chairmanship lasted for only three years, he would remain as a professor at Columbia until 1968. Enthralled by the important issue of how separate biological species arise during evolution, his research focused on the mechanism of speciation in frogs, which provided one of the most accessible systems for studying the general issue. As a developmental biologist skilled in experimental embryology, he carried out many cross-fertilization experiments, in which the sperm of one type of frog was used to fertilize the eggs of a different type and the subsequent development of the hybrid embryos carefully recorded in the laboratory. In this way, using the group of North American frog species now known as the *Rana pipiens* complex, John sought to assess how the genetic compatibility of the frogs he had caught in different regions correlated with geographical differences. In later, more sensitive experiments, he switched to the use of androgenetic haploid hybridization, in which the nucleus was removed from the egg prior to sperm addition, so that the embryo was forced to develop with only the male's genetic information in the female cytoplasm. He also meticulously compared the effect of a range of temperatures on the embryonic development of the frogs that he had collected in parts of the United States and Mexico with very different climates. The intent in all cases was to examine how patterns of genetic incompatibility and environmental adaptation contribute to the important evolutionary process of speciation (1944, 1949, 1966).

John always described himself as a developmental biologist, but his research quickly brought him to the center of the ferment around the new evolutionary synthesis formulated by Ernst Mayr in his book *Systematics and the Evolution of Species* (Mayr, 1942). John's results seemed to show that what was then considered a very widespread single species, *Rana pipiens,* displayed a phenomenon known as "isolation by distance," so that the further apart geographically two samples were, the more likely it was that matings between them would run into developmental problems. This appeared to be speciation in action, exactly according to the rules formulated by Theodosius Dobzhansky (at Columbia) and Mayr (at Harvard), the leaders in this field with whom John interacted closely.

In retrospect, because John used state boundaries to establish the limits of his samples rather than smaller, local populations, he overlooked some features that are now known to distinguish distinct species within a state. And with time, naturalists gradually began discovering places where two distinct kinds of frogs occur in the same population but do not even attempt to mate due to isolating factors besides genetic incompatibility. A graduate student at the University of Michigan, Ann Pace, published a monograph in 1974 showing that there were two distinct frogs in the eastern United States that had originally been called *Rana pipiens*, and she classified them as two distinct species (Pace, 1974).

In 1975 John published a gracious article acknowledging the new reality. But it took a long time for the true complexity of the situation to be revealed (and in 2011 it is still a work in progress). By 1988 when David Hillis reviewed the situation, the former *Rana pipiens* in the United States had been classified as many different species that are distributed geographically like a patchwork quilt. In his review Hillis summarizes the very extensive laboratory studies that John conducted, citing 14 of his publications. He also points out how, with the new taxonomy, there is still much of value and interest for development and genetics to be derived from the results of John's published experiments (Hillis, 1988).[4]

Modern methods of DNA analysis have brought powerful new tools to bear on the central issues that John investigated so thoroughly in his laboratory. And yet our understanding of speciation, a process central to biological evolution, remains incomplete. In fact, even the precise definition of a species (the "species concept") is still contentious.

In 1968 at age 53 John was enticed to leave Columbia University and move across the United States to the 14-year-old University of California, Riverside. At Riverside he greatly enjoyed making frequent field trips with his wife, Betty, into the mountains and deserts of California, collaborating with her and others to study the population genetics of the fruit fly *Drosophila* in the wild. Later Betty would fondly recall how they had collected flies until dusk "from Whitney Portal high in the Sierras to Furnace Creek in Death Valley, from Santa Cruz Island in the Channel Islands to Andreas Canyon in Palm Springs."[5] Although John formally retired from the University of California at the mandatory age of 65 in 1980, he retained his office in the Biology Department and would teach and write at Riverside until his death at age 86.

John was always a passionate and dedicated teacher, and he taught an unusually broad range of biological subjects. From the very beginning of his time as a young faculty member he taught general biology, the introductory course for college undergraduates. But his curriculum vitae also lists courses taught in botany, invertebrate zoology, ecology, general physiology, general embryology, genetics, evolution, experimental embryology, speciation, biological concepts, biology and human problems, introduction to science, and teaching biology at the college level. In 1946 alongside his many research papers John began to publish laboratory manuals and biology course syllabi that quickly became hundreds of pages long. The end result was his magnificent 680-page textbook, *Principles of Zoology*, published by Oxford University Press in 1957.

Through *Principles of Zoology* and its subsequent derivatives published as *Heredity and Development* (1972), John inspired an entire generation of students to become scientists. Elegantly presented as a series of important concepts about biology, these textbooks brought science to life as an exciting and profound human endeavor. Thus, for example, starting with Darwin's mistaken Theory of Pangenesis—and proceeding through Fleming, Mendel, Boveri and Sutton, T. H. Morgan, and Calvin Bridges—John carefully explained how the mystery of heredity was solved step by step by scientists using a combination of clever experimentation and logic. The 1957 publication of John's college textbook signaled the start of the profound, broad leadership role that John would soon play for science education at all levels in the United States. His most lasting legacy is the one that he leaves in education, both through his pioneering textbooks and through his articulate, forceful, and insightful emphasis on "science as a special way of knowing" about the world.

Principles of Zoology provided my own introduction to genetics. As a freshman in Harvard's Biology 1 course in 1956, I had suffered through a dreary, dry semester of botany. Then, as if by magic, his new textbook appeared as the assigned reading for the second semester. Wisely the lecturers chose not to repeat what John's book had so elegantly explained, merely testing for the material on exams. Nearly 40 years later John would encounter my tattered copy of this book prominently displayed on a bookshelf in my home. When I asked if he might sign it, with characteristic humor he wrote, "If I had known who would use this book, I would have worked much harder."

In October 1957 the Soviet Union launched the first satellite into orbit around the earth. This "Sputnik moment" quickly galvanized the United States into action. In 1958 the U.S. Congress passed the National Defense Education Act, initiating a broad effort to stimulate science education. This encouraged the National Science Foundation (NSF) to fund the development of new science textbooks, with the aim of producing the new generation of outstanding scientists and engineers deemed necessary for the United States to surpass the Soviet Union both militarily and in space. And in 1961 President John F. Kennedy announced that America would land an astronaut on the moon within the decade.

With NSF funding the nonprofit Biological Sciences Curriculum Study (BSCS) was founded in 1958, with headquarters at the University of Colorado, Boulder. John was recruited as chair of its Content of the Curriculum unit, with the aim of quickly producing several new precollege biology textbooks and laboratory exercises. He also served as the supervisor of the so-called “Yellow Version” textbook for two experimental and three commercial editions, produced from 1960 to 1976 (the first commercial edition was published in 1963, after three years of extensive testing). Laboratory blocks that promoted inquiry were also produced. This highly successful effort, which involved a large team of outstanding scientists and high school teachers, required that John spend several months each summer completely devoted to the task, in addition to innumerable hours spent throughout the year writing, editing, and rewriting in response to organized teacher feedback. In John’s words, “Those early days were intense, at times acerbic, enormously hurried, and for me a high point in my life…I was so involved that I am sure that my friends thought that I acted as though any obstacle to the completion of the Yellow Version was an affront to humanity.”[6] By 1970, eighty percent of incoming college freshmen would report that they had used one of the three different BSCS biology texts (Yellow, Blue, and Green) in high school. The Yellow Version alone would sell more than 2 million copies, and would be adapted for use in 11 other nations, often being translated into a different language.

In recognition of John’s internationally recognized leadership abilities, he served as the program chair for the 16th International Congress of Zoology, which had the ambitious aim of reuniting the fragmented zoological sciences into a coherent, broad discipline. For three years John worked to create an enormously ambitious agenda, including arranging for general plenary symposia to cover all of the major areas of zoology. The Congress—held in Washington, D.C. in August 1963—was attended by 2500 scientists from around the globe. For the guests John created his own 116-page illustrated *Guide to Washington,* and he and Betty personally paid for opening the National Gallery of Art for an evening reception. Following the Congress, John heavily edited its six symposia and produced major writings to produce the book *Ideas in Modern Biology*, which was distributed to 10,000 teachers of biology around the world.[7]

John was elected to the American Academy of Arts and Sciences in 1960 and to the National Academy of Sciences in 1963. He would eventually serve on 12 different committees for the National Academy of Sciences/National Research Council that dealt with science and science education. He was a member of the Committee to Evaluate the International Biological Program (IBP) from 1973 to 1976, and in the early 1980s he was a member of the Commission on Human Resources.

For the Commission, John wrote a unique 74-page treatise entitled *Reforming Education in America: A Critical National Need.*[8] This masterly effort—produced as a substitute for an NSF-funded effort by the Academy that the Commission rejected as inadequate—is still valuable today. For example, John wrote that it is "preeminently important that our citizens understand the difference between opinions based on science and opinions which are not." Stressing that "the goal should be to develop minds, not to stuff them," he entreats

> the scholars in the universities to see beyond their specialties and their laboratories to the problems of general education and to be willing to join with colleagues in the schools of education to work towards excellence in the substance of education; in short, to seek to make education as respectable a commitment as scholarly research and publishing.

John also recommended that colleges require a common core of learning for graduation that requires about one-third of a student's total effort over four years, and he specifically proposed a set of courses in "civilization"—"an in-depth study of the problems and accomplishments of human beings, worldwide, for the last 10,000 years." These courses would be taught jointly by "historians, anthropologists, geographers, biologists, and those trained in comparative religions, agriculture, and the social sciences." And they would be associated with laboratories in which students might

> raise a crop, make a clay pot, smelt some ore, make a bronze tool, weave cloth, clean a chicken, play a simple musical instrument, study a steam engine, study an internal combustion engine, paint a picture, begin with a view camera and end with a photographic print, study the physics of familiar home appliances and the chemistry of familiar processes, take several geological field trips while studying Lyell, spend evenings studying the stars, visit local mines, farms, utilities, factories, learn simple navigation, make a map, take several biological field trips when talking about Linnaeus, Darwin, and the early naturalists, listen to great music and poetry readings, study prints and slides of great art, go to different churches.

John originally prepared this document for Frank Press, president of the National Academy of Sciences in 1981; John would later send a copy to me (Bruce Alberts, then Academy president), with a letter pointing out that "the sad part is that after 20 years what was said in 1981 is about right today. Can we ever get the show on the road?"

From 1983 to 1989 John dedicated himself to an enormously ambitious project that he led for the American Society of Zoology (now the Society for Integrative and Comparative Biology) entitled *Science as a Way of Knowing* (SAAWOK). John aimed to create nothing less than a conceptual framework for all of biology through a series of annual symposia that he organized: evolutionary biology, human ecology, genetics, developmental biology, form and function, cell and molecular biology, and neurobiology and behavior. For nearly all of these seven symposia he wrote a major essay, which was published in *American Zoologist* alongside the shorter papers that his invited authors prepared. These writings are impressive demonstrations of John's comprehensive scholarship. For example, his highly original, insightful essay on Human Ecology (1985) starts with a primer on basic ecology and then proceeds to describe how environmental degradation has played a central part in driving human history since the first civilizations (the salting of irrigated soils in Mesopotamia, the washing of hills to the sea in ancient Greece, and soil degradation in the declining Roman Empire). With 1000 references and special attention to specific topics for classroom discussion in the three sections dealing with "The Air We Breathe," "The Water We Drink," and "The Food We Eat," *Human Ecology* remains a terrific resource for any course on biology and human problems. (John taught such a course at the University of California, Riverside, for many years.) Similarly John's scholarly 165-page genetics essay contains more than 500 references (1986).

To sum up the SAAWOK project, John's own "Conceptual Framework for Biology" was published in three parts in *American Zoologist,* totaling 400 pages (1989, 1990, 1991). Funds were raised to distribute an estimated 100,000 copies of these volumes to biology teachers in colleges and universities around the world.

The ideas that John developed in his massive SAAWOK effort were then used to prepare an invaluable, less technical 500-page book for the general public entitled *Science as a Way of Knowing: the Foundations of Modern Biology* (1993). In this book—dedicated to his wife, Betty, and to his longtime collaborator from BSCS days, Ingrith Deyrup-Olsen—John starts with Paleolithic cave drawings in a chapter entitled "The Antecedents of Scientific Thought." He then proceeds to introduce the Greeks in a section peppered with several long quotes from Aristotle. John's personality resonates throughout, as for example where—referring to Aristotle's statement that "some animals are stationary and some move about. The stationary ones are found in water; no land-animal is stationary"—he exclaims, "Just try to imagine what breadth of knowledge is necessary for Aristotle to make such a statement." Likewise, in attempting to fix a date for the start of modern science John writes, "Some historians date the onset of the Scientific Revolution at about 1660. My preference is 1543 ... [which] saw three key events in the history of science. One was the recovery, translation, and publication of the works of the Greek physicist and mathematician Archimedes (287-212 BC)." The other two, also carefully explained, are "the publication of *Revolutionibus Orbium Coelestrium* by Polish physician, clergyman, and astronomer Nicolaus Copernicus (1473-1543)" and "the publication of *De Humani Corporis Fabrica* by Andreas Vesalius (1514-1564)." This begins his detailed history of biology, which continues until the book ends more than 400 pages later with the DNA double helix, the genetic code, and the experiments in experimental embryology that have since led to our ability to manipulate stem cells.

As John hoped, his SAAWOK publications would have a major influence on the teaching of biology at the college level, just as his previous BSCS textbooks had influenced biology education at lower levels. Thus, Neil Campbell, the author of the best-selling introductory college biology textbook (subsequently coauthored with Jane Reece and now in its ninth edition), thanks John extensively for his guidance and inspiration in the preface to the first edition (Campbell, 1987).

In 1991 I invited John to give the keynote address to everyone involved in an NSF-funded, ambitious five-year program to prepare all of San Francisco's public school teachers to teach inquiry science in grades K-5. His talk, presented at the University of California, San Francisco to the 100 teachers being prepared as teacher-leaders, has been preserved on videotape. John's words are unfortunately as accurate today as they were then. Thus, he emphasized that

> we always say the proper role [of education] is to prepare young people to take their places in society and to make those wise decisions that are required in any democracy. But what do we find? If you read the newspapers these days,…there are all sorts of important problems out there that impinge on science and technology. And just ask yourself, in the K-12 or even in the K-16 years, to what extent are we preparing young people to make those wise decisions, or even to know what the problems are? You listen to many of our politicians and you get that very weak feeling…that they really do not understand the problems. And when you have people who do not understand the problems of science and technology in a day when science and technology tend to dominate our civilization, we are in real trouble.

Beginning in the 1970s and extending throughout the rest of his life, John was a passionate, energetic, and highly effective defender of the fact of biological evolution against those who challenged the scientific view of the world on religious grounds. In the 1980s he was a member of the Project 2061 panel that produced the life science content for the landmark publication *Science for All Americans* (Rutherford and Ahlgren, 1989), where he generated a treatment of evolution that was scientifically sound without seeming confrontational. He also served as an invaluable member of the Academy committees that produced the landmark *National Science Education Standards* (1996), in which both biological evolution and teaching science as inquiry play a central part. John coauthored the chapter on "Evolution and the Nature of Science" for an Academy effort aimed at aiding beleaguered U.S. biology teachers, entitled *Teaching About Evolution and the Nature of Science* (1998). He also helped to produce the Academy's *Science and Creationism: A View from the National Academy of Sciences* (2nd ed., 1999), a booklet widely distributed to school boards. Then, after John failed to convince the Academy to include information about biblical analyses in this volume, he took on the task himself by publishing the 220-page book *From Genesis to Genetics: The Case of Evolution and Creationism* (2002). Here John not only patiently explains, step by step, the overwhelming scientific evidence for biological evolution; he also dissects the scriptures to emphasize that there are actually two very different accounts of creation in Genesis—a point ignored by creationists who insist on the accuracy of the biblical account of origins.

John had a unique skill for taking complex subjects and dissecting their essential elements in clear, accessible prose, and he clearly derived immense pleasure from the challenges of doing so. In his own words, " I find it so compelling to try to take very complex ideas and simplify them so that a general arts student in a beginning class can understand them. That's something that I've always liked very, very much. And I like to try to pull things together. I like to try to synthesize fields in writing as well as lectures." We are fortunate that because of digital technologies and the digital library movement, his major writings will be preserved for posterity. Thus, for example, the entire SAAWOK series is available on the Web at *www.sicb.org/dl/saawok.php3*, and his *Heredity and Development* is likewise freely accessed at *www.nap.edu/catalog.php?record_id=13199*. In addition, an extensive collection of John's papers is archived in the library of the University of California, Riverside.

At the time of his death John was in the midst of writing yet another major book—this one on the history of illumination, beginning with early humans and ending when kerosene lighting disappeared with the introduction of electricity. For this project he had been collecting antique lamps for decades.

Several of John's character traits remain to be emphasized, without which no memoir would be complete. First, John had a warm personality with a self-deprecating sense of humor, reinforced by a laconic Virginia accent. The quotes scattered throughout this document reveal a bit of this charm. Despite his great accomplishments he was a humble man. When I recruited him in his 80s to speak to the Council of the National Academy of Sciences in Irvine, California, I had great difficulty in getting him to accept the car service that we hired to transport him from his home in Riverside because "I can't feel comfortable in a fancy black car." John was also a straightforward man of action. In a letter written to the National Academy of Sciences in 2000, proposing that the Academy launch an ambitious new type of study of the entire U.S. education system, he proclaimed, "A study of the sort proposed requires brave persons who will give a truly deep look at the system, and a bold and honest set of recommendations. Most studies of education produce a pablum product in an attempt to please all of the individuals involved. This task is too important for stroking. Raising hell is more appropriate."[9] As his daughter, Sally, wrote shortly after his death, "He truly believed that science education could be improved at all levels and that, eventually, the nation would come around to a rational, evolutionary approach to the study of the natural world."[10]

In closing this memoir of a man who was a great scientist, a great citizen, and a great humanist, it is fitting to reprint the ending of John's last book (2002), in which he praises those on whose shoulders we all stand. Those who through science

> have given us the modern world and the possibility of truly great improvement of the human condition. They have replaced the primitive view of nature as chaotic, mysterious, and often threatening with a view of the universe and life as responding in patterns that are precise, beautiful, and awe-inspiring. Beyond giving pleasure to the inquisitive, analytical mind, this progress in understanding provides previously unimagined ways to feed the hungry, heal

the sick, and lessen toil. Lives are poorly lived when they look out upon a cold, hostile, inscrutable world; lives are enhanced when they look out upon a world with appreciation of its beauty and order and its suitability as a warm and friendly home. It matters little for the great moral and ethical questions facing humanity whether or not the human brain and mind are the consequences of random events in evolution, though scientists are convinced they are. However, it matters a great deal that we use our brains and minds honestly, humanely, intensively, and effectively to preserve and improve the world for ourselves and for generations that follow.

NOTES

1. J. A. Moore. Short-eared owl (*Asio flammeus*) in Virginia. *Auk* 48(1931):425.
2. Oral history interview with John A. Moore, July 23, 1998. Library of University of California, Riverside.
3. From letter to Joshua Lederberg from John A. Moore, April 8, 1987.
4. I am deeply indebted to National Academy of Sciences member David Wake (University of California, Berkeley) for his expert retrospective analysis of John Moore's research on frogs that is reproduced here.
5. From early draft of J. Shaker and B. Moore. Friend's Friend Betty Clark Moore, *UCR Botanic Gardens Newsletter* 24(4), 2004.
6. From *The BSCS Story: A History of the Biological Sciences Curriculum Study*. Colorado Springs: BSCS, 2001.
7. J. A. Moore, ed. *Ideas in Modern Biology*. Garden City, N.Y.: Natural History Press, 1965.
8. J. A. Moore, Unpublished 76 pp paper, R*eforming Education in America: a Critical National Need.* In NAS Archives, Central File: Administration: Publications: Reforming Education in America: Moore J A: 1981.
9. Letter from John Moore to Bruce Alberts, August 31, 2000 in NAS Archives, Central File: NAS: Membership: Moore J A: 2000
10. Letter from S. M. Gall to Bruce Alberts, January 26, 2004.

REFERENCES

Campbell, N. A. 1987. *Biology*. San Francisco: Benjamin Cummings.

Hillis, D. M. 1988. Systematics of the *Rana pipiens* complex: Puzzle and paradigm. *Annu. Rev. Ecol. Syst.* 19:39-63.

Mayr, E. 1942. *Systematics and the Origin of Species.* New York: Columbia University Press.

Pace, A. E. 1974. Systematic and biological studies of the leopard frogs (*Rana pipiens* complex) of the United States. *Mus. Zool. Misc. Publ. Univ. Mich.* 184:1-140.

Rutherford, F. J., and A. Ahlgren. 1989. *Science for All Americans.* Oxford: Oxford University Press.

SELECTED BIBLIOGRAPHY

1939

Temperature tolerance and rates of development in the eggs of Amphibia. *Ecology* 20:459-478.

1941

Developmental rate of hybrid frogs. *J. Exp. Zool.* 86:405-422.

1942

The role of temperature in speciation of frogs. *Biol. Symp.* 6:189-213.

An embryological and genetical study of *Rana burnsi* weed. *Genetics* 27:408-416.

1944

Geographic variation in Rana pipiens Schreber of eastern North America. *Bull. Am. Mus. Nat. Hist.* 82:345-370.

1946

Incipient intraspecific isolating mechanisms in *Rana pipiens*. *Genetics* 31:304-326.

Hybridization between *Rana palustris* and different geographical forms of *Rana pipiens*. *Proc. Natl. Acad. Sci. U. S. A.* 32:209-212.

1947

Hybridization between *Rana pipiens* from Vermont and eastern Mexico. *Proc. Natl. Acad. Sci. U. S. A.* 33:72-75.

1949

Geographic variation of adaptive characters in *Rana pipiens* Schreber. *Evolution* 3:1-24.

Patterns of evolution in the genus *Rana*. In *Genetics, Paleontology, and Evolution*, eds. G. L. Jepsen, G. G. Simpson, and E. Mayr, pp. 315-338. Princeton, N.J.: Princeton University Press.

1950

Further studies on *Rana pipiens* racial hybrids. *Am. Nat.* 84:247-254.

1952

Competition between *Drosophila melanogaster* and *Drosophila simulans.* II. The improvement of competitive ability through selection. *Proc. Nat. Acad. Sci. U. S. A.* 38:813-817.

1955

Abnormal combinations of nuclear and cytoplasmic systems in frogs and toads. *Adv. Genet.* 7:139-182.

1957

Principles of Zoology. Oxford: Oxford University Press.

An embryologist's view of the species concept. In *The Species Problem,* ed. E. Mayr, pp. 325-338. Washington, D.C.: American Association for the Advancement of Science.

1958

The transfer of haploid nuclei between *Rana pipiens* and *Rana sylvatica. Exp. Cell Res.* (suppl. 6):179-191.

1960

Serial back-transfers of nuclei in experiments involving two species of frogs. *Dev. Biol.* 2:535-550.

1961

The frogs of eastern New South Wales. *Bull. Am. Mus. Nat. Hist.* 121:149-386.

1962

Nuclear transplantation and problems of specificity in developing embryos. *J. Cell. Comp. Physiol.* 60(suppl. 1):19-34.

1963

Supervisor. *Biological Science: An Inquiry into Life.* New York: Harcourt, Brace & World.

Supervisor. *Student Laboratory Guide. Biological Science: An Inquiry into Life.* New York: Harcourt, Brace & World.

1966

Evolutionary divergence in the frog, *Rana pipiens. Science* 156:541.

Diploid and haploid hybridization of different populations of the *Rana pipiens* complex. 1. Experiments with females from Mexico. *J. Exp. Zool.* 165:1-19.

Diploid and haploid hybridization of different populations of the *Rana pipiens* complex. 1. Experiments with females from Oklahoma. *J. Exp. Zool.* 165:461-474.

1972

Heredity and Development, 2nd ed. New York: Oxford University Press.

1973

Supervisor. *Biological Science: An Inquiry into Life*, 3rd ed. New York: Harcourt Brace Jovanovich.

1975

Rana pipiens—the changing paradigm. *Am. Zool.* 15:837-849.

1979

With C. E. Taylor and B. C. Moore. The Drosophila of Southern California. I. Colonization after a fire. *Evolution* 33:156-171.

1982

With J. A. Coyne, I. A. Boussy, T. Prout, S. H. Bryant, and J. Jones. Long-distance migration of Drosophila. *Am. Nat.* 119:589-595.

1984

Science as a way of knowing—evolutionary biology. *Am. Zool.* 24:467-543.

1985

Science as a way of knowing. II. Human ecology. *Am. Zool.* 25:483-637.

1986

Science as a way of knowing. III. Genetics. *Am. Zool.* 26:573-747.

1987

Science as a way of knowing. IV. Developmental biology. *Am. Zool.* 27:415-573.

1988

Science as a way of knowing. Understanding nature—form and function. *Am. Zool.* 28:449-584

Ed. *Genes, Cells and Organisms.* Great Books in Experimental Biology Series. (Seventeen reprinted books.) New York: Garland Press.

1989

A conceptual framework for biology. Part I. *Am. Zool.* 29:671-812.

1990

A conceptual framework for biology. Part II. *Am. Zool.* 30:723-858.

1991

A conceptual framework for biology. Part III. *Am. Zool.* 31:349-471.

1993

Science as a Way of Knowing: The Foundations of Modern Biology. Cambridge: Harvard University Press.

2002

From Genesis to Genetics: The Case of Evolution and Creationism. Berkeley: University of California Press.