

ORIGINAL CONTRIBUTION

“The Branches into Which Bacteriology Is Now Ramifying” Revisited

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The American Society for Microbiology was originally founded in 1899 as the Society of American Bacteriologists. The transition from “bacteriology” to “microbiology” and from an emphasis on the identity of the membership (bacteriologists) to an emphasis on the discipline (microbiology) was a contentious one that occurred in several steps. This article reviews the history and events that accompanied this development.

The professional society now known as the American Society for Microbiology (ASM)^c called itself the Society of American Bacteriologists (SAB) from 1899 until 1960. Although many members of SAB studied non-bacterial life forms, for decades they were comfortable calling themselves bacteriologists. How did the term “bacteriology” come to stand for all of microbiology in America? It is argued that this scientific synecdoche was based on the fact that early bacteriologists distinguished themselves more by the methods they used than by the taxonomic status of the organisms they studied. In addition, at the time SAB was founded, German scientific influences were strong, and the systematics of microscopic life forms

were poorly understood. Committees of SAB were instrumental in stabilizing and clarifying bacterial taxonomy. As the profound differences between prokaryotes and eukaryotes were elucidated, it became increasingly difficult to unify the microbiological sciences under the rubric “bacteriology.” In changing the name, members of the society had come to agree that “bacteriology” was too restrictive a term to describe the full activities of the profession. Yet as SAB/ASM celebrates its Centennial, microbiology itself may have become a scientific synecdoche. Microbiological systems and microbiological techniques have permeated all of molecular and cell biology. Changes in professional self-appellation have been reflected

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^c Abbreviations: SAB, Society of American Bacteriologists; ASM, American Society for Microbiology.

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in the name of the Society's quarterly review journal. Founded as *Bacteriological Reviews* in 1937, and becoming *Microbiological Reviews* in 1977, the journal renamed itself *Molecular and Microbiological Reviews* in 1997.

DEFINITIONS AND DESIGNATIONS

A botanist is one who studies plants; a zoologist is one who studies animals. By this simple lexical logic, a bacteriologist is one who studies bacteria. Nevertheless, from the time of its founding in 1899 as the Society of American Bacteriologists, the society now known as the American Society for Microbiology has included a substantial membership of scientists who studied organisms that were *not* bacteria (e.g., brewing yeasts, malarial protozoa, "filterable" viruses, and so forth). Why did early microbiologists call themselves bacteriologists? What is the difference between a bacteriologist and a microbiologist? Does it matter?

It has been said that we are all taxonomists at heart. Certainly, among biologists, there is a strong need to label and categorize our professional interests. Sometimes distinctions are made between applied and fundamental disciplines. Applied biological sciences are subdivided into categories such as agriculture, industry, and medicine. In recent years, the rubric "biotechnologist" has come into vogue, encompassing people in all three of these areas who use the new molecular tools of genetic engineering, immunology, genomics, and such. The fundamental biological sciences are also divided up in various ways. Traditionally, the kind of organism studied is the organizational principle of choice: e.g., mycology (the study of fungi); phycology (the study of algae); protozoology (the study of protozoa). Cross-organismal labels based in scientific approach are also used: e.g., ecology, genetics, neurobiology, physiology,

and systematics. More recently, hybrid labels are popular: biochemistry, biophysics, molecular biology, environmental science, and so forth.

Microbiology is often defined as "the scientific study of organisms too small to be seen with the naked eye." Viewed in this way, microbiology is a traditional but "artificial" classification based on the minute size of the life forms under study. The formal taxonomic categories span several kingdoms and include archebacteria, eubacteria, microfungi, protozoa, unicellular algae, and viruses; the cognate scientific disciplines are bacteriology, protozoology and virology; and parts of mycology, parasitology, and phycology. When defined in this way, the essential tool of the microbiologist is the microscope. Indeed, the compound microscope is often employed as the defining icon of the microbiological sciences; for example, it was adopted as the new ASM logo in celebration of the Society's centennial (Figure 1c). Nevertheless, despite the prominent exploitation of the microscope as a unifying symbol, it is not an entirely satisfactory emblem. Microbiologists are concerned with much more than the size of organisms. Many outstanding microbiologists rarely if ever use a microscope. More importantly, early bacteriologists elucidated the nature of viruses, entities too small to be seen with a light microscope, by relying on the non-microscopic tools of their trade. It is in these other tools that we must seek the origins and the nature of the profession that called itself bacteriology.

THE FOUNDING OF SAB

During the end of the nineteenth century, a time of profound technological change and belief in scientific progress, many scientific disciplines were undergoing a period of professionalization. The Society of American Bacteriologists was

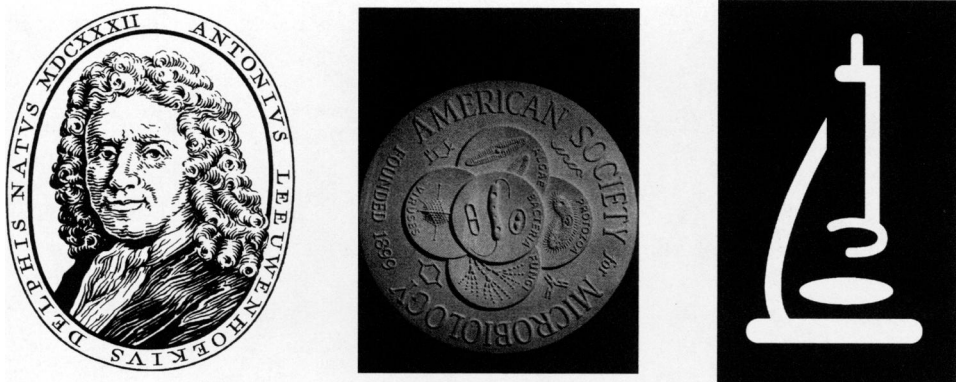


Figure 1. ASM logos from 1916 to present. Figure 1a, left. Drawing by Antonie Van Leeuwenhoek used as logo in *Journal of Bacteriology* publications beginning in 1916. **Figure 1b**, center. Logo designed in 1974 for 75th anniversary of ASM. **Figure 1c**, right. Logo designed for ASM centennial in 1999.

founded by three members of the American Society of Naturalists: A. C. Abbott (University of Pennsylvania), E. O. Jordan (University of Chicago) and H. W. Conn (Wesleyan University). According to published records, they met informally in 1898 about the feasibility of establishing a society devoted specifically to bacteriology, appointed themselves as a committee, and then sent out a letter describing their goals:

It is thought that such an association will conduce to unification of methods and aims, will emphasize the position of bacteriology as one of the biological sciences, and will bring together workers interested in the various branches into which bacteriology is now ramifying [1, p. 287].

In this and subsequent organizational letters, the venture was referred to as “a society of American bacteriologists” or a “proposed Society of American bacteriologists.” Thus, at the earliest stages, there was a presumption that what would form the basis of the society was a common interest in “bacteriology.” The organizational meeting was held on December 28, 1899, at Yale University in New Haven, Connecticut, with approximately 30 people in attendance. A scientific program

was presented; a constitution was adopted; Dr. William T. Sedgwick of MIT was elected president; and 59 people were enrolled as charter members (consisting of the 30 people attending the New Haven meeting plus anyone else who had responded to the letter of inquiry) [1, 2]. Although some of the charter members worked with non-bacterial microbes, by voting to adopt the constitution they called themselves a Society of American Bacteriologists. There is no record of a discussion about the consideration of the alternate term, “microbiologists,” and apparently none took place.

SAB held its next meeting at Baltimore, Maryland, in 1900. Sedgwick’s presidential address on “The Origin, Scope and Significance of Bacteriology” attempted to define and circumscribe the discipline. The speech barely mentioned the microscope; rather, it addressed the way in which early bacteriologists developed a number of special experimental techniques to circumvent the difficulties inherent in studying organisms invisible to the naked eye. Sedgwick began with a grandiloquent genealogy: “Bacteriology is a child of the 19th century. It is the offspring of chemistry and biology, enriched

by physics with the gift of the achromatic microscope . . .” [3, p. 121]. Bacteriology, according to Sedgwick, traced its origins to the study of fermentation, putrefaction, decomposition and decay, nitrification, spontaneous generation, and infectious diseases. Bacteriology, Sedgwick believed, resembled breeding, gardening and agriculture more than disciplines such as ornithology or bryology that defined themselves by the organism they studied. Curiously, he chose beekeeping (apiculture) as a particularly appropriate analogy.

Bacteriology is a kind of microscopic horticulture or apiculture, and its methods, introduced in the first instance by Pasteur for yeasts and twenty years later vastly improved by Koch, are applicable to many bacteria and yeasts — though certainly not equally to all — and also to some other fungi, and, to some extent, to certain algae and protozoa [3, p. 127].

This emphasis on methods (the “microscopic horticulture” of Pasteur and Koch) and the sprawling attempt to be inclusive about the targets of study (“many bacteria and yeasts . . . some fungi . . . certain algae and protozoa”) is typical of attempts then and now to define the scope of the field. Sedgwick also proposed a definition: “*Bacteriology then is a subdivision of microbiology and is conveniently defined as the science of the culturable microorganisms*” [3, p. 127]. A quasi-tautology, Sedgwick’s definition both subsumes and equates bacteriology with microbiology.

THE PAST IS PROLOGUE

Sedgwick was merely the first of many SAB Presidents and other members to struggle with the definition and circumscription of bacteriology. Moreover, although contemporary microbiologists may have trouble comparing bacteria to bees, or Petri dishes to hives, his apiculture-bacteriology analogy had merit. Early

bacteriologists were developing approaches unlike those used by other biologists. Before the era of industrial agriculture, beekeeping was one of the purest forms of animal monoculture. Sedgwick recognized that a defining criterion of the early bacteriologists was their practice of growing bacterial monocultures in the laboratory. Thus, the cornerstone of the bacteriological/microbiological sciences was, and is, an experimental attitude: the pure culture method, the application of Koch’s postulates, the ready adoption of biochemical tests, and the search for the chemical nature of biological phenomena. The contradiction to the usual lexical straitjacket (bacteriologists study only bacteria) was easily submerged in the more important abstraction: bacteriologists are those who use a certain set of experimental approaches to analyze the living world. For the early members of SAB, all organisms studied in this way became “honorary” bacteria. At least one historian has argued that early bacteriology developed largely as an applied science and that “beyond technique bacteriologists had little in common” [4, p. 387].

What’s in a name? For the first sixty years, American Society for *Microbiology* was called the Society of American *Bacteriologists*. The early name put the emphasis on the membership (i.e., the bacteriologists) rather than on the discipline (i.e., bacteriology). This emphasis was likewise reflected in the choice of Antony van Leeuwenhoek, the Delft lens grinder who first observed “wretched beasties” through his primitive microscope, as the logo for the *Journal of Bacteriology* (Figure 1a)

In a 1903 address to the Laboratory Section of the American Public Health Association, another enclave for early bacteriologists, H. L. Russell spoke on the diffuse roots of American bacteriology, noting that its practitioners has been recruited from “widely different preparatory fields,” and “had their preliminary training in lines

of work which are strikingly remote from each other" [5, p. 331]. In Europe, Russell went on to say, this work was connected with medical faculties, while in North America, bacteriology was taught as part of general biological instruction, with bacteriologists as likely to work in agriculture or engineering as in medicine. He drew attention to the fact that much of this diverse work "did not fall within the strict province of the bacteriologist;" and stated further: "the French idea is rapidly gaining ground, and that our science would be more correctly denominated if it was called microbiology . . ." [5, p. 334].

SOME ETYMOLOGY

Russell's allusion to a "French idea" speaks to a nationalistic element in the bacteriology/microbiology choice of nomenclature. The terms *bacterium* and *bacteria* had been used in two ways by nineteenth century German biologists. Derived from the Greek, *bacterium* denotes a short rod or stick. In the morphology-based early classification schemes, *Bacterium* was the genus name for rod-shaped microscopic organisms [6]. By 1872, Ferdinand Cohn was using the term to refer collectively to "the smallest and at the same time the simplest and lowest of all living forms" [7, p. 7]. Robert Buchanan later summarized Cohn's nomenclatural perspective as follows:

He defined bacteria as having cells free from chlorophyll, spherical, oblong or cylindric, straight or bent, multiplying exclusively by fission and either isolated or vegetating in cell families. Four tribes [Sphaerobacteria, Microbacteria, Desmobacteria, and Spirobacteria] with a total of six genera were recognized [6, p. 22].

As a discipline, then, early bacteriology was the study of these smallest and simplest living forms. As bacterial taxonomy developed, *Bacterium* as a generic epithet came to refer to a group of Gram-neg-

ative non-spore forming rods (coliforms); however, it was often debased to include all non-spore forming rods. Because of its indiscriminate use, *Bacterium* was eventually declared a rejected generic name by an international nomenclature committee [8].

"Microbe" (whence "microbiology") never had precise nomenclatural status; rather, it was coined in France to serve as a general term. During the late 1800s, there was substantial debate as to whether microscopic organisms belonged to the plant or the animal kingdoms. A compromise was offered:

It was at the Paris Academy of the Sciences, on the 11th of March, 1878, that Sedillot took part in one of the probably interminable discussions between the advocates of the Microzoaria and those of the Microphyta and he suggested . . . the word *microbe*, to which it appeared to him that every one could give their assent. . . . In fact, the word *microbe*, which only designates a small living being, decides nothing as to the animal or vegetable nature of the beings in question. . . . It has been in common use in France for the last four or five years, and may now be regarded as definitively adopted in the French language. The word has not yet been fully introduced into the English and German languages. In order to indicate the organisms which produce diseases, they make use of the word *Bacteria*, which is only the name of one of the peculiar species assigned to this group . . . In this case, the name is generalized and applied to an entire group [9, pp. 4-5].

Sedillot's coinage was based on the Greek terms for "small" and "life;" however, it has been pointed out that "microbiology" is etymologically suspect in several ways. The Oxford English Dictionary notes that the Greek $\beta\iota\omicron\sigma$ is here, as in modern scientific formations generally, used in an incorrect sense: the Greek sense of $\mu\iota\chi\rho\beta\iota\omicron\sigma$ would be "short lived." Cowan also finds fault with the term and defines *microbiology*, *-ist* as:

An unfortunate name for the study of (and those who study) microbes. Microbiology means little biology and little biologist is an appellation that few bacteriologists would appreciate, however much algologists, mycologists and molecular biologists may like the term [10, p. 162].

SCIENTIFIC SYNECHDOCHE AND SHIFTING SEMANTICS

Synecdoche is a figure of speech in which the part is named, but the whole is understood (e.g., “wheels” for car, “strings” for violins, cellos, and the like). The founders of SAB had identified themselves as “bacteriologists,” a distinctive new category of biologist, and inadvertently reinforced a scientific synecdoche. The reasons for the choice of “bacteriologists” over “microbiologists” for the name of the young society, or whether in fact it was a conscious decision at all, will likely never be known. Certainly the German and French derivation of the words may have reflected some nationalistic biases in the years after the Franco-Prussian War. If so, it is worth noting that most American bacteriologists who took European training went to Germany, not France. Whatever the explanation, from the outset, many authorities were uncomfortable with “bacteriology” as the name of the new discipline, and this discomfort was addressed in several of their early writings. Interpretations tended to fall into two categories: those who automatically assumed that bacteriology was defined by the object of its study (i.e., the taxonomic category called bacteria), and those who recognized that bacteriologists were studying a hodge-podge of microscopic life forms and, therefore, defined bacteriology by its experimental techniques. The authors of the entry in the 11th Edition of the *Encyclopedia Britannica* fell into the first category.

The minute organisms which are commonly called “bacteria” are also known popularly under other designations e.g., “microbes,” “micro-organisms,” “microphytes,” “bacilli,” “micrococci.” All these terms, including the usual one of bacteria, are unsatisfactory; for “bacterium,” “bacillus,” and “micrococcus” have narrow technical meanings, and the other terms are too vague to be scientific. The most satisfactory designation is that proposed by Naegeli in 1857, namely “schizomycetes,” and it is by this term that they are usually known among botanists; the less exact term, however, is also used and is retained in this article since the science is commonly known as “bacteriolog.” [10, p. 156].

The *Encyclopedia* evaded the issue by suggesting “schizomycetes” as a better term than “bacteria,” but refrained from completing the syllogism and re-naming the discipline “schizomycetology.” Writing the same year, C. E. Marshall justified the adoption of “microbiology” for the title of his textbook by emphasizing the taxonomic diversity of the organisms studied by a bacteriological set of methods (“technic”):

... the branch of science commonly recognized as “*Bacteriology*” has for many years included, besides the bacterial forms, those microorganisms yielding to the same laboratory methods of study and investigations. This is a policy or purpose instituted by Pasteur. It is also the result of investigations and added knowledge, more definite arrangements of available facts, and the highly specialized training required for the work. . . . In the light of such circumstances, it appears more pertinent to designate this text-book as “*Microbiology*” . . . Primarily the *technic* of the microbiologist together with, in part, the *economic bearing* of the subject seems to be the determinant factor of limitation [11, pp. vii, 9].

Similarly, Robert Buchanan, writing with his wife Estelle, accounted for the synecdochal usage of bacteriology by placing emphasis on methods:

Bacteriology may be defined as that branch of science which treats of the forms, functions and activities of bacteria. The lines of demarcation between the bacteria and the yeasts and molds on the one hand, and certain of the protozoa on the other, are very poorly marked. Furthermore, these latter groups are studied most readily by the methods that have been developed in the bacteriological laboratory. The meaning of the term *Bacteriology* has, therefore, gradually broadened until now it is generally understood to include a consideration of the true bacteria, the yeasts, the molds, and certain of the protozoa. The word *Microbiology* is sometimes used in the same sense and possibly may supplant *Bacteriology* as a more general and appropriate term [12, p. 1].

Robert Buchanan had an unusual gift for nomenclatural issues and was a leading force in the SAB committee that eventually brought a measure of stability to the difficult topic of bacterial taxonomy. When, in 1920, this SAB Committee issued its final report on bacterial classification [13], much of the nomenclature it included was based on a series of ten papers Buchanan had published between 1916 and 1918 [see 14 for exact citations]. SAB was also active in the support of *Bergey's Manual* [15], a reference guide ultimately adopted internationally for the classification of bacteria. A review of these massive taxonomic efforts is beyond the scope of this essay; it suffices to say that as the comprehension of bacterial taxonomy became more exact, and the vast differences among viruses, prokaryotes, and eukaryotes became more apparent, the intellectual justification for calling all microbiologists "bacteriologists" became more difficult to sustain. Simultaneously, as times changed, SAB membership grew. The increased numbers of scientists who studied viruses, molds, antibiotics, immunology, and other non-bacteriological topics created mounting dissatisfaction with the Society's name. In 1958, at the Annual Meeting held in Chicago, Illinois, it was

proposed that SAB should become the Society of American Microbiologists and that the flagship journal, the *Journal of Bacteriology*, should become the *Journal of Microbiology*. The proposed changes were voted down by the Society's governing Council in 1959 during the meeting in St. Louis, Missouri [16]; however, the naming issue festered and in 1960, SAB became ASM, the American Society for Microbiology. Both the flagship monthly *Journal of Bacteriology*, founded in 1916, and the long established quarterly review journal, *Bacteriological Reviews*, founded in 1937, retained their names. At the 75th Jubilee, *Bacteriological Reviews* was described as "devoted to the publication of reviews and monographs dealing with the broadest possible aspects of microbiology" [17, p. 3]. Nevertheless, the continuing semantic contradiction irked many scientists of the time. *Bacteriological Reviews* became *Microbiological Reviews* in 1977; a leading advocate for change was S. Bartnicki-Garcia, a fungal physiologist anxious to highlight the large number of non-bacterial topics reviewed in the journal. More recently, the editors of *Microbiological Reviews* felt their name might again be "too restricted," and in 1997, the journal changed its name to *Microbiology and Molecular Biology Reviews*, reflecting the fact that "molecular biology had become an indispensable tool to studies on microorganisms, as microorganisms had long been to the development of molecular biology" [18, p. 264].

The images by which the Society has represented itself offer an interesting perspective on its identity. Beginning in 1916 with the appearance of *Journal of Bacteriology*, Society publications used line drawings of Antonie Van Leeuwenhoek as a colophon (Figure 1a). That this solitary Dutch draper was somehow representative of a Society of American Bacteriologists is due, of course, to the fact that he was the

first to observe and describe bacteria. In addition, his renown as a microscopist associated him with the techniques for studying the smallest living things. In preparation for its 75th anniversary celebration in 1974, the Society commissioned a new logo (Figure 1b), with a specific and encompassing emphasis on its objects of study: bacteria, fungi, algae, protozoa, and viruses. Also included were representations of the molecular structure of an immunoglobulin; the chemical skeleton of para-aminobenzoic acid; the chemical structure of 6-aminopenicillanic acid; and the double helix structure of nucleic acid. When the Society wanted a new logo in association with its Centennial in 1999, it was clear that something cleaner and simpler was desirable, if only from a marketing, public relations point of view. After much discussion, a design featuring a stylized light microscope (Figure 1c) was chosen, providing a clear, albeit classical, association in the logo between the ASM and the methods, rather than the objects of study, of microbiology.

POSTMODERN MICROBIOLOGY

Early bacteriologists laid the intellectual foundation for microbiology as we know it today. From the beginning, bacteriologists felt they were different from other biologists. Since morphology and direct observation played a secondary role in bacteriological studies, early bacteriologists were pioneers of experimental biology. Since the organisms they studied were well suited for the study of fundamental biological processes in physiology, enzymology, and genetics, microbiologists were major players in the development of modern biology. The "one-gene, one-enzyme" hypothesis was based on research conducted using a mold; DNA was proven to be the transforming principle using bacteria-based experiments. Microbiology has been at the center of

molecular biology ever since. In fact, it is not an exaggeration to say that the revolution in molecular methodologies and genetic engineering was almost entirely developed by scientists who either called themselves microbiologists, or by scientists who called themselves something else but who worked with microbes.

Nowadays, the distinctions between microbiology and the other rubrics biologists use to describe themselves have blurred even more. The methods of microbiology have been so widely adopted across the biological sciences, especially by those who call themselves "molecular biologists," that some people fear that microbiology itself is in danger of losing its identity. Contemporary biologists regularly model the mammalian cell as a "microbe" and study microbial colonies as "multicellular organisms."

The study of microscopic organisms is thriving, as are the experimental techniques developed by microbiologists. Arguably the most flourishing of the professional societies in biology, SAB/ASM and the discipline it represents, have retained their vigor for over a century. The history of the Society demonstrates a successful effort to maintain a "big tent" definition of the science. Microbiology is of fundamental importance to all the biological sciences. As a professional organization, ASM/SAB both echoes and establishes scientific priorities. The study of microbes continues to play a fundamental role in the study of life. In Joshua Lederberg's felicitous phraseology in the Introduction to the *Encyclopedia of Microbiology*, microbes are "the canonical substrates for many investigations on genes, enzymes, and metabolic pathways" [19 p. vii]. The practices of microbiologists have become the norm for much of biotechnology and molecular biology. Human hormones are now manufactured in microbial "factories;" cell biologists routinely manipulate tissue cultures from multicol-

lular plants and animals as if they were microbial colonies; the human genome is being deciphered with yeast artificial chromosomes as a major technical tool. There are so many branches of biology into which microbiology is now ramifying that it is possible that ASM's membership may follow the lead of its quarterly journal and someday become The American Society for Molecular Biology and Microbiology. Whether or not that should happen, the ASM's current mission statement attempts to maintain the Society's "big tent" identity by speaking of "advancing the microbiological sciences." Under this banner the members of ASM continue to be at the forefront of the scientific study of life, and to make crucial contributions to both fundamental and applied biology.

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