Int Microbiol (2001) 4: 103–109
DOI 10.1007/s101230100021

PERSPECTIVES

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Bergey's manuals and the classification of prokaryotes

Published online: 11 September 2001

After 1965, Sam Cowan's concept of "taxonomic trinity," as applied to bacterial systematics, became famous among microbiologists interested in the principles of taxonomy. The components of such a trinity are classification, nomenclature and identification [5]. Although those who are not experts in taxonomy, or who consider taxonomy to be a minor or "wee" branch of the biology tree, might mistake one for the two others, the existence of such a trinity is completely justified and necessary. Following Cowan, taxonomy is almost synonymous with systematics, and is divided into three parts: (1) "classification," the orderly arrangements of units into groups; (2) "nomenclature," the labeling of the units defined in (1); and (3) "identification," the recognition of the coincidence of unknown organisms with the units defined and labeled in (1) and (2) [5]. Microbial classification tries to put order among the complex presence of so many diverse microorganisms. Nomenclature assigns a name to the different groups observed. Identification tries to discern to which of the previously accorded groups does the specific microorganism that we are trying to recognize belong; if we do recognize it, we will attribute a name to it. The real limits between "classification," which is always more or less arbitrary, "systematics," which searches for a natural order, and "taxonomy," which recapitulates the path of phylogeny, sometimes lie mainly in the eyes of the beholder, or in the hands of an editor at the time of choosing the title for a new book on the topic.

We can now celebrate the release of a book that is the latest step in the long ladder of efforts to impose order on the microbial world: the first volume of *Bergey's manual of systematic bacteriology*, 2nd edn (Fig. 1). Nevertheless, this is only the end (for now) of a long, long story, here summarized.

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Putting order into chaos

Species totae sunt sicut Deus creauit. So wrote Linnaeus (Carl von Linné, 1707–1778), who thought that all species had been created separately in the beginning, and that no species had become extinct nor new species been created. Little could he suspect, however, that the system he devised to classify first plants and later other organisms would be a preliminary step towards the notion of evolution. Linnaeus had a passion for classification; his tidy mind led him to list the plant species in his collections and to gather them into related groups, and then place those groups into other groups and so on. His classification of plants, based on morphological sexual characteristics, was not natural, but it was schematic and allowed the classification of plants into 24 classes, subdivided into orders. In addition, Linnaeus's classification allowed the system of living organisms to be represented as a tree, as it was later represented in evolutionary studies. Nevertheless, his greatest contribution was probably the introduction of binomial nomenclature in 1749, giving each plant a Latin name that consisted of a generic noun followed by a specific adjective. More than 250 years later, his nomenclature serves to name all living cellular beings, including, indeed, the prokaryotes. [Note that the spelling prokaryote/eukaryote will be used throughout the text. When citing a sentence or section's heading from Bergey's manual, however, procaryote/eucaryote will be used because it is the spelling used in the book.] In the 12th edition of the *Systema naturae*, Linnaeus grouped all "animalcules" (i.e., microscopic organisms) into three poorly defined genera: *Volvox*, *Furia* and *Chaos*; and all "infusoria" into a single species called *Chaos infusorium* [6].

Linnaeus was neither the first nor the only one to try to put order into the apparent chaos of nature. Fabio Colonna (1567–1650) established affinities between

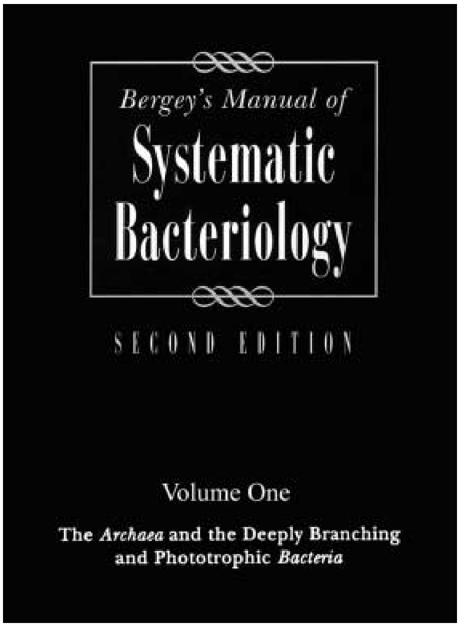

Fig. 1 *Bergey's manual of systematic bacteriology*, 2nd edn (2001), vol 1. The *Archaea* and the deeply branching and phototrophic *Bacteria*. Boone DR, Castenholz RW (eds, vol 1). G.M. Garrity, Editor-in-Chief. Springer, New York, Berlin, Heidelberg. 721 pp. 28.5 × 22 cm. Price: DM 155.55 (79.53 Euro). ISBN 0-387-98771-1

plants by comparing their flowers, fruits and seeds. His work inspired Joseph Pitton de Tournefort (1656–1708), who is considered the first to try to establish a natural system to classify plants. In 1694, Tournefort published the three-volume *Élements de botanique* (also published in Latin under the name *Institutiones rei herbariae*, in 1700). He was convinced that it was possible to make an objective classification of plants. In fact, genera did exist independently of the people classifying them; it was necessary to find a way to arrange plants in their natural order. Most of the genera and families he described and named were maintained by Linnaeus. Families such as Labiatae, Cruciferae, Umbelliferae and Liliaceae, which he described, turned out to be natural groups [17]. John Ray (1627–1705) had also collected and gathered plants in groups following a rational scheme. He published *Historia plantarum*, which contained groups corresponding to present-day cryptogams, phanerogams, monocotyledons and dicotyledons [9].

French botanists Michel Adanson (1727–1806), Bernard de Jussieu (1699–1777) and Antoine-Laurent de Jussieu (1748–1836) laid the foundations to establish the natural classification that others had sought. Antoine-Laurent de Jussieu noticed that, among Ranunculaceae, there were common traits that allowed them to be grouped in a natural family, even though their flowers might have very different shapes, structures and symmetries. He recognized around 100 families that are still accepted nowadays, most of them without later modification. Adanson was especially innovative in his development of a system that considered all characteristics as equally significant [17]; it was an objective system that was updated in the mid-20th century, when computers allowed the use of statistical approaches to analyze many characters from many individuals objectively. Sneath was the first to apply computer-assisted classification – the grouping by numerical methods of taxonomic units into taxa based on shared characters – to bacterial classification. The main goal was to assign individual bacterial strains to homogeneous groups (taxospecies) by using large sets of phenotypic data [7]. In 1963, Sokal and Sneath described the application to bacteria of such a system – currently known as "numerical taxonomy," because the analysis has to deal with numbers, or as "Adansonian taxonomy," after Michel Adanson. Numerical analysis allows individual strains of bacteria to be sorted into homogeneous groups, which are considered "species." Each strain is defined by a series of unit characters, which should no be less than about 60, and may be anatomical, cultural or biochemical. Serology and sensitivities to attack by bacteriophages have also been used in numerical taxonomy [16]. In medical microbiology, bacterial identification is crucial for diagnostics, and must be based on characters that are easily determined, avoiding features that demand difficult techniques or special equipment [1].

Naming and classifying microorganisms: first attempts

During the second half of the 17th century, the distinguished English scientist Robert Hooke (1635–1703) and the humble Dutch draper Antony van Leeuwenhoek (1632–1723) observed – in many places and independently – what the latter called "animalcules." (i.e., little animals). Hooke was the first to describe the structure that he (and we) called "cell," which he observed in cork, whereas van Leeuwenhoek discovered both protists (in barrels containing rain-water, and in the water of Delft's canals) and bacteria (in his own teeth) [6]. The oldest known illustration of a microorganism is probably the spiral-like creature (very likely a globigerina, a protist) in Robert Hooke's *Micrographia* (Fig. 2) [11]. Hooke described it as something that resembled "the shell of a small water snail," which was "no bigger than the point of a pin" [8].

Since the early days of microbiology, microscopists put names to the organisms they found. However, they did not attempt any classification, at least along the lines laid down in the first half of the 18th century by Linnaeus. As long ago as 1773, Danish naturalist Otto Frederick Müller (1730–1784), who put names to some organisms now included among bacteria, made the earliest attempt to arrange microorganisms in a system [3]. In his work *Vermium terrestrium et fluviatilium seu animalium infusorium ... succinta historia*, he described and named two genera (*Monas* and *Vibrio*), which comprised ten and 30 species, respectively [2]. In his

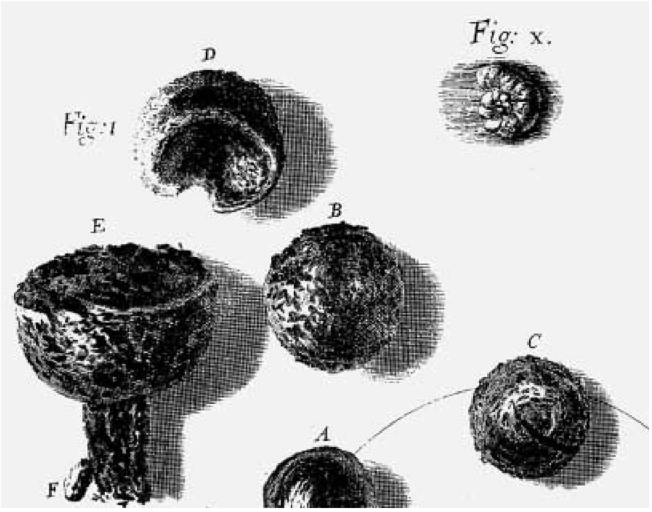

Fig. 2 Upper portion of Plate V (p 45) of Robert Hooke *Micrographia or some physiological descriptions of minute bodies made by magnifying glasses with observations and inquiries thereupon* (1665). Figure X is probably a globigerina, a protist

Animalcula infusoria fluviatilia et marina, published after his death and edited by Otto Fabricius, Müller attempted a greatly enlarged classification and added new species [3]. At that time, however, microscopists made no distinction between what would later be called Protozoa and Bacteria; they classed them all as Infusoria (i.e., coming from infusions), a term that had been coined by Heinrich August Wrisberg (1739–1808) in 1765. Still today, the large and diverse world of protists is in dispute, as discussed recently by Scamardella [15].

Over the first half of the 19th century, other microscopists adopted Müller's nomenclature, which was extended by Christian Gottfried Ehrenberg (1795–1876) in his *Die infusionsthierchen als vollkommene organismen* (1838). In his classification, the families Monadina, Cryptomonadina and Vibrionia comprised forms that were later recognized as bacterial. Besides *Monas* and *Vibrium*, previously named by Müller, he described the genera *Bacterium*, *Spirochaeta*, *Spirillum*, *Spirodiscus*. Although some of those names have persisted, many of Ehrenberg's species cannot be recognized today. In 1841, French zoologist Félix Dujardin (1801–1860) presented another, simpler description of *Monas* and *Vibrium* in his *Histoire naturelle des zoophytes* [3].

In 1852, German naturalist Maximilian Perty (1804–1884) attempted a classification of bacteria in his *Zur Kenntniss kleinster Lebensformen*. He considered that some of the organisms called infusoria were not animals; he called them Phytozoidia (plant–animals), and subdivided them into three sections [3]. Two years later, German botanist Ferdinand Cohn (1828–1898) published *On the development of microscopic algae and fungi*, where he suggested that Ehrenberg's family of Vibrionia should belong to the plant kingdom rather than to the animal kingdom, because of the close analogies to some microscopic algae. He proposed to place them among the Mycophyceae or *Wasserpilz* (water fungi). Nevertheless, from 1860 on he focused his research on the study of bacteria and is considered one of the founders of present-day bacteriological doctrines. He wrote about classification, and felt concerned by the great confusion there was in the nomenclature of bacteria, where the rule of priority had been completely disregarded. At the same time, he was aware of the difficulties lying in the small numbers of characteristics available for their classification, and thought that the genera of bacteria "do not have the same significance as do the genera of higher plants and animals, since bacteria only reproduce by vegetative reproduction, not sexually." [4]. When, in 1857, Carl von Nägeli (1817–1891) found cellulose in the cell walls of two bacteria (*Acetobacter xylinum* and *Sarcina ventriculi*), he assumed they were plants and called them Schizomycetes [9], a name that has persisted for more than a century. In fact some books on botany still state that Division I of the Kingdom Plantae are the "schizomycetes" ("i.e., fungi which divide in the middle"), or bacteria, and Division II are the "schizophyceae" ("i.e., algae which divide in the middle"), or "cyanophyceae." Furthermore, one morphologically conspicuous group of bacteria is still commonly called "actinomycetes" (although this name has been changed to actinobacteria). Some bacteriologists tried the Linnaean approach to naming microorganisms. Nevertheless, there was no agreement even on general names. "Vegetaux cryptogames microscopiques," "animalcules," "champignons," "infusoires," "torulacées," "bactéries," "vibrioniens," "monads," "mucor," "mucédinées," "levures" and even "virus" were names that Louis Pasteur (1822–1895) used on different occasions, without the meaning that we could give to them today. French surgeon Charles-Emmanuel Sédillot (1804–1883) first used the word "microbe," which was enthusiastically and rapidly adopted by Pasteur. The difficulties of observing microorganisms, however, precluded sufficient discrimination in the characters available to allow any efficient system of classification. Unlike bacteria, and all other cellular organisms, viruses do not have Latin binomial names. They are named either by using letters and numbers (bacteriophages), or by a shorthand description of their main characteristics (plant and animal viruses). Nevertheless, there have been attempts to give binomial names to viruses, such as the LHT system proposed in 1962 by Lwoff, Horne and Tournier. If the LHT nomenclature had been widely accepted, nowadays we would enjoy such interesting names as *Androphagovirus bacterii* or *Rabiesvirus canis* [12].

The birth of Bergey's manuals

At the turn of the 20th century there were different approaches to bacterial classification, most of them reflecting the field of expertise of their authors. Medical and veterinary bacteriologists considered that identifying bacteria was more relevant than classifying them and did not care much for systematics. In the United States, bacteriologists evolving from the field of botany were in a larger proportion than in Europe, where they came mainly from medicine and engineering. Robert Earle Buchanan (1883–1973) and David Hendricks Bergey (1860–1937) made it possible to logically organize the information available on bacterial species (whatever they are) and to prepare a systematics treatise. Buchanan started to collect and record the names that had been used and applied to bacteria; between 1916 and 1918 he wrote ten papers, all of them under the general title "Studies on the nomenclature and classification of the bacteria." Bergey began to compile his *Manual of determinative bacteriology* soon after his term as president of the Society of American Bacteriologists (SAB) – now the American Society for Microbiology (ASM) – in 1915 [13]. In this task, he had four collaborators: Francis C. Harrison, Robert S. Breed, Bernard W. Hammer and Frank H. Huntoon.

People not acquainted with Bergey's manuals may not distinguish between *Bergey's manual of determinative bacteriology* and *Bergey's manual of systematic bacteriology*. Until its 8th edition, the Determinative bacteriology manual combined both systematic and determinative identifications. When the 9th edition was released in 1994, the four-volume Systematic bacteriology manual had already been published (from 1984–1989), and the editors decided that the new Determinative bacteriology manual should serve as a reference to help to identify bacteria that have been described and cultured, whereas systematic information should be sought in the Systematic bacteriology manual.

The first Bergey's manual was published under the auspices of the SAB in 1923, and soon became a most useful tool for bacteriologists that had to identify bacterial isolates in the laboratory. Nevertheless, it had not been officially recognized by the SAB, and there was no agreement about the names of bacteria. Besides, botanists had considered bacteria to be plants, and continued to apply the botanical code of nomenclature to them. Since 1923, nine editions of the Determinative bacteriology manual have been published (Table 1).

The International Association of Microbiological Societies, IAMS (which became the International Union of Microbiological Societies, IUMS, in 1980), set up in 1930, encouraged the development of an international committee to deal with the nomenclature of bacteria. It formed that very year and its name was the Nomenclature Committee for the International Society for Microbiology, but it was referred to as the "Nomenclature Committee" – at that time it was not customary to use acronyms or abbreviations [10]. In 1939 it was renamed the International Committee on Bacteriological Nomenclature. Three years earlier, in 1936, a non-profit trust – the Bergey's Manual Trust – had been set up to develop a bacteriological code of nomenclature, which was eventually approved at the 4th International Congress for Microbiology (Copenhagen, 1947). One of the aims of the bacteriological code was to stabilize nomenclature. Nomenclature, however, depends on classification, which is subjective. The classification adopted determines the correct names of organisms; the rules of nomenclature are a guide to choosing the proper name, but a change may be necessary when an organism is moved from one group to another [1]. The bacteriological code was first published in the *Journal of Bacteriology* (1948, 55: 287–306), then, in 1949, in the proceedings of the Copenhagen Congress, and reprinted in the *Journal of General Microbiology* (1949, 3:444). Translations into French, German, Spanish, and Japanese followed. A revised version was approved at the Rome Congress in 1953; it was published in 1958 as the *International code of nomenclature of bacteria and viruses*, with annotations by R.E. Buchanan that included comparisons with the botanical and zoological codes of the time, and illustrations of how the rules should be applied. Despite the existence of the bacteriological code, the botanical code kept references to bacteria until 1975 [5].

At the Moscow Congress in 1966, the code was officially called the *International code of nomenclature of bacteria*. A committee chaired by S.P. Lapage revised it, and it was approved at the First International Congress of Bacteriology (Jerusalem, 1973). This *Code* includes principles, rules, recommendations, appendices, and the statutes of both the International Committee on Systematic Bacteriology (ICSB) and IAMS. After editing, it was published on behalf of the IAMS by the ASM in 1975 and became effective from 1 January 1976. A new revision was approved by the Plenary Session of the 15th International Congress of Microbiology (Osaka, 1990) [5].

Table 1 Different editions of *Bergey's manual of determinative bacteriology*

Edition	Year	Editors	Pages
1st	1923	Bergey DH, Harrison FC, Breed RS, Hammer BW, Huntoon FM	442
2nd	1925	Bergey DH, Breed RS, Hammer BW, Huntoon FM, Murray EGD, Harrison FC	462
3rd	1930	Bergey DH, Breed RS, Hammer BW, Huntoon FM, Murray EGD, Harrison FC	589
4th	1934	Bergey DH, Breed RS, Hammer BW, Huntoon FM, Murray EGD, Harrison FC	664
5th	1939	Bergey DH, Breed RS, Murray EGD, Hitchens AP	1032
6th	1948	Breed RS, Murray EGD, Hitchens AP	1530
7th	1957	Breed RS, Murray EGD, Smith NR	1094
8th	1974	Buchanan RE, Gibbons NE	1268
9th	1994	Holt JG, Krieg NR, Sneath PHA, Staley JT, Williams ST	787

As in others fields of biology, bacteriology chose a starting date for nomenclature. Botanists have different dates for the different groups (fungi, algae, plants, fossil plants). Zoological nomenclature starts in 1758, with the publication of the 10th edition of Linnaeus *Systema naturae*. When bacteriological nomenclature followed the rules of the *Botanical code*, the starting date was 1753 – the year Linnaeus published the 1st edition of *Species plantarum*. Long independent of botany, it was decided that 1 January 1980 would be the date accepted as the starting date for modern bacterial nomenclature. As it took several years of discussion to decide the new starting date, it was agreed that names published after 1 January 1977 should conform to the Code published in 1975 [5].

Seventeen years have already passed since the first volume of *Bergey's manual of systematic bacteriology,* 1st edn was published in 1984 (Table 2). The last two decades have witnessed a dramatic increase in both the description of new bacterial species and rearrangements of others. Systematics studies have greatly expanded, especially with the application of 16S rRNA analyses.

The *International Journal of Systematic and Evolutionary Microbiology* (IJSEM) – previously known as *International Bulletin of Bacteriological Nomenclature and Taxonomy* (1951–1965), and as *International Journal of Systematic Bacteriology* (IJSB, 1966–1999) – is the publication that validates new names and combinations of names of bacteria. The latest change of name was due to the aim of the journal to cover the evolution and systematics of all microorganisms, not only prokaryotes. The IJSEM publishes papers dealing with all phases of the systematics of microorganisms including taxonomy, nomenclature, identification, characterization and culture preservation. According to the rules of nomenclature published in the *International code of nomenclature of bacteria* (1990 revision). *Bacteriological code*, any new name or combination must be published in the IJSEM to obtain validity. If published elsewhere, the new name or combination is not valid until it is published in the validation lists in the IJSEM. The date of publication in this journal is the official date of publication of the name or combination [14]. The IJSEM went from publishing 473 pages in its 1990 four-issue volume, to 2,309 pages in its 2000 six-issue volume, which reflected not only its wider scope, but also changes in bacterial systematics.

Bergey's manual of systematic bacteriology, 2nd edn (2001)

Such great changes in bacterial systematics made a new edition of the systematic bacteriology manual necessary. As the Editor-in-Chief of the 2nd edition, George M. Garrity, expresses in the Preface, the sequence databases have become large enough, and the taxonomic coverage broad enough, to make a universally applicable natural classification of *Bacteria* and *Archaea*. Thus, the systematic bacteriology manual, rather than following a phenotypic structure, follows a phylogenetic framework based on analysis of the nucleotide sequence of the small ribosomal subunit RNA. The name "archaea" is given preference over the formerly used "Archae(o)bacteria," although the manual is said to be only "of systematic bacteriology" and not "of systematic bacteriology and archaeology." Therefore, it is implied that bacteria continues to be almost synonymous with prokaryote.

After the Preface, and before starting the description of species, the systematic bacteriology manual includes 15 sections which readers will surely find of great interest. "The history of Bergey's manual" is a 15-page description of the antecedents and steps leading to its 1st edition, the international efforts to regulate taxonomy, how the manual has enlarged its initial scope, and how the publication process has proceeded. "On using the manual" tries to acquaint the reader with the arrangement of the manual– from big groups to species –, to facilitate use. Differently from the 1st edition, all accepted genera have now been placed into a provisional taxonomic framework based either on the best available 16S rDNA sequence data or – when there are no 16S rDNA available for the type species – phenotypic characteristics or data derived from a closely related species. "Procaryotic domains" describes the main features of prokaryotes, highlighting those that differentiate them from eukaryotes, and showing the differences between Archaea and Bacteria (and, among those Bacteria that do have a cell wall, the main features of Gram-positive and Gram-negative bacteria are also described). "Classification of procaryotic organisms and the concept of bacterial speciation" is an introduction to taxonomy, the science of classification of organisms; it describes the ranks used in bacterial classification, which

Table 2 *Bergey's manual of systematic bacteriology*, 1st edn

Volume	Year	Pages	Editors	Contents
1	1984	1–964	Krieg NR, Holt JG	Gram-negative bacteria of industrial or commercial interest
2	1986	965–1600	Sneath PH, Mair NS, Sharpe ME, Holt JG	Gram-positive bacteria of industrial or commercial interest
3	1989	1601–2298	Staley JT, Bryant MP, Pfennig N, Holt JG	Other Gram-negative bacteria
4	1989	2299–2648	Williams ST, Sharpe ME, Holt JG	Actinomycetes and related bacteria. Bergey's classification of bacteria

differs from that of other groups because the concept of species is less definitive in bacteria that in other organisms. ‘‘Identification of procaryotes’’ shows the schemes used to identify bacteria, which may differ between groups; it points out the advantage of obtaining pure cultures for ease of identification, and describes universal systems for identifying pure cultures and the use of probes for identifying particular species or multiple species in mixed cultures. ‘‘Numerical taxonomy’’ and ‘‘Polyphasic taxonomy’’ deal with two different approaches to bacterial classification. Numerical taxonomy establishes polythetic groups of organisms whose members share a high proportion of characteristics. Polyphasic taxonomy – a term introduced by Rita R. Colwell in 1970 – establishes groups by assembling and assimilating many levels of information, from molecular to ecological. ‘‘Overview: a phylogenetic backbone and taxonomic framework for procaryotic systematics’’ summarizes the methods used to explore and reconstruct phylogenetic relationships between microorganisms suggested by 16S rRNA analyses and other molecular chronometers, and to justify the use of 16S rRNA-based prokaryotic systematics to structure the 2nd edition of the systematic bacteriology manual. ‘‘Nucleic acid probes and their application in environmental microbiology’’ deals with the increasing use of nucleic acid probes, focusing on the basic principles behind such techniques; the steps necessary for directed design and some examples of the use of nucleic acid probes in environmental microbiology are discussed. ‘‘Bacterial nomenclature’’ describes the rules that regulate scientific Latin names of bacteria. In ‘‘Etymology in nomenclature of procaryotes,’’ which complements the preceding section, Hans G. Trüper offers his expertise in monitoring the correctness of new Latin names and giving advice in etymology and other matters in prokaryote nomenclature. ‘‘Microbial ecology – new directions, new importance’’ discusses the relevance of microbial ecology to pure culture studies and that of pure culture to microbial ecology. ‘‘Culture collections: an essential resource for microbiology’’ shows the need for culture collections both as a source of strains for teaching purposes and as an archive of reference material for research, taxonomy or patent purposes. Despite the increasing use of molecular phylogenetic characterization and analysis, culture collections are still necessary to assess subtle phenotypic differences. ‘‘Intellectual property of procaryotes’’ is an outline of the state of intellectual property relating to prokaryotes in the United States in 1998, and deals with patents, trademarks and related concepts, and copyrights. ‘‘The road map to the manual’’ is a guide for the readership, and it intends to help the reader to find his or her way through the manual, especially to find the precise location of a given taxon when searching for one that may be less familiar. Archaea have been subdivided into two phyla, and Bacteria into 23 (Table 3). Volume 1 includes phototrophic species together, as a phenotypically coherent group, thus deviating slightly from the phylogenetic model adopted in this edition of the systematic bacteriology manual. At the end of this introductory section, ‘‘Taxonomic outline of the Archaea and Bacteria’’ shows the arrangement of bacteria in the different groups; such an arrangement is, however, work-in-progress that may change in the following volumes as new data become available. The outline uses an arbitrary numbering scheme that may also change as new taxa are described and more information is available from the Ribosomal Database Project.

Coda

If the phylogenetic relationships between all prokaryotes were known, the only purpose of systematics would be to arrange taxa. The kind of arrangement chosen would depend on the taste and imagination of ‘‘systematists.’’ However, to date, most bacterial phylogenetic relationships are unknown. Maybe in the future they will be easily established, and researchers will be able to identify bacteria by using probes in a way similar to that used to identify chemicals. At present, however, a uniform approach for bacterial classification is not possible; systematists must use a mixed system. As far as current

Table 3 General contents of the *Bergey's manual of systematic bacteriology*, 2nd edn (2001)

Contents	Pages	No. of genera
Introductory chapters (fifteen)	1–166	
Domain Archaea		
Crenarchaeota (Phylum AI)	169–210	22
Euryarchaeota (Phylum AII)	211–355	46
Domain Bacteria		
Deep-branching bacteria (Phyla BI–BV)	359–425	15
Chloroflexi, Thermomicrobia, Nitrospirae, Deferribacteres (Phyla BVI–BIX)	427–471	14
Cyanobacteria (Phylum BX)	473–599	56
Chlorobi (Phylum BXI) (green sulphur bacteria)	601–623	5
Firmicutes (Phylum BXIII) (more genera in future volumes)	625–630	4
Anoxygenic phototrophic purple bacteria (introduction to the group; description in future volumes)	631–637	
Bibliography	639–701	
Index of scientific names	705–721	

knowledge of phylogeny allows, phylogenetic relationships are the preferred method of grouping bacteria. There are groups, however, that are more conveniently assigned by basing them on phenetic characteristics, such as the grouping of phototrophic bacteria in volume 1 of *Bergey's manual of systematic bacteriology* (2nd edn). In *The magic mountain*, Thomas Mann (1875–1955) wrote that "order and simplification are the steps toward the mastery of a subject – the actual enemy is the unknown." Putting order in bacterial systematics and simplifying the apparent initial chaos will lead microbiologists the way to the mastery of some of the mysteries of life.

References

1. Barrow GI, Feltham RKA (1993) Cowan and Steel's manual for identification of medical bacteria, 3rd edn. Cambridge University Press, New York
2. Buchanan RE (1925) General systematic bacteriology. History, nomenclature, groups of bacteria. Williams and Wilkins, Baltimore
3. Bulloch W (1938) The history of bacteriology. Oxford University Press, London (reprinted 1960)
4. Cohn F (1875) Studies on bacteria. In: Contributions to the biology of plants (in German), vol 1, pp 127–222. Translated and reproduced in Brock T (ed) (1961) Milestones in microbiology. Prentice-Hall, Englewood Cliffs, NJ, pp 210–215
5. Cowan ST (1978) A dictionary of microbial taxonomy. Cambridge University Press, Cambridge (published posthumously, edited by L.R. Hill)
6. Dobell C (1958) Antony van Leeuwenhoek and his "little animals": being some account of the father of protozoology & bacteriology and his multifarious discoveries in these disciplines. Russell & Russell, New York
7. Goodfellow M, O'Donnell A (1993) Roots of bacterial systematics. In: Goodfellow M, O'Donnell A (eds) Handbook of new bacterial systematics. Harcourt Brace, London, pp 3–54
8. Hooke R (1961) Micrographia or some physiological descriptions of minute bodies made by magnifying glasses with observations and inquiries thereupon (Facsimile of the 1665 first edition). Dover Publications, New York
9. Kandler O (1985) Evolution of the systematics of bacteria. In Schleifer KH, Stackebrandt E (eds) Evolution of prokaryotes. Academic Press, London, pp 335–361
10. Lapage SP, Sneath PHA, Lessel EF, et al (eds) (1992) International code of nomenclature of bacteria. Bacteriological code (1990 revision). American Society for Microbiology, Washington, D.C.
11. Lechevalier HA, Solotorovsky M (1965) Three centuries of microbiology. McGraw-Hill, New York
12. Lwoff A, Tournier P (1966) The classification of viruses. Annu Rev Microbiol 20:45–74
13. Murray RGE, Holt JG (2001) The history of the *Bergey's Manual*. In: Boone DR, Castenholz RW (eds) Bergey's manual of systematic bacteriology, 2nd edn. Springer, New York Berlin Heidelberg, pp 1–13
14. Parte A (2000) A short history of the official journal of bacterial names. Int J Syst Evol Microbiol 50:1
15. Scamardella JM (1999) Not plants or animals: a brief history of the origin of Kingdoms Protozoa, Protista and Protoctista. Int Microbiol 2:207–216
16. Skerman VBD (1967) A guide to the identification of the genera of bacteria. With methods and digests of generic characteristics. Williams and Wilkins, Baltimore
17. Taton R (1995) La science moderne. De 1450 à 1800. Quadrige, Presses Universitaires de France, Paris