

Classification of Bacteria

Bacterial Classification

- Modern bacterial nomenclature is rooted in the binomial system proposed by the 18th-century naturalist Carl Linnaeus, who established the concept of taxonomy based on a genus and species.
- Initially, genus and species names were derived from visualized organism characteristics or the names of the individuals who first described or discovered the organism.
- Later, after growing organisms from culture in the laboratory was well established, Bergey's first edition of *Determinative Bacteriology* systematically classified bacteria into hierarchies based on distinguishing phenotypic characteristics.

Bacterial Classification

- Originally compiled in 1923 by David Hendricks Bergey, **Bergey's Manual** is the international standard reference for bacterial taxonomy.
- Over time, the scope of microbiology outgrew a single book, leading to a split into two entirely distinct reference pathways: **Determinative** (for practical laboratory identification) and **Systematic** (for evolutionary classification).

History of Bergey's Manual

Year	Development
1923	First edition of Bergey's Manual of Determinative Bacteriology published
1936	Bergey's Manual Trust established
1984	First edition of Bergey's Manual of Systematic Bacteriology introduced
2001–2012	Second edition of Systematic Bacteriology published in five volumes
2015 onwards	Online Bergey's Manual of Systematics of Archaea and Bacteria (BMSAB) with continuous updates replaced the printed systematic edition.

Bergey's Manual of Determinative Bacteriology

Purpose and Philosophy

- The Determinative manual is written entirely for **laboratory identification** of unknown bacterial cultures.
- It acts as a diagnostic toolkit.
- When a microbiologist isolates an unknown bacterium from a clinical sample or soil, this manual helps determine its genus and species using readily available laboratory tests.
- **First published:** 1923 by David Hendricks Bergey and colleagues.
- **Latest edition:** 9th edition (1994), edited by John G. Holt.

Basis of the System

- This book relies strictly on **phenetic (phenotypic) traits**.

...Bergey's Manual of Determinative Bacteriology

It intentionally ignores evolutionary relationships in favor of traits that can be physically observed or tested in a standard lab setting.

- **Cell Wall Anatomy:** Gram-positive vs. Gram-negative staining.
- **Morphology:** Shape (rods, cocci, spirilla) and structural arrangements (chains, clusters).
- **Motility:** Presence and arrangement of flagella.
- **Oxygen Requirements:** Aerobic, anaerobic, or facultative.
- **Biochemical Profiles:** Nutrient utilization, sugar fermentation, and enzymatic activities.

Organization (The 9th Edition)

- The definitive standalone print edition (9th Edition) breaks the kingdom of prokaryotes into **4 major divisions** based on cell wall types, further split into **35 practical groups**:
- **Division I: Gracilicutes**
 - Gram-negative bacteria with complex cell walls.
 - *Includes*: Spirochetes, sulfur-reducing bacteria, Chlamydias, and Rickettsias (Groups 1–16).
- **Division II: Firmicutes**
 - Gram-positive bacteria with thick, rigid cell walls.
 - *Includes*: Gram-positive cocci, endospore-forming rods, and non-spore-forming rods (Groups 17–29).
- **Division III: Tenericutes**
 - Prokaryotes that completely lack a cell wall.
 - *Includes*: The genus *Mycoplasma* (Group 30).
- **Division IV: Mendosicutes**
 - Prokaryotes with atypical cell walls lacking traditional peptidoglycan.
 - *Includes*: The Archaeobacteria (methanogens, extreme halophiles, and hyperthermophiles) (Groups 31–35).

Bergey's Manual of Systematic Bacteriology

- Because it has not been possible in the past to classify procaryotes satisfactorily based on phylogenetic relationships, the system given in the **first edition** of *Bergey's Manual of Systematic Bacteriology* is primarily phenetic.
- Each of the 33 sections in the four volumes contains procaryotes that share a few easily determined characteristics and bears a title that either describes these properties or provides the vernacular names of the procaryotes included.
- The characteristics used to define sections are normally features such as general shape and morphology, Gram-staining properties, oxygen relationship, motility, the presence of endospores, the mode of energy production, and so forth.
- Procaryotic groups are divided among the four volumes in the following manner:
 - (1) gram negative bacteria of general, medical, or industrial importance;
 - (2) gram-positive bacteria other than actinomycetes;
 - (3) gram negative bacteria with distinctive properties, cyanobacteria, and archaea;
 - (4) actinomycetes (gram-positive filamentous bacteria).

Second Edition

- **Polyphasic Taxonomy**
- Modern bacterial taxonomy integrates:
 - Phenotypic characteristics
 - Genotypic characteristics
 - Phylogenetic analysis
 - Chemotaxonomic data
 - Ecological information
- This integrated approach is known as **polyphasic taxonomy**.
- In particular, the sequencing of rRNA, DNA, and proteins has made phylogenetic analysis of procaryotes feasible.
- As a consequence, the second edition of *Bergey's Manual* will be largely phylogenetic rather than phenetic and thus quite different from the first edition.
- The second edition is organized into **five distinct volumes**, separating domains (Archaea and Bacteria) and branching them down into phyla, classes, orders, families, and genera.
 - Volume 1—*The Archaea, and the Deeply Branching and Phototrophic Bacteria*
 - Volume 2—*The Proteobacteria*
 - Volume 3—*The Low G + C Gram-Positive Bacteria*
 - Volume 4—*The High G + C Gram-Positive Bacteria*
 - Volume 5—*The Planctomycetes, Spirochaetes, Fibrobacteres, Bacteroidetes, and Fusobacteria*

Volume 1: The Archaea and the Deeply Branching and Phototrophic Bacteria

- This volume covers the domain Archaea and the most ancient, evolutionary "deep" lineages of the domain Bacteria, including many extremophiles and photosynthetic groups.

1. Domain: Archaea

- Though not bacteria, they are included in the manual as prokaryotes.
- **Phylum Euryarchaeota:** Methanogens (*Methanobacterium*), extreme halophiles (*Halobacterium*), and hyperthermophiles.
- **Phylum Crenarchaeota:** Mostly hyperthermophilic sulfur-metabolizers (*Sulfolobus*, *Pyrodictium*).

2. Domain: Bacteria (Deeply Branching & Phototrophic)

- **Phylum Aquificae:** The oldest branching hyperthermophilic, chemolithotrophic bacteria (*Aquifex*).
- **Phylum Thermotogae:** Thermophilic rod-shaped bacteria with a toga-like outer sheath (*Thermotoga*).
- **Phylum Deinococcus-Thermus:** Highly resistant to radiation (*Deinococcus radiodurans*) and thermophiles (*Thermus aquaticus*).
- **Phylum Chloroflexi:** Green non-sulfur bacteria (anoxygenic phototrophs).
- **Phylum Chlorobi:** Green sulfur bacteria (strict anaerobic phototrophs).
- **Phylum Cyanobacteria:** Oxygenic photosynthetic bacteria (formerly "blue-green algae"), such as *Anabaena* and *Nostoc*.

Volume 2: The Proteobacteria

- This is the largest and most diverse group of **Gram-negative bacteria**. It is divided into five major classes based on RNA lineages, named with Greek letters.
- **Class I: Alphaproteobacteria**
 - Many live in close association with eukaryotic hosts (symbionts or pathogens).
 - *Examples: Rhizobium* (nitrogen-fixing), *Rickettsia* (obligate intracellular pathogens), *Agrobacterium*.
- **Class II: Betaproteobacteria**
 - Utilize organic decomposition products; often found in wastewater or soil.
 - *Examples: Neisseria* (gonorrhea/meningitis), *Bordetella pertussis* (whooping cough), *Nitrosomonas*.
- **Class III: Gammaproteobacteria**
 - The largest subgroup, containing many medically and scientifically vital organisms.
 - *Orders include:*
 - *Enterobacteriales: Escherichia coli, Salmonella, Shigella, Yersinia.*
 - *Pseudomonadales: Pseudomonas aeruginosa.*
 - *Vibrionales: Vibrio cholerae.*
- **Class IV: Deltaproteobacteria**
 - Includes bacteria that prey on other bacteria and those important to the sulfur cycle.
 - *Examples: Bdellovibrio* (predatory), *Myxococcus* (fruiting-body formers), *Desulfovibrio* (sulfate-reducer).
- **Class V: Epsilonproteobacteria**
 - Microaerophilic, helical, or vibrioid rods.
 - *Examples: Campylobacter* (gastroenteritis), *Helicobacter pylori* (peptic ulcers).

Volume 3: The Firmicutes (Low G+C Gram-Positive Bacteria)

- This volume contains Gram-positive bacteria that have a **low G+C ratio** in their DNA (typically less than 50%).
- **Class I: Clostridia**
 - Obligate anaerobes capable of producing endospores.
 - *Examples: Clostridium tetani* (tetanus), *Clostridium botulinum* (botulism).
- **Class II: Bacilli**
 - Aerobic or facultative anaerobic spore-formers and non-spore-formers.
 - *Orders include:*
 - *Bacillales: Bacillus anthracis* (anthrax), *Staphylococcus aureus*.
 - *Lactobacillales:* Non-spore-forming lactic acid bacteria like *Lactobacillus*, *Streptococcus*, and *Enterococcus*.

Volume 4: The Bacteroidetes, Spirochaetes, Tenericutes, and Other Phyla

- This volume acts as a gathering place for a wide variety of structurally diverse, specialized Gram-negative and wall-less bacterial phyla.
- **Phylum Bacteroidetes:** Major components of the human gut microbiota (*Bacteroides*) and environmental degraders (*Flavobacterium*).
- **Phylum Spirochaetes:** Helical, flexible bacteria that move via axial filaments (endoflagella).
 - *Examples: Treponema pallidum* (syphilis), *Borrelia burgdorferi* (Lyme disease).
- **Phylum Tenericutes (Class Mollicutes):** Unique because they completely **lack a cell wall** and contain sterols in their plasma membranes.
 - *Example: Mycoplasma pneumoniae* (atypical pneumonia).
- **Phylum Chlamydiae:** Obligate intracellular parasites with a unique developmental cycle (elementary and reticulate bodies).
 - *Example: Chlamydia trachomatis*.
- **Phylum Planctomycetes:** Aquatic bacteria that blur the line between prokaryotes and eukaryotes by possessing internal membrane-bound compartments (*Gemmata*).
- **Phylum Fusobacteria:** Anaerobic, spindle-shaped rods found in the oral cavity and GI tract (*Fusobacterium*).

Volume 5: The Actinobacteria (High G+C Gram-Positive Bacteria)

- This volume is dedicated entirely to Gram-positive bacteria that have a **high G+C ratio** in their DNA (typically greater than 50%).
- They are structurally diverse, ranging from simple rods to complex, branching filaments that resemble fungal mycelia.
- **Subclass Actinobacteridae:**
 - *Order Actinomycetales*: Highly relevant to medicine, soil ecology, and biotechnology.
 - **Family Mycobacteriaceae**: Acid-fast rods. *Examples: Mycobacterium tuberculosis, Mycobacterium leprae.*
 - **Family Streptomycetaceae**: Filamentous soil bacteria; primary source of commercial antibiotics. *Example: Streptomyces.*
 - **Family Corynebacteriaceae**: Club-shaped cells. *Example: Corynebacterium diphtheriae.*
 - **Family Bifidobacteriaceae**: Common, beneficial inhabitants of the human intestinal tract (*Bifidobacterium*).
 - **Family Propionibacteriaceae**: Used in Swiss cheese production and linked to acne (*Cutibacterium/Propionibacterium acnes*).

Quick-Reference Classification Summary

Volume	Major Group	Primary Identifying Characteristic	Key Genera
Vol 1	Archaea & Deep Branches	Evolutionarily ancient, extremophiles, phototrophs	<i>Aquifex</i> , <i>Deinococcus</i> , <i>Cyanobacteria</i>
Vol 2	Proteobacteria	Gram-negative, highly diverse (alpha, beta, gamma, delta, epsilon classes)	<i>Escherichia</i> , <i>Pseudomonas</i> , <i>Helicobacter</i>
Vol 3	Firmicutes	Gram-positive, Low G+C ratio	<i>Bacillus</i> , <i>Clostridium</i> , <i>Streptococcus</i>
Vol 4	Diverse Phyla	Morphologically distinct Gram-negatives & wall-less	<i>Bacteroides</i> , <i>Treponema</i> , <i>Mycoplasma</i> , <i>Chlamydia</i>
Vol 5	Actinobacteria	Gram-positive, High G+C ratio, often filamentous	<i>Streptomyces</i> , <i>Mycobacterium</i> , <i>Corynebacterium</i>

Major Differences Between the Two Manuals

Feature	Determinative Manual	Systematic Manual
Purpose	Identification of unknown bacteria	Scientific classification and taxonomy
Main use	Diagnostic laboratories	Research and taxonomy
Basis	Phenotypic characters	Polyphasic taxonomy (phenotypic + molecular + phylogenetic)
Organization	35 practical phenotypic groups	Evolutionary hierarchy (Domain to Species)
Focus	Identification keys	Taxonomic descriptions
Molecular data	Very limited	Extensive
Evolutionary relationships	Not emphasized	Primary focus
Users	Students, clinicians, laboratory personnel	Researchers, taxonomists, microbiologists
Speed	Faster for routine identification	More detailed and comprehensive
Common edition	9th Edition (1994)	2nd Edition (2001–2012), now replaced by the online Systematics edition

Modern Note

- To keep up with rapid advancements in genomics, the physical print volumes have transitioned into an online, continuously updated digital encyclopedia known as **Bergey's Manual of Systematics of Archaea and Bacteria (BMSAB)**, which integrates data directly with the Genome Taxonomy Database (GTDB).