الجامعة المستنصرية
كلية العلوم
قسم علوم الحياة
المرحلة الثالثة- فرع المايكرو
صباحي _مسائي

تصنيف بكتريا نظري
مادة كاملة

السعر- 2250 عادي
5000 ملون

* Volume 3

- Gram-positive low G+C DNA composition
- Three classes of the phylum Firmicutes (Phylum B13) شعبة واحدة
  - Class 1- Clostridia - tend to be anaerobic and endospore formers O. ~~Chlo~~Clostridial F. Chloridineae G. Clost.
  - Class 2- Mollicutes - mycoplasmas (no cell walls) → Mycoplasma
  - Class 3- Bacilli - Gram-positive aerobes or facultative anaerobes, rods or cocci, some endospore formers O. Lactobacillales F. Streptococcaceae G - Streptococcus O. Bacillales F. Staphylococcaceae G. Staphylococcus O. Bacillales F. Bacillaceae G. Bacillus ← F. Listeriaceae G. Listeria

* Volume 4

- Gram-positive high G+C DNA composition
- All belong to the phylum Actinobacteria (Phylum B14) → Mycobacte + Corynebac تضم شعبة واحدة
- Some are filamentous

* Volume 5

- Gram-negative (Phylum B15 through B23)
- Various morphologies
- Nine phyla of which four are presented below تضم ٩ شعب
  - Phylum Planctomycetes - some have a membrane-bound nucleus
  - Phylum Chlamydiae - obligate intracellular parasites important in disease جيدا
  - Phylum Spirochaetes - helical-shaped, Gram-negative motile bacteria (axial filaments) O. Spirochaetales F. Spirochaetaceae Treponema pallidum
  - Phylum Bacteroidetes - ecologically significant species are found in this phylum G - Bacteroides

~~[illegible]~~

Survey of the Procaryotes

- مصنف بركي الحالي ليضم ٢٥ شعبه
- ◆ Bergey's Manual of Systematic Bacteriology (2nd ed.) covers 25 phlya
- ◆ Bergey's Manual of Systematic Bacteriology (2nd ed.) covers 25 phlya
- ◆ Groups covered by each volume:
  - * Volume 1 (The Archaea and Deeply Branching and Phototrophic Bacteria covers phyla A1, A2 and B1 through B
    - Domain Archaea
      - Phylum Crenarchaeota - thermophylic and hyperthermophylic sulfur metabolizers
      - Phylum Euryarchaeota - methanogens, halophiles, and thermophilic sulfur reducers
    - Domain Bacteria (Deeply Branching and phototrophic bacteria)
      - Phylum Aquificiae - earliest branch of bacteria that contain autotrophs which utilize hydrogen for energy production
      - Phylum Thermotogae - anaerobic, thermophilic, and fermentative Gram-negative bacteria
      - Phylum "Deinococcus–Thermus" - radiation resistant bacteria
      - Phylum Chloroflexi - green non-sulfur bacteria that carries out anoxygenic photosynthesis
      - بكتريا التركيب الضوئي الاوكسجينيه — Phylum Cyanobacteria - oxygenic photosynthetic bacteria
      - بكتريا الكبريت الخضراء — Phylum Chlorobi - green sulfur bacteria that carry out anoxygenic photosynthesis — Chlorobi [illegible]
  - * Volume 2 (The Proteobacteria (Phylum B12)
    - Phylum Proteobacteria - Gram negative
    - All major nutritional types
    - Five classes based upon rRNA data
      - 1. Class Alphaproteobacteria - oligotrophic forms including the purple nonsulfur photosynthesizers + آركيا Bruce
      - 2 Betaproteobacteria - metabolically similar to alphaproteobacteria — Burkhd. Neiss.
      - 3 Gammaproteobacteria - diverse methods of energy metabolism — F. Enter F. Pseudomo
      - 4 Deltaproteobacteria - includes predators and the fruiting myxobacteria
      - 5 Epsilonproteobacteria - contains pathogens O. Campylobacterales

F. Campylobacteraceae

C. jejuni

F. Helicobacteraceae

H. pylori

Naming Conventions
by Jay Hardy CLS(ASCP), SM(NRM)

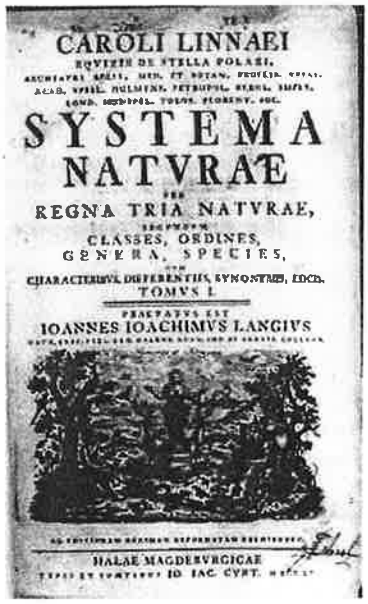
Nomenclature of Microorganisms

The Origin of Names

The Greek philosopher Aristotle attempted to classify all living things as either Plant or Animal. He grouped animals into Land Dwellers, Water Dwellers, and Air Dwellers. Although this system made sense to Aristotle, we would have a difficult time in grouping elephants and earthworms, whales and water striders, flies and falcons together.

Subsequent scientists later tried to classify living creatures by means of locomotion, grouping butterflies and bats (flying), barnacles and barley (both rooted in place). This system of classification was obviously flawed as well.

The efforts to classify living things saw great progress in the work of **Carl Linnaeus**, a Swedish botanist. He developed his naming system in the middle 1700's, which essentially the same one we use today. He attempted to name all known plants, animals, and minerals using Latin and Greek names. One of his books, ***Systema Naturae,*** meaning "The Natural Classification", was published in 1735 and was based on his religious belief that one could understand God by studying his creation.



CAROLI LINNAEI
EQVITIS DE STELLA POLARI,
SYSTEMA
NATVRÆ
REGNA TRIA NATVRAE,
CLASSES, ORDINES,
GENERA, SPECIES,
CHARACTERIBVS, DIFFERENTIIS, SYNONYMIS, LOCIS.
TOMVS I.
IOANNES IOACHIMVS LANGIVS
HALAE MAGDEBVRGICAE
IO. IAC. CVRT.

Today, microorganism names originate from four different sources:

1. Descriptive – For example *Staphylococcus aureus* (grape-like cluster of spheres, golden in color), *Streptococcus viridans* (chains of spheres, green in colony color), *Proteus vulgaris* (first and common), *Helicobacter pylori* (spiral shaped rod at the entrance to the duodenum)

2. Scientist's names – e.g., *Escherichia coli* (Theodor Esherich), *Erlichia* (Paul Erlich), *Nessieria* (Albert Neisser), *Listeria* (Joseph Lister), *Pasturella* (Louis Pasteur*)*, *Yersinia* (AlexandreYersin), *Bartonella* (Alberto Barton), *Morganella* (H. de R. Morgan), *Edwardsiella* (P. R. Edwards)

3. Geographic places – e.g., *Legionella longbeachiae* (Long Beach, California), *Pasturella tularensis* (Tulare County, California), *Pseudomonas fairmontensis* (Fairmount Park, Pennsylvania), *Mycobacterium genavense* (Geneva, Switzerland), *Blastomyces brasiliensis* (Brazil), *Providencia* spp. (Brown University, Providence, RI)

4. Organizations – e.g., *Legionella* (American Legion), *Afipia felis* (Air Force Institute of Pathology), *Cedecea* spp. (Centers for Disease Control), *Bilophila wadsworthia* (VA Wadsworth Medical Center in Los Angeles)

Taxonomy

Kingdom (American system has six: Animalia, Plantae, Fungi, Protista, Archaea, Bacteria)
Phylum (there are 23+ bacterial phyla)
Class
Order
Family
Genus (aka, generic name)
Species (aka, specific name, specific epithet)
Subspecies

For example, the bacteria used in yogurt production would be classified as follows...

Kingdom: Bacteria
Phylum: Firmicutes
Class: Bacilli
Order: Lactobacillales
Family: Lactobacillaceae
Genus: Lactobacillus
Species: *L. delbrueckii*
Subspecies: *L. d. bulgaricus*

Known as the "Father of Modern Taxonomy" Carl Linnaeus was the first to consistanly name plants and animals using the binomial system of Latin names for genus and species.

Rules of Nomenclature

1. **Use Binary Names** - Binary names (invented by Linnaeus), consisting of a generic name and a species epithet (e.g., *Escherichia coli*), must be used for all microorganisms. Names of categories at or above the genus level may be used alone, but species and subspecies names (species names) may not. In other words...never use a species name alone.

2. **When to Capitalize** – The genus name (and above) is always capitalized, the species name is never capitalized, e.g. *Bacillus anthracis*

3. **When to Italicize** - Names of all taxa (kingdoms, phyla, classes, orders, families, genera, species, and subspecies) are printed in italics and should be underlined if handwritten; strain designations and numbers are not. If all the surrounding text is italic, then the binary name would be non-italic (Roman typeface) or underlined (e.g. *A common cause of diarrhea is* E. coli 0157*, a gram negative bacillus).*

4. **When to use Initials** - A specific epithet must be preceded by a generic name, written out in **full** the first time it is used in a paper. Thereafter, the generic name should be abbreviated to the initial capital letter (e.g., *E. coli*), provided there can be no confusion with other genera used in the paper. Be careful with the "S" words; Salmonella, Shigella, Serratia, Staphylococcus, Streptococcus, etc.

5. **Common Names** - Vernacular (common) names should be in lowercase roman type, non-italic (e.g., streptococcus, brucella). However when referring to the actual genus name (or above) always capitalize and italicize.

6. **Subspecies and Serovars** - For *Salmonella*, genus, species, and subspecies names should be rendered in standard form: *Salmonella enterica* at first use, *S. enterica* thereafter; *Salmonella enterica* subsp. *arizonae* at first use, *S. enterica* subsp. *arizonae* thereafter. Names of serovars should be in roman type with the first letter capitalized: *Salmonella enterica* serovar Typhimurium. After the first use, the serovar may also be given without a species name: *Salmonella* serovar Typhimurium.

7. **Abbreviations for Species** – use "sp." for a particular species, "spp." for several species ("spp" stands for "species plural"). These abbreviations are not italicized; e.g. *Clostridium* sp. or *Clostridium* spp.

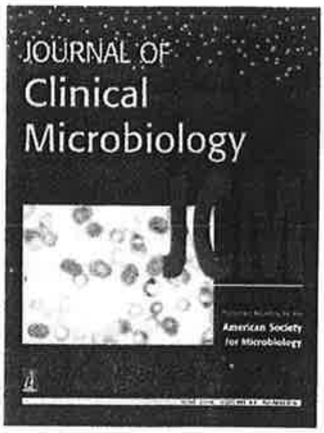
Other Abbreviations:

e.g. meaning 'for example' (it comes from the Latin, exempli gratia)
i.e. meaning 'that is' (from the Latin id est). Note that 'i.e.' specifies particular things, whereas 'e.g.' gives examples.
etc. meaning 'and so forth' (from the Latin et cetera) [Some people, wrongly, write ect.]
et al. meaning 'and others' (from the Latin et alia). You would use this only when citing references.

8. **Plural Forms**

Plural of genus is genera
Plural of species (sp.) is species (spp.)

Plural of medium is media (never say "this culture media")
Plural of fungus is fungi
Plural of streptococcus is streptococci (staphylococcus - staphylococci; enterococcus - enterococci, etc)
Plural of bacillus is bacilli
Plural of bacterium is bacteria
Plural of alga is algae
Plural of protozoan is protozoa



9. Listing References

Always use the "Journal of Clinical Microbiology" as a guideline. List the authors (in bold), publication date, name of article, name of journal, volume (in bold), then pages. For example:

1. **Agouridas, C., A. Bonnefoy, and J. F. Chantot.** 1997. Antibacterial activity of RU 64004 (HMR 3004), a novel ketolide derivative active against respiratory pathogens. Antimicrob. Agents Chemother. **41:**2149-2158.

2. **Angot, P., M. Vergnaud, M. Auzou, R. Leclercq, and Observatoire de Normandie du Pneumocoque.** 2000. Macrolide resistance phenotypes and genotypes in French clinical isolates of *Streptococcus pneumoniae*. Eur. J. Clin. Microbiol. Infect. Dis. **19:**755-758.

Additional rules:

- List your sources in an alphabetical order according to the author's last name.
- If no author is listed, begin with the main word of the article or book title (ignoring *A*, *An*, or *The*).
- Underline or italicize the title of books or magazines.

10. O vs. 0 – Mind your "O's" and zeros. It is *E. coli* O157, not *E. coli* 0157

Question for the Ages:

When referring to filamentous fungi….Is it MOLD or MOULD? Hint: it depends on which side of the Atlantic you are on.

Lecture 1: Introduction to Microbial Taxonomy

Taxonomy: science of biological classification, consists of three separate but interrelated part.

classification – arrangement of organisms into groups (taxa; s., taxon)

nomenclature – assignment of names to taxa

identification – determination of taxon to which an isolate belongs.

Polyphasic Taxonomy:Used to determine the genus and species of a newly discovered prokaryote. Incorporates information from genetic, phenotypic, and phylogenetic analysis

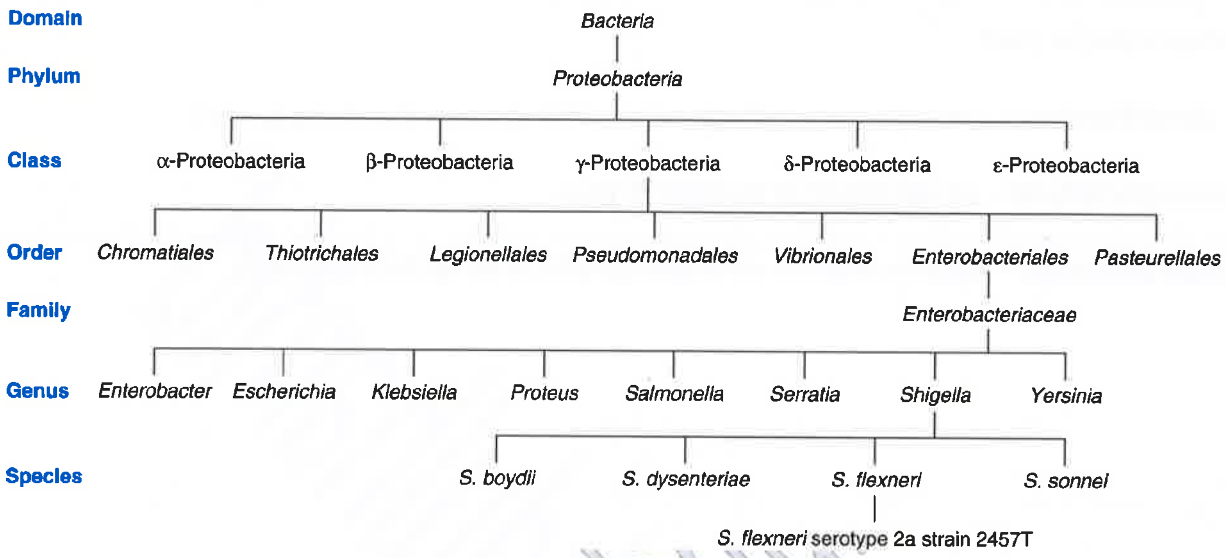
Phenetic Classification: Groups organisms together based on mutual similarity of phenotypes Can reveal evolutionary relationships, but not dependent on phylogenetic analysis i.e., doesn't weigh characters, best systems compare as many attributes as possible.

Phylogenetic Classification: Also called phyletic classification systems

Phylogeny: evolutionary development of a species, Usually based on direct comparison of genetic material and gene products, Woese and Fox proposed using small subunit (SSU) rRNA nucleotide sequences to assess evolutionary relatedness of organisms

Genotypic Classification: Comparison of genetic similarity between organisms,

individual genes or whole genomes can be compared,70% homologous belong to the same species.



Taxonomic Ranks :Microbes are placed in hierarchical taxonomic levels with each level or rank sharing a common set of specific features, highest rank is domain, within domain: phylum, class, order, family, genus, species epithet, some microbes have subspecies.

Bacteria and Archaea – microbes only

Eukarya – microbes and macroorganisms

Species: collection of strains that share many stable properties and differ significantly from other groups of strains

Also suggested as a definition of species: collection of organisms that share the same sequences in their core housekeeping genes

Strains:Descended from a single, pure microbial culture, Vary from each other in many ways

1- **biovars** –a variant strain differ biochemically and physiologically

2-**morphovars** – a variant strain differ morphologically

3-**serovars** – a variant strain differ in antigenic properties

Type Strain: Usually one of first strains of a species studied, Often most fully characterized, Not necessarily most representative member of species

Genus: Well-defined group of one or more strains, clearly separate from other genera, often disagreement among taxonomists about the assignment of a specific species to a genus

Binomial System of Nomenclature: Devised by Carl von Linné (Carolus Linnaeus)

Each organism has two names, genus name – italicized and capitalized (e.g., Escherichia), species epithet – italicized but not capitalized (e.g., coli), Can be abbreviated after first use (e.g., E. coli)

A new species cannot be recognized until it has been published in the **International Journal of Systematic and Evolutionary Microbiology**

Techniques for Determining Microbial Taxonomy and Phylogeny:

Classical characteristics:

1-morphological

2-physiological

3-biochemical

4-ecological

5-genetic

Table 19.1 Some Morphological Features Used in Classification and Identification

Feature	Microbial Groups
Cell shape	All major groups[1]
Cell size	All major groups
Colonial morphology	All major groups
Ultrastructural characteristics	All major groups
Staining behavior	Bacteria, some fungi
Cilia and flagella	All major groups
Mechanism of motility	Gliding bacteria, spirochetes, protists
Endospore shape and location	Some Gram-positive bacteria
Spore morphology and location	Bacteria, protists, fungi
Cellular inclusions	All major groups
Colony color	All major groups

[1] Used in classifying and identifying at least some bacteria, archaea, fungi, and protists.

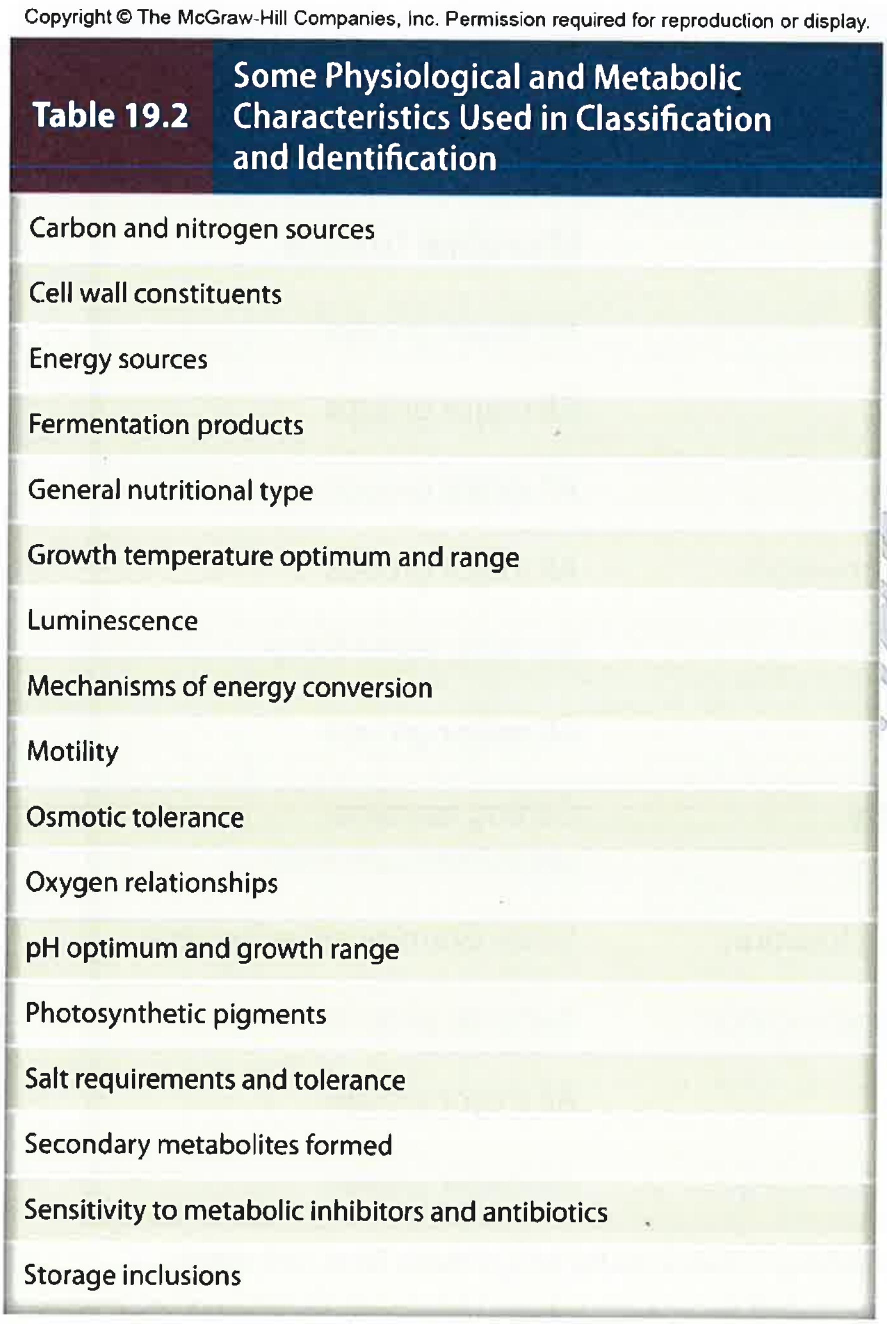


Table 19.2 Some Physiological and Metabolic Characteristics Used in Classification and Identification
Carbon and nitrogen sources
Cell wall constituents
Energy sources
Fermentation products
General nutritional type
Growth temperature optimum and range
Luminescence
Mechanisms of energy conversion
Motility
Osmotic tolerance
Oxygen relationships
pH optimum and growth range
Photosynthetic pigments
Salt requirements and tolerance
Secondary metabolites formed
Sensitivity to metabolic inhibitors and antibiotics
Storage inclusions

Ecological Characteristics:

1-Life-cycle patterns

2-Ability to cause disease

3-Habitat preferences

4-Growth requirements

5-Molecular Approaches: Extremely important because almost no fossil record was left by microbes

Allows for the collection of a large and accurate data set from many organisms

Phylogenetic inferences based on these provide the best analysis of microbial evolution currently available

Molecular Characteristics:

1-Nucleic acid base composition

2-Nucleic acid hybridization

3-Nucleic acid sequencing

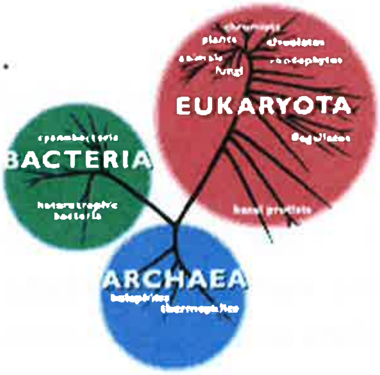
4-Genomic fingerprinting

5-Amino acid sequencing

Table 19.3 Representative G + C Content of Microorganisms

Organism	Percent G + C	Organism	Percent G + C	Organism	Percent G + C
Bacteria		*Streptococcus*	33–44	*Paramecium* spp.	29–39
Anabaena	39–44	*Streptomyces*	69–73	*Trichomonas*	29–34
Caulobacter	62–65	**Archaea**		*Trypanosoma*	45–59
Chlamydia	41–44	*Halobacterium*	66–68	**Fungi**	
Chlorobium	49–58	*Methanobacterium*	32–50	*Agaricus bisporus*	44
Deinococcus	62–70	*Sulfolobus*	31–37	*Amanita muscaria*	57
Escherichia	48–59	**Protists**		*Aspergillus niger*	52
Mycobacterium	62–70	*Acetabularia mediterranea*	37–53	*Candida albicans*	33–35
Myxococcus	68–71	*Amoeba proteus*	66	*Coprinus lagopus*	52–53
Neisseria	48–56	*Chlamydomonas*	60–68	*Mucor rouxii*	38
Pseudomonas	58–69	*Chlorella*	43–79	*Neurospora crassa*	52–54
Rhodospirillum	62–66	*Dictyostelium*	22–25	*Rhizopus nigricans*	47
Staphylococcus	30–38	*Euglena gracilis*	46–55	*Saccharomyces cerevisiae*	36–42

Introduction to the Archaea



Life's extremists. . .

The Domain Archaea wasn't recognized as a major domain of life until quite recently. Until the 20th century, most biologists considered all living things to be classifiable as either a plant or an animal. But in the 1950s and 1960s, most biologists came to the realization that this system failed to accommodate the fungi, protists, and bacteria. By the 1970s, a system of Five Kingdoms had come to be accepted as the model by which all living things could be classified. At a more fundamental level, a distinction was made between the prokaryotic bacteria and the four eukaryotic kingdoms (plants, animals, fungi, & protists). The distinction recognizes the common traits that eukaryotic organisms share, such as nuclei, cytoskeletons, and internal membranes.

The scientific community was understandably shocked in the late 1970s by the discovery of an entirely new group of organisms -- the Archaea. Dr. Carl Woese and his colleagues at the University of Illinois were studying relationships among the prokaryotes using DNA sequences, and found that there were two distinctly different groups. Those "bacteria" that lived at high temperatures or produced methane clustered together as a group well away from the usual bacteria and the eukaryotes. Because of this vast difference in genetic makeup, Woese proposed that life be divided into three domains: Eukaryota, Eubacteria, and Archaebacteria. He later decided that the term Archaebacteria was a misnomer, and shortened it to Archaea. The three domains are shown in the illustration above at right, which illustrates also that each group is very different from the others.

Further work has revealed additional surprises, which you can read about on the other pages of this exhibit. It is true that most archaeans don't look that different from bacteria under the microscope, and that the extreme conditions under which many species live has made them difficult to culture, so their unique place among living organisms long went unrecognized. However, biochemically and genetically, they are as different from bacteria as you are. Although many books and articles still refer to them as "Archaebacteria", that term has been abandoned because they aren't bacteria -- they're Archaea.

Archaeans include inhabitants of some of the most extreme environments on the planet. Some live near rift vents in the deep sea at temperatures well over 100 degrees Centigrade. Others live in hot springs (such as the ones pictured above), or in extremely alkaline or acid waters. They have been found thriving inside the digestive tracts of cows, termites, and marine life where they produce methane. They live in the anoxic muds of marshes and at the bottom of the ocean, and even thrive in petroleum deposits deep underground.

Some archaeans can survive the desiccating effects of extremely saline waters. One salt-loving group of archaea includes Halobacterium, a well-studied archaean. The light-sensitive pigment bacteriorhodopsin gives Halobacterium its color and provides it with chemical energy. Bacteriorhodopsin has a lovely purple color and it pumps protons to the outside of the membrane.

Archaeans may be the only organisms that can live in extreme habitats such as thermal vents or hypersaline water. They may be extremely abundant in environments that are hostile to all other life forms. However, archaeans are not restricted to extreme environments; new research is showing that archaeans are also quite abundant in the plankton of the open sea. Much is still to be learned about these microbes, but it is clear that the Archaea is a remarkably diverse and successful clade of organisms.

Many features Archaea are in common with Eukarya :

genes encoding protein: replication, transcription, translation

Features in Archaea are common with Bacteria:

genes for metabolism

Other elements are unique to Archaea:

-unique tRNA gene structure

-capable of methanogenesis

Like bacteria archaea are highly diverse with respect to morphology, physiology, reproduction, and ecology. Best known for growth in anaerobic, hypersaline, pH extremes, and high-temperature habitats. Also found in marine arctic temperature and tropical waters.

Two phyla currently accepted on Bergey's Manual:

1-Euryarchaeota

2-Crenarchaeota

Phylum *Crenarchaeota*: Some are acidophiles, many are sulfur-dependent, Most are extremely thermophilic, hyperthermophiles (they grow at hydrothermal vents), Most are strict anaerobes, Include organotrophs and lithotrophs (sulfur-oxidizing and hydrogen-oxidizing), and Contains 25 genera two best studied are *Sulfolobus* and *Thermoproteus.*

Genus *Thermoproteus:*

Long thin rod, bent or branched, Thermoacidophiles,grow at temperature from70–97 °Some species are acidophiles with optimum pH value between 3-4,while other are neutrophils. Anaerobic metabolism, lithotrophic on sulfur and hydrogen, organotrophic on sugars, amino acids, alcohols, and organic acids using elemental sulfur as electron acceptor, Autotrophic using CO or CO2 as carbon source. They are found in hot springs and other aquatic habitat rich in sulfur.

Lansing Prescott

Above photo:The Yellow sStone National Park ,the water is at its boiling point and very rich in sulfur . *Sulfolobus* spp. grow well in such habitat.

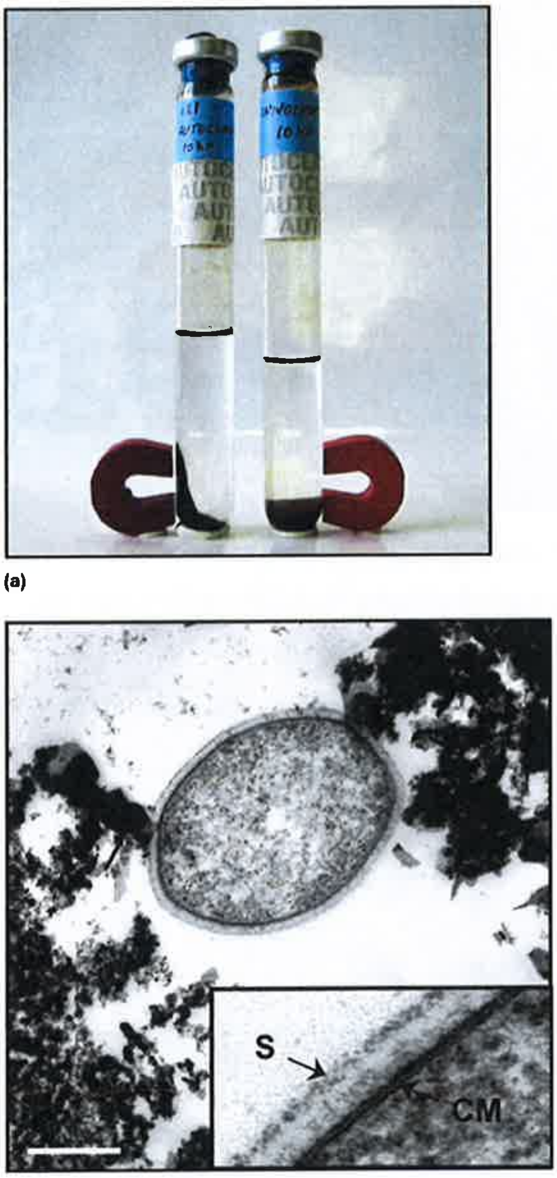
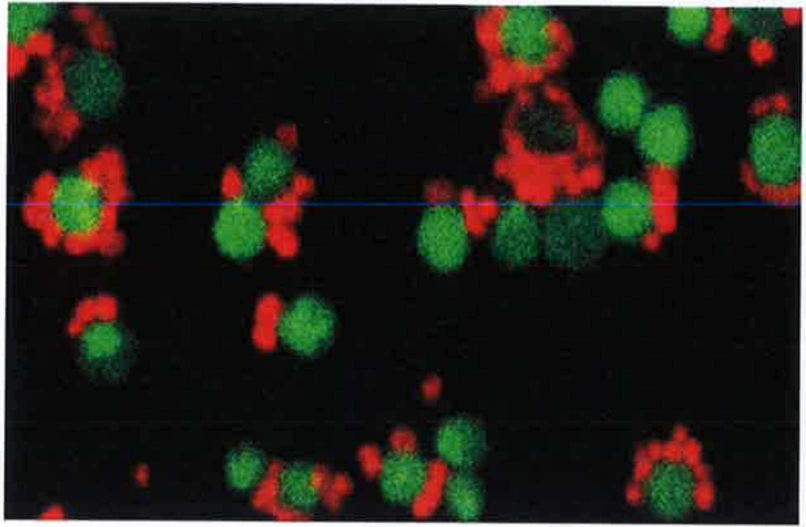


Fig 1A & 1C from Kashefi & Lovley, Extending the Upper Temperature Limit for Life. *Science* 301:934 (Aug. 2004). Copyright by the AAAS

Above figure A- represent an extremely hyperthermophilic *Crenarchaeote*, this microbe can grows following autoclaving at 121C for 1 hour, as shown by its ability to reduce Fe111 to magnetite when incubated anaerobically, tube in right is sterile control-a transmission electron micrograph shows the S layer cell envelope (S)and plasma membrane (CM).



Karl O. Stetter, M. Hohn

Above photo:hydrothermal vent home to the only parasitic archaeon,*Nanoarchaeum equitans* *(red)* (an euryarchaeote)which relies on its crenarchaeal host *Ignicoccus hospitalis* (green),for replication.

Five major physiological and morphological groups within the phylum Euryarchaeota:الجدول للاطلاع

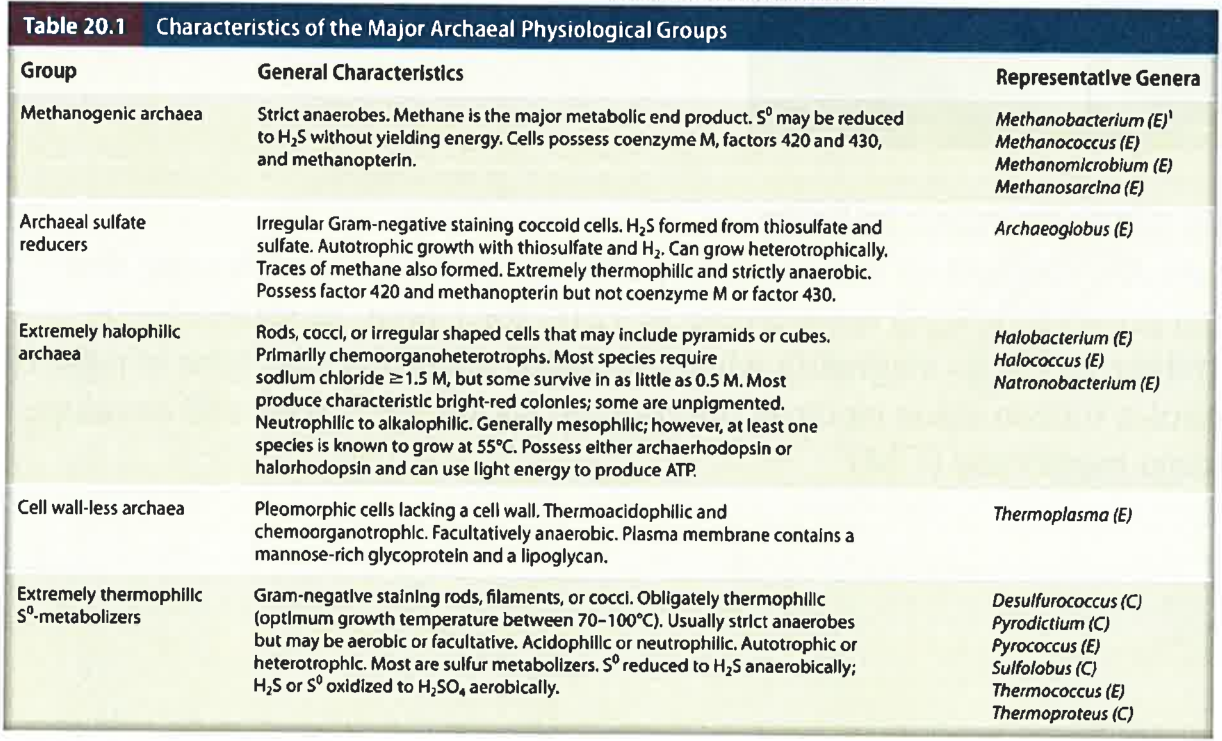


Table 20.1 Characteristics of the Major Archaeal Physiological Groups

Group	General Characteristics	Representative Genera
Methanogenic archaea	Strict anaerobes. Methane is the major metabolic end product. S^0 may be reduced to H_2S without yielding energy. Cells possess coenzyme M, factors 420 and 430, and methanopterin.	*Methanobacterium (E)*[1] *Methanococcus (E)* *Methanomicrobium (E)* *Methanosarcina (E)*
Archaeal sulfate reducers	Irregular Gram-negative staining coccoid cells. H_2S formed from thiosulfate and sulfate. Autotrophic growth with thiosulfate and H_2. Can grow heterotrophically. Traces of methane also formed. Extremely thermophilic and strictly anaerobic. Possess factor 420 and methanopterin but not coenzyme M or factor 430.	*Archaeoglobus (E)*
Extremely halophilic archaea	Rods, cocci, or irregular shaped cells that may include pyramids or cubes. Primarily chemoorganoheterotrophs. Most species require sodium chloride ≥ 1.5 M, but some survive in as little as 0.5 M. Most produce characteristic bright-red colonies; some are unpigmented. Neutrophilic to alkalophilic. Generally mesophilic; however, at least one species is known to grow at 55°C. Possess either archaerhodopsin or halorhodopsin and can use light energy to produce ATP.	*Halobacterium (E)* *Halococcus (E)* *Natronobacterium (E)*
Cell wall-less archaea	Pleomorphic cells lacking a cell wall. Thermoacidophilic and chemoorganotrophic. Facultatively anaerobic. Plasma membrane contains a mannose-rich glycoprotein and a lipoglycan.	*Thermoplasma (E)*
Extremely thermophilic S^0-metabolizers	Gram-negative staining rods, filaments, or cocci. Obligately thermophilic (optimum growth temperature between 70–100°C). Usually strict anaerobes but may be aerobic or facultative. Acidophilic or neutrophilic. Autotrophic or heterotrophic. Most are sulfur metabolizers. S^0 reduced to H_2S anaerobically; H_2S or S^0 oxidized to H_2SO_4 aerobically.	*Desulfurococcus (C)* *Pyrodictium (C)* *Pyrococcus (E)* *Sulfolobus (C)* *Thermococcus (E)* *Thermoproteus (C)*

[1] Indicates phylum; *E, Euryarchaeota, C, Crenarchaeota*

Phylum *Euryarchaeota*:

Consists of many classes, orders, and families, often divided informally into five major groups: 1 -methanogens2-halobacteria 4-thermoplasms 5-extremely hemophilic S0-metabolizers 5-sulfate-reducers

1-Methanogens:

All methanogenic microbes are Archaea, called methanogens: produce methane Methanogenesis: last step in the degradation of organic compounds, occurs in anaerobic environments, e.g., animal rumens, anaerobic sludge digesters, within anaerobic protozoa, 26 genera, largest group of cultured archaea.

Methanogenic archae: strict anaerobes that obtaine energy through the synthesis of methane . They have several coenzymes and cofactors that are involved in methanogenesis. ATP production linked with methanogenesis

Ecological and Practical Importance of Methanogens:

1-Important in wastewater treatment

2-Can produce significant amounts of methane that can be used as clean burning fuel and energy source

3- Methane is greenhouse gas absorbs radiation and is more potent than CO2,and may contribute to global warming

4-an oxidize iron, contributes significantly to corrosion of iron pipes

5- Can form symbiotic relationships with certain bacteria, assisting carbon/sulfur cyclingالجدول ادناه للاطلاع

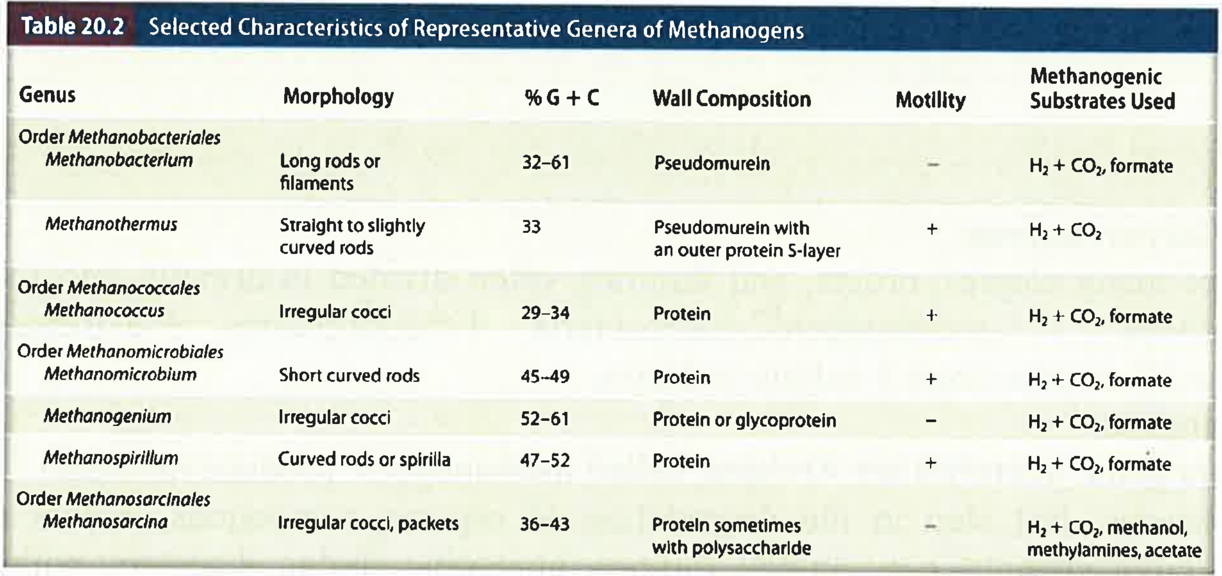


Table 20.2 Selected Characteristics of Representative Genera of Methanogens

Genus	Morphology	% G + C	Wall Composition	Motility	Methanogenic Substrates Used
Order *Methanobacteriales*					
Methanobacterium	Long rods or filaments	32–61	Pseudomurein	–	$H_2 + CO_2$, formate
Methanothermus	Straight to slightly curved rods	33	Pseudomurein with an outer protein S-layer	+	$H_2 + CO_2$
Order *Methanococcales*					
Methanococcus	Irregular cocci	29–34	Protein	+	$H_2 + CO_2$, formate
Order *Methanomicrobiales*					
Methanomicrobium	Short curved rods	45–49	Protein	+	$H_2 + CO_2$, formate
Methanogenium	Irregular cocci	52–61	Protein or glycoprotein	–	$H_2 + CO_2$, formate
Methanospirillum	Curved rods or spirilla	47–52	Protein	+	$H_2 + CO_2$, formate
Order *Methanosarcinales*					
Methanosarcina	Irregular cocci, packets	36–43	Protein sometimes with polysaccharide	–	$H_2 + CO_2$, methanol, methylamines, acetate

2-Halobacteria:

Order *Halobacteriales*; 17 genera in one family, *Halobacteriaceae*

Extreme halophilic archaea (halobacteria), are aerobic, respiratory, chemoheterotrophs with complex nutritional requirements that require at least 1.5 M NaCl, cell wall disintegrates if [NaCl] < 1.5 M, growth optima near 3–4 M NaCl,found in habitats such as salterns and salt lakes.

Strategies to Cope with Osmotic Stress:

1- Increase cytoplasmic osmolarity by accumulating small organic molecules called **compatible solutes.**

2-use antiporters/symporters to increase concentration of KCl and NaCl to level of external environment

3-Acidic amino acids tend to be located on the surface of the folded proteins ,where they attract cataions,which form a hydrated shell around the protein, thereby maintaining its solubility.

e.g., *Halobacterium salinarium (H. halobium):* Has unique type of photosynthesis,

not chlorophyll based, uses modified cell membrane (contains bacteriorhodopsin) absorption of light by bacteriorhodopsin.

3-Thermoplasms: Archaea in the class *Thermoplasmata* are thermoacidophiles that lack cell walls.

Genus *Thermoplasma:* Thermoacidophiles; grow in refuse piles of coal mines at 55–59°C, pH 1–2,these piles contains large amount of pyrite(FeS)which is oxidized to sulfuric acid by chemolithotrophic bacteria.As a result the piles become very hot and acidic.This an ideal habitat for this archaea.

Genus *Thermoplasma* cell structure: shape depends on temperature, may be flagellated and motile,although they lack cell wall, cell membrane strengthened by diglycerol tetraethers, lipopolysaccharides, and glycoproteins, their DNA is condenced.

4-Extremely Thermophilic S0-Reducers:

Class *Thermococci;* one order, *Thermococcales* One family containing three genera, *Thermococcus, Paleococcus, Pyrococcus* These archeae are:Motile by flagella, Optimum growth temperatures 88–100°C, Strictly anaerobic, Reduce sulfur to sulfide

5-Sulfate-Reducing *Euryarchaeota*: class *Archaeoglobi;* order *Archaeoglobales*; one family with one genus, *Archaeoglobus*

***Archaeoglobus* spp.:**contain irregular coccoid cells with cell walls consist of glycoprotein subunits, extremely thermophilic (optimum 83°C), isolated from marine hydrothermal vents,they are lithotrophic or organotrophic,can reduce sulfate, sulfite, or thiosulfite to sulfide,some species possess some methanogen coenzymes.

Volume one Domain BACTERIA

phylum *Aquificae*;

The Aquificae phylum is a diverse collection of bacteria that live in harsh environmental settings. The name 'Aquificae' was given to this phylum based on an early genus identified within this group, Aquifex ("water maker"), which is able to produce water by oxidizing hydrogen. They have been found in springs, pools, and oceans. They are autotrophs, and are the primary carbon fixers in their environments. These bacteria are Gram-negative, nonspore-forming rods. They are true bacteria (domain Bacteria) as opposed to the other inhabitants of extreme environments, the Archaea.
Scientific classification

Domain:	Bacteria
Phylum:	*Aquificae*
Class:	*Aquificae*

Orders: *Aquificales*

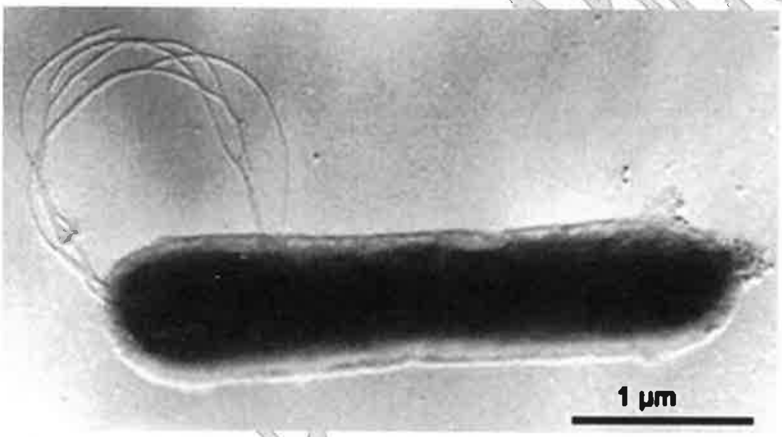
Family: *Aquificaceae*

Genus:*Aquifex*

Aquifex is a genus of bacteria, one of the few in the phylum *Aquificae*. There is one species of *Aquifex* with a validly published name - *A. pyrophilus* - but "" is sometimes considered as species though it has no *A. aeolicus* standing as a name given it has not been validly or effectively published. *Aquifex* spp. are extreme thermophiles, growing best at temperature of 85 °C to 95 °C. They are members of the [Bacteria] as opposed to the other inhabitants of extreme environments, the Archaea.

Aquifex spp. are rod-shaped bacteria with a length of 2 to 6 µm and a diameter of around 0.5 µm. They are non-sporeforming, Gram negative autotrophs. *Aquifex* means water-maker in Latin, and refers to the fact that its method of respiration creates water. *Aquifex* tend to form cell aggregates composed of up to 100 individual cells.

Aquifex spp. are thermophilic and often grow near underwater volcanoes or hot springs. *A. aeolicus* requires oxygen to survive, but can grow in levels of oxygen as low as 7.5 ppm. *A. pyrophilus* can even grow anaerobically by reducing nitrogen instead of oxygen. Like other thermophilic bacteria, *Aquifex* has important uses in industrial processes.



Aquifex pyrophilus (platinum shadowed).

:

Approximately 2 meters downstream of the spring pictured to the right. Pink microbial filaments containing Aquifex and Thermotoga were found in this channel. The tempurature was measured to be 83 degrees Celsius and the pH was found to be 8.

Even though *Aquifex* has the ability to survive at extreme temperatures, there are only a few specific heat-resistance indicators evident in the *A. aeolicus* genome.; the genome of this complex organism is only one-third of the E. coli genome.. Comparison of the Aquifex genome to other organisms showed that 16% of it genes originated from archaea bacteria.

Phylum Thermotogae:

Scientific classification

Domain:	Bacteria
Phylum:	Thermotogae
Order:	Thermotogales
Family:	Thermotogaceae
Genus:	*Thermotoga*

The Thermotogae are a phylum of the domain Bacteria. The phylum Thermotogae is composed of Gram-negative staining, anaerobic, and mostly thermophilic and hyperthermophilic bacteria.

Characteristics:

The name of this phylum is derived from the existence of many of these organisms at high temperatures along with the characteristic sheath structure, or "toga", surrounding the cells of these species as shown in photo above, Recently, some Thermotogae existing at moderate temperatures have also been identified. Although Thermotogae species exhibit Gram-negative staining, they are bounded by a single-unit lipid membrane, hence they are monoderm bacteria. Because of the ability of some Thermotogae species to thrive at high temperatures, they are considered attractive targets for use in industrial processes. The metabolic ability of Thermotogae to utilize different complex-carbohydrates for production of hydrogen gas led to these species being cited as a possible biotechnological source for production of energy alternative to fossil fuels.

phylum Deinococcus–Thermus:

Deinococcus–Thermus is a phylum of bacteria that are highly resistant to environmental hazards, also known as extremophiles. These bacteria have thick cell walls that give them gram-positive stains, but they include a second membrane and so are closer in structure to those of gram-negative bacteria.

Deinococcus (from the Greek: δεινός, deinos, "dreadful, strange" and κόκκος, kókkos, "granule") is one genus of three in the Deinococcales group of the Deinococcus-Thermus phylum of bacteria highly resistant to environmental hazards. These bacteria have thick cell walls that give them Gram-positive stains, but they include a second membrane and so are closer in structure to Gram-negative bacteria. Deinococcus survive when their DNA is exposed to high doses of gamma and UV radiation.

Where other bacteria change their structure in the presence of radiation, such as endospores, Deinococcus tolerate it without changing their cellular form and do not retreat into a hardened structure. They are also characterized by the presence of the carotenoid pigment deinoxanthin that give them their pink color. They are usually isolated according to these two criteria.

Domain: Bacteria

Phylum: Deinococcus-Thermus

Class: Deinococci

Order: Deinococcales

Family: Deinococcaceae

Genus: *Deinococcus*

D. radiodurans

(a)

Gross L (2007) Paradox Resolved? The Strange Case of the Radiation-Resistant Bacteria. PLoS Biol 5(4): e108 doi:10.1371/journal.pbio.0050108

Deinococcus radiodurance tetracoccus or cluster of 4 cells

Phyla of Photosynthetic Bacteria

1-Phylum Chloroflexi – green nonsulfur bacteria

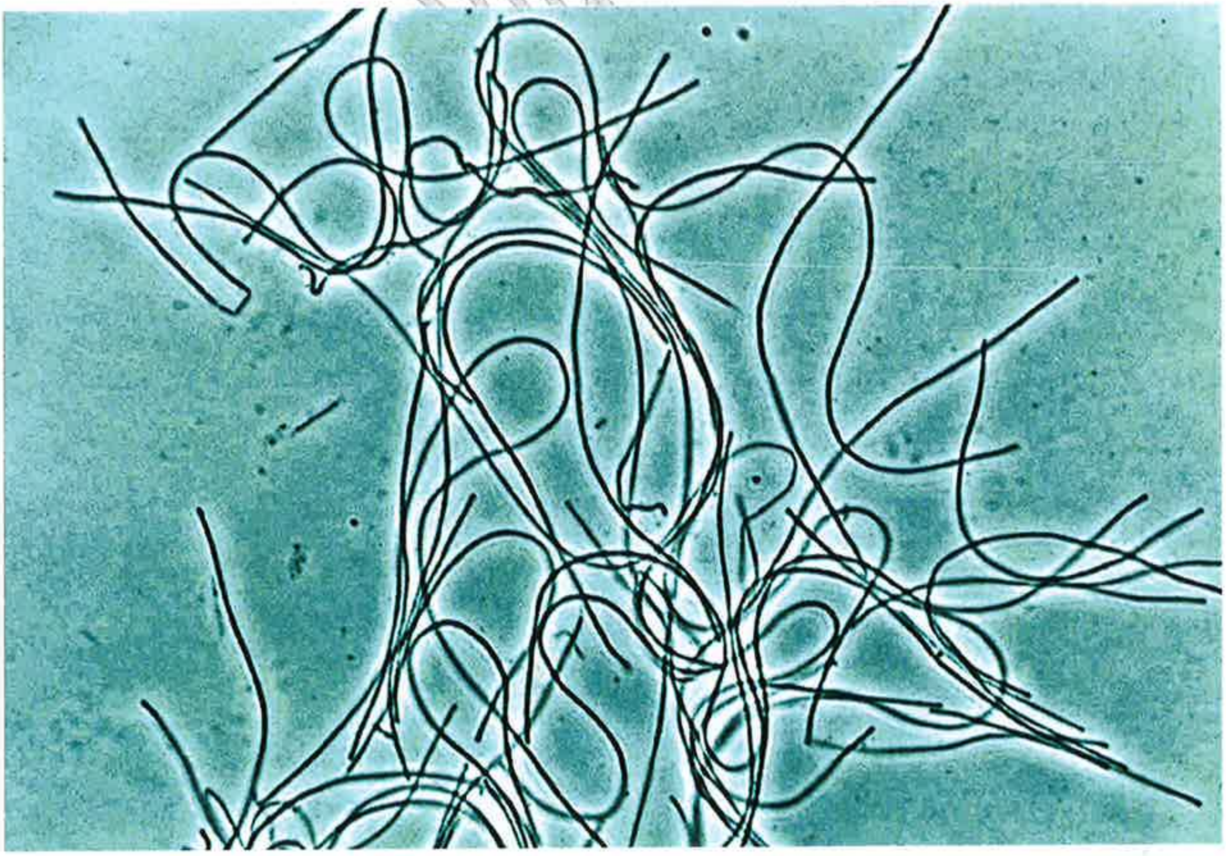
2-Phylum Chlorobi – green sulfur bacteria

3-Phylum Cyanobacteria

Phylum Chloroflexi – green nonsulfur bacteria:

Ha sboth photosynthetic and nonphotosynthetic members

e.g., genus *Chloroflexus* spp. – are photosynthetic ,filamentous,move by gliding motility ,thermophilic often isolated from neutral to alkaline hot springs; grow in orange-reddish mats,their metabolismdepends on anoxygenic photosynthesis(does not use water as electron donor),they are photoheterotroph and can grow aerobically as a chemoheterotroph.

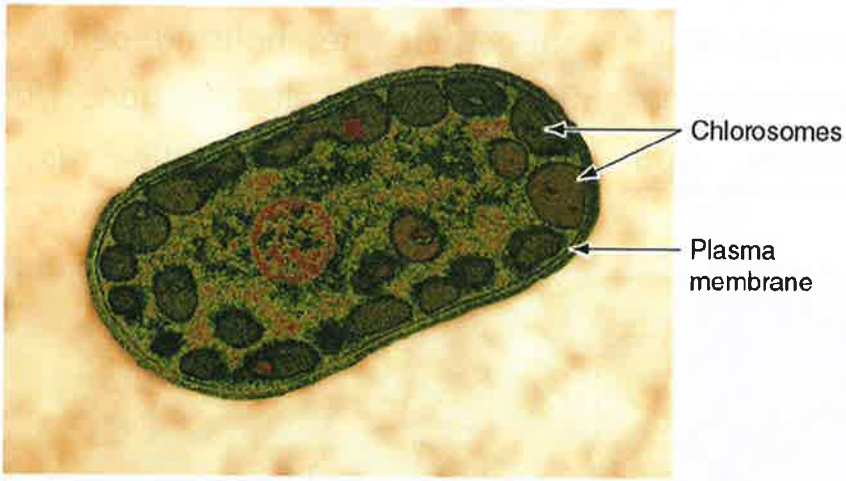


Phylum Chlorobi: green sulfur bacteria

consists of one class, Chlorobia; one order, Chlorobiales; one family, Chlorobiaceae, representative geneus is *Chlorobium*

Green sulfur Bacteria are morphologically diverse,they thrive in sulfide rich areas,they have chlorosomes(ellipsoidal vesicles attached to plasma membrane contain accessory photosynthetic pigments very efficient light harvesting complexes).

(a)



Chlorobi lack flagella; nonmotile, some have gas vesicles to adjust depth of cell for light/H_2S, they are obligate anaerobic photolithoautotrophs, Obligate anaerobic photolithoautotrophs that use use H_2S, elemental sulfur, and H_2 as electron sources.When sulfide is oxidized elemental sulfur deposited outside cell.

The reaction center bacteriochlorophyll in plasma membrane

Phylum Cyanobacteria:

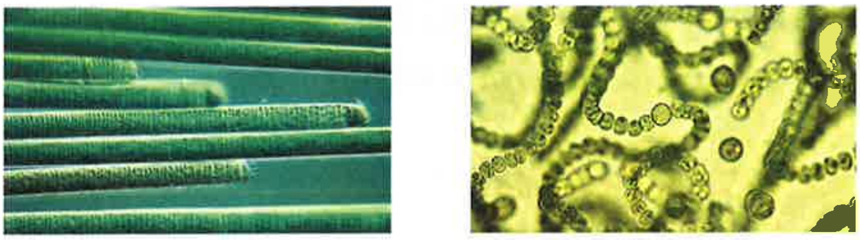
Largest, most diverse group of photosynthetic bacteria they are classified as *Chlorophyceae* – blue green algae common term. The discovery that these microbes are really Gram negative bacteria did not resolve their taxonomic issue. Many are obligate photolithoautotrophs; some can grow slowly in dark as chemoheterotrophs

Classification of Cyanobacteria:

Bergey's Manual divides into five subsections major characteristics include morphology and reproductive patterns, other characteristics used ultrastructure ,genetic, physiology and biochemistry, habitat/ecology.

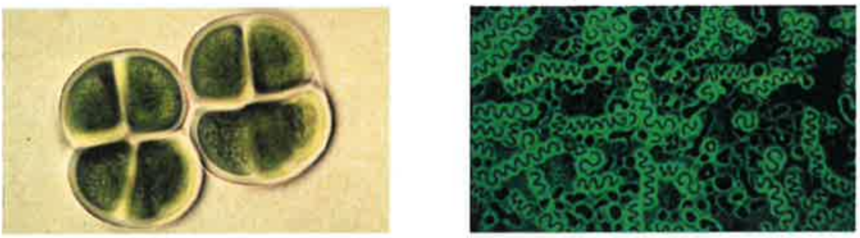
Photosynthesis in Cyanobacteria:

The cyanobacterial photosynthesis resembles that of eukaryotes have photosystems I and II, have chlorophyll a,and thereby perform oxygenic photosynthesis, one species performs anoxygenic photosynthesis using H_2S as electron source.
Cyanobacteria also vary grately in shape and appearance, they range in diameter from ~1 to 10 mm, and may be unicellular, colonial, or filaments called trichomes (a row of cells in close contact)



(a) *Oscillatoria*

(c) *Nostoc*



(b) *Chroococcus turgidus*

(d) *Anabaena spiroides* and *Microcystis aeruginosa*

a © M.I. Walker/Photo Researchers, Inc.; b © T.E. Adams/Visuals Unlimited; c © Ron Dengler/Visuals Unlimited; d © T.E. Adams/Visuals Unlimited

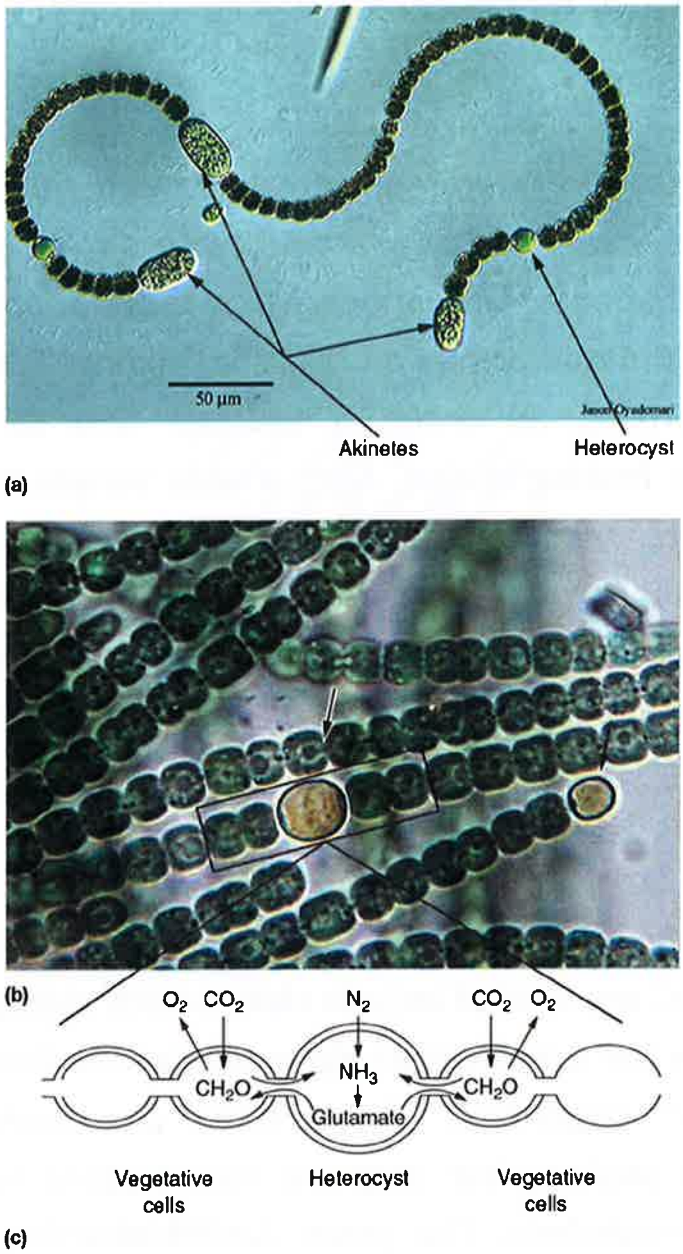
Pigmentation:

most appear blue-green due to presence of phycocyanin, presence of phycoerythrin in many ocean isolates gives them red or brown coloration cyanobacteria modulate the relative amounts of these pigments in aprocess known as chromatic adaption(modulation of pigment concentrations in different light),when orange light is sensed phycocyanin pigment is stimulated,whereas blue and blue –green light is sensed phycoerythrin pigment is stimulated. Many cyanobacteria species use gas vacuoles to position themselves in optimum illumination in water column – a form of Phototaxis.

Reproductive Cells and Structures:

Binary fission, budding, fragmentation, multiple fission .In the last process,a cell enlarges and then divides several times to produce many smaller progecncy,called **baeocytes** which are released upon rupture of the parental cell,, **Hormogonia**(which is a small, motile fragments of filamentous cyanobacteria).Some species develop **akinetes** (, specialized dormant, thick-walled resting cells resistant to desiccation, often germinate to form new filaments).

Many filamentous cyanobacteria fix nitrogen by means of special cells called **heterocysts,** thick heterocyst wall prevents O2 diffusion into heterocyst which would inactivate nitrogenase.



a: Jason K. Oyadomari, www.keweenawalgae.mtu.edu; b: Micrographia

Ecology of Cyanobacteria: Cyanobacteria may live in a wide range of habitat,some Tolerant of environmental extremes
thermophilic species can grow at temperatures up to 75°C, Cyanobacteria are
often primary colonizers, Can cause blooms in nutrient-rich ponds and lakes, some produce toxins that can kill animals that drink the water.

Volume 2of Bergey s manual of systemic Bacteriology

The Proteobacteria:

Characteristics: All "Proteobacteria" are gram-negative (though some may stain Gram-positive or Gram-variable in practice), with an outer membrane mainly composed of lipopolysaccharides. Many move about using flagella, but some are nonmotile or rely on bacterial gliding. The latter include the Myxobacteriales, an order of bacteria that can aggregate to form multicellular fruiting bodies. Also, a wide variety in the types of metabolism exists. Most members are facultatively or obligately anaerobic, chemolithoautotrophic, and heterotrophic, but numerous exceptions occur. A variety of genera, which are not closely related to each other, convert energy from light through photosynthesis.

Taxonomy:

The group is defined primarily in terms of ribosomal RNA (rRNA) sequences. The "Proteobacteria" are divided into six classes with validly published names, referred to by the Greek letters alpha through epsilon and the Acidithiobacillia and Oligoflexia. These were previously regarded as subclasses of the phylum, but they are now treated as classes. These classes are monophyletic. The genus Acidithiobacillus, part of the Gammaproteobacteria until it was transferred to class Acidithiobacillia in 2013, was previously regarded as paraphyletic to the Betaproteobacteria according to multigenome alignment studies. In 2017, the Betaproteobacteria was subject to major revisions and the class Hydrogenophilalia was created to contain the order Hydrogenophilales.

Proteobacterial classes with validly published names include some prominent genera:
Gammaproteobacteria: Escherichia, Shigella, Salmonella, Yersinia, Buchnera, Haemophilus, Vibrio, Pseudomonas, etc.
Deltaproteobacteria: Desulfovibrio, Geobacter, Bdellovibrio, etc.
Epsilonproteobacteria: Helicobacter, Campylobacter, Wolinella, etc.
Oligoflexia: Oligoflexus.
Acidithiobacillia: Acidithiobacillus thiooxidans, Thermithiobacillus tepidarius
Hydrogenophilalia: Hydrogenophilus thermoluteolus, Tepidiphilus margaritifer

Scientific classification

Domain:	Bacteria
Phylum:	Proteobacteria

Class
1-Alphaproteobacteria[3]
2-Betaproteobacteria
3-Hydrogenophilalia
4-Gammaproteobacteria
5-Acidithiobacillia
6-Deltaproteobacteria
7-Epsilonproteobacteria
8-Oligoflexia

Carl Woese established this grouping in 1987, calling it informally the "purple bacteria and their relatives". Because of the great diversity of forms found in this group, it was named after Proteus, a Greek god of the sea capable of assuming many different shapes and is not named after the genus Proteus.

1-Alphaproteobacteria: *Brucella, Rhizobium, Agrobacterium, Caulobacter, Rickettsia, Wolbachia,* etc.

Some Alphaproteobacteria can grow at very low levels of nutrients and have unusual morphology such as stalks and buds. Others include agriculturally important bacteria capable of inducing nitrogen fixation in symbiosis with plants. The type order is the Caulobacterales, comprising stalk-forming bacteria such as Caulobacter. Caulobacter crescentus

Scientific classification

Kingdom: Bacteria

Phylum: Proteobacteria

Class: Alphaproteobacteria

Order: Caulobacterales

Family: Caulobacteraceae

Genus: *Caulobacter*

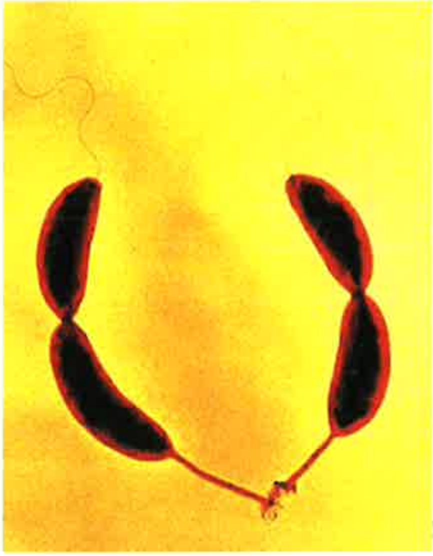
Species: *C. crescentus*

Binomial name

Caulobacter crescentus

Caulobacter crescentus is a Gram-negative, oligotrophic bacterium widely distributed in fresh water lakes and streams.

Caulobacter is an important model organism for studying the regulation of the cell cycle, asymmetric cell division, and cellular differentiation. *Caulobacter* daughter cells have two very different forms. One daughter is a mobile "swarmer" cell that has a single flagellum at one cell pole that provides swimming motility for chemotaxis. The other daughter, called the "stalked" cell has a tubular stalk structure protruding from one pole that has an adhesive holdfast material on its end, with which the stalked cell can adhere to surfaces.



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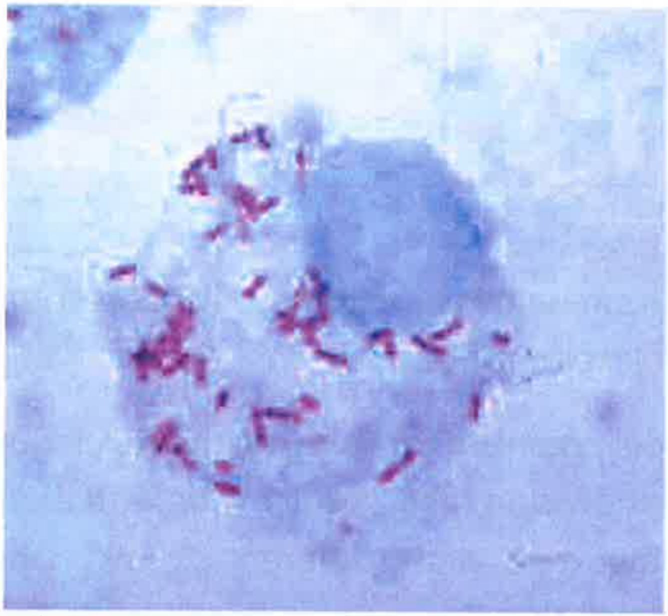
Domain: Bacteria
Phylum: Proteobacteria
Class: Alphaproteobacteria
Subclass: Rickettsidae
Order: Rickettsiales
Family: Rickettsiaceae
Genus: *Rickettsia*



Berleman et al., Hypercyst Mutants in Rhodospirillum centenum Identify Regulatory Loci Involved in Cyst Cell Differentiation J. Bacteriol. 2004 186, fig. 1, pg. 5836

(above photo)A thick hemolymph cell filled with Rickettsia rickettsia the causative agent of Rockey mountain spotted fever

Rickettsia is a genus of nonmotile, gram-negative, nonspore-forming, highly pleomorphic bacteria that can be present as cocci (0.1 μm in diameter), rods (1–4 μm long), or thread-like (10 μm long). The term rickettsia, named after Howard Taylor Ricketts, is often used interchangeably for any member of the Rickettsiales. Being obligate intracellular parasites, the Rickettsia survival depends on entry, growth, and replication within the cytoplasm of eukaryotic host cells (typically endothelial cells) Rickettsia cannot live in artificial nutrient environments and is grown either in tissue or embryo cultures; typically, chicken embryos are used,.

*Rickettsi*a species are transmitted by numerous types of arthropod, including chigger, ticks, fleas, and lice, and are associated with both human and plant disease. Most notably, *Rickettsia* species are the pathogens responsible for many diseases.

Domain: Bacteria

Phylum: Proteobacteria

Class: Alphaproteobacteria

Order: Rhizobiales

Family: Brucellaceae

Genus: *Brucella*

Brucella is a genus of Gram-negative bacteria named after David Bruce (1855–1931). They are small (0.5 to 0.7 by 0.6 to 1.5 µm), nonencapsulated, nonmotile, facultatively intracellular coccobacilli.

Brucella is the cause of brucellosis, which is a zoonosis transmitted by ingesting contaminated food (such as unpasteurized milk products), direct contact with an infected animal, or inhalation of aerosols. Transmission from human to human, for example through sexual intercourse or from mother to child, is exceedingly rare, but possible. Minimum infectious exposure is between 10 and 100 organisms.

The different species of *Brucella* are genetically very similar, although each has slightly different host specificity. Hence, the NCBI taxonomy includes most *Brucella* species under *B. melitensis*.

The many names of brucellosis include (human disease/animal disease):

Malta fever/Bang's disease, Undulant fever/enzootic abortion, Mediterranean fever/epizootic abortion

2-Class *Betaproteobacteria*:

The *Betaproteobacteria* are a class comprising over 75 genera and 400 species of bacteria..Together, the *Betaproteobacteria* represent a broad variety of metabolic strategies and occupy diverse environments from obligate pathogens living within host organisms to oligotrophic groundwater ecosystems. Whilst most members of the *Betaproteobacteria* are heterotrophic, deriving both their carbon and electrons from organocarbon sources, some are photoheterotrophic, deriving energy from light and carbon from organocarbon sources. Other genera are autotrophic, deriving their carbon from bicarbonate or carbon dioxide and their electrons from reduced inorganic ions such as nitrite, ammonium, thiosulfate or sulfide, - many of these chemolithoautotrophic Betaproteobacteria are economically important, with roles in maintaining soil pH and in elementary cycling. Other economically important members of the Betaproteobacteria are able to use nitrate as their terminal electron acceptor and can be used industrially to remove nitrate from wastewater by denitrification. A number of *Betaproteobacteria* are diazotrophs, meaning that they can fix molecular nitrogen from the air as their nitrogen source for growth - this is important to the farming industry as it is a primary means of ammonium levels in soils rising without the presence of leguminous plants.

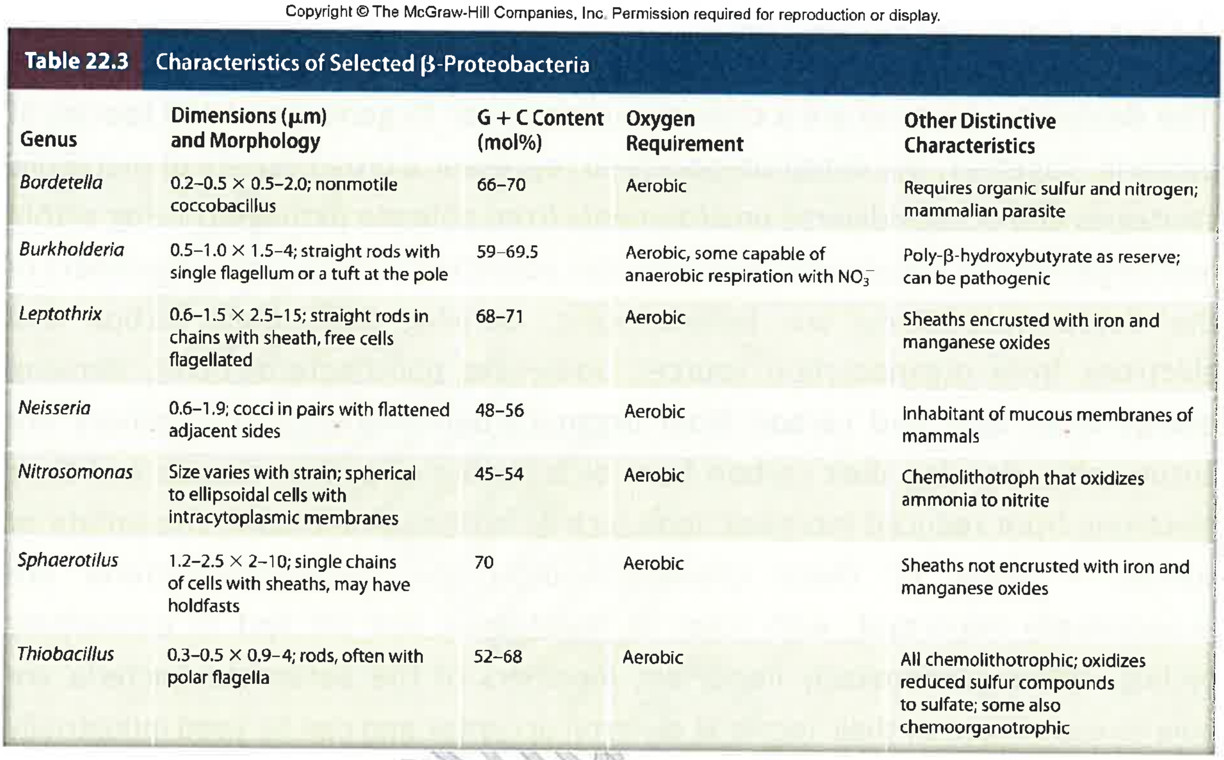


Table 22.3 Characteristics of Selected β-Proteobacteria

Genus	Dimensions (μm) and Morphology	G + C Content (mol%)	Oxygen Requirement	Other Distinctive Characteristics
Bordetella	0.2–0.5 × 0.5–2.0; nonmotile coccobacillus	66–70	Aerobic	Requires organic sulfur and nitrogen; mammalian parasite
Burkholderia	0.5–1.0 × 1.5–4; straight rods with single flagellum or a tuft at the pole	59–69.5	Aerobic, some capable of anaerobic respiration with NO_3^-	Poly-β-hydroxybutyrate as reserve; can be pathogenic
Leptothrix	0.6–1.5 × 2.5–15; straight rods in chains with sheath, free cells flagellated	68–71	Aerobic	Sheaths encrusted with iron and manganese oxides
Neisseria	0.6–1.9; cocci in pairs with flattened adjacent sides	48–56	Aerobic	Inhabitant of mucous membranes of mammals
Nitrosomonas	Size varies with strain; spherical to ellipsoidal cells with intracytoplasmic membranes	45–54	Aerobic	Chemolithotroph that oxidizes ammonia to nitrite
Sphaerotilus	1.2–2.5 × 2–10; single chains of cells with sheaths, may have holdfasts	70	Aerobic	Sheaths not encrusted with iron and manganese oxides
Thiobacillus	0.3–0.5 × 0.9–4; rods, often with polar flagella	52–68	Aerobic	All chemolithotrophic; oxidizes reduced sulfur compounds to sulfate; some also chemoorganotrophic

الجدول للاطلاع

Role in disease:Some members of the Betaproteobacteria can cause disease in various eukaryotic organisms, including in humans, such as members of the genus *Neisseria*: *N. gonorrhoeae* and *N. meninngit*ides being primary examples, which cause gonorrhea and meningitis respectively, as well as *Bordetella pertussis* which causes whooping cough. Other members of the class can infect plants, such as *Burkholderia cepa*cia which can degrades >100 organic molecules, very active in recycling organic material, Plant pathogen, Has become a major nosocomial pathogen

Economic Importance:

Various human activities, such as fertilizer production and chemical plant usage, release significant amounts of ammonium ions into rivers and oceans. Ammonium buildup in aquatic environments is potentially dangerous because high ammonium content can lead to eutrophication. Biological wastewater treatment systems, as well as other biological ammonium-removing methods, depend on the metabolism of various Bacteria including members of the *Nitrosomonadales* of the *Betaproteobac*teria that undergo nitrification and a wide range of organisms capable of denitrification to remove excessive ammonia from wastewater by first oxidation into nitrate and then nitrite and then reduction into molecular nitrogen gas, which leaves the ecosystem and is carried into the atmosphere.

3-Class *Hydrogenophilalia*

Scientific classification

Kingdom: Bacteria

Phylum: *Proteobacteria*

Class: *Hydrogenophilalia*

Order *Hydrogenophilales*

class *Hydrogenophilalia* in the Bacteria was circumscribed in 2017 when it was demonstrated that the order Hydrogenophilales was distinct from the *Betaproteobacteria* on the basis of physiology, biochemistry, fatty acid profiles, and phylogenetic analyses on the basis of the 16S rRNA gene and 53 ribosomal protein sequences concatenated .

Scientific classification

Kingdom: Bacteria

Phylum: *Proteobacteria*

Class: *Hydrogenophilalia*

Order *Hydrogenophilales*

4-class *Gammaproteobacteria* comprises several medically and scientifically important groups of bacteria, such as the *Enterobacteriaceae, Vibrionaceae, and Pseudomonadaceae.* A number of important pathogens belong to this class, e.g. *Salmonella* spp. (enteritis and typhoid fever), *Yersinia pestis* (plague), *Vibrio cholerae* (cholera), *Pseudomonas aeruginosa* (lung infections in hospitalized or cystic fibrosis patients), and *Escherichia coli* (food poisoning). Important plant pathogens such as *Pseudomonas syringae*. Members of *Chromatium* are photosynthetic and oxidize hydrogen sulfide instead of water, producing sulfur as a waste product. Some *Gammaproteobacteria* are methane oxidizers, and many are symbiotic with geothermic ocean vent-dwelling animals.

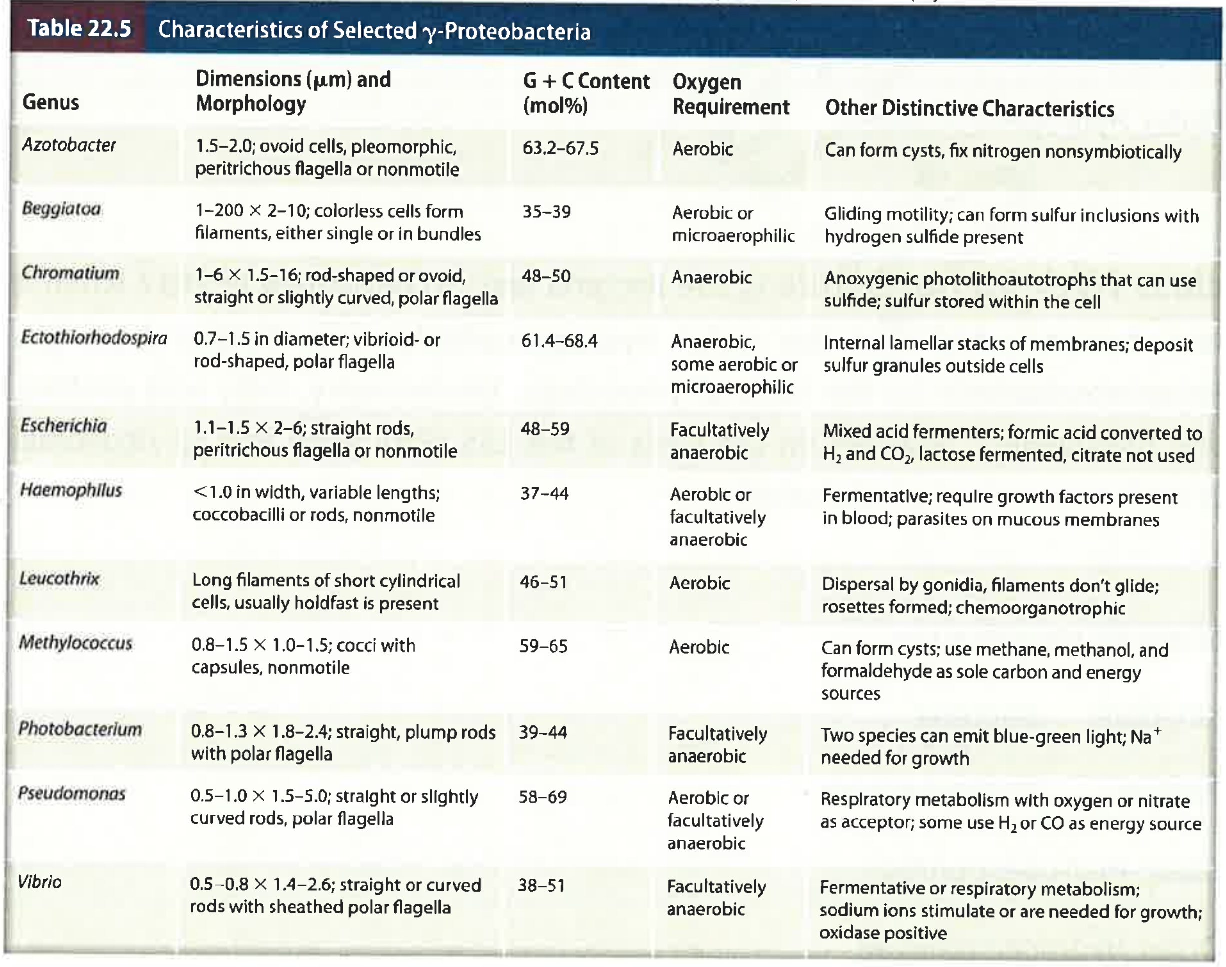


Table 22.5 Characteristics of Selected γ-Proteobacteria

Genus	Dimensions (μm) and Morphology	G + C Content (mol%)	Oxygen Requirement	Other Distinctive Characteristics
Azotobacter	1.5–2.0; ovoid cells, pleomorphic, peritrichous flagella or nonmotile	63.2–67.5	Aerobic	Can form cysts, fix nitrogen nonsymbiotically
Beggiatoa	1–200 × 2–10; colorless cells form filaments, either single or in bundles	35–39	Aerobic or microaerophilic	Gliding motility; can form sulfur inclusions with hydrogen sulfide present
Chromatium	1–6 × 1.5–16; rod-shaped or ovoid, straight or slightly curved, polar flagella	48–50	Anaerobic	Anoxygenic photolithoautotrophs that can use sulfide; sulfur stored within the cell
Ectothiorhodospira	0.7–1.5 in diameter; vibrioid- or rod-shaped, polar flagella	61.4–68.4	Anaerobic, some aerobic or microaerophilic	Internal lamellar stacks of membranes; deposit sulfur granules outside cells
Escherichia	1.1–1.5 × 2–6; straight rods, peritrichous flagella or nonmotile	48–59	Facultatively anaerobic	Mixed acid fermenters; formic acid converted to H_2 and CO_2, lactose fermented, citrate not used
Haemophilus	<1.0 in width, variable lengths; coccobacilli or rods, nonmotile	37–44	Aerobic or facultatively anaerobic	Fermentative; require growth factors present in blood; parasites on mucous membranes
Leucothrix	Long filaments of short cylindrical cells, usually holdfast is present	46–51	Aerobic	Dispersal by gonidia, filaments don't glide; rosettes formed; chemoorganotrophic
Methylococcus	0.8–1.5 × 1.0–1.5; cocci with capsules, nonmotile	59–65	Aerobic	Can form cysts; use methane, methanol, and formaldehyde as sole carbon and energy sources
Photobacterium	0.8–1.3 × 1.8–2.4; straight, plump rods with polar flagella	39–44	Facultatively anaerobic	Two species can emit blue-green light; Na^+ needed for growth
Pseudomonas	0.5–1.0 × 1.5–5.0; straight or slightly curved rods, polar flagella	58–69	Aerobic or facultatively anaerobic	Respiratory metabolism with oxygen or nitrate as acceptor; some use H_2 or CO as energy source
Vibrio	0.5–0.8 × 1.4–2.6; straight or curved rods with sheathed polar flagella	38–51	Facultatively anaerobic	Fermentative or respiratory metabolism; sodium ions stimulate or are needed for growth; oxidase positive

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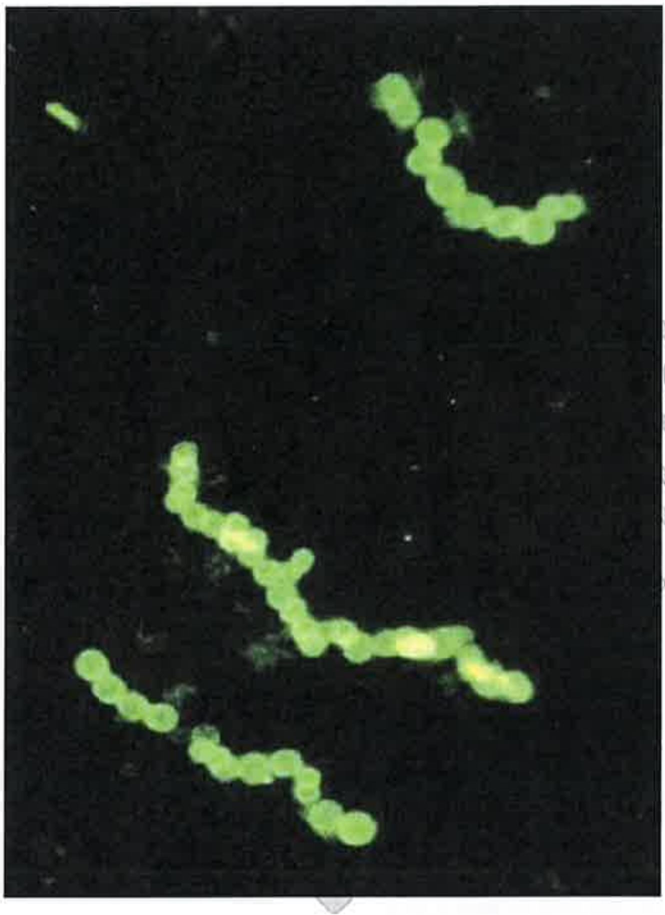
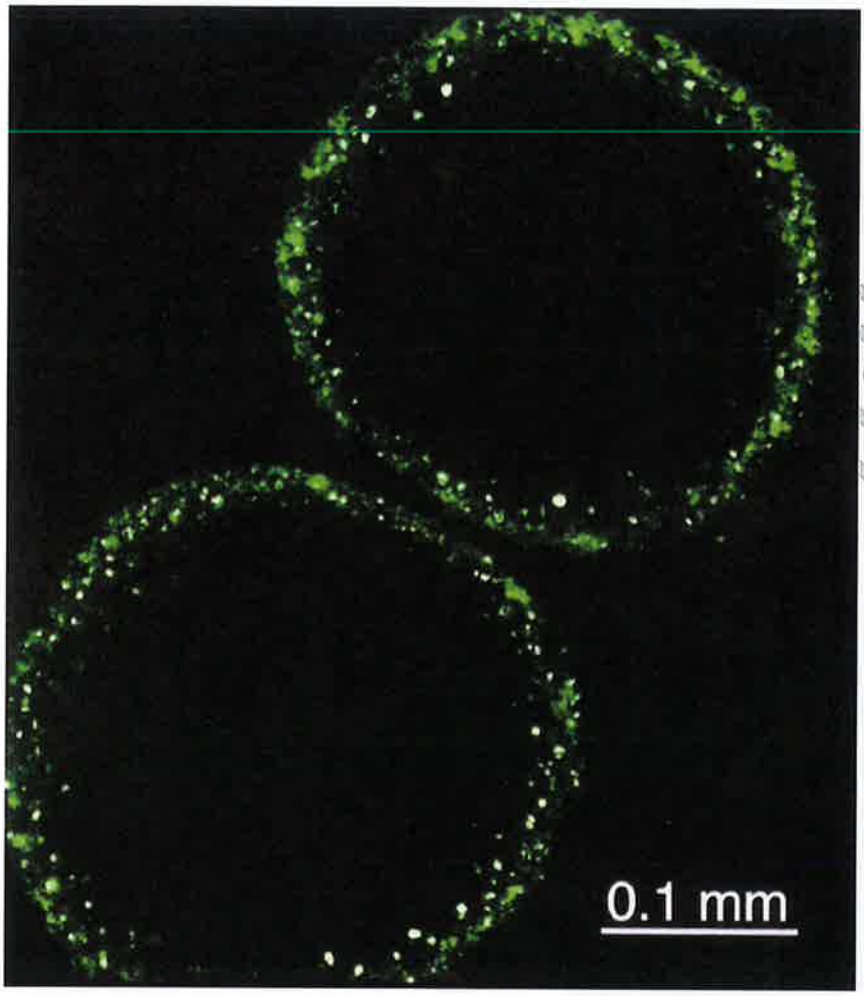
Stained micrograph of *Thiomargarita namibiensis*





Reprinted with permission from Schulz; H.N., Brinkhoff, T., Ferdelman, T.G., Hernandez Marine, M., Teske, A., and Jorgensen, B.B. 1999. Dense Populations of a Giant Sulfur Bacterium in Namibian Shelf Sediments. *Science* 284, 493–495, fig 1. © 1999 AAAS. Image courtesy of Heide Schulz

With their lack of movement, *Thiomargarita* have adapted by evolving very large nitrate-storing bubbles, called vacuoles, allowing them to survive long periods of nitrate and sulfide starvation. The vacuoles give them the ability to stay immobile, just waiting for nitrate-rich waters to sweep over them once again. These vacuoles are what account for the size that scientists had previously thought impossible. Scientists disregarded large bacterium, because bacteria rely on diffusion to move chemicals around, a process that works only over tiny distances. This implies that the cytoplasm has to be close to the cell wall, greatly limiting their size. But *Thiomargarita* are an exception to this size constraint, as their cytoplasm forms along the periphery of the cell, while the nitrate-storing vacuoles occupy the center of the cell. As these vacuoles swell, they greatly contribute to the record-holding size. It holds the record for the world's largest bacteria, with a volume three million times more than that of the average bacteria.

Domain: Bacteria

Phylum: *Proteobacteria*

Class: *Gammaproteobacteria*

Order: *Thiotrichales*

Family: *Thiotrichaceae*

Genus: *Thiomargarita*

Species: *T. namibiensis*

Binomial name

Thiomargarita namibiensis

Schulz et al., 1999

Thiomargarita namibiensis is a gram-negative coccoid Proteobacterium, found in the ocean sediments of the continental shelf of Namibia. It is the largest bacterium ever discovered, as a rule 0.1–0.3 mm (100–300 µm) in diameter, but sometimes attaining 0.75 mm (750 µm). Cells of *Thiomargarita namibiensis* are large enough to be visible to the naked eye.

The *Enterobacteriace*ae are a large family of Gram-negative bacteria that includes, along with many harmless symbionts, many of the more familiar pathoge*ns, such as* Salmonella, *Escherichia coli, Yersinia pestis, Klebsiella, and Shigella.* Other disease-causing bacteria in this family include *Proteus, Enterobacter, Serratia, and Citrobacter.* This family is the only representative in the order *Enterobacteriales* of the class *Gammaproteobacteria* in the phylum *Proteobacteria.*

Scientific classification

Domain: Bacteria

Phylum: *Proteobacteria*

Class: *Gammaproteobacteria*

Order: *Enterobacteriales*

Family: *Enterobacteriaceae*

Rahn, 1937

5- class Acidith iobacillia is a of the "Proteobacteria". Its type order, the Acidithiobacillales, was formerly classified within the Gammaproteobacteria,

Domain: Bacteria

Kingdom: *Eubacteria*

Phylum: *Proteobacteria*

Class: *Acidithiobacillia*

Order: *Acidithiobacillales*

Family: *Acidithiobacillaceae*

Genus: *Acidithiobacillus*

Acidithiobacillus is a genus of the *Acidithiobacillia* in the "*Proteobacteria*". Like all "Proteobacteria", *Acidithiobacillus* spp. are Gram-negative. Some members of this genus were classified as *Thiobacillus* spp., before they were reclassified in 2000.

Acidithiobacillus ferrooxidans (basonym *Thiobacillus ferrooxidans*) can be isolated from iron-sulfur minerals such as pyrite deposits, oxidising iron and sulfur as energy sources to support autotrophic growth and producing ferric iron and sulfuric acid. Acidithiobacillus thiooxidans (basonym Thiobacillus thiooxidans, Thiobacillus concretivorus oxidizes sulfur and produces sulfuric acid; first isolated from the soil, it has also been observed causing biogenic sulfide corrosion of concrete sewer pipes by altering hydrogen sulfide in sewage gas into sulfuric acid.

6- class Deltaproteobacteria comprise a branch of predominantly aerobic genera, the fruiting body-forming Myxobacteria which release myxospores in unfavorable environments, and a branch of strictly anaerobic genera, which contains most of the known sulfate- (Desulfovibrio, Desulfobacter, Desulfococcus, Desulfonema, etc.) and sulfur-reducing bacteria (e.g. spp.) alongside several other anaerobic bacteria with different (e.g. ferric iron-reducing Geobacter spp. A pathogenic intracellular Deltaproteobacterium has recently been identified.

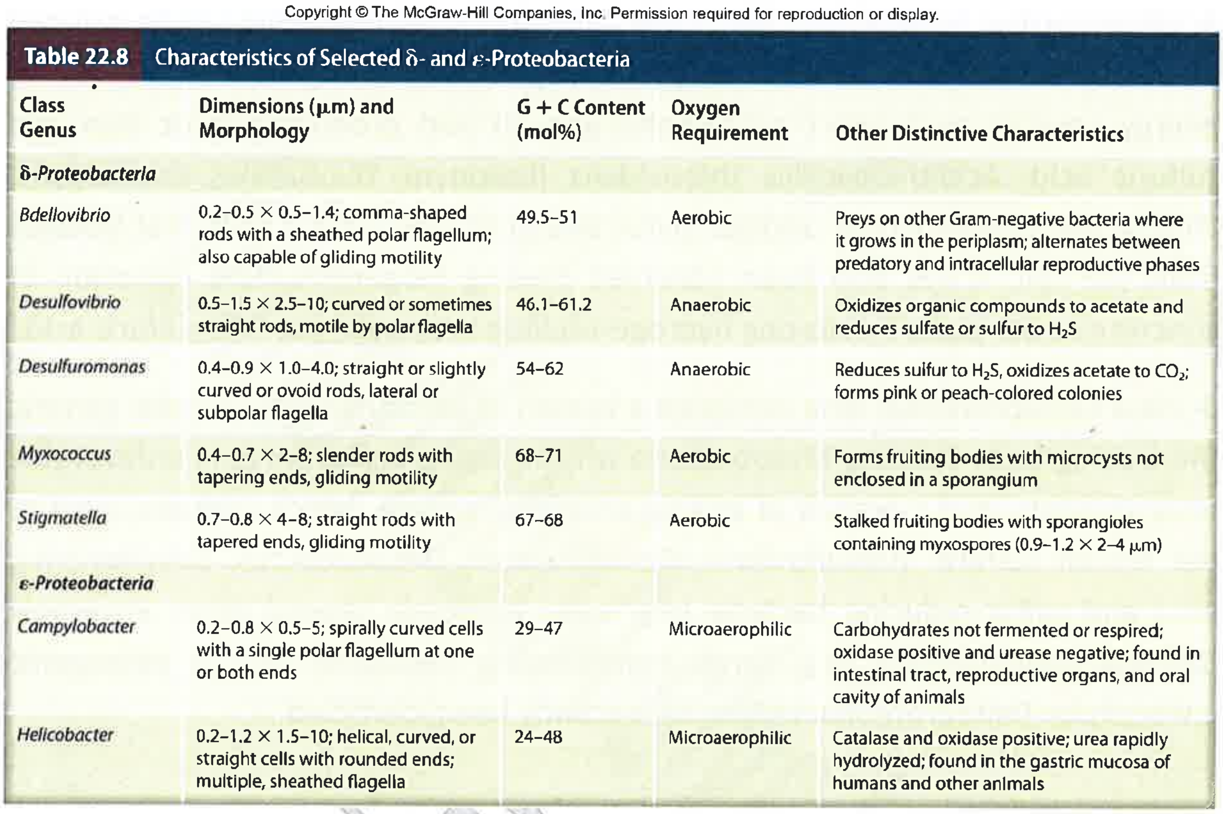


Table 22.8 Characteristics of Selected δ- and ε-Proteobacteria

Class Genus	Dimensions (μm) and Morphology	G + C Content (mol%)	Oxygen Requirement	Other Distinctive Characteristics
δ-Proteobacteria				
Bdellovibrio	0.2–0.5 × 0.5–1.4; comma-shaped rods with a sheathed polar flagellum; also capable of gliding motility	49.5–51	Aerobic	Preys on other Gram-negative bacteria where it grows in the periplasm; alternates between predatory and intracellular reproductive phases
Desulfovibrio	0.5–1.5 × 2.5–10; curved or sometimes straight rods, motile by polar flagella	46.1–61.2	Anaerobic	Oxidizes organic compounds to acetate and reduces sulfate or sulfur to H_2S
Desulfuromonas	0.4–0.9 × 1.0–4.0; straight or slightly curved or ovoid rods, lateral or subpolar flagella	54–62	Anaerobic	Reduces sulfur to H_2S, oxidizes acetate to CO_2; forms pink or peach-colored colonies
Myxococcus	0.4–0.7 × 2–8; slender rods with tapering ends, gliding motility	68–71	Aerobic	Forms fruiting bodies with microcysts not enclosed in a sporangium
Stigmatella	0.7–0.8 × 4–8; straight rods with tapered ends, gliding motility	67–68	Aerobic	Stalked fruiting bodies with sporangioles containing myxospores (0.9–1.2 × 2–4 μm)
ε-Proteobacteria				
Campylobacter	0.2–0.8 × 0.5–5; spirally curved cells with a single polar flagellum at one or both ends	29–47	Microaerophilic	Carbohydrates not fermented or respired; oxidase positive and urease negative; found in intestinal tract, reproductive organs, and oral cavity of animals
Helicobacter	0.2–1.2 × 1.5–10; helical, curved, or straight cells with rounded ends; multiple, sheathed flagella	24–48	Microaerophilic	Catalase and oxidase positive; urea rapidly hydrolyzed; found in the gastric mucosa of humans and other animals

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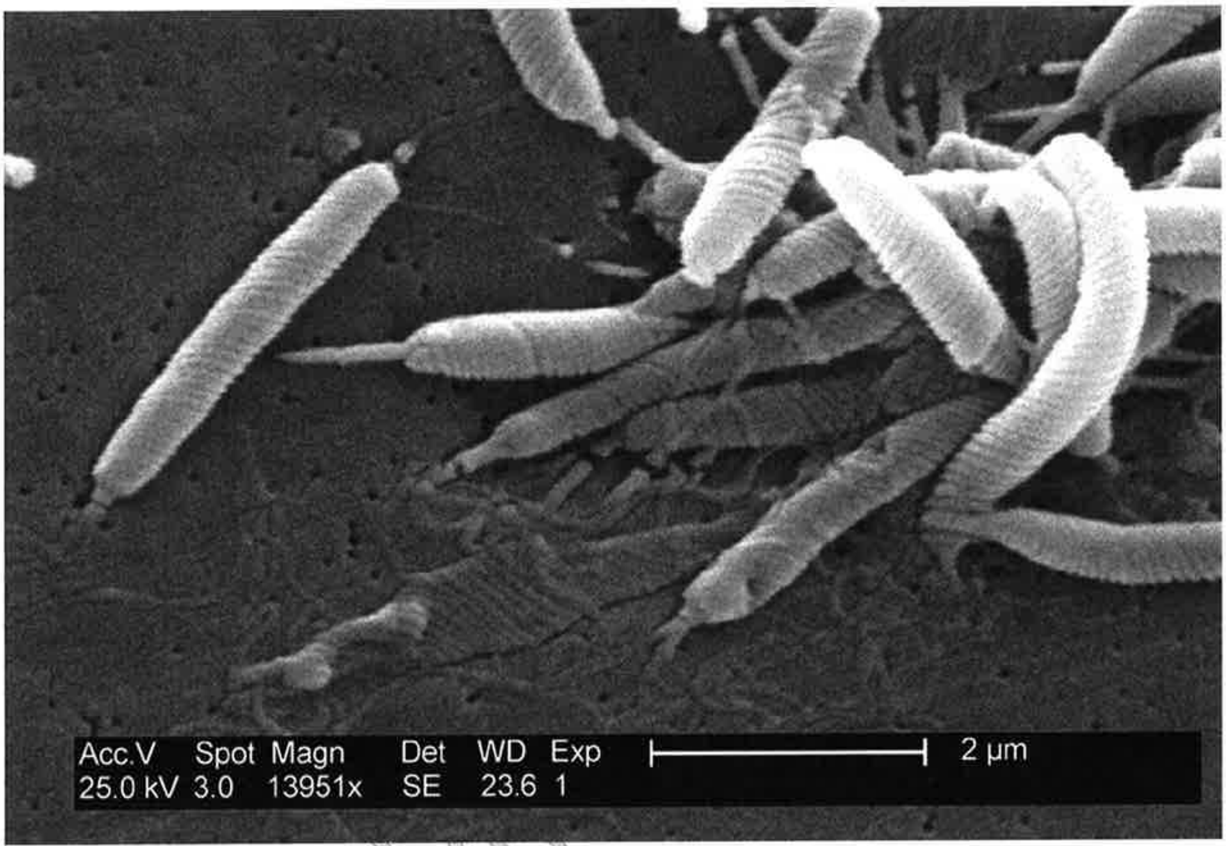
7-class *Epsilonproteobacteria* consist of few known genera, mainly the curved to spirilloid , *Helicobacter* spp., and *Campylobacter* spp. Most of the known species inhabit the digestive tracts of animals and serve as pathogens (*Helicobacter* spp. in the stomach, *Campylobacter* spp. in the duodenum).



Scanning electron micrograph of Helicobacter bacteria

Scientific classification

Domain: Bacteria

Phylum: *Proteobacteria*

Class: *Epsilonproteobacteria*

Order: *Campylobacterales*

Family: *Helicobacteraceae*

Genus: *Helicobacter*

Goodwin et al. 1989

Helicobacter is a genus of Gram-negative bacteria possessing a characteristic helical shape. They were initially considered to be members of the *Campylobacter* genus, but in 1989, Goodwin et al. published sufficient reasons to justify the new genus name *Helicobacter*. Some species have been found living in the lining of the upper gastrointestinal tract, as well as the liver of mammals and some birds. The most widely known species of the genus is H. pylori, which infects up to 50% of the human population. It also serves as the type species of the genus. Some strains of this bacterium are pathogenic to humans, as they are strongly associated with peptic ulcers, chronic gastritis, duodenitis, and stomach cancer. Helicobacter species are able to thrive in the very acidic mammalian stomach by producing large quantities of the enzyme urease, which locally raises the pH from about 2 to a more biocompatible range of 6 to 7. Bacteria belonging to this genus are usually susceptible to antibiotics such as penicillin, are microaerophilic

Most Campylobacter species can cause disease and can infect humans and other animals. The bacterium's main reservoir is poultry, humans can contract the disease from eating food contaminated with Campylobacter species. Another source of infection is contact with infected animals, which often carry Campylobacter asymptomatically. At least a dozen species of Campylobacter have been implicated in human disease, with C. jejuni and C. coli being the most common. C. jejuni is now recognized as one of the main causes of bacterial foodborne disease in many developed countries.

Scientific classification

Domain: Bacteria

Phylum: *Proteobacteria*

Class: *Epsilonproteobacteria*

Order: *Campylobacterales*

Family: *Campylobacteraceae*

Genus: *Campylobacter*

Sebald & Véron, 1963

Class *Bacilli:*

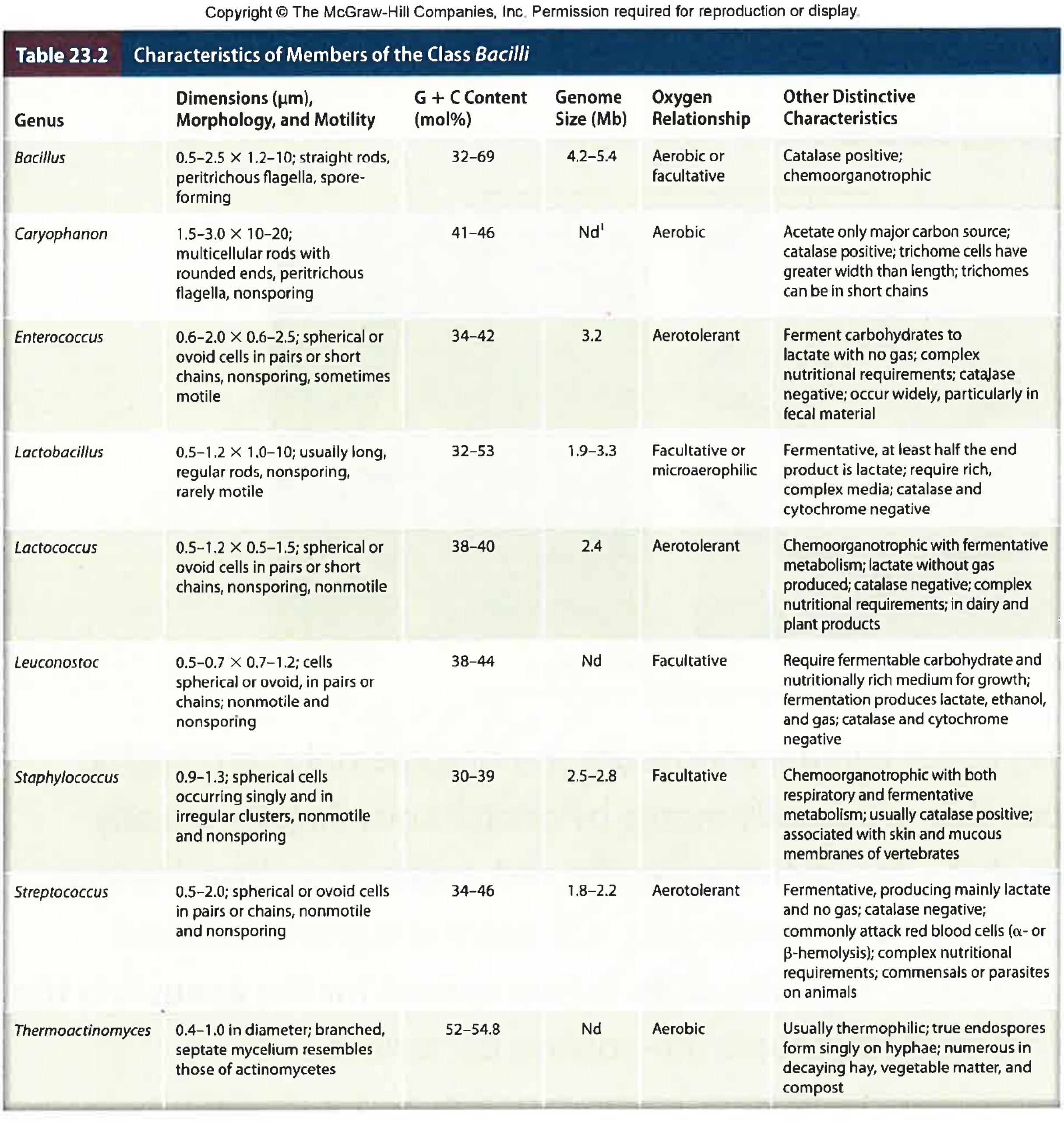


Table 23.2 Characteristics of Members of the Class *Bacilli*

Genus	Dimensions (µm), Morphology, and Motility	G + C Content (mol%)	Genome Size (Mb)	Oxygen Relationship	Other Distinctive Characteristics
Bacillus	0.5–2.5 × 1.2–10; straight rods, peritrichous flagella, spore-forming	32–69	4.2–5.4	Aerobic or facultative	Catalase positive; chemoorganotrophic
Caryophanon	1.5–3.0 × 10–20; multicellular rods with rounded ends, peritrichous flagella, nonsporing	41–46	Nd[1]	Aerobic	Acetate only major carbon source; catalase positive; trichome cells have greater width than length; trichomes can be in short chains
Enterococcus	0.6–2.0 × 0.6–2.5; spherical or ovoid cells in pairs or short chains, nonsporing, sometimes motile	34–42	3.2	Aerotolerant	Ferment carbohydrates to lactate with no gas; complex nutritional requirements; catalase negative; occur widely, particularly in fecal material
Lactobacillus	0.5–1.2 × 1.0–10; usually long, regular rods, nonsporing, rarely motile	32–53	1.9–3.3	Facultative or microaerophilic	Fermentative, at least half the end product is lactate; require rich, complex media; catalase and cytochrome negative
Lactococcus	0.5–1.2 × 0.5–1.5; spherical or ovoid cells in pairs or short chains, nonsporing, nonmotile	38–40	2.4	Aerotolerant	Chemoorganotrophic with fermentative metabolism; lactate without gas produced; catalase negative; complex nutritional requirements; in dairy and plant products
Leuconostoc	0.5–0.7 × 0.7–1.2; cells spherical or ovoid, in pairs or chains; nonmotile and nonsporing	38–44	Nd	Facultative	Require fermentable carbohydrate and nutritionally rich medium for growth; fermentation produces lactate, ethanol, and gas; catalase and cytochrome negative
Staphylococcus	0.9–1.3; spherical cells occurring singly and in irregular clusters, nonmotile and nonsporing	30–39	2.5–2.8	Facultative	Chemoorganotrophic with both respiratory and fermentative metabolism; usually catalase positive; associated with skin and mucous membranes of vertebrates
Streptococcus	0.5–2.0; spherical or ovoid cells in pairs or chains, nonmotile and nonsporing	34–46	1.8–2.2	Aerotolerant	Fermentative, producing mainly lactate and no gas; catalase negative; commonly attack red blood cells (α- or β-hemolysis); complex nutritional requirements; commensals or parasites on animals
Thermoactinomyces	0.4–1.0 in diameter; branched, septate mycelium resembles those of actinomycetes	52–54.8	Nd	Aerobic	Usually thermophilic; true endospores form singly on hyphae; numerous in decaying hay, vegetable matter, and compost

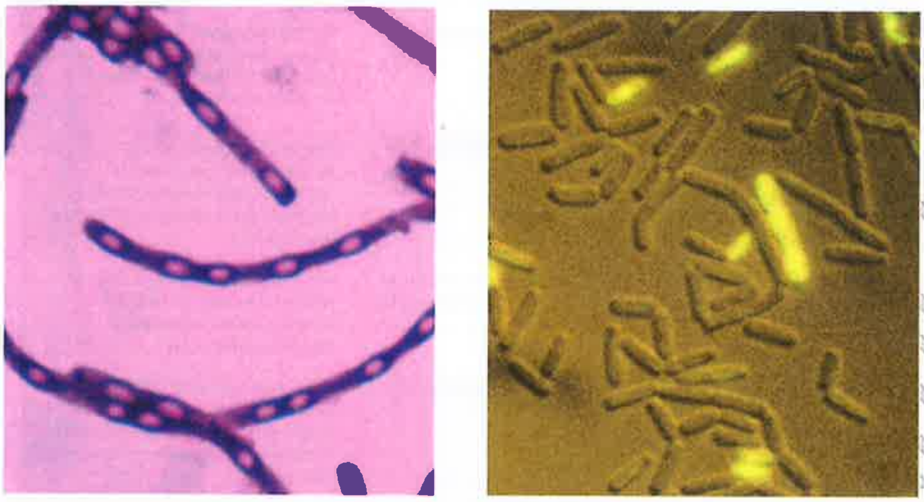
[1] Nd: Not determined; genome not yet sequenced.

The class *Bacilli* is very large contains two orders, *Bacillales* and *Lactobacillales,* 17 families and over 70 genera ,include variety of Gram-positive organisms cocci orendospore forming rod.

Order *Bacillales*

Family *Bacillaceae*

Genus *Bacillus*:



(a) *Bacillus anthracis* **(b)** *B. cereus*

a: © Arthur M. Siegelman/Visuals Unlimited; b: Courtesy of Molecular Probes, Inc.

This genus contain endospore forming chemoheterotrophic rods that are usually motile by peritrichous flagella, usually aerobic or facultative anaerobe and catalase positive, Various species produce antibiotics e.g. bacitracin,gramicidin and polymyxin., Bacillus subtilis is type species for the genus it is the most studied genus Gram-positive bacterium.

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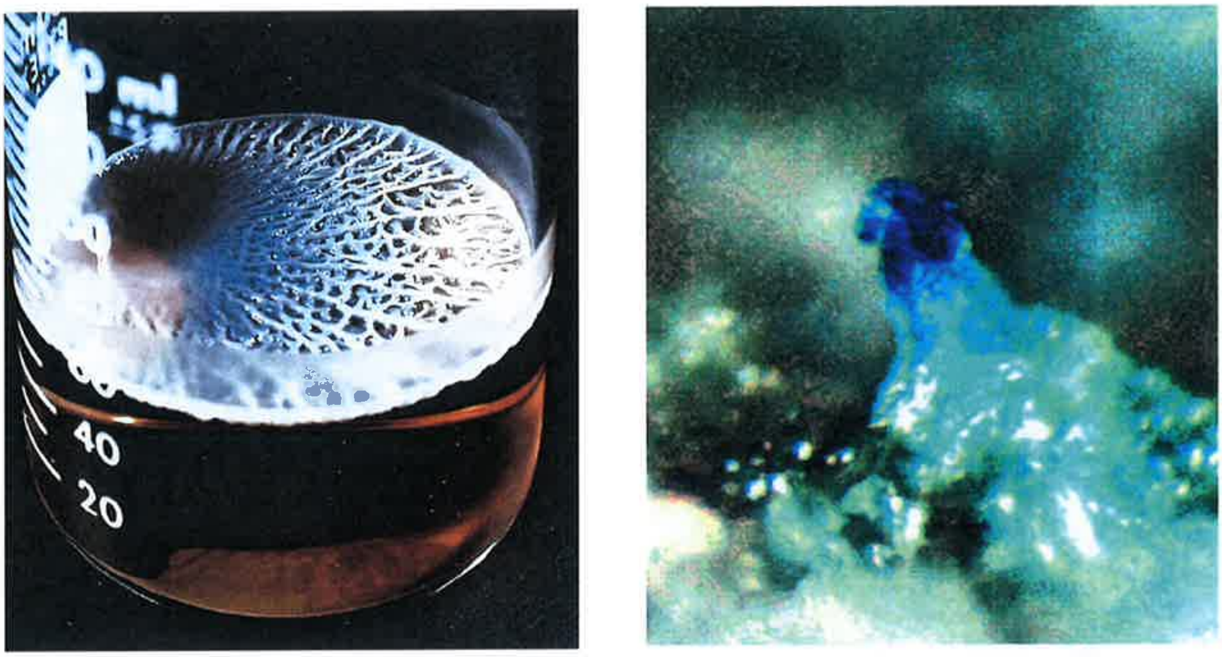
Bacillus subtilis is a soil-dwelling, spore forming,may develop biofilms made up of vegetative cells at the base and differentiated structures containing spores at the tip.



(a) Biofilm formation

(b) Fruiting body formation

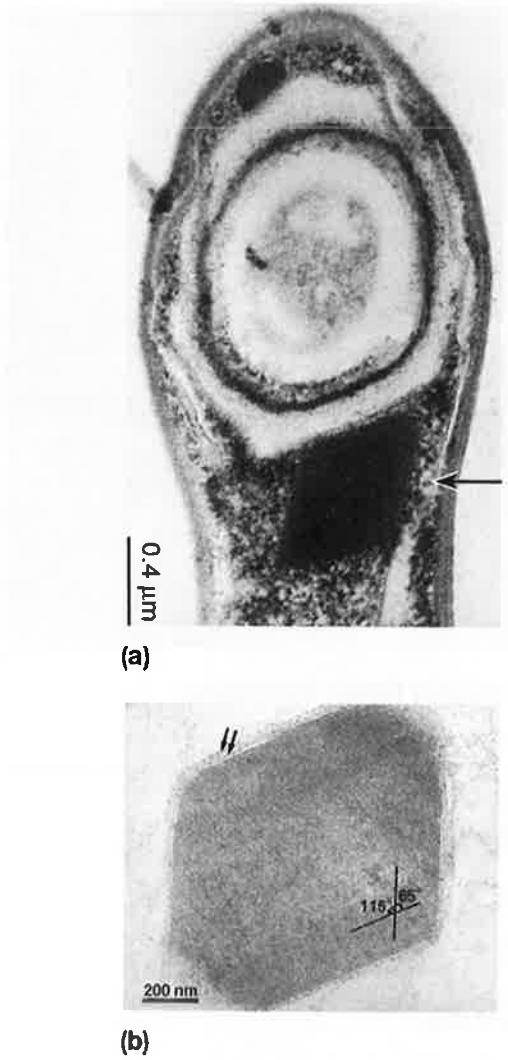
Branda et al., Proc. Nat. Acad. *Science* 25 Dept. 2001, vol. 98, fi g 1A, p. 11623 Copyright National Academy of Sciences, U.S.A.

(Above) biofilm formation by*Bacillus subtilis*

B. cereus –causes food poisoning

*B. anthrac*is – causes the disease anthrax

B. thuringiensis and *B. sphaericus* – used as insecticide both form a solid protein crystal that contains toxin,the parasporal body , next to their endospores during endospore formation.



a: Courtesy of Dr. A.A. Yousten; b: From H. de Barjac & J.F. Charles, Une nouvelle toxine active sur les moustiques, presente dans des inclusions cristallines produites par Bacillus sphaericus, C.R. Acad. Sci. Paris ser. II: 296: 905–910, 1983

a-an electron micrograph of B. sphaericus sporulating cell containing a parasporal body

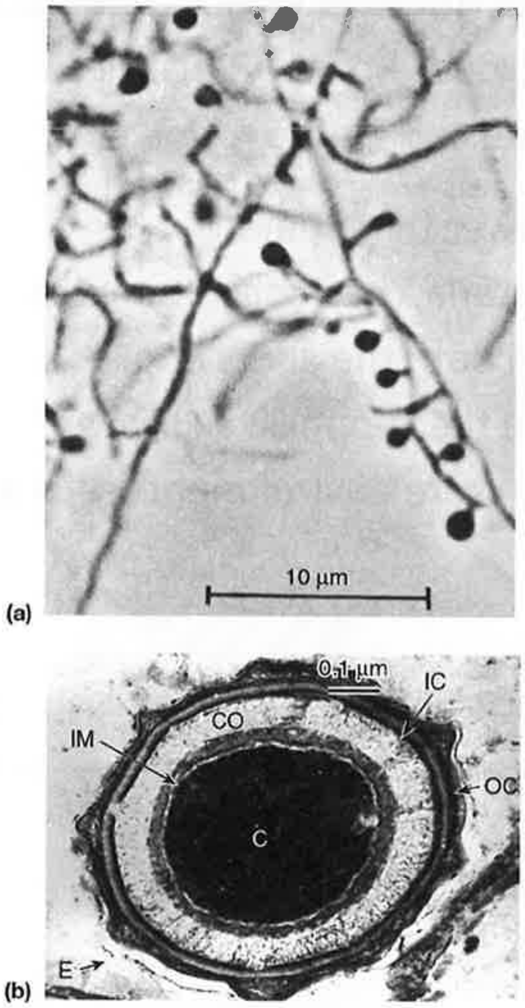
b-the crystalline parasporal body

Genus *Thermoactinomyces*:

Historically classified as actinomycete because like these microbes, their soil association substrate hyphae differentiate into upwardly growing aerial hyphae.However Phylogenetic analysis places it with low G + C microbes in order Bacillales, family ThermoactinomycetaceaeTrue endospore former.

Their G + C content is considered lower than that of actinobacteria.also unlike actinobacteria,Thermoactinomyces species form true endosporeswithin both the aerial and substrate hyphae.These bacteria are thermophilic ,and grow between 45-60 cfound in high temperature environments such as composts.

May be cause of farmer’s lung



a: From M.P. Starr, et al. (Eds.), *The Prokaryotes*, Springer-Verlag; b: From S.T. Williams, M.E. Sharpe and J.G. Holt (Eds.), *Bergey's Manual of Systematic Bacteriology*, Vol. 4, © 1989 Williams and Wilkins Co., Baltimore

a-*Thermoactinomyces*,aerial mycelium with endospore at tip of hyphae b-thin section of *Thermoactinomyces* endospore

Domain: *Bacteria*

phylum: *Firmicutes*

Class: *Bacilli*

Order: *Bacillales*

Family: *Panococcaceae*

Genus: *Sporosarcina*

Species: *Sporosarcina ureae*

(Beijerinck 1901) Kluyver and van Niel 1936

Sporosarcina ureae is a type of bacteria of the genus *Sporosarcina*, and is closely related to the genus Bacillus. S. ureae is an aerobic, motile, spore-forming, Gram-positive coccus, originally isolated in the early 20th century from soil. S. ureae is distinguished by its ability to grow in relatively high concentrations of urea through production of at least one exourease, an enzyme that converts urea to ammonia. S. ureae has also been found to sporulate when environmental conditions become unfavorable, and can remain viable for up to a year .

Only known endospore - former that has coccoid and not rod shape

Tolerates pH up to 10

degrades urea to ammonia and carbon dioxide

Isolated from agricultural soils where animals urinate

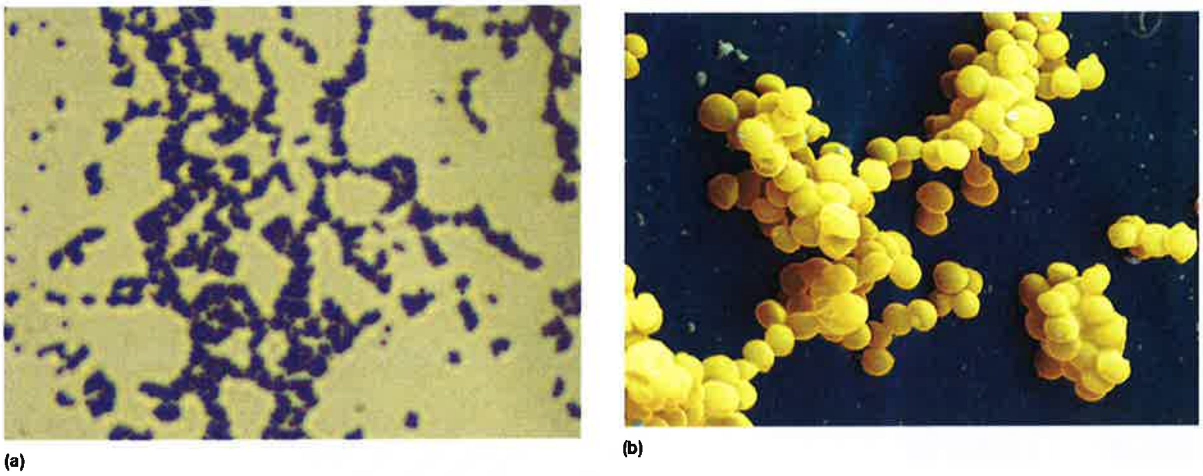
Scientific classification

Domain: *Bacteria*
Phylum: *Firmicutes*
Class: *Bacilli*
Order: *Bacillales*
Family: *Staphylococcaceae*
Genus: *Staphylococcus*
Rosenbach 1884

Staphylococcus aureus

SEM micrograph of S. aureus colonies: Note the grape-like clustering common to Staphylococcus species.

Staphylococcus is a genus of Gram-positive bacteria under the microscope, they appear spherical (cocci), and form in grape-like clusters. *Staphylococcus* species are facultative anaerobic organisms (capable of growth both aerobically and anaerobically). The name was coined in 1882 by Scottish surgeon and bacteriologist Alexander Ogston (1844-1929), following the pattern established five years earlier with the naming of Streptococcus. It combines the prefix "staphylo-" (from Ancient Greek: σταφυλή, translit. staphylē, lit. 'bunch of grapes'. and suffixed by the Modern Latin: coccus, lit. 'spherical bacterium' (from Ancient Greek: κόκκος, translit. kókkos, lit. 'grain, seed, berry'.



a: Joanne M. Willey Ph.D.; b: © Photo Researchers, Inc.

Staphylococcus aureus is a is a usual member of the microbiota of the body, frequently found in the upper respiratory tract and on the skin. It is often positive for catalase and nitrate reduction and is a facultative anaerobe that can grow without the need for oxygen.] Although S. aureus usually acts as a commensal of the human microbiota it can also become an opportunistic pathogen, being a common cause of skin infections including abscesses, respiratory infections such as sinusitis, and food poisoning. Pathogenic strains often promote infections by producing virulence factors such as potent protein toxins ,coagulase which causes blood plasma to clot, the toxin β-hemolysin lyses cells. The emergence of antibiotic-resistant strains of S. aureus such as methicillin-resistant S. aureus (MRSA) is a worldwide problem in clinical medicine. Despite much research and development, no vaccine for S. aureus has been approved.

Staphylococcus epidermidis: Common skin resident, sometimes responsible for endocarditis and for infections of patients with lowered resistance e.g., wound infections, surgical infections, and urinary tract infections

Domain: Bacteria

phylum: *Firmicutes*

Class: *Bacilli*

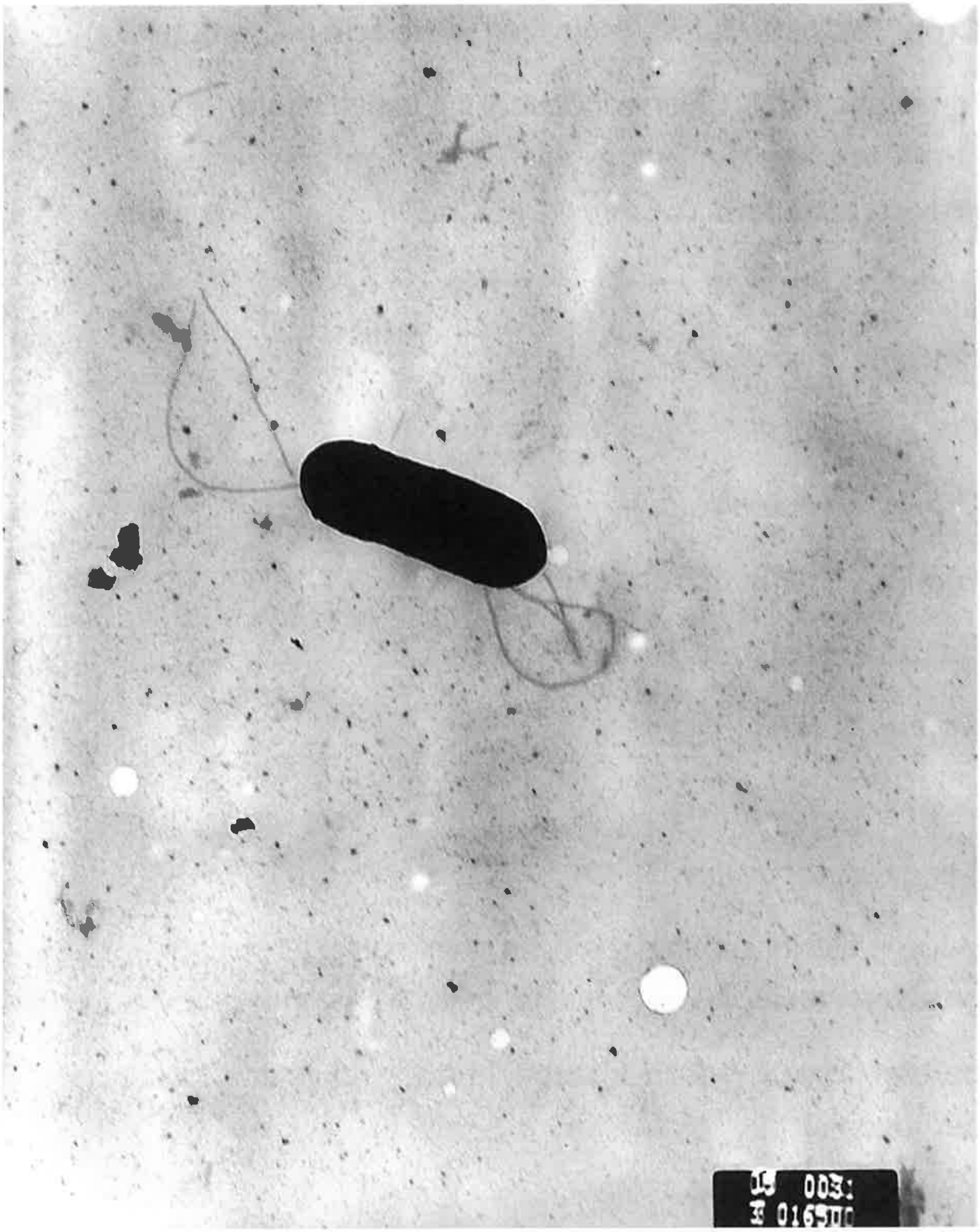
Order: *Bacillales*

Family: *Listeriaceae*

Genus: *Listeria*

Pirie 1940

Genus *Listeria*: Short rods, facultative anaerobic, catalase positive Motile by peritrichous flagellawide distribution in nature, common in decaying matter



*L. monocyt*ogenes pathogen of humans and animals, listeriosis - food-borne infection

Order *Lactobacillales*: Also called lactic acid bacteria (LAB)

Morphologically diverse, nonsporing, usually nonmotile, Ferment sugars for energy, fastidious, Contains several important genera

Domain: *Bacteria*

Phylum: *Firmicutes*

Class: *Bacilli*

Order: *Lactobacillales*

Family: *Lactobacillaceae*

Genus: *Lactobacillus*

Beijerinck 1901

Genus *Lactobacillus*:

Widely distributed in nature, on plant surfaces, in dairy products, meat, water, sewage, beer, fruits, and other materials

normal flora of mouth, intestinal tract, and vagina, usually not pathogenic.

Importance of Lactobacilli:

-Fermented products

-vegetable products (sauerkraut, pickles, and silage)

-beverages (beer, wine, juices, milk)

-Sour dough bread

-Swiss cheese and other hard cheeses, yogurt ,Sausages

-Sausages

L. acidophilus – sold as probiotic agent

Food spoilage – beer, wine, milk, meat

Kingdom: *Bacteria*

Division: *Firmicutes*

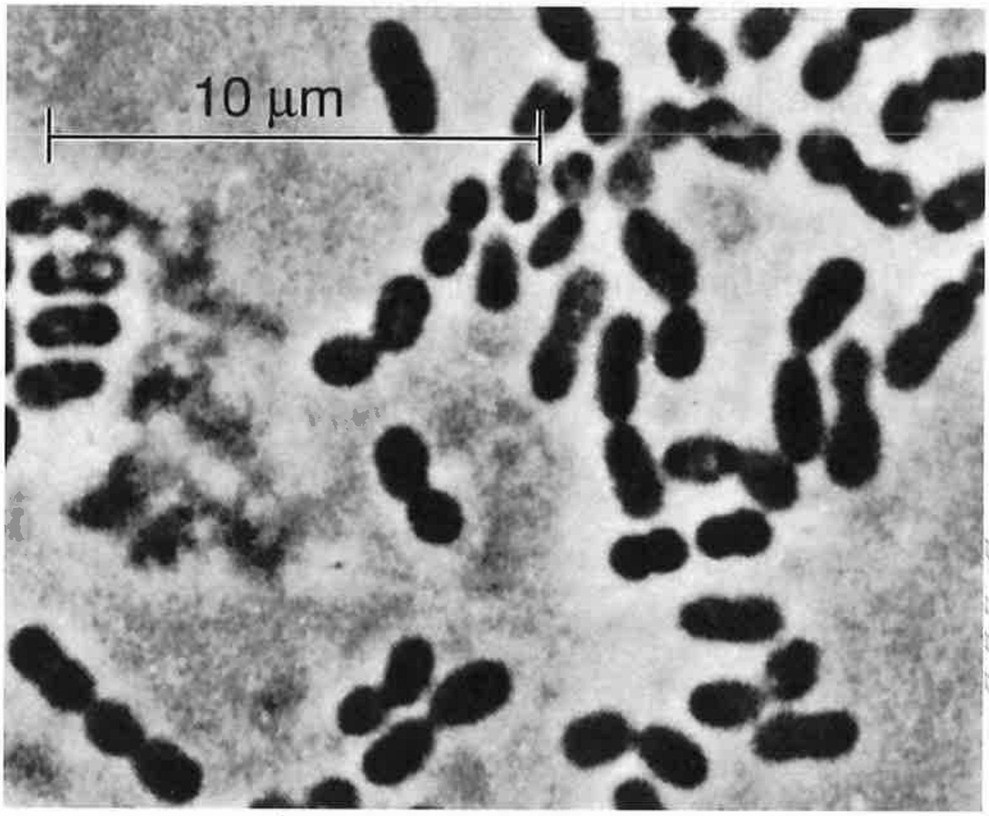
Class: *Bacilli*

Order: *Lactobacillales*

Family: *Leuconostocaceae*

Genus: *Leuconostoc*

van Tieghem 1878



From M.P. Starr, et al. (Eds.), *The Prokaryotes*, Springer-Verlag

Leuconostoc:Facultative, Gram-positive cocci

Isolated from plants, silage, and milk

Importance of *Leuconostoc*:

Wine production, Production of sauerkraut and pickles, Production of buttermilk, butter, and cheese

Synthesis of dextrans (*L. mesenteroides*)

Involved in food spoilage

tolerate high sugar concentrations

grow in heavy syrup

Domain: *Bacteria*

Phylum: *Firmicutes*

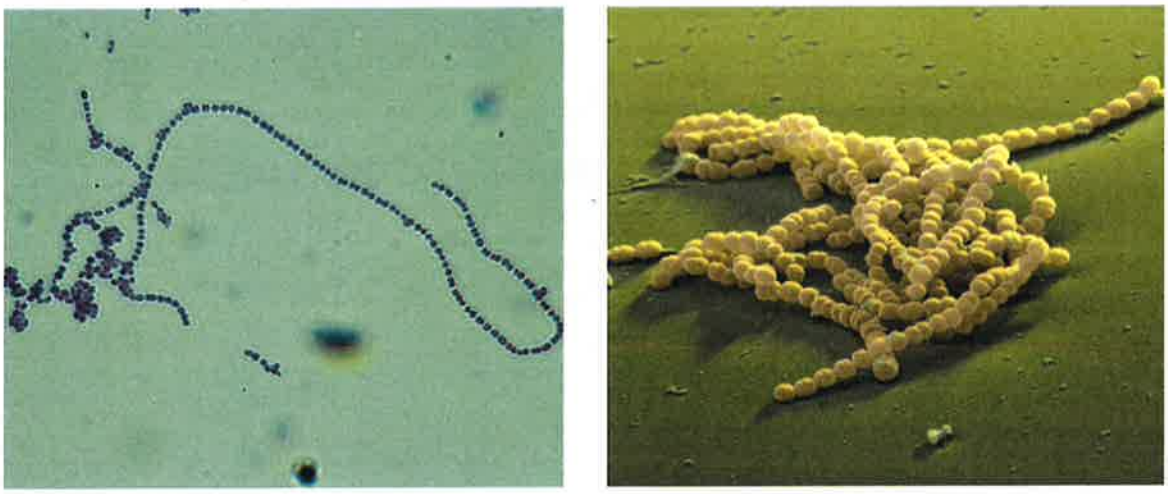
Class: *Bacilli*

Order: *Lactobacillales*

Family: *Streptococcaceae*

Genus: Streptococcus

streptococci



(a) *Streptococcus pyogenes* **(b)** *S. agalactiae*

a: © Thomas Tottleben/Tottleban Scientific Company; b: © Photo Researchers, Inc

Genus *Streptococcus*:

Hemolysis patterns used in Lancefield grouping

alpha (a) – hemolysis, incomplete lysis of red blood cells, seen as greenish zone around colony on blood agar

beta (b) – hemolysis, complete lysis of red blood cells, seen as clear zone around colony on blood agar

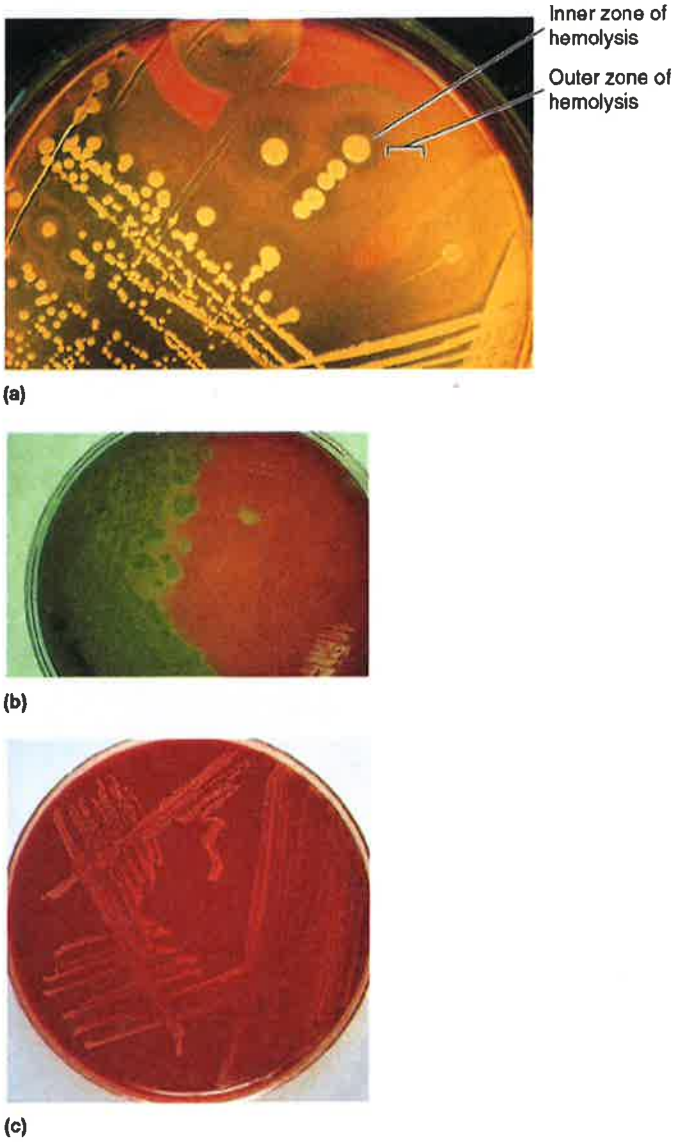
Three Groups of Streptococci:

Pyogenic (pus producing) streptococci, e.g., S. pyogenes – streptococcal sore throat, and rheumatic fever

Oral streptococci e.g., S. mutans – dental caries

Other streptococci:

e.g., S. pneumoniae – lobar pneumonia and otitis media



a: © Kathy Park Talaro/Visuals Unlimited; b: © Evans Roberts; c: © Fred E. Hossler/Visuals Unlimited

Phylu *Firmicutes:* The *Firmicutes* (Latin: firmus, strong, and cutis, skin, referring to the cell wall) are a phylum of bacteria, most of which have Gram-positive cell wall structure. A few, however, such as *Selenomonas* have a porous pseudo-outer membrane that causes them to stain Gram-negative. Scientists once classified the *Firmicutes* to include all Gram-positive bacteria, but have recently defined them to be of a core group of related forms called the low-G+C group, in contrast to the *Actinobacteria*. They have round cells, called cocci (singular coccus), or rod-like forms (bacillus).

Many *Firmicutes* produce endospores, which are resistant to desiccation and can survive extreme conditions. They are found in various environments, and the group includes some notable pathogens. Those in one family, the heliobacteria, produce energy through photosynthesis. *Firmicutes* play an important role in beer, wine, and cider spoilage. The low G + C Gram-Positive Bacteria Bergey's Manual placed in phylum *Firmicutes* contain10 orders, 34 families

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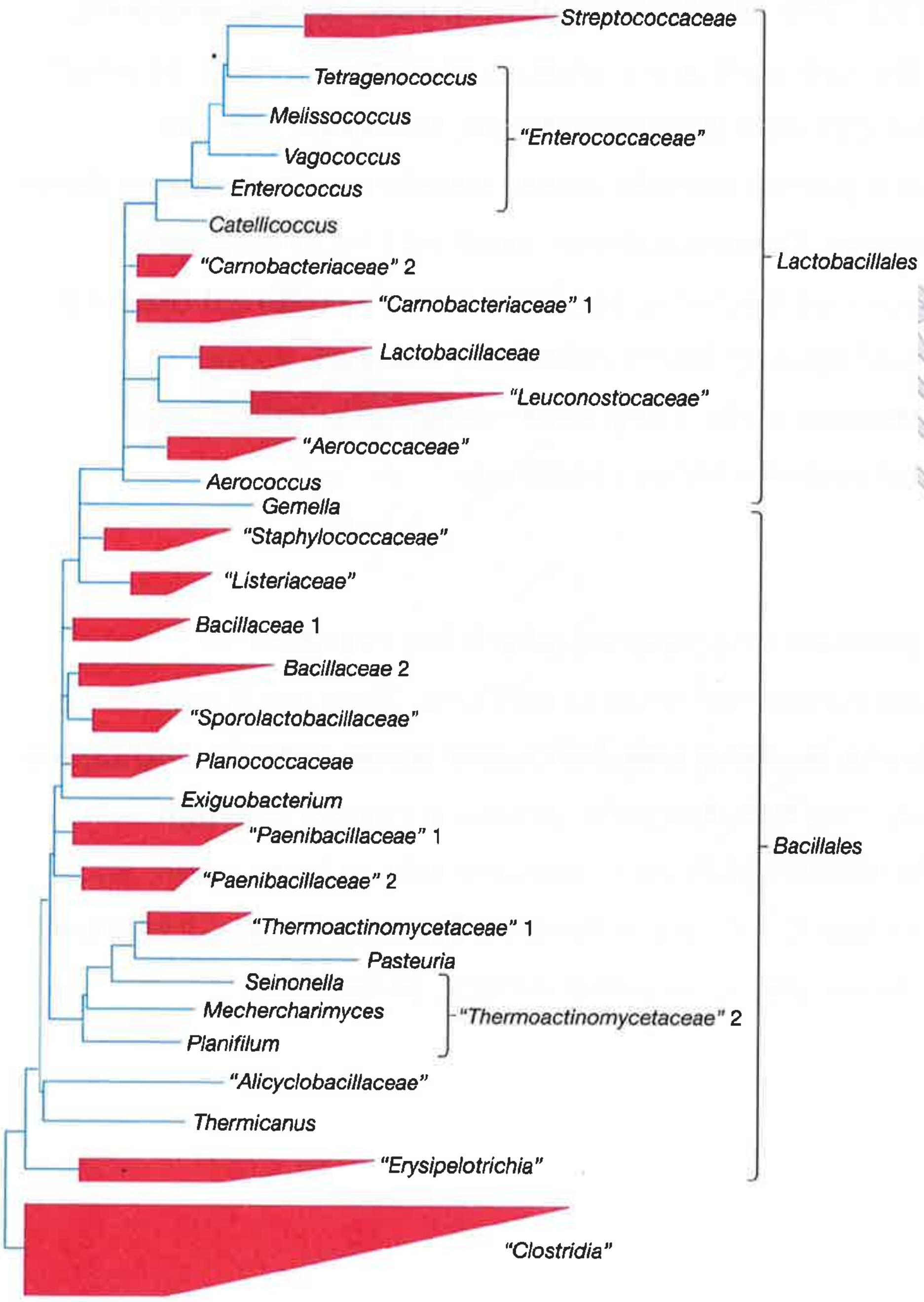


Above figure represent phylogenetic relationships in the phylum *Firmicutes* divided into 2 classes *Clostridia* and *Bacilli*
Class *Clostridia*: 3 orders, 11 families

Scientific classification

Domain: Bacteria

Phylum: *Firmicutes*

Class: *Clostridia*

Order: *Clostridiales*

Family: *Clostridiaceae*

Genus: *Clostridium*

Prazmowski 1880

The *Clostridia* :include *Clostridium* and other similar genera. They are distinguished from the Bacilli by lacking aerobic respiration. They are obligate anaerobes and oxygen is toxic to them. Species of the class Clostridia are often but not always Gram-positive and have the ability to form spores.

Most species of the genus *Clostridium* are saprophytic organisms found in many places in the environment, most notably the soil. However, the genus does contain some human pathogens (outlined below). The toxins produced by certain members of the genus *Clostridium* are among the most dangerous known. Examples are tetanus toxin (known as tetanospasmin) produced by *C. tetani* and botulinum toxin produced by *C. botulinum*. Some species have been isolated from women with bacterial vaginosis

The Clostridia are distinguished from the Bacilli by lacking aerobic respiration. They are obligate anaerobes and oxygen is toxic to them. Species of the class Clostridia are often but not always Gram-positive (see *Halanaerobium hydrogenoformans*) and have the ability to form spores.

Genus *Clostridium* include over 100 species in distinct phylogenetic clusters, Fermentative metabolism, ferment amino acids in a process called Stickland reaction ,by fermenting amino acids to produce ATP by oxidation of one amino acid using another as electron acceptor,this reaction generates ammonia,hydrogen sulfide,and fatty acidsduring the anaerobic decomposition of proteins, fermentation products responsible for unpleasant odors associated with putrefaction.

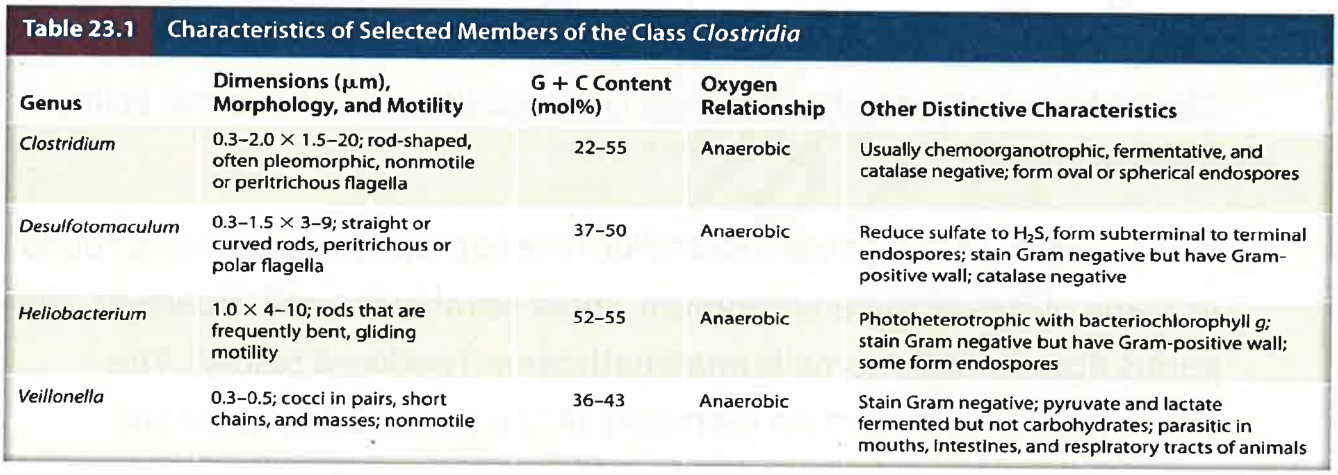


Table 23.1 Characteristics of Selected Members of the Class *Clostridia*

Genus	Dimensions (μm), Morphology, and Motility	G + C Content (mol%)	Oxygen Relationship	Other Distinctive Characteristics
Clostridium	0.3–2.0 × 1.5–20; rod-shaped, often pleomorphic, nonmotile or peritrichous flagella	22–55	Anaerobic	Usually chemoorganotrophic, fermentative, and catalase negative; form oval or spherical endospores
Desulfotomaculum	0.3–1.5 × 3–9; straight or curved rods, peritrichous or polar flagella	37–50	Anaerobic	Reduce sulfate to H_2S, form subterminal to terminal endospores; stain Gram negative but have Gram-positive wall; catalase negative
Heliobacterium	1.0 × 4–10; rods that are frequently bent, gliding motility	52–55	Anaerobic	Photoheterotrophic with bacteriochlorophyll *g*; stain Gram negative but have Gram-positive wall; some form endospores
Veillonella	0.3–0.5; cocci in pairs, short chains, and masses; nonmotile	36–43	Anaerobic	Stain Gram negative; pyruvate and lactate fermented but not carbohydrates; parasitic in mouths, intestines, and respiratory tracts of animals

© Alfred Pasieka/Getty Images

Figure shows *Clostridium tetani* endospores that are round and terminal

Important Species of Clostridium:

C. botulinum cause food spoilage (especially canned foods); botulism

C. tetani – cause tetanus

C. perfringens –cause gas gangrene and food poisoning

C. acetobutylicum used to manufacture butanol

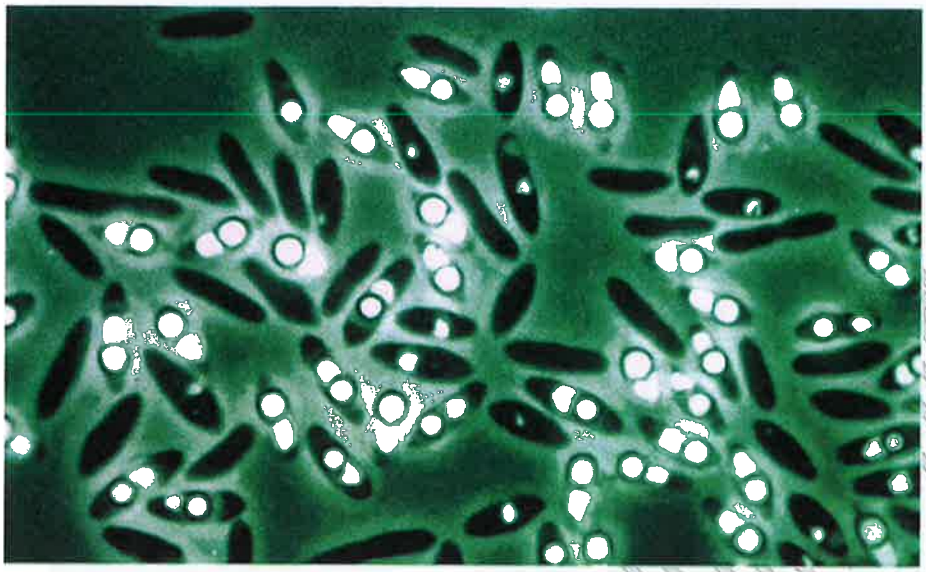


Figure shows Genus *Desulfotomaculum*

Genera *Heliobacterium and Heliophilum*:contain unusual anaerobic, photosynthetic species characterized by the presence of bacteriochlorophyll g,they have photosystem similar to green sulfur bacteria, pigments in plasma membrane.

Heliobacteria

Scientific classification

Domain: *Bacteria*

Phylum: *Firmicutes*

Class: *Clostridia*

Order: Clostridiales

Family: *Heliobacteriaceae*

Genera

Heliobacterium

Heliophilum

RNA trees place the heliobacteria among the *Firmicutes*, but they do not stain Gram-positively. They have no outer membrane and like certain other firmicutes (Clostridia), they form heat-resistant endospores, which contain high levels of calcium and dipicolinic acid. Heliobacteria are the only firmicutes known to conduct photosynthesis.

Heliobacteria are photoheterotrophic, requiring organic carbon sources, and they are exclusively anaerobic. Bacteriochlorophyll g is inactivated by the presence of oxygen, making them obligate anaerobes (they cannot survive in aerobic conditions). So far, heliobacteria have only been found in soils, and are apparently widespread in the waterlogged soils of paddy fields. They are avid nitrogen fixers, so are probably important in the fertility of paddy fields.

Heliobacteria should not be confused with Helicobacter, which is a genus of bacteria with quite different characteristics.

Genus *Veillonella*:

Scientific classification

Kingdom:	Bacteria
Phylum:	*Firmicutes*
Class:	*Negativicutes*
Order:	*Vellionellales*
Family:	*Veillonellaceae*
Genus:	*Veillonella*

Veillonella are Gram-negative bacteria (Gram stain pink) . Members of this genus are anaerobic cocci.

Natural habitats: Is widely distributed in the oral, genitourinary, respiratory, and intestinal biotas of humans and animals.

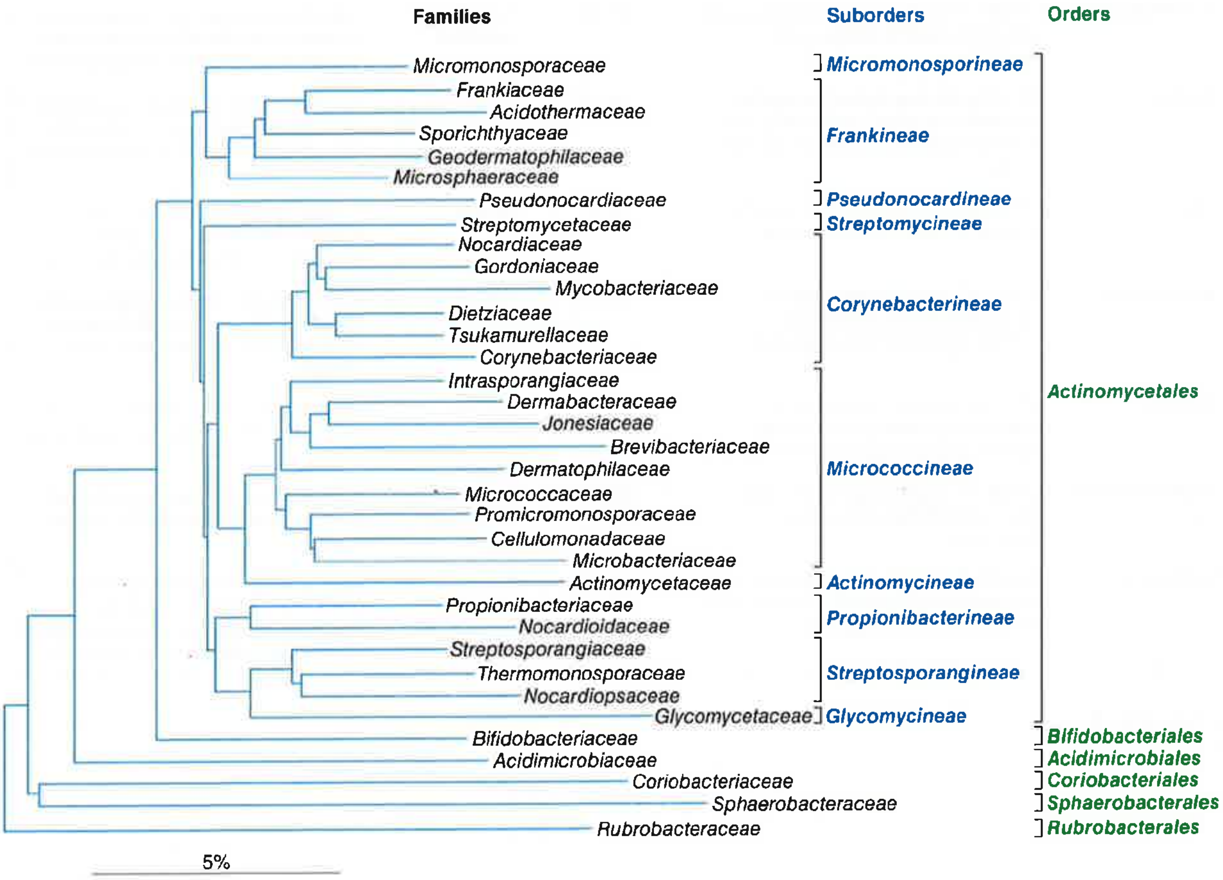
Clinical significance: *Veionella* species strains are frequently isolated from clinical specimens in aerobic-anaerobic polymicrobial cultures. In humans they have been implicated in cases of osteomyelitis and endocarditis, for example with the species *Veillonella parvula,*all have complex nutritional requirements.

Phylum *Actinobacteria*: The High G + C Gram-Positive Bacteria

Volume 4 of Bergey’s Manual of Systematic Bacteriology, 2nd Edition

Based on 16S rRNA sequence data ,all members of this phylum are placed in a single class,Actinobacteria, many *Actinobacteria* are also called *Actinomycetes.*

Actinomycetes are Gram-positive, aerobic bacteria that produce filamentous cells called hyphae and differentiate into asexual spores ,**actinomycetes are** adapted to climates similar to fungi.



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(above figure)classification of the phylum *Actinobacteria*:the phylogenetic relationship between orders, suborders, and families based on 16S r RNA data.

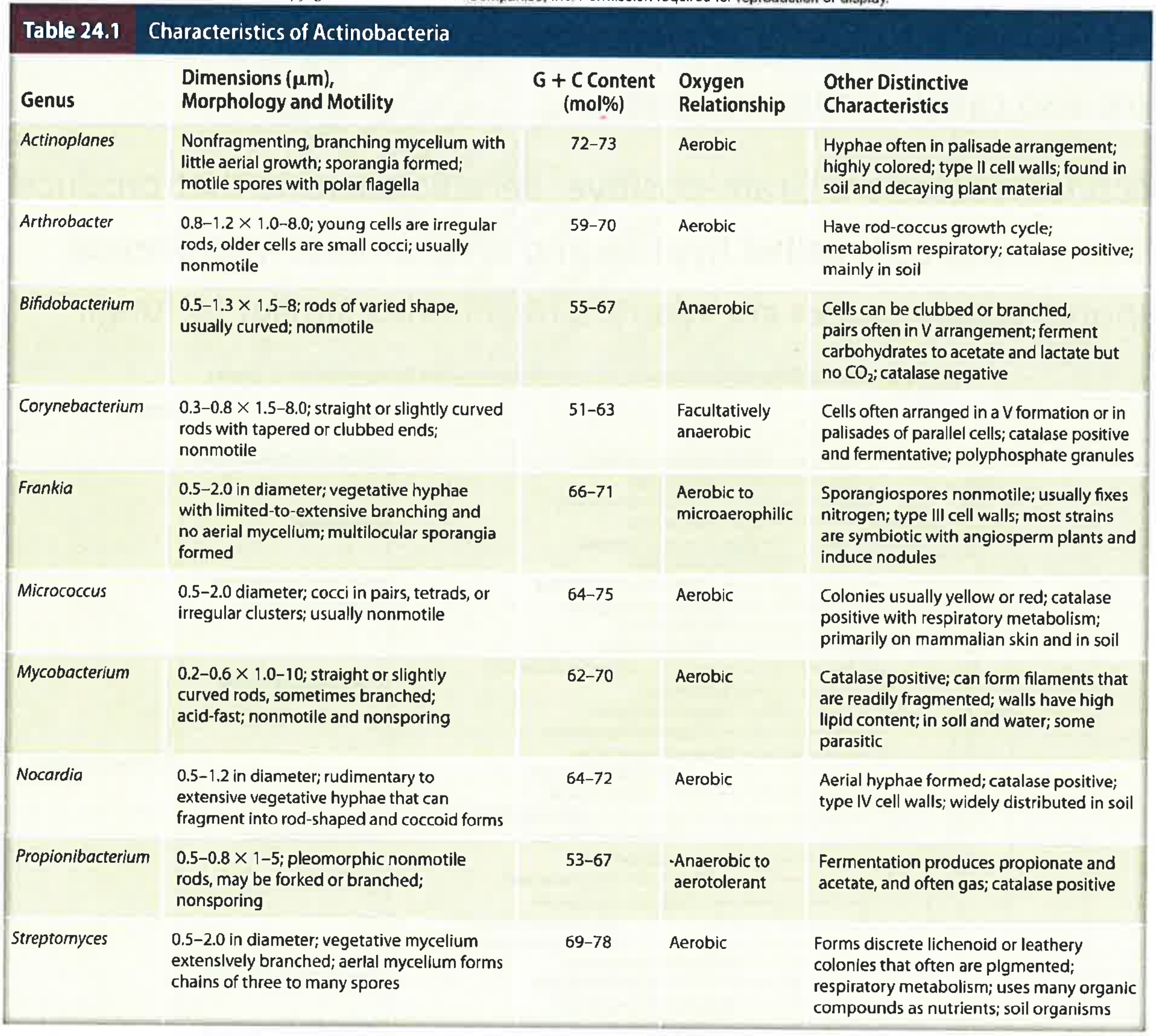


Table 24.1 Characteristics of Actinobacteria

Genus	Dimensions (μm), Morphology and Motility	G + C Content (mol%)	Oxygen Relationship	Other Distinctive Characteristics
Actinoplanes	Nonfragmenting, branching mycelium with little aerial growth; sporangia formed; motile spores with polar flagella	72–73	Aerobic	Hyphae often in palisade arrangement; highly colored; type II cell walls; found in soil and decaying plant material
Arthrobacter	0.8–1.2 × 1.0–8.0; young cells are irregular rods, older cells are small cocci; usually nonmotile	59–70	Aerobic	Have rod-coccus growth cycle; metabolism respiratory; catalase positive; mainly in soil
Bifidobacterium	0.5–1.3 × 1.5–8; rods of varied shape, usually curved; nonmotile	55–67	Anaerobic	Cells can be clubbed or branched, pairs often in V arrangement; ferment carbohydrates to acetate and lactate but no CO_2; catalase negative
Corynebacterium	0.3–0.8 × 1.5–8.0; straight or slightly curved rods with tapered or clubbed ends; nonmotile	51–63	Facultatively anaerobic	Cells often arranged in a V formation or in palisades of parallel cells; catalase positive and fermentative; polyphosphate granules
Frankia	0.5–2.0 in diameter; vegetative hyphae with limited-to-extensive branching and no aerial mycelium; multilocular sporangia formed	66–71	Aerobic to microaerophilic	Sporangiospores nonmotile; usually fixes nitrogen; type III cell walls; most strains are symbiotic with angiosperm plants and induce nodules
Micrococcus	0.5–2.0 diameter; cocci in pairs, tetrads, or irregular clusters; usually nonmotile	64–75	Aerobic	Colonies usually yellow or red; catalase positive with respiratory metabolism; primarily on mammalian skin and in soil
Mycobacterium	0.2–0.6 × 1.0–10; straight or slightly curved rods, sometimes branched; acid-fast; nonmotile and nonsporing	62–70	Aerobic	Catalase positive; can form filaments that are readily fragmented; walls have high lipid content; in soil and water; some parasitic
Nocardia	0.5–1.2 in diameter; rudimentary to extensive vegetative hyphae that can fragment into rod-shaped and coccoid forms	64–72	Aerobic	Aerial hyphae formed; catalase positive; type IV cell walls; widely distributed in soil
Propionibacterium	0.5–0.8 × 1–5; pleomorphic nonmotile rods, may be forked or branched; nonsporing	53–67	Anaerobic to aerotolerant	Fermentation produces propionate and acetate, and often gas; catalase positive
Streptomyces	0.5–2.0 in diameter; vegetative mycelium extensively branched; aerial mycelium forms chains of three to many spores	69–78	Aerobic	Forms discrete lichenoid or leathery colonies that often are pigmented; respiratory metabolism; uses many organic compounds as nutrients; soil organisms

الجدول للاطلاع

General Properties of the *Actinomycetes*:

Source of most currently used antibiotics, also produce metabolites that are anticancer, antihelminthic, and immunosuppressive

Their mode of growth in many cases involves a complex life cycle, manyactinomyces make filamentous cells,called hyphae, instead of more familiar , smaller rods or cocci.

Most are not motile

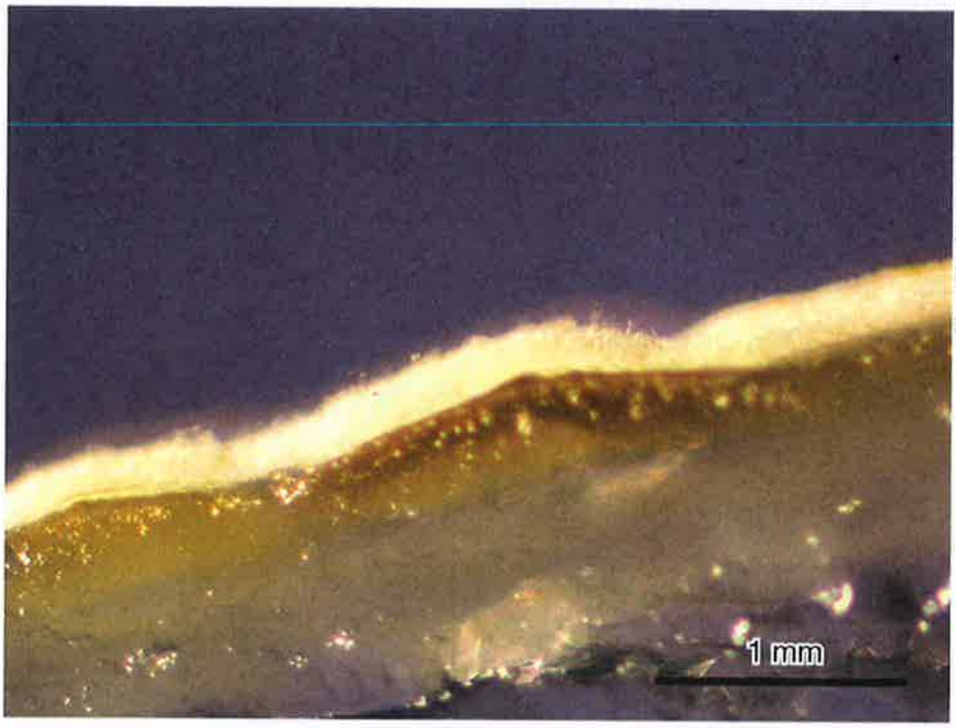
motility is restricted to flagellated spores

:

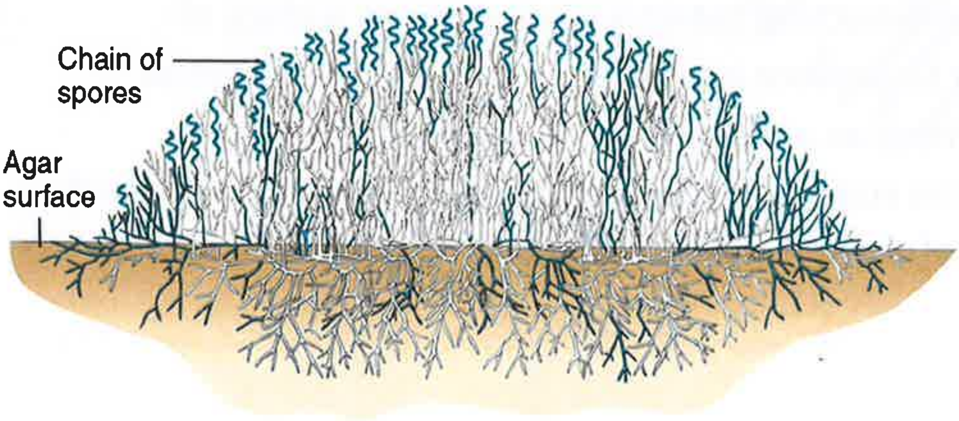
Life Cycle of *Actinomycetes*:

Involves development of filamentous cells (hyphae) and spores

Hyphae can form branching network when grow on surface of substrate/into it to produce a substrate mycelium. Some hyphae differentiate to form an aerial mycelium which extends above substratum, at this stage secondary metabolites form, some of which are medically useful.



(a)



(b)

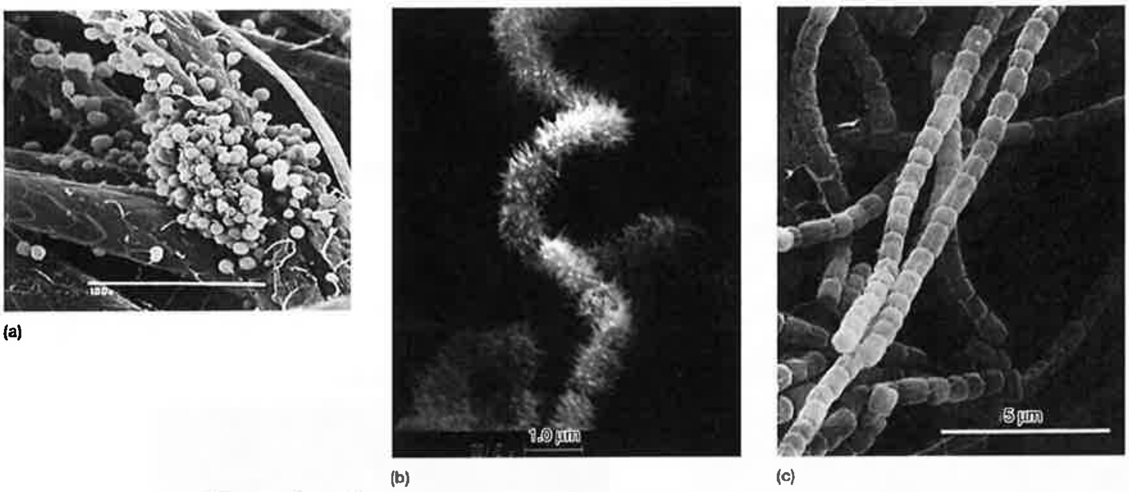
Photo © Dr. Alisa A. Gaskell

(above)cross section of an Actinomycetes colony

- *a*- A photomicrograph of *Streptomyces griseus*
- b- B-live hyphae are blue dead hyphae are white

Life Cycle of *Actinomycetes*:Aerial mycelium form exospores which are called sporangiospores if they are located in a sporangium like spore formation in other bacteria ,actinomycete sporulation is in response to nutrient deprivation and chemical signals between microbes to withstand desiccation but not heat resistant

spores dispersed by wind for new bacteria



(a) (b) (c)

From S.T. Williams, M.E. Sharpe and J.G. Holt (Eds.), *Bergey's Manual of Systematic Bacteriology*, Vol. 4, © 1989 Williams and Wilkins Co., Baltimore

(above)examples of Actinomycetes spores

Ecological Significance of *Actinomycetes:*

Widely distributed in soil

Play important role in mineralization of organic matter

Most are free living, but a few are pathogens

Phylum *Actinobacteria*16S rRNA evidence shows 1 class (*Actinobacteria)*, five subclasses, six orders, 14 suborders, 44 families

Consists of actinomycetes and their high G + C gram-positive relatives.

1-**Suborder *Actinomycineae*;**

This suborder includes one family with five genera,most are irregularly shaped, gram-positive rods,the rods may be straight or slightly curved and usually have swelling, club shapes, or other deviations from normal rod morphology, with aerobic or facultative metabolism.

Genus *Actinomyces*:

Straight or slightly curved rods and slender filaments with true branching, may have swollen, clubbed, or clavate ends,they are either facultative or obligate aerobes (require CO2).*Actinomyces* cause ocular infection and actinomycoses in human.

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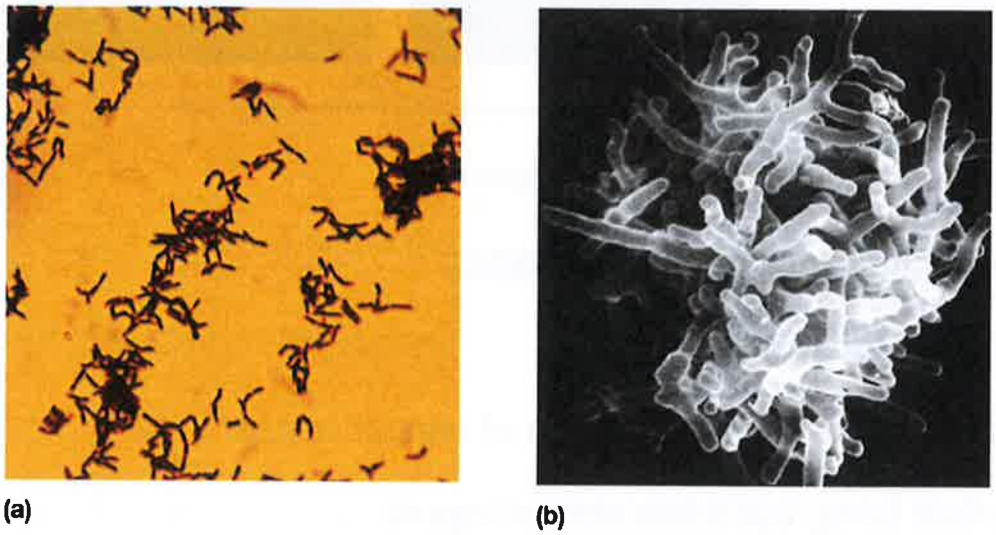


a: © E.C.S. Chan/Visuals Unlimited; b: © David M. Phillips/Visuals Unlimited

a-Genus *Actinomyces* gram stain b-scanning electron micrograph , note the filamentous nature of colony

2-Suborder *Micrococcineae*

Genus *Micrococcus*

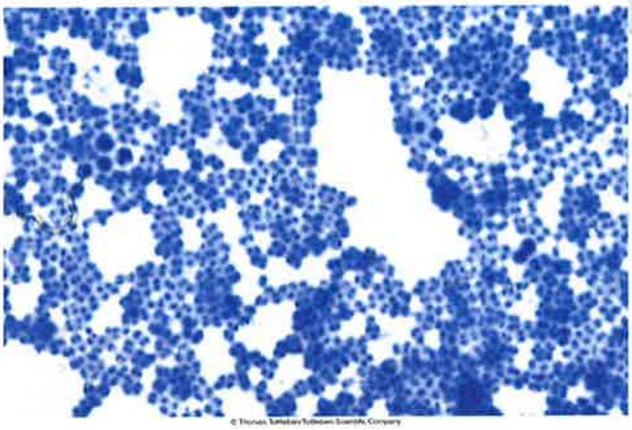
Aerobic, catalase-positive rods that occur in pairs, tetrads, or irregular clusters

Usually nonmotile

Often pigmented yellow, orange, or red

Widespread in soil, water, and on human skin

Does not undergo morphological differentiation



***Micrococcus* stained with methylene blue**

Suborder *Corynebacterineae*:

Domain: Bacteria

Phylum: *Actinobacteria*

Class: *Actinobacteria*

Subclass: *Actinobacteridae*

Order: *Actinomycetales*

Suborder: *Corynebacterineae*

Families:

Corynebacteriaceae (Coryneform bacteria)

Mycobacteriaceae

Nocardiaceae

Has seven families with many known genera such as:

Corynebacterium

Mycobacterium

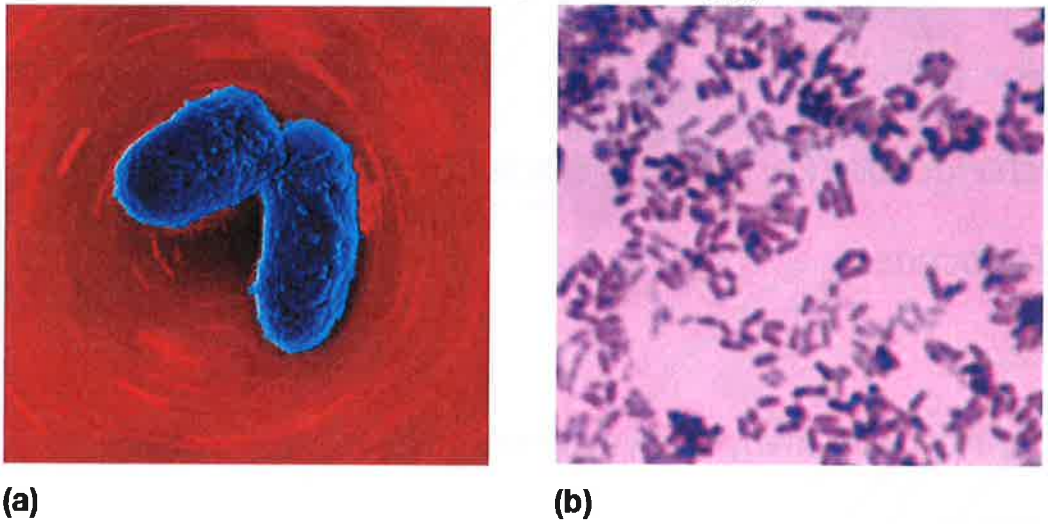
Nocardia

Genus *Corynebacterium*:

The principal features of the genus *Corynebacterium* are :gram-positive, catalase-positive, nonspore-forming, nonmotile, rod-shaped bacteria that are straight or slightly curved. Metachromatic granules are usually present representing stored phosphate regions. Their size falls between

2 and 6 µms in length and 0.5 µm in diameter. The bacteria group together in a characteristic way, which has been described as the form of a "V", "palisades", or "Chinese letters". They may also appear elliptical. They are aerobic or facultatively anaerobic, chemoorganotrophs. They are pleomorphic through their lifecycles, they occur in various lengths, and they frequently have thickenings at either end, depending on the surrounding conditions.

Some are harmless soil and water saprophytes, many are animal and human pathogens, e.g., *C. diphtheriae* – diphtheria



a: © Dr. Gary Gaugler/Photo Researchers, Inc.; b: © A.M. Siegelman/ Visuals Unlimited

Corynebacterium dipheriathe paires of cells results in palaside arrangement (rows of cells lined up side by side).

Genus *Mycobacterium:* the family *Mycobacteriaceae* contain the Genus Mycobacterium,which is composed of straight or slightly curved rods that sometimes branch or form filaments.Mycobacterial filaments readily fragment into rods and coccoid bodies . They are aerobic and catalase positive.Mycobactria grow very slowly on culture media and must be inocubated for2 to40 days after inoculation on a complex medium to form a visible colony.

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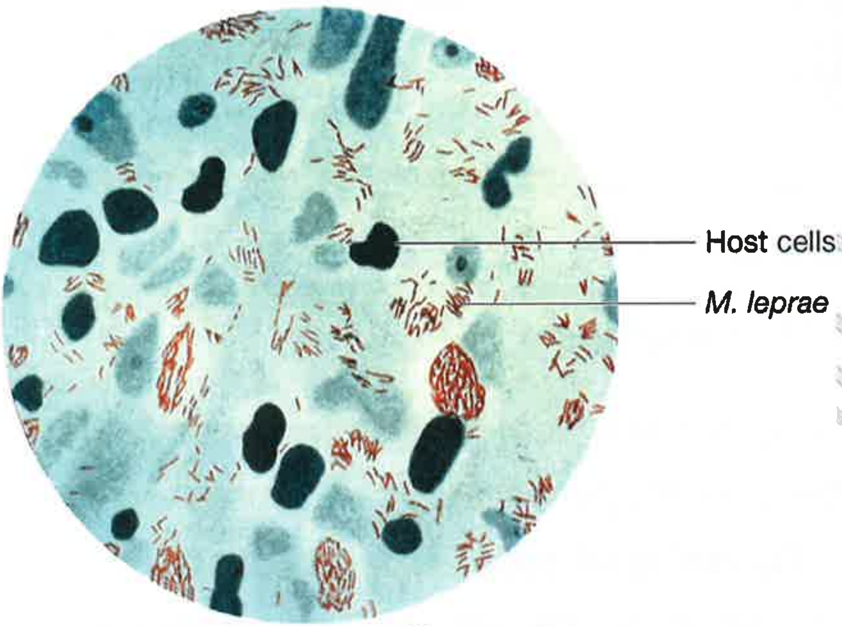


CDC

(Above figure)the Mycobacteria.*Mycobacterium leprae* from leprosy skin lesion ,acid fast stain

Mycobacterial Cell Walls:

Contain waxes with 60 to 90 carbon mycolic acids

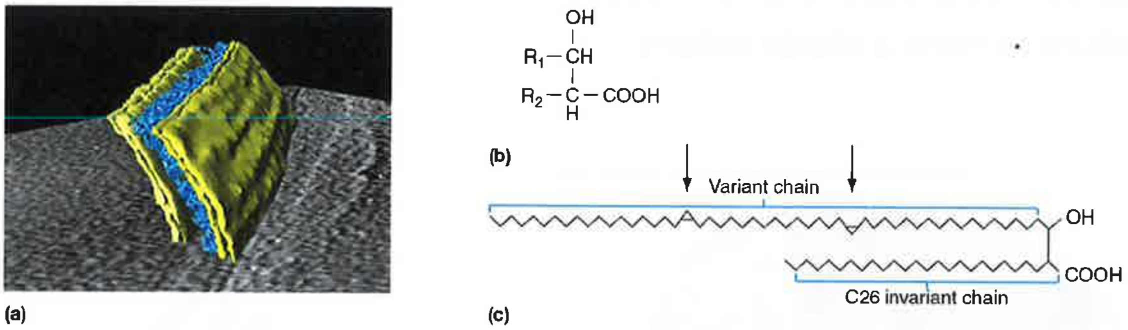
Cell wall surface contains the glycolipid trehalose dimycolate

cell wall very hydrophobic

impenetrable by antibiotics

acid-fast

basic fuchsin dye not removed by acid alcohol treatment



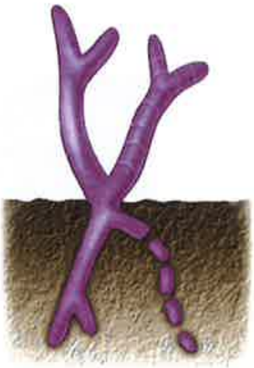
a: Courtesy Harald Engelhardt, MPI of Biochemistry, Martinsried. Reprinted from *Trends in Microbiology*, Vol 18, Michael Niederweis, Olga Danilchanka, Jason Huff, Christian Hoffmann, Harald Engelhardt, Mycobacterial outer membranes: in search of proteins, March 2010, with permission from Elsevier

(Above figure)Mycobacterial cell wall

Important Species of *Mycobacterium:*

although some mycobacteria are free living saprophytes , they are best known as animal pathogenes. *M. bovis* causes tuberculosis in cattle. Currently *M. tuberculosis* causes tuberculosis in humans. *M. leprae* causes Leprosy in humans.

Genus *Nocardia*: belong to the family *Nocardiaceae,* these bacteria develop a substrate mycelium that readily breaks into rods and coccoid elements. Some also form an aerial mycelium and conidia.



Nocardia

Impact of *Nocardia:*

Most are free-living saprophytes

can degrade many molecules

e.g., petroleum hydrocarbons, detergents, benzene

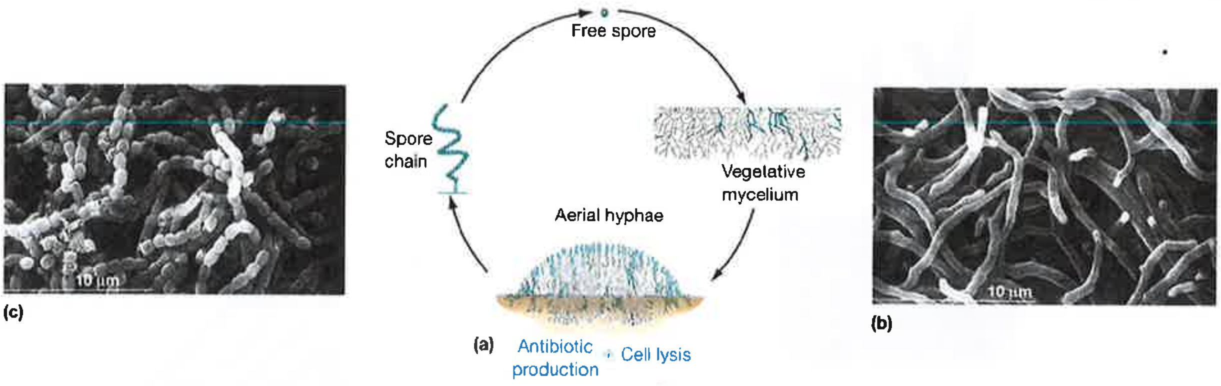
involved in biodegradation of rubber joints in water and sewage pipes

Some are opportunistic pathogens causing nocardiosis

usually infect lungs; can infect central nervous system

Suborder *Streptomycineae:*

One family *Streptomycetaceae*, three genera, the most important is Genus *Streptomyces*.



b,c: Joanne M. Willey, Ph.D.

(Above figure)*Streptomyces* life cycle (a)streptomycetes form three types of cells :exospores germinate to produce vegetative (also called substrate) hyphae,which then differentiate into aerial hyphae . These give rise to chains of exospores. Scanning electron micrographs are shown of (b)*S.coelicolor* vegetative hyphae and (c) chains of exospores.

Genus *Streptomyces*:

Are 1 to 20% of culturable soil microbiota

produce geosmin,a volatile substance that is source of moist earth odor

important in mineralization process

aerobically degrade many resistant substances (e.g., pectin, lignin, and chitin)

Produce vast array of antibiotics, other bioactive compounds, and antibiotic resistance genes

Most are nonpathogenic saprophytes

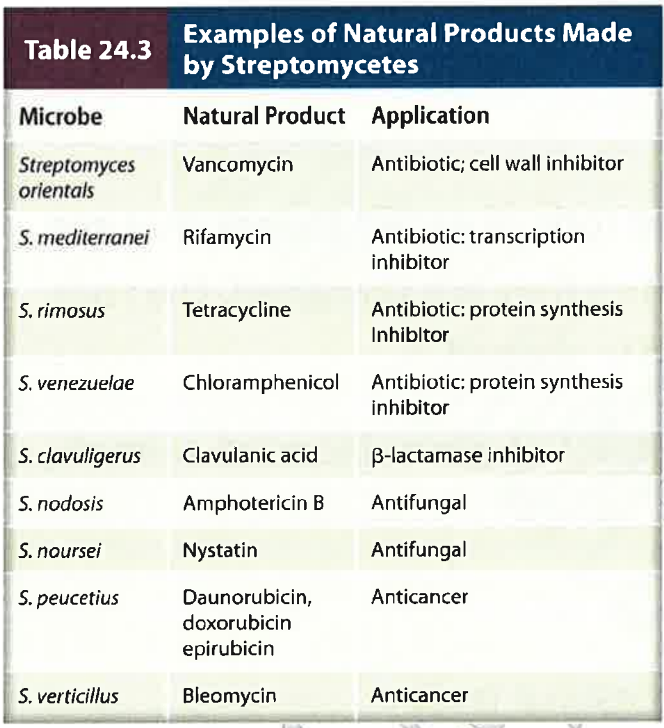
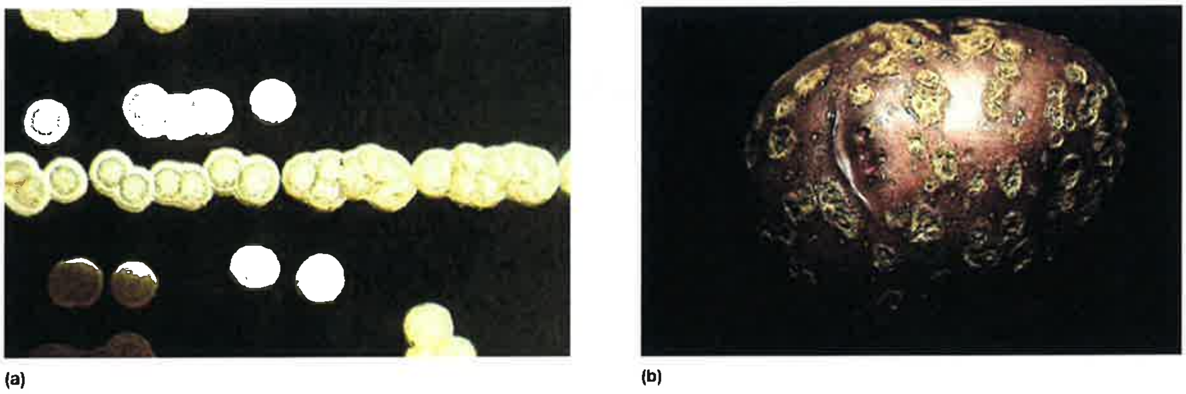


Table 24.3 **Examples of Natural Products Made by Streptomycetes**

Microbe	Natural Product	Application
Streptomyces orientals	Vancomycin	Antibiotic; cell wall inhibitor
S. mediterranei	Rifamycin	Antibiotic: transcription inhibitor
S. rimosus	Tetracycline	Antibiotic: protein synthesis Inhibitor
S. venezuelae	Chloramphenicol	Antibiotic: protein synthesis inhibitor
S. clavuligerus	Clavulanic acid	β-lactamase inhibitor
S. nodosis	Amphotericin B	Antifungal
S. noursei	Nystatin	Antifungal
S. peucetius	Daunorubicin, doxorubicin epirubicin	Anticancer
S. verticillus	Bleomycin	Anticancer



a: © Christine L. Wilkins/Visuals Unlimited; b: © Sherman Thompson/Visuals Unlimited

(Above figure)(a)*Streptomyces griseus* colonies(b)*S. scabies* growing on potato.

Order *Bifidobacteriales:*

One family *Bifidobacteriaceae:*

and ten genera e.g., e.g., *Bifidobacterium*

Genus *Bifidobacterium* :

nonsporing rods, Gram positive rods of varied shapes that are slightly curved and clubbed often they are branched, the rods can be single or in clusters and v- shaped

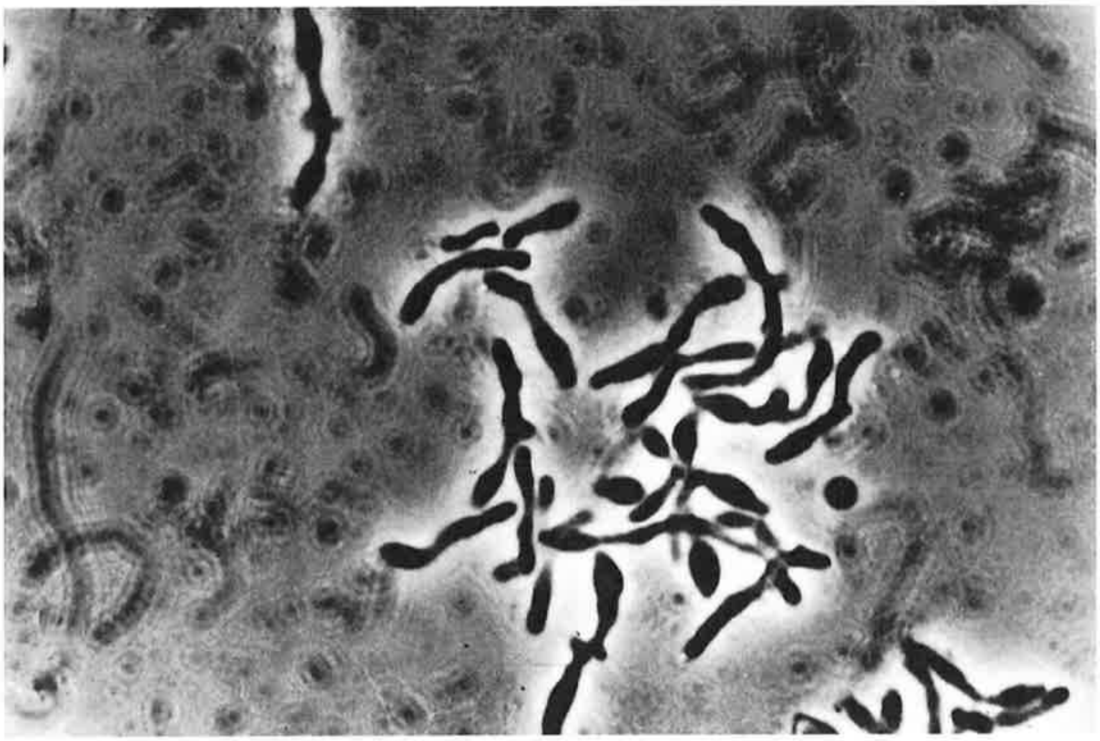
found in mouth and intestinal tract of warm-blooded animals, in sewage, and in insects

e.g., *Bifidobacterium bifidus*:

Pioneer colonizer of human intestinal tract

Does not appear to be major cause of disease

Bifidobacterium species are sold as Probiotic agent (particulary in yougurt)



Staley, *Bergey's Manual Systematic Bacteriology*, Vol. 2 page 1418, figure 1596a. Courtesy Prof. Bruno Biavati, Instituto Di Microbiologia

Bifidobacterium bifidus

Phylum *Planctomycetes:*

Some Planctomycetes ,such as *Gemmata obscuringlobus* enclose their genome in a compartment called nuclear body,unlike the eukaryotic nucleus, the nuclear body contain ribosomes as well as nucleic acids.

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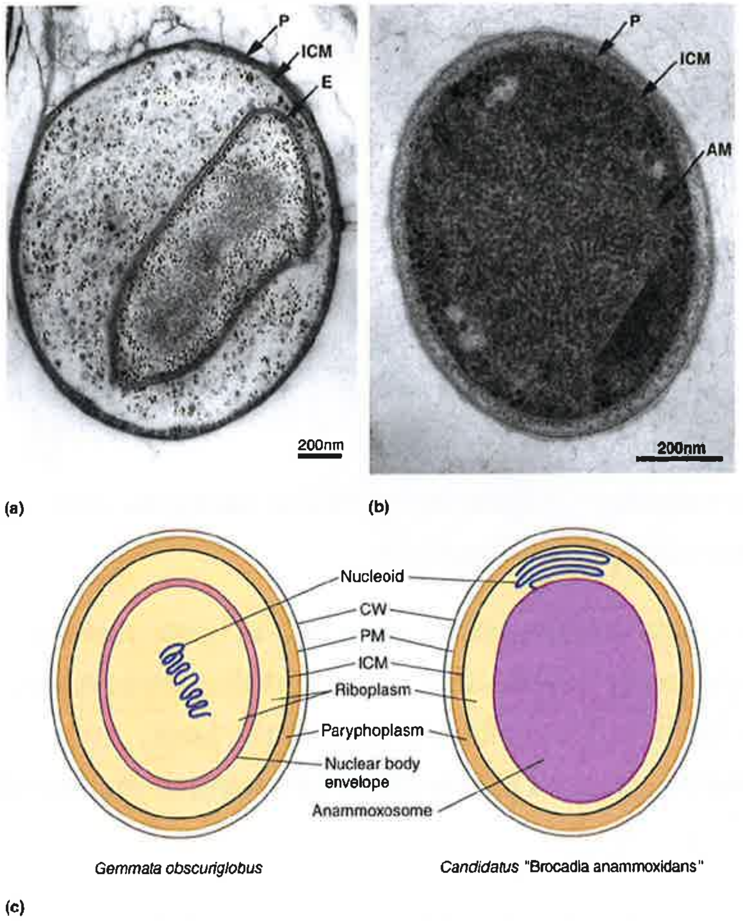


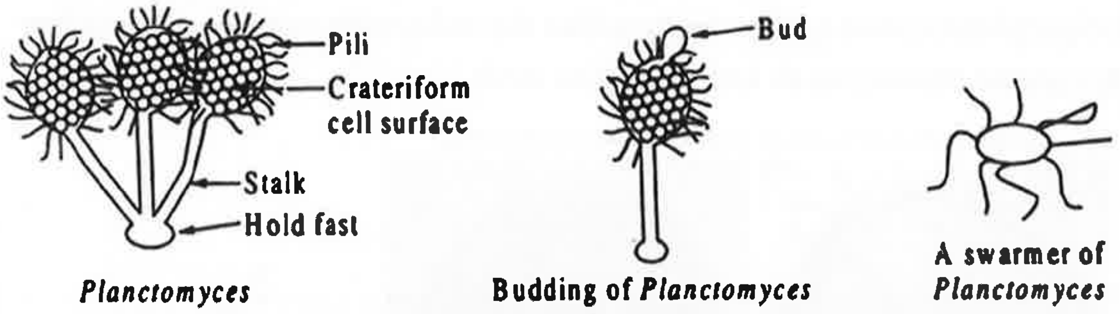
Image courtesy John A. Fuerst and Richard I. ebb, from Novel Compartmentalization in Planctomycete Bactria, *Microsc & Microanal*, 2004 10 (Suppl 2)

الشكل للاطلاع وتوضيح الشرح اعلاه

Genus ***Planctomyces*** :

Members of the genus attaches to surfaces through stalk and holdfast, Other genera lack stalk,

most have life cycles in which sessile cells bud to produce motile swarmer cells, the swarmer cells are flagellated and swim for a while before cells ultimately settle down, attach, and reproduce.



Planctomyces

Budding of *Planctomyces*

A swarmer of *Planctomyces*

Fig. 4.15 : Morphological features of *Planctomyces*

الشكل للاطلاع وتوضيح الشرح اعلاه

Phylum *Chlamydiae*:

Phylum Chlamydiae re aGram-negative Obligate intracellular parasites, this means they must grow and reproduce inside host cells.

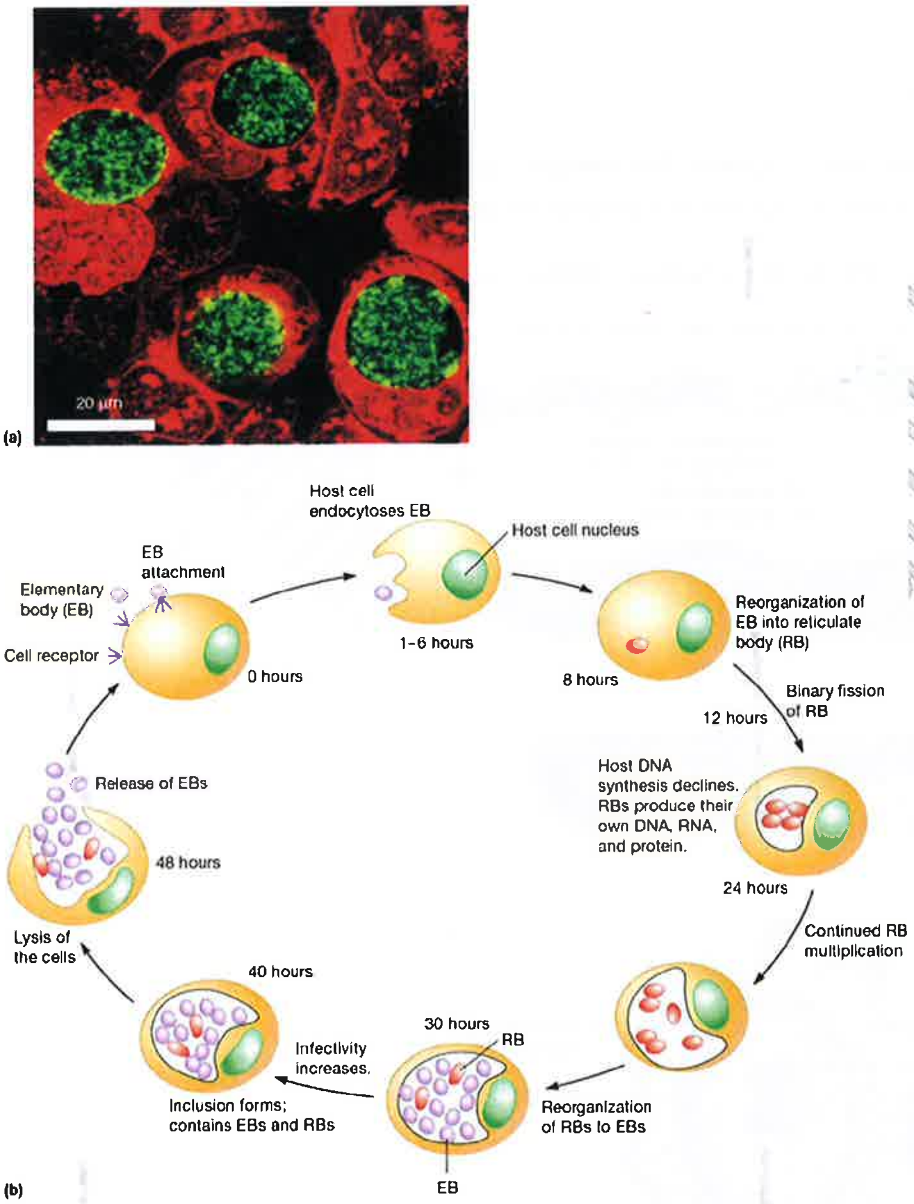
.Although known for ability to cause disease, many grow within hosts such as protists, and animal cells without adverse effects It is thought that these hosts represents a natural reservoir for the Chlamydiae. In the human host , C,trachomatis is the most common cause of preventable blindness in the world.

Genus Chlamydia:

Members of this genus are nonmotile, coccoid, Gram-negative bacteria

have very small genomes

They are obligate intracellular parasites with unique developmental cycle,They reproduce within cytoplasmic vesicles of host cells by a unique developmental cycle.



Dr. Peter Braun, Max Planck Institute for Infection Biology, Dept. of Molecular Biology, Berlin, Germany

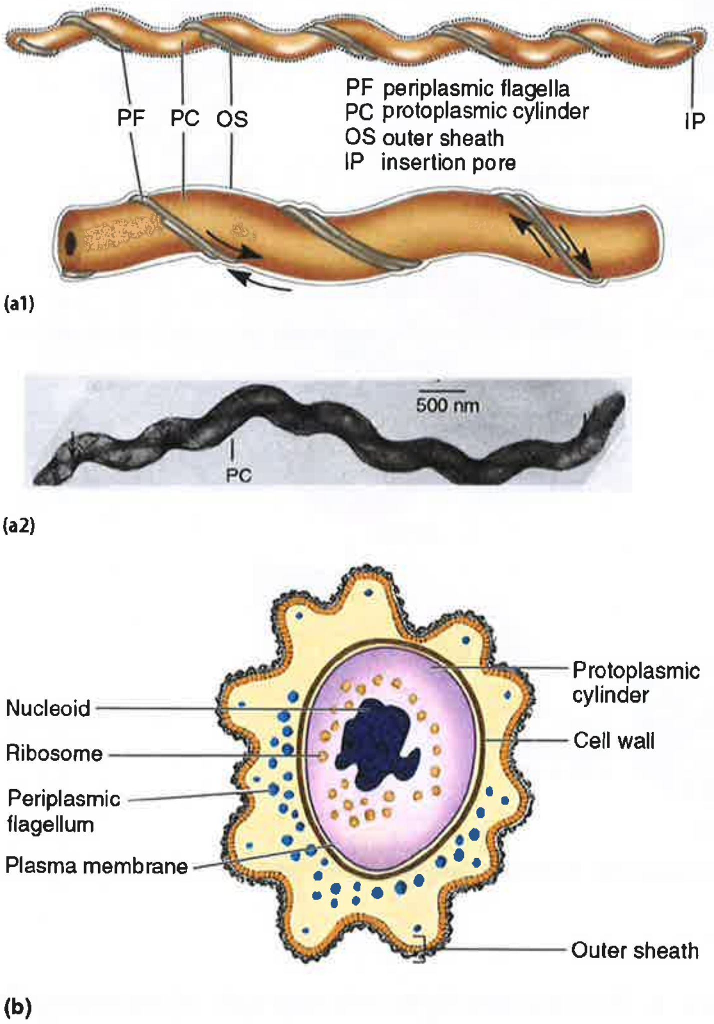
الشكل للاطلاع Above figure shows a- fluorescent light micrograph of human cells (red)infected with *C. trachomatis*(green),b-generalized life cycle of Chlamydiae

Clamydiae are extremely limited metabolically,relying on their host cells for key metabolites,this reflected the size of their genome, they have very small genomes.

Phylum *Spirochaetes*:

Phylum Spirochaetes contains Gram-negative, chemoheterotrophic bacteria with distinctive structure and motility, Spirochetes are morphologically unique.they are slender, long with flexible helical shape.

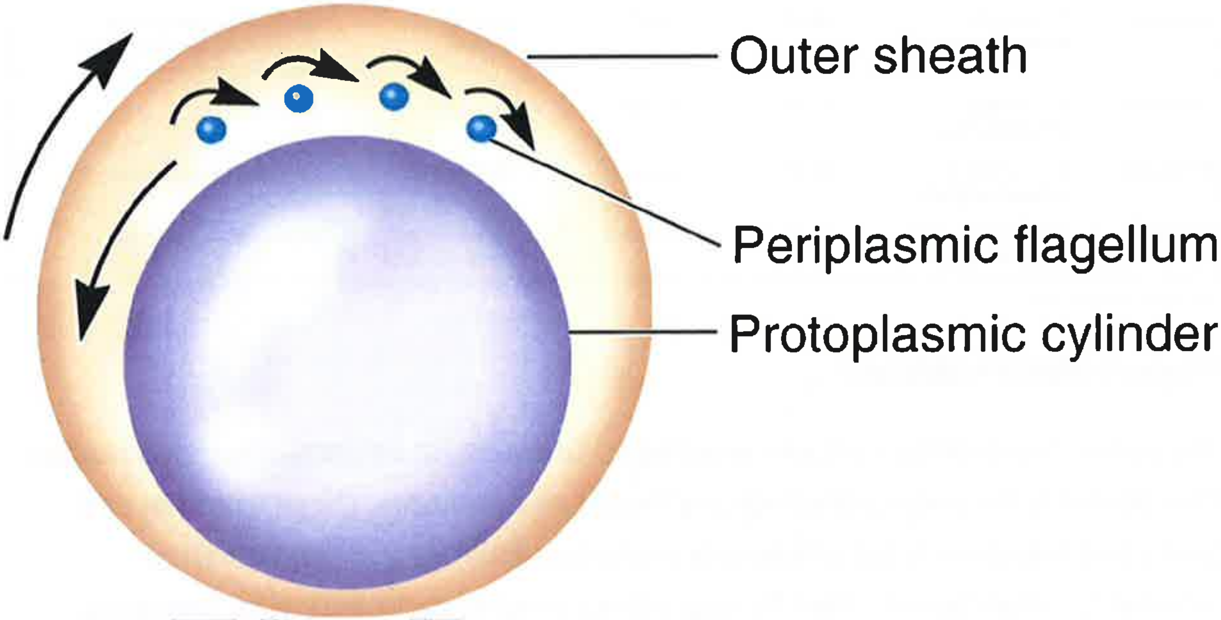
Their creeping (crawling) motility due to a structure called an axial filament.



From S.C. Holt, Anatomy and chemistry of spirochetes. *Microbiological Reviews* 42) (1):122, 1978 American Society for Microbiology

Treponema flagella الشكل للاطلاع

Spirochaetes Motility



Axial filament lies inside outer sheath

rotate, causing corkscrew-shaped outer sheath to rotate and move cell through surrounding liquid

Motility adapted to moving through viscous solutions

Disease: Lyme disease and syphilis are spirochete diseases

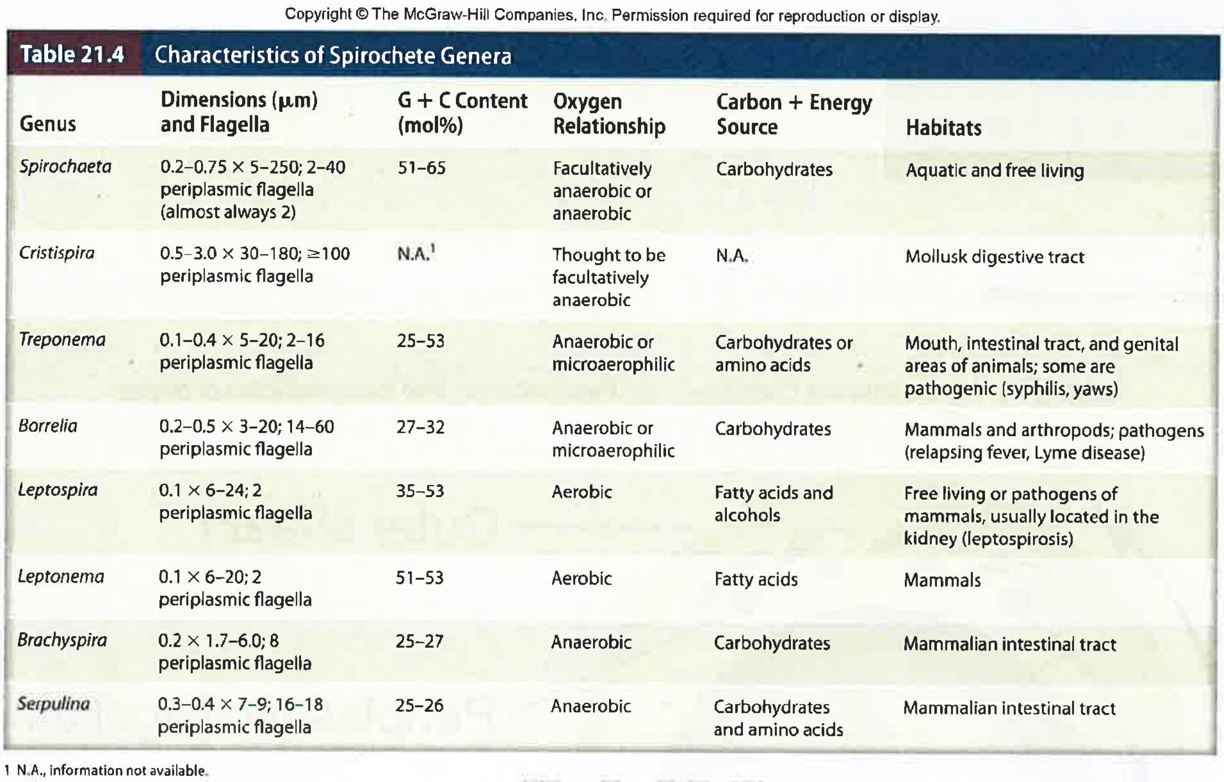


Table 21.4 Characteristics of Spirochete Genera

Genus	Dimensions (μm) and Flagella	G + C Content (mol%)	Oxygen Relationship	Carbon + Energy Source	Habitats
Spirochaeta	0.2–0.75 × 5–250; 2–40 periplasmic flagella (almost always 2)	51–65	Facultatively anaerobic or anaerobic	Carbohydrates	Aquatic and free living
Cristispira	0.5–3.0 × 30–180; ≥100 periplasmic flagella	N.A.[1]	Thought to be facultatively anaerobic	N.A.	Mollusk digestive tract
Treponema	0.1–0.4 × 5–20; 2–16 periplasmic flagella	25–53	Anaerobic or microaerophilic	Carbohydrates or amino acids	Mouth, intestinal tract, and genital areas of animals; some are pathogenic (syphilis, yaws)
Borrelia	0.2–0.5 × 3–20; 14–60 periplasmic flagella	27–32	Anaerobic or microaerophilic	Carbohydrates	Mammals and arthropods; pathogens (relapsing fever, Lyme disease)
Leptospira	0.1 × 6–24; 2 periplasmic flagella	35–53	Aerobic	Fatty acids and alcohols	Free living or pathogens of mammals, usually located in the kidney (leptospirosis)
Leptonema	0.1 × 6–20; 2 periplasmic flagella	51–53	Aerobic	Fatty acids	Mammals
Brachyspira	0.2 × 1.7–6.0; 8 periplasmic flagella	25–27	Anaerobic	Carbohydrates	Mammalian intestinal tract
Serpulina	0.3–0.4 × 7–9; 16–18 periplasmic flagella	25–26	Anaerobic	Carbohydrates and amino acids	Mammalian intestinal tract

[1] N.A., information not available.

Phylum *Bacteroidetes:*

The genus Bacteroides contains anaerobic, Gram-negative rods of various shapes they do not form endospore,they are motile or nonmotile. Often found in oral cavity and intestinal tract of humans and other animals and the rumen of ruminants, often benefit host by degrading complex carbohydrates, providing extra nutrition to host, constitute up to 30% of bacteria from human feces,

some cause disease.