The Phylum *Proteobacteria*

The largest phylogenetically coherent bacterial group with more than **500** genera.Remarkable diverse morphologically, physiologically, and other ways.

Volume **2** of *Bergey's Manual (2nd edition*) is devoted to this group of bacteria.

Lineages of *Proteobacteria*

Proteobacteria may have arose from a single photosynthetic ancestor . **16S rRNA** shows five distinct lineages:

1-*Alphaproteobacteria*

2-*Betaproteobacteria*

3-*Gammaproteobacteria*

4-*Deltaproteobacteria*

5-*Epsilonproteobacteria*

1-Class *Alphaproteobacteria*

Classified into seven orders and **20** families , can be distinguished with the following criteria:

1-*Rickettsiales* may have been the earliest α-proteobacteria.

2-Most of them are oligotrophic bacteria.

3-Most abundant bacteria in oceans.

4-Evolved to live within plants and animals resulting in genome reduction or expansion.

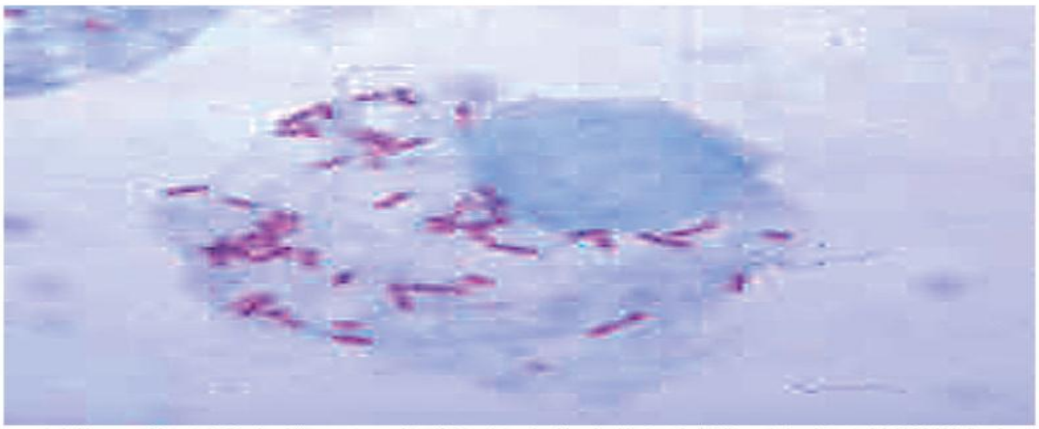
5-Metabolically diverse: methylotrophy, chemolithotrophs, nitrogen fixers (**Table .1**).

Table 1 Characteristics of Selected α-Proteobacteria

Genus	Dimensions (μm) and Morphology	G + C Content (mol%)	Genome Size (Mb)	Oxygen Requirement	Other Distinctive Characteristics
Agrobacterium	0.6–1.0 × 1.5–3.0; motile with peritrichous flagella, nonsporing rods	57–63	2.5	Aerobic	Chemoorganotroph that can invade plants and cause tumors
Caulobacter	0.4–0.6 × 1–2; comma-shaped with polar flagellum and prostheca with holdfast	62–65	4.0	Aerobic	Chemoorganotrophic and oligotrophic; asymmetric cell division
Hyphomicrobium	0.3–1.2 × 1–3; rod-shaped or oval with polar prosthecae	59–65	3.6	Aerobic	Reproduces by budding; methylotrophic
Nitrobacter	0.5–0.9 × 1.0–2.0; rod- or pear-shaped, sometimes motile by flagella	59–62	3.4	Aerobic	Chemolithotroph, oxidizes nitrite to nitrate
Rhizobium	0.5–1.0 × 1.2–3.0; motile rods with flagella	57–66	5.1	Aerobic	Invades leguminous plants to produce nitrogen-fixing root nodules
Rhodospirillum	0.7–1.5 wide; spiral cells with polar flagella	62–64	4.4	Anaerobic, microaerophilic, aerobic	Anoxygenic photoheterotroph under anoxic conditions
Rickettsia	0.3–0.5 × 0.8–2.0; short nonmotile rods	29–33	1.1–1.3	Aerobic	Obligate intracellular parasite

1-Genus *Rickettsia*

Very small, Gram-negative, non-flagellated (Fig.1) diverse morphology. All species are parasitic or mutualistic grows in vertebrate erythrocytes, macrophages, vascular endothelial cells , live in blood sucking arthropods vectors or primary .Genome sequence similar to mitochondria ,arose from endosymbiotic association, free living, aerobic bacterium became intracellular parasite of proto-eukaryotic cell that lacked organelles, gene reduction occurred and loss of free living ability . Lack glycolytic pathway ,do not use glucose as energy source . Oxidize glutamate and TCA cycle intermediates (e.g., succinate) .Take up and use ATP and other materials from host cell.



Berleman et al., Hypercyst Mutants in Rhodospirillum centenum Identify Regulatory Loci Involved in Cyst Cell Diff erentiation J. Bacteriol. 2004 186, fi g. 1, pg. 5836

Figure 1 : *Rickettsia*

Scientific classification

Domain :Bacteria
Phylum :Proteobacteria
Class : Alphaproteobacteria
Order : *Rickettsia*les
Family : *Rickettsia*ceae
Genus : *Rickettsia*
Species :*R. typhi*

Important pathogens

Rickettsia prowazekii and *Rickettsia typhi* causes typhus fever

Rickettsia rickettsii causes Rocky Mountain or Spotted Fever.

Reproduction

Rickettsia enters host by phagocytosis , escapes phagosome and reproduces in cytoplasm causing host cell bursts.

2-Genus *Brucella*

Important human and animal pathogen ,it is the causative agent of undulant fever zoonosis . This bacterium appear as tiny, faintly staining Gram-negative coccobacilli.

2-Class *Betaproteobacteria*

This group contains **7** orders and **12** families ,it is considered metabolically diverse (Table 2)

Table 2 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

1- Order *Neisseriales*

One family only; *Neisseriaceae* including15 genera .Members in this family are non -motile, Gram-negative cocci most often occur in pairs with adjacent sides flattened may have capsules and fimbriae as well as aerobic chemoorganotrophs , oxidase positive and usually catalase positive.

Genus *Neisseria*

This genus will be explained as a representative genus for the family , it may have capsules and fimbriae . Inhabitants of mucous membranes of mammals , some species in this genus are human pathogens like *Neisseria gonorrhoeae* that causes gonorrhea and *Neisseria meningitidis* which causes meningitis.

2- Order *Burkholderiales*

Well –Known genera in this order including ; Burkholderia, Bordetella, Sphaerotilus, and *Leptothrix* . Some members have a sheath which is hollow tubelike structure surrounding chain of cells may contain ferric or manganic oxides , it's functions are attachment to surfaces and obtaining nutrients from slowly running water as well as for cell protection.

1- Genus *Burkholderia*

Gram-negative, non–spore-forming, straight rods ,most motile with single flagellum or tuft of polar flagella. Aerobic and mesophilic . Nonfermentative, chemoorganotrophs catalase positive; often oxidase positive , most use poly-β-hydroxybutyrate as carbon reserve.

Burkholderia cepacia

Degrades **>100** organic molecules ,very active in recycling organic material. Plant pathogen . Has become a major nosocomial pathogen since it constitute particular problem for cystic fibrosis patients.

Scientific classification

Domain :Bacteria
Phylum :Proteobacteria
Class : Betaproteobacteria
Order : Burkholderiaceae
Genus: *Burkholderia*
Species: *B. cepacia*

2- Genus *Bordetella*

Gram-negative coccobacilli, some have capsules. Aerobic chemoorganotrophs , metabolism by respiration not fermentation ,require organic sulfur and amino acids for growth. Mammalian parasites that multiply in respiratory epithelial cells, nonmotile, encapsulated species,causing whooping cough and kennel cough.

3- Class *Gammaproteobacteria*

Largest subgroup of proteobacteria contains **14** orders and **28** families .Very diverse physiological types some are chemoorganotrophs , others are photolithotrophs, or chemolithotrophs , as well as methylotrophs , aerobic and anaerobic . Many deeply branching (Table 3).

Table 3 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

1-Order *Pseudomonadales*

The typical family *is* *Pseudomonadaceae* and *Pseudomonas* is the most important genus in the order Pseudomonadales it is heterogenous as it is includes 60 species .Gram-negative straight or slightly curved rods (0.5 - 1.0)μm by (1.5 - 5.0)μm in length motile by one or several polar flagella , lack prosthecae or sheaths.

Genus *Pseudomonas*

Chemoheterotrophs with respiratory metabolism, usually use oxygen as electron acceptor , sometimes use nitrate as electron acceptor , have functional TCA cycle , most hexoses are degraded by Entner-Duodoroff pathway.

Scientific classification

Domain: Bacteria
Phylum: Proteobacteria
Class : Gammaproteobacteria

Order :Pseudomonadales
Family :Pseudmonadaceae
Genus :Pseudomonas
Species :*P. aeruginosa*

Practical Importance of Pseudomonads

1-Degrade wide variety of organic molecules

2-Mineralization: microbial breakdown of organic materials to inorganic substrates

3-Important experimental subjects

4-Some are major animal and plant pathogens

5.Some cause spoilage of refrigerated food because can grow at 4°C