Bacterial Classification and Nomenclature

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What is Taxonomy

✓ Taxonomy is the science of the classification of organisms, with the goal of showing evolutionary relationships among organisms.

✓ Taxonomy includes:
  (a) Identification.
  (b) Nomenclature.
  (c) Classification.
**Identification** – is the process of studying and recording the identical and distinguishing features.

**Nomenclature** – is the process of assigning names to the various taxonomic ranking of each living organism.

**Classification** – is the orderly arrangement of organisms into groups, preferably in a format, that shows evolutionary relationships.
Basis of Taxonomy

✓ Phenetic system groups organisms based on mutual similarity of phenotypic characteristics. May or may not correctly match evolutionary grouping, e.g. motile v/s non motile bacteria.

✓ Phylogenetic system groups organisms based on shared evolutionary genetic heritage.
Taxonomy of bacteria

✓ Living organisms were once divided into only two kingdoms: plantae and animaliae: bacteria, fungi, and algae were classified with plants; protozoa were classified as animals.

✓ Haeckel in 1865 proposed third kingdom Protista for unicellular microorganisms such as bacteria, algae, fungi and protozoa.

✓ Bacteria were separated into the Kingdom Procaryotae or Monera in 1969 by Whittaker – five kingdoms
Whittaker 5 Kingdom classification

Based on cellular organization and nutritional patterns:

**Procaryotae or Monera** - prokaryotic, unicellular, variable nutrition patterns – bacteria.

**Protista** - eukaryotic, unicellular or colonial, heterotrophic – protozoa, slime molds, some algae.

**Myceteae or Fungi** - eukaryotic, unicellular or multicellular, heterotrophic or absorptive – molds, yeasts, mushrooms.

**Plantae** - eukaryotic, multicellular or colonial, autotrophic – plants, some algae, mosses, ferns.

**Animalia** - eukaryotic, multicellular, heterotrophic or ingestive – animals.
The Three Domains
(Carl Woese and George Fox, 1977)

Currently, living organisms are divided into three super kingdoms, called as **domains**, 

- **Eukarya Domain** include plants, animals, fungi, and protists
- **Eubacteria Domain** include bacteria with peptidoglycan in cell wall.
- **Archaea Domain** include bacteria (Archaea) with unusual cell walls
Based on cellular rRNAs sequence primarily

- cell membrane lipid structure and sensitivity to antibiotics.

- rRNA molecules throughout nature carry out the same function and genetically stable very little over time.

- This system proposes that a common ancestor cell ("Cenancestor") gave rise to three different cell types, each representing a domain.
Three Cellular Domains

BACTERIA
- Purple bacteria
- Gram-positive bacteria
- Cyanobacteria
- Flavobacteria
- Thermotoga
- Aquifex

ARCHAEA
- Thermoproteus
- Pyrodictium
- Methanococcus
- Methanobacterium
- Halobacterium
- Methanopyrus

EUKARYA
- Entamoebae
- Slime molds
- Animals
- Fungi
- Plants
- Ciliates
- Flagellates
- Microsporidia
- Diplomonads
The *Archaea* (archaebacteria)

- *Archaea* are prokaryotic cells.
- Contain rRNA that is unique to the *Archaea* distinctly different from the rRNA of *Bacteria* and *Eukarya*.
- Cell membranes composed of branched hydrocarbon chains attached to glycerol by ether linkages.
- Cell walls of *Archaea* does not have peptidoglycan.
- *Archaea* are not sensitive to some antibiotics that affect the *Bacteria*, but are sensitive to some antibiotics that affect the *Eukarya*.
Membrane Lipids of Bacteria and Eukarya

Membrane Lipids of Archaea
The *Bacteria* (eubacteria)

- *Bacteria* are prokaryotic cells.
- contain rRNA that is unique to the *Bacteria* distinctly different from the rRNA of *Archaea* and *Eukarya*.
- cell membranes composed of unbranched fatty acid chains attached to glycerol by ester linkages.
- cell walls contain peptidoglycan.
- *Bacteria* are sensitive to traditional antibacterial antibiotics but are resistant to most antibiotics that affect *Eukarya*. 
The *Eukarya* (eukaryotes)

- *Eukarya* have eukaryotic cells.
- contain rRNA that is unique to the *Eukarya* distinctly different from the rRNA of *Archaea* and *Bacteria*.
- Cell membranes composed of unbranched fatty acid chains attached to glycerol by ester linkages.
- Not all *Eukarya* possess cell wall, but those having a cell wall does not contains peptidoglycan.
- *Eukarya* are resistant to traditional antibacterial antibiotics but are sensitive to most antibiotics that affect eukaryotic cells.
Methods of Identifying Bacteria

✓ Morphological characteristics
✓ Biochemical tests
✓ Serological tests
✓ Phage typing
✓ Sequences of amino acids in proteins
✓ Percentage of G-C pairs in the nucleic acid
✓ Number and sizes of DNA fragments produced by restriction enzymes
✓ Sequence of bases in 16S rRNA (Ribotyping)
Nomenclature of Bacteria

Scientific Nomenclature

✓ According to scientific nomenclature, each bacteria is assigned two names (binomial nomenclature): a genus and a species.

✓ Rules for the assignment of names to bacteria are established by the International Committee on Systematic Bacteriology.
Taxonomic hierarchies

- Kingdom
- Phylum
- Class
- Order
- Family
- Genus
- Species
Linnaean hierarchy

Example for *E. coli*

Domain: Eubacteria

Kingdom: *Procaryotae*

Division/Phylum: *Gracilicutes*

Class: *Scotobacteria*

Family: *Enterobacteriaceae*

Genus: *Escherichia*

Species: *coli*
Methods of Classifying Bacteria

The Intuitive Method

In this method a microbiologist who is thoroughly familiar with the properties of the organisms decides that a particular organism represent a species or genus.
Dichotomous Key

1a Gram-positive  Go to 2
1b Not Gram-positive  Go to 3

2a Cells spherical in shape  Gram-positive cocci
2b Cells not spherical in shape  Go to 4

3a Gram-negative  Go to 5
3b Not Gram-negative (lack cell wall)  Mycoplasma

4a Cells rod-shaped  Gram-positive bacilli
4b Cells not rod-shaped  Go to 6

5a Cells spherical in shape  Gram-negative cocci
5b Cells not spherical in shape  Go to 7

6a Cells club-shaped  Corynebacteria
6b Cells variable in shape  Propionibacteria

7a Cells rod-shaped  Gram-negative bacilli
7b Cells not rod-shaped  Go to 8

8a Cells helical with several turns  Spirochetes
8b Cells comma-shaped  Vibrioids
Numerical taxonomy

In this method of taxonomy of many (100 to 200) characteristics for each bacterial strain is determined, giving each characteristic equal weight. Then percentage similarity (%S) of each strain to every other known strain is calculated by the formula:

\[ %S = \frac{NS}{NS + ND} \]

where,

NS = number of characteristics that are same (positive or negative) for the two strains,

ND = number of characteristics that are different.

strains having a higher %S to each other are placed into same group.
Organism A has traits 1, 2, 3, 4, and 5.

Organism B has traits 1, 2, 3, 4, 6, and 7.

Organisms C and D have traits 1, 2, 3, 4, 6, and 8 in common and are probably strains of the same species.

Organism E has traits 1, 2, 3, and 9.

Organism F has traits 1, 2, 10, and 11.

Organism G has traits 1, 2, 10, and 12.

Organism H has traits 1, 2, 10, and 13.

Organism I has traits 1 and 14.

GROUP I
Organisms in this group share traits 1, 2, 3, and 4.

GROUP II
Organisms in this group share traits 1, 2, and 10.
Genetic Relatedness

➢ most reliable method of classification
➢ based on the degree of genetic relatedness between organisms
➢ relies upon G+C content, DNA homology, ribosomal RNA homology (16S rRNA for prokaryotes and 18S rRNA for eukaryotes – ribotyping).
Genetic homologies (similarities) can be determined by looking at:

- Base compositions
- DNA-DNA or DNA-RNA Hybridization
- DNA or RNA sequencing
The Bergey’s Manual

Bergey’s Manual of Determinative Bacteriology

✓ International standard for bacterial taxonomy.
✓ First published in 1923.
✓ 9 editions have been published.
✓ From 1980 it is renamed as Bergey’s Manual of Systemic Bacteriology published as a 4 volume set from 1984.
✓ In 2012 – 5 volume set.
In the original 4 volumes of *Bergey’s Manual of Systematic Bacteriology*, bacteria were classified in 33 sections based on phenotypic, not phylogenetic characteristics.

**Kingdom:** Procaryotae  
**Divisions:**

- **Gracilicutes** (thin skin): Procaryotes with a Gram-negative cell wall.
- **Firmicutes** (thick skin): Procaryotes with a Gram-positive cell wall.
- **Tenericutes** (soft or tender skin): Procaryotes that lack a cell wall.
- **Mendosicutes** (skin with faults): Procaryotes with unusual cell wall.

The current 5 volumes define taxa not in terms of phenotype, but solely on 16S phylogeny.