A study material for M.Sc. Biochemistry (Semester: IV) Students
on the topic (EC-1; Unit I)

Taxonomy of Bacteria

Classification of the invisibles

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Taxonomy

Taxonomy - the science of biological classification

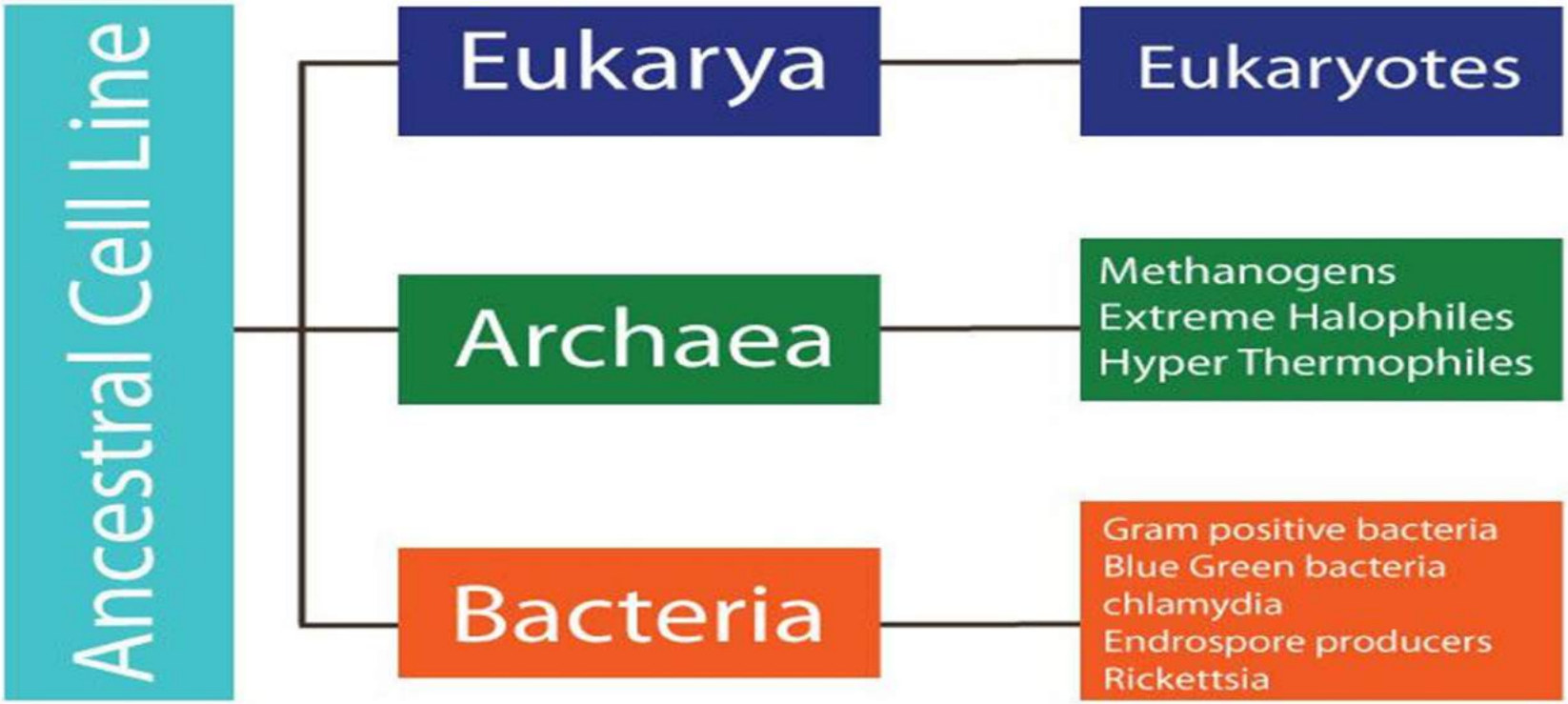
Microbial Taxonomy is a means by which microorganisms can be grouped together. Organisms having similarities with respect to the criteria used are in the same group, and are separated from the other groups of microorganisms that have different characteristics. Taxonomy is the science of biological classification. Classification is the arrangement of organisms into groups (taxa) Nomenclature refers to the assignment of names to taxonomic groups. Identification refers to the determination of the particular taxon to which a particular isolate belongs.

- In other words- It is a branch of science that deals with identification, nomenclature and Classification of any organism.
- Classification - arrangement of organisms into groups or taxa (s., taxon) based upon similarities or evolutionary relatedness
- Nomenclature - assignment of names to taxonomic groups using special rules
- Identification - determining to which recognized taxon a particular organism belongs.

Systematics: Study of organisms with the ultimate objective of characterizing and arranging them in an orderly manner

Importance of taxonomy

- Permits the organization to organize huge amounts of information about organism
- Allows predictions and hypotheses to be made upon this information
- Places organisms in useful groups with precise names that permit effective communication between investigators
- Essential for the identification of organisms



Hierarchical arrangement in Taxonomy

Domain: Bacteria

Phylum: Proteobacteria

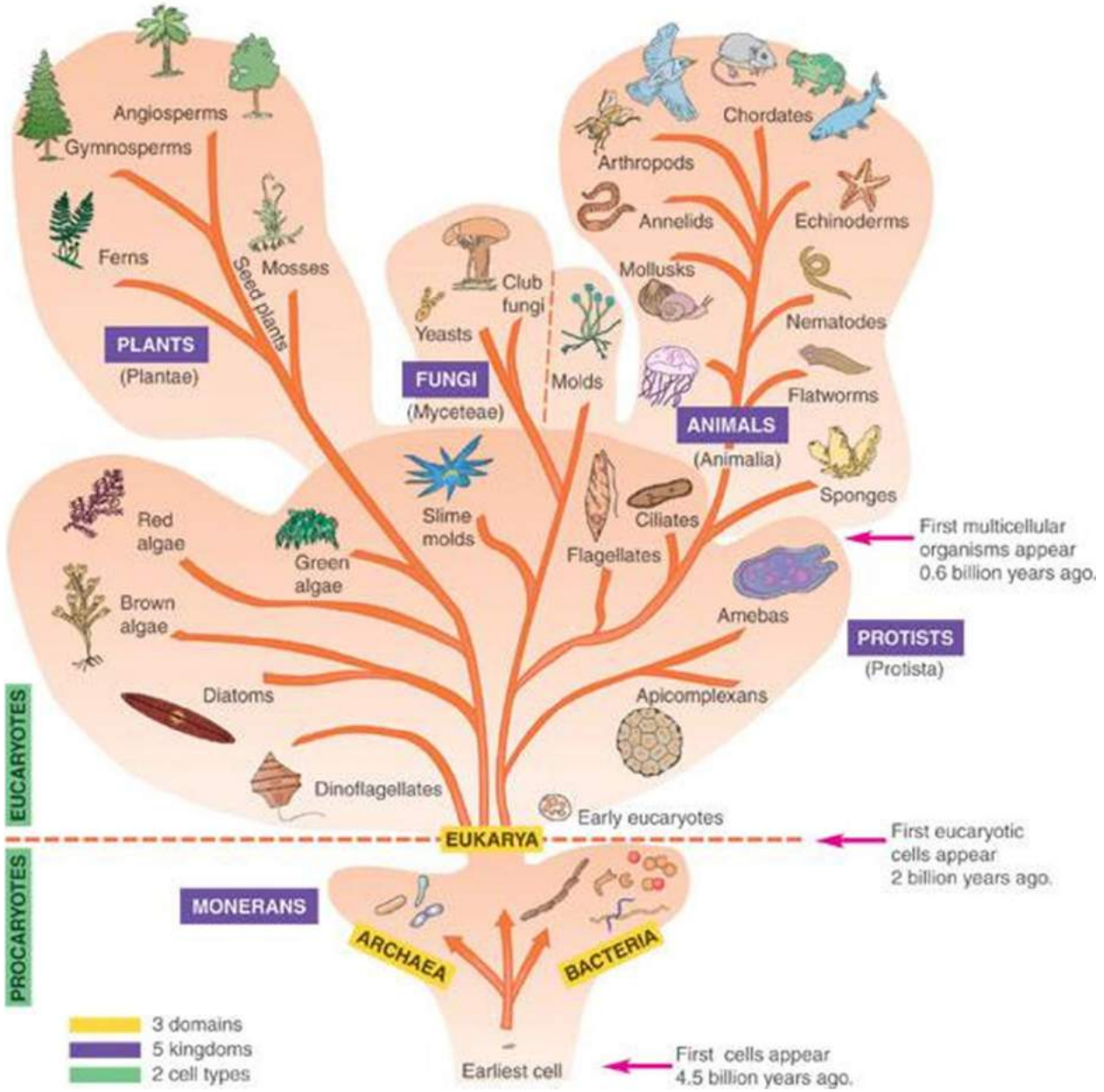
Class: Gamma Proteobacteria

Order: Enterobacteriales

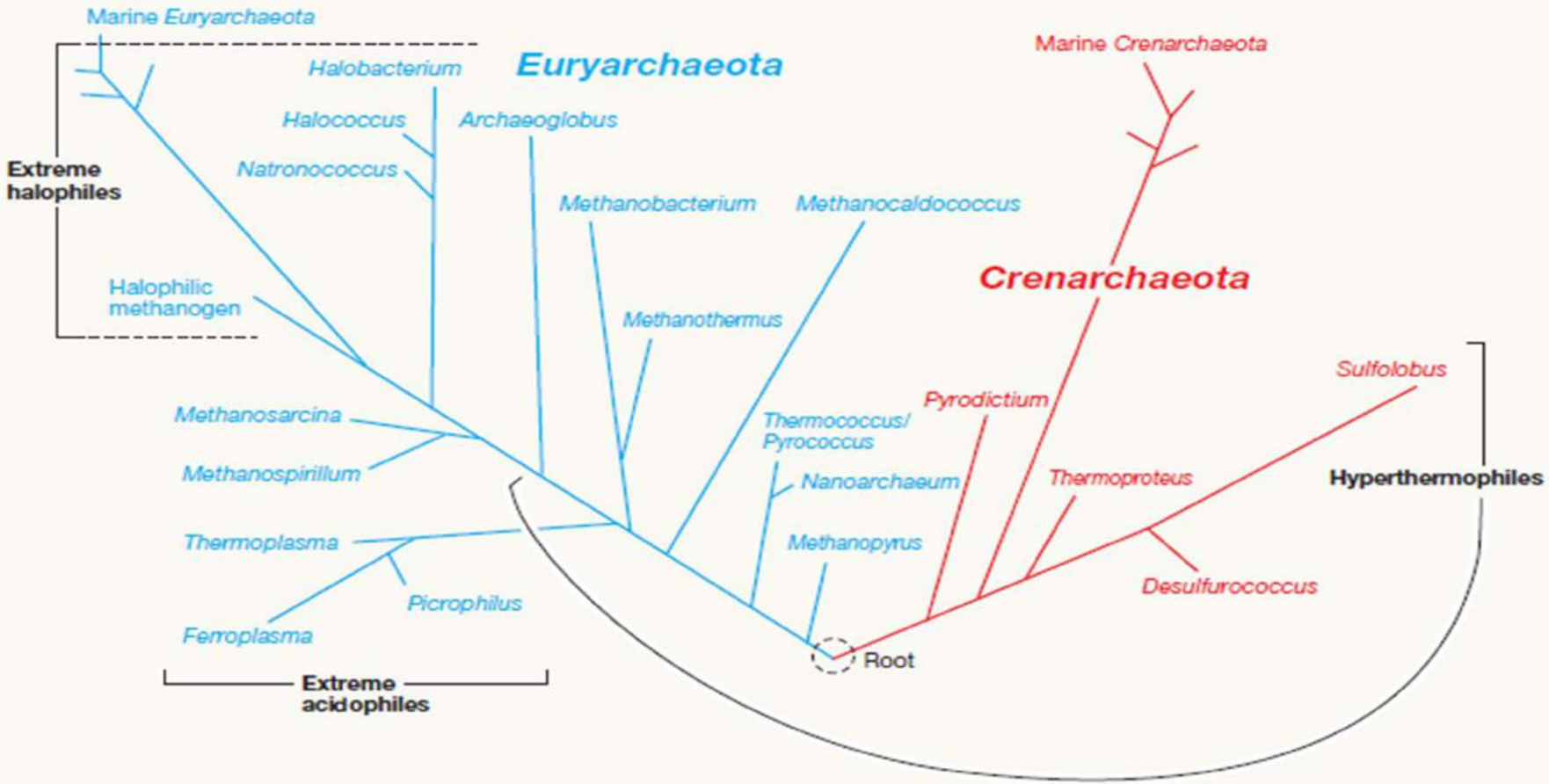
Family: Enterobacteriaceae

Genus: *Escherichia*

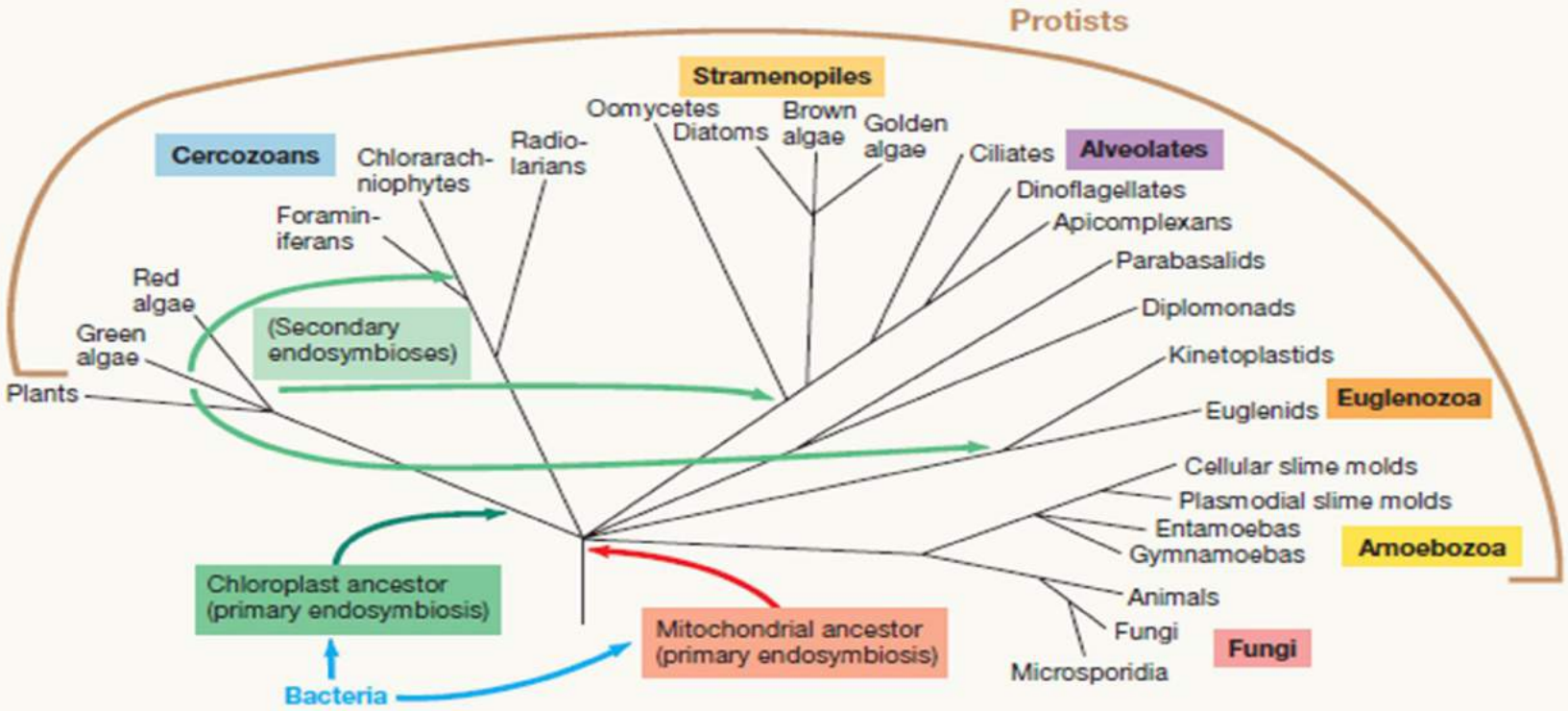
Species: *Escherichia coli*

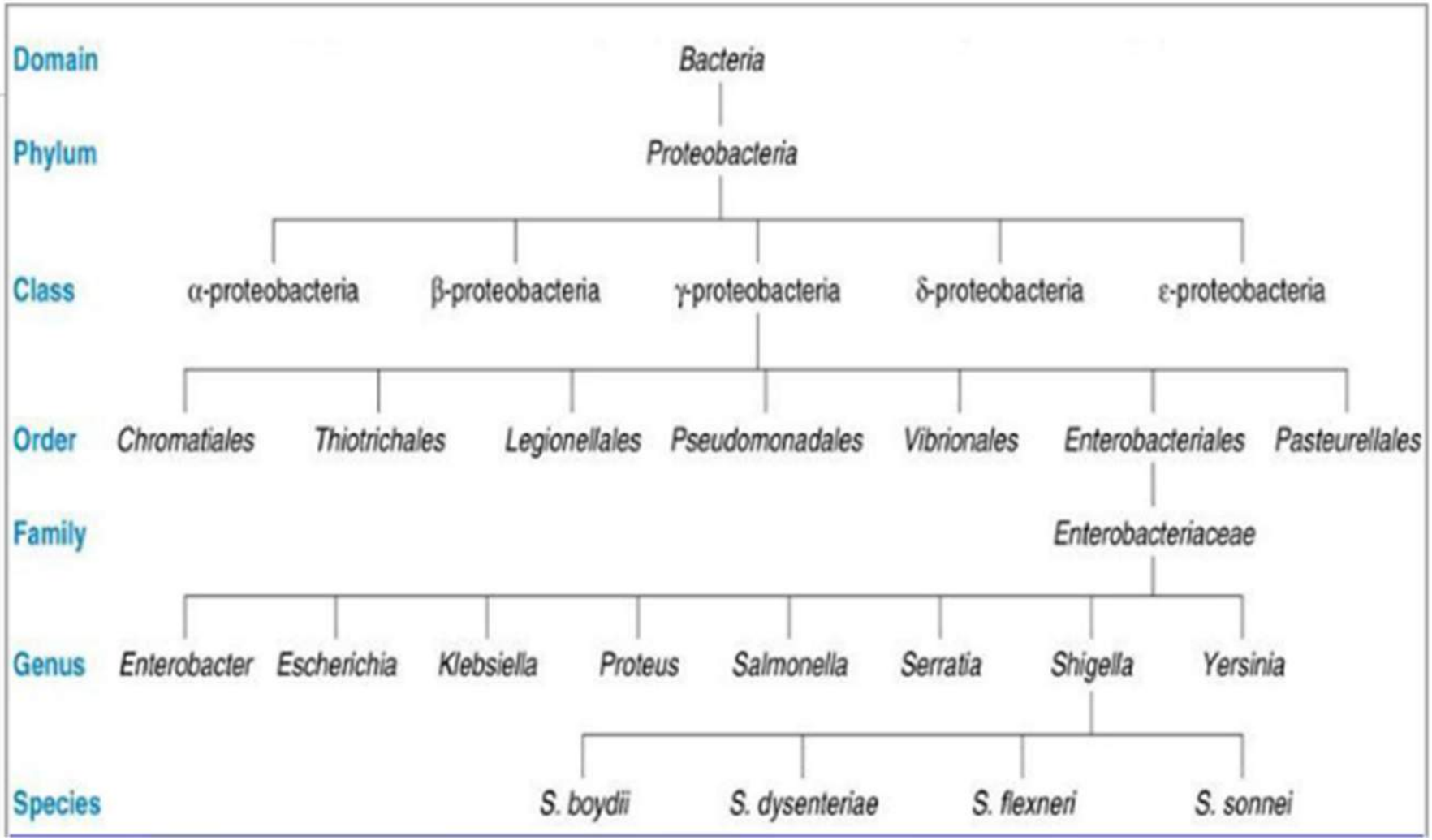


The Phylogeny of *Archaea*



The Phylogeny of *Eukarya*




Domain
Bacteria
Phylum
Proteobacteria
Class
α-proteobacteria
β-proteobacteria
γ-proteobacteria
δ-proteobacteria
ε-proteobacteria
Order
Chromatiales
Thiotrichales
Legionellales
Pseudomonadales
Vibrionales
Enterobacteriales
Pasteurellales
Family
Enterobacteriaceae
Genus
Enterobacter
Escherichia
Klebsiella
Proteus
Salmonella
Serratia
Shigella
Yersinia
Species
S. boydii
S. dysenteriae
S. flexneri
S. sonnei

Criteria for the classification of bacteria

- Morphological characteristics
- Physiological and metabolic characteristics
- Ecological characteristics
- Biochemical Characteristics
- Serological method
- Genetic analysis
- Molecular characteristics

Morphological characteristics

- Cell shape
- Cell size
- Cilia and flagella
- Cellular inclusions
- Color
- Endospore shape and location
- Spore morphology and location
- Colonial morphology
- Staining behavior

Physiological, Metabolic and Ecological Characteristics

- Carbon and nitrogen sources
- Cell wall constituents
- Energy sources
- Fermentation products
- Motility
- Osmotic tolerance
- Storage inclusions
- General nutritional type
- Growth temperature optimum and range
- pH optimum and growth range
- Photosynthetic pigments
- Salt requirements and tolerance
- Secondary metabolites formed
- Sensitivity to antibiotics

Biochemical Characreristics

- Fermentation of carbohydrates.
- Hydrolysis of starch and cellulose
- Production of indole, hygrogen sulphide, acetyl methyl carbonol, etc. in media
- Reduction of Nitrate, Sulphate, Methylene blue or Litmus in media.
- Production of specific enzymes (Phosphatse, Hyaluronidase, Cellulase etc.)

Serological method

- Use group specific antiserum isolated from the plasma of organism that have been sensitized to the organism
  - The antiserum contains antibody proteins that react with antigens on the unknown organism.
  - The reaction can be detected by examining agglutination or by using sera labeled with fluorescent labels

Genetic analysis

- The study of transformation and conjugation and Transduction in bacteria.
- Extrachromosomal elements such as Plasmid, Transposon etc.
- Life cycle i.e. Lytic cycle and Lysogenic cycle.

Molecular characteristics: Proteins or Genes

- **DNA fingerprinting**
- **Comparison of Proteins**
  - Determination of Amino Acid sequence
  - Comparison of electrophoretic mobility
- **Nucleic acid base sequence:**

$$\text{Mol\% (G+C)} = \frac{\text{G+C}}{\text{G+C+A+T}} \times 100\%$$

  - Estimated by determining the melting temperature of the DNA
  - Higher G + C gives a higher melting temperature
- **Nucleic acid sequencing**
- **Nucleic acid hybridization**
  - By mixing ssDNA from two different species and determining the percentage of the DNA that can form dsDNA hybrids
  - The greater the percent hybridization, the closer the species
- **16 S rDNA sequence analysis:**
- Highly conserved primer binding sites.
- Gene sequences contain hypervariable regions that can provide species-specific signature sequences useful for bacterial identification

Numerical Taxonomy (Taximetrics)

- The branch of taxonomy that uses mathematical methods to evaluate observable differences and similarities between taxonomic groups.
- It aims to create a taxonomy using numeric algorithms like cluster rather than using subjective evaluation of their properties.
- The concept was first developed by Robert R. Sokal & Peter H. A. Sneath in 1963 but first it was approached by Adanson and hence it is called as **Adansonian Taxonomy**.
- All characteristics are given equal weight (either 0 , 1 or +, -) and a computer based analysis is carried out to group the bacteria according to shared properties.

Logical Steps of Numerical taxonomy

- Collecetion of Data
- Coding of Data
- Calculation of Similarity or Dissimilarity Matrix based on computer analysis.
- Formation of Dendrogram
- Interpretation of results

Operation Taxonomic Units (OTUs) :

Most taxonomic work with bacteria is carried out on individual strains even though species, genera and bigger groups may also be studied. These entities are called OTUs.

Bergey's Manual

- David Bergeys at University of Pennsylvania published in 1923 a manual for the identification of bacterial species and called it Bergey's Manual of Determinative Bacteriology.
- It classifies the bacteria only on the morphological character and do not include phylogenetic character (With out numerical taxonomy).
- Total eight editions of Bergey's Manual of Determinative Bacteriology is published.
- In 1984, a new approach was adopted in the compilation of Bergey's Manual. It was renamed as Bergey's Manual of Sytematic Bacteriology instead of it Bergey's Manual of Determinative Bacteriology. It includes phylogenetic character (With Numerical taxonomy).
- Total Two editions of this manual is publishes and each edition contains four volumes.

1st Edition:

1st Volume: Gracilicutes: Bacteria with Gram negative cell wall

2nd Volume: Firmicutes: Bacteria with Gram positive cell wall

3rd Volume: Tenericutes: Bacteria lacking cell wall

4th Volume: Mendosicutes: Bacteria lacking peptidoglycan in cell wall

2nd Edition:

- **It was published in 2001. It is classified based on 16S rRNA (It was not in 1st edition)**
- **2nd edition is more phylogenetic and systematic as compared to 1st edition**
- **It has 5 volume**

  1st Volume: Archaea

  2nd Volume: Proteobacteria (Gram Negative)

  3rd Volume: Low G+C gram Positive bacteria

  4th Volume: High G+C gram positive bacteria

  5th volume: Plectomycetes

Acknowledgement and Suggested Readings:

1. Microbiology, An Introduction; Tortora, Funke and Case; Pearson Publication
2. Microbiology; Prescott, Harley and Klein; The MacGraw-Hill Companies
3. Microbiology: Principles and Explorations; Jacquelyn G Black; John Wiley and Sons Inc.
4. Brock Biology of Microorganisms; Madigan, Martinko, Stahl and Clark; Benjamin Cummings (Pearson Publication)

Thanks