Classification of Microorganisms

Organisms were first named and classified more than 2,000 years ago by the Greek philosopher Aristotle. He classified everything as either a plant or an animal and then grouped them into land dwellers, water dwellers, and air dwellers. This system worked very well for a period of time but eventually, new species studied during course of time didn't fit into his categories.

In 1735 Carolus Linnaeus, widely known as 'Father of Taxonomy', classified the organisms into two kingdoms:

Kingdom *Plantae* - Plants and Fungi
Kingdom *Animalia*- Animals

Binomial System of Nomenclature

Carolus Linnaeus introduced binomial nomenclature system i.e., two Latin names for identification of an organism for the first time. Each organism is given a 'generic' name called Genus (plural= genera) and a specific name i.e., species. Generic name and specific name together forms a scientific name (Systematic Name). When written, a scientific name is always either italicized, or, if hand-written, is underlined. The genus is capitalized and the species name is written in a lower case. e.g., *Escherichia coli*.

The binomial (or binominal) nomenclature was originally codified in the works of Linnaeus, *Species Plantarum* (1753) and *Systema Naturae, 10th Edition* (1758). These publications are the decided starting points for the modern biological nomenclature in most groups of plants and animals.The binomial system has been a successful system because it is functional, has been the only system that has been universally accepted, and has been used over the last 250 of nomenclature.

Meningococcus (*Neiserria meningitidis*)

Group A Streptococcus (*Streptococcus pyogenes*)

Genus name + species name are italicized or underlined. **Genus name** is capitalized and may be abbreviated. Species name is never abbreviated. A genus name may be used alone to indicate a genus group; a species name is never used alone eg., *Bacillus subtilis*

Nomenclature

Common or descriptive names (trivial names): Names for organisms that may be in common usage, but are not taxonomic names: eg: tubercle bacillus (*Mycobacterium tuberculosis*)

Taxonomy: Classification of living organisms into groups

Phylogenetic Classification System: Groups reflect genetic similarity and evolutionary relatedness

Phenetic Classification System: Groups do not necessarily reflect genetic similarity or evolutionary relatedness. Instead, groups are based on convenient, observable characteristics.

Natural Classification (Benthem & Hooker) **:** Groups mainly for plant, based on resemblance, mostly gross morphology.

Taxon:

A group or "level" of classification. Hierarchical; broad divisions are divided up into smaller divisions:

Kingdom (Not used by most bacteriologists)>**Phylum** (Called "Division" by botanists)>**Class**>**Order>Family**>**Genus** (plural: Genera)>Species (Both singular & plural)

The "basic unit" of taxonomy, representing a specific, recognized type of organism. For sexually reproducing organisms, a fundamental definition of "species" has been reproductive compatibility. This definition fails for many microbial species (including bacteria), because they do not reproduce sexually.

Definition of "**Species**" in microbiology: A collection of microbial strains that share many properties and differ significantly from other groups of strains

Species are identified by comparison with known "type strains": well-characterized pure cultures; references for the identification of unknowns. There are several collections of type strains, including the American Type Culture Collection (ATCC).

Strain: A population of microbes descended from a single individual or pure culture. Different strains represent genetic variability within a species

Biovars: Strains that differ in biochemical or physiological differences

Morphovars: Strains that vary in morphology

Serovars: Stains that vary in their antigenic properties

Carolus Linnaeus - His system for naming, ranking and classifying organisms is still widely used today with sort of changes. Unicellular organisms were not taken into consideration.

In 1866 **Ernest H. Haeckel**, German Zoologist, proposed new **third kingdom Protista** for unicellular organisms that are typically neither plants nor animals.Viruses not being cellular structure were not classified as Protists. Bacteria re referred to be lower protists and whereas others fungi, algae, protozoa are called higher Protists. Multicelluar organisms were also grouped by some taxonomists. Bacteria were grouped under separate group **Monera** within the Protista kingdom.

Kingdom *Plantae* **-** Plants and Fungi
Kingdom *Animalia*- Animals
Kingdom *Protista*- Bacteria

Based on differences in biochemical and cellular internal structures the **kingdom Protista** has been divided into two cell types i.e., **Procaryotes** (Bacteria and blue-green algae) and **Eucaryotes**(Fungi, protozoa, other algae, slime moulds).

Features	**Procaryote**	**Eucaryote**
Groups/ unit of structure	Bacteria	Algae, fungi, protozoa, plants and animals
Size of organisms	1-2 by 1-4um or less	Greater than 4 um
Genetic system		
Location	Nucleoid, chromatin body, nuclear material	Nucleus, mitochondria, chloroplasts
Structure of nucleus	Not bounded by nuclear membrane, one circular chromosome	Bounded by nuclear membrane, More than one chromosome
	Chromosomes does not contain histones, no mitotic division	Chromosomes contain histones, Mitotic nuclear division
	Nucleolus absent; functionally related genes may be clustered	Nucleolus present; functionally related genes not clustered
Sexuality	Zygote nature is merozygotic(Partial diploid)	Zygote is diploid
Cytoplasmic nature and structures		
Cytoplasmic streaming	Absent	Present
Pinocytosis	Absent	Present
Gas vacuoles	Can be preent	Absent
Mesosome	Present	Absent
Ribosomes	70S distributed in cytoplasm	80S present on membranes as in endoplasmic reticulum; 70S in mitochondria nd chloroplasts
Mitochondria	Absent	Present
Chloroplasts	Absent	May be Present
Golgi structures	Absent	Present
Endoplasmic reticulum	Absent	Present
Membrane bound (true vacuoles)	Absent	Present
Outer cell structures		
Cytoplasmic membrane	Generally donot contain sterols; contain part of respiratory and in some, photosynthetic machinery	Sterols present; donot carry out respiration and photosynthesis
Cell wall	Peptidoglycan (Murein of mucopeptide)	Peptidoglycan absent
Locomotor organelles	Simple fibrill	Multifibrilled with ''9+2'' microtubules

Pseudopodia	Absent	Present sometime
Metabolic mechanisms	Broad. Anaerobic energy yielding reactions; some fix nitrogen gas; some accumulate poly-b-hydroxybutyrate as reserve material	Anaerobic energy - yielding mechanism - Glycolysis pathway
DNA base ratio (G+C%)	28 to73	40

S- Svedberg unit- The sedimentation co-efficient of a particle in the ultracentrifuge.

New fourth kingdom, **Monera,** for bacteria only, was proposed by Herbert Copeland in 1938.

	PROKARYOTES	**EUKARYOTES**		
Kingdom	**Monera** (Prokaryote)	**Protista**	**Plantae**	**Animalia**
Organisms	Bacteria	Amoebas, diatoms, and other single-celled eukaryotes, and sometimes simple multicellular organisms, such as seaweeds.	Plants Fungi	Animals

In 1957 **Robert H. Whittaker** proposed **fifth kingdom** for and as **Fungi .**

Criterion for Whittaker Five Kingdom Classification:

1. Complexity of cell structure: Prokaryotic and eukaryotic
2. Complexity of organisms: Unicellular or Multicellular
3. Mode of nutrition: Autotrophs (Plantae), Heterotrophs and saprobic absorption (Fungi), Heterotrophs and ingestion (Animalia)
4. Life style: Producers (Plantae), Consumers (Animalia), Decomposers (Fungi)
5. Phylogenetic relationships: Unicellular to multicellular organisms.

Kingdom	Monera (Prokaryote)	Protista	Fungi	Plantae	Animalia
Organisms	Bacteria	Amoebas, diatoms, and other single-celled eukaryotes, and sometimes simple multicellular organisms, such as seaweeds.	Multicellular, filamentous organisms that absorb food	Multicellular organisms that make food through photosynthesis	Multicellular organisms that ingest food

In 1990, **Carl Woese** **formed a new category, called a** **Domain**, to reflect evidence from nucleic acid studies that precisely revealed evolutionary, or family, relationships. He found that a group of organisms previously classified under Bacteria belong to a separate taxon. They are the **Archea** . They have distinct molecular structures and physiological characteristics. They live in extremely hot, saline, or acidic anaerobic environments. He proposed three domains, **Archaea**, **Bacteria**, and **Eucarya**, based largely on the type of ribonucleic acid (RNA) in cells.

	PROKARYOTES		**EUKARYOTES**			
Domain:	**Archaea**	**Bacteria**	**Eucarya**			
Kingdom:	Crenarchaeota	Euryarchaeota	Protista	Fungi	Plantae	Animalia
Organisms:	Ancient bacteria that produce methane	Ancient bacteria that grow in high temperatures				

Useful Properties in Classification

Colony morphology, Cell shape & arrangement, Cell wall structure (Gram staining), Special cellular structures, Biochemical characteristics,

Serological Tests

Use group specific antiserum isolated from the plasma of animals 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 colorimetric or fluorescent labels.

Advantages:

Highly specific, does not usually require the organism to be isolated into pure culture. Can be used to identify organisms that can't be grown on medium.

G + C content

Estimated by determining the melting temperature of the DNA. Higher G + C gives a higher melting temperature.

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

Nucleic acid sequencing

The nucleic acid sequence for the complete genome of several species is now available. 5S and 16S rRNA (ribosomal RNA) sequences; comparison of these sequences has been extensively used to determine the phylogenetic relationships of microbial groups.

Bergey's Manual of Systematic Bacteriology

In 1927, David Bergey & colleagues published *Bergey's Manual of Determinative Bacteriology*, a manual that grouped bacteria into phenetic groups, used in identification of unknowns. It is now in its 9th edition.In 1984, a more detailed work entitled *Bergey's Manual of Systematic Bacteriology*was published, still primarily phenetic in its classification.

Publication of the second edition of *Bergey's Manual of Systematic Bacteriology*was begun in 2001. The 2nd edition gives the most up-to-date phylogenic classification of prokaryotic organisms, including both eubacteria and archaea, it consist of 5 volumes. The classification in *Bergey's Manual* is accepted by most microbiologists as the best consensus for prokaryotic taxonomy.

Domains

Based on the research of Woese and others in the 1980s and 1990s, most biologists divide all living organisms into 3 domains:

Domain *Archaea*
Domain *Bacteria*
Domain *Eucarya,* rRNA sequence data suggests that *Archaea* & *Eucarya* may share a more recent common ancestor with each other than with *Bacteria.*

Many microbiologists reject the "kingdom" designation. Each domain is divided into phyla, phyla into classes. etc. There is often great metabolic and ecological diversity among the members of a group, perhaps reflecting parallel evolution of such things as fermentation pathways, photosynthetic pathways, etc

Phylogeny of domain *Archaea*

Based primarily on rRNA sequence data, domain *Archaea*is divided into two phyla:

Phylum *Crenarchaeota*

Originally containing thermophilic and hyperthermophilic sulfur-metabolizing archaea

Recently discovered *Crenarchaeota*are inhibited by sulfur & grow at lower temperatures

Phylum *Euryarchaeota*

Contains primarily methanogenic archaea, halophilic archaea, and thermophilic, sulfur-reducing archaea

Phylogeny of domain *Bacteria*

The 2nd edition of *Bergey's Manual of Systematic Bacteriology* divides domain *Bacteria* into 23 phyla. Nine of the more notable phyla are described here.

Phylum *Aquiflexa*

The earliest "deepest" branch of the *Bacteria*

Contains genera *Aquiflex*and *Hydrogenobacter* that can obtain energy from hydrogen via chemolithotrophic pathways

Phylum *Cyanobacteria*

Oxygenic photosynthetic bacteria

Phylum *Chlorobi*

The “green sulfur bacteria”

Anoxygenic photosynthesis, includes genus *Chlorobium*

Phylum *Proteobacteria*

The largest group of gram-negative bacteria

Extremely complex group, with over 400 genera and 1300 named species

All major nutritional types are represented: phototrophy, heterotrophy, and several types of chemo-lithotrophy

Sometimes called the “purple bacteria,” although very few are purple; the term refers to a hypothetical purple photosynthetic bacterium from which the group is believed to have evolved

Divided into 5 classes: *Alphaproteobacteria*, *Betaproteobacteria*, *Gammaproteobacteria*, *Deltaproteobacteria*, *Epsilonproteobacteria*

Significant groups and genera include:

Photosynthetic genera such as *Rhodospirillum*(a purple non-sulfur bacterium) and *Chromatium* (a purple sulfur bacterium)

Sulfur chemolithotrophs, genera *Thiobacillus* and *Beggiatoa*

Nitrogen chemolithotrophs (nitrifying bacteria), genera *Nitrobacter* and *Nitrosomonas*

Other chemolithotrophs, genera *Alcaligenes, Methylobacilllus, Burkholderia*

The family *Enterobacteriaceae*, the “gram-negative enteric bacteria,” which includes genera *Escherichia, Proteus, Enterobacter, Klebsiella, Salmonella, Shigella, Serratia,* and others

The family *Pseudomonadaceae*, which includes genus *Pseudomonas* and related genera

Other medically important *Proteobacteria* include genera *Haemophilus*, *Vibrio, Camphylobacter, Helicobacter, Rickessia, Brucella*

Phylum *Firmicutes*

"Low G + C gram-positive" bacteria

Divided into 3 classes

Class I – Clostridia; includes genera *Clostridium* and *Desulfotomaculatum,* and others

Class II – *Mollicutes*; bacteria in this class cannot make peptidoglycan and lack cell walls; includes genera *Mycoplasma, Ureaplasma,* and others

Class III – Bacilli; includes genera *Bacillus, Lactobacillus, Streptococcus, Lactococcus, Geobacillus, Enterococcus, Listeria, Staphylococcus*, and others

Phylum *Actinobacteria*

"High G + C gram-positive" bacteria

Includes genera *Actinomyces, Streptomyces, Corynebacterium, Micrococcus, Mycobacterium, Propionibacterium*

Phylum *Chlamidiae*

Small phylum containing the genus *Chlamydia*

Phylum *Spirochaetes*

The spirochaetes characterized by flexible, helical cells with a modified outer membrane (the outer sheath) and modified flagella (axial filaments) located within the outer sheath

Important pathogenic genera include *Treponema, Borrelia,* and *Leptospira*

Phylum *Bacteroidetes*

Includes genera *Bacteroides, Flavobacterium, Flexibacter,* and *Cytophyga*; *Flexibacter* and *Cytophyga* are motile by means of "gliding motility"

Phylogeny of domain *Eucarya*

The domain *Eucarya* is divided into four kingdoms by most biologists:

Kingdom *Protista*, including the protozoa and algae

Kingdom *Fungi*, the fungi (molds, yeast, and fleshy fungi)

Kingdom *Animalia*, the multicellular animals

Kingdom *Plantae*, the multicellular plants

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