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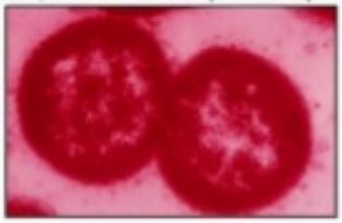
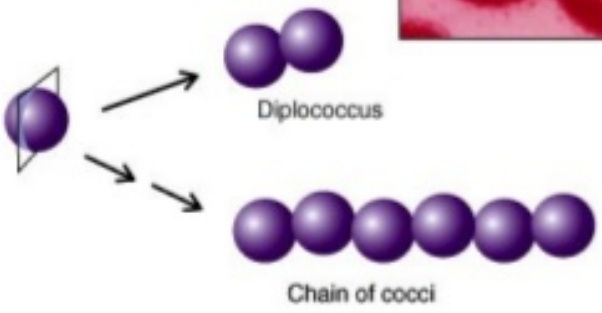
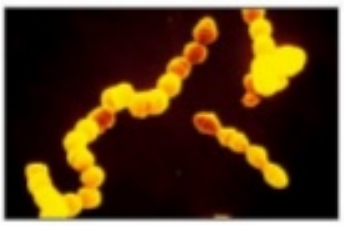


(a) Chains

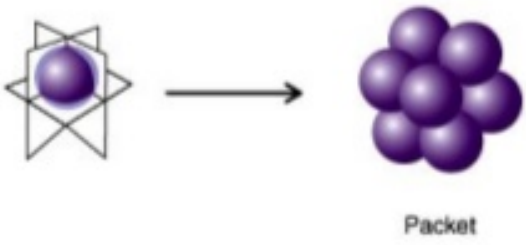
Cell divides
in one plane





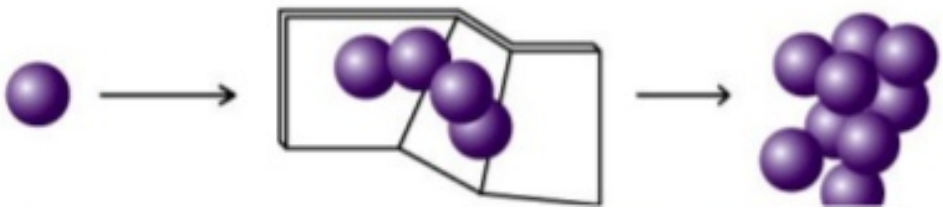
(b) Packets

Cell divides
in two or more planes
perdendicular
to one another



(c) Clusters

Cell divides in several
planes at random



Based on environmental factors

- **Temperature**
- **Oxygen dependence**
- **pH**
- **Salt concentration**
- **Atmospheric pressure**

Other ways of classification

- **Motile/Non-motile**
- **Pathogenic/Non-pathogenic**
- **Sensitive/Resistant (to particular antibiotic/ chemicals)**
- **Lactose fermenter/Lactose non-fermenter**
- **Bergey's Manual of Determinative Bacteriology**
  - Gram-negative eubacteria that have cell walls
  - Gram-positive eubacteria that have cell walls
  - Cell wall-less eubacteria: Mycoplasma
  - Archaeobacteria

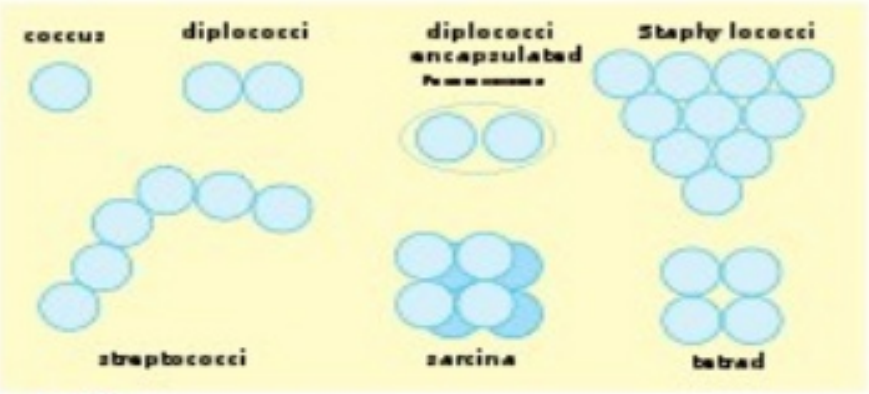
Morphological classification

- Bacteria can be classified into **six** major groups on morphological basis.

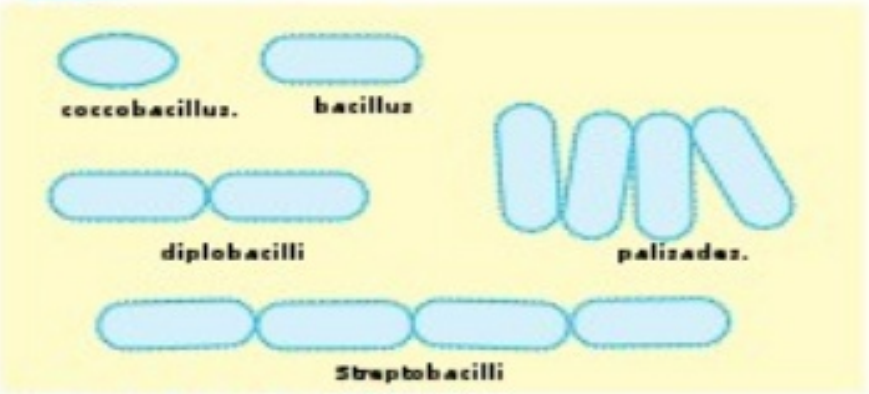
1. TRUE BACTERIA

- **Cocci** – These are spherical or oval cells. On the basis of arrangement of individual organisms they can be described as
  - **Monococci** (Cocci in singles) – *Monococcus* spp.
  - **Diplococci** (Cocci in pairs) – *Streptococcus pneumoniae*
  - **Staphylococci** (Cocci in grape-like clusters) – *Staphylococcus aureus*
  - **Streptococci** (Cocci in chains) – *Streptococcus pyogenes*
  - **Tetrad** (Cocci in group of four) - *Micrococcus* spp.
  - **Sarcina** (Cocci in group of eight)

Cocci



Bacilli



Budding and appendaged bacteria

Others

- **Bacilli** – These are rod-shaped bacteria. On the basis of arrangement of organisms, they can be described as
  - **Diplobacilli**
  - **Streptobacilli**
  - **Palisades**
  - **Chinese-letter form**
  - **Coccobacilli**
  - **Comma-shaped**

Based on Anatomical features

- Capsule
  - **Capsulate**– *Streptococcus pneumoniae*
  - **Non-capsulate** – Viridans streptococci
- Flagella
  - **Flagellate** –
    - **Monotrichous**
    - **Lophotrichous**
    - **Amphitrichous**
    - **Peritrichous**
  - **Aflagellate** – *Shigella* spp.
- Spore
  - **Spore-forming** – *Bacillus* spp.
  - **Non-sporing** – *Escherichia coli*

Based on Staining reaction

- **GRAM'S STAIN**
  - **Gram-positive cocci –** *Staphylococcus aureus*
  - **Gram-negative cocci –** *Neisseria gonorrhoeae*
  - **Gram-positive rods –** *Clostridium* spp.
  - **Gram-negative rods –** *E. coli*

- **ACID FAST STAIN**
  - **Acid-fast bacilli –***Mycobacterium tuberculosis*
  - **Non-acid-fast bacilli –** *Staphylococcus aureus*

Based on Cultural characteristics

- Extra growth factors requirements
  - **Fastidious** – *Hemophilus influenzae*
  - **Non-fastidious** – *Escherichia coli*
- Hemolysis on Sheep Blood Agar
  - **Alpha-hemolysis** – *Streptococcus pneumoniae*
  - **Beta-hemolysis** – *Streptococcus pyogenes*
- Utilization of carbohydrates
  - **Oxidative** - *Micrococcus*
  - **Fermentative** – *Escherichia coli*

Based on Cultural characteristics

- Growth rate
  - **Rapid growers**– *Vibrio cholerae*
  - **Slow growers** – *Mycobacterium tuberculosis*

- Pigment production
  - **Pigment producer** – *Staphylococcus aureus*
  - **Pigment non-producer** – *Escherichia coli*

Based on Nutrition

- **Autotrophs**
- **Heterotrophs**

Temperature

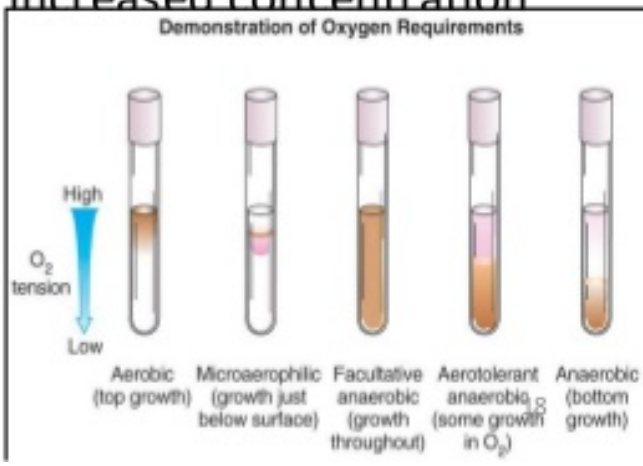
- **Psychrophiles** (15-20^{0}C) – *Pseudomonas fluorescens*
- **Mesophiles** (20-40^{0}C) – *Escherichia coli, Salmonella enterica, Staphylococcus aureus*
- **Thermophiles** (50-60^{0}C)- *Bacillus stearothermophilus*
- **Extremely thermophiles** (as high as 250^{0}C)

Oxygen dependence

- **Aerobe** (grow in ambient temperature, which contains 21% O_2 and a small amount of CO_2, 0.03%)
- **Obligate aerobes** – Strictly require O_2 for their growth (*Pseudomonas aeruginosa*)
- **Microaerophilic** (grow under reduced O_2, 5-10% and increased CO_2, 8-10%)- *Campylobacter jejuni*, *Helicobacter pylori*

Oxygen dependence

- **Facultative anaerobe** (capable of growing either in presence or absence of O_2)- *E. coli*
- **Obligate anaerobe** – *Clostridium* spp.
- **Capnophilic** (require increased concentration of CO_2, i.e., 5-10%) –
  H. influenzae,
  N. gonorrhoeae
- **Aerotolerant**



pH

- **Acidophiles** (*Lactobacillus acidophilus*)
- **Alkaliphiles** (*Vibrio*)
- **Neutralophiles** (pH 6-8)

Majority of the medically important bacteria grow best at neutral or slightly alkaline reaction (pH 7.2-7.6)

Salt concentration

- **Halophiles**
- **Non-halophiles**