مبادئ علم الاحياء الطبية

قسم تقنيات العلاج الطبيعي

المرحلى الاولى

اعداد

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Structure of Bacteria

The general structure of bacteria component from the following:

1. Capsule .
2. Cell wall.
3. Cytoplasmic membrane.
4. Cytoplasm.
5. Nucleus.
6. Ribosomes.
7. Flagella .
8. Pili.
9. Spore.

1. Capsule

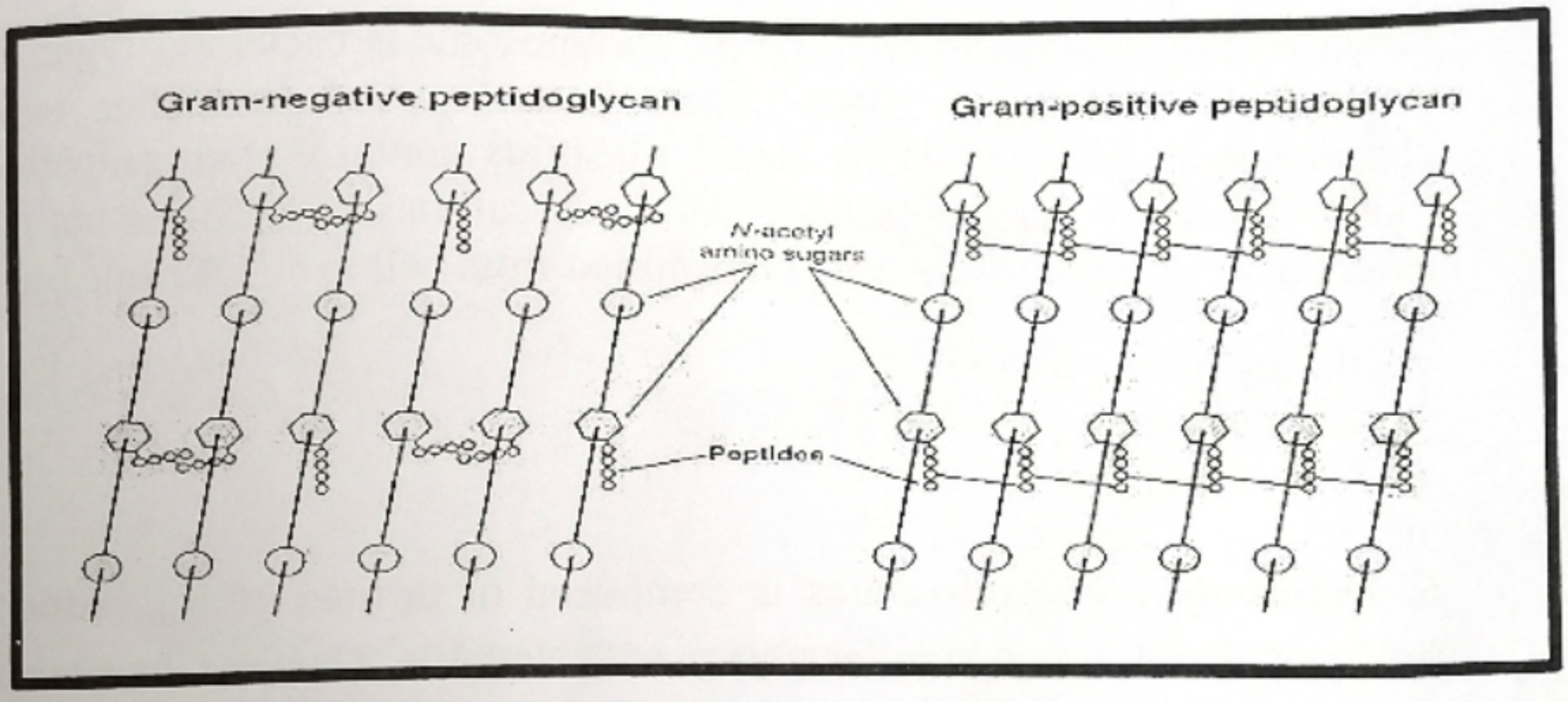
it is gelatinous secretion of bacteria which get organized as thick coat around the cell wall it may be composed of polysaccharide e.g *klebsella* or polypeptide e.g *bacillus anthrax* or hyaluronic acid e.g *S. pyogenes*

a. protect the cell wall
b. having capsule means that the bacteria were more virulent due to the capsule protect the bacteria from immune response.

2. Cell wall

The layers of cell envelope lying between the cytoplasmic membrane and the capsule are referred to collectively as cell wall.
account 20% of the total dry weight of the cell. Only mycoplasma bacteria lack the cell wall
a. give the shape of bacteria
b. rigid structure, protect the bacterial cell against physical and chemical treatment.
c. freely permeable
d. important in cell division
e. important in classification of bacteria

Both Gram-positive and Gram-negative bacteria possess cell wall peptidoglycans are unique to prokaryotic organisms and consist of a glycan backbone of muramic acid and glucosamine (both N-acetylated), and peptide chains highly cross-linked with bridges in Gram-positive bacteria (e.g., *Staphylococcus aureus*) or partially cross-linked in Gram-negative bacteria (e.g., *Escherichia coli*).



Diagrammatic representation of peptidoglycan structures

Lysozyme enzyme cause lysis of the bacteria they act by splitting cell wall mucopeptide linkages when lysozymes act on gram positive .

Protoplast is formed consisting of cytoplasm membrane and contents with gram negative bacteria the result **Spheroplast.**

3. Cytoplasmic membrane

The bacterial membrane is composed primarily of protein and phospholipid (about 3:1). It performs many functions, including biosynthesis, and energy transduction.

a. selective permeability contain (permease) enzyme play important role in passage through membrane
b. biosynthesis, and energy transduction.
c. cell growth

4. Cytoplasm

The cytoplasm it is gel-like in consistency and includes the prokaryotic chromosome, ribosomes, vacuole and Constituents of cytoplasm include the suspension of organic and in organic compound in viscous watery solution

The cytoplasm also lacks organelles such as mitochondria, Golgi apparatus or endoplasmic reticulum.

5.Nucleus

absence of nuclear membrane and the chromosome in bacteria is typically a single, closed circle DNA .some bacteria possess smaller extra chromosomal pieces of DNA called **plasmids** confer certain properties like toxigenecity , drug resistance and hydrocarbons breakdowns but not essential for the life of the cell. Transmitted from cell to another one by

a. during binary fission
b. conjugation
c. bacterial phage
d.

6. Ribosomes: The ribosomes is composed of termed 70 S (Svedberg units) divided in two smaller units to 50s and 30s. They are the sites of protein synthesis.

7. Flagella

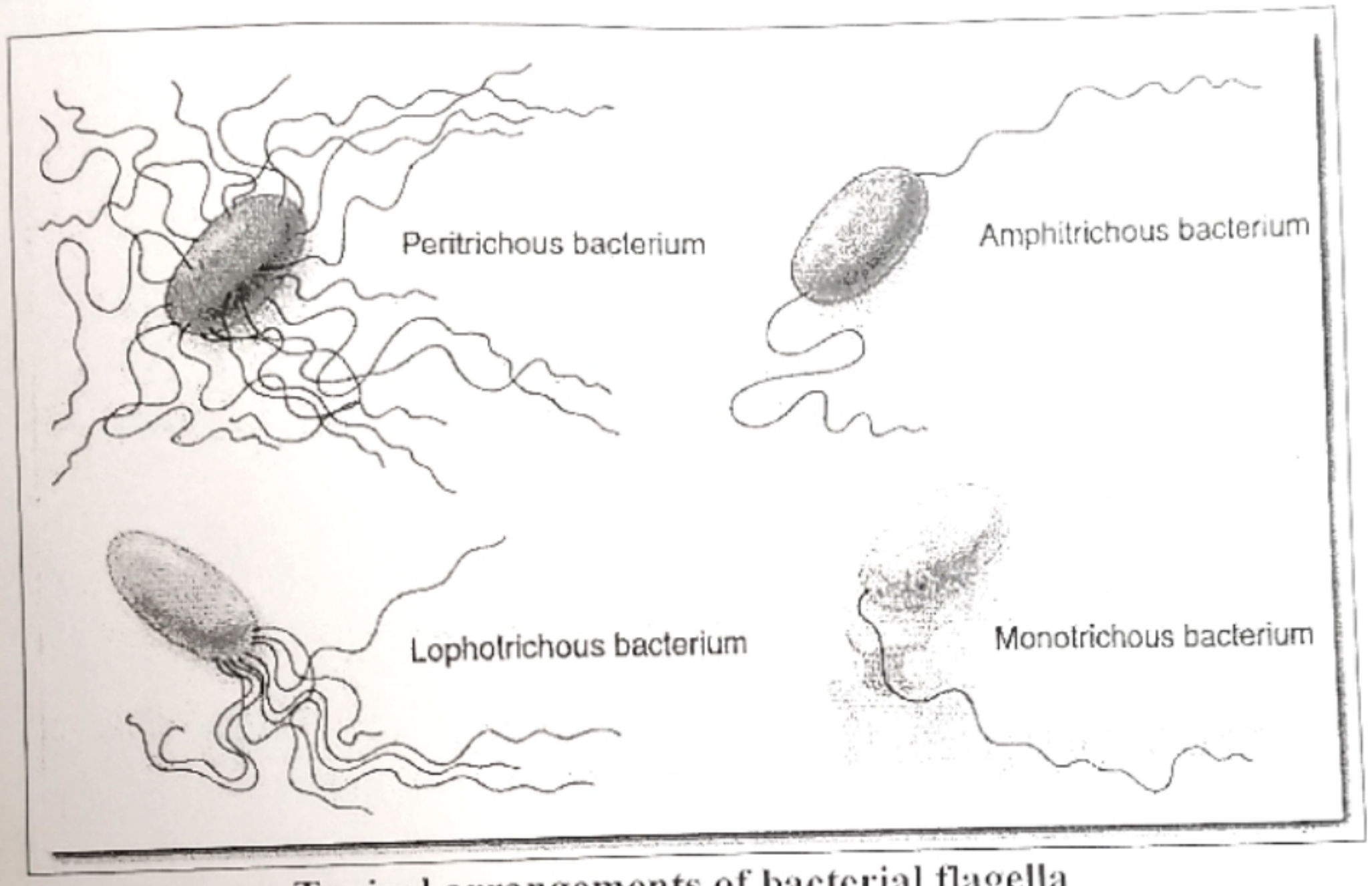
Almost all motile bacteria possess flagella as the organ of locomotion composed of protein called flagellin. Such bacteria tend to move towards or away from the source of stimulus. These stimuli can be chemicals (chemotaxis), light (phototaxis)
Flagella arrangements are:

1- Monotrichous – a single flagellum at one pole (also called polar flagellum) E.g. Vibrio , pseudomonas .

2- Amphitrichous – single flagellum at both poles. E.g. Spirilla.

3- Lophotrichous – two or more flagella at one or both poles of the cell E.g. Bartonella.

4- Peritrichous- completely surrounded by flagella E.g. *E. coli*
Other mechanisms of bacterial locomotion include gliding and motion by axial filament contraction.



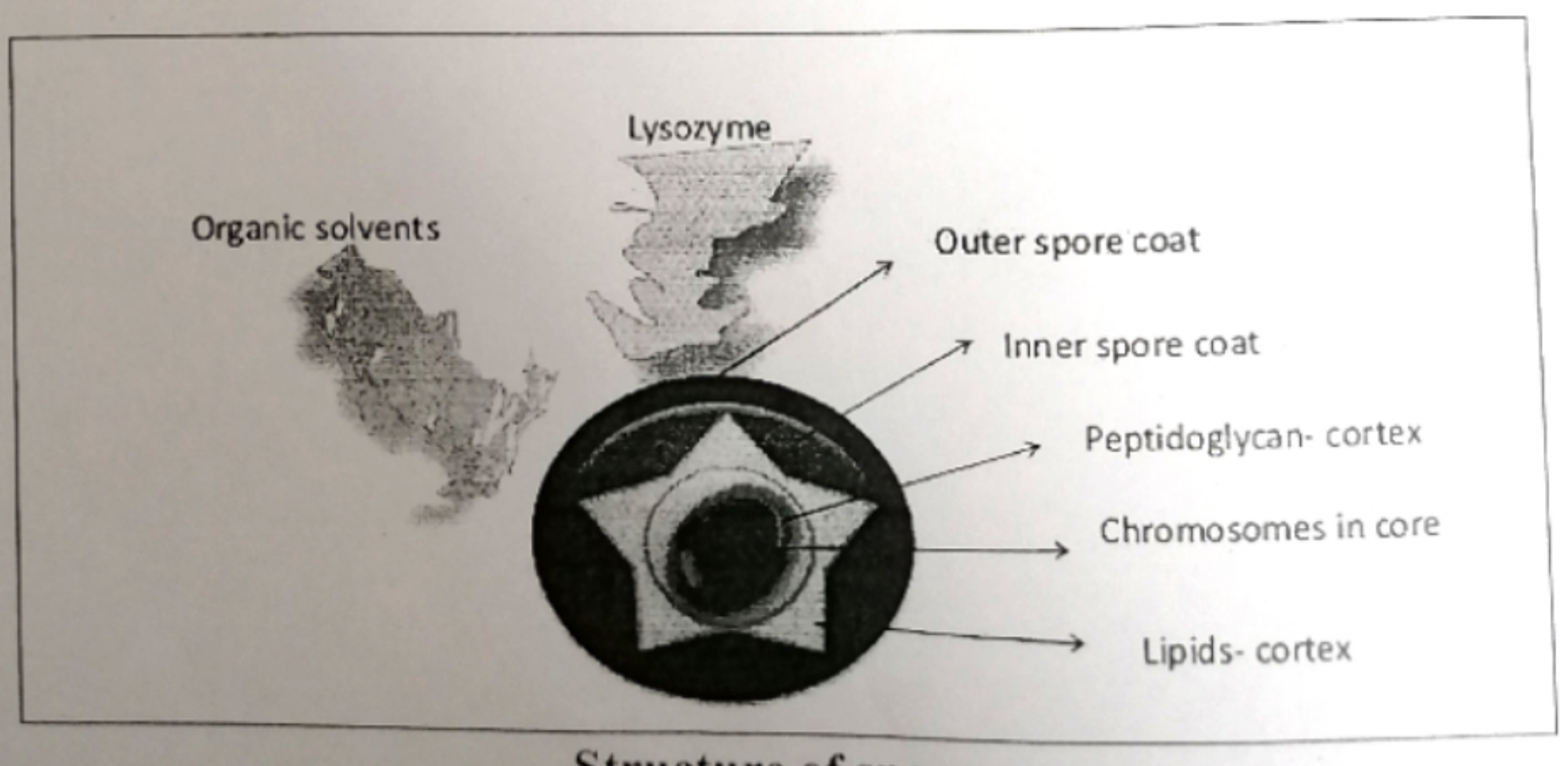
Typical arrangements of bacterial flagella

8- Pili (fimbriae)

They are filamentous short thin straight hair it is smaller than flagella at as sex pili and used for adhesion on the surface.

9- Spores

They are highly resistance dormant state of bacteria found in certain genera e.g bacillus and clostridium they make survival under unfavorable condition like drying, freezing, heating and toxic chemical the location of spore central or sub terminal or terminal.



Structure of spore

Morphology of Bacteria: (Shape of Bacteria)

Bacteria can be classified into four bases shape as under.

1- Single Round or spherical form cocci like *Micrococcus*

a. Diplococci two cocci adhering to each other like *Neisseria*

b. Chain like Streptococci if fission continues while they remain attached forming chains

c. Cluster (random clumps) like Staphylococci cell division not in one plane and daughter cells remain attached in irregular cluster.

d. *Peptococcus tetracocci* aggregate of 4 cocci

e. *Sarcinacocci* aggreate of 8 cocci

2- Rod form –bacilli: the bacilli are not forms as many grouping like *Bacillus* and *Salmonella.*in some of organism's length approximates the width these are called coccobacilli e.g. *B.pertussis* .

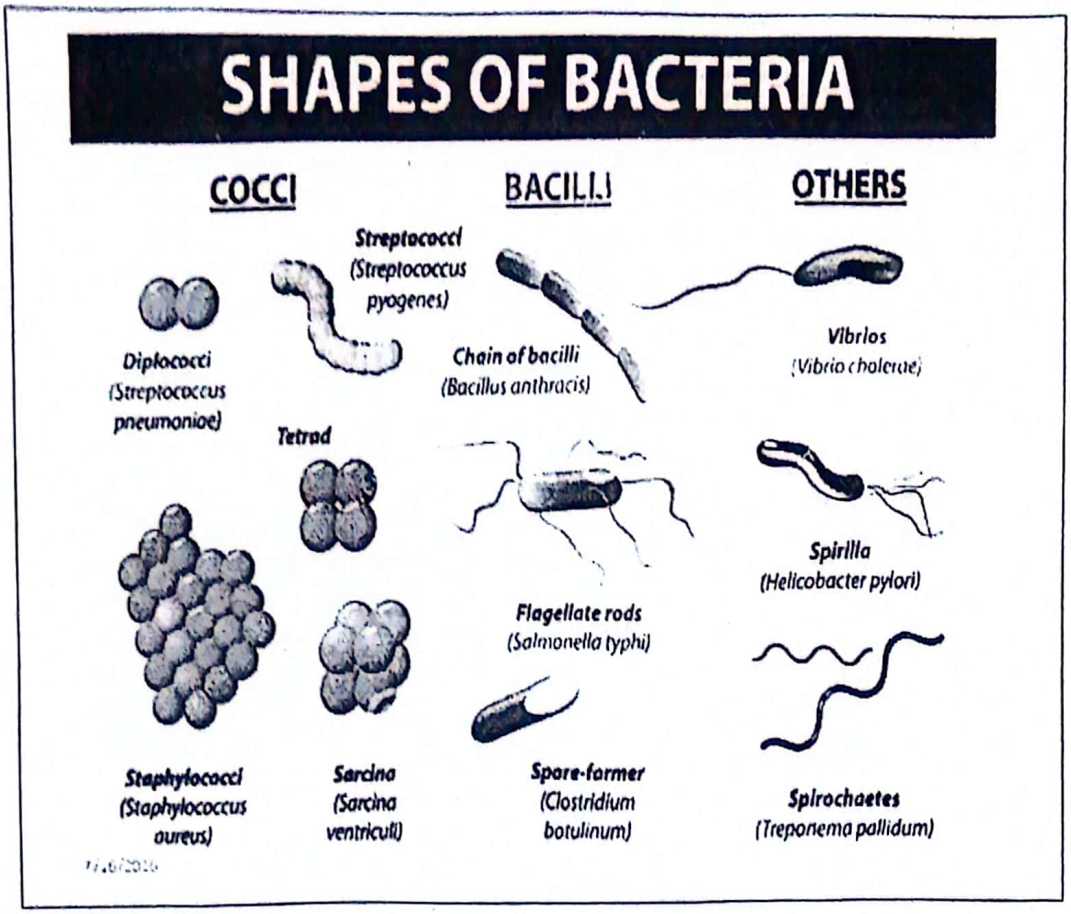
3- Curved of shaped bacilli, comma shape for ex: *vibrio* spp. as *vibrio cholera.*

1. Spiral form: *Spirochete, Treponemia.*

2. Chines letter arragment : corynebacteria .

3. Branching filamentous : actinomycets .

4. Don't possess stable morphology : mycoplasma bacteria lack cell wall they are oval or rounded bodies with interlacing filaments.



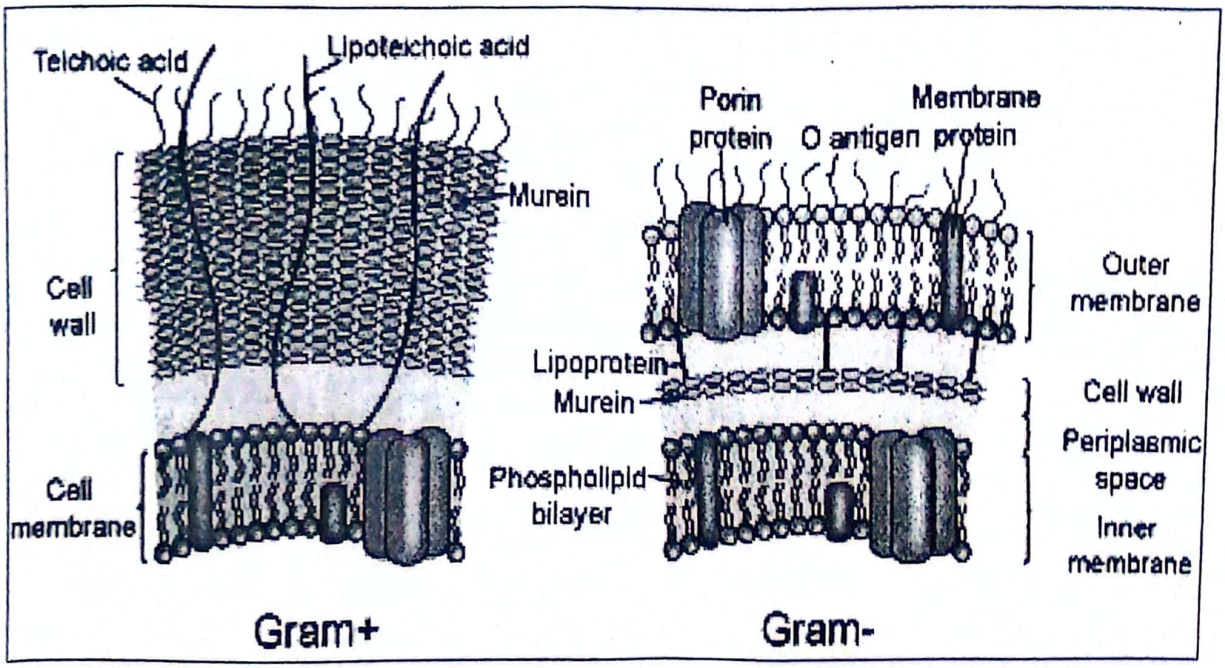
Morphology of bacterial shapes

Gram Positives and Gram Negatives: Key Differences

1. Gram positive bacteria have simpler, but thicker walls, with a relatively large amount of peptidoglycan. The walls of Gram negative bacteria are thinner and have less peptidoglycan but are more complex in structure.

2.An outer membrane on the Gram positive cell wall contains **Teichoic acids** are ploy phosphate polymers bearing a strong negative charge They are strongly antigenic and An outer membrane on the Gram positive cell wall envelope contains **Lipoteichoic acids** as membrane teichoic acids are polymers of amphiphitic glycophosphates with the lipophilic glycolipid and anchored in the cytoplasmic membrane. They are antigenic, cytotoxic and adhesions (e.g., *Streptococcus pyogenes*). on the Gram positive cell wall envelope contains **lipopolysaccharides** (LPS) These are endotoxic substances responsible for making Gram negative organisms more threatening .

Gram negative	Gram positive
1- The walls of Gram negative bacteria are thinner and have less peptidoglycan but are more complex in structure and thickness10-15 mμ .	1- Gram positive bacteria have thicker walls with relatively large amount of peptidoglycan and thickness 15-23 mμ
2-Lipid High 15-20 %	2-Lipid Low 2-4%
3- An outer membrane on the Gram negative cell wall contains **lipopolysaccharides (LPS)**	3- An outer membrane on the Gram positive cell wall contains **teichoic acids and Lipoteichoic acids**



Comparison of the thick cell wall of Gram-positive bacteria with the comparatively thin cell wall of Gram-negative

	Eukaryotic Cell	Prokaryotic Cell
Nucleus	Present	Absent
Number of chromosomes	More than one	One--but not true chromosome: Plasmids
Cell Type	Usually multicellular	Usually unicellular (some cyanobacteria may be multicellular)
True Membrane bound Nucleus	Present	Absent
Example	Animals and Plants	Bacteria and Archaea
Lysosomes	Present	Absent
Microtubules	Present	Absent or rare
Endoplasmic reticulum	Present	Absent
Mitochondria	Present	Absent
Ribosomes	Larger	smaller
Vesicles	Present	Present
Golgi apparatus	Present	Absent
Chloroplasts	Present (in plants)	Absent; chlorophyll scattered in the cytoplasm
Flagella	Microscopic in size; membrane bound; usually arranged as nine doublets surrounding two singlets	Submicroscopic in size, composed of only one fiber
Permeability of Nuclear Membrane	Selective	not present
Plasma membrane with steroid	Yes	Usually no
Cell wall	Only in plant cells and fungi (chemically simpler)	Usually chemically complexed
Vacuoles	Present	Present
Cell size	10-100um	1-10um

Requirement of Bacteria

Physiology of Bacteria

If an individual organism is to survive it must be able to react to changes in its environment. It must be able to feed, respire and must be able to reproduce. **Metabolism** refers to all the biochemical reactions that occur in a cell or organism and divided into **Anabolism** is the (building up) - synthesizes large molecules from smaller or precursor components, usually requiring energy in the process and **Catabolism** is the (breaking down) - a series of destructing chemical reactions that break down complex molecules into smaller units, and in most cases releasing energy in the process.

Nutrition of Bacteria

Bacteria can be divided into groups based on their nutritional requirement in two different ways.
a. how they obtain their **energy**?
b. how they obtain the **carbon** needed for synthesis of all organic molecules?
So:-
1. Some bacteria obtain energy from **sunlight** through the agency of pigments. These are called ***phototrophs***
2. Some bacteria are able to grow with **inorganic molecule like Co_2** as the main source. These are called ***autotrophs.***
3. Most of the human pathogenic bacteria require to be supplied with **organic carbon molecules**. These are called ***heterotrophs.***

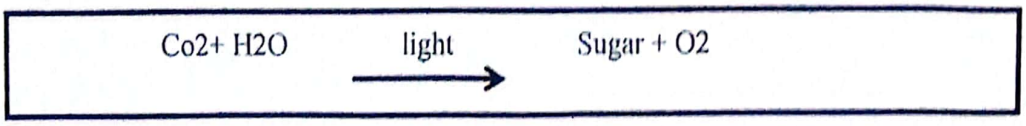
Autotrophic Bacteria

These are bacteria which are able to synthesize their own organic food from inorganic substances. They use carbon dioxide for obtaining carbon and utilize hydrogen sulphide (H2S) or ammonia (NH3) or hydrogen (H2) as the source of hydrogen to reduce carbon. These bacteria can be distinguished further into two types as follows:

Photoautotrophic Bacteria

The photoautotrophic bacteria possess photosynthetic pigments in membrane bound lamellae (or thylakoids) and utilize solar energy. The bacterial photosynthesis is different from that of green plants since here water is not used as a hydrogen donor. Hence oxygen is not released as a byproduct. For this reason, the process is described as an oxygenic photosynthesis. Photosynthetic bacteria include the green purple bacteria and the cyanobacteria

$$CO_2 + H_2S \xrightarrow{\text{light energy}} \text{sugars} + \text{sulphur} + \text{water}$$



Chemoautotrophic Bacteria

These are bacteria which manufacture organic compounds from inorganic raw materials utilizing energy liberated from the oxidation of inorganic substances. Following are the common types of chemo autotrophic bacteria.

1. Nitrifying bacteria which derive energy by oxidizing ammonia into nitrates. Eg: Nitrosomonas, Nitrobacter.

$$NH_4^+ + 2O_2 \rightarrow NO_2 + 2H_2O + \text{energy}$$

2. Sulphur bacteria which derive energy by oxidizing hydrogen sulphide to sulphur. Eg: Thiobacillus, Beggiatoa.

$$2H_2S + O_2 \rightarrow 2S + 2H_2O + \text{energy}$$

3. Iron Bacteria which derive energy by oxidizing ferrous ions into ferric form. Eg: *Ferrobacillus, Gallionella.*

The Main Forms of Energy Capture

	General group	Subgroup (s)	Energy source	Carbon source
1	Autotroph	Photoautotroph chemoautotroph	Light Inorganic Substances	CO_2
2	Heterotroph	Photo heterotroph like heliobacteria chemoheterotrophic like human, pathogenic bacteria	Light Organic compounds	Organic compounds

ANTIBIOTICS & THE BASES OF CHEMOTHERAPY

Chemotherapeutic agents: antimicrobial agents of synthetic origin useful in the treatment of microbial or viral disease. Examples: sulfonamides, isoniazid…

Antibiotics: antimicrobial agents produced by microorganisms that kill or inhibit other microorganisms.

*Antimicrobial agents divided into classes in the type of **action**:-

Bacteriostatic drugs: - inhibit the microbial growth e.g tetracycline, chloramphenicol .

Bactericidal drugs: - kill the bacteria have lethal action e.g penicillin's, cephalosporin .

The range of bacteria or other microorganisms that are affected by a certain antibiotic are is expressed as its **spectrum of action**. Antibiotics effective against prokaryotes which kill or inhibit a wide range of Gram-positive and Gram-negative bacteria are said to be **broad spectrum** . If effective mainly against Gram-positive or Gram-negative bacteria, they are **narrow spectrum**. If effective against a single organism or disease, they are referred to as limited spectrum.

Kinds of Antimicrobial Agents and their site and mechanisms of modes of action :

1. **Cell wall synthesis inhibitors**: Cell wall synthesis inhibitors generally inhibit some step in the synthesis of bacterial peptidoglycan. Generally they exert their selective toxicity against bacteria because human cells lack cell walls.e.g Beta lactam antibiotics the products of two groups of fungi, Penicillium and Cephalosporium, The beta lactam antibiotics inhibit the last step in peptidoglycan synthesis, the final cross-linking between peptide side chains.

Semisynthetic penicillin's :- (6-aminopenicillanic acid) which can be modified chemically by the addition of side chains increased spectrum of activity like Amoxycillin and Ampicillin or inhibits beta lactamase enzymes like Methicillin

Bacitracin: is a polypeptide antibiotic produced by Bacillus species It prevents cell wall growth.

2. **Cell membrane inhibitors**: disorganize the structure or inhibit the function of bacterial membranes. The integrity of the cytoplasmic and outer membranes is vital to bacteria, and compounds that disorganize the membranes rapidly kill the cells, like Polymyxin, produced by Bacillus polymyxis , Polymyxin bind to membrane phospholipids and thereby interfere with membrane function

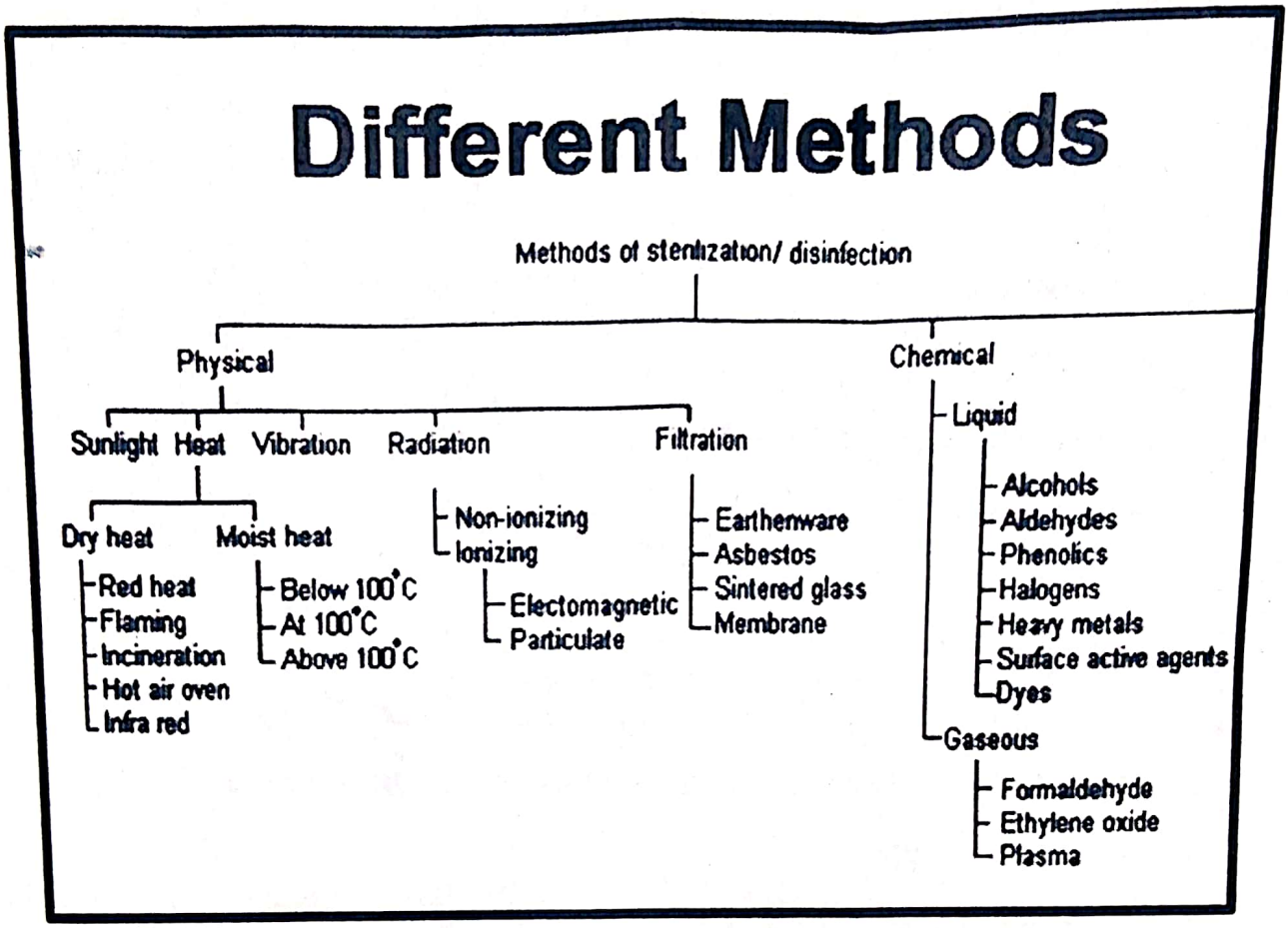
3. **Protein synthesis inhibitors**: have an specificity for 70S ribosomes, like aminoglycosides antibiotics are products of Streptomyces species and are represented by streptomycin, kanamycin, erythromycin, chloramphenicol and gentamicin. These antibiotics exert their activity by binding to bacterial ribosomes and preventing the initiation of protein synthesis.

4.**Effects on Nucleic Acids:** Some chemotherapeutic agents affect the synthesis of DNA or RNA, can block the growth of cells , like Nalidixic acid and Rifampin.

Sterilization and Disinfection

Sterilization: is defined as the process of elimination for all the living microorganisms, including vegetative bacterial or spore state are killed.

Disinfection: is the process of elimination of most pathogenic microorganisms (excluding bacterial spores) on inanimate objects. Disinfection can be achieved by physical or chemical methods. Chemicals used in disinfection are called disinfectants. Not all disinfectants can kill all microorganisms. Some methods of disinfection such as filtration do not kill bacteria, they separate them out.



Physical Methods of Sterilization

1-Sunlight: The activity of sunlight is mainly due to the presence of ultra violet rays in it. It is responsible for spontaneous sterilization in natural conditions. The sunlight is more effective in killing germs due to combination of ultraviolet rays and heat.

2-Heat: Heat is considered to be most reliable method of sterilization. Heat acts by oxidative effects as well as denaturation and coagulation of proteins. Heat is divided into two type :

1. Dry heat

A . Red heat: it is used to sterilize metallic objects by holding them in flame till they are red hot e.g. inoculating wires, needles, forceps, spatulas ... etc.

B. Flaming: The article is passed over flame without allowing it to become red hot e.g. mouth of culture tubes, flasks, glass slid.

C. Incineration: This is excellent method for rapidly destroying material e.g. experimental dead animals and pathological materials... etc.

D. Hot air oven: This the best method for sterilizing all glass, Petri dishes, test tubes, flask, pipettes, scalpels, scissors.

E. Infra- red radiation: To sterilize metal instruments and glass syringes.

2. Moist heat

1- At temperature below 100 °C

a. pasteurization of milk temp. Employed is either 65°C for 30 min or 72 for 15-20 sec.

2- At temperature of 100°C

a. Tyndallization: Which medium is placed at 100°C for (20-30) min each on 3 successive days? Used for sterilizing media containing sugars.

b. Boiling: For needles and instruments boil in water for (10-30) min. is sufficient to sterilize

c. Steam at 100°C: Is used to sterilize culture media which may decompose if subjected to higher temp. Like (gelatin agar)

3- At temperature above 100°C: we used Autoclave to sterilized inoculated media.

3. Filtration: For sterilize the fluids that do not stand heating e.g. plasma, vitamins, carbohydrates solutions and antibiotics

4- Radiation:

a. ultraviolet radiation and lamps: It is chief bactericidal factor present in sunlight kill the germs .

b. X-rays and other ionizing radiation: They are useful for sterilization of disposable material like disposable syringes and adhesive dressing ... etc.

5- **Ultrasonic and sonic vibrations**: They are bactericidal causing mechanical agitation and rupture of bacteria.

B- Chemical methods

1- Acids and alkaline: They are in inhibitory to the grow of bacteria. *Microbacteria* are more resistant to acid than alkaline;

2- Metallic ions: $Hgcl_2$ and $AgNo_3$ prevent the growth on many bacteria in concentration less than 1 ppm.

3- Inorganic anions: They are much less toxic to bacteria such as fluoride inhibits many enzyme of bacteria.

4- Halogens: Iodine is used chiefly for skin –chlor for water.

5- Oxidizing agents: They are weak antiseptic e.g. H_2O, potassium permanganate.

6- Formaldehyde: It is useful in sterilization bacteria vaccine also is highly lethal (irritant water soluble) to kill all kinds of microorganisms and spores.

7- Phenol group: It is used for sterilizing surgical instrument; Lysol and cresol are used generally in 3% solution.

8- Soap and detergents: Bacteriostatic for G+ and some acid fast organism.

9- Alcohol: Ethyl alcohol is most effective in 70% solution than 100% alcohol. It doesn't kill spores.

10- Dyes: Gentian violet... are active against G+ bacteria.

وزارة التعليم العالي والبحث العلمي

الجامعة التقنية الشمالية

كلية التقنيات الصحية والطبية / الدور

قسم العلاج الطبيعي

المرحلة الأولـــى

Lec : 1

الاحياء المجهرية

مدرس المادة :

د . لؤي مناع

2024

2023

Microbiology

is the study of small living things. Generally this means living things that are too small to see without the use of a microscope. These life forms are called microorganisms or microbes. Microorganisms include bacteria, archaea , viruses, protozoa (single-cell eukaryotes like amoeba), microscopic fungi and yeasts, and microscopic algae (plant-like organisms). Microorganisms were discovered over three hundred years ago and it is thought that many new microbes have yet to be discovered. Microbiology is a wide area of science that includes bacteriology, virology, mycology, phycology, parasitology, and other branches of biology.

History

- In 1676, Anton van Leeuwenhoek observed bacteria and other microorganisms , using a single-lens microscope of his own design.

- In 1796, Edward Jenner developed a method using cowpox to successfully immunize a child against smallpox. The same principles are used for developing vaccines today.

- Following on from this, in 1857 Louis Pasteur also designed vaccines against several diseases such as anthrax, cholera and as well as pasteurization for food preservation.

- In 1867 Joseph Lister is considered to be the father of antiseptic surgery. By sterilizing the instruments with diluted carbolic acid and using it to clean wounds, post-operative infections were reduced, making surgery safer for patients.

- In the years between 1876 and 1884 Robert Koch provided much insight into infectious diseases. He was one of the first scientists to focus on the isolation of bacteria in pure culture. This gave rise to the germ theory, a certain microorganism being responsible for a certain disease.

- A major milestone in medical microbiology is the Gram stain. In 1884 Hans Christian Gram developed the method of staining bacteria to make them more visible and differentiable under a microscope. This technique is widely used today.

- In 1929 Alexander Fleming developed the most commonly used antibiotic substance both at the time and now penicillin.

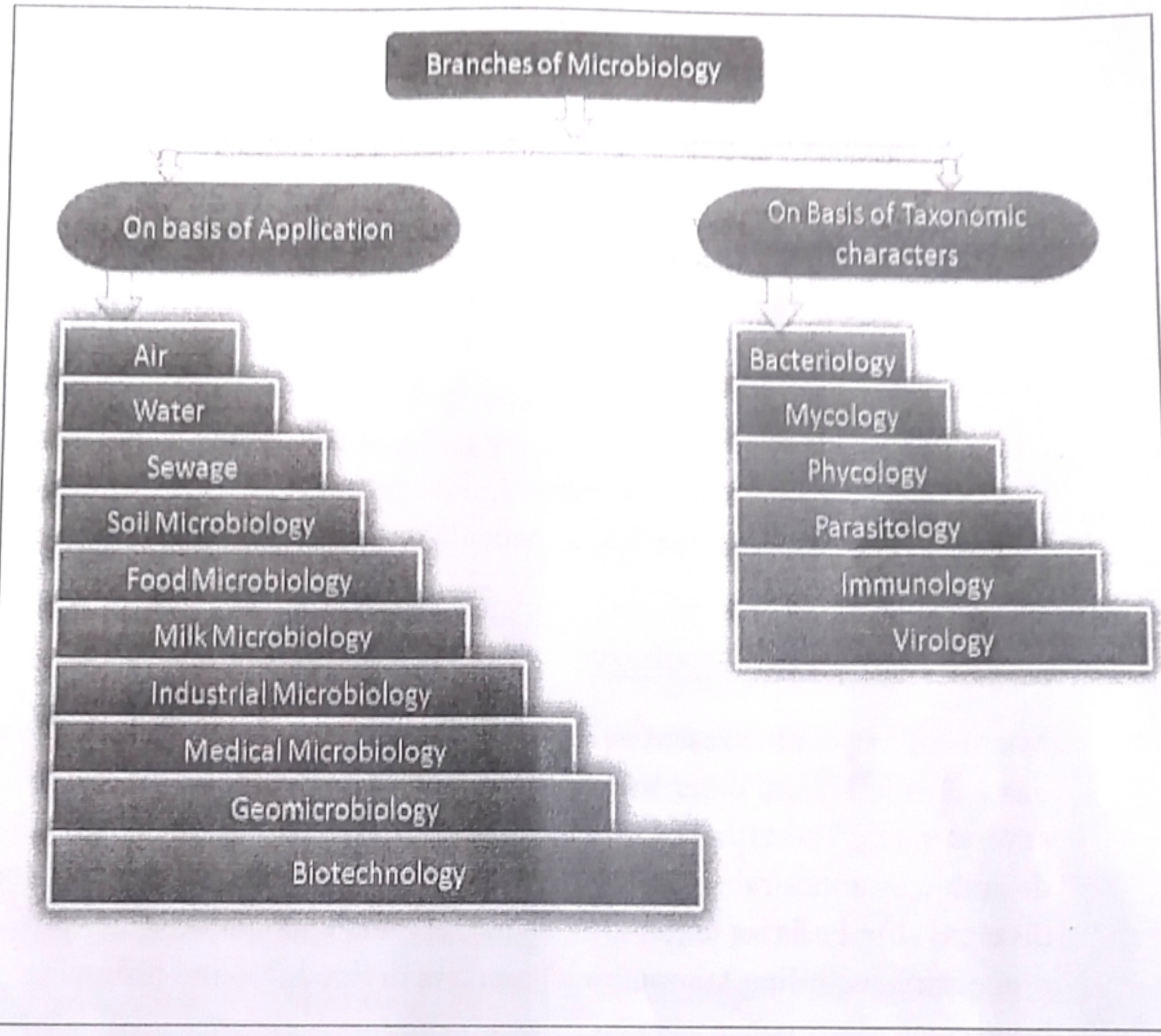
- DNA sequencing, a method developed by Walter Gilbert and Frederick Sanger in 1977. caused a rapid change the development of Vaccines , medical treatments and diagnostic methods. Some of these include synthetic the first genetically vaccine in 1986 for hepatitis B.

Branches of Microbiology

Micro-organism are present everywhere in nature and this micro-organism has a great effect on other life form like human being ,plants and animals in several ways. The effect of micro-organism to the environment may be desirable or undesirable .These bacteria show wide range of activity and diversity. On basis on taxonomic characters and application of micro-organism . according taxonomic characters divided into the following branches :

1. Bacteriology

Bacteriology is a branch of Microbiology that deals with study of Bacteria. This Bacteria are prokaryotic, unicellular in nature .Their mode of multiplication is by Binary fission .Bacteria can be parasitic or can be free living in atmosphere .The nuclear material is not bound to nuclear membrane .This bacteria may be motile or non-motile .They may vary in their shape like rod, spiral or cocci and they may be aerobic, non-aerobic or facultative anaerobic in nature. On the basis of mode of nutrition some bacteria may have autotrophic or hetrotrophic mode of nutrition.



2.Mycology

Mycology is a branch of microbiology that deals with study of Fungus. This fungus cells are eukaryotic in nature the nuclear material is surrounded by Chitin or cellulose or both. This fungal cells are non-photosynthetic and chemoorganotrophic in nature .These fungal cells are divided into two types and that is yeast and molds.

- **Yeast** -The yeast cell may occur in single cell or pseudomycelium form. The mode of reproduction is by budding or by Spore formation. Yeast are also know as Ascomycetes and this yeast cells may be oval, rod or spherical in shape.
- **Molds**-The molds grow in form of multi-cellular filamentous structure called as hyphae. They can reproduce by both means of sexual and asexual mode of reproduction.

3. Phycology

Phycology is a branch of microbiology that deals with the study of algae.They are photosynthetic,eukaryotic,and multi cellular organism.

4. Parasitology

It is a branch of biology that deals with the study of parasites. This branch mainly include the study of three major group of bacteria parasitic protozoa, parasitic worms, and arthropods. In the relationship between host and parasite is also studied. This parasites may be unicellular or multi-cellular. This parasites are mainly responsible for causing infection in humans and animals.

5.Immunology

Immunology is a branch of microbiology that deals with the study of Immune system of all organism specially human being and animals. In this branch of microbiology the relationships between host body ,pathogen and immunity is studied.

6. Virology

This branch of microbiology deals with the study of Viruses .Viruses are very small ultra-microscopic in nature and they are visible through electron microscope. Viruses are metabolically inert and are completely dependent on host cell for replication .Viruses are capable to infect all types of cells from a bacteria to a human .It contain only one type of nucleic acid that is either DNA or RNA.

Factors effecting growth of bacteria

1. Physical factors

A. The requirement of Oxygen and carbon dioxide:

1- Obligate aerobes:

Need oxygen to grow. E.g. *Pseudomonas aeruginosa.*

2- Obligate anaerobes: not need oxygen. Some are killed by free oxygen. E.g. *Clostridium sp.*

3- Microaerophiles: means little-air- loving. Need large amount of CO_2 and trace amounts of oxygen. E.g. *Treponema pallidum (syphilis).*

4- Facultative Anaerobe (Facultative aerobe or facultative): can use oxygen if available, but can survive without it too. E.g. *Escherichia coli.*

B. pH: there are three groups of microorganisms according to pH.

1- Neutrophils: Most bacteria grow between pH 7.2-7.6.

2- Acidophilus: these grow in an acidic pH(1-5) like lactobacillus.

3- Alkalophiles: these grow optimally under alkaline conditions pH (8-9.5) like vibrio.

C. Temperature: there are (3) groups of microorganisms according to temperature

1- Psychrophilic: grow at an optimal temperature of 0 to 20° C. like water bacteria.

2- Mesophiles: They grow at optimal temp between of (30-40) these include bacteria producing disease.

3-Thermophiles: Which have an optimal temperature of (55-75)°C like bacillus.

D- Moisture:

All actively metabolizing bacteria generally require some water in their respective environments.

E. Osmotic pressure : Bacteria are usually resistant to changes in osmotic pressure, 0.5% Nacl is add to almost all cultural media to make isotonic.

F. radiation:

Various forms of radiant energy, such as gamma rays or ultraviolet radiation can cause mutations and /or kill bacteria. Some organisms have protective pigments or enzymes that can repair radiation-caused DNA damage.

2- Chemical factors

A- Nitrogen

- In amino acids, proteins
- Most bacteria decompose proteins
- A few bacteria use N_2 in nitrogen fixation

B- Sulfur

- In amino acids, thiamine, biotin
- Some bacteria use SO_4^{-2} or H_2S

C- Phosphors

- In DNA, RNA, ATP, and membranes
- is a source of phosphorus PO_4

d- Carbon

- Structural organic molecules, energy source
- Chemo heterotrophs use organic carbon source

Functions of Some Common Vitamins in Microorganisms		
Vitamin	**Functions**	**Examples of Microorganisms Requiring Vitamin**
Biotin	Carboxylation (CO_2 fixation) One-carbon metabolism	*Leuconostoc mesenteroides* (B)
Cyanocobalamin (B12)	Molecular rearrangements One-carbon metabolism—carries methyl groups	*Lactobacillus* spp
Folic acid	One-carbon metabolism	*Enterococcus faecalis*
Lipoic acid	Transfer of acyl groups	*tetrahymena* spp
Pantothenic acid	Work at coenzyme A—carries acyl groups	*Morganella morganii*
Pyridoxine (B6)	Amino acid metabolism (e.g., transamination)	*Lactobacillus* spp.
Niacin (nicotinic acid)	carry electrons and hydrogen atoms	*Haemophilus influenzae*
Riboflavin (B2)	carry electrons and hydrogen atoms	*Caulobacter vibrioides*
Thiamine (B1)	Aldehyde group transfer	*Bacillus anthracis*

مصنع حسب كلام الدكتور