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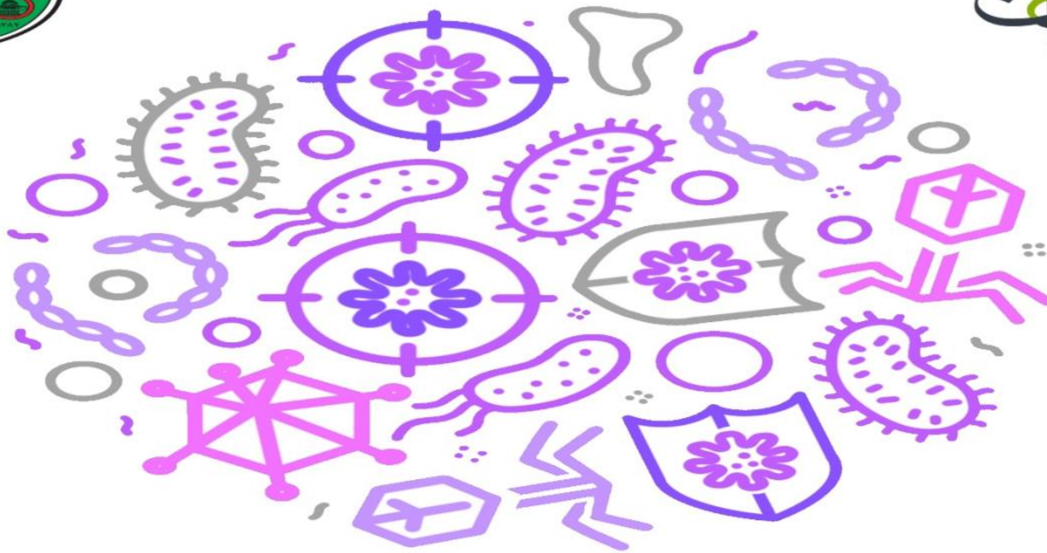

MICROBIOLOGY & IMMUNOLOGY

DOCTOR 2019 | MEDICINE | JU

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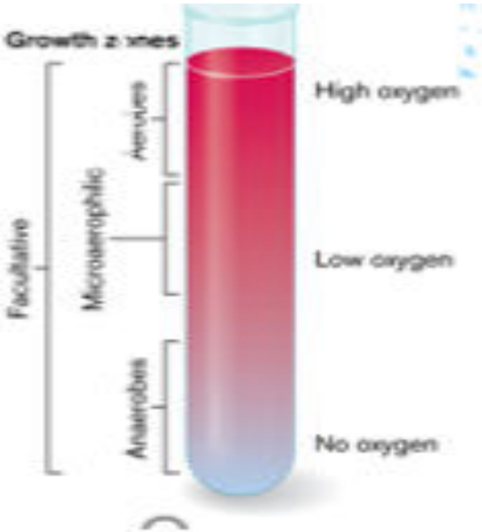
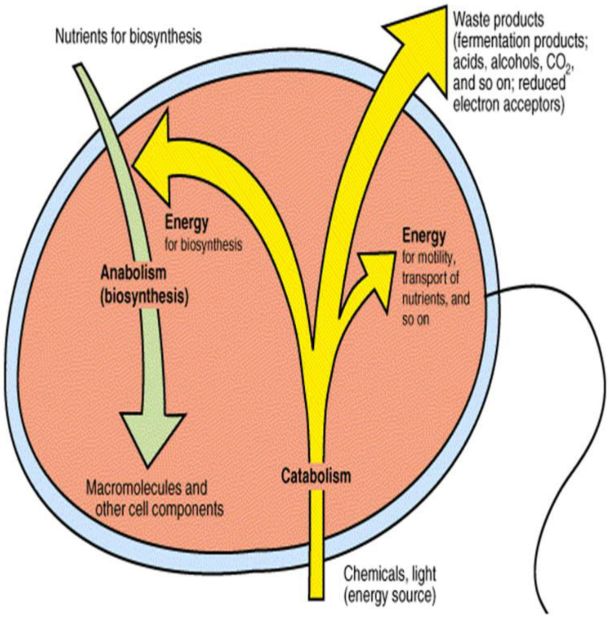
Bacterial metabolism and physiology





Bacterial metabolism and physiology

INTRODUCTION about metabolism in bacteria

* Metabolism in bacteria leads to faster growth than our bodies metabolism.
* Bacteria use many compounds as energy sources.
* Bacterial nutritional requirements much more diverse than our cells requirement. will be explained later
* Some biosynthetic processes, such as those producing peptidoglycan, lipopolysaccharide (LPS), and teichoic acid, are unique to bacteria. and our cells don't under go such processes

Bacterial metabolism and physiology

*Metabolism: sum total of the chemical reactions occurring in the cell (i.e. biosynthetic and degradative)

Anabolism. Catabolism.

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Eventually, biosynthesis and degradation needs energy

And the production of this energy in the bacterial cell is equal to its consumption

* Energy Production = Energy Consumption.
* Metabolism = Anabolism + Catabolism.

Anabolism = synthesis.

Catabolism = degradation.

* Metabolism in bacteria is essential for their existence, for environment, and products are commercially and medically important for human beings.

(Bacterial metabolic products)

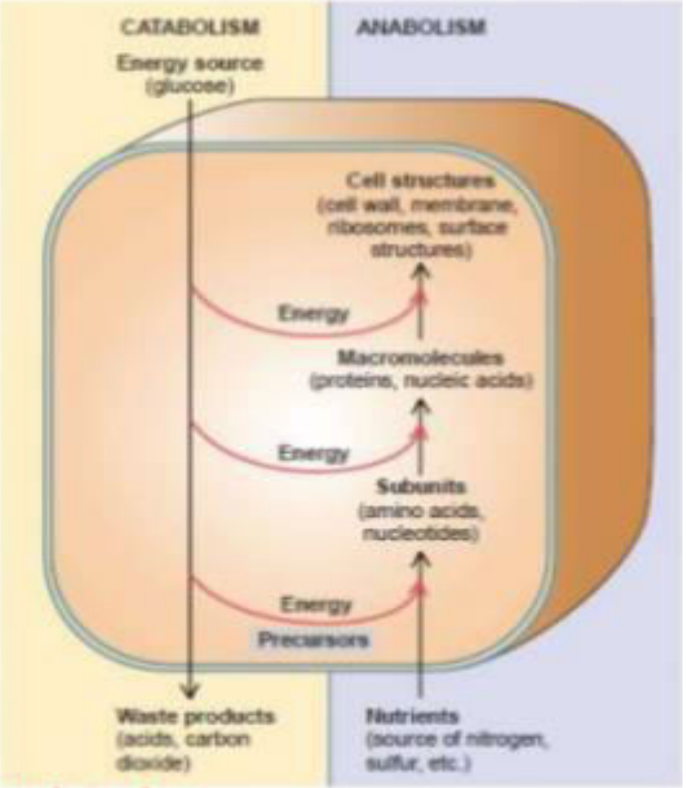
Why to study bacterial metabolism and physiology?

* Understanding physiology & metabolism is necessary for bacterial identification & to design antibacterial agents.

CATABOLIC AND ANABOLIC REACTIONS

- Reactions that cause breakdown of complex molecules into simpler form with relase of energy is **catabolic reactions.**

- Energy requiring reactions that build up complex organic molecules from simpler ones is **anabolic reactions.**



TABLE

6.1 A Comparison of Two Key Aspects of Cellular Metabolism

Anabolism	Catabolism
Buildup of small molecules	Breakdown of large molecules
Products are large molecules	Products are small molecules
Photosynthesis	Glycolysis, citric acid cycle
Mediated by enzymes	Mediated by enzymes
Energy generally is required (endergonic)	Energy generally is released (exergonic)
ممتصة للطاقة	مطلقة للطاقة

Utilizes chemical energy produced by:

Produces chemical energy by:

Components of metabolism

COMPONENTS	FUNCTIONS
Enzymes	Biological catalyst, fascilitates each step of metabolic reaction by lowering the activation energy of reaction.
Adenosine triphosphate (ATP)	serves as energy currency of cell , عملة الطاقة في الخلية
Energy source	Compund that is oxidised to release energy , also called an **electron donor.**
Electron carriers	carry the electrons that are removed during the oxidation of energy source (NAD^+, $NADP^+$, and FAD (their reduced form NADH , NADPH , and $FADH_2$) .
Precursor metabolites	Intermediate metabolite that link anabolic and catabolic pathways, like pyruvate, acetyl-coA, glucose -6-p, etc.

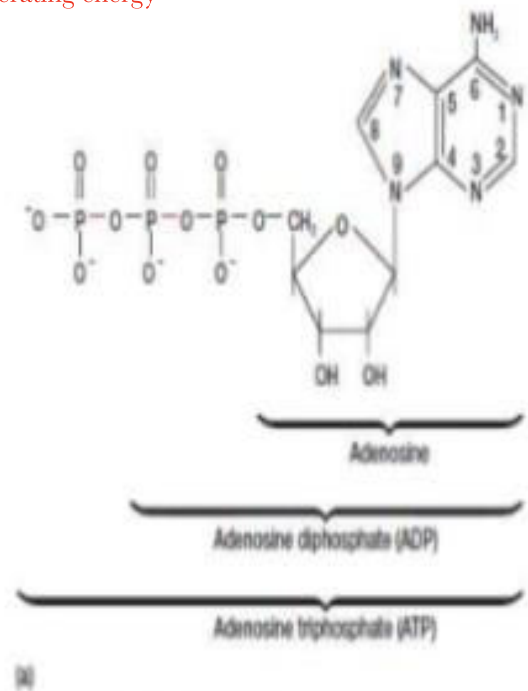
Santosh Yadav

Role of ATP

- Is energy currency of cell, serving as ready and immediate donor of free energy.
- Energy is released when phosphate bond is broken, hence it is called high energy phosphate bond.
- Synthesis and breakdown of ATP continuously occurs in cell during degradative and synthetic process.

Through this reaction
Adenosine triphosphate (ATP) -----> Adenosine diphosphate (ADP) + Pi +energy

Breaking down the phosphate bond
leads to generating energy



Generation of ATP

* * Bacteria uses three mechanisms of phosphorylation to generate ATP from ADP. ADP ⟶ ATP

1- Substrate level phosphorylation.

2- Oxidative phosphorylation .

3- Photophosphorylation.

Metabolic pathways of Energy Generation

Through catabolism

* Glycolysis (mainly)
  - the Embden–Meyerhof glycolytic pathway

** Pathways alternative to glycolysis : many bacteria have another pathway in addition to glycolysis for degradation of glucose.

1 - Pentose phosphate pathway; and

2- Entner Doudoroff pathway.

* Bacteria generate energy by two ways fermentation and / or oxidation.

* Generation of ATP (energy) is mediated by electrons and/or protons transfer to a final acceptor.

This energy allows certain carriers in the chain to transport hydrogen ions (H+ or protons) across a membrane. In an electron transport system, electrons pass from carrier to carrier through a series of oxidation-reduction reactions. During each transfer, some energy is released.

Source of metabolic energy

Cells can generate energy by either :
1. FERMENTATION (anaerobic respiration)
2. RESPIRATION (aerobic respiration)

*__Fermentation__: is a metabolic process that produces chemical changes in organic compounds through the action of enzymes, that takes place in the absence of oxygen. The change usually results in the production of organic acids and energy.

*__Respiration__: The biochemical process in which the cells of an organism obtain energy, typically with the intake of oxygen and the release of carbon dioxide from the oxidation of complex organic substances.

-Cellular respiration formula:

glucose+ oxygen → carbon dioxide+ water+ energy (ATP)

*Types of respiration:

1- Aerobic respiration

2- Anaerobic respiration

Cellular respiration and fermentation

Glycolysis

- Pyruvate obatained from glucose breakdown are channeled either to respiration or to fermentation.

RESPIRATION:- is ATP generating process in which molecules are oxidized and the final electron acceptor is an inorganic molecules.

TYPES OF RESPIRATION :-

Aerobic respiration:- final electron acceptor is O_2 and occurs in aerobes.

Anaerobic respiration: final electron acceptor is inorganic molecule other than O_2 .

In aerobic respiration, Glycolysis is the FIRST phase
Krebs cycle is the SECOND phase, which takes place in the mitochondrial matrix
And the THIRD phase is the electron transport chain which takes place in the inner membrane of the mitochondria
In case of Bacterial Aerobic Respiration, they use their cell membrane; since they don't have mitochondria

COMPARISON OF METABOLISM:

1. Aerobic respiration (oxidation):
* Total ATP Prokaryotes=38, Eukaryotes=34
  - Final electron receptor is usually oxygen.

2. Fermentation:
* Yield = 2 ATP (less efficient).

* Final electron receptor is organic molecule.
* End products: acids/Alcohol. Lactic acid and Ethanol.

CO_2 is produced in both.

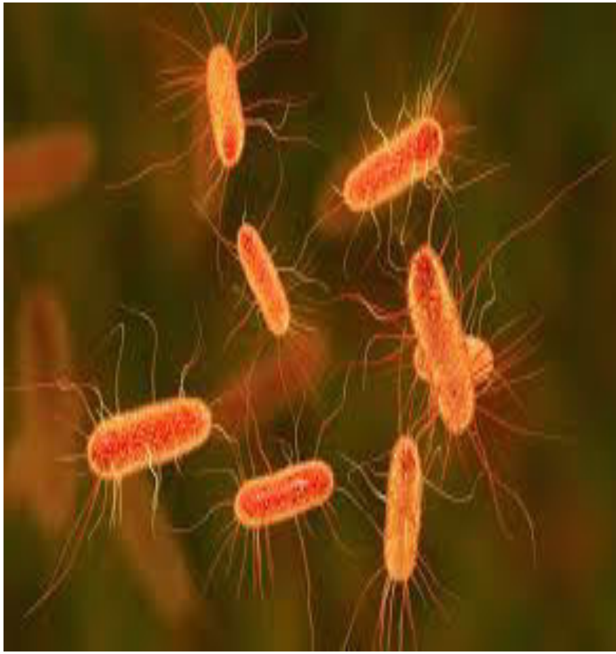
What are the requirements for bacterial growth

Through the left slides we will talk about every one of these requirements in details

A- Nutrients source.

B- Energy source.

C- Environmental factors



Bacterial Nutrition and Growth

- **Nutrient Requirements:**
  - Water
  - Carbon source (C)
  - Nitrogen source (N)
  - Inorganic salts
  - Growth factors
  - Sulfur source (S)
  - Phosphorus source (P)

- **Environmental factors for bacteria growth:**
  - Temperature
  - Gas (oxygen)
  - pH
  - Osmotic pressure

Bacterial physiology and metabolism

First: **Nutritional requirements:**

1. includes many elements like:

Nutritional requirements also include:
2 -Organic factors, like amino acids or nucleic acids
3 -vitamins

A. carbon, hydrogen, O2 , nitrogen, phosphorus & sulphur: needed for the synthesis of structural components.

B. potassium, calcium magnesium and iron: needed for cellular functions.

2. Can be obtained from simple elements or by breaking down large molecules such as protein breakdown into amino acids using bacterial enzymes.

Bacterial physiology and metabolism

3. many bacteria have to synthesize some nutrients such as folic acid which makes these bacteria susceptible to agents that interfere with the biosynthesis of folic acid, e.g. by trimethoprim & sulfonamides antibiotics.

Mechanism of action of these two antibiotics :

The effectiveness of these combinations is attributed to their

Combined : synergistic effect in inhibiting folic acid metabolism in bacteria.

1 Sulfonamides are competitive inhibitors by preventing addition of para-aminobenzoic acid (PABA) into the folic acid molecule.

2 Trimethoprim inhibits the enzyme dihydrofolate reductase, the enzyme that catalyzes the last step of bacterial folic acid synthesis.

Bacterial physiology and metabolism

* Nutritional requirements differ among bacteria and can be used for identification.

*Nutrients can be obtained from different sources.

1. Elements such as:

A. hydrogen & oxygen are obtained from water.

B. Carbon: usually obtained from degradation of carbohydrates by oxidation or fermentation.

Carbon is necessary to provide energy in the form of ATP (adenosine triphosphate).

C. Nitrogen: from ammonia in the environment or proteins 'deamination' using bacterial enzymes.

Removal of amino acids

Bacterial physiology and metabolism

2. Organic factors (from exogenous source/can't be synthesized by bacteria) such as:

**Amino acids: e.g. from proteins breakdown, an important precursor for Purines and pyrimidines synthesis.

**Nucleic acids are polymers of nucleotides.

Nucleotide synthesis is an anabolic mechanism generally involving the chemical reaction of phosphate, pentose sugar, and a nitrogenous base, and must be converted into nucleotides & nucleosides before being incorporated into the DNA or RNA.

3. Vitamins: most are needed for the formation of coenzymes in some bacteria.

Major elements, their sources and functions in bacterial cells.

Summary

Element	% of dry weight	Source	Function
Carbon	50	organic compounds or CO_2	Main constituent of cellular material
Oxygen	20	H_2O, organic compounds, CO_2, and O_2	Constituent of cell material and cell water; O_2 is electron acceptor in aerobic respiration
Nitrogen	14	NH_3, NO_3, organic compounds, N_2	Constituent of amino acids, nucleic acids nucleotides, and coenzymes
Hydrogen	8	H_2O, organic compounds, H_2	Main constituent of organic compounds and cell water
Phosphorus	3	inorganic phosphates (PO_4)	Constituent of nucleic acids, nucleotides, phospholipids, LPS, teichoic acids
Sulfur	1	SO_4, H_2S, So, organic sulfur compounds	Constituent of cysteine, methionine, glutathione, several coenzymes
Potassium	1	Potassium salts	Main cellular inorganic cation and cofactor for certain enzymes
Magnesium	0.5	Magnesium salts	Inorganic cellular cation, cofactor for certain enzymatic reactions
Calcium	0.5	Calcium salts	Inorganic cellular cation, cofactor for certain enzymes and a component of endospores
Iron	0.2	Iron salts	Component of cytochromes and certain nonheme iron-proteins and a cofactor for some enzymatic reactions

Second:

* ENERGY SOURCE

The name of the bacteria, Depending on the way it obtain energy

a. Phototrophs —can use light energy (photosynthesis)

b. Chemotrophs —must obtain energy from oxidation-reduction of external chemical compounds

HYDROGRN DONOR:

source

- organotroph if bacteria requires organic sources of hydrogen

The name of the bacteria, Depending on the way it obtain hydrogen or electron

- lithotroph if it can use inorganic sources (e.g. ammonia or hydrogen sulphide

Energy and Hydrogrn

دمج مصطلحين مع بعضهم البعض، بناء
على الجهات المانحة للطاقة والهيدروجين

* Energy and Hydrogen donor designations are referred to routinely by combining the two terms:

- Chemo-organotrophs

الحظمى

* (the vast majority of currently recognized medically important organisms) If the bacteria obtains energy from oxidation-reduction chemical reactions
  And hydrogn from organic compounds

- chemolithotrophs e.g. some Pseudomonas spp.

  If the bacteria obtains energy from oxidation-reduction chemical reactions
  And hydrogn from inorganic compounds

*CARBON SOURCE

a. Autotrophs —can draw carbon from carbon dioxide environmentally

b. Heterotrophs —carbon from organic compounds

c. Mixotrophic – carbon is obtained from both organic compounds and by fixing carbon dioxide

Energy and Carbon

دمج مصطلحين مع بعضهم البعض، بناء
على الجهات المانحة للطاقة والكربون

- Energy and carbon sometimes:

- Chemoheterotrophs —energy from chemical compounds, carbon from organic compounds, this group includes most as well as all protozoa, fungi, and animals.

Third:

Environmental conditions governing growth:

Environmental factors for bacteria growth

1 Temperature

- Different microbial species are vary widely in their optimal temperature ranges for growth:

Mesophilic forms	30-37 °C
** All human microbial pathogens belong to this forms	
Psychrophilic forms	15-20 °C
Thermophilic forms	50-60 °C

Environmental factors for bacteria growth

2 Gas Requirements

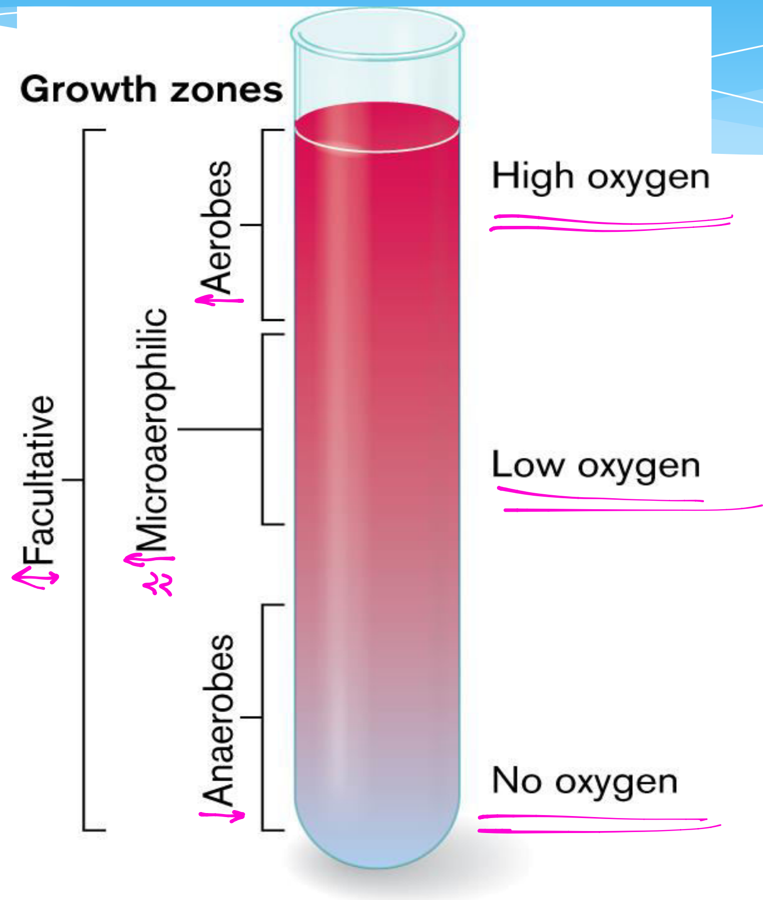
According to the requirement of O_2 during bacteria growth, bacteria can be divided into four groups:

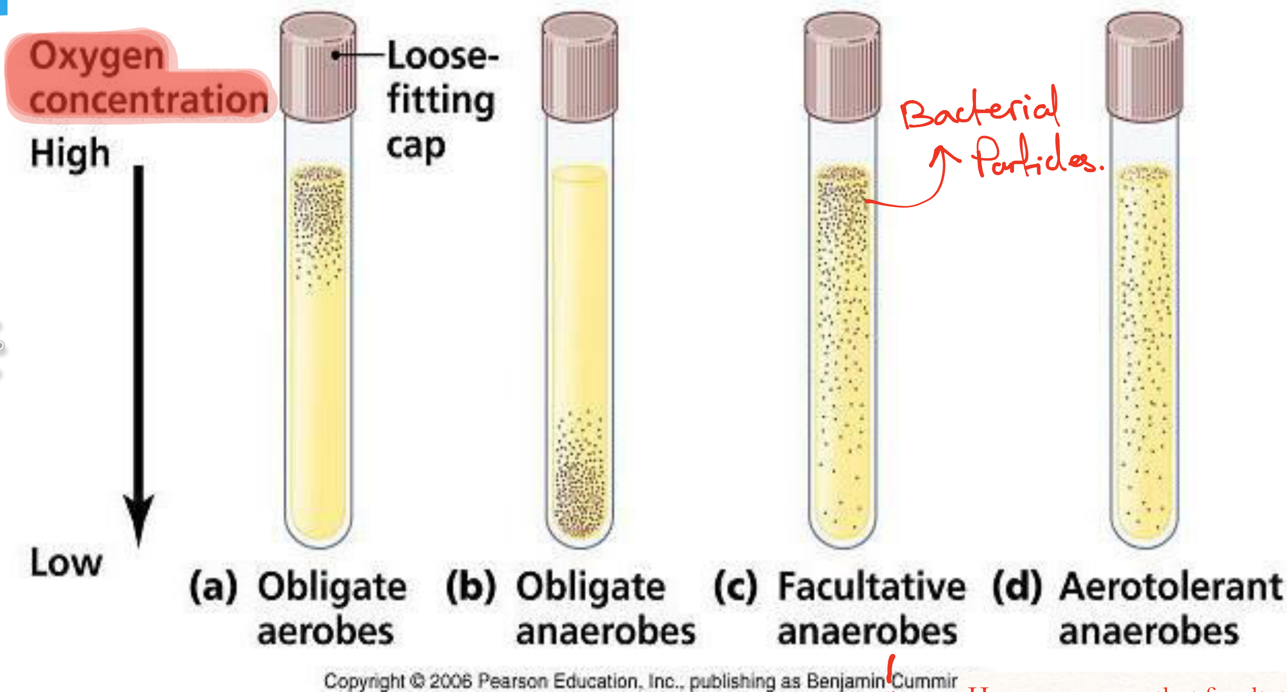
	Aerobic: Requires oxygen to grow	Anaerobic : Doesn't live or grow with oxygen
1. Obligate aerobe:	Growth	No growth
محبة لكميات قليلة O_2 2. Microaerophile:	Growth at low O_2	No growth
3. Obligate Anaerobe:	No growth	Growth
4. Facultative aerobe: اختيارية	Growth	Growth

في نوع خامس اسمه
Aerotolerance

Oxygen-related growth zones in a standing test tube

Test tube:
يساعد في معرفة مناطق النمو
البكتيري المرتبطة بالاكسجين





Here we can see that facultative anaerobes grow more at high oxygen concentrations, this is due to high energy production in aerobic respiration compared to anaerobic respiration

5- Aerotolerance. They cannot use oxygen, but tolerate its presence

E.g. Enterococcus faecalis ignore O2 and grow equally well whether if it present or not.

* Metabolism in the presence of oxygen may give rise to some toxic substances, hydrogen peroxide (H_2O_2) and the superoxide radical (O^{2-}) سبحان الله ♡

* Obligate aerobes and facultative anaerobes usually contain the enzymes **superoxide dismutase** and **catalase** ,which catalyse the destruction of superoxide radicle and hydrogen peroxide, respectively.

- Bacteria that possess these protective enzymes can grow in the presence of oxygen.

$2(O^{2-}) + 2H^{+} \rightarrow O_2 + H_2O_2$ (superoxide dismutase)

$2H_2O_2 \rightarrow 2H_2O + O_2$ (Catalase)

③ pH

- Most organisms grow BEST at neutral or slightly alkaline pH 6 and 8, **neutrophiles**
- **Acidophiles**: grow BEST at low pH (acid: pH 0 – 1.0)
  - (Helicobacter pylori)
- **Alkalophiles:** grow BEST at high pH (alkaline: pH 10.0)
  - V. cholera - pH 8.4-9.2

descriptive terms used to categorize bacteria according to their growth requirement

Growth atmosphere	Property	Example
Strict (obligate) aerobe	Requires atmospheric oxygen for growth	*Pseudomonas aeruginosa*
Strict (obligate) anaerobe	Will not tolerate oxygen	*Bacteroides fragilis*
Facultative anaerobe	Grows best aerobically, but can grow anaerobically	*Staphylococcus* spp., *E. coli*, etc.
Aerotolerant anaerobe	Anaerobic, but tolerates exposure to oxygen	*Clostridium perfringens*
Micro-aerophilic organism	Requires or prefers reduced oxygen levels	*Campylobacter* spp., *Helicobacter* spp.
Capnophilic organism	Requires or prefers increased carbon dioxide levels	*Neisseria* spp.
Growth temperature		
Psychrophile	Grows best at low temperature (e.g. <10°C)	*Flavobacterium* spp.
Thermophile	Grows best at high temperature (e.g. >60°C)	*Bacillus stearothermophilus*
Mesophile	Grows best between 20–40°C	Most bacterial pathogens

الحمد لله الذي
أنعم علينا
بهذا