لجنة الصيدلة

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أكاديمية القصور

BIOLOGY

103

Subject: Second Exam - Chapter Nine

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1) أكاديمية القصور بفروعها 2) جمعية التصوير الطبية (مدرج التمريض).

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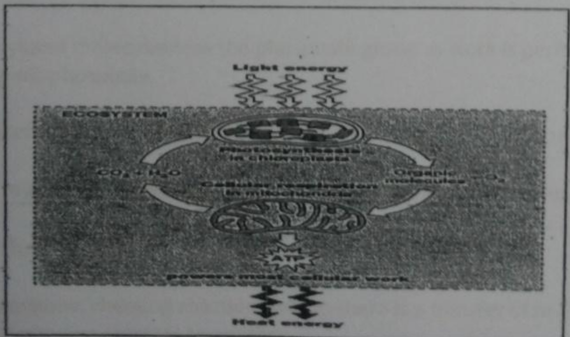
Cellular Respiration

-There are two methods used to yield energy:

1. **Fermentation:** partial degradation of sugars that occurs without oxygen

2. **Cellular Respiration:** most prevalent & efficient catabolic pathway in which oxygen is consumed as a reactant along with the organic fuel in mitochondria



Organic compound + O2 → CO2 + H20 + Energy

مستمرون بالعطاء

-CHO, fats, and proteins can all be used as fuel, track degradation of sugar ($C_6H_{12}O_6$)

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy (ATP + Heat)}$$

-**Exergonic Reaction:** has free energy change of -686 Kcal (-2870 KJ) per mole of glucose decomposed ($\Delta G = -686 Kcal/mol$)

-Negative ΔG indicate that products of chemical process store less energy than reactants and the reaction can happen spontaneously (without input of energy)

ATP: Adenosine Triphosphate

-Phosphate group transfer is a mechanism responsible for most types of cellular work

-Enzymes shift a phosphate group to some other molecule

-This phosphorylated molecule undergoes a change that performs work such as:

1. ATP drives active transport by phosphorylating specialized proteins built into membranes
2. ATP drives mechanical work by phosphorylating motor proteins (e.g ones that move organelles along cytoskeletal tracks in cell)
3. ATP drives chemical work by phosphorylating key reactants

-Phosphorylated molecules lose the phosphate group as work is performed leaving ADP and inorganic phosphate

-Cell respiration replenishes ATP supply by powering phosphorylation of ADP

-Working muscle cell recycles its ATP at a rate of 10 million molecules/second

Cellular Respiration is a Type of Redox Reactions

-**Redox Reactions:** chemical reactions where there is a transfer of one or more electrons from one reactant to another

-Transfer of electrons & their relocation releases the energy stored in food molecules & this energy is used to synthesize ATP

-**Oxidation:** loss of electron from one substance **(electron donor, reducing agent, Sugar)**

-**Reduction:** addition of electron to another substance **(electron acceptor, oxidizing agent, Oxygen)**

-Cellular respiration doesn't involve complete transfer of e- from sugar to oxygen, but changing the degree of electron sharing in covalent bonds

-Electrons and H atoms fall from organic molecules to oxygen during cellular respiration

-When O_2 reacts with H to form water, the electrons of the covalent bonds are drawn closer to O_2 as it is very electronegative & one of the most potent oxidizing agent (C & H electronegativites are about the same)

-As a result electrons lose potential energy and reaction releases this energy to surroundings making it available for ATP synthesis, that can be put to work

The fall of Electrons during Respiration is Stepwise, via NAD^+ & an Electron Transport Chain

-Glucose & other organic fuels are broken down gradually in a series of enzyme catalyzed steps

-At key steps, H atoms are removed from glucose but they are not transferred directly to O_2 they passed first to coenzyme called NAD^+ (oxidizing agent)

-Dehydrogenases remove a pair of hydrogen atoms from the substrate (sugar or other fuel) and delivers 2 electrons with one proton to its coenzyme, **NAD^+**

-Other proton is released as an H ion (H^+) into solution

$$\text{H—C—OH} + NAD^+ \xrightarrow{\text{Dehydrogenase}} \text{C=O} + NADH + H^+$$

-**NAD^+:** oxidized form, charged, gains electron, electron acceptor
-**NADH:** reduced form, electrically neutral

-Exergonic reaction of H with O to form water release energy in form of heat and light (explosion)

$$H_2 + 1/2\ O_2 \rightarrow Heat \rightarrow H_2O$$

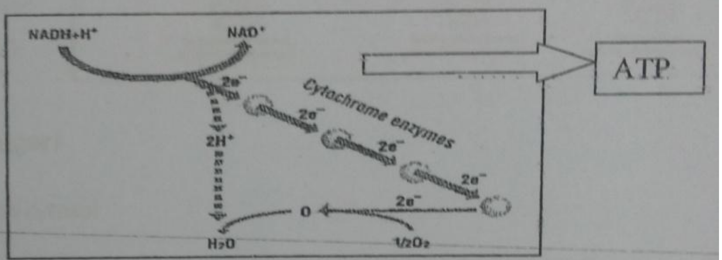
Electron Transport Chain

-In cellular respiration, electron transport chain breaks the fall of electron in this reaction into a series of smaller steps & stores some of the released energy in a form that can be used to make ATP (the rest of the energy is released as heat)

-Consists of proteins mostly that built into inner membrane of mitochondrion

-Electrons removed from food are shuttled by NADH to the `top' end of the chain

-At the `bottom' end, O captures these electrons along with H^+ forming water



Electron transfer from NADH to O_2

-Is exergonic (free energy change of -53 Kcal/mol)

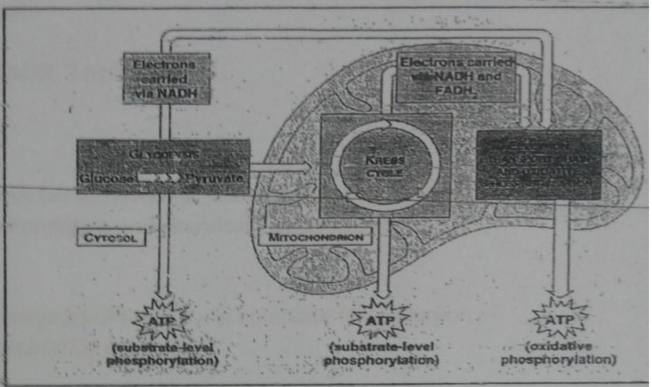
-Instead of this energy being wasted in an explosion, electrons cascade down chain from one carrier to next, losing a small amount of energy with each step until they finally reach O_2 (terminal electron acceptor)

-O_2 pulls electron down the chain in an energy-yielding tumble

-The downhill route of electron travel in cellular respiration:

Food → NADH → Electron Transport Chain → O_2

The Process of Cellular Respiration



1.Glycolysis (cytosol)

2.Krebs cycle, Citric Acid Cycle (mitochondrial matrix)

3.Electron transport chain and oxidative phosphorylation (Inner membrane of the mitochondria)

1. Glycolysis (splitting of sugar)

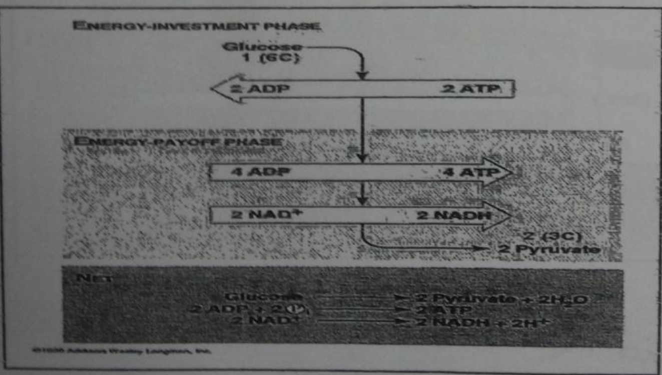
-Occurs outside mitochondria in cytosol

-Glucose (6-C) will be oxidized & atoms rearranged, so broken down into 2 Pyruvate (3C)

-Consists of 10 steps (2 phases) catalyzed by specific enzyme:

a. Energy investment (first 5 steps): ATP is spent to phosphorylate fuel molecules

b. Energy payoff (next 5 steps): ATP is produced by substrate level phosphorylation & NAD^+ is reduced to NADH by oxidation of food



-Less than a quarter of chemical energy stored in glucose is released, and most of energy remains stocked in the 2 pyruvate

-Each glucose molecule gives 2ATP, 2NADH, 2 pyruvate

-Occurs whether or not O_2 is present

-if O_2 present, energy stored in NADH can be converted to ATP energy when electron transport chain drives oxidative phosphorylation and chemical energy in pyruvate can be extracted by Krebs cycle

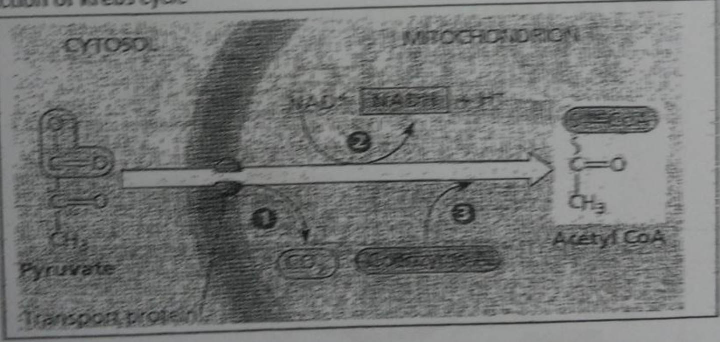
-Pyruvate enters mitochondria where enzymes of Krebs cycle complete the oxidation of sugar, but Pyruvate first converted to acetyl Co-A

Protein of inner mitochondrial membrane translocates Pyruvate into mitochondrial matrix & then:

1. Carboxyl group of pyruvate is removed as CO2 (diffuses out)

2. The remaining 2-C fragment is oxidized forming **acetate**, while NAD^+ is reduced to NADH

3. Finally the 2-C acetyl group is attached to coenzyme A, which has sulfur atom which attaches to the acetyl fragment by an unstable bond activates the acetyl group for the first reaction of Krebs cycle



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2.Krebs Cycle (Tricarboxylic Acid Cycle)

-Named after Hans Krebs (1930), occurs inside mitochondrial matrix

-Pyruvate will give CO2

-NADH transfers electron from glycolysis & Krebs cycle to electron transport chains

-8 steps catalyzed by a specific enzyme

-2 C atoms enter cycle via acetyl CoA, and 2 different C atoms leave in completely oxidized form of CO2

-For each acetate entering the cycle, **3 NAD$^+$** are reduced to NADH steps (3), (4), (8)

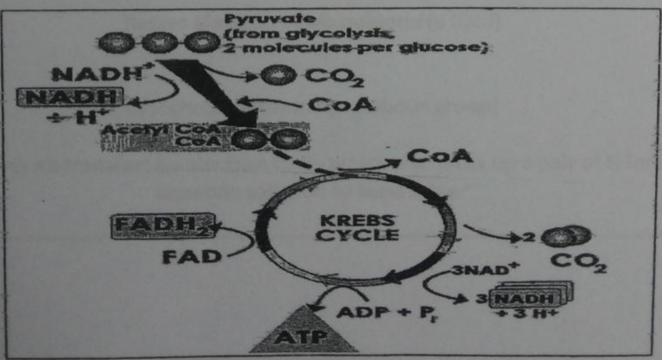
-In one oxidative step (6) electron transferred to FAD (riboflavin; vitamin B). FADH2 donates its electron to electron transport chain as does NADH (FADH2 feeds its electron at a lower energy level

-In step 5, **1 ATP** formed directly by substrate-level phosphorylation

-Glycolysis and Krebs cycle produce only **4ATP/glucose**

-For each **pyruvate** molecule enters krebs cycle: **3 NADH, 1 FADH2, 2 CO2, 1 ATP**

-For each **glucose** molecule enters krebs cycle: **6 NADH, 2 FADH2, 4 CO2, 2 ATP**



3. Electron Transport Chain & Oxidative Phosphorylation

-It is a collection of milecules embedded in the inner membrane of the mitochondria providing a space for 1000's of copies of the chain in each mitochondria

-Converts chemical energy to a form that can be used to drive oxidative phosphorylation, which accounts for most of the ATP generated by cellular respiration

-Most components of chain are proteins

-Prosthetic groups are tightly bound to the proteins, they are essential for catalytic functions of certain enzymes

-During electron transport, prosthetic groups alternate between reduced & oxidized states as they accept & donate electron

-Another source of electron for transport chain is FADH2 which adds its electron at lower energy level that is 1/3 less energy for ATP synthesis when electron donor is FADH2 rather than NADH

Electron transferred by NADH to flavoprotein
(Prosthetic group, Flavin mononucleotide)

Flavoprotein returns to oxidized form as it passes electron to Iron-sulfur protein

Passes electron to ubiquinone (a lipid)

Cytochromes (heme prosthetic group)

Cytochromes a3 transfers its electron to O_2 which also picks up a pair of H ions from aqueous solution to form water

Chemiosmosis (The Energy-Coupling Mechanism)

-Electron transport chain makes no ATP directly; Chemiosmosis couples electron transport & energy release to ATP synthesis

-**Chemiosmosis:** is an energy-coupling mechanism that uses energy stored in the form of H+ gradient to drive cellular work such as synthesis of ATP

-Electron transport chain firstly, uses exergonic flow of electron to pump H+ across membrane, from matrix into the intermembranous space

-Then, the H+ leaks back across membrane diffusing down its gradient through channel protein complex called ATP synthases, which is the only parts of mitochondrial inner membrane freely permeable to H^+

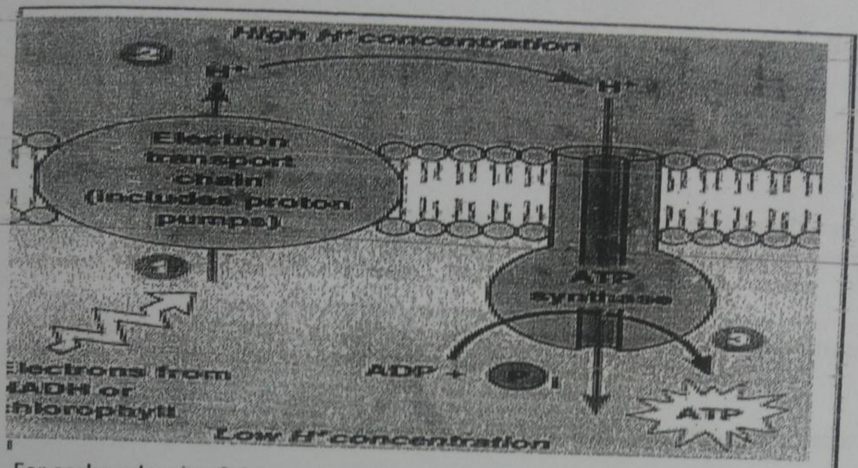
-ATP synthases work like an ion pump running in reverse, as they use the energy of H^+ gradient to drive phosphorylation of ADP **(proton-motive force)**

-H^+ gradient couples the redox reactions of the electron transport chain to ATP synthesis

-ATP synthase form a protein complex on mitochondrial (inner) and chloroplasts membrane and in the plasma membrane of prokaryotes

-ATP synthase has 4 parts with a number of protein subunits:

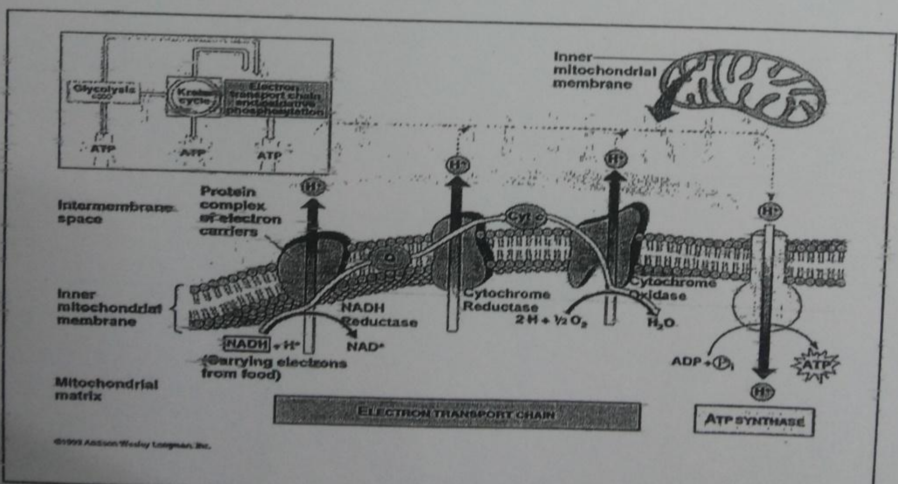
1. **Cylindrical component:** is a rotor within membrane that spins clockwise when H+ flows through it down a gradient
2. **Protruding knob:** in the matrix of mitochondria
3. **Rod (stalk):** connecting these 2 parts, also spins, bringing about a conformational change in the knob, activating catalytic sites ADP and inorganic phosphate combine to make ATP
4. **Stator:** anchored in the membrane holds the knob stationary



-For each molecule of glucose degraded to carbon dioxide & water by respiration, the cell makes about **36 molecules** of ATP

Glucose → NADH → Electron Transport Chain → Proton-Motive Force → ATP

-Each **NADH** that transfers a pair of electron from food to electron transport chain contributes enough to proton-motive force to generate maximum of **2.5 ATPs**, while each **FADH2**, worth maximum of **1.5 ATP**



-In some eukaryotes, this lower yield per electron pair (1.5 ATP) also applies to NADH produced by glycolysis in cytosol

-The mitochondrial inner membrane is impermeable to NADH, NADH in cytosol is segregated from the machinery of oxidative phosphorylation

-The 2 electron of NADH captured in glycolysis goes to mitochondrion by shuttle system which uses either, **NAD+**(2.5 ATP from mitochondrial NAD+), or **FAD** (1.5 ATP maximum from each cytosolic NADH)

-Assuming: max of 32 ATP from oxidative phosphorylation, and 4 ATP from substrate level phosphorylation, gives **32 ATP**; this is the estimate of maximum ATP yield

-Efficiency of respiration is 34% = maximum ATP yields per glucose, the rest is lost as heat

Sample Questions

1. A molecule becomes more oxidized when it:

a. Changes shape
b. Gains a hydrogen ($H+$) ion
c. Loses a hydrogen ($H+$) ion
d. Gains an electron
e. Loses an electron

2. In the overall process cellular respiration, ... is oxidized and ......is reduced

a. Oxygen ... ATP
b. ATP ... oxygen
c. Glucose ... oxygen
d. Carbon dioxide ... water
e. Glucose ... ATP

3. Most of the ATP produced in cellular respiration comes from:

a. Glycolysis
b. Oxidative phosphorylation
c. Reduction of NADH
d. Substrate-level phosphorylation
e. The citric acid cycle

4. The function of cellular respiration is to:

a. Reduce CO2
b. Extract CO2 from the atmosphere
c. Extract usable energy from glucose
d. Synthesize macromolecules from monomers
e. Produce carbohydrates

5. $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$, which compound is reduced in the reaction?

a. Oxygen
b. Glucose
c. Carbon dioxide
d. Water
e. Both glucose and carbon dioxide

Questions Answers

Question	Answer
1	e. Loses an electron
2	c. glucose ... oxygen
3	b. Oxidative phosphorylation
4	c. Extract usable energy from glucose
5	a. Oxygen

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