Ch 15

* Metabolism ⟶ collection of all Biochemical reactions happening inside our cells / body

* 2 Major types ⟶

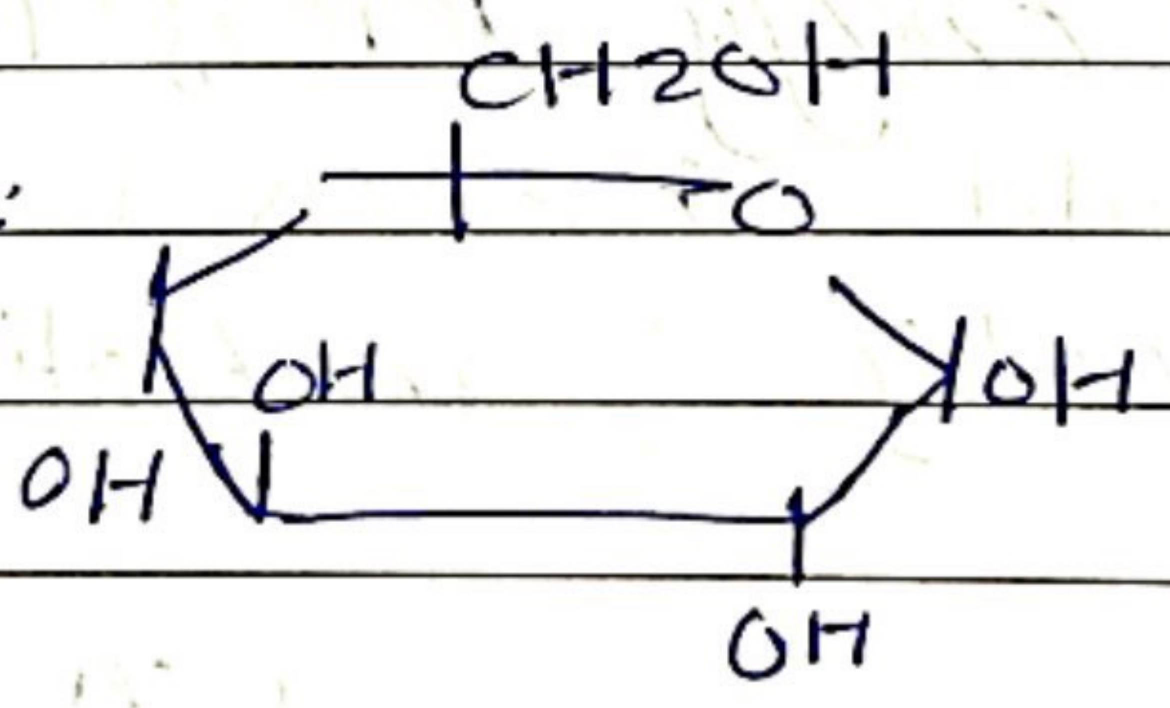
[1] Catabolic

- Biochemical reactions used to convert complex molecules (fatts → fatty acid, polysa. → monosa., proteins → a.a, smaller molecules, DNA) to smaller molecules

وعشان أعمل هيك بنا & Oxidative reactions

↳ Electrons will be removed from these large molecules

ex → Sugar:



وعشان أكسروا لازم أكسر Cova. bond

$C \dot{-} H$ → high energy electrons

عشان أكسرها بحرك ال ē عملية

Oxidative

* لحي تا .... بـ الراقة ؟

To extract energy stored & to make small molecules that could be used to build new biological molecules needed by a cell & this require anabolic reaction

[2] Anabolic

- Reductive reaction (need to make cova. bond → need to put electrons → need energy)

- products of catabolic are used as inputs for anabolic

- Energy released from catabo. could be used to build new molecules (anabolic)

* لو Cell عاوزة تعمل Certain type of protein the cell need

Energy (Come from food)

A.A

* Catabolic / Anabolic → need
Oxidation − Reduction reaction

* Each sub. have Reduction potential

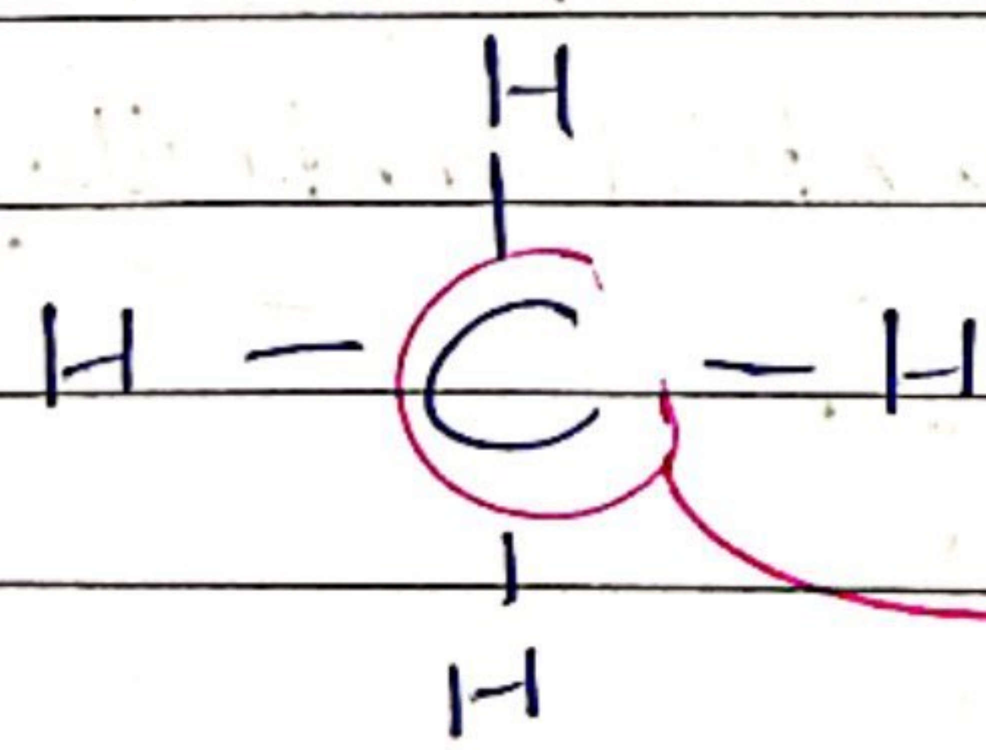
→ Measure the ability of Sub. to loss / Gain electrons

→ ↑ accept electrons ; ↓ loss electrons

* اي catabo. لازم يكون معاه anabolic ē &

- When we start moving ē from 1 sub. to another, these ē lose some of their energy. This is how energy could be extracted from Carbo. & lipids

- Oxidation number of any atom is determine by looking to other atoms connected to it



→ −4
مكتسب
4ē

ē
بتجرد من
low electro. negati
↓
high

* Cell capable of releasing energy by having electrons through oxidative reaction & the cell use the energy in a useful work

↳ build molecule, move our muscle, active transport molecule across membrane

* Energy stored in our body is stored in form of carbohy Not ATP

* ATP is used by the cell to transfer energy from 1 place to another

* During oxidative reaction if you followed up the oxidation number of carbons, in carbohy., lipid, a.a, you will see oxidative number will be increasing as more oxidative reaction is happening & more energy will be released from the carbon, & the carbon of the Glucose for ex will be converted eventually to carbons within CO_2

↳ فاستنفذ

energy extraction from it, so that's why our cells releases CO_2 from our body

* بتاعة O2 & ...

Allows to carry out oxidative reaction by receiving electrons final e acceptor بتاعه

* one way of following the movement of electrons during oxidative reaction is to do lewis dot concept

* Co enzyme $NAD^+/NADH$ they are used in catabolic oxidative reaction & the electrons will be moving in the form of hydride ion $H:^-$ (proton with $2\bar{e}$)

* another Co-enzyme involved in oxidative reaction → $FAD/FADH_2$

* 1 common theme in metabolism is coupling of a reaction that produces energy & another reaction that requires energy

* فكرة إنه

In order to drive the reactions that are endergonic (+ΔG, need energy), another reaction that produces energy might be coupled with this endergonic reaction

Ex

$A + B \longrightarrow C \quad \Delta G^{\circ} = +$

energy وتعطينا

immediately →

$X + Y \longrightarrow W + \text{Energy} \quad \Delta G^{\circ} = -$

* Now remember
oxidative reactions اللي
that are used to release some of chemical potential energy stored in sugar / lipid / a.a, the energy released can't be used directly

* هال coupling يعتمد على high energy bonds
↳ When it's broken they indirectly release energy

* هيك منعرف انو تكسير الروابط بتطلب طاقة بس
و روابط
indirectly result in releasing of energy that could be used by the cell

- So one of the molecules that has this high energy bond is ATP molecule
  - 2 high energy bond at least
  - Allow the cell to transfer energy between reactions that releases energy & a reaction that require energy

* ATP hydrolyzed with presence of H_2O produces ADP & proton & inorganic phosphate

$$ATP + \overset{\text{needed}}{H_2O} \rightarrow ADP + P_i + H^+$$

$\Delta G^{\circ\prime} = -30.5\ kJ/mol$ $\quad \Delta G^{\circ\prime} = -7.3\ kcal/mol$

energy released طاقة

- So removing a phosphate Group from ATP is exergonic reaction

→ it although it's thermo. favored but kina. it's not favored it require alot of activation energy

* ATP → thermo. : unstable
→ kinet. : stable

→ this reaction doesn't happen by itself

e thermo. favored ← *

[1] higher entropy of product

[2] products have less energy & more stable because of resonance due to new bonds formed

↑ entropy

[3] 4 negative charges on ATP which make it unstable because of repultion. ADP have 3 negative charges

[4] ↑ water solvation (surrounding of these molecules with water) more stable & around the products it's high

* There are other molecules in our bodies that carry out high energy bond
organophosphate
↓ when they lose phosphate energy released

مثال آخر على Coupling

Exergonic $PEP + H_2O \rightarrow pyruvate + P_i + energy$

phosphate released & energy will be used to make ATP

endergonic $P_i + energy + ADP \rightarrow ATP$

* Extraction of energy from Glucose requires several reactions - بيصير بالتدريج - & we will have small amount of energy

للتعبير - Cov. bond of Glucose are being broken & ē of cov. bond are being moved to the oxygen & while they are moving to oxygen energy will be released (as heat to the enviro. or to make our bodies warm or to make ATP but not all of the energy)

* 1 mol of Glucose could be used to syn. up to 32 ATP

* Some other path. in producing energy → Anaerobic respiration yeilds only 2 ATP

Glucose $\xrightarrow[\text{anaerobic respiration}]{}$ lactic acid / ethanol

2 ATP بيعطي بس

* In some of metabolic path you will see some steps that are actually an activation step

In activation step more reactive sub. will be formed
↳ high energy bond which mean during activation step this sub. can be used to drive a reaction that is endergonic

A + Coenzyme → A - Coenzyme

A - Coenzyme + B → AB + Coenzyme

bond is broken, energy released, drive another reaction

$*NAD^+ + 2\bar{e} + H^+ \longrightarrow NADH$

... فيتامين، اكل

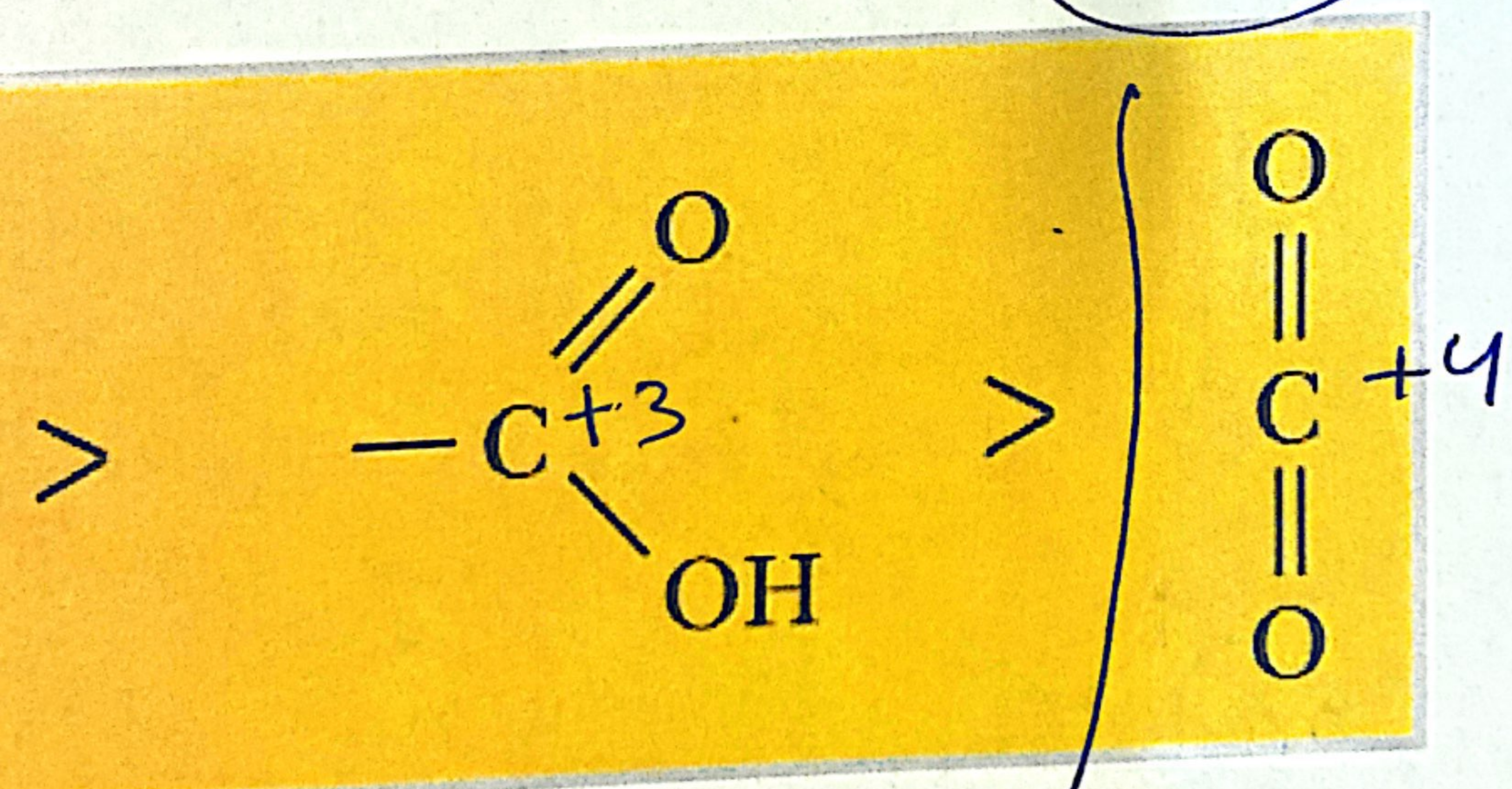
electron carrier.
carry the electrons so that eventually these electrons will reach to produce H_2O

$H^+ + 2\bar{e} + O_2 \longrightarrow H_2O$

- & once the electrons are moving from NADH, through electron transport chain, these $\bar{e}$ will loss some of their energy & this energy will be used to make ATP

Carboxylic acid

Carbon dioxide



most oxida
Carbon

Redox Reactions

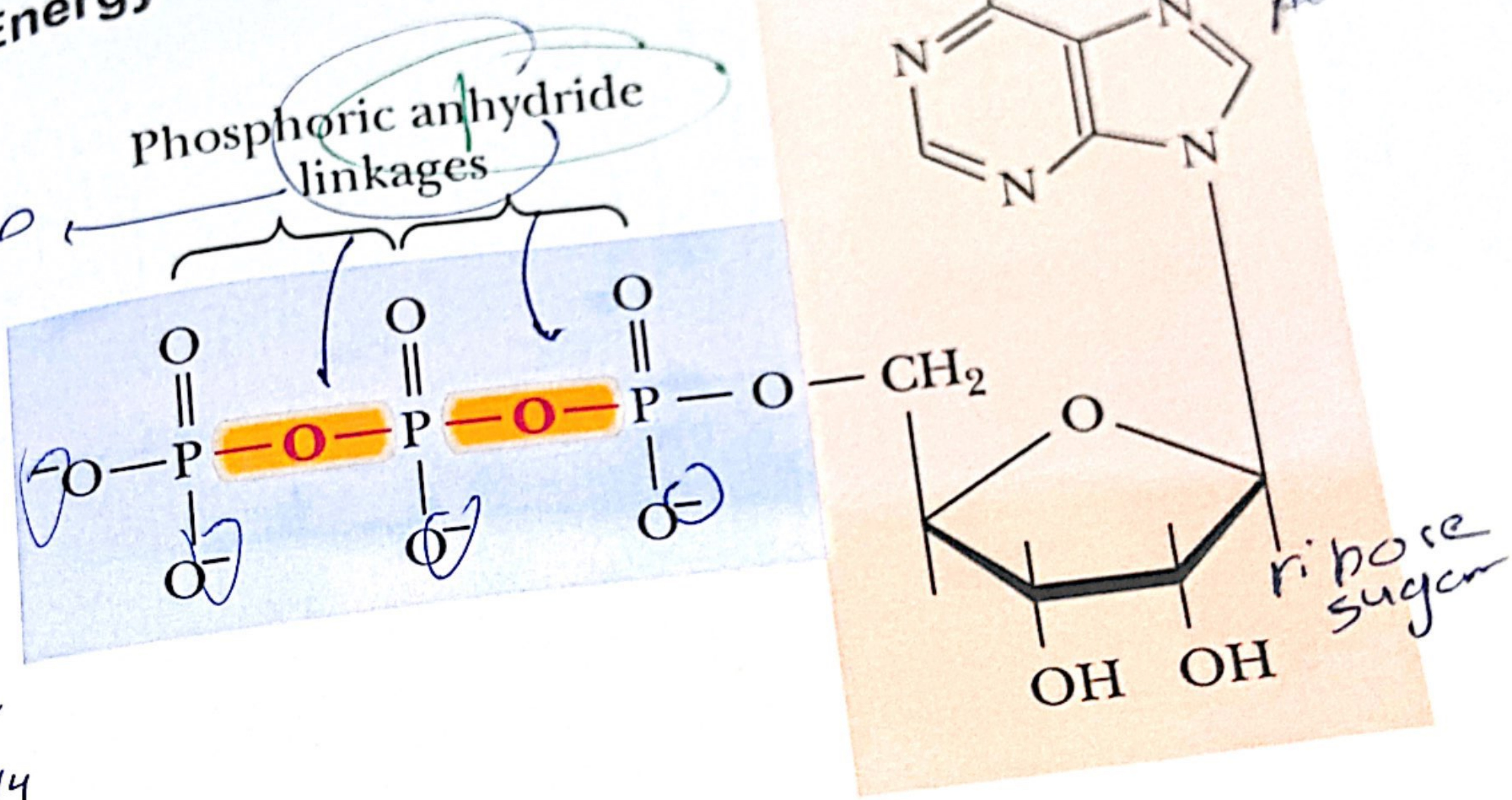
- Conversion of ethanol to acetaldehyde is a two-electron oxidation

The half reaction of oxidation of ethanol to acetaldehyde

Ethanol (12 electrons in groups involved in reaction)

Acetaldehyde (10 electrons in groups involved in reaction)

"High Energy" Bonds are in red



صدور هعنة
high energy bond
حيفا مش
انه اذا كسرناها
directly
لح يصير عندي energy

ATP
(adenosine-5'-triphosphate)

الفكرة عشان نكسر
صدور الروابط لازم
energy input
but once these energies are broken, free energy will be released indirectly

ATP

- **Why is ATP less stable, charge-wise, than ADP?**

TP and ... ADP, therefore

Biochemical reactions happening inside our cells / body

Organophosphate as an energy source

- Organophosphates release higher energy when hydrolyzed than ATP.
- The energy released from hydrolysis of Organophosphates is used to phosphorylate ADP to ATP

Table 15.1

Free Energies of Hydrolysis of Selected Organophosphates

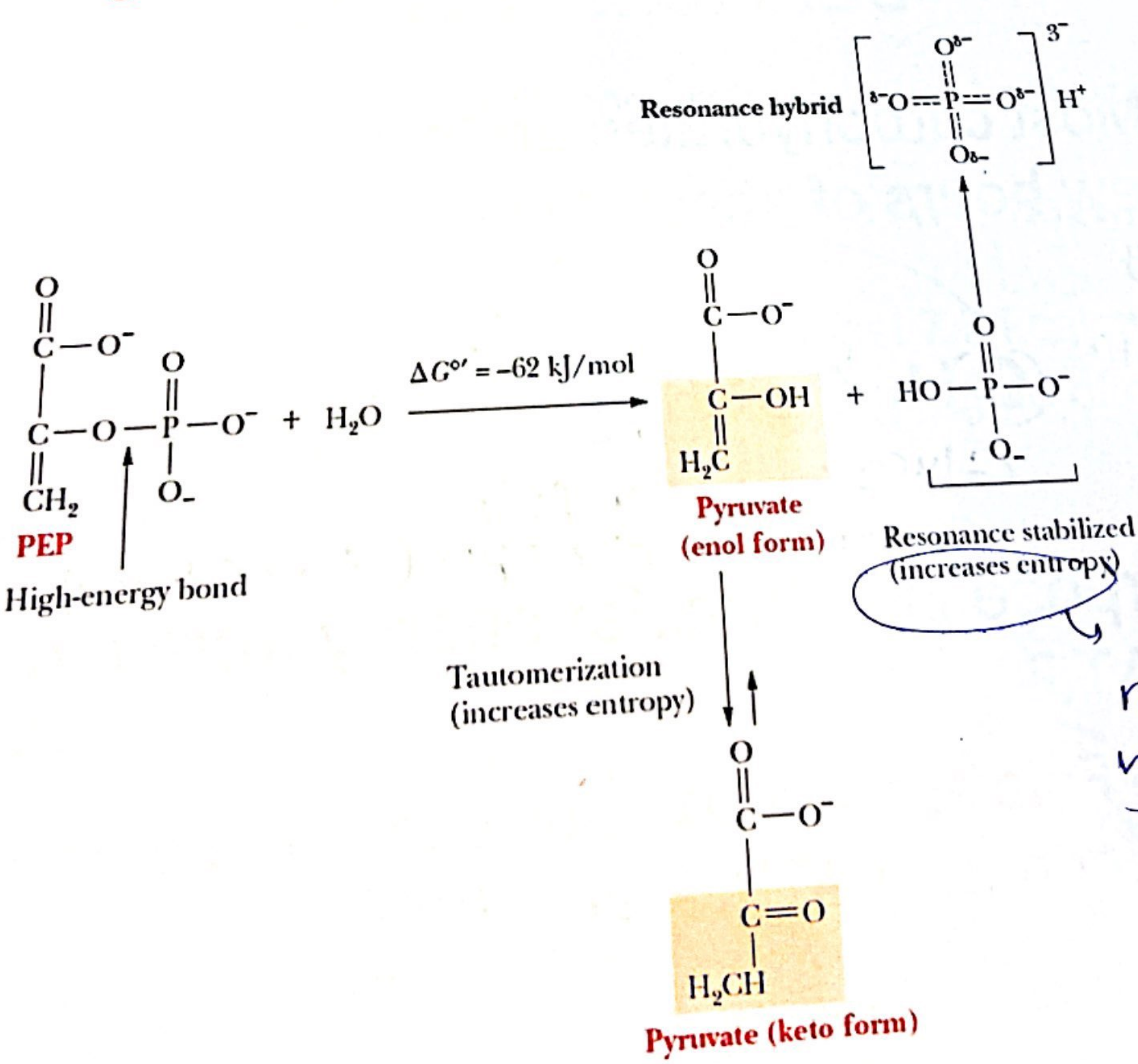
Compound	$\Delta G^{\circ\prime}$ kJ mol^{-1}	$\Delta G^{\circ\prime}$ kcal mol^{-1}
Phosphoenolpyruvate	−61.9	−14.8
Carbamoyl phosphate	−51.4	−12.3
Creatine phosphate	−43.1	−10.3
Acetyl phosphate	−42.2	−10.1
ATP (to ADP)	−30.5	−7.3
Glucose-1-phosphate	−20.9	−5.0
Glucose-6-phosphate	−12.5	−3.0
Glycerol-3-phosphate	−9.7	−2.3

PEP

high energy molecule

low energy molecules

Organophosphate as an energy source



Make reaction highly favo

Products of anabolism

Precursors

Catabolism of Food

- Most carbohydrates are catabolized within a few hours of absorption

During cellular respiration

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Glucose

C —H

$\bar{e}$

final $\bar{e}$ acceptor (e of C bond)

- Purpose is to transfer energy from glucose to ATP
  - Fats and amino acids can also be used to generate ATP. or heat

fatty acid,
a.a → smaller
molecules

ed

How efficient is respiration in generating ATP?

- Complete oxidation of glucose releases 686 kcal per mole.
- Some of this energy is used to produce ATP that will perform cellular work.
- Formation of each ATP requires at least 7.3 kcal/mole.
  - 32 moles of ATP are formed from one mole of glucose
- Efficiency of respiration

$$\frac{\dfrac{32 \text{ moles ATP/mole glucose} \times 7.3 \text{ kcal/mole ATP}}{}}{686 \text{ kcal/mole glucose}} \times 100 = 34\%$$

ATP

- The other approximately 66% is lost as heat.

CoA in activation of metabolic pathways

- A step frequently encountered in metabolism is activation
  - **Activation**: the formation of a a more reactive substance
  - A metabolite is bonded to some other molecule and the free-energy change for breaking the new bond is negative .
  - Causes next reaction to be exergonic

A + CoA → A~CoA
A~CoA → A + CoA + energy
A + B → AB
coupled reac.

a Group is transfera into coenzyme

c. bond (high energy bond)

A + Coenzyme → A—Coenzyme   **Activation step**

A—Coenzyme + B → AB + Coenzyme $\Delta G^{\circ\prime} < 0$ **Exergonic reaction**

energy → A + B → AB, $\Delta G > 0$ reaction release energy indirectly

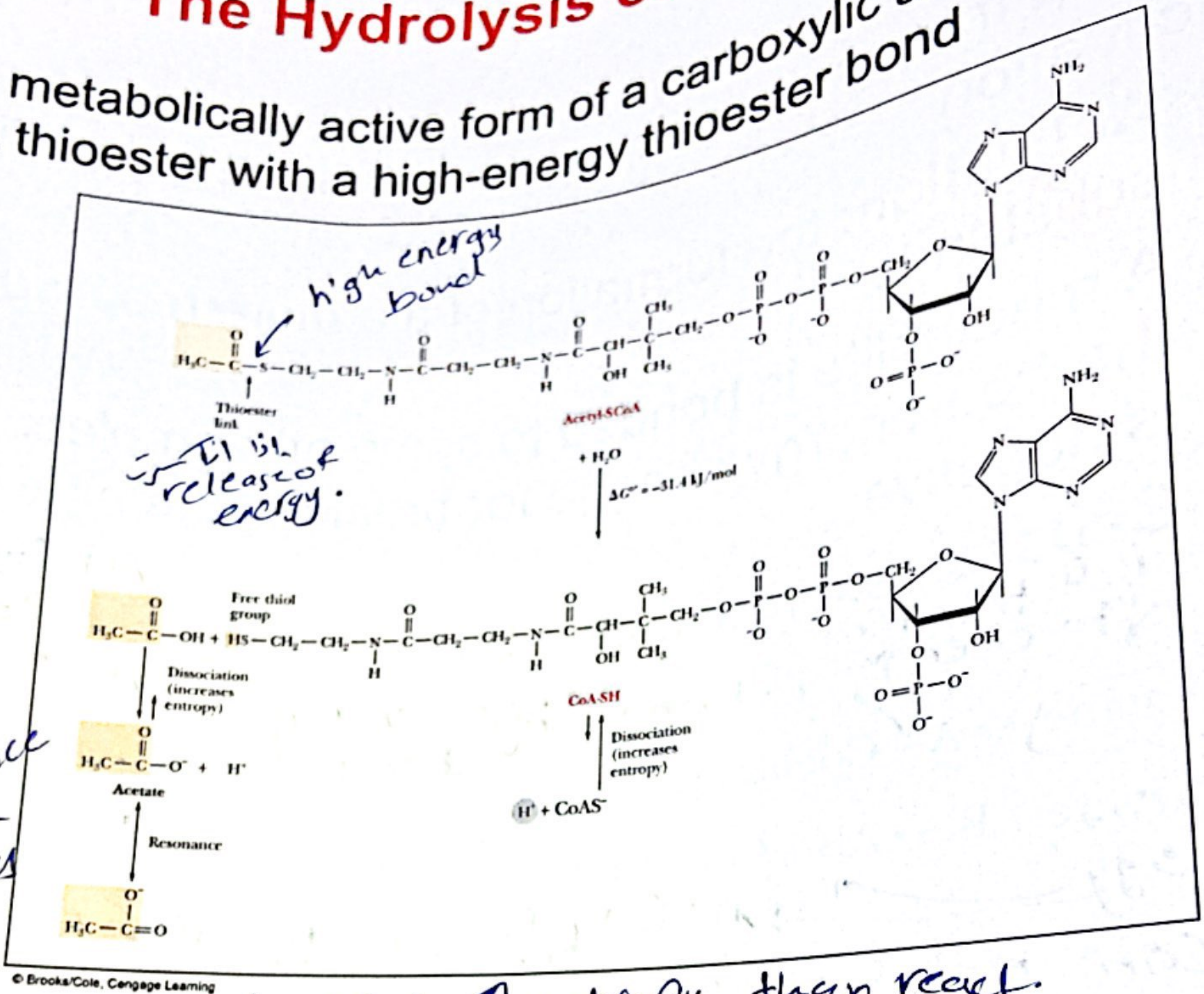
can make a high energy bond whenever it can reserve another molecu

Two Ways of Looking at Coenzyme A

Coenzyme A (CoA-SH) contains pantothenic acid, 3′,5′-ADP and 2-mercaptoethylamine

The Hydrolysis of Acetyl-CoA

The metabolically active form of a carboxylic acid is the acyl-CoA thioester with a high-energy thioester bond



produ. ↑ entropy than react. which make thermod. favorable

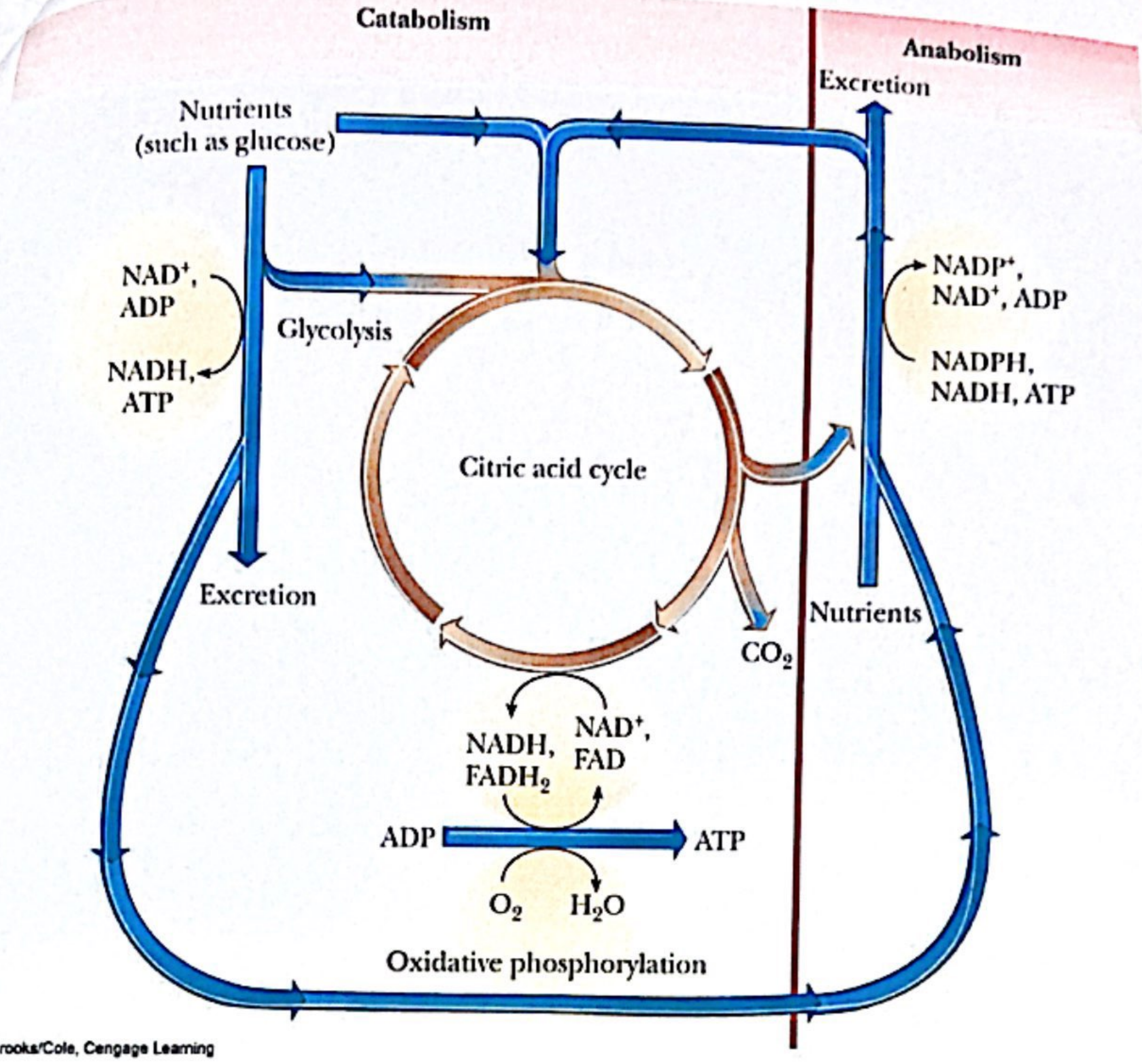
$NAD^+/NADH$

oxidation/reduction reaction — Coenzymes

- In catabolism NAD^+ act as oxidizing agent
- In anabolism NADH act as reducing agent
  - NADH is oxidize to form NAD^+ and $H^+ + e^-$
- This lead to reduction and elec...

next substr...

Electron Transfer & ATP Production in Metabolism



* some of NADH produced during catab. could be used to drive some of anaboli. reaction, but also some of the NADH could be used to make more ATP by a process called oxidative phosphorylation