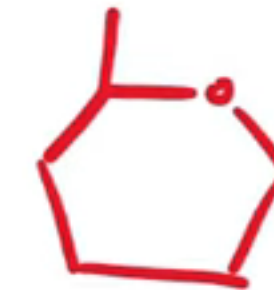


Chapter 12: Respiration

what is respiration?

- breakdown of organic molecules
(carbs, proteins, lipids)
- to release energy for cellular work

eg:

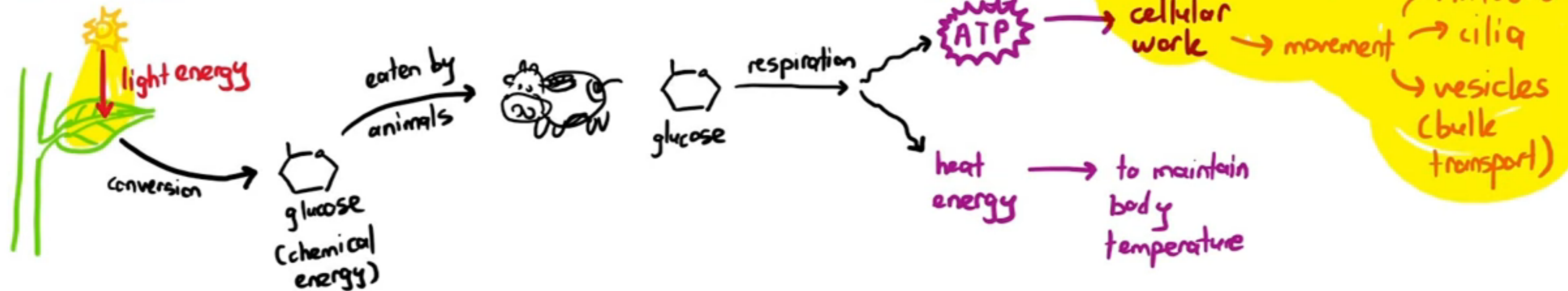


glucose



Chapter 12: Respiration

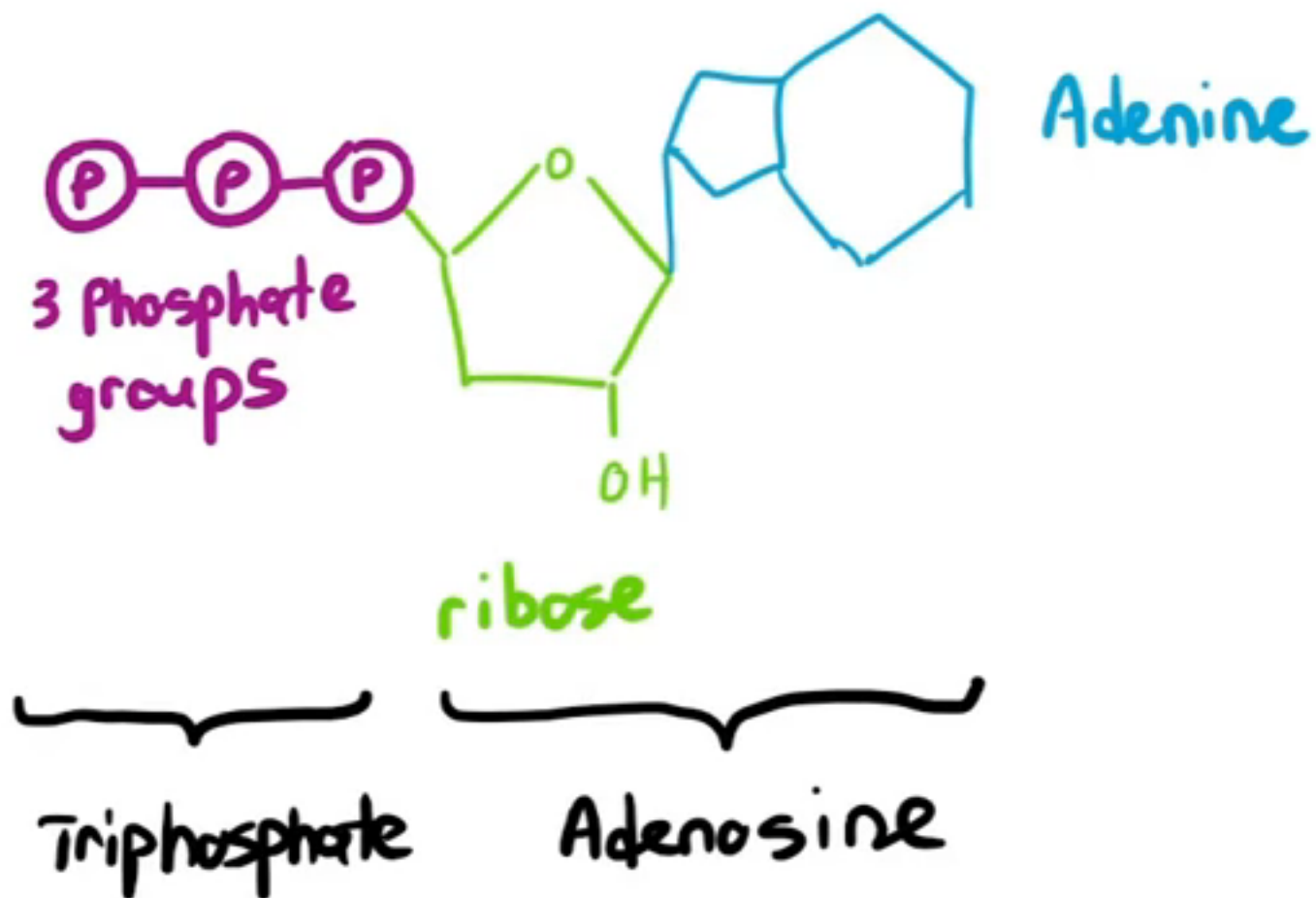
Flow of energy...



ATP??

① what is ATP?

Adenosine Triphosphate = a type of nucleotide

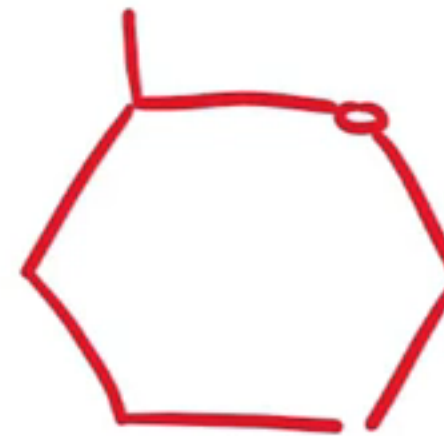


ATP??

(2) what is ATP used for?



is an energy molecule
(chemical energy)



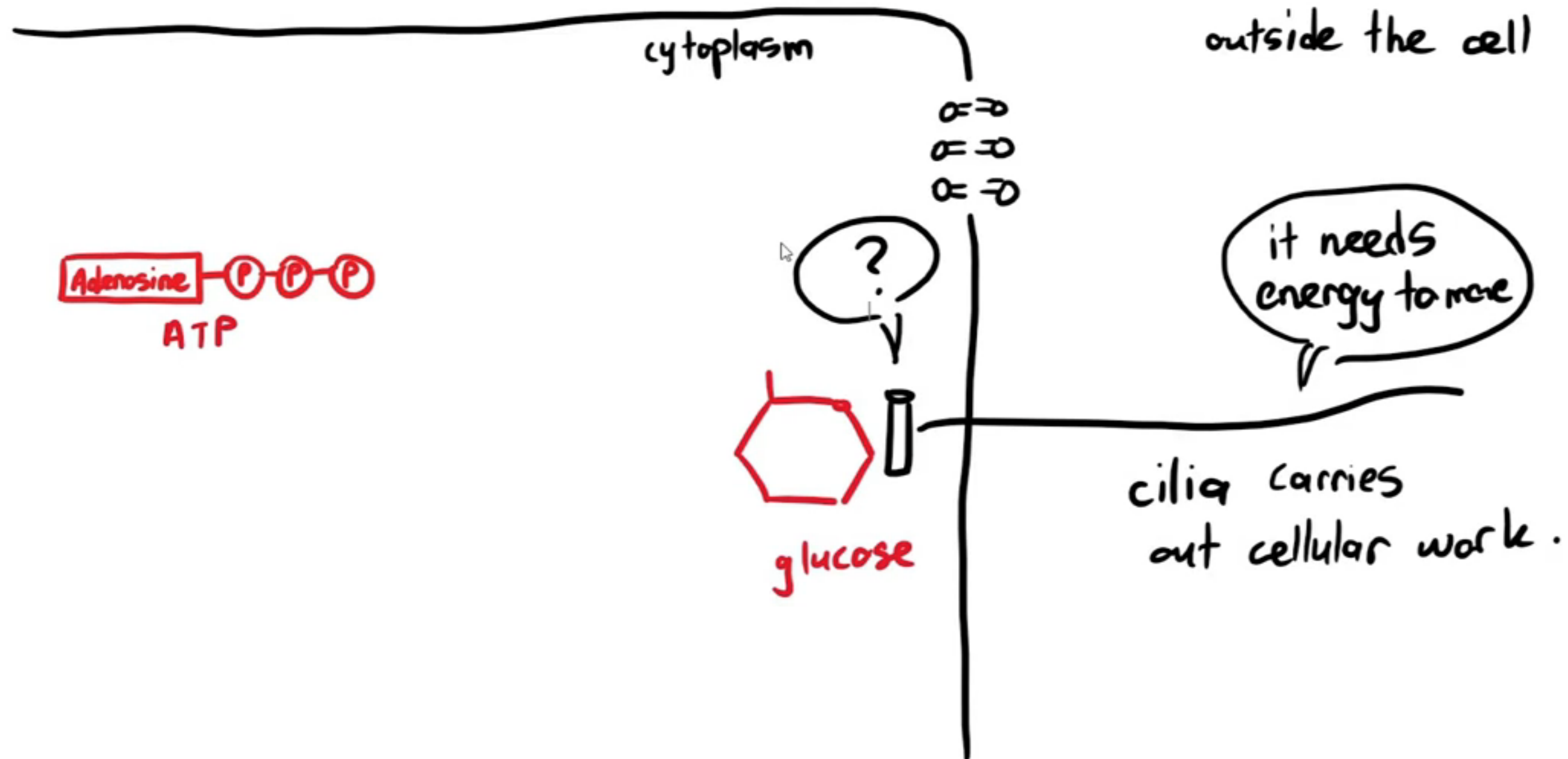
α -glucose is an energy molecule
(chemical energy)



which energy
do I need??

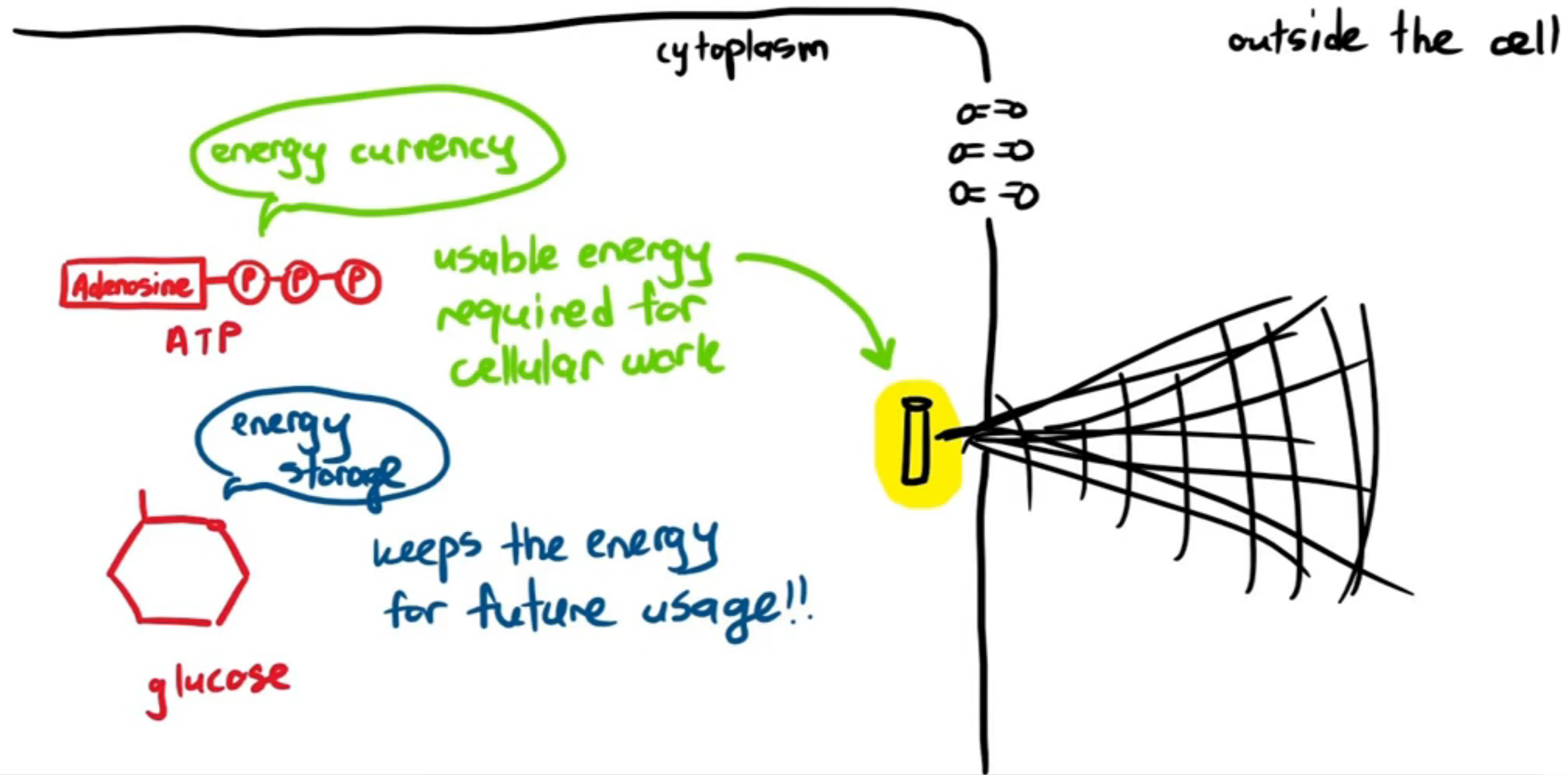
ATP??

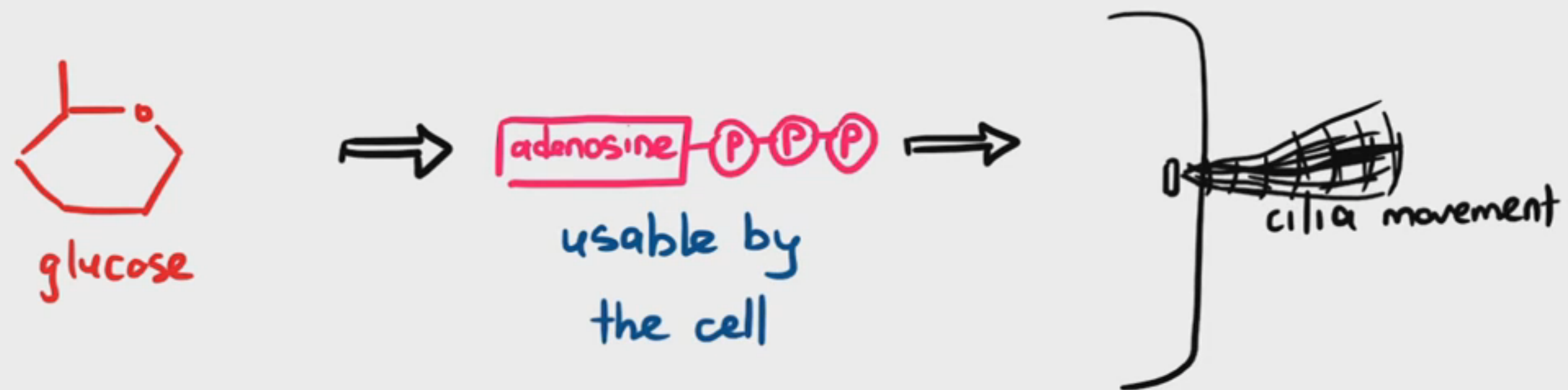
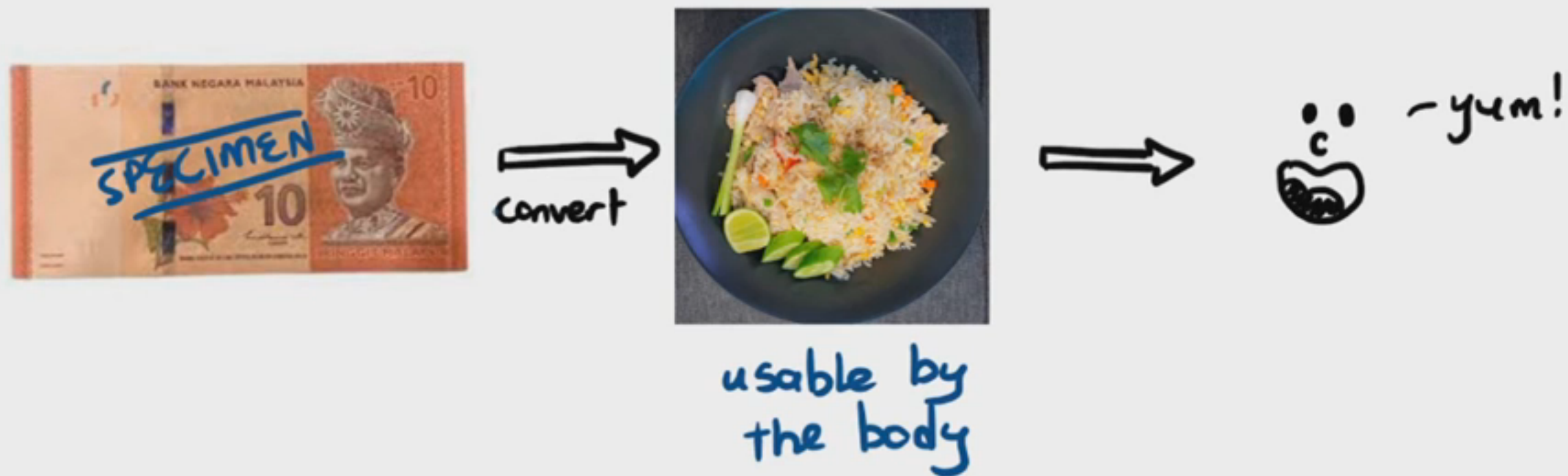
(2) what is ATP used for?



ATP??

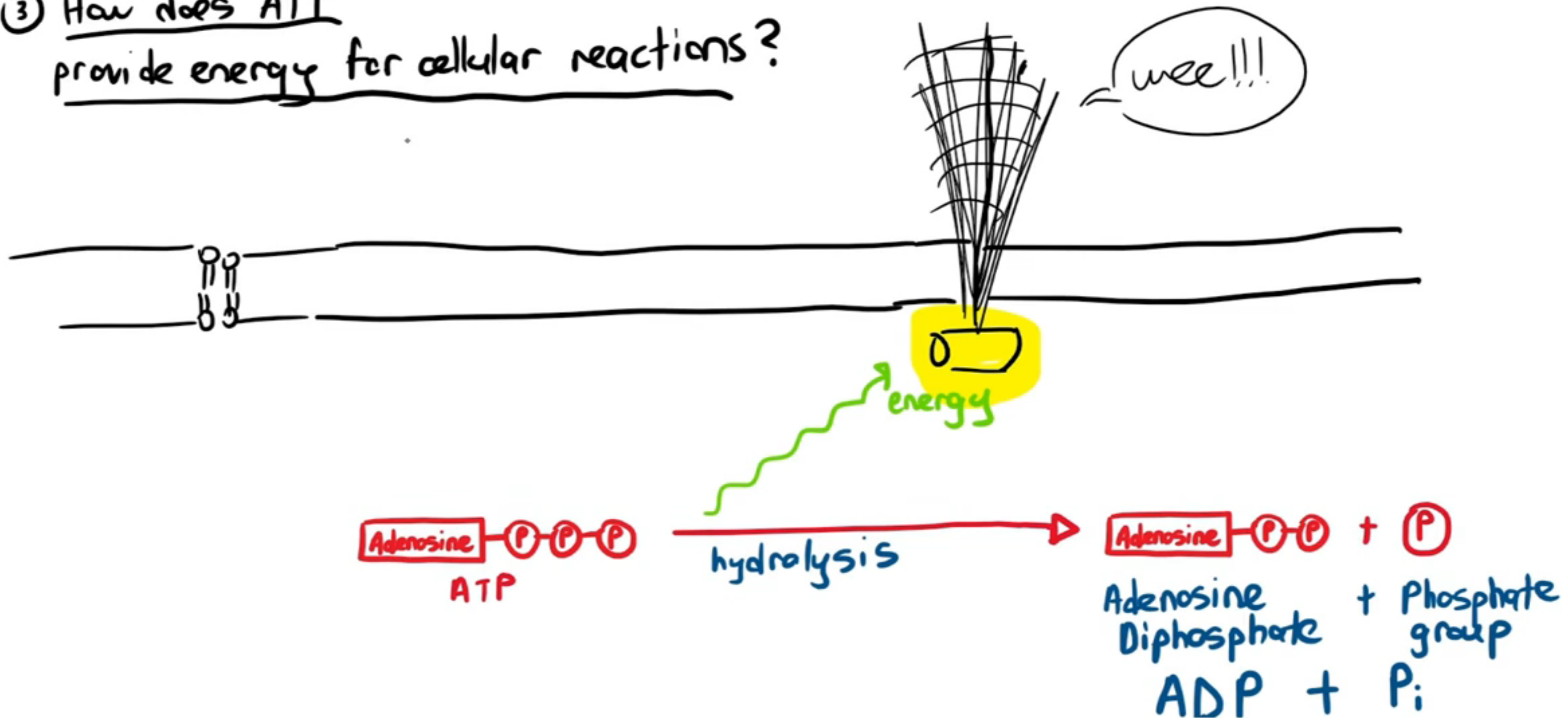
(2) what is ATP used for?

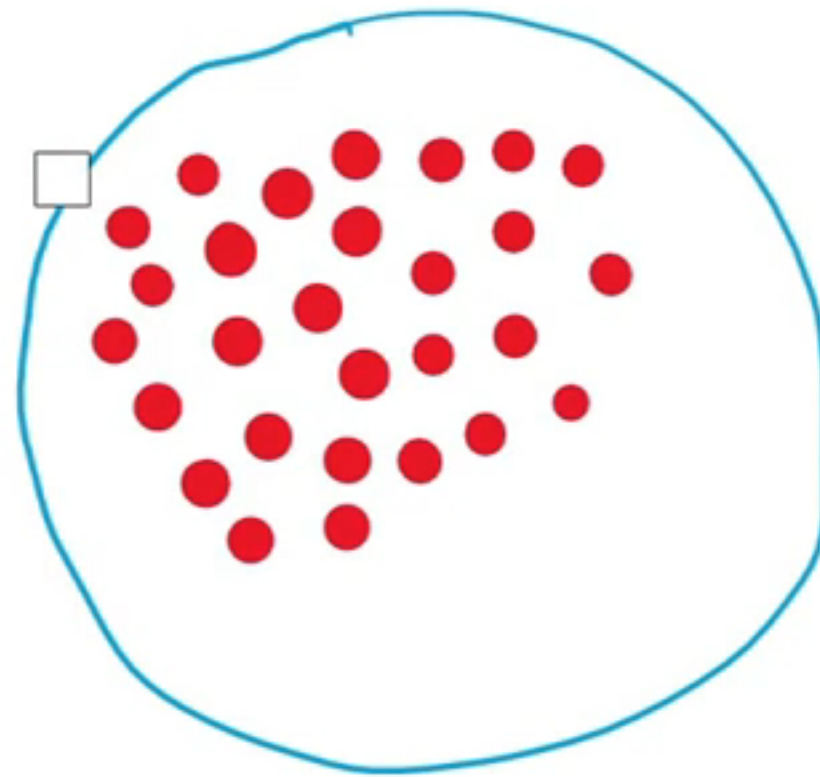




ATP??

③ How does ATP provide energy for cellular reactions?





ATP
(full of energy!!!)

energy

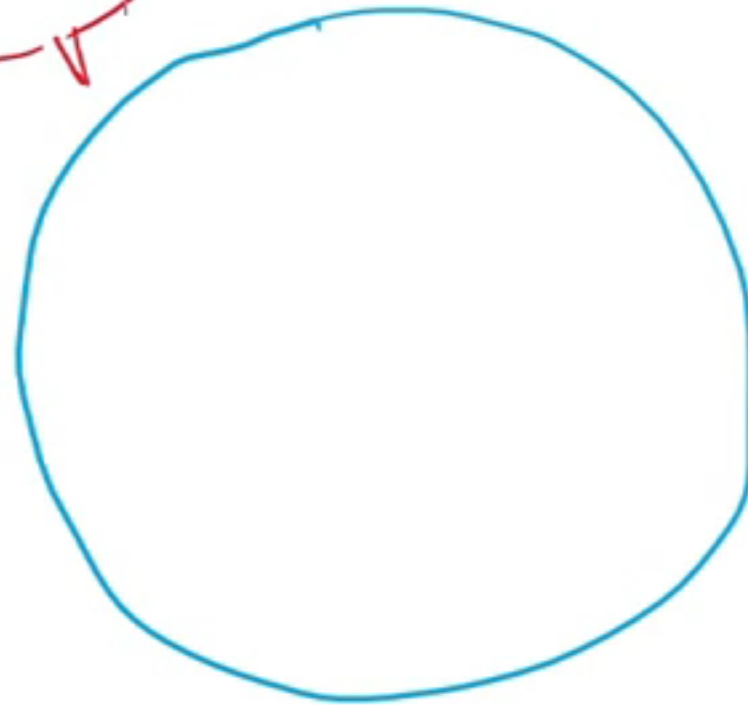
cellular
work
eg: Protein Syn



ADP + P_i
(less energy)

ATP??

no more
ATP !!!
!!!



ATP
(full of energy!!!)

energy

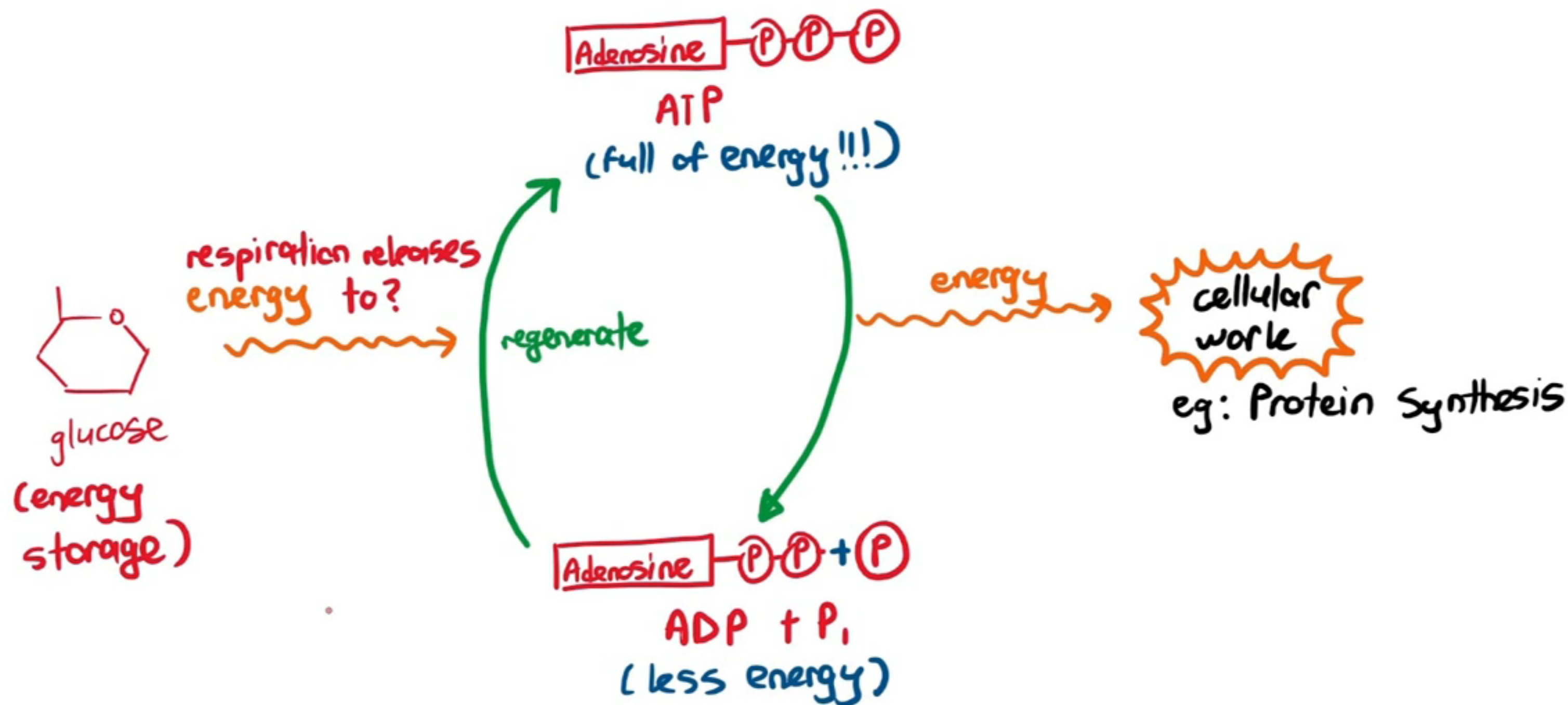
cellular
work

eg: Protein Synthesis



ADP + P_i
(less energy)

ATP??



ATP??

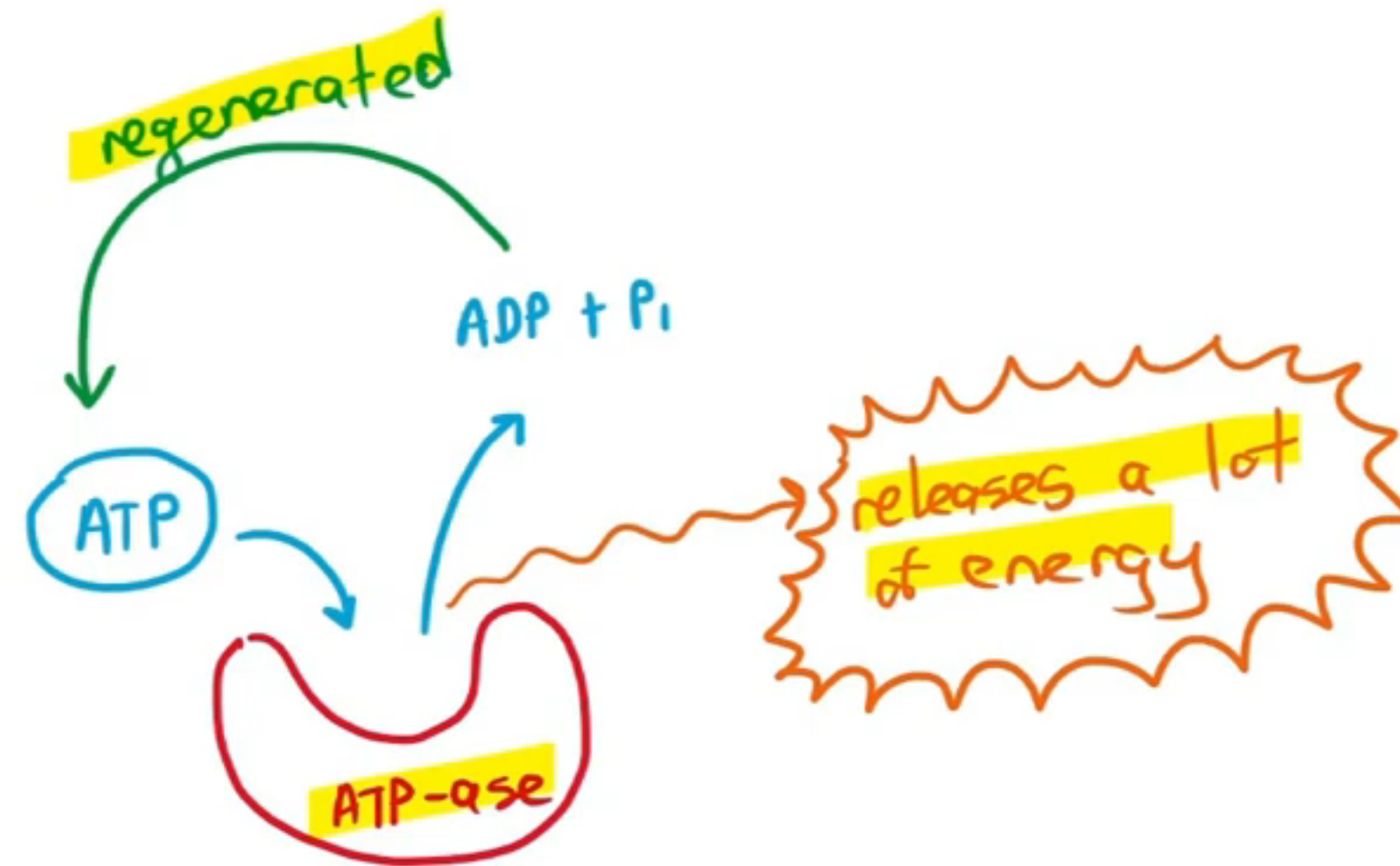
④ why is ATP such a good energy currency molecule?

a) ATP can be regenerated after being hydrolyzed.

b) ATP can be easily hydrolyzed - so you can release energy!!

c) ATP cannot spontaneously hydrolyze but can only be broken down using ATP-ase

d) Hydrolysis of ATP releases large amounts of energy!!!!

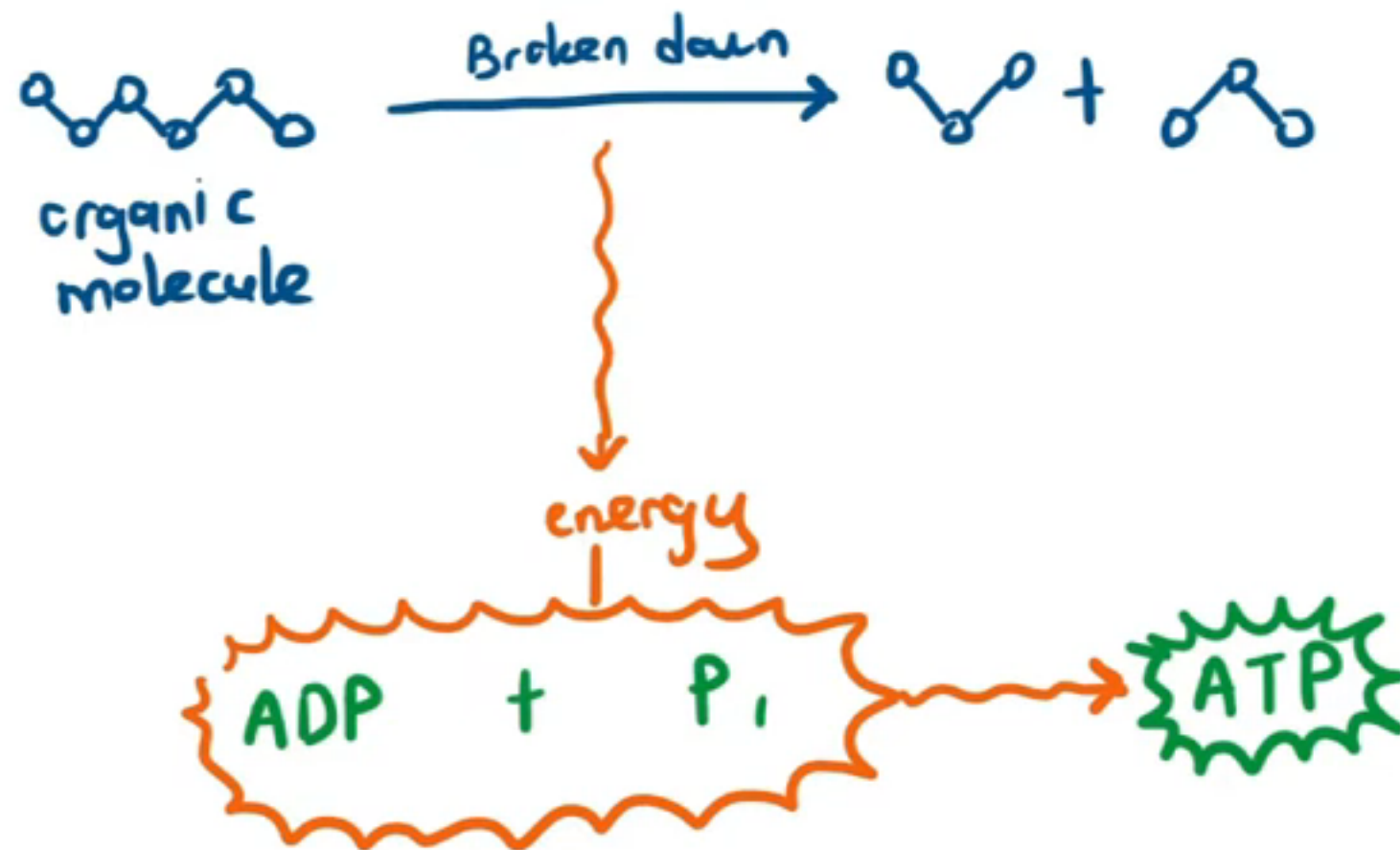


ATP??

⑤ How is ATP synthesized?



a) Substrate linked reaction



using the **energy** released
from another chemical reaction...

the **P_i & ADP** are linked
together to form ATP!!

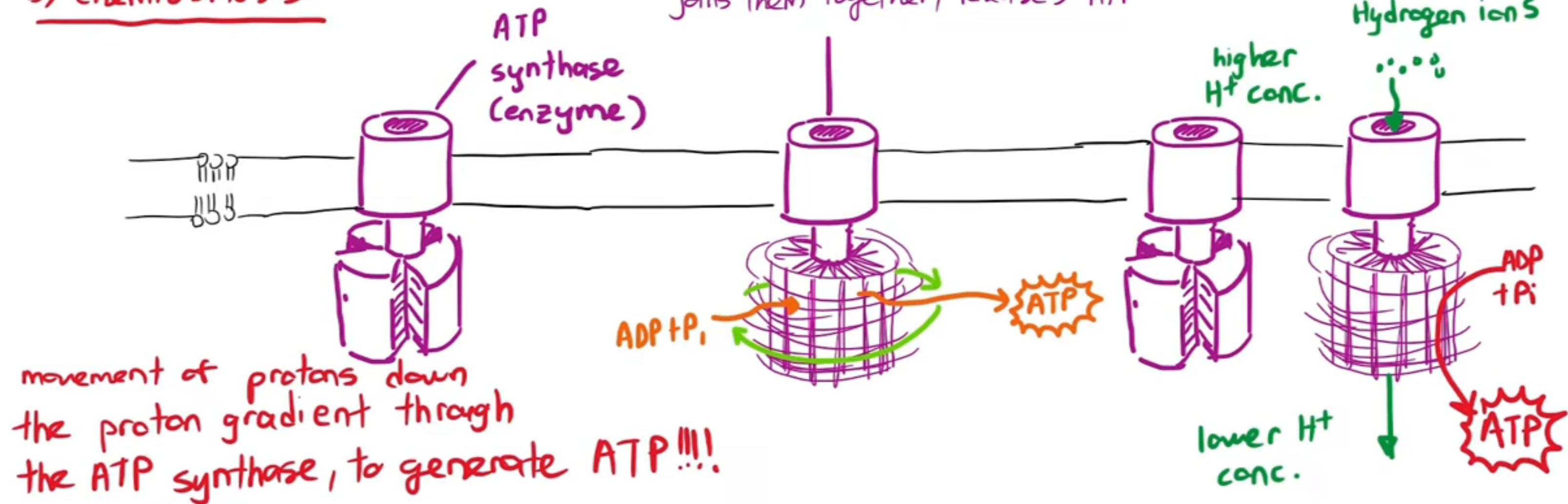
ATP??

⑤ How is ATP synthesized?

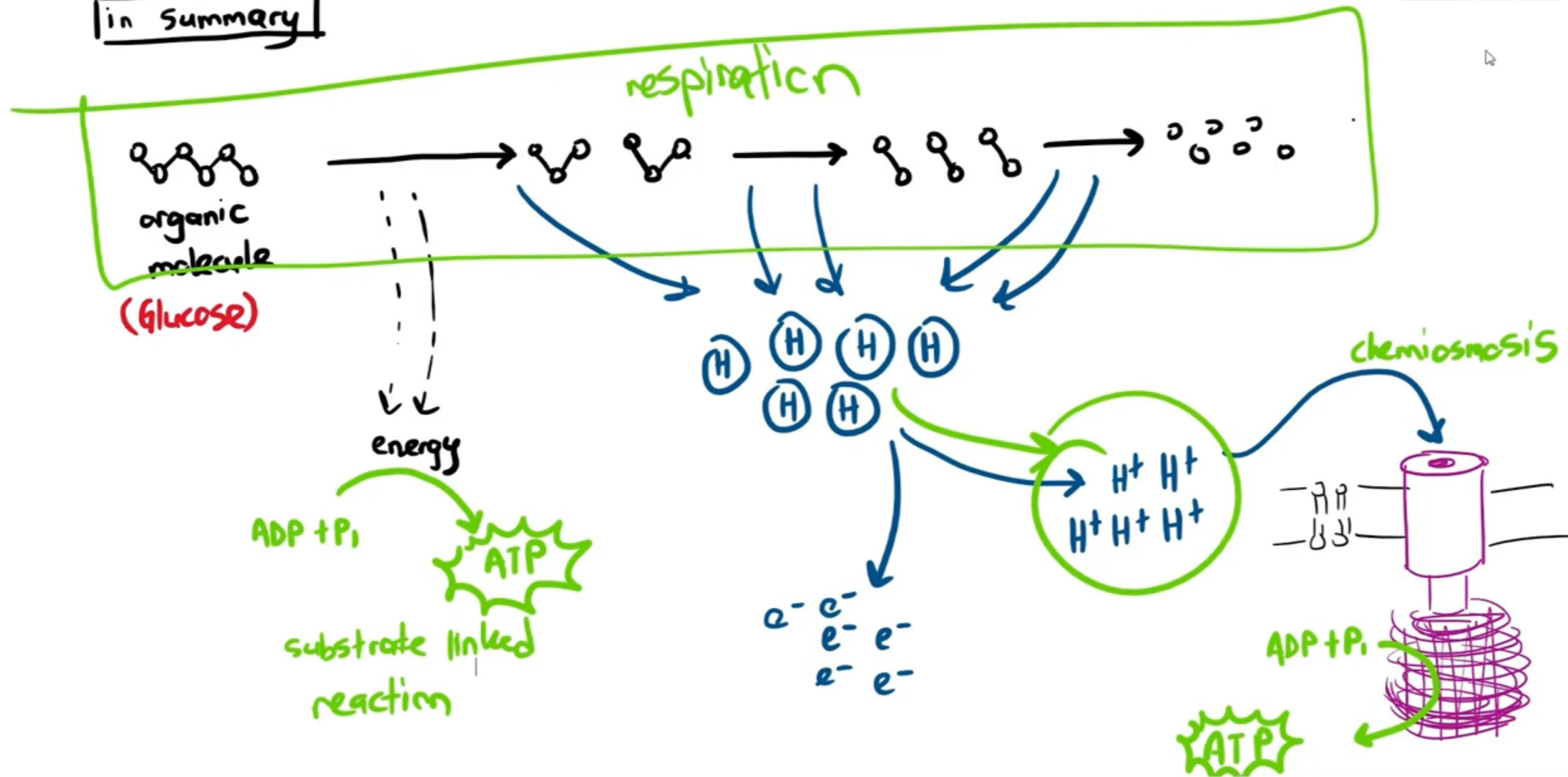


b) chemiosmosis

when the ATP synthase rotates, it accepts $\text{ADP} + \text{P}_i$, joins them together, releases ATP

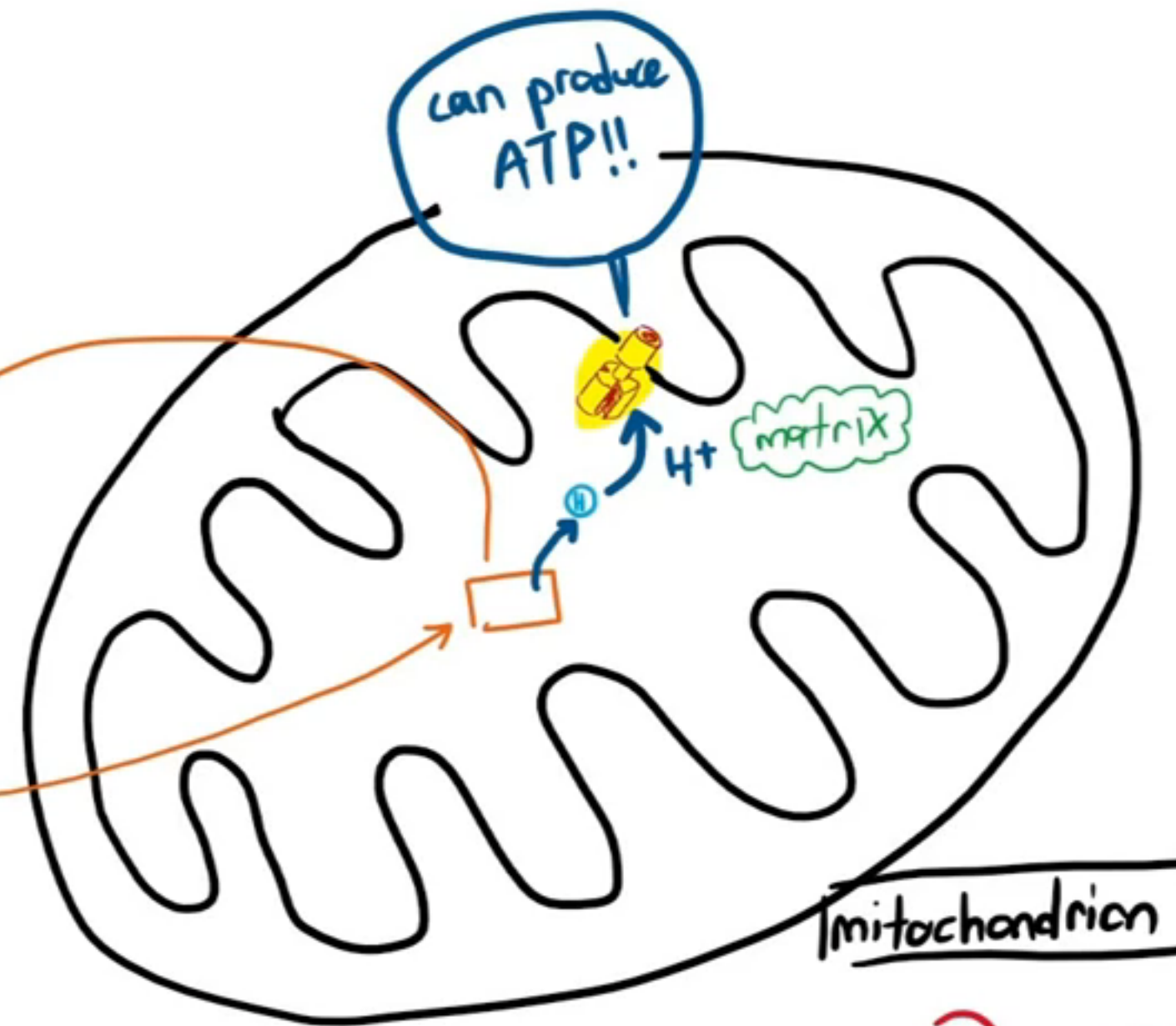
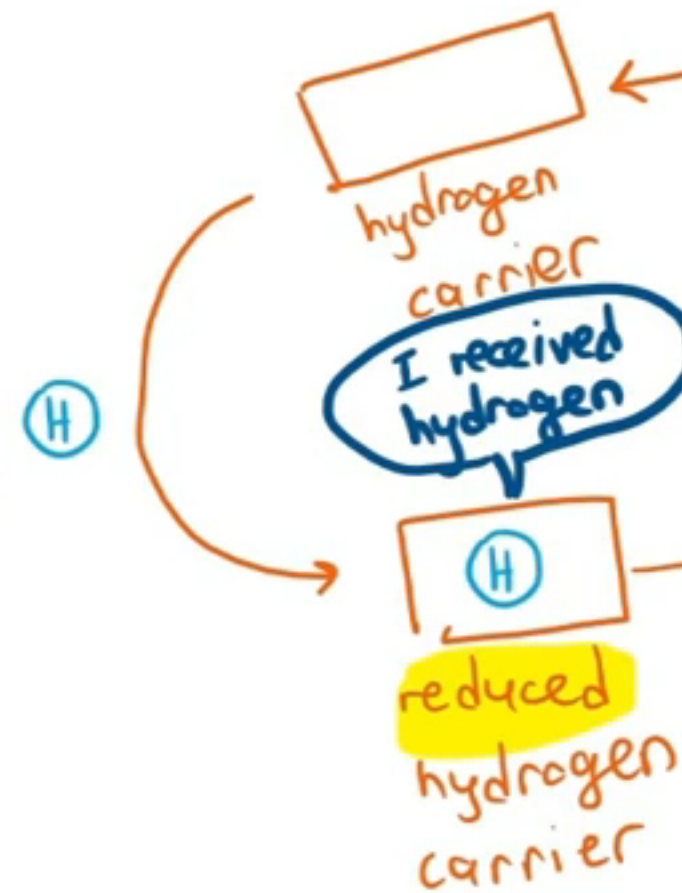
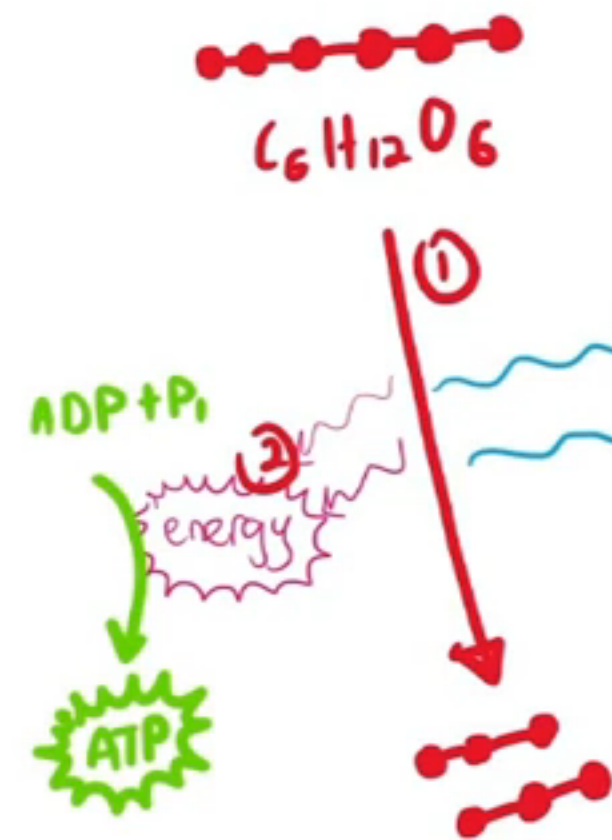


in Summary



ATP can be synthesized
in 2 ways

cytoplasm

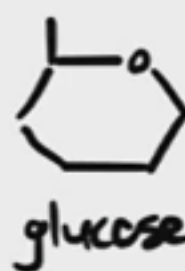


- ① Glucose is broken down | ② some energy released produced ATP by SLR. | ③ Also releases H⁺ which is transported by Hydrogen carriers towards the ATP synthase!!

Hydrogen carriers in respiration

NAD
FAD } we just represent
them like this!!

what do they do??



Broken down



releases
Hydrogen ATOMS

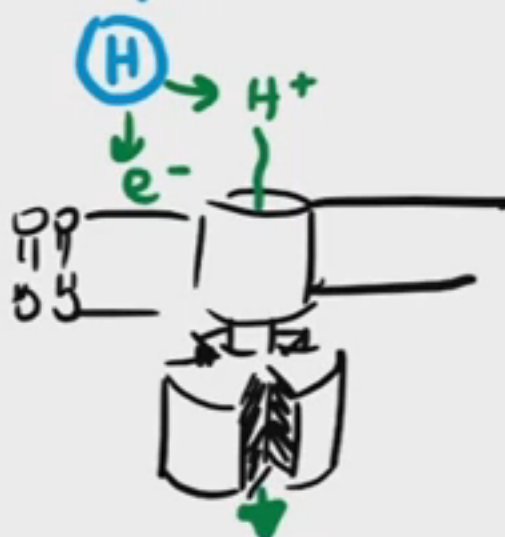
why reduced? because
it accepted H!

reduced
NAD

undergoes
oxidation

oxidized
NAD

why oxidized? because
it releases H!

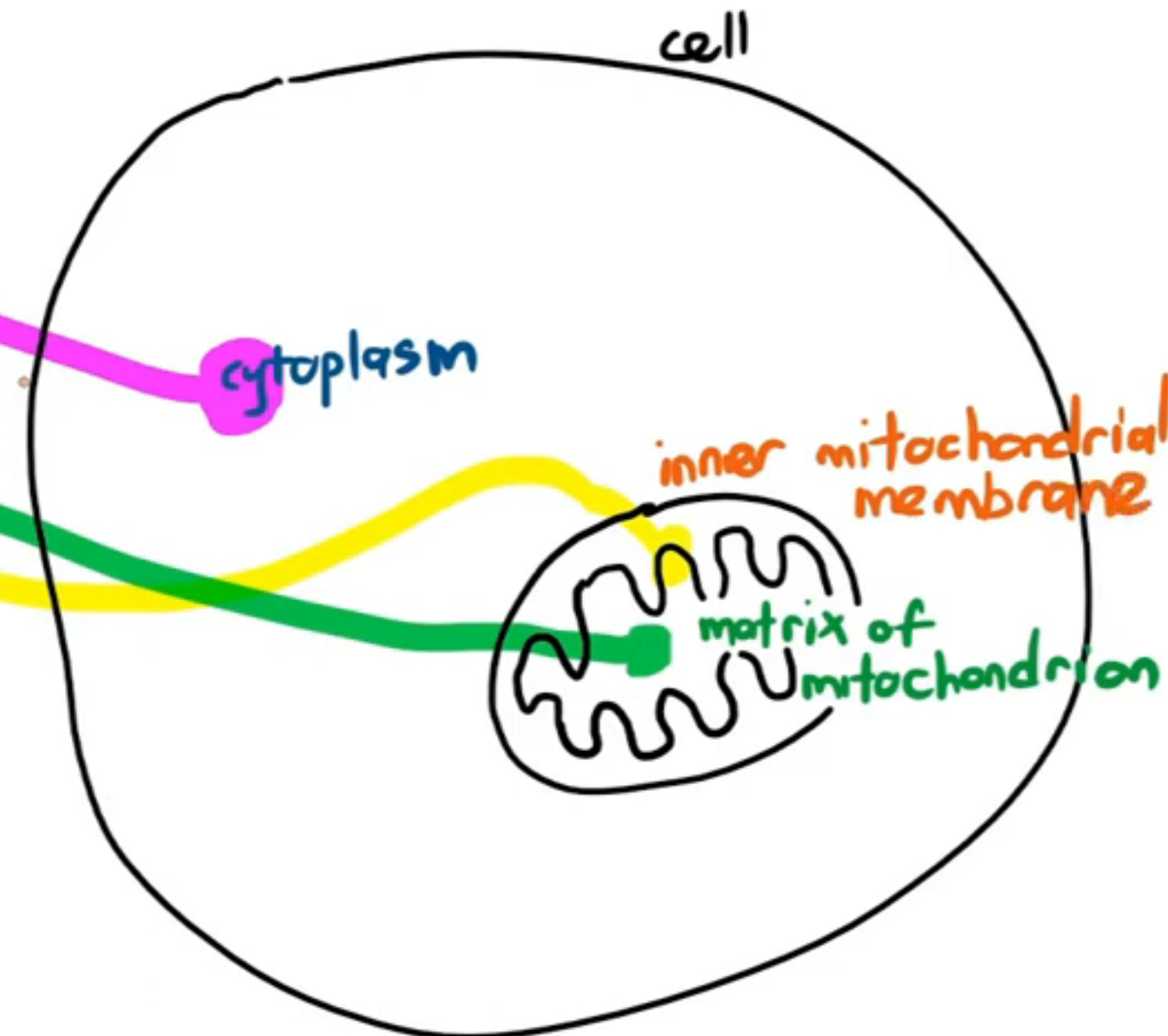


You don't have to
write oxidized NAD
in the exam.
Just 'NAD' is
sufficient!!

Aerobic respiration

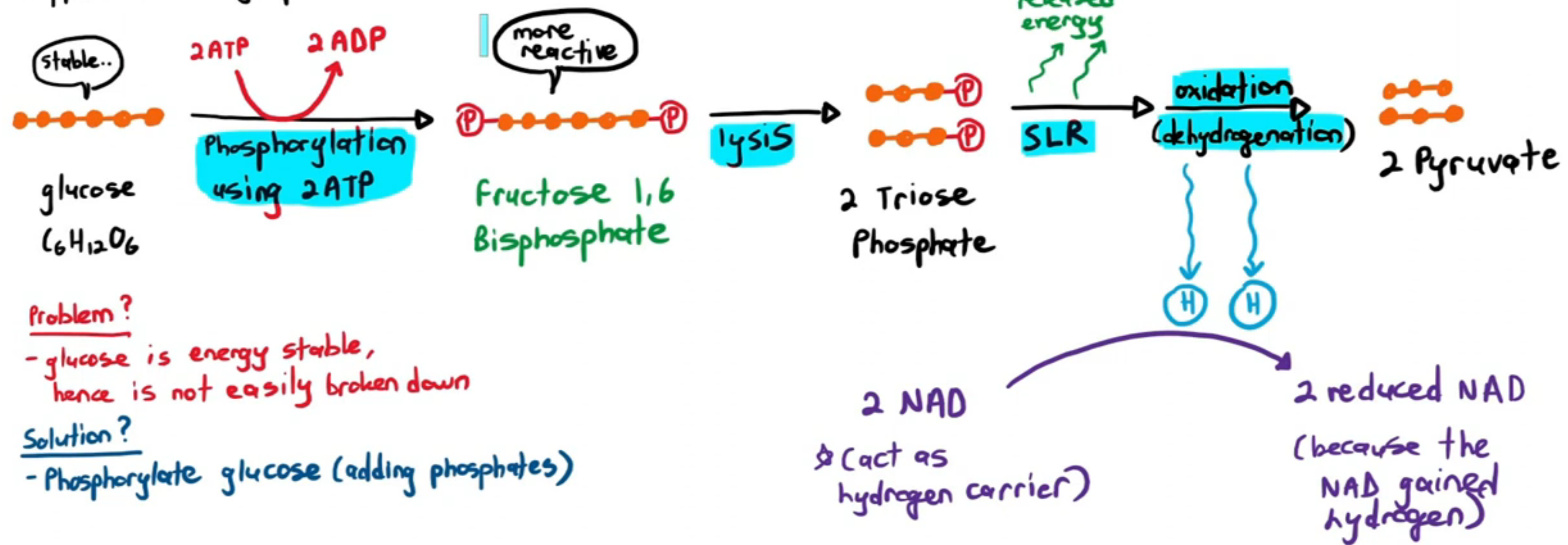
4 stages

- a) glycolysis
- b) Link reaction
- c) Krebs Cycle
- d) oxidative phosphorylation & chemiosmosis



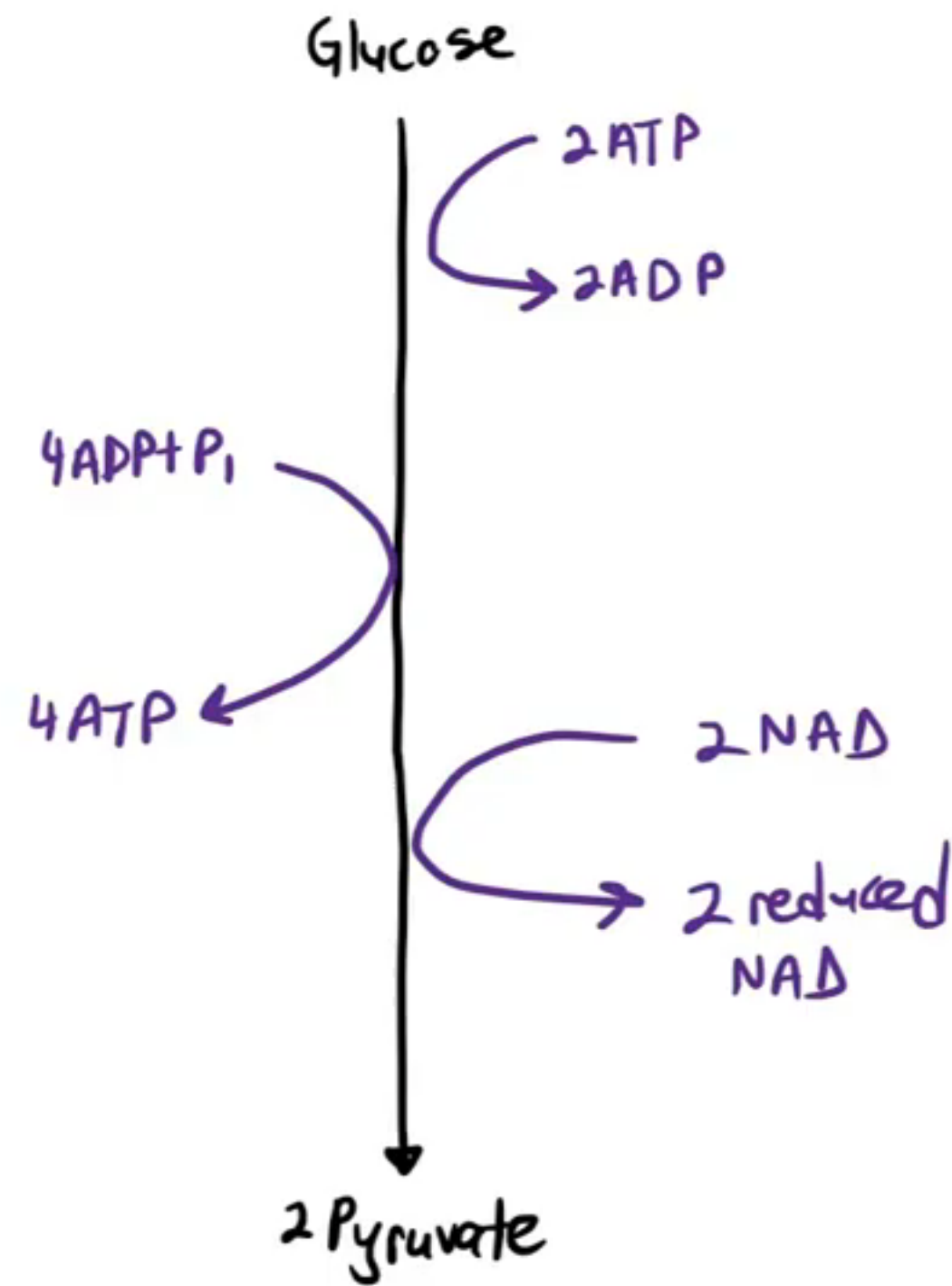
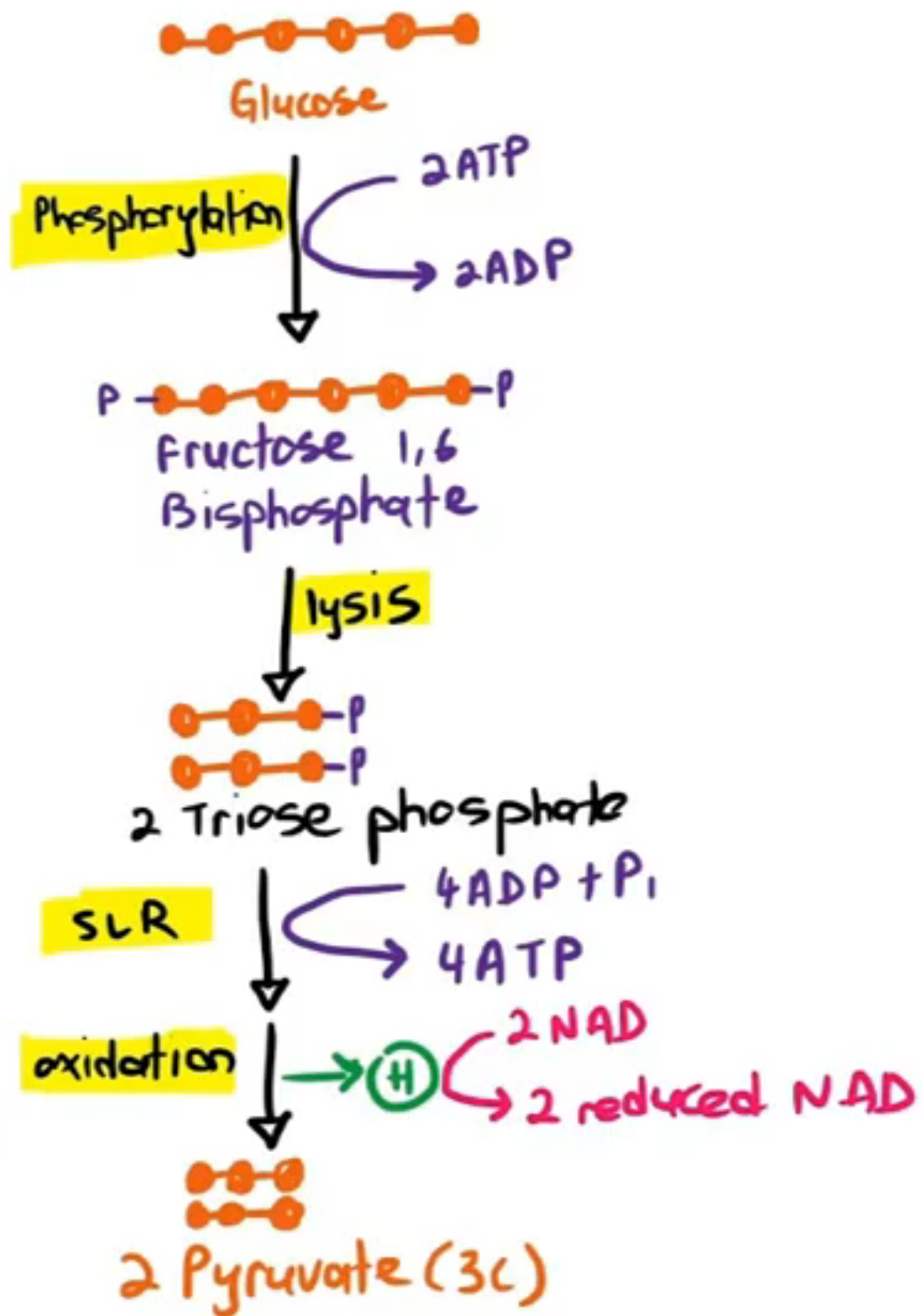
Glycolysis

- happens in the cytoplasm



Glycolysis

- happens in the cytoplasm

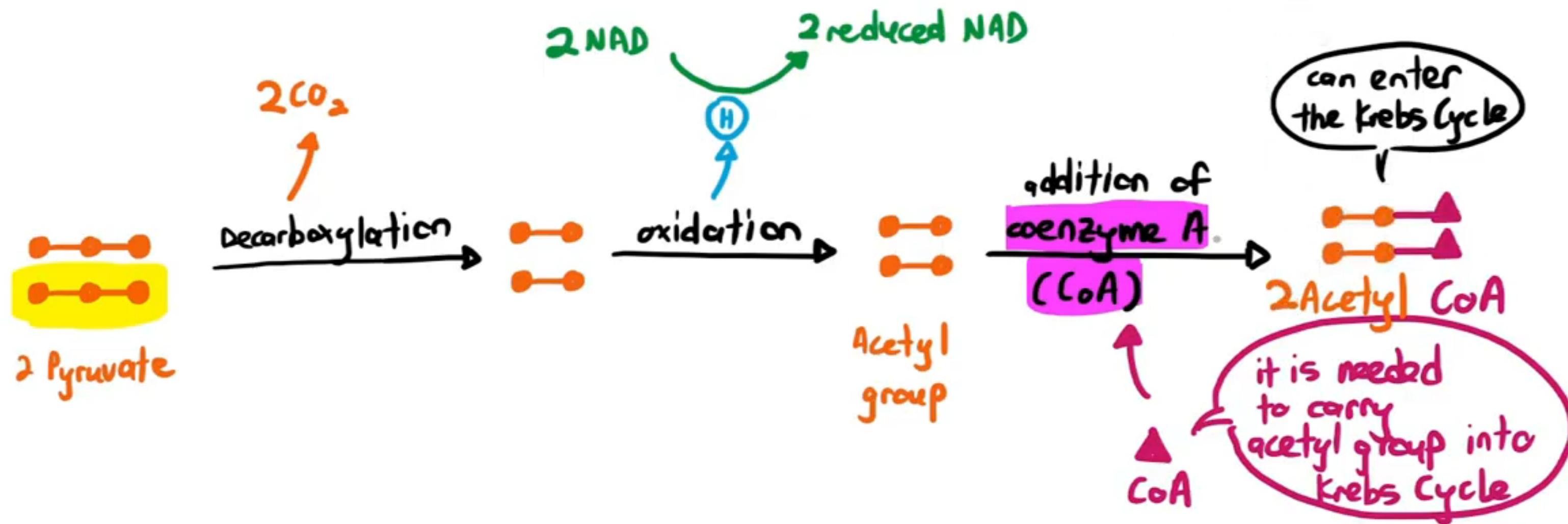


Link Reaction : in the matrix of mitochondrion

- steps:
- Decarboxylation
 - oxidation (dehydrogenation)
 - addition of **coenzyme A (CoA)**

coenzyme

- a molecule required for other enzymes to function

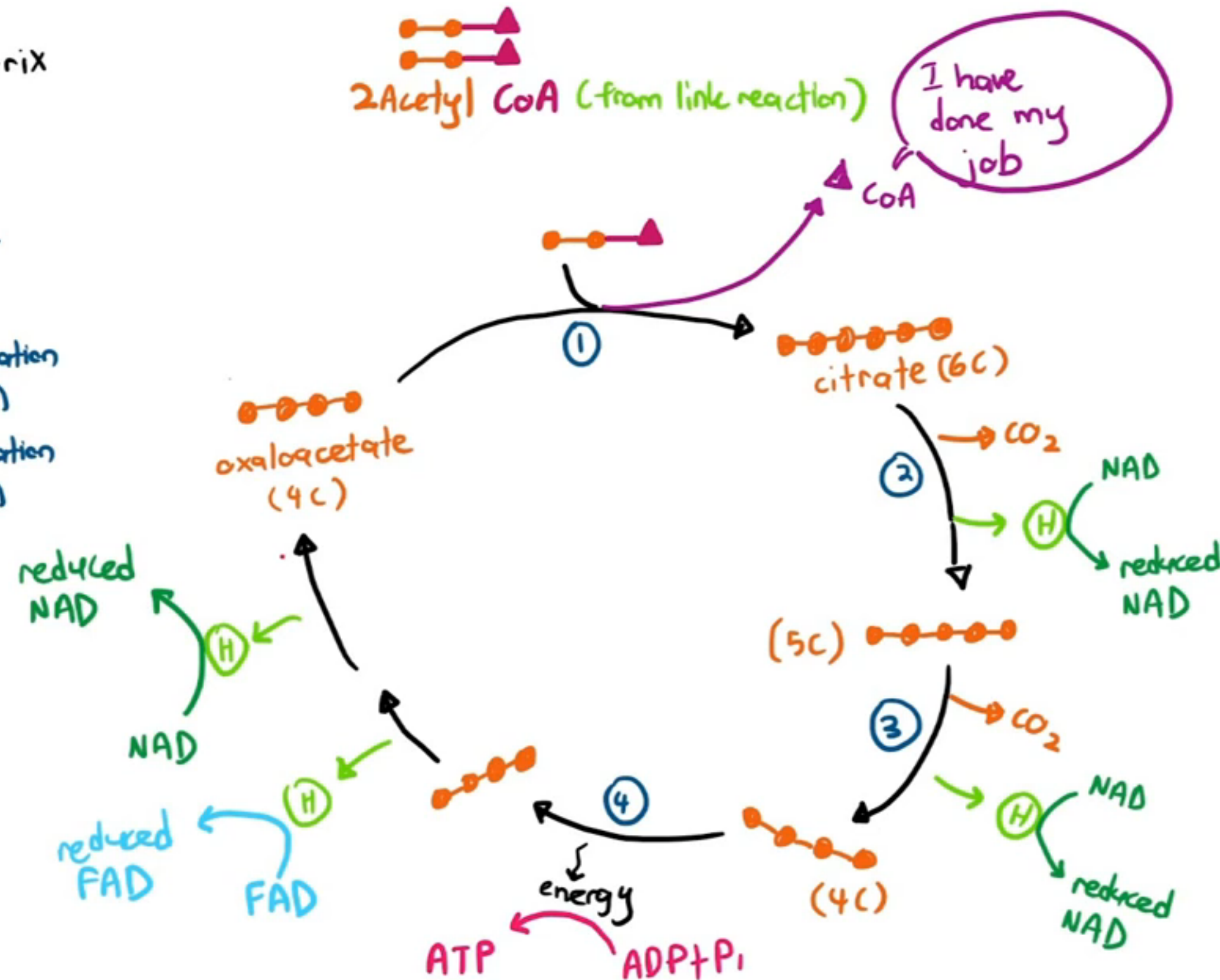


Krebs Cycle

- happens in mitochondrial matrix

STEPS

- 1 - Acetyl group + oxaloacetate (2C) (4C)
- 2 - Decarboxylation & Dehydrogenation (oxidation)
- 3 - Decarboxylation & Dehydrogenation (oxidation)
- 4 - SLR
- 5 - Dehydrogenation (oxidation)
- 6 - Dehydrogenation (oxidation)

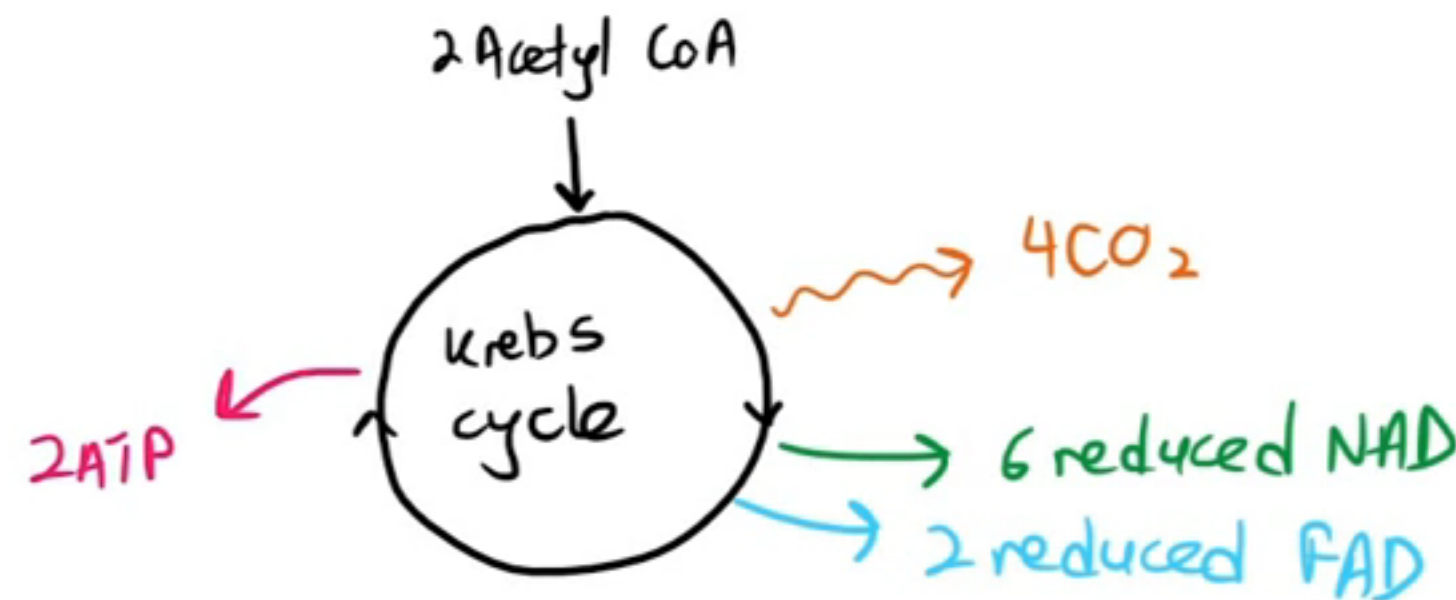
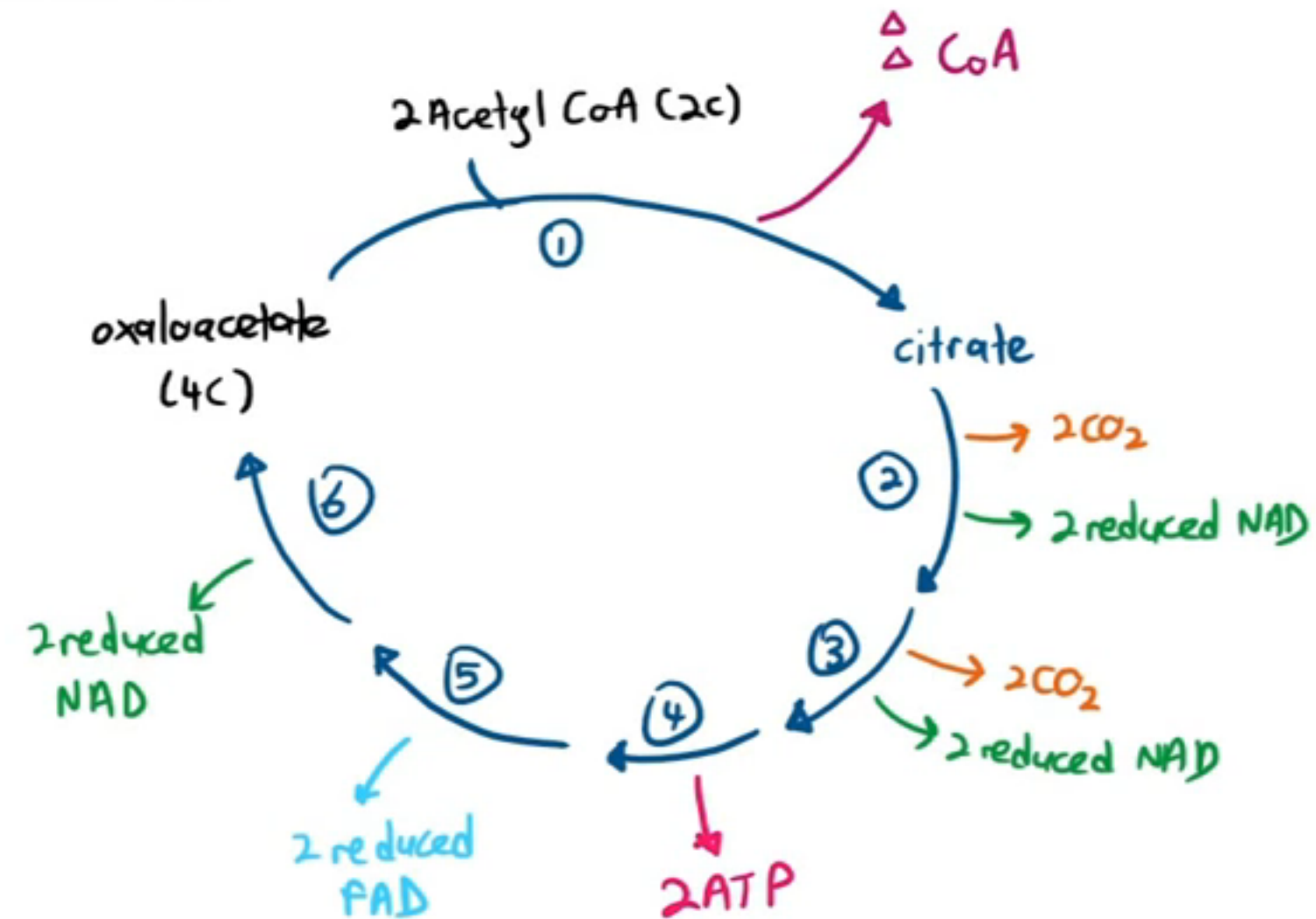


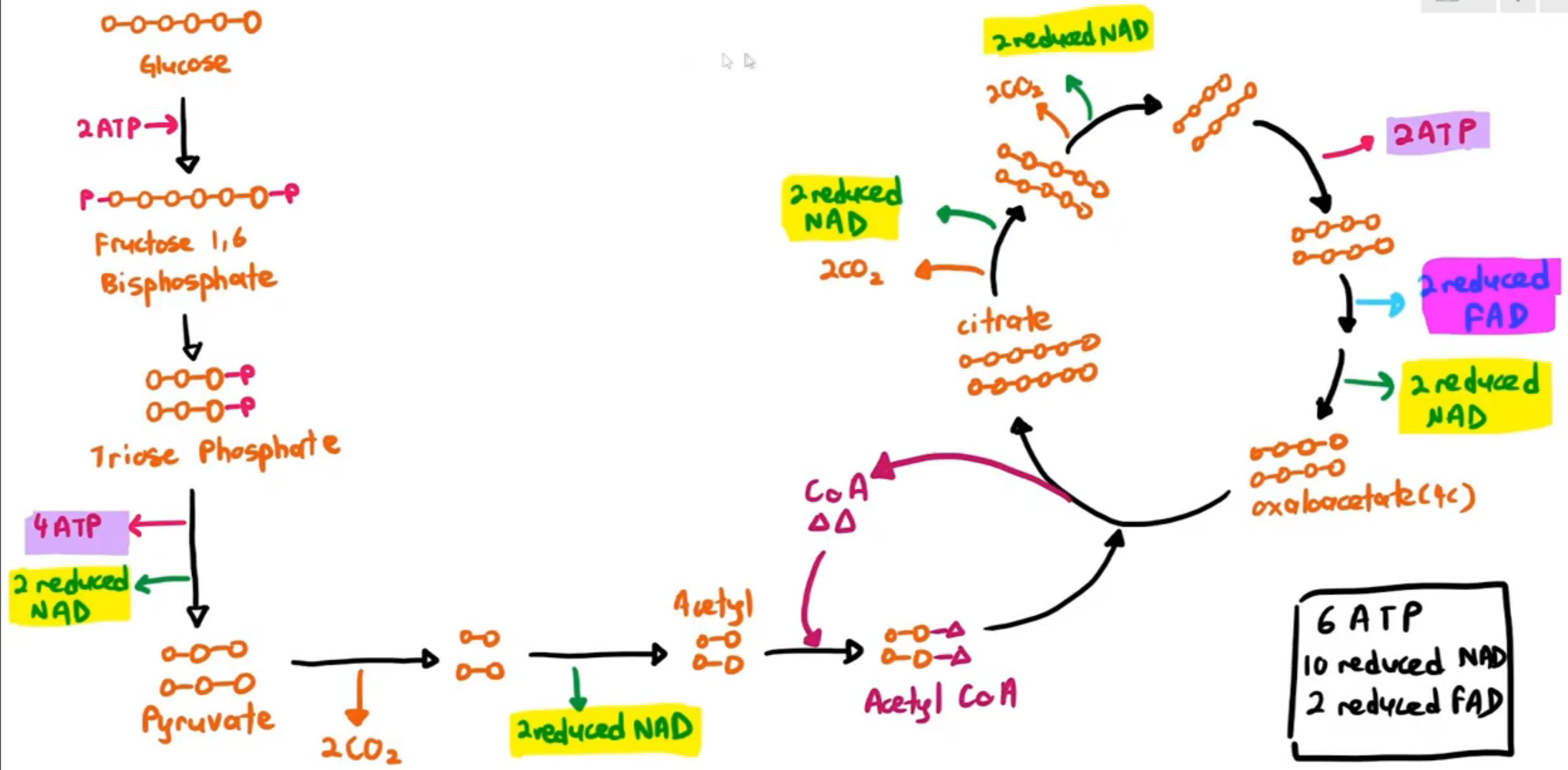
Krebs Cycle

- happens in mitochondrial matrix

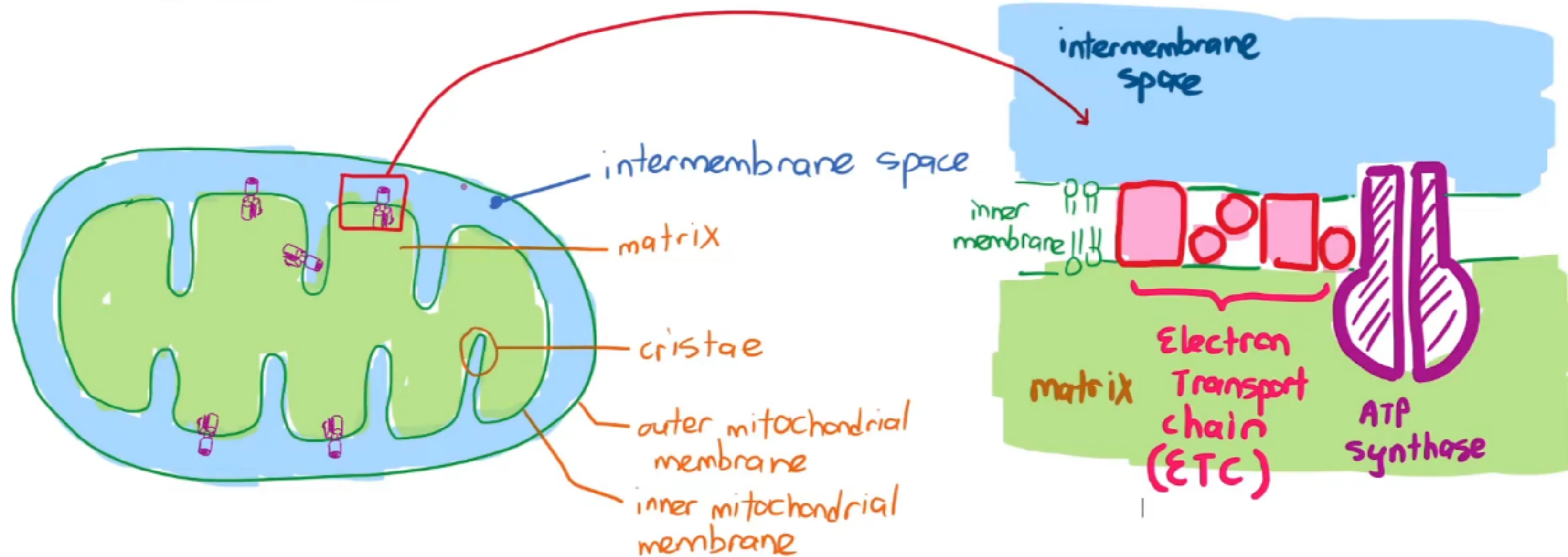
STEPS

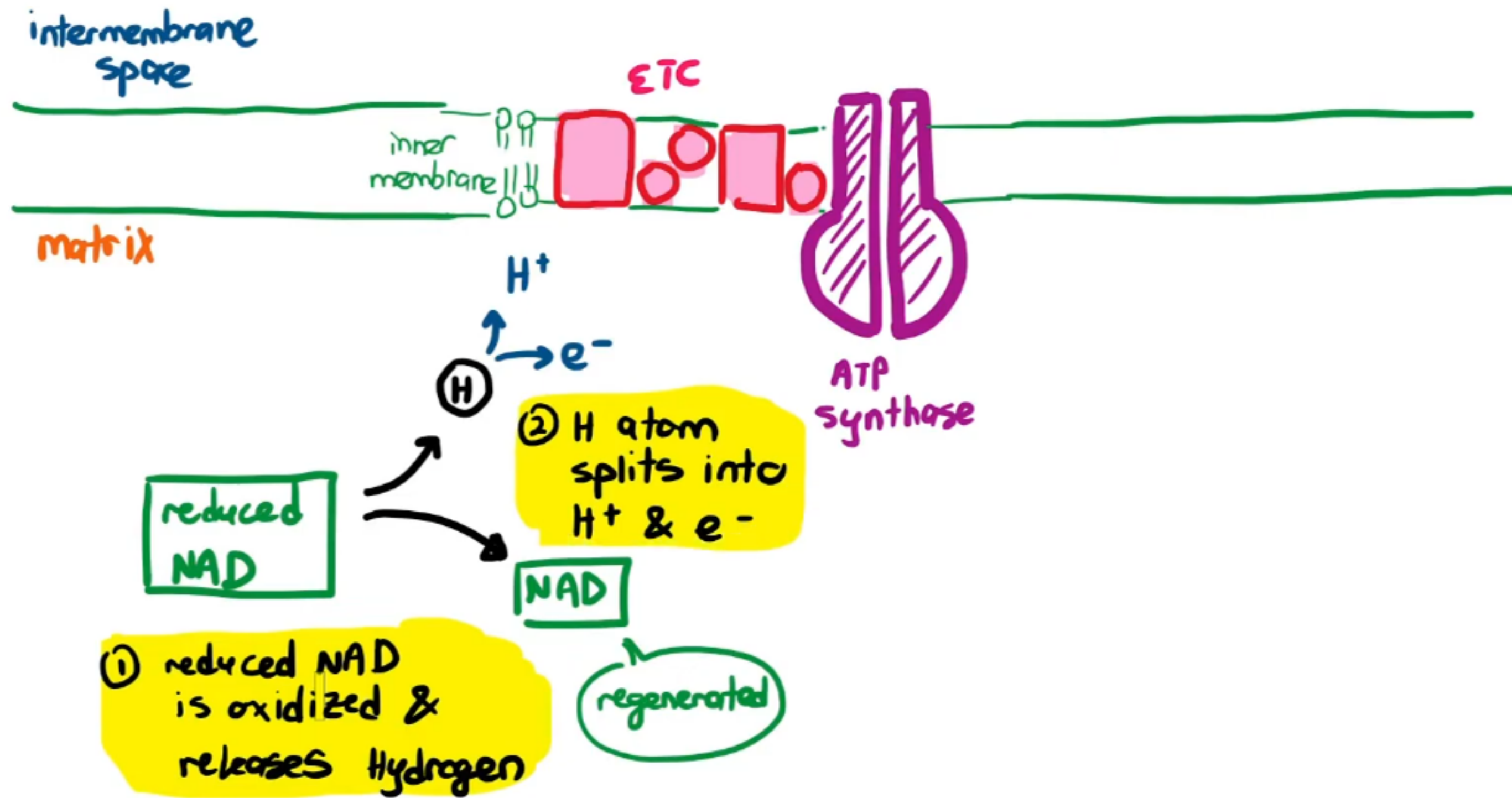
- 1 - Acetyl group + oxaloacetate (2c) (4c)
- 2 - Decarboxylation & Dehydrogenation (oxidation) → 2CO₂, 2 reduced NAD
- 3 - Decarboxylation & Dehydrogenation (oxidation) → 2CO₂, 2 reduced NAD
- 4 - SLR → 2ATP
- 5 - Dehydrogenation (oxidation) → 2 reduced FAD
- 6 - Dehydrogenation (oxidation) → 2 reduced NAD

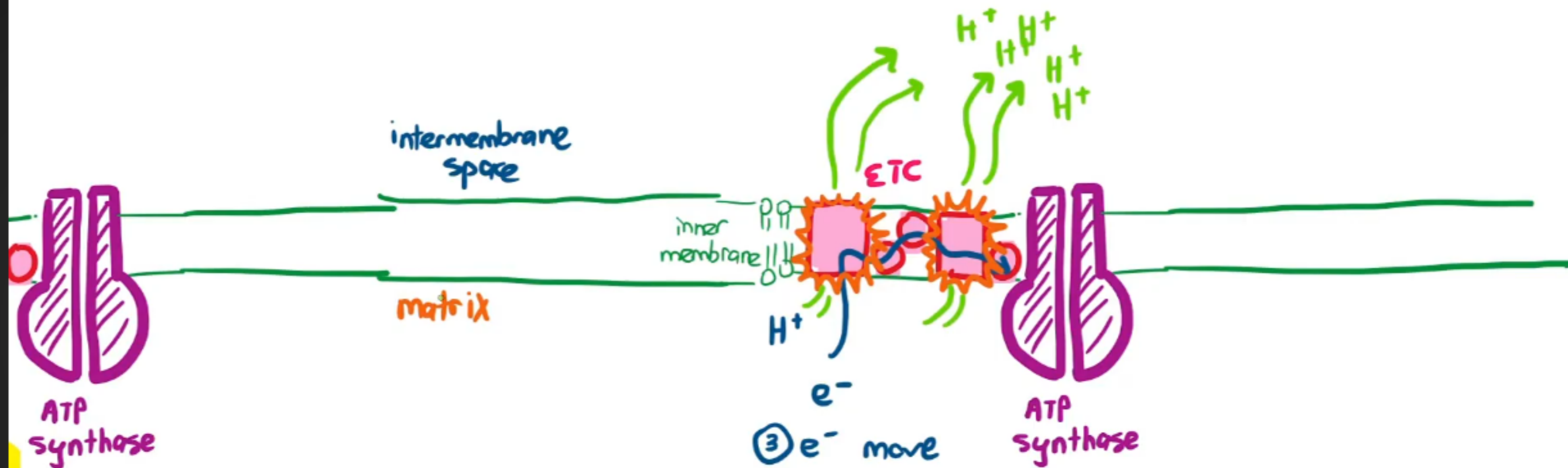




④ oxidative phosphorylation & chemiosmosis

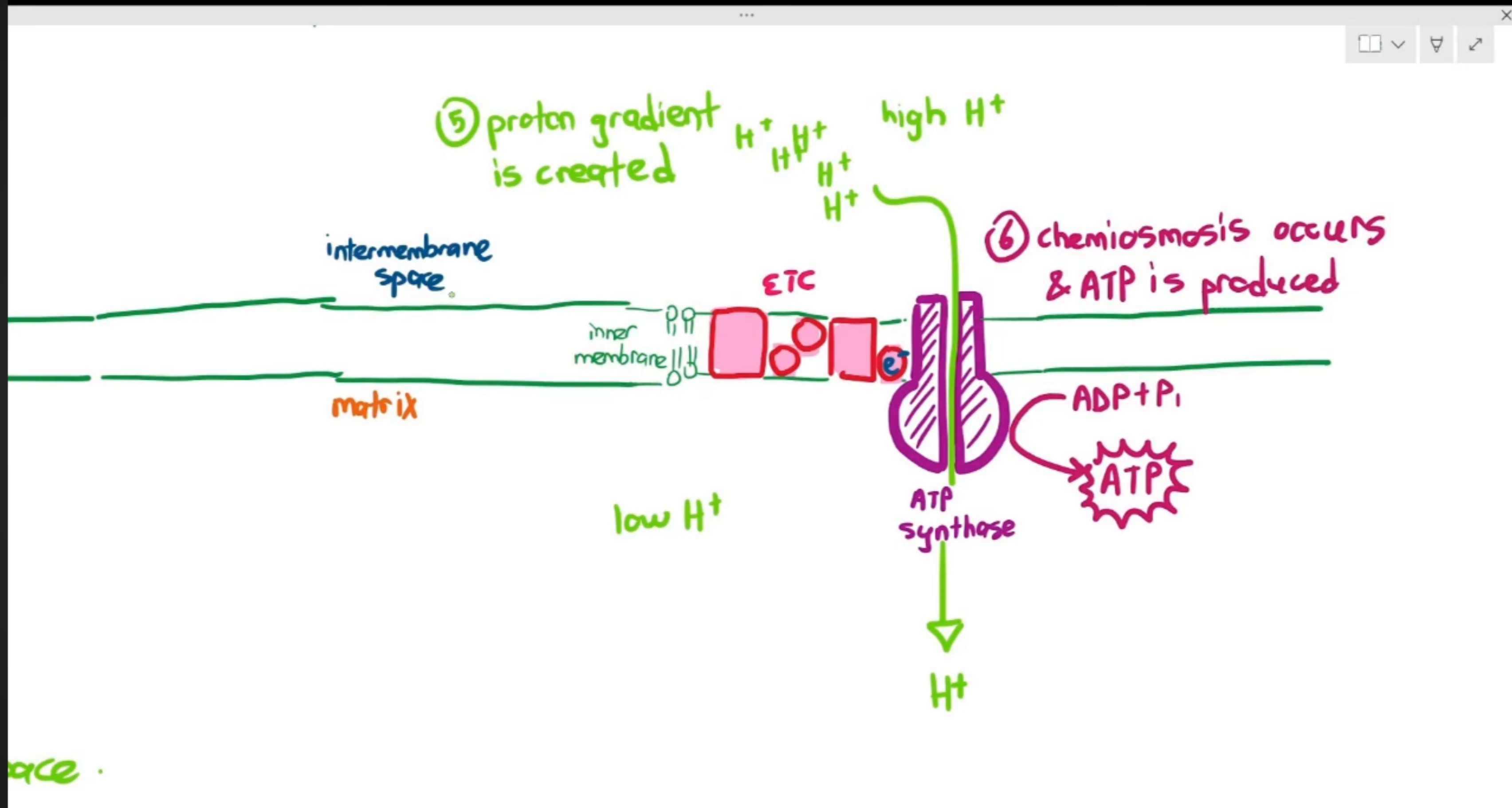






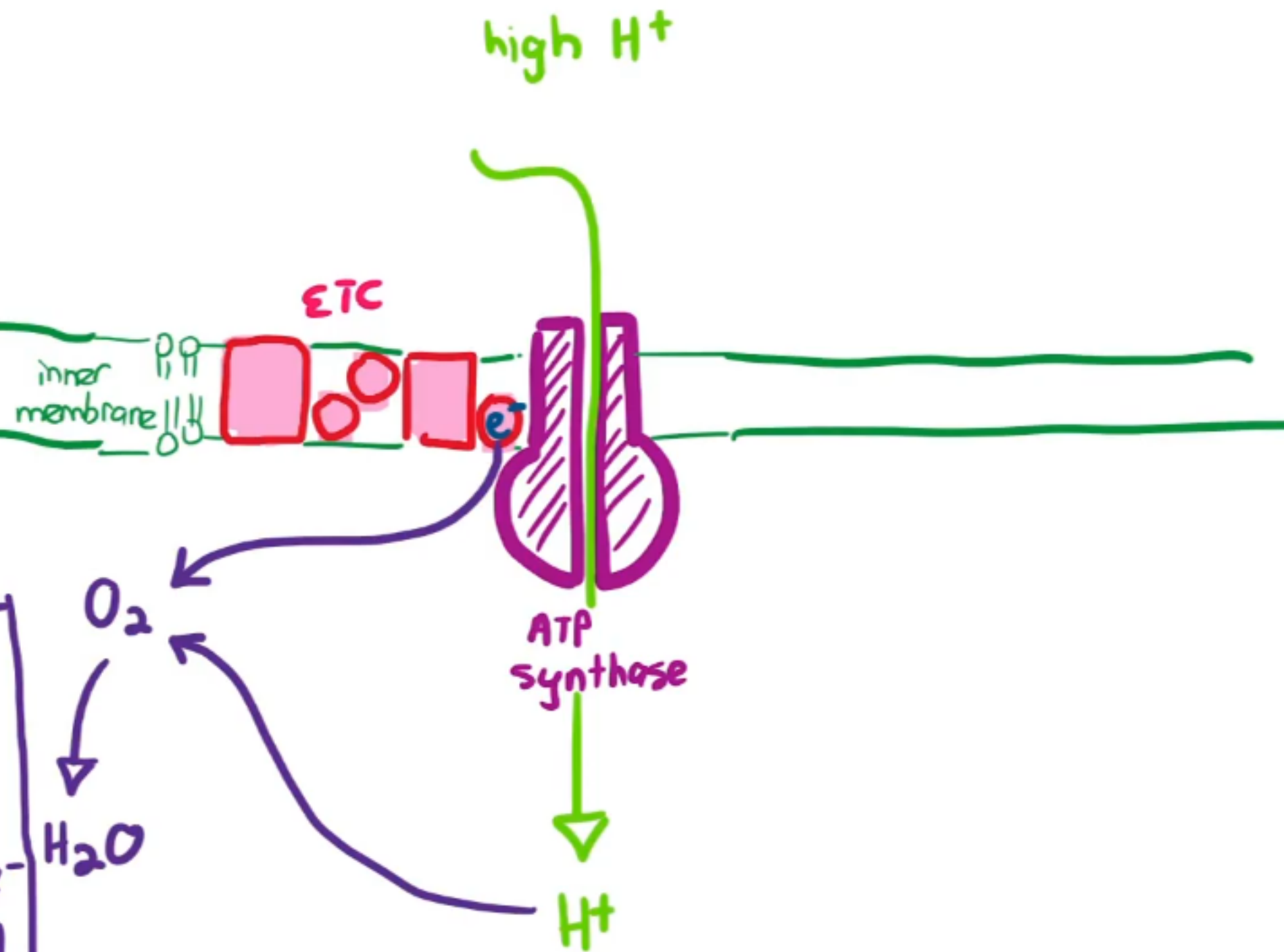
③ e^- move
along the ETC
& powers it

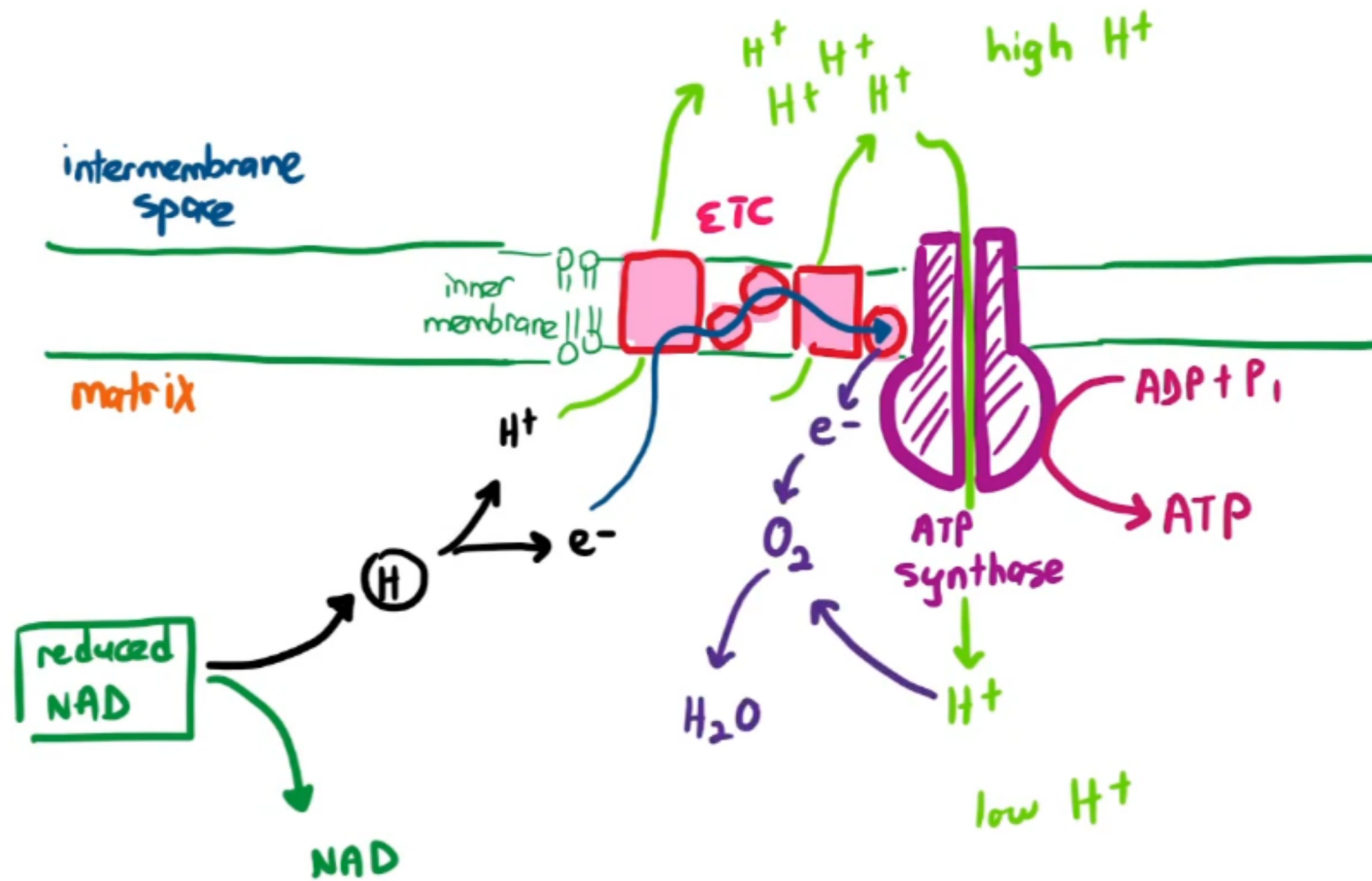
④ ETC pumps H^+
into the intermemb



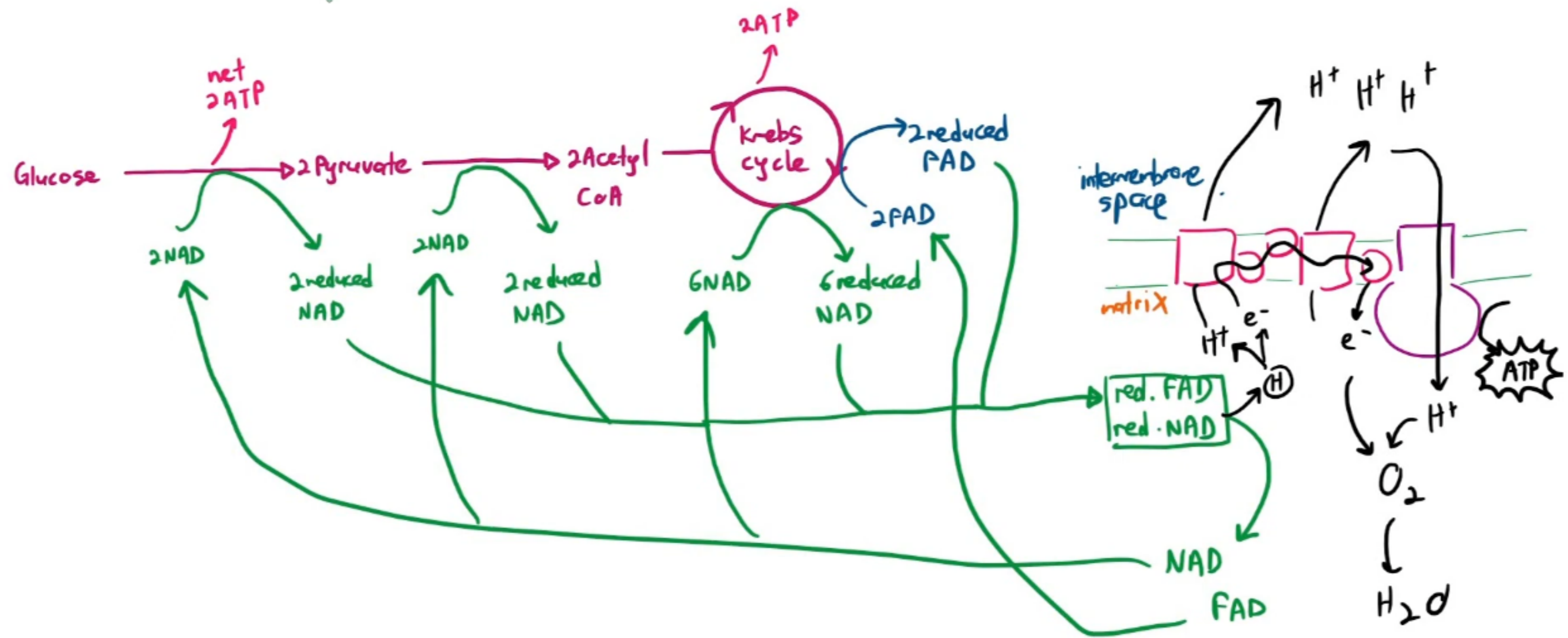
is occurs
produced

⑦ O_2 is the final electron acceptor & binds to H^+ & e^- to form $H_2O!!!$

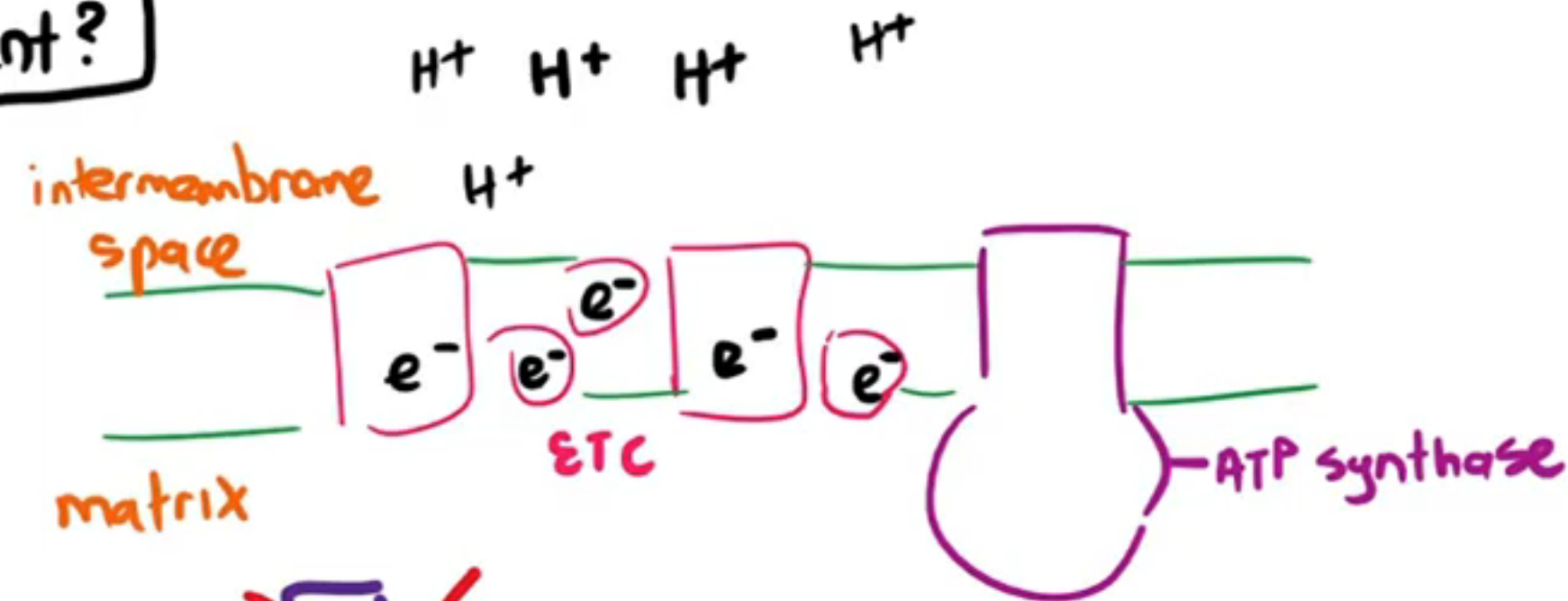




To summarize
everything in
aerobic respiration



What if O_2 was not present?

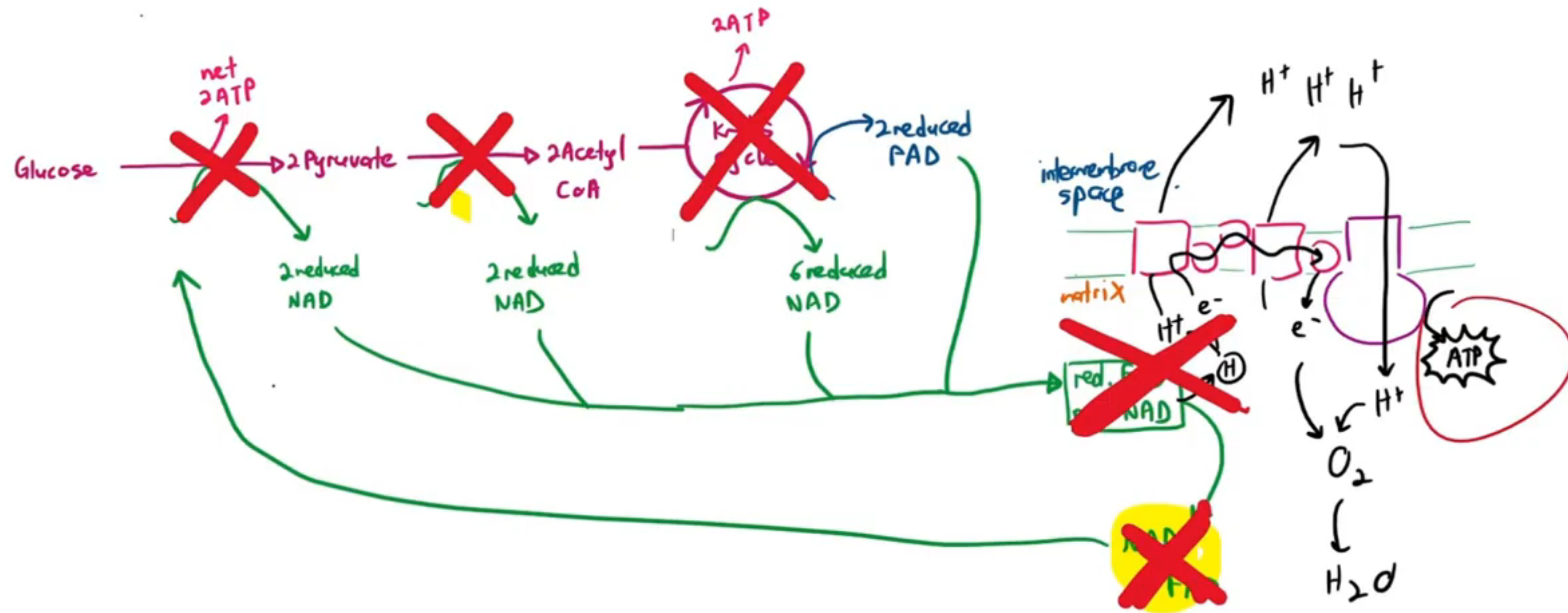


~~reduced NAD~~
① cannot be oxidized!!

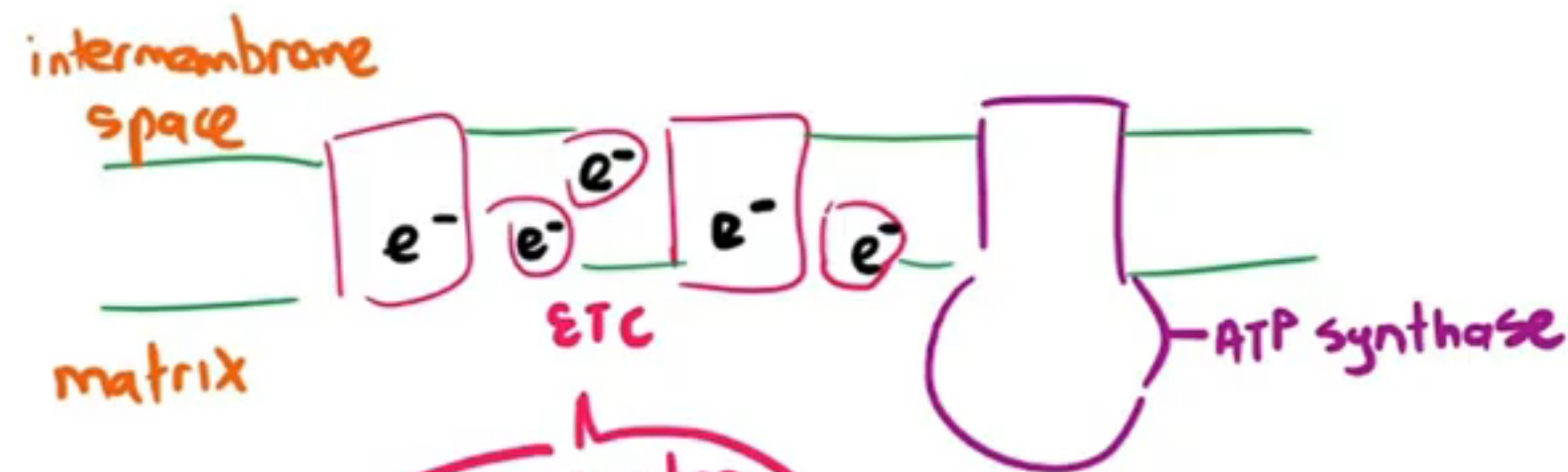
a) **NAD is not regenerated!!!**

- link reaction & Krebs cycle stops too (they require NAD & FAD to function)

everything in
aerobic respiration



What if O_2 was not present?



no electron flow!!

b) Electron flow in ETC stops

- no proton gradient established

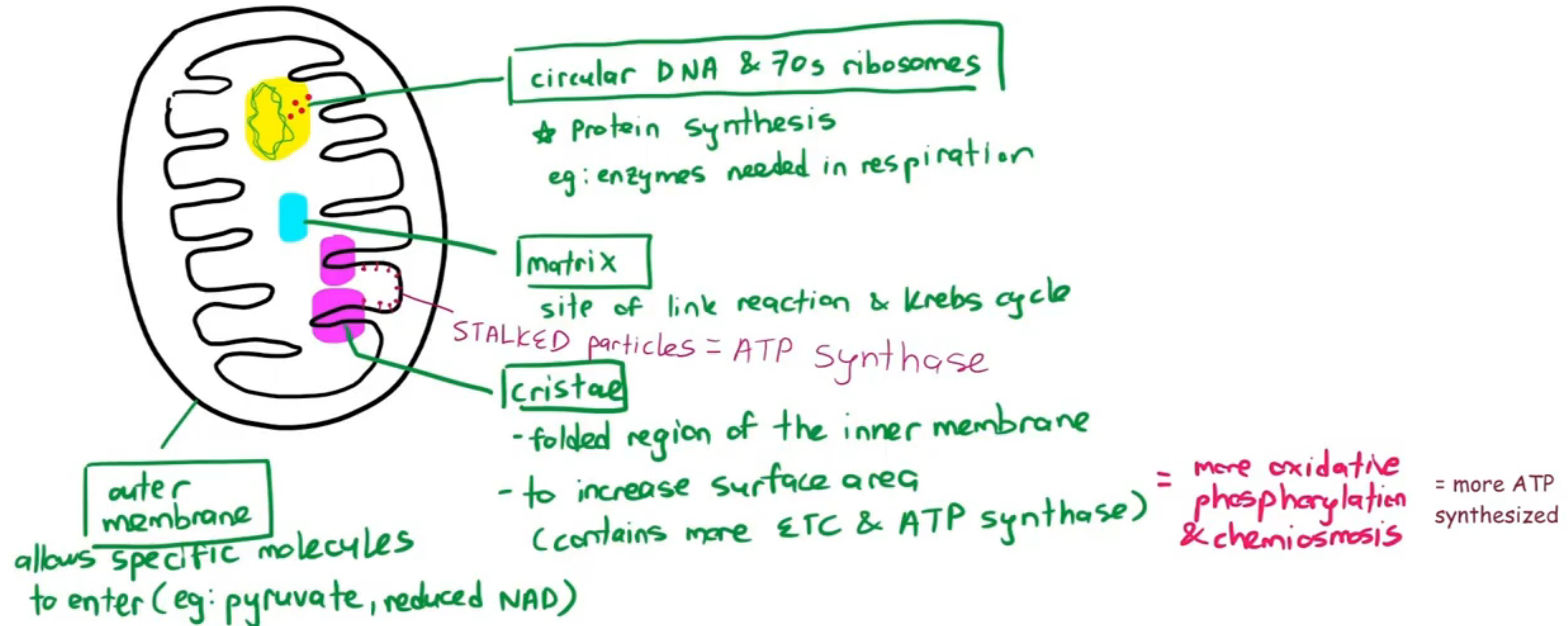
no chemiosmosis, therefore no ATP synthesis

a) NAD is not regenerated!!!

- link reaction & Krebs cycle stops too (they require NAD & FAD to function)



mitochondrion Structure & function



Anaerobic respiration

- respiration in the absence of O_2

10-level revision

* happens in cytoplasm

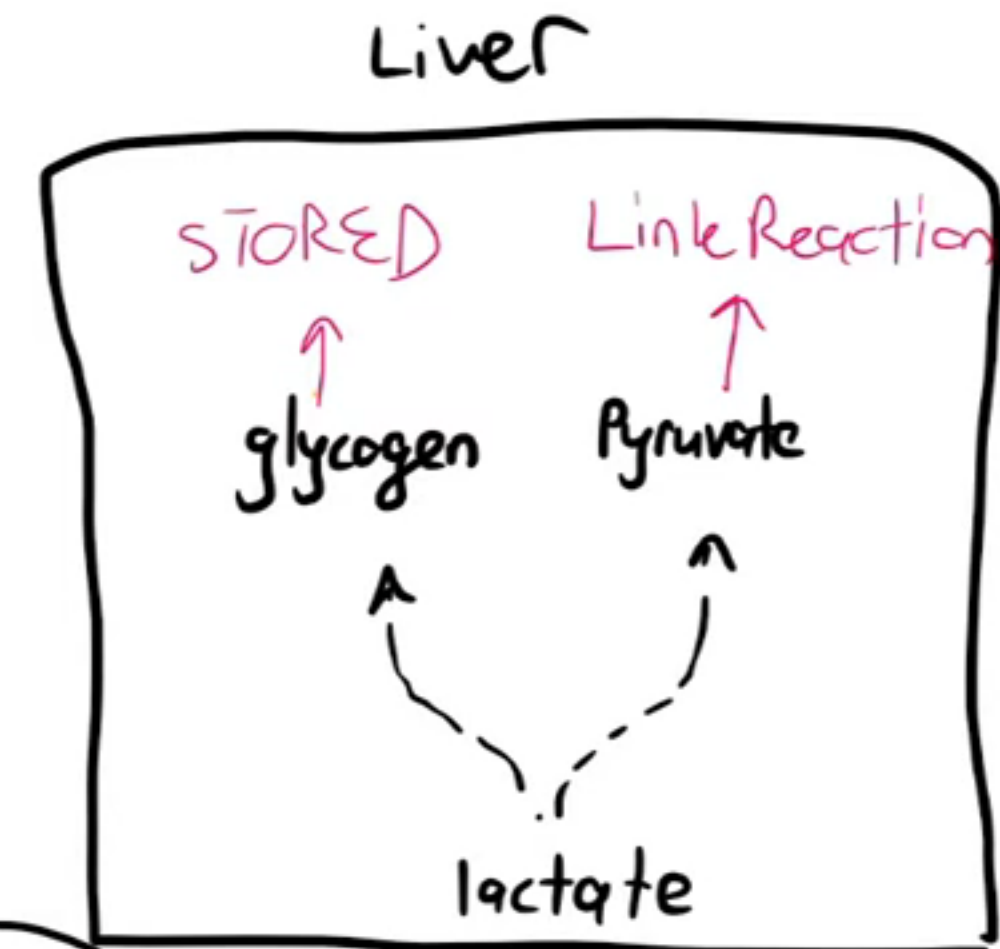
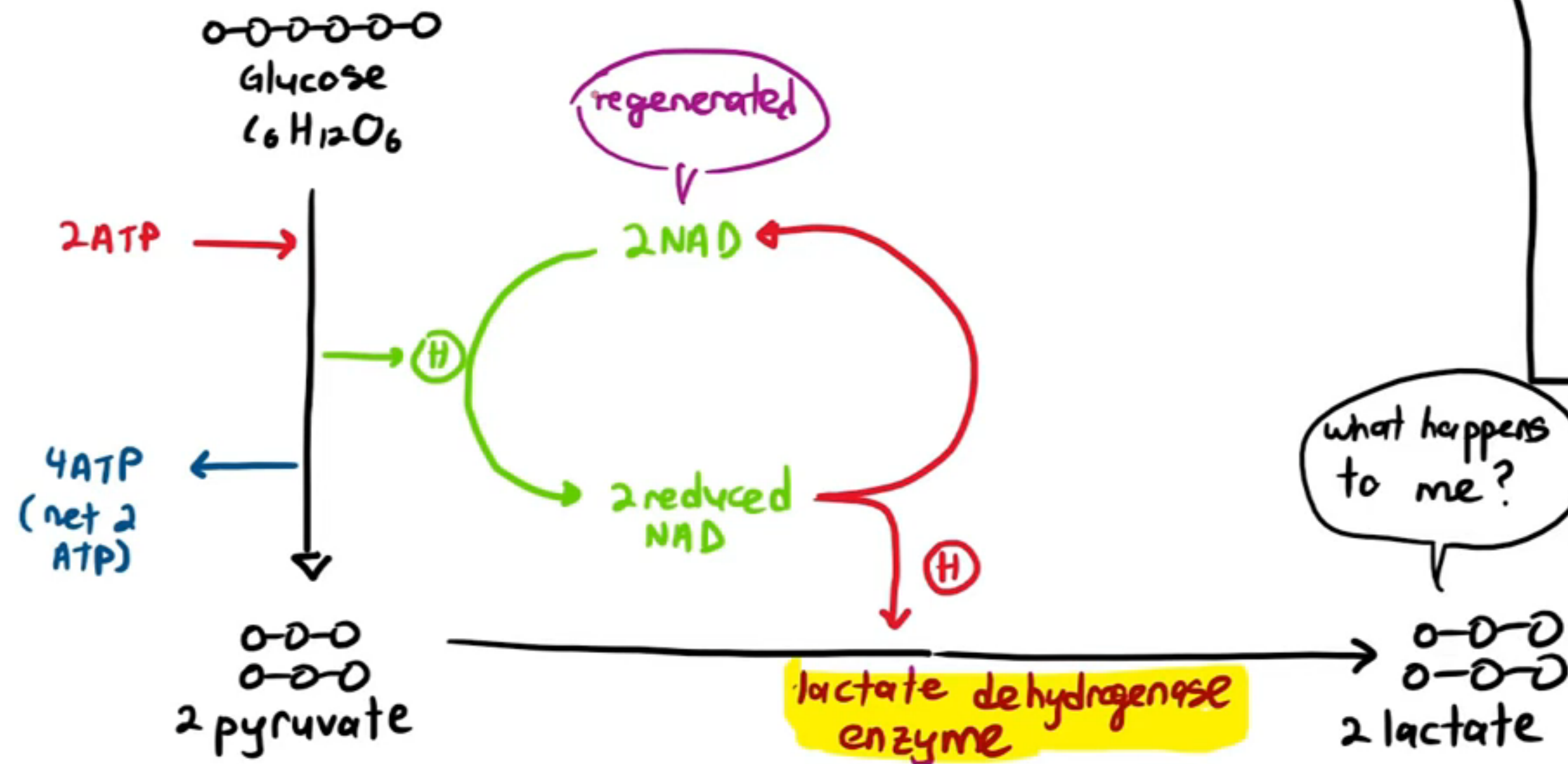
* in animals: $\text{Glucose} \longrightarrow 2 \text{lactic acid} + \text{ATP} \dots$

in plants or yeast: $\text{Glucose} \longrightarrow 2 \text{CO}_2 + 2 \text{C}_2\text{H}_5\text{OH} + \text{ATP}$
carbon dioxide ethanol

Happens when they don't have enough oxygen.

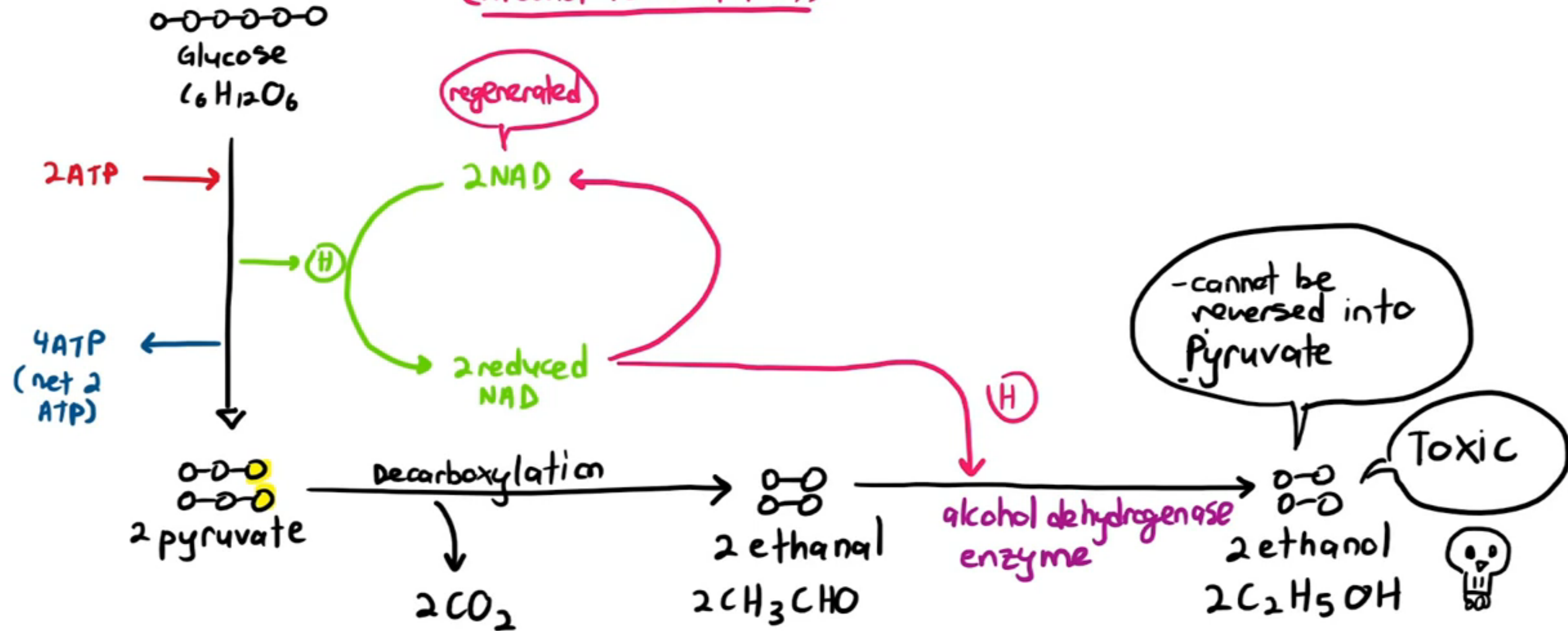
Anaerobic respiration in animals

(Lactate Fermentation)



Anaerobic respiration in plants or yeast

(Alcohol fermentation)



Anaerobic respiration

Animals

Plants

- happens in cytoplasm
- involves glycolysis

end product

Lactate

CO₂ & ethanol

enzyme

Lactate
dehydrogenase

Alcohol
dehydrogenase

Decarboxylation

X

✓

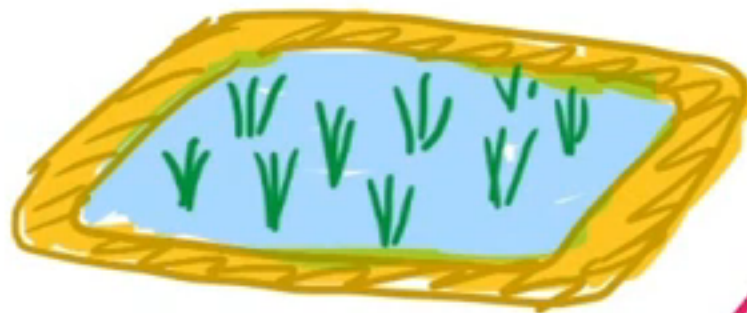
can pyruvate
be regenerated

✓

X

Rice plants

Adaptation of rice plants



Problem?

① roots cannot easily get O_2

② Ethanol is toxic to the plants

①

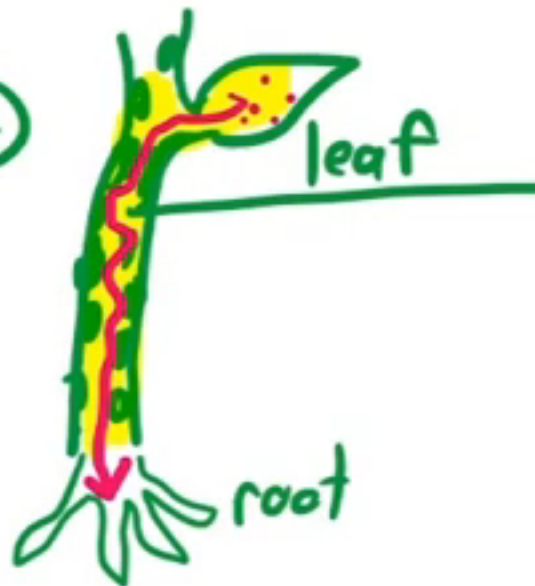


- long stems ensure leaves grow above H_2O

so?? The leaves can easily get O_2



②



stem contains loosely packed tissues (aerenchyma)

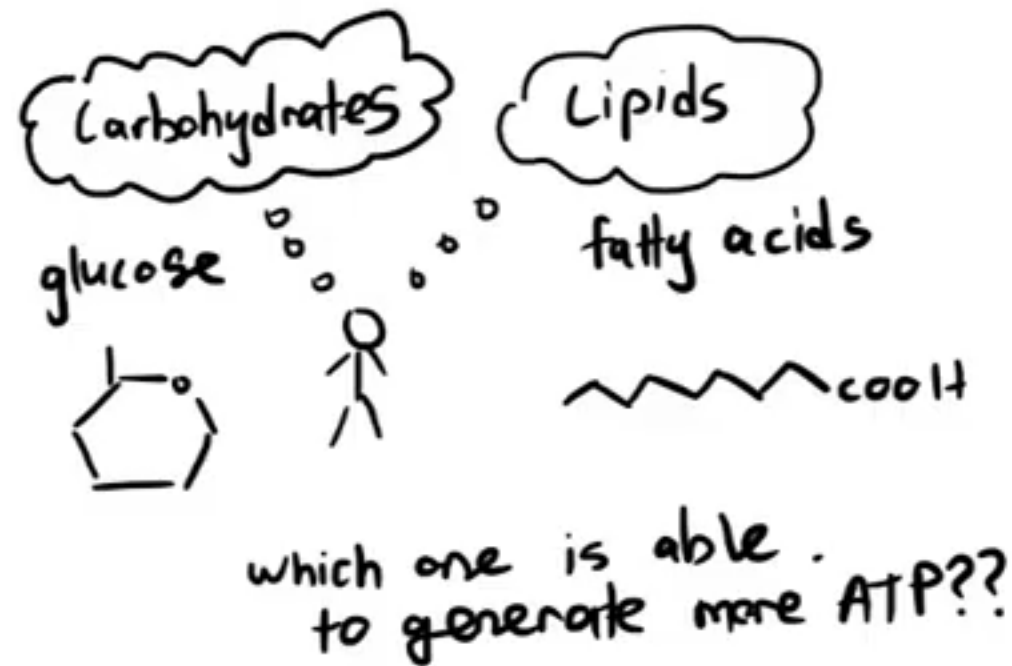
- O_2 can easily diffuse to the roots

③ Rice plants are more tolerant to ethanol

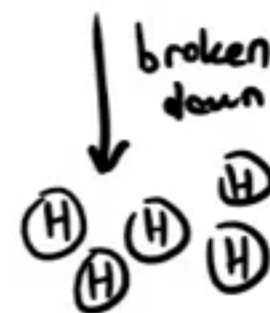
④ Alcohol dehydrogenase in rice plants can break down ethanol

Respiratory Substrate

-organic molecules that
can be broken down
to generate ATP



glucose
 $C_6H_{12}O_6$
(less C-H
bonds)



less reduced
NAD & reduced
FAD

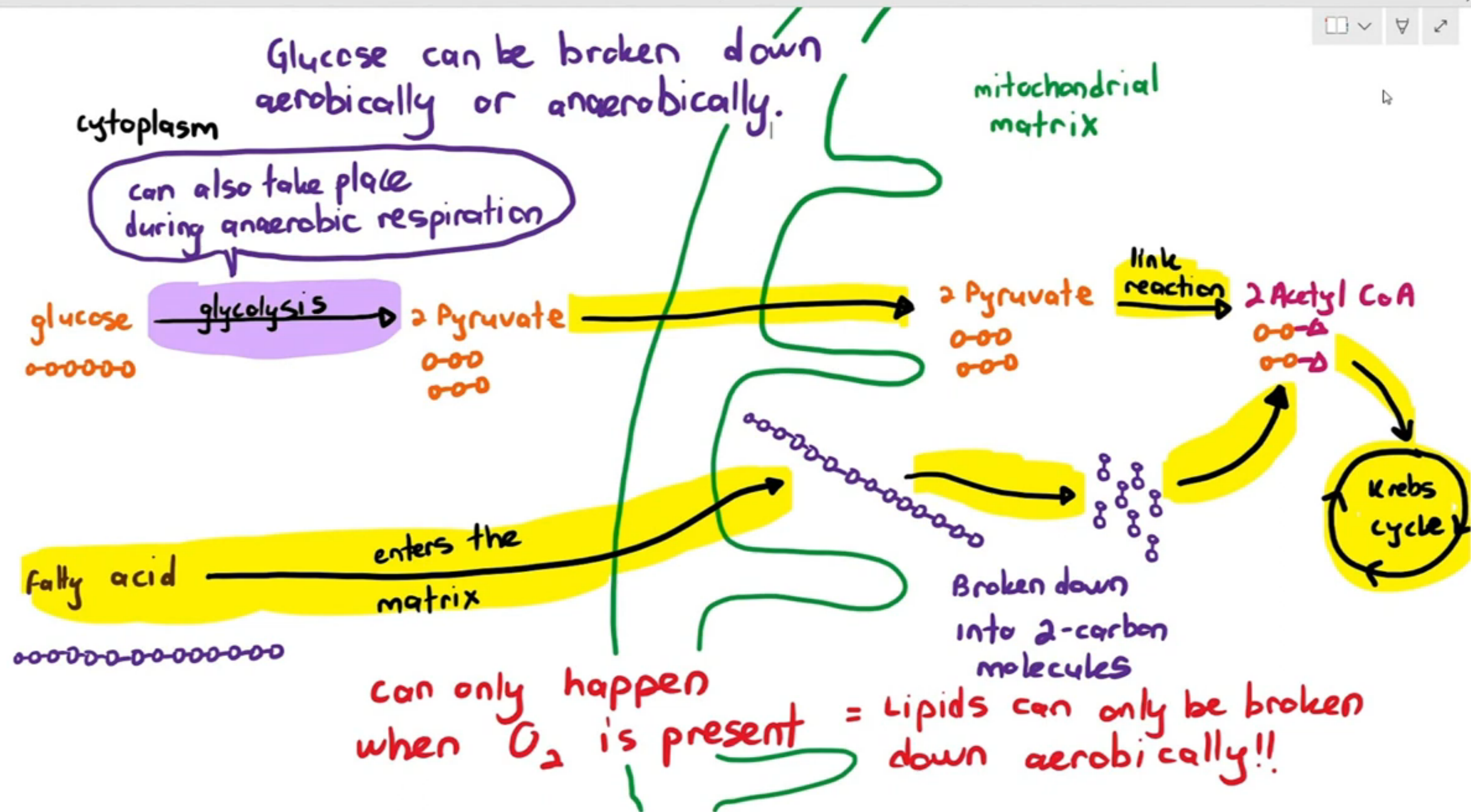
lower rate of
oxidative phosphorylation
↓
less ATP

fatty acid
 $C_{18}H_{34}O_2$
(more C-H
bonds)



more reduced
NAD & reduced
FAD

higher rate of
oxidative phosphorylation
↓
more ATP



Respiratory Quotient (RQ)

Definitions $\left\{ \begin{array}{l} \text{mole of CO}_2 \text{ produced} \div \text{mole of O}_2 \text{ used up} \\ \text{in a period of time during respiration} \end{array} \right.$

$\left\{ \begin{array}{l} \text{volume of CO}_2 \text{ produced} \div \text{volume of O}_2 \text{ used up} \\ \text{in a period of time during respiration} \end{array} \right.$

eg: Aerobic respiration
of glucose



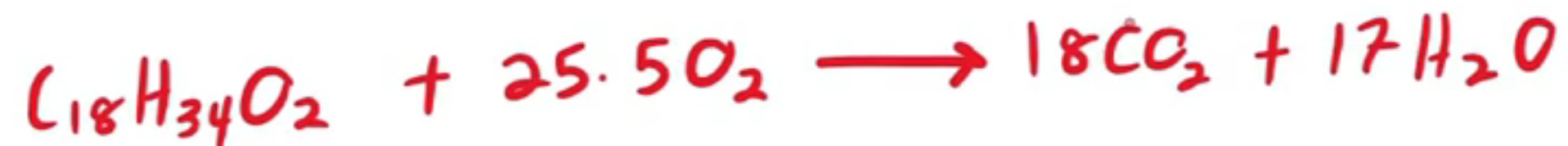
$$\begin{array}{l} \text{RQ} \\ \text{of} \\ \text{glucose} \end{array} = \frac{6}{6} = 1.0$$

Respiratory Quotient (RQ)

Definitions $\left\{ \begin{array}{l} \text{mole of CO}_2 \text{ produced} \div \text{mole of O}_2 \text{ used up} \\ \text{in a period of time during respiration} \end{array} \right.$

$\left\{ \begin{array}{l} \text{volume of CO}_2 \text{ produced} \div \text{volume of O}_2 \text{ used up} \\ \text{in a period of time during respiration} \end{array} \right.$

Aerobic respiration
of fatty acid



$$\begin{aligned} \text{RQ of fatty acid} &= \frac{18}{25.5} \\ &= 0.7 \end{aligned}$$

Respiratory Quotient (RQ)

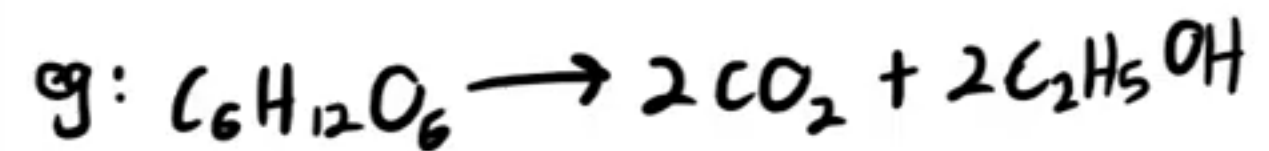
Definitions — mole of CO_2 produced $\div$ mole of O_2 used up
in a period of time during respiration

— volume of CO_2 produced $\div$ volume of O_2 used up
in a period of time during respiration

Respiratory Substrates	RQ
Carbohydrates	1.0
Proteins	0.9
Lipids	0.7

} needs to
be memorized

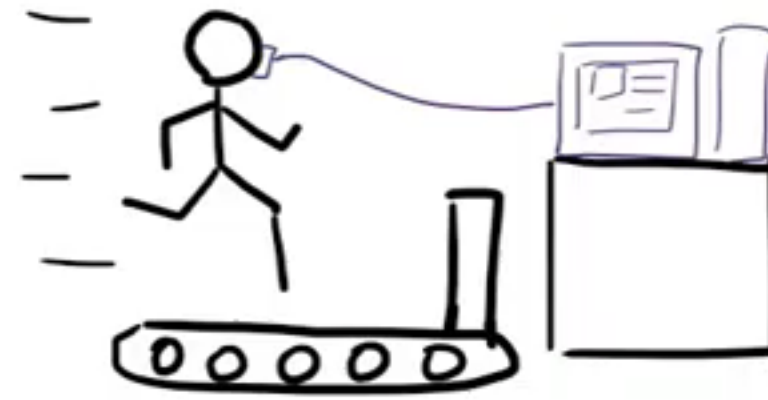
Can we calculate RQ for
anaerobic respiration?



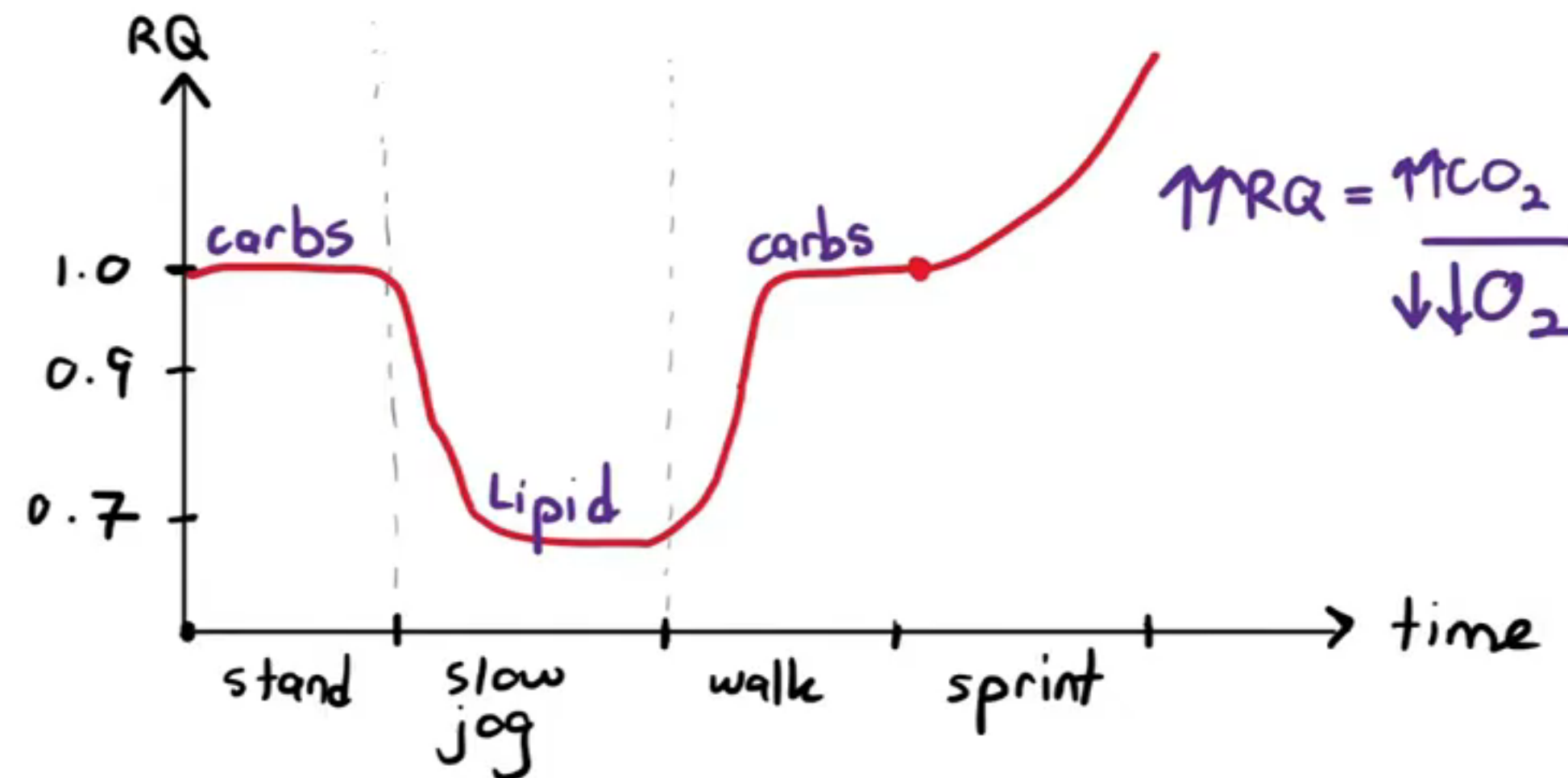
$$\text{RQ} = \frac{2 \text{ moles of } \text{CO}_2}{0 \text{ moles of oxygen}} = \text{impossible!!!}$$

Respiratory Substrates	RQ
Carbohydrates	1.0
Proteins	0.9
Lipids	0.7

Situation

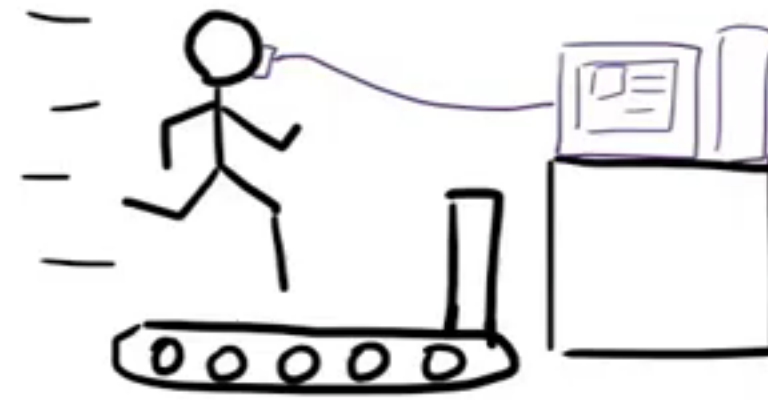


- calculates the volume of CO_2 produces & volume of O_2 used up
- calculate RQ value!!

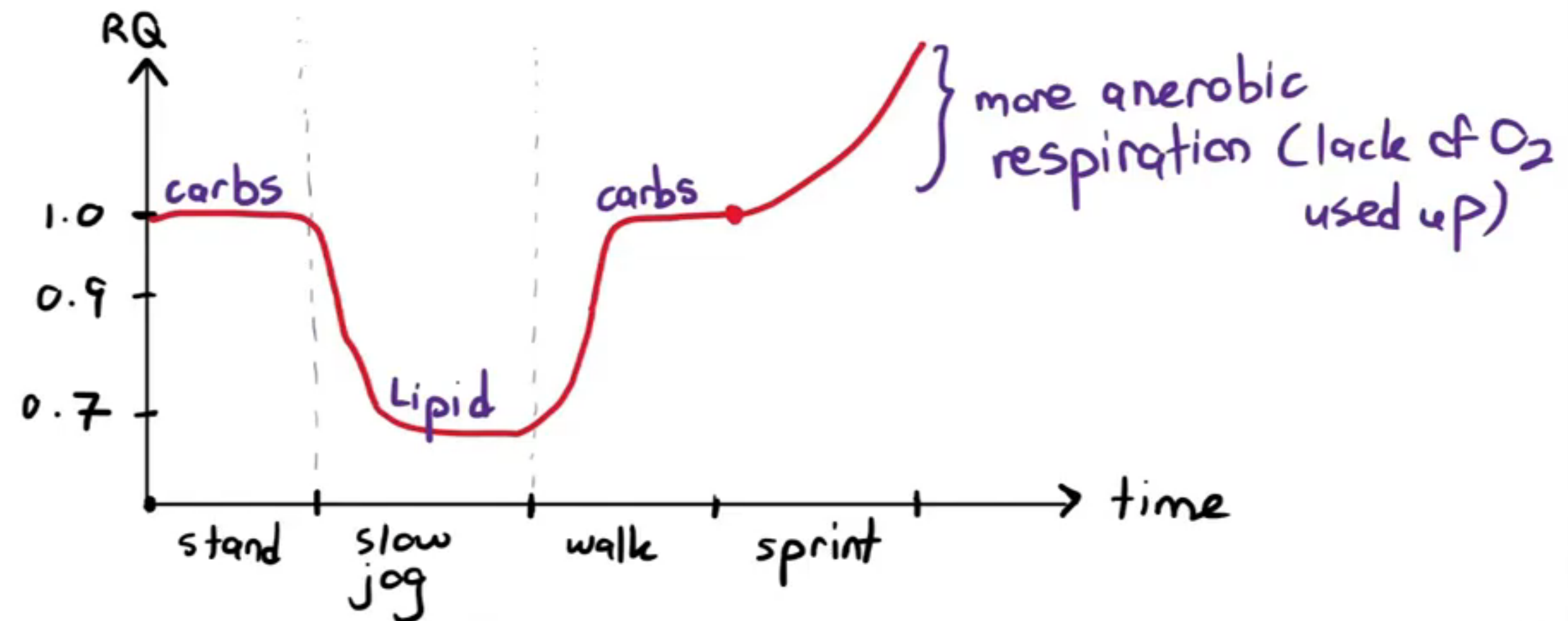


Respiratory Substrates	RQ
Carbohydrates	1.0
Proteins	0.9
Lipids	0.7

Situation

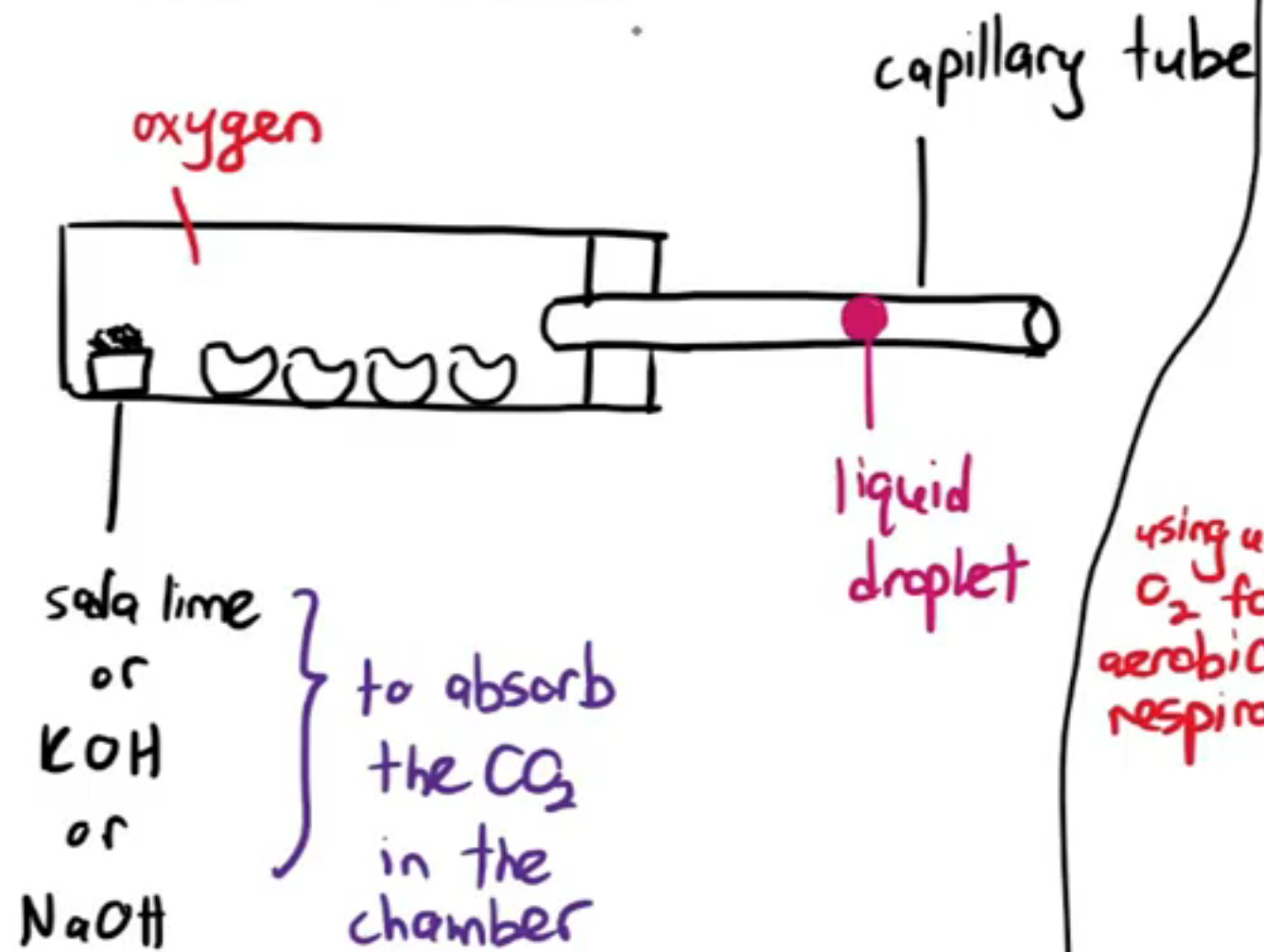


- calculates the volume of CO_2 produces & volume of O_2 used up
- calculate RQ value!!

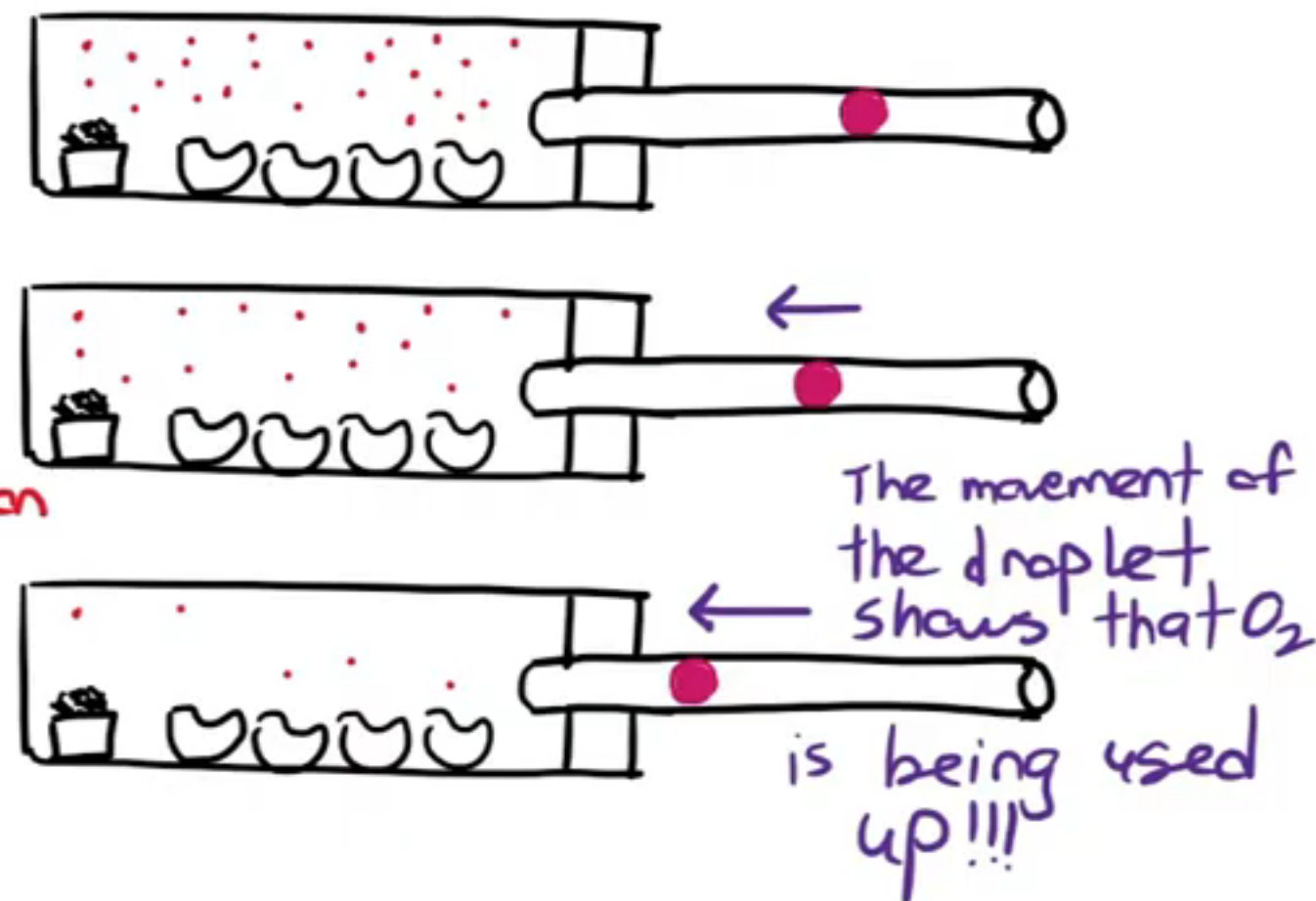


Experiment

measure RQ value



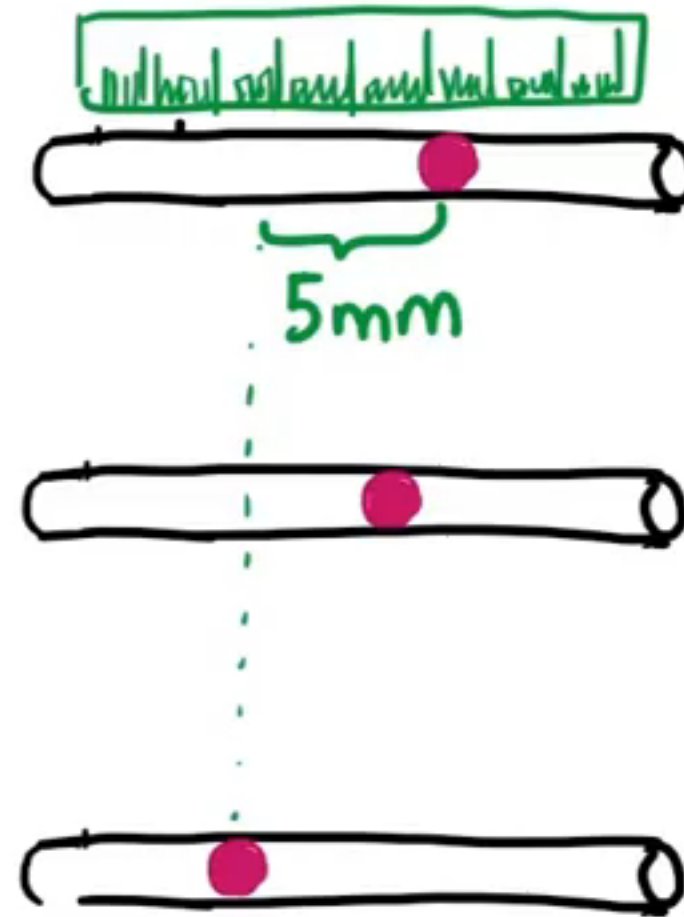
using up O₂ for aerobic respiration



what is the volume of O₂ used up by the seeds????

movement of
droplet
such that O_2
being used

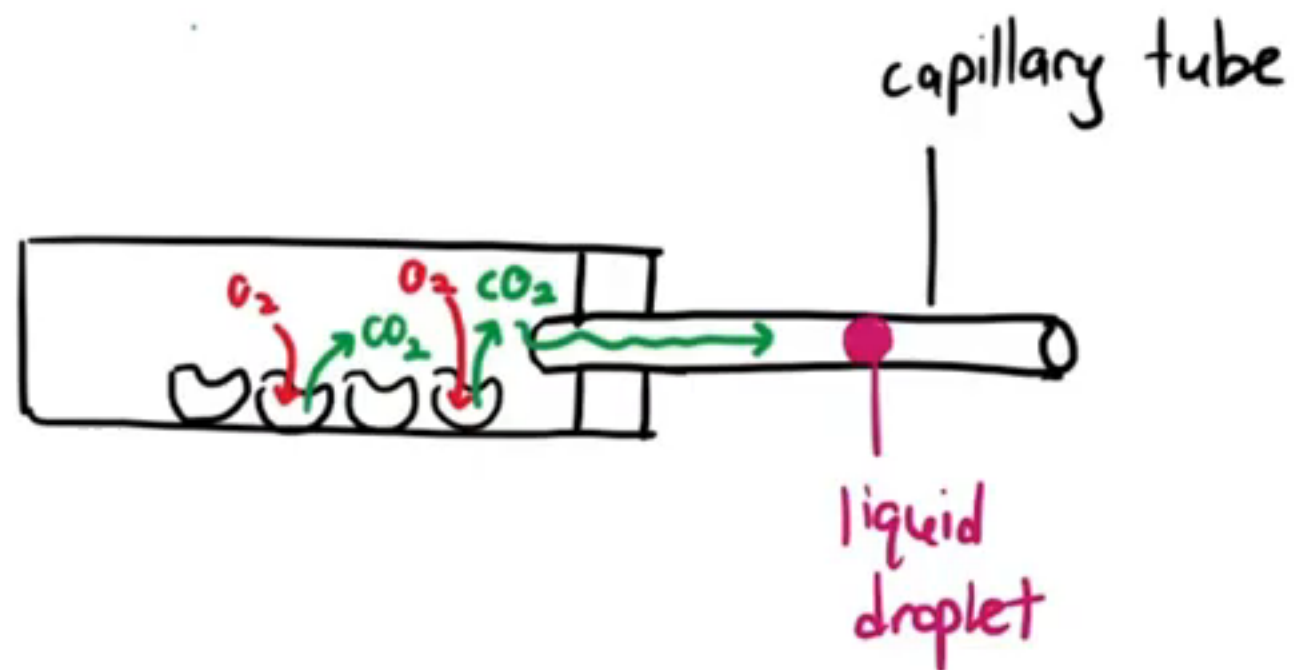
ds????



droplet moved 5mm
volume??



$$\begin{aligned} & \pi r^2 \times L \\ &= \pi (1)^2 \times 5 \\ &= 15.7 \text{ mm}^3 \text{ of } O_2 \\ & \text{was used up!!} \end{aligned}$$



How do we find out
the volume of CO_2 produced??

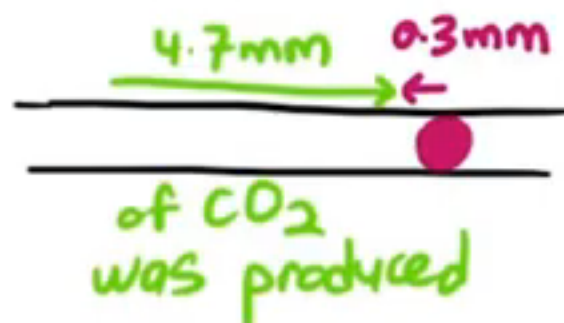
★ Repeat the experiment..
(without soda lime)

At the end of the experiment,
the liquid droplet only moved
0.3 mm !!!

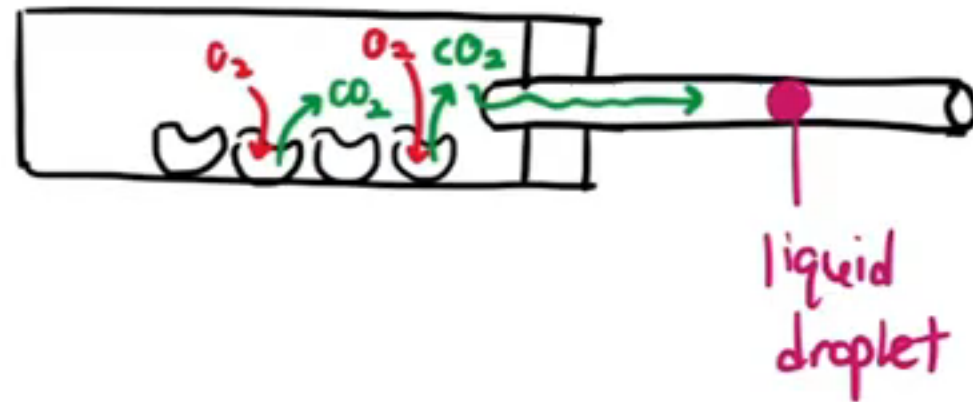
with soda lime



without soda lime



volume of
 CO_2 = 14.8 mm³ of CO_2
produced

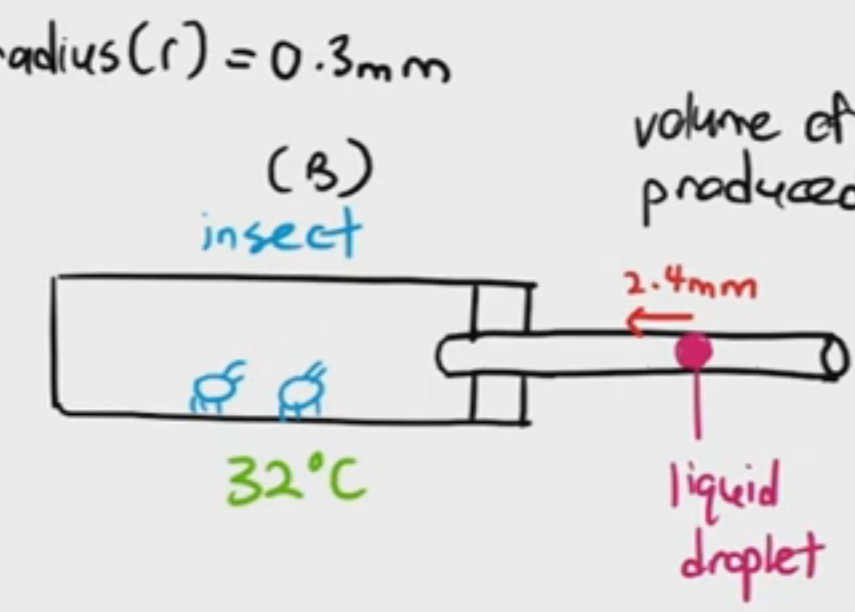
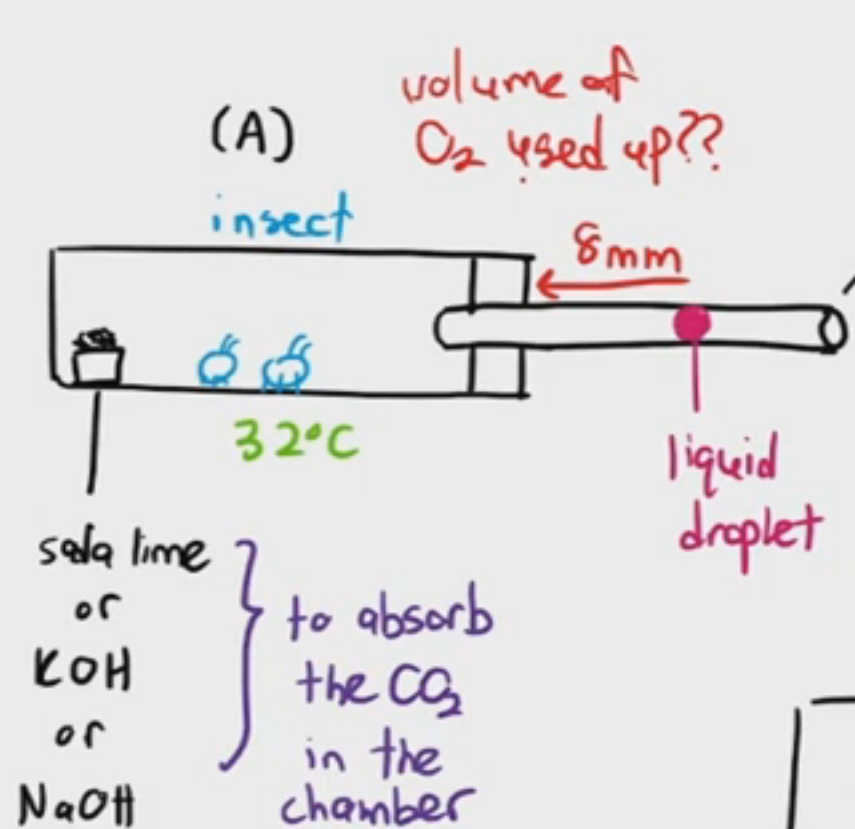


used up 15.7 mm^3 of O_2
produced 14.8 mm^3 of CO_2

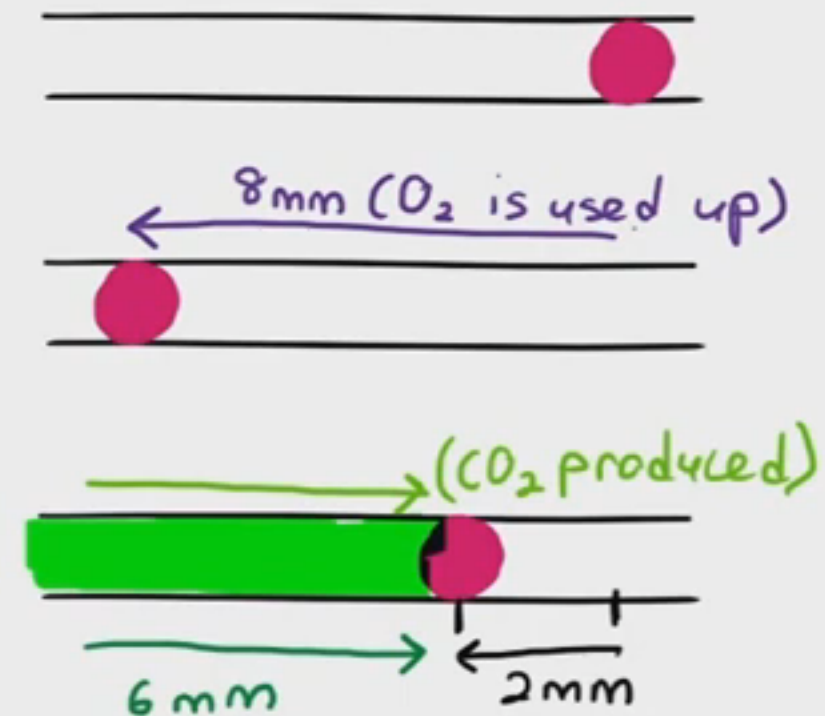
$$RQ = \frac{14.8}{15.7}$$

$$= 0.94$$

(Proteins or carbs
are used as
respiratory
substrates during
germination!!)



Chamber	Distance the droplet moved (mm)
A	8.0mm
B	2.0mm



$$\begin{aligned} \text{volume of O}_2 \text{ used up} &= \pi r^2 \times L \\ &= \pi (0.3)^2 \times 8\text{mm} \\ &= 2.3\text{mm}^3 \end{aligned}$$

$$\begin{aligned} RQ &= \frac{\text{volume of CO}_2 \text{ produced}}{\text{volume of O}_2 \text{ produced}} \\ &= \frac{1.7}{2.3} = 0.74 \end{aligned}$$

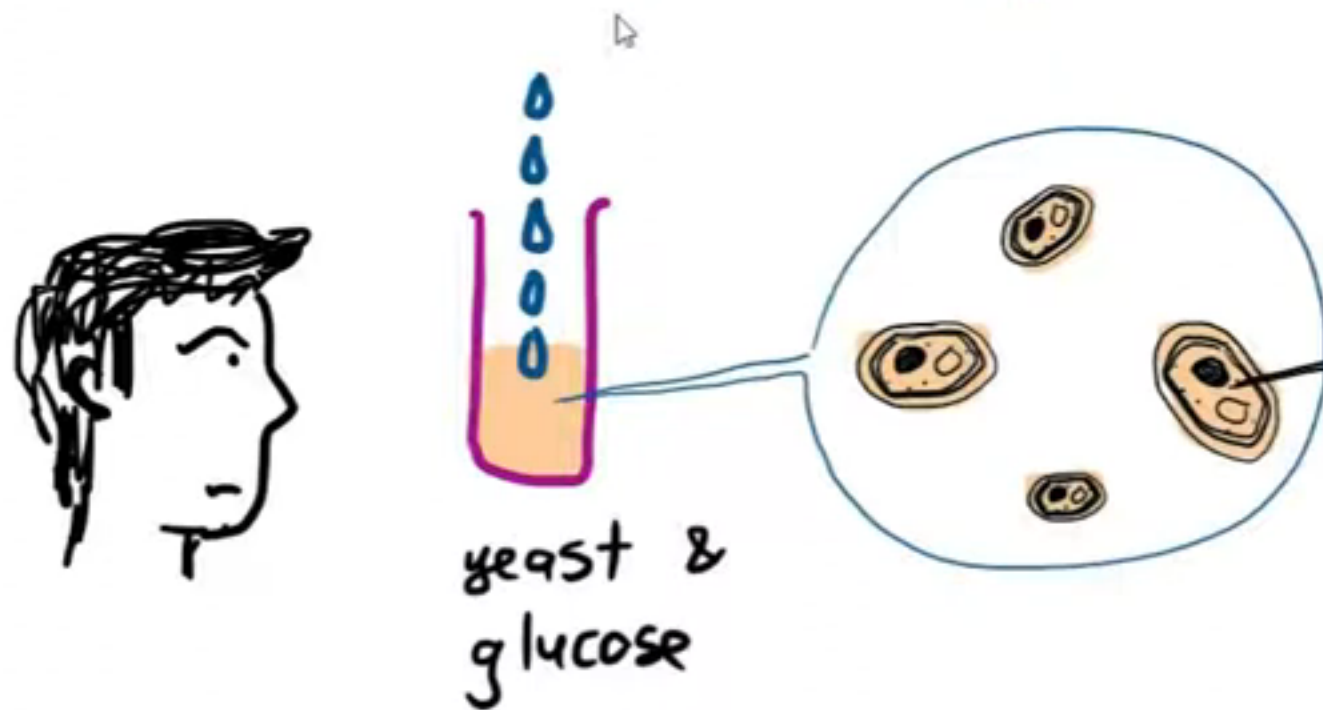
LIPIDS are BROKEN DOWN!

$$\begin{aligned} \text{volume of CO}_2 \text{ produced} &= \pi r^2 \times L \\ &= \pi (0.3)^2 \times 6 \\ &= 1.7\text{mm}^3 \end{aligned}$$

Another experiment on respiration

Rate of respiration in yeast

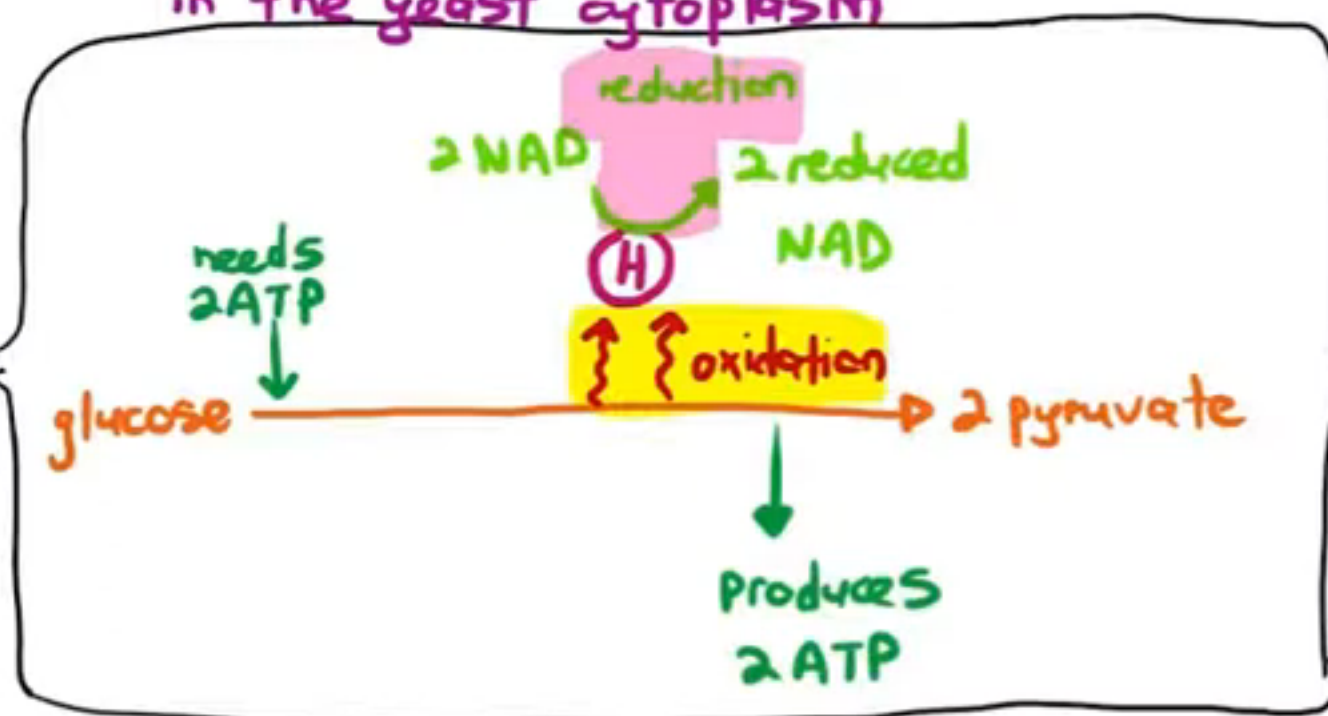
use a redox indicator < DCPIP
methylene blue



Normally...

is there a way for us to 'see' it happening??

in the yeast cytoplasm

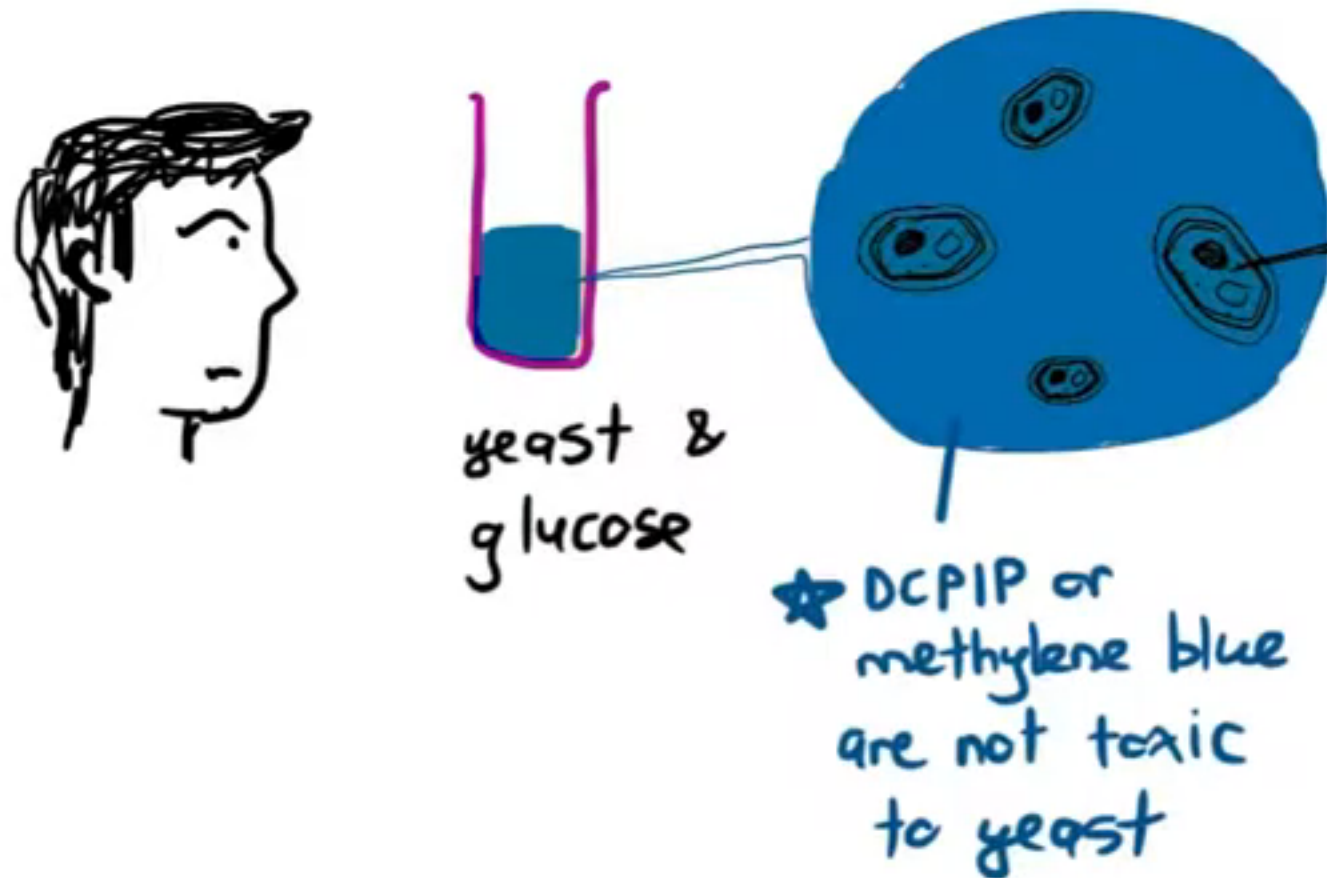


cannot be seen
with our eyes!!!

Another experiment on respiration

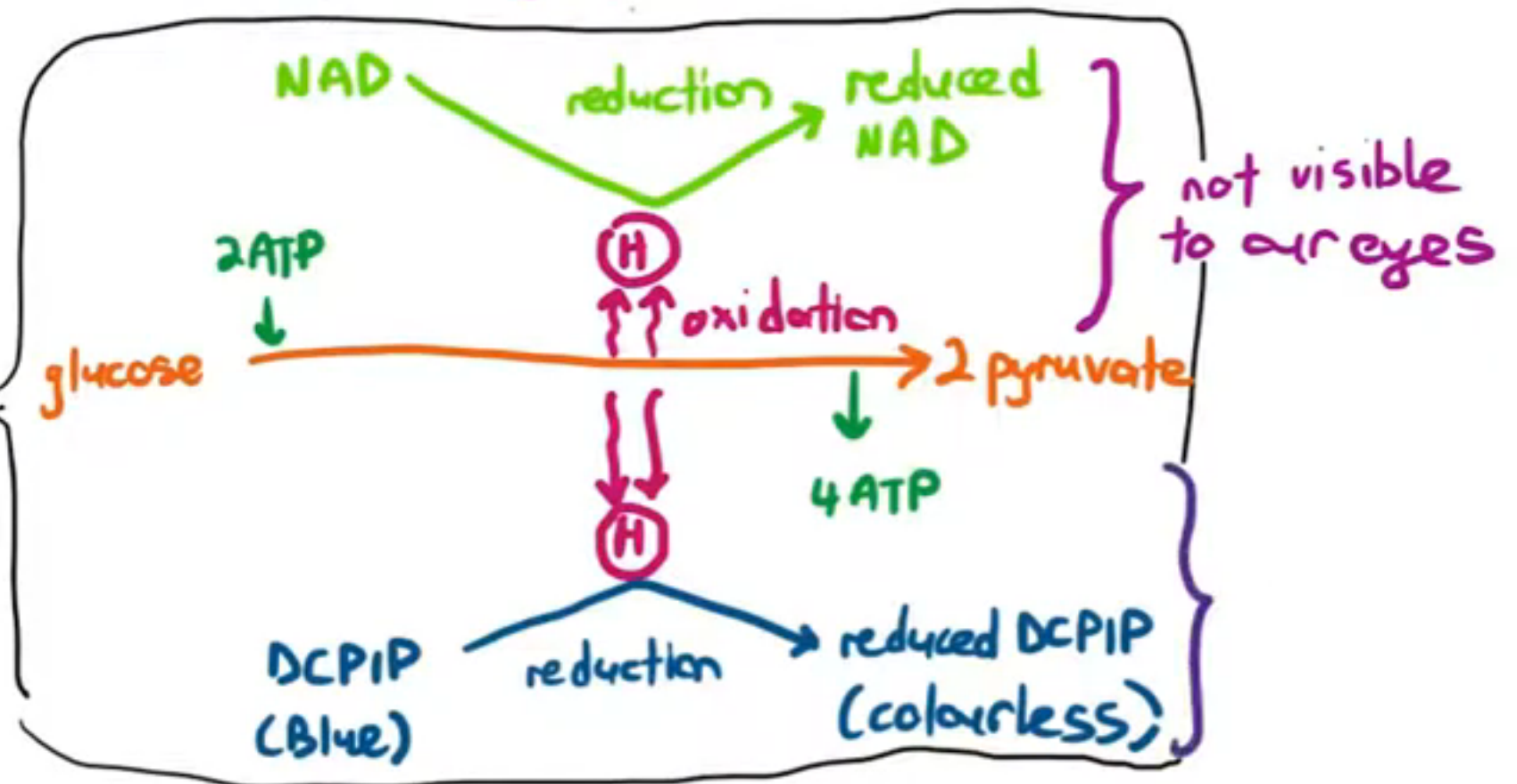
Rate of respiration in yeast

use a redox indicator < DCPIP
methylene blue



Normally...

in the yeast cytoplasm

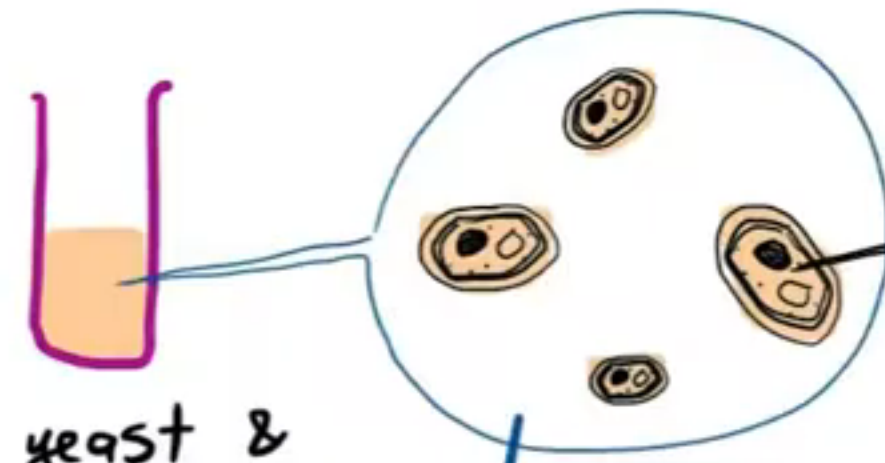


why DCPIP
or methylene blue???

Another experiment on respiration

Rate of respiration in yeast

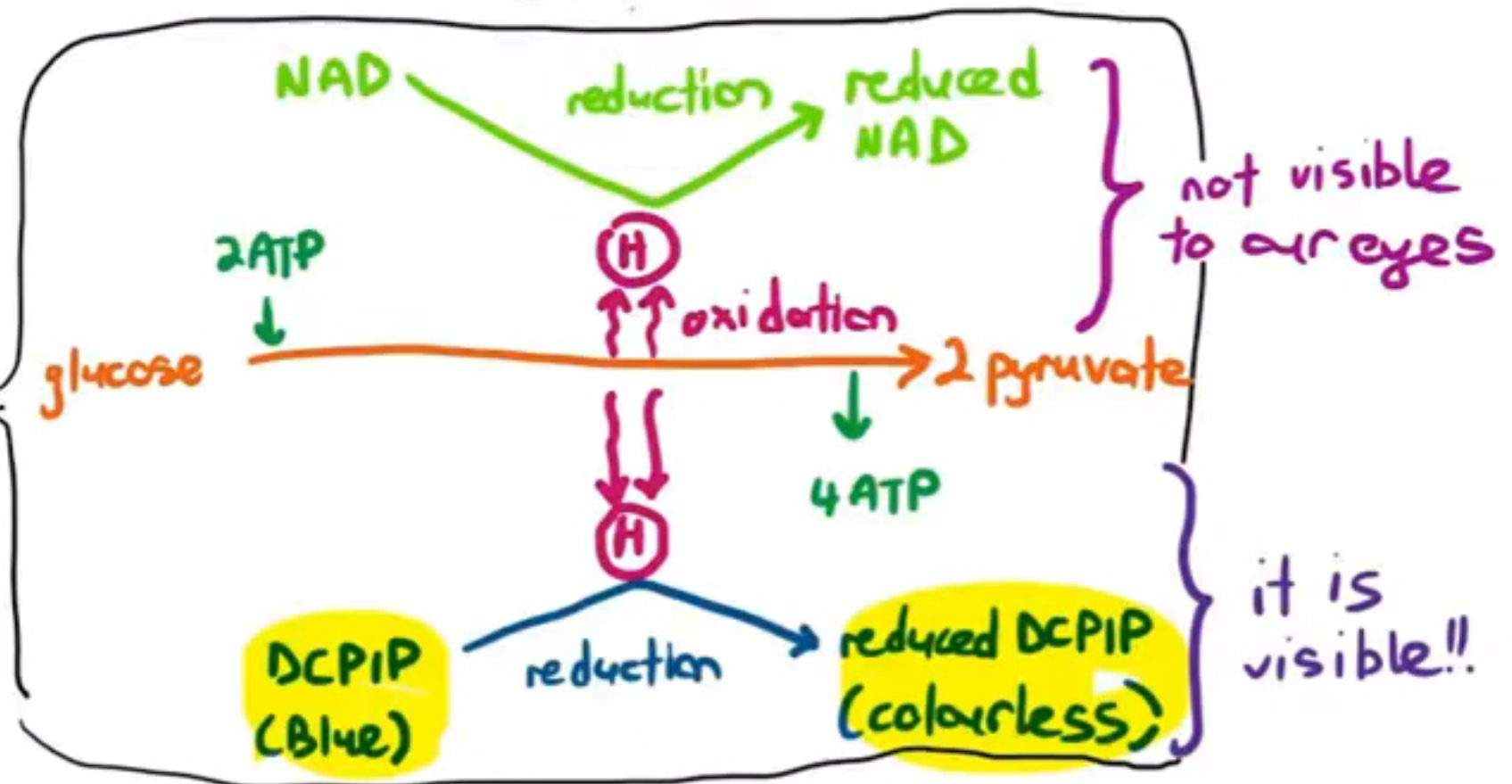
use a **redox indicator** < DCPIP
methylene blue



★ DCPIP or
methylene blue
are not toxic
to yeast

Normally...

in the yeast cytoplasm



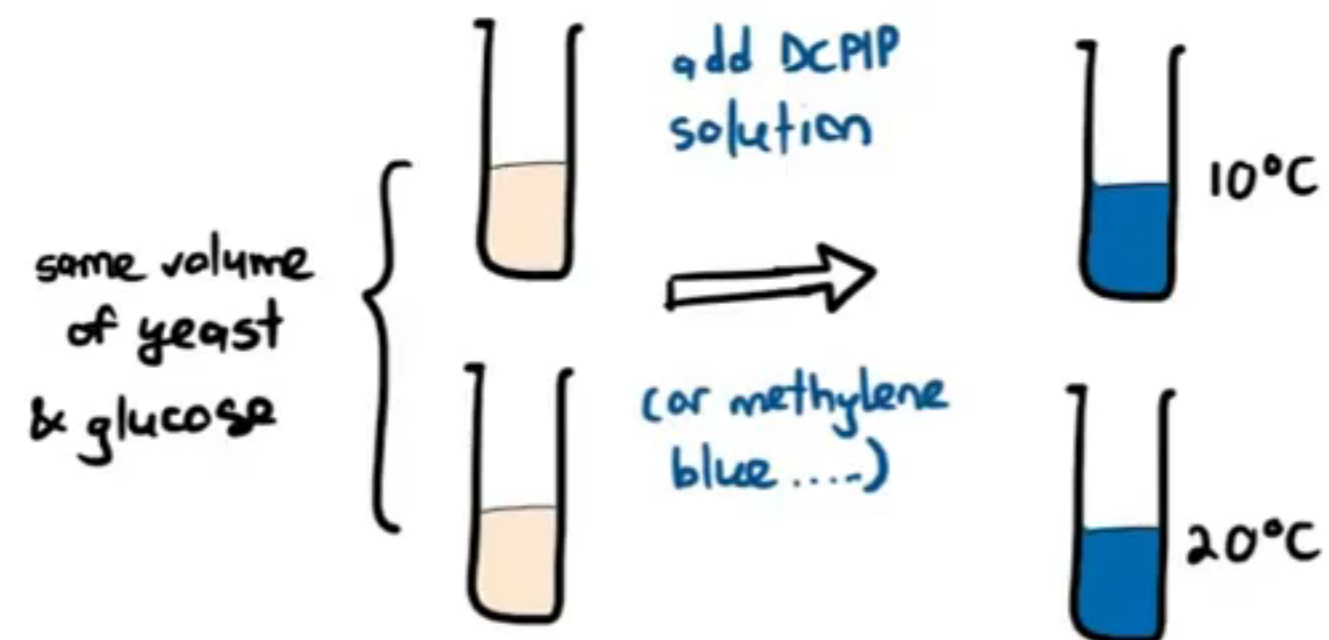
why DCPIP
or methylene blue???

= it can accept the hydrogen
& be reduced into
a colourless compound!!

Another experiment on respiration

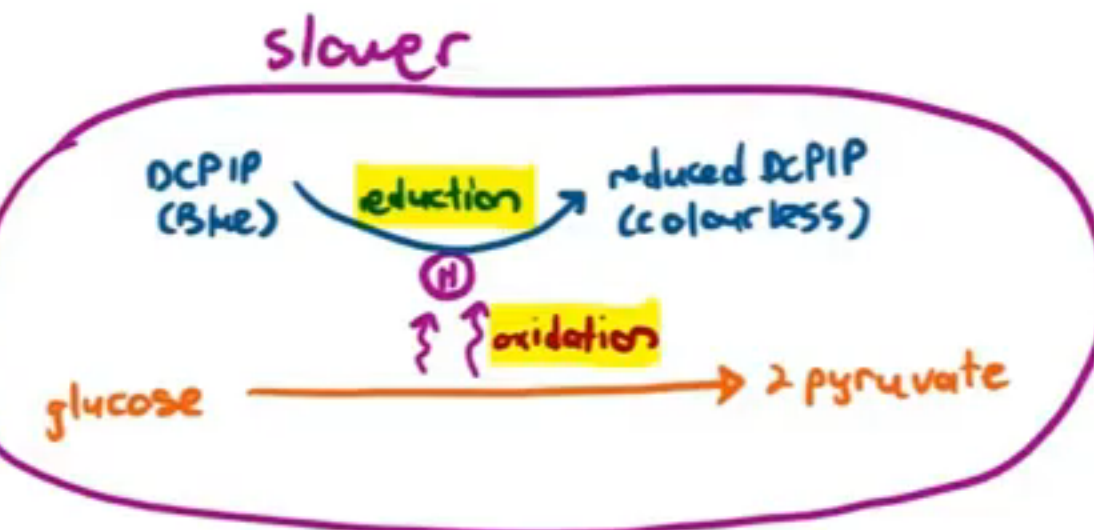
-Rate of respiration in yeast

use a redox indicator < DCPIP
methylene blue



lower respiration
rate

higher respiration
rate



faster

Another experiment on respiration

Rate of respiration in yeast

use a redox indicator < DCPIP
methylene blue

⌚ stop watch
(measure the time taken for
DCPIP to decolourize!!)

