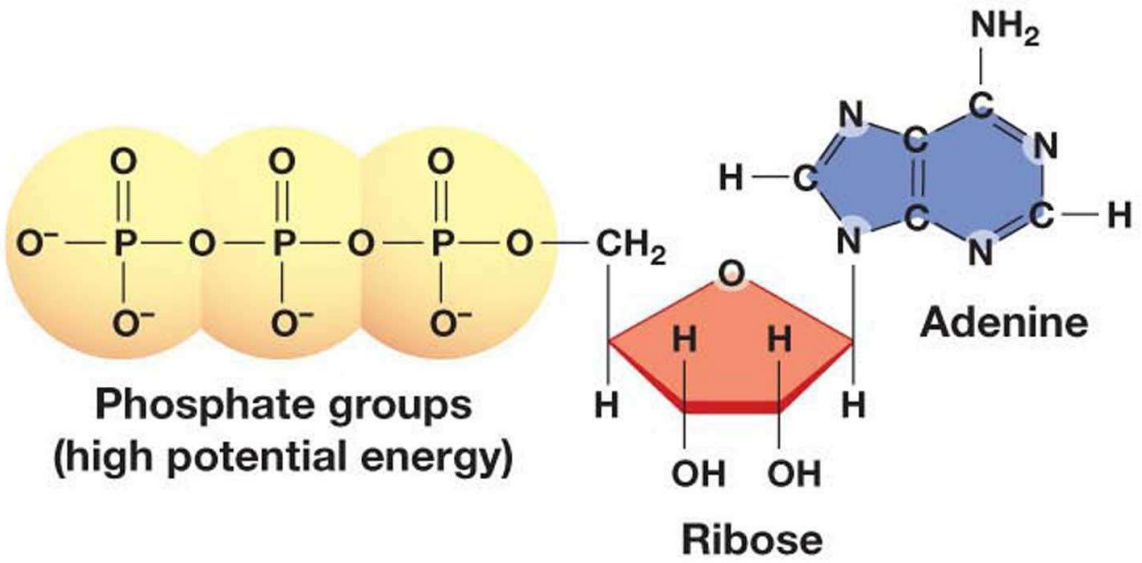


Energy metabolism

ATP- the energy currency of the body

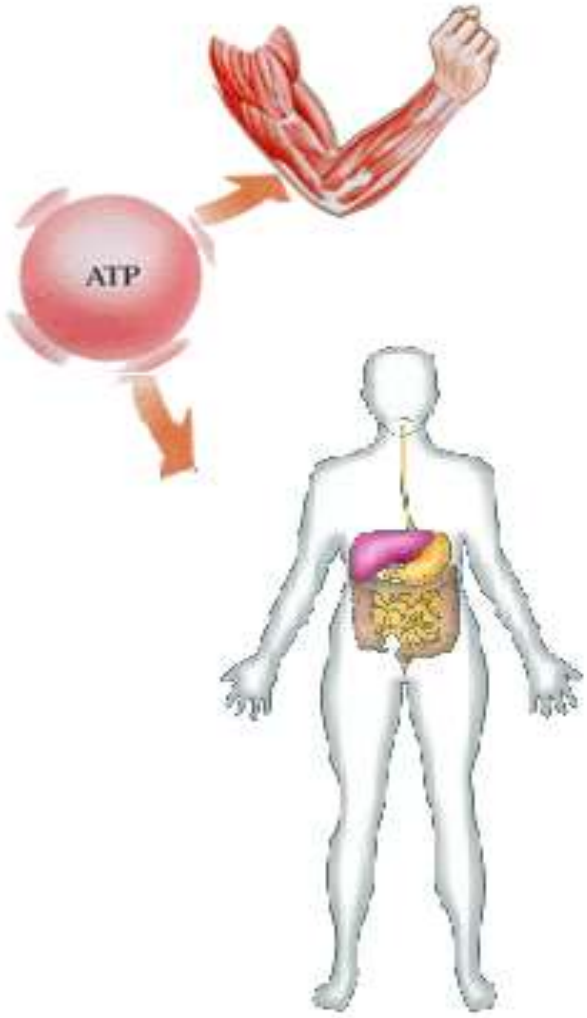


- ATP is the direct energy source of the muscle
- The amount of ATP in the muscle is small.
- It is sufficient for 2-3 s max. work
- Must be regenerated from ADP and Pi

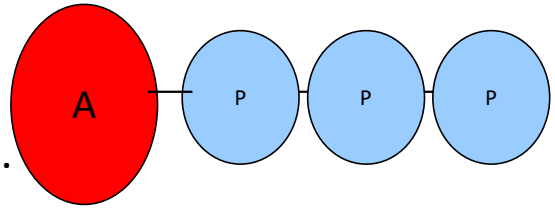
Processes that consume ATP

The energy from ATP is used for:

- Physical activity
- The nervous system function
- The function of the organs
- The immune system
- Growth & development



ATP as energy carrier



- When ATP releases a phosphate group in hydrolysis, energy is released.
- ATP + H2O -> ADP + Pi + energy
- ATP can transfer energy to another molecule by transferring a phosphate group to the molecule (phosphorylate)
- The molecule that receives the phosphate group receives chemical energy
- The phosphorylated molecule can then participate in reactions that otherwise would not be possible
- ATP is recreated by phosphorylation of ADP. The energy required for this is due to the decomposition of energy-generating nutrients (carbohydrate, fat, protein)

Three systems to regenerate ATP

3 Energy Systems participate in the Regeneration of ATP

1. The phosphorus system

2. The glycolytic system

3. The aerobic system

3 systems to regenerate ATP

1. **The phosphagen system** (or ATP CP sysem).

Creatine phosphate (CrP) cleaves and "donates" a P to ADP, forming ATP

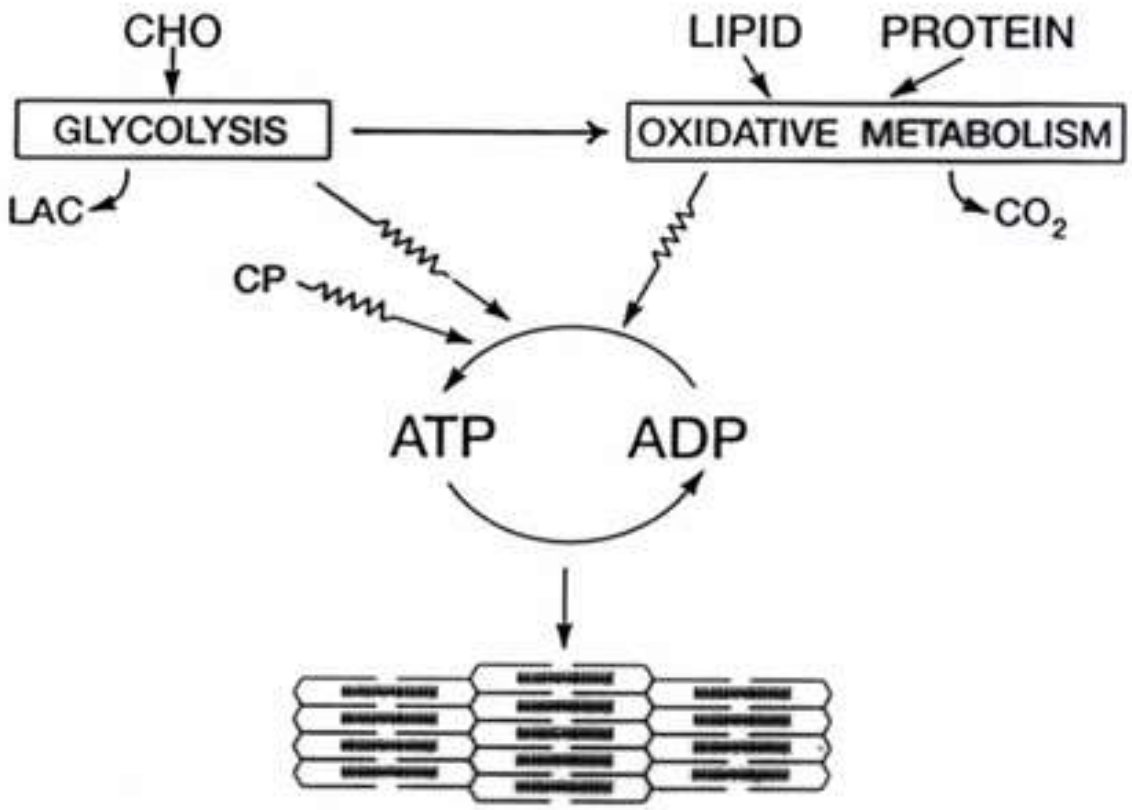
2. The glycolytic system (or anaerobic lactic system)

Glycogen or glucose is converted into lactate in several steps, forming ATP

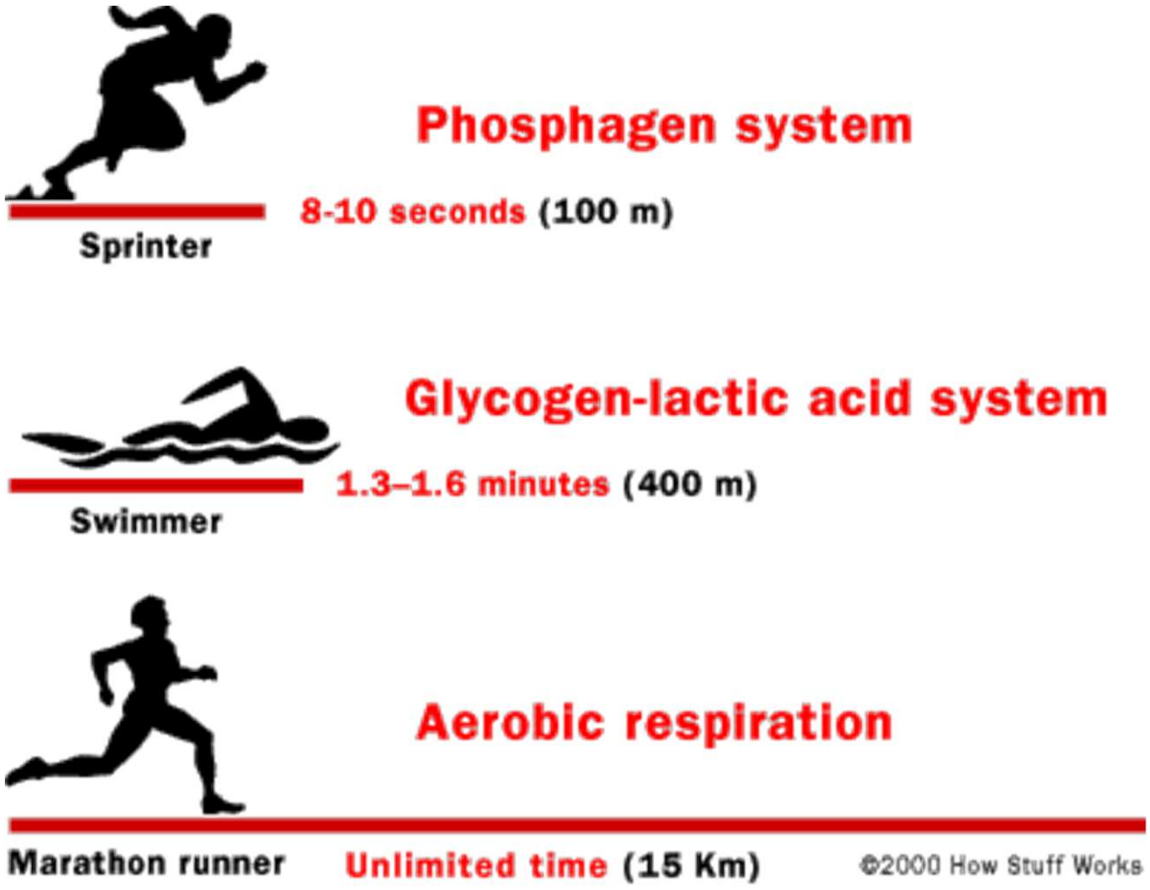
3. The aerobic system

CHO and fat are oxidized via the citric acid cycle, oxidative phosphorylation and the electron transport chain, whereby ATP is produced.

Production of ATP



The intensity of work determines which energy system dominates



Different energy systems dominate at different intensities

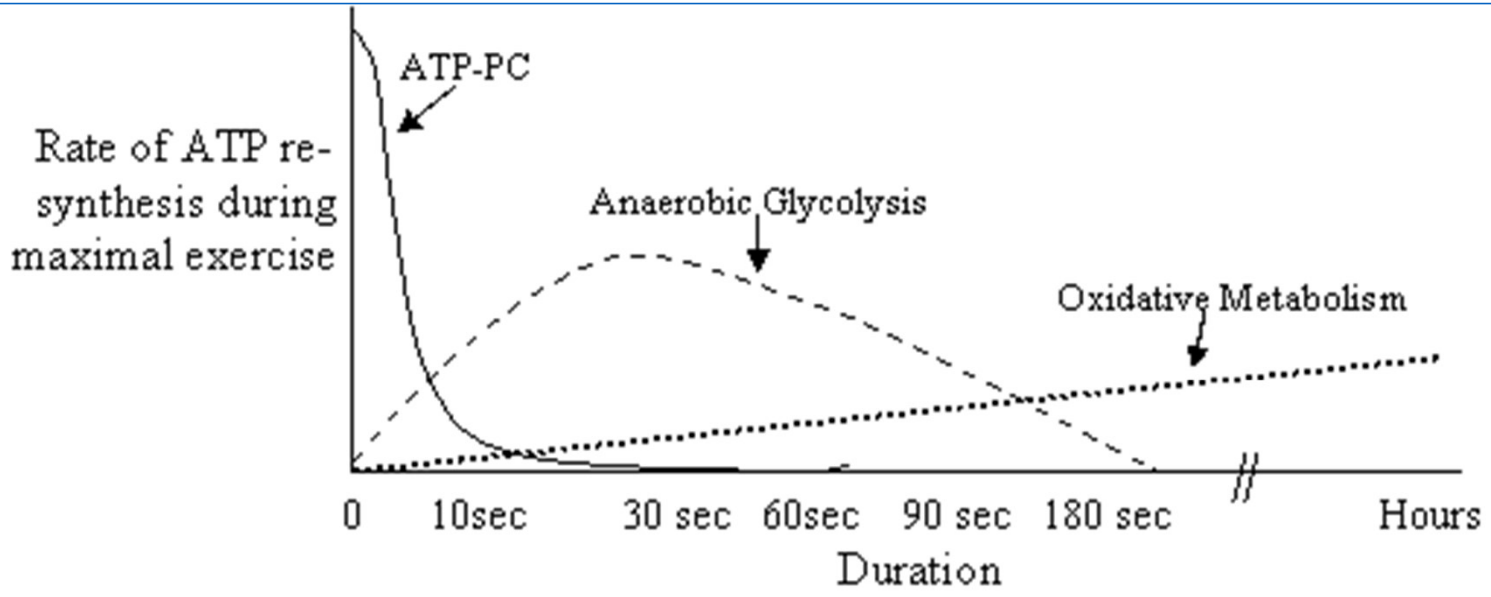


Figure 1. Relative role of the different energy systems in making ATP during maximal exercise of different durations.

Anaerobic vs. aerobic work

Anaerobic work

Ex. weight lifting, sprint

Short duration but great power development

Type-2 (fast) fibers.

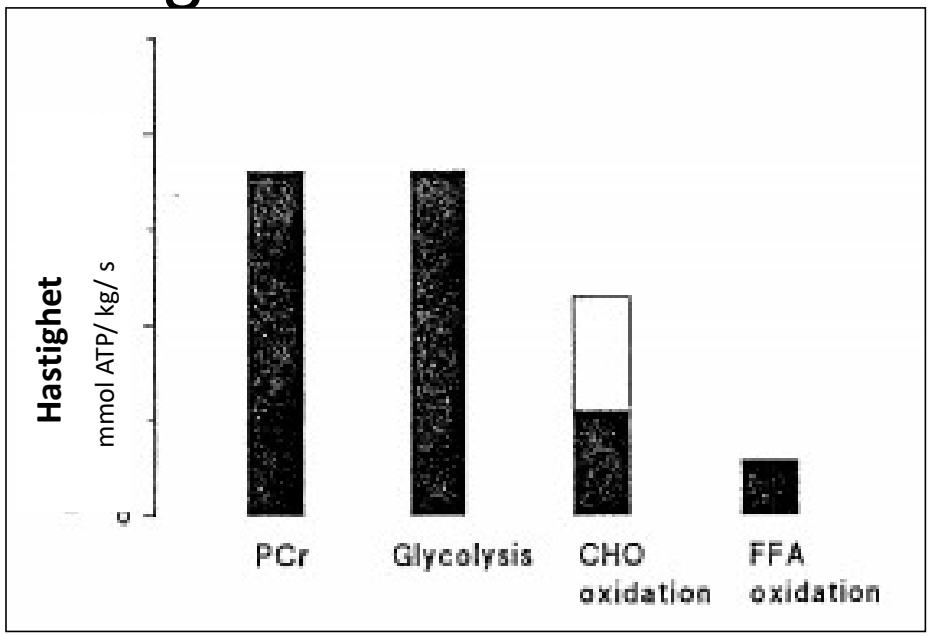
Aerobics work

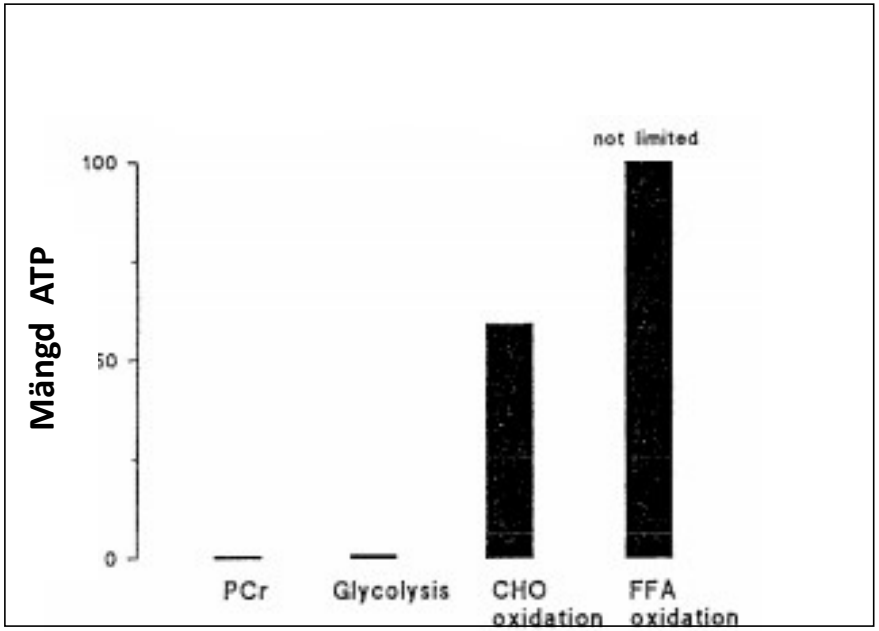
Ex. Long-distance running, cycling, swimming, skiing.

Long-term work but with lower intensity

Type 1 (slow pulling) fibers.

The ability of the energy systems to regenerate ATP





Speed of formation of ATP (Power)

Amount of ATP that can be formed (Capacity)

- Anaerobic processes can form ATP fast but in small amount
- Aerobic processes form ATP slowly but in large amounts

Questions

- What is the direct source of energy for muscle work?

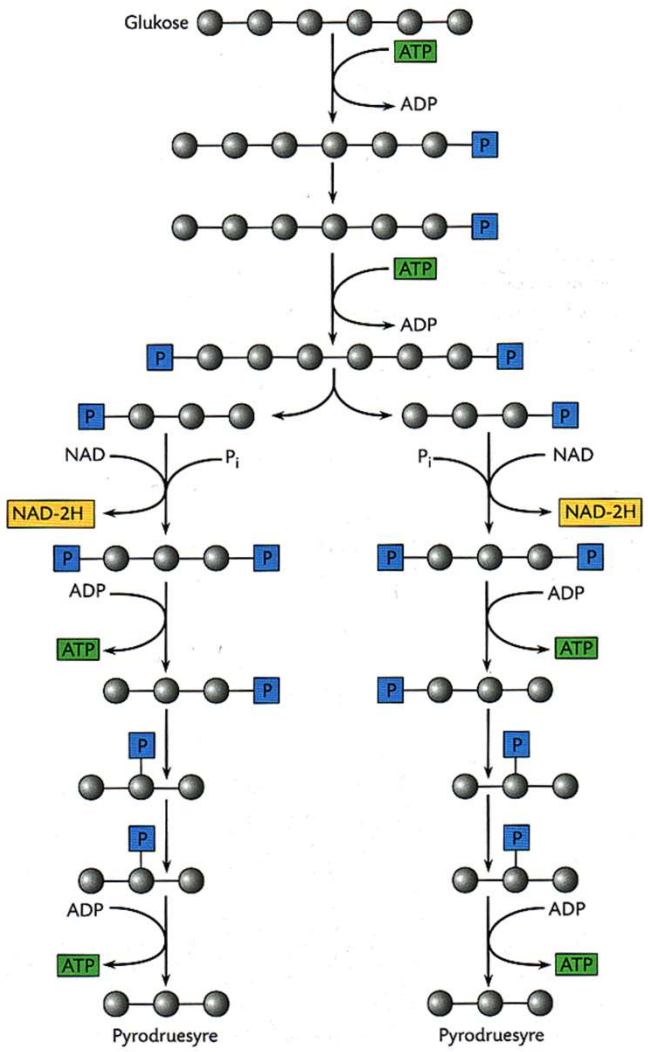
- Give examples of three sport activities where you perform
  a) aerobic work
  b) anaerobic work?

What energy systems are involved in the regeneration of ATP for muscle work?

The glycolysis

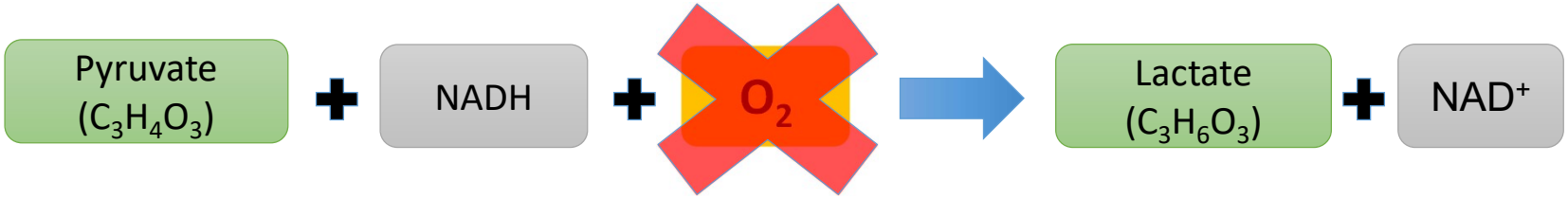
- The glycolysis = First step in the degradation of glucose. A process in which glucose is broken down to pyruvate
- The glycolysis occurs in the cytosol
- In the process, 2 ATP molecules and 2-reduced co enzymes (NADH) are formed for each glucose
- The formation of pyruvate from glucose does not require O2 (anaerobic)

The glycolysis



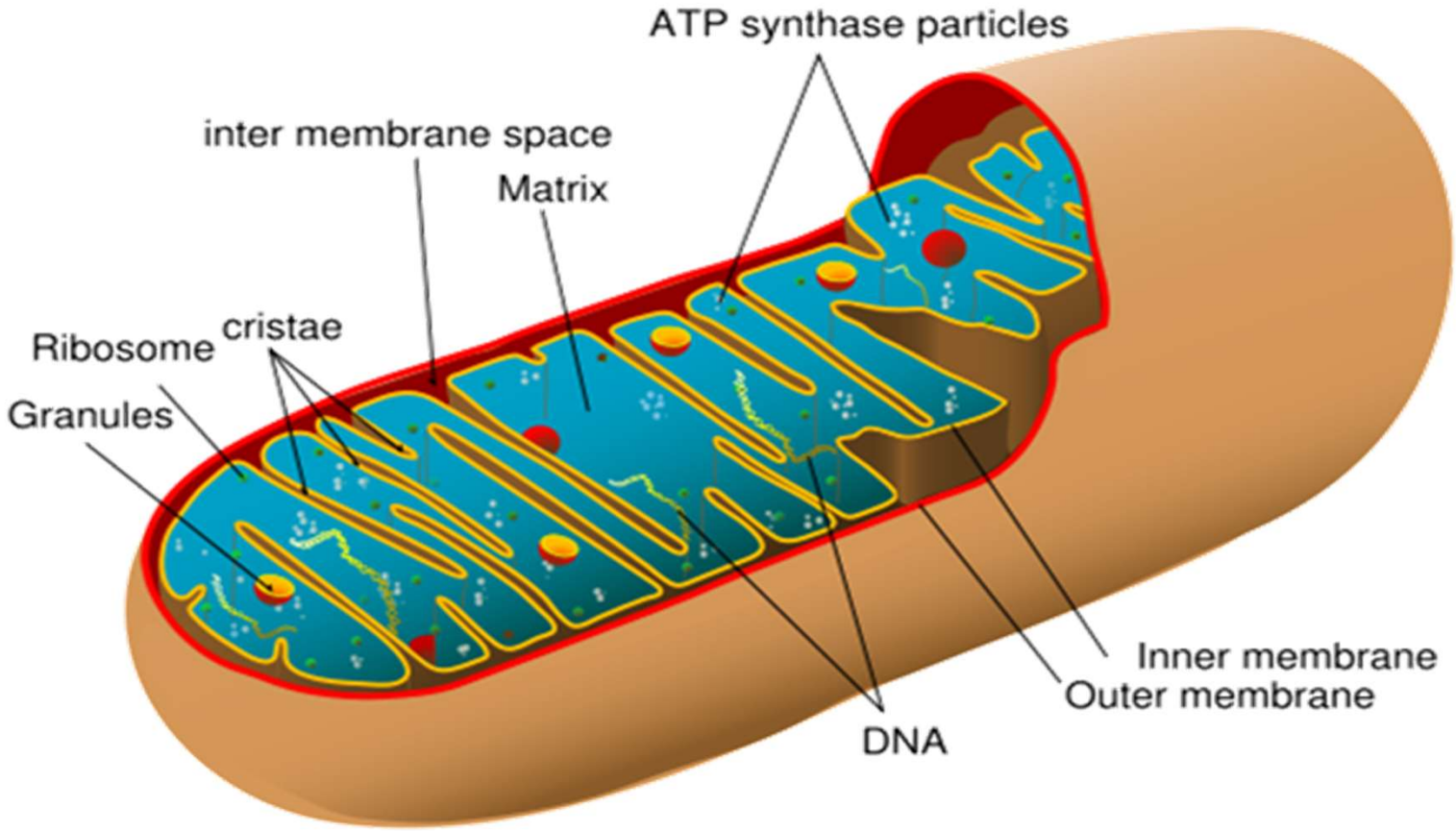
What happens to pyruvate depends on whether O2 is available (aerobic) or not (anaerobic)

The anaerobic reaction for pyruvate in the muscle cells:

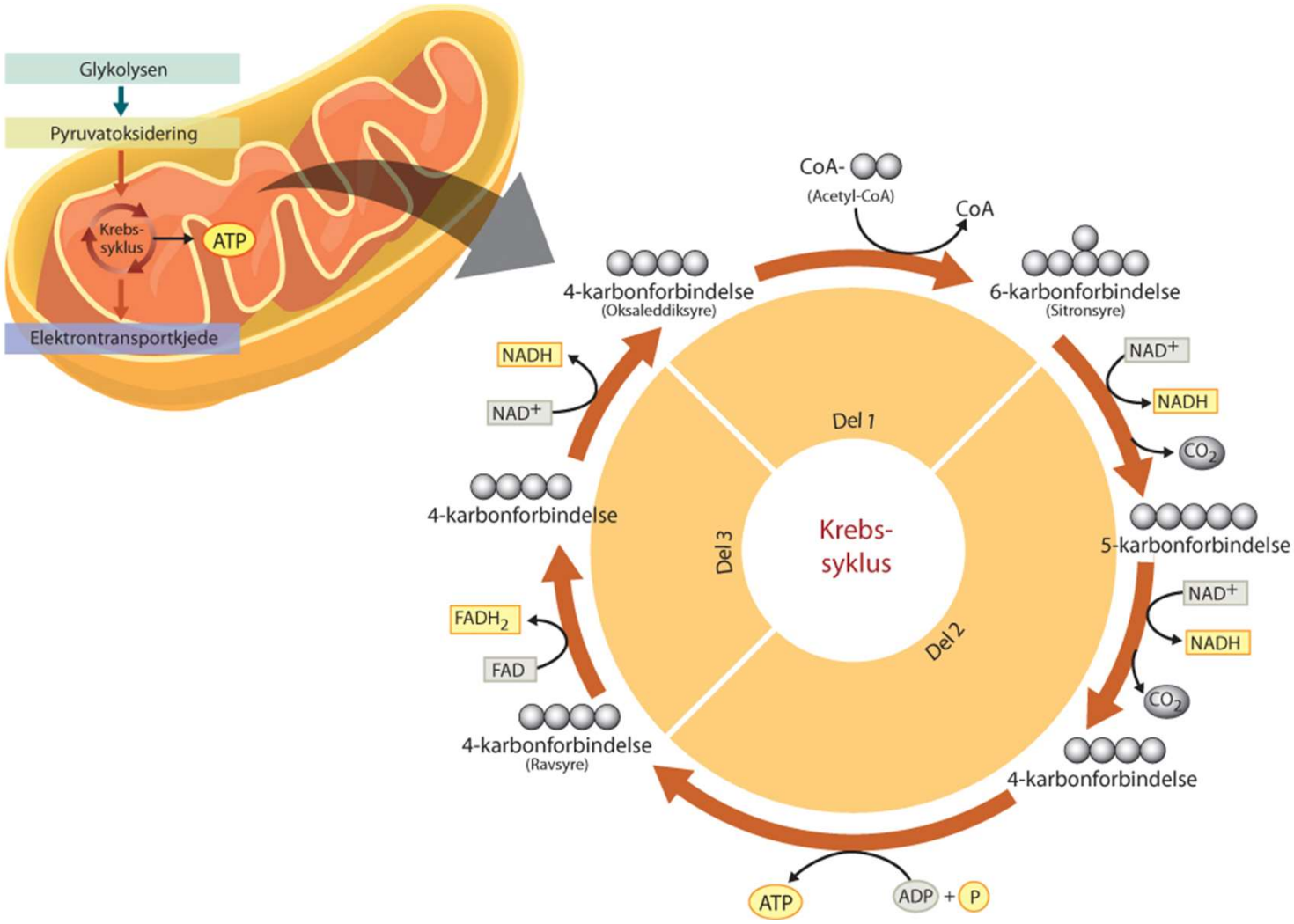


- Pyruvat takes up H (and is reduced)
- NADH releases H (and is oxidized)

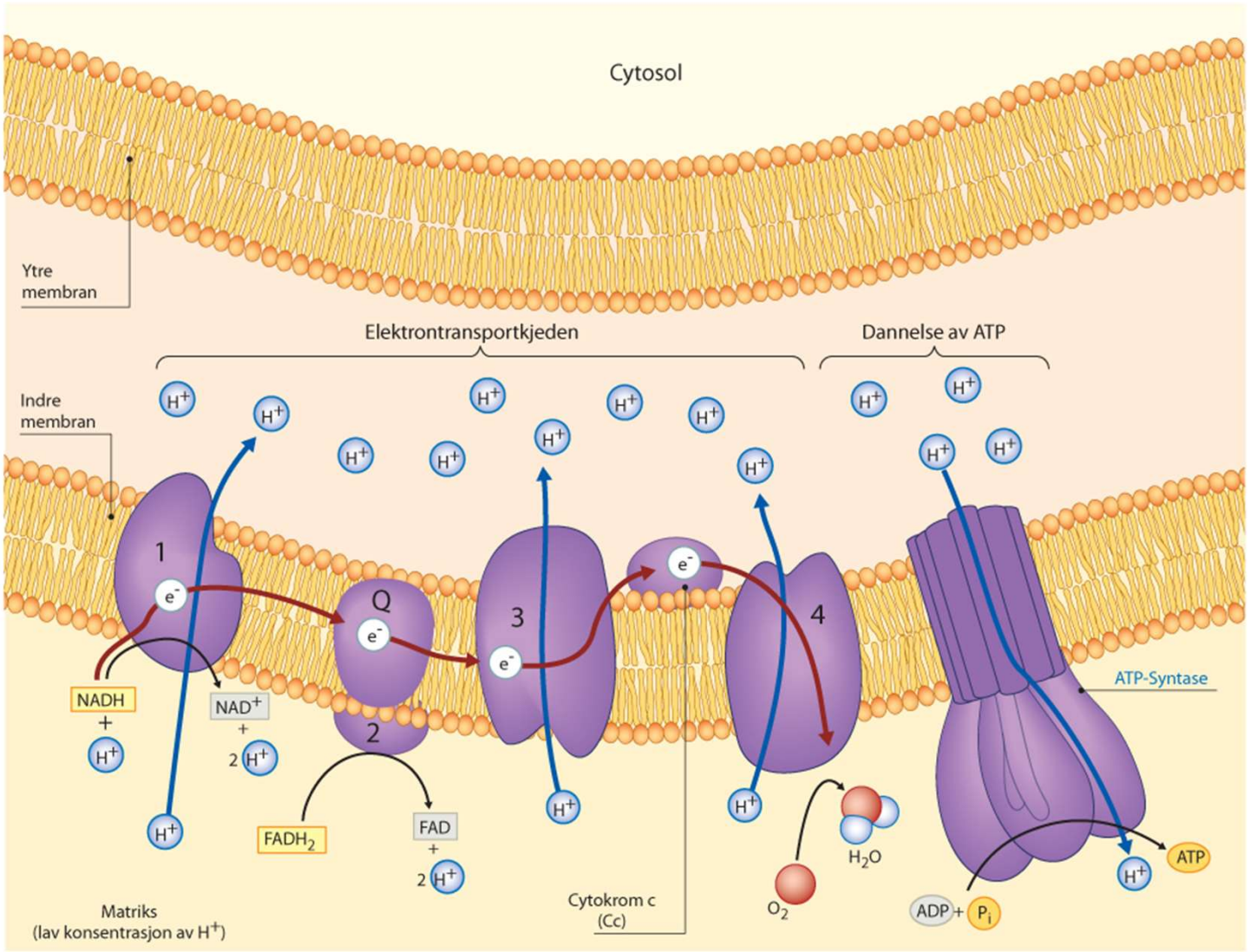
Mitochondria – the power plant of the cell



Krebs cycle


Glykolysen
Pyruvatoksidering
Krebs-syklus
ATP
Elektrontransportkjede
CoA-
(Acetyl-CoA)
CoA
4-karbonforbindelse
(Oksaleddiksyre)
6-karbonforbindelse
(Sitronsyre)
NADH
NAD+
NAD+
NADH
CO2
Del 1
4-karbonforbindelse
Del 3
Krebs-syklus
5-karbonforbindelse
NAD+
NADH
FADH2
FAD
Del 2
CO2
4-karbonforbindelse
(Ravsyre)
4-karbonforbindelse
ATP
ADP + P

The electron transport chain



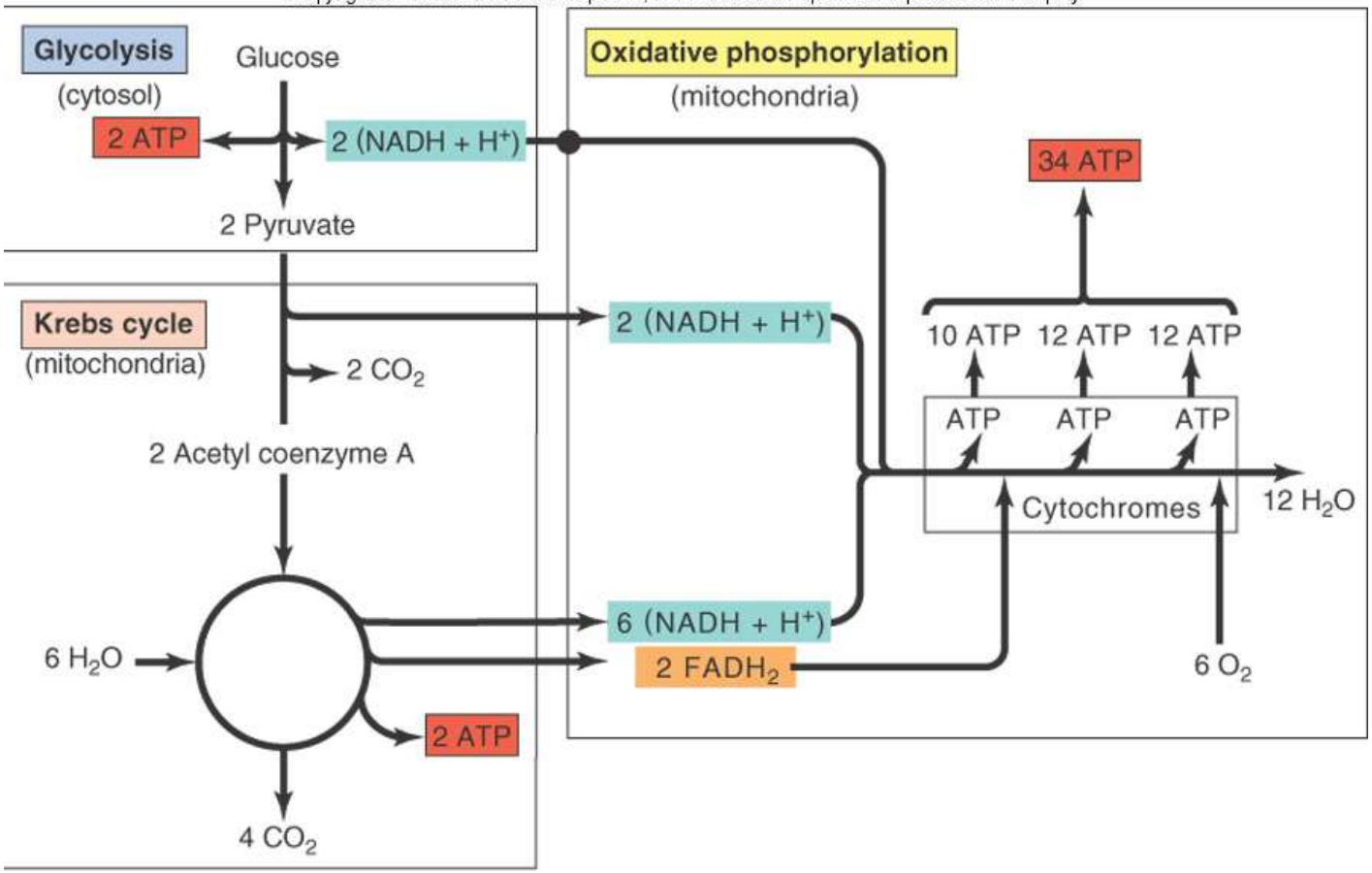
The outer mitochondrial membrane

The inner mitochondrial membrane

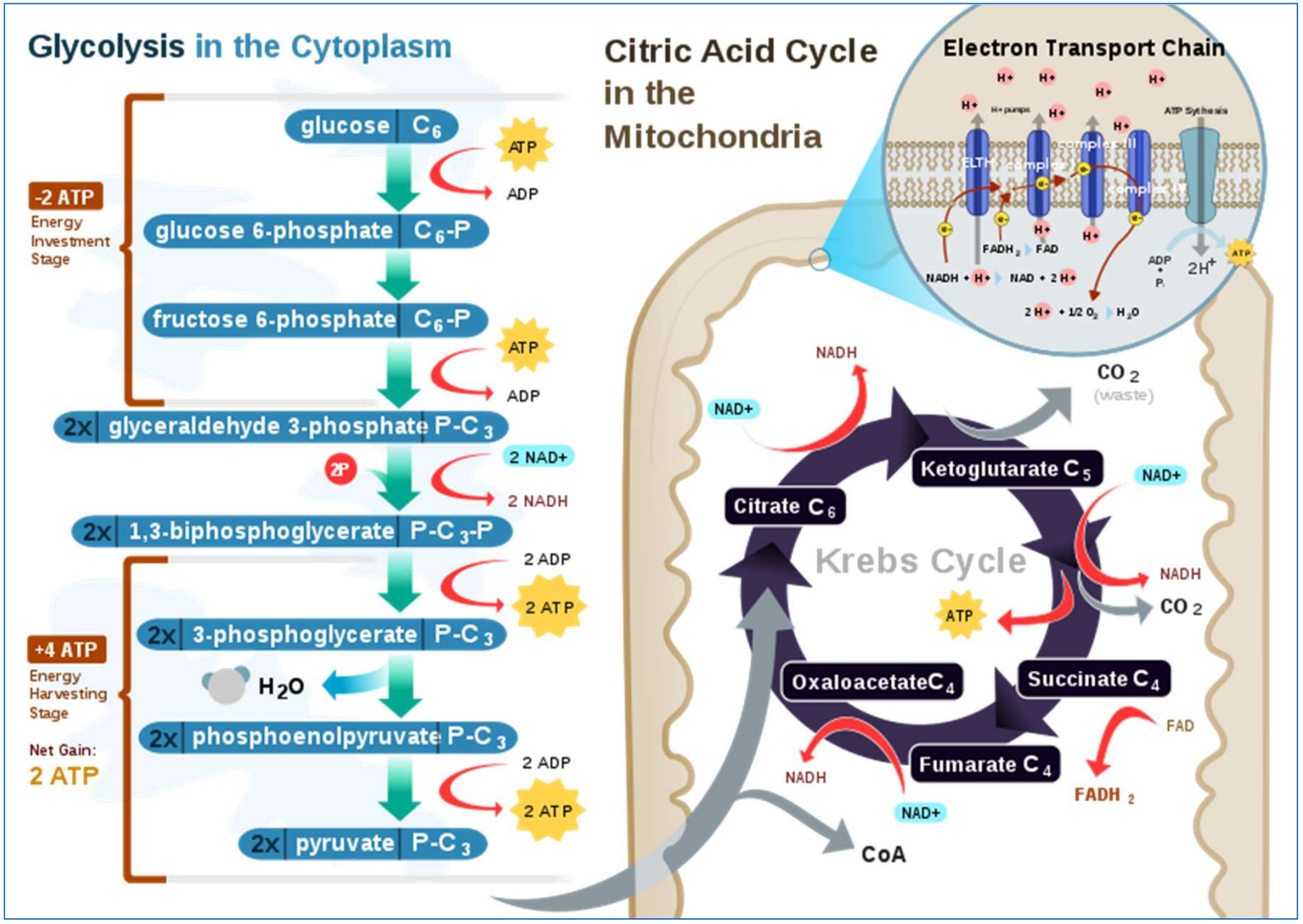
The electron transport chain

- Few ATP molecules are formed in the glycolysis and citric acid cycle
- The reduced co enzymes (NADH and FAD-2H) emit electrons to the electron transport chain
- The electrons are transferred from one XXX to another and finally transferred to molecular oxygen, whereby water is formed
- H+ is simultaneously pumped from the inner space of the mitochondriae to the "intermembrane space" (from low to high concentration)
- When H + flows back (spontaneously) by ATP synthase, the energy in created is used to convert ADP to ATP
- Under aerobic conditions, oxidative phosphorylation may yield 34 ATP. In total, 36 ATP per glucose molecule can be produced

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



$$C_6H_{12}O_6 + 6\,O_2 + 38\,ADP + 38\,P_i \longrightarrow 6\,CO_2 + 6\,H_2O + 38\,ATP$$


Glycolysis in the Cytoplasm
glucose C6
ATP
ADP
-2 ATP
Energy Investment Stage
glucose 6-phosphate C6-P
fructose 6-phosphate C6-P
ATP
ADP
2x glyceraldehyde 3-phosphate P-C3
2P
2 NAD+
2 NADH
2x 1,3-biphosphoglycerate P-C3-P
2 ADP
2 ATP
2x 3-phosphoglycerate P-C3
H2O
2x phosphoenolpyruvate P-C3
2 ADP
2 ATP
2x pyruvate P-C3
+4 ATP
Energy Harvesting Stage
Net Gain:
2 ATP
Citric Acid Cycle in the Mitochondria
Electron Transport Chain
NADH
NAD+
CO2 (waste)
Ketoglutarate C5
Citrate C6
Krebs Cycle
ATP
NADH
CO2
OxaloacetateC4
Succinate C4
FAD
FADH2
Fumarate C4
NADH
NAD+
CoA

Questions

- Which energy system has the highest speed for forming ATP?
- Which energy system can form the most ATP?
- Indicate three situations where anaerobic metabolism takes over?
- What limits production of anaerobic energy?