

Oxygen and life: energy *vs* death

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Cornelis Drebbel (1620)
Netherlands

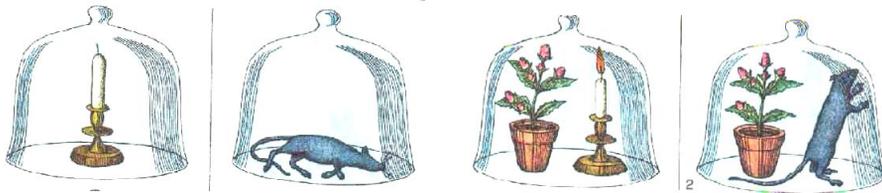


Breathable gas production for the first submarine

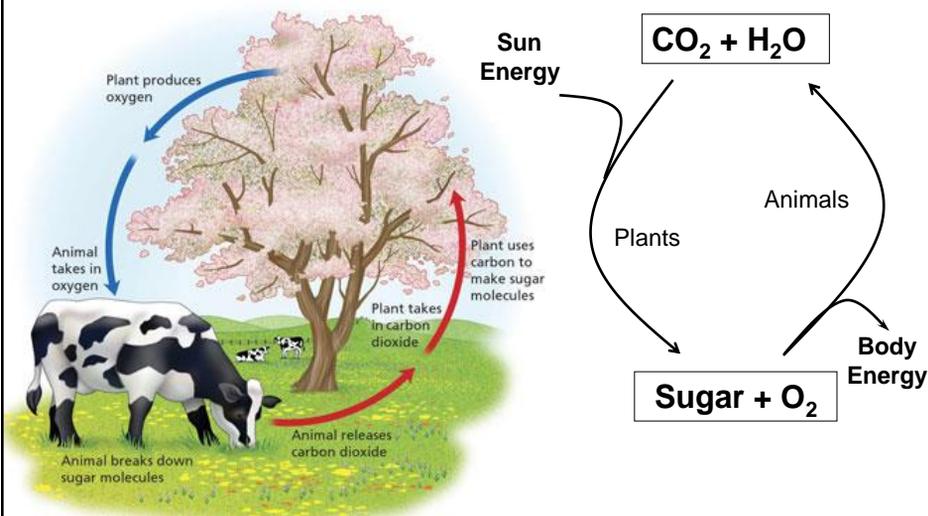
Joseph Priestley

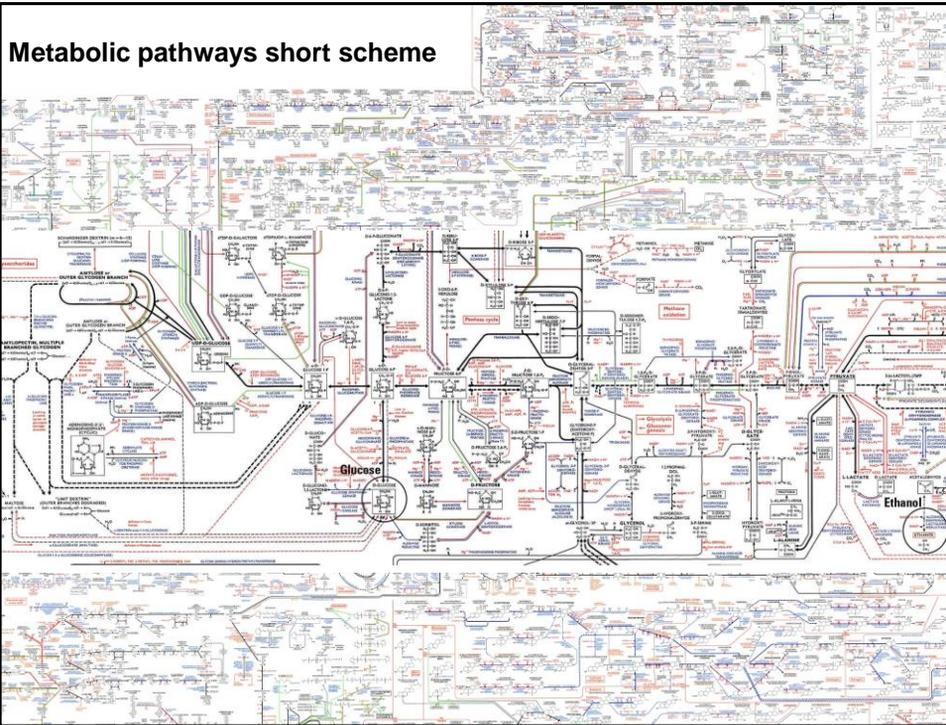
Discovery of oxygen 1774-1779

He found that a mouse kept with a plant would survive. These kinds of observations led Priestley to offer an interesting hypothesis that plants restore to the air whatever breathing animals and burning candles remove - what was later coined by Lavoisier "oxygen".

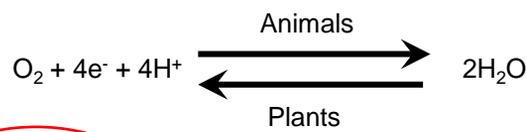


Energy and oxygen





What is happening with oxygen?



Oxygen molecules are being reduced by our body into water (O_2 accept electrons and water H_2O is formed)

RESPIRATION



Plants are able to oxidise water molecules and release O_2 (H_2O loses electrons)

PHOTOSYNTHESIS



And now chemistry!!!

#Redox reactions

(reduction-oxidation reactions)

Reduced compound A
(reducing agent)

Oxidized compound A

Oxidizing compound B
(oxidizing agent)

Reduced compound B

Electrons sitting on A
have higher energy
then electrons sitting
on B !!!

$$\text{Carbon}_{\text{red}} + \text{O}_2 \rightarrow \text{Carbon}_{\text{ox}} + \text{H}_2\text{O}$$

$$\text{Carbon}_{\text{red}} \rightarrow \text{Carbon}_{\text{ox}} + 2\text{H}^+ + 2\text{e}^-$$

$$\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}$$

Where is it happening?

Adult consumes around 380 litres of O₂ each day
(top athletes can sustain 10 times greater rate)

Cell

→

Mitochondria

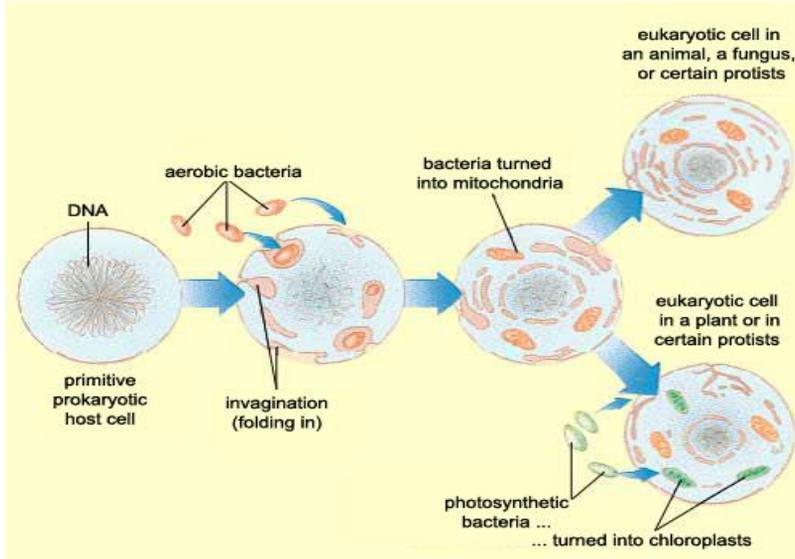
90-99% of oxygen we breath in is consumed by mitochondria

~10¹⁵ mitochondria in our body ~ 10% of the body weight

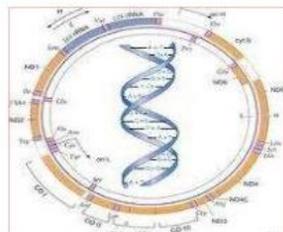
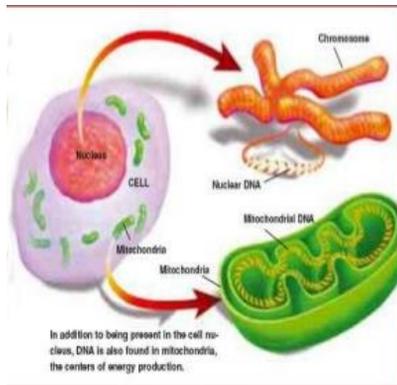
Mitochondria contains its own DNA and probably are result of a symbiosis

Origin of mitochondria?

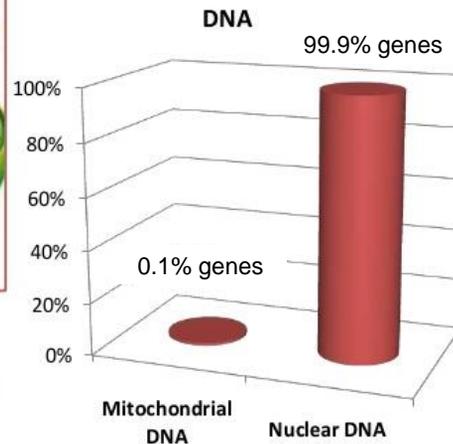
Endocymbiotic theory



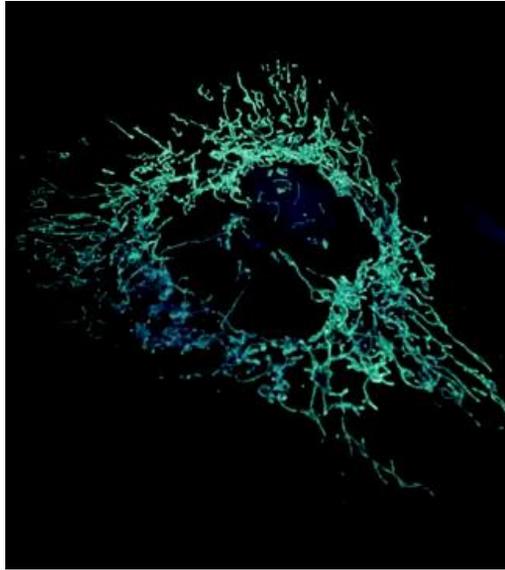
Mitochondrial DNA and nuclear DNA



nDNA 1 copy per cell
mtDNA 100-10000 copies per cell



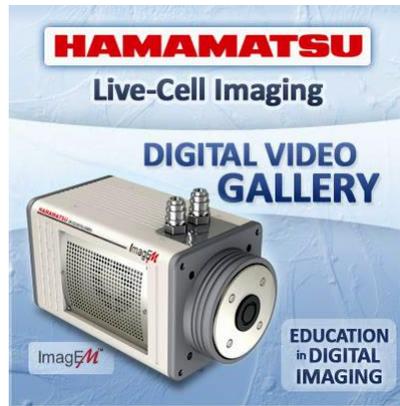
Mitochondria are not sausages – it is a network!



Tracking mitochondria in live cell

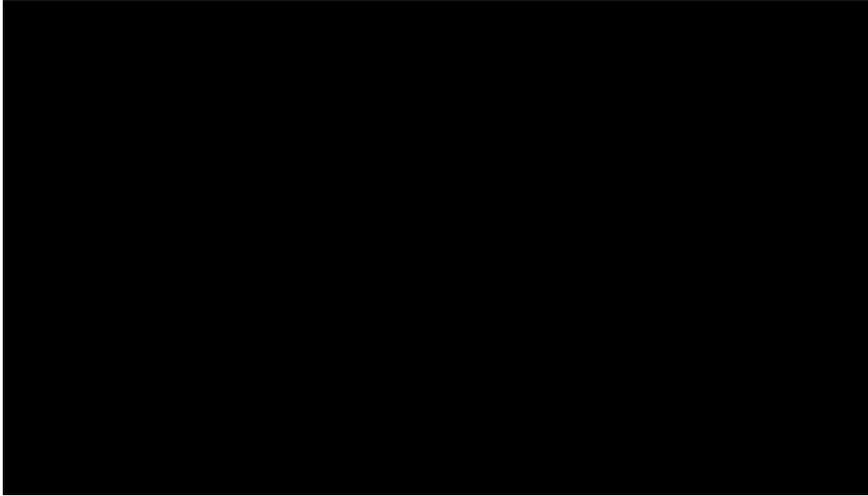


Rhodamin-like dye



Green fluorescent protein

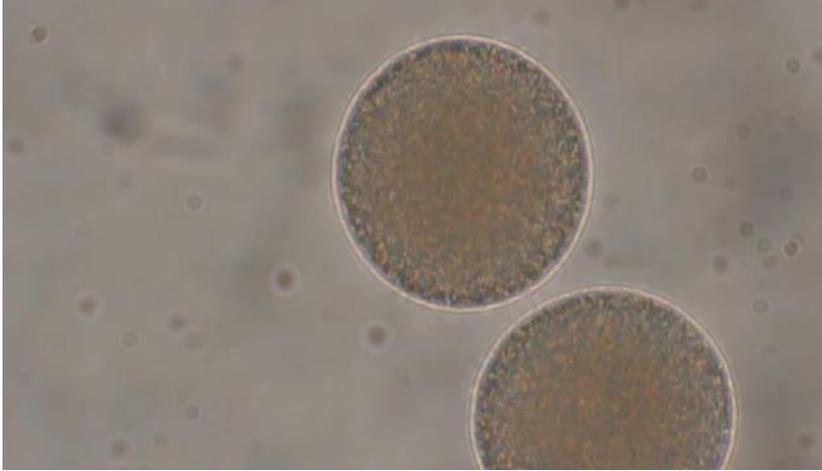
Mitochondria can be transported
within the cell!



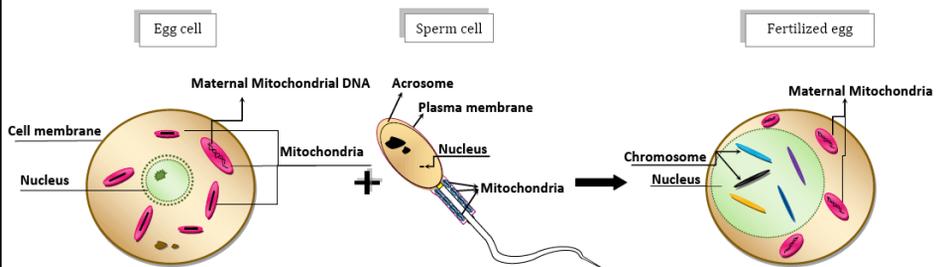
Maternal inheritance



Maternal inheritance

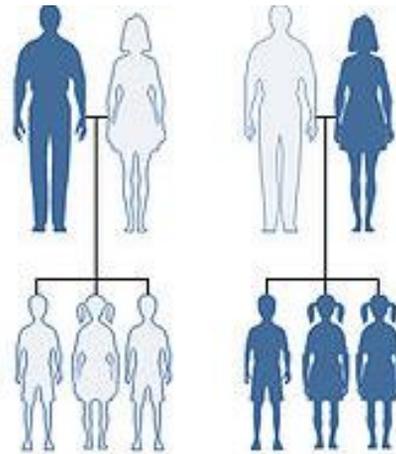


Maternal inheritance



In all of us mitochondria come from the mother!!!

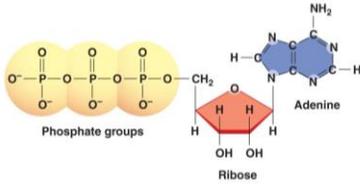
Maternal inheritance of mitochondrial DNA



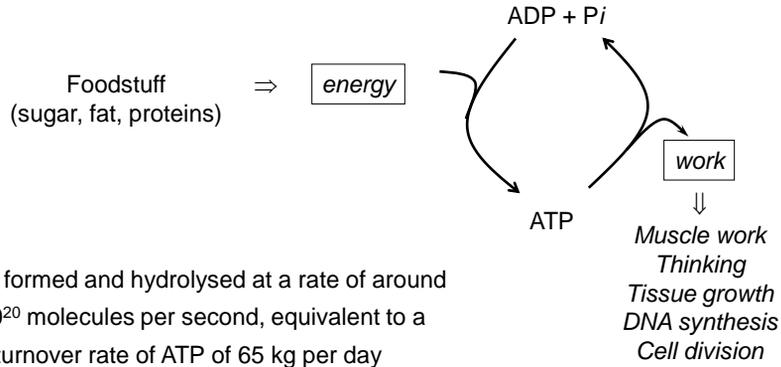
Mitochondria

Power stations of the cell – what does it mean???

How is energy generated?

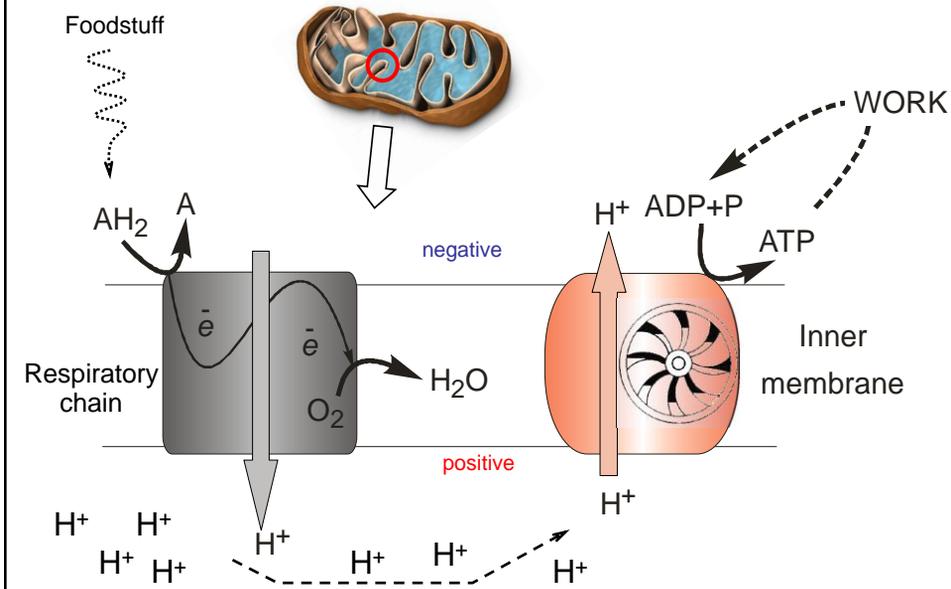


ATP is regarded as a universal source of energy occurring in all cell types. In animals it is produced during the degradation of foodstuff.



ATP is formed and hydrolysed at a rate of around 9×10^{20} molecules per second, equivalent to a turnover rate of ATP of 65 kg per day

Respiratory chain couples oxygen consumption with ATP synthesis



ATP-synthase

The rotary catalytic mechanism of mitochondrial
ATP synthase.

© Medical Research Council

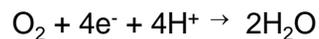


Mitochondria are main source of energy
production in a cell

Most likely mitochondria are responsible for production of 90% of our ATP.

Inner mitochondrial membrane ~1400m²

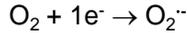
During respiration in mitochondria oxygen undergoes
4-electron reduction:



but...

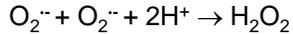
Reactive oxygen species (ROS)

One electron reduction of molecular oxygen



Superoxide radical
(photochemistry or biological systems)

Dismutation of superoxide radical



Hydrogen peroxide
(hair lightening)

Transition metal ions catalyse

Fenton reaction



Hydroxyl radicals
(house bleach)

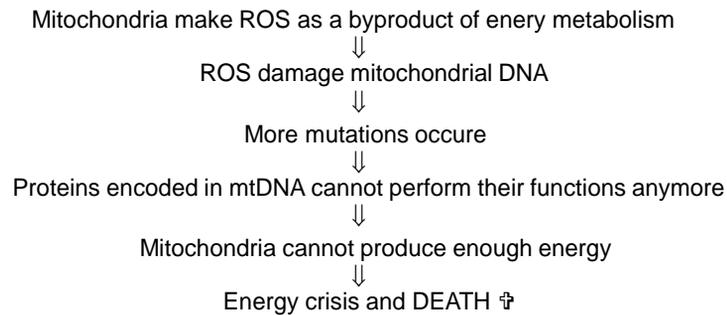
Small fraction of electrons can “leak” from the respiratory chain. Some of oxygen molecules can be reduced by less than 4 electrons and form “free oxygen radicals” or reactive oxygen species (ROS) – these molecules urgently want to accept or to release electrons to go to the low energy state \Rightarrow they are highly reactive and can interact with other molecules in a cell – proteins, DNA and membrane lipids.

Sources of ROS

- Enzymatic = leak from mitochondria and other systems
- Toxic compounds (paraquat, sulfa drugs, antimalarial drugs)
= these can be called “pro-oxidants”
- Smoking
- Ionising radiation and UV

Why mitochondria killed us in the end?

Mitochondrial free radicals theory of ageing



How to change the situation?

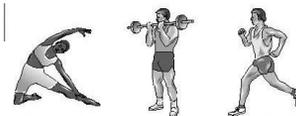
Molecules that can scavenge ROS are called antioxidants (found in fruits and vegetables).



Caloric restriction after 40 yo – the less electrons are going through the mitochondria, the less leak would happen.

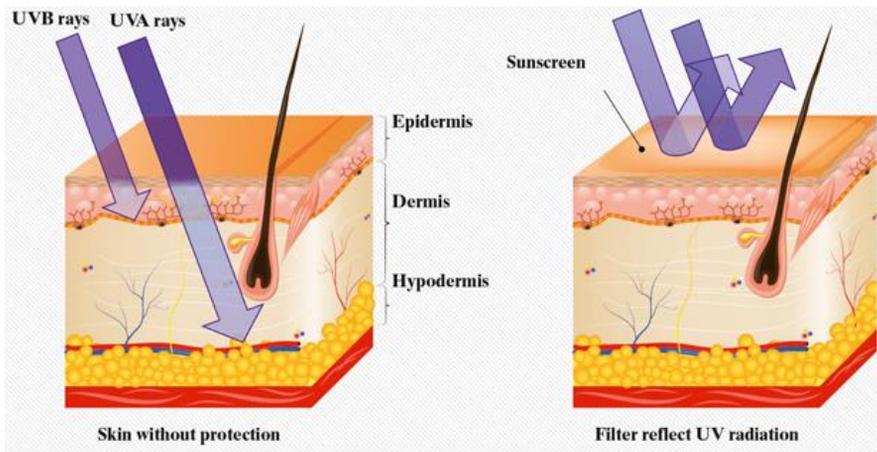


Physical exercises strongly stimulate natural mechanisms of ROS detoxification



Girls and boys! Fruits, caloric restriction after 30-40 yo and exercise!

Use sun screen - the earlier the better!



Ugly exception: Naked rat mole



Naked mole rats live ~30 years (not 3-4 years as other rodents)

They are mammals but their temperature is not constant

Has only 100 hairs

Underground colonies are organized like an insect community around a single breeding queen and workers and soldiers.

Ugly exception: Naked rat mole



More info and bioenergetics links

<http://agalkin.complexi.org/>