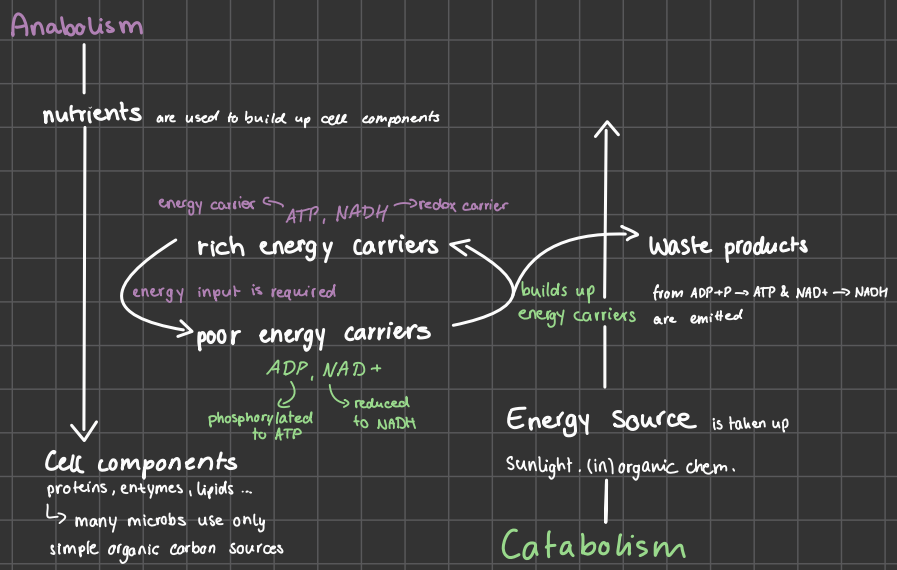
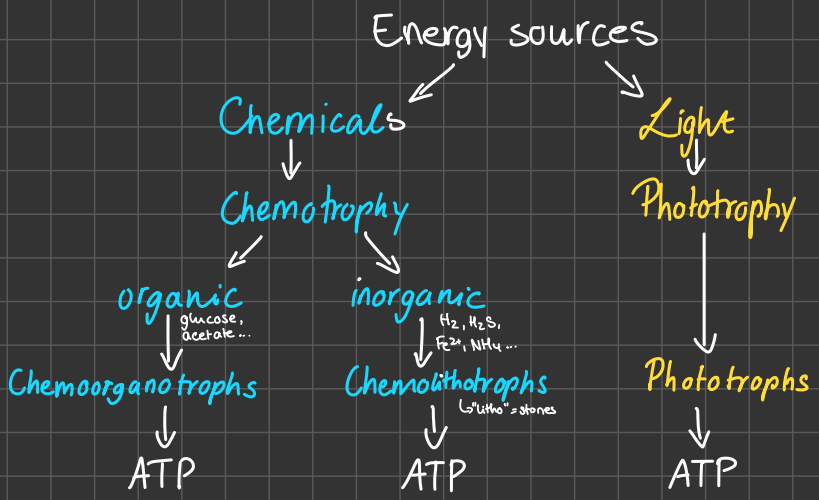
Metabolism: Anabolism & Catabolism



Where microbs get their energy from



Coupling of endergonic & exergonic reactions – redox reactions

glucose is burned with O_2 → producing CO_2 & H_2O
↳ this encloses $\Delta G^{0'} = -2863$ kJ/mol of energy, which is released through this exergonic reaction → 1 mol of glucose

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

reverse reaction, USES the same amount of energy in form of ATP to make glucose
($\Delta G^{0'} = +2863$ kJ/mol)
→ endergonic reaction

Half reaction: donating e^-

$H_2 \longrightarrow 2e^- + 2H^+$

$\frac{1}{2}O_2 + 2e^- \longrightarrow O^{2-}$

Half reaction: accepting e^-

$H_2O \longrightarrow H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$ → net charge = 0

↳ 2 protons

→ 2 electrons

Calculating free energy ($\Delta G^{0'}$)

$\Delta G^{0'} = -n \cdot F \cdot \Delta E^{0'}$ → redox potential difference

↳ Faraday's constant 96.5 kJ $mol^{-1} V^{-1}$

↳ number of transferred electrons

free energy change

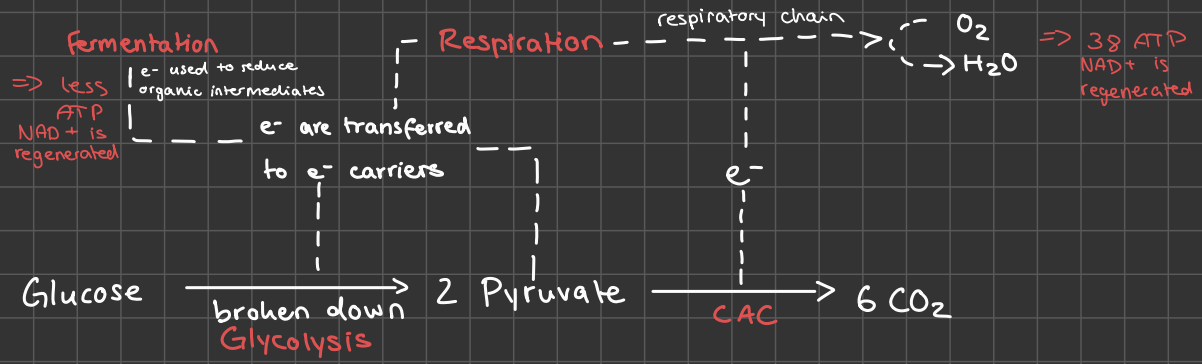
$\Delta G < 0$ → exergonic

$\Delta G > 0$ → endergonic

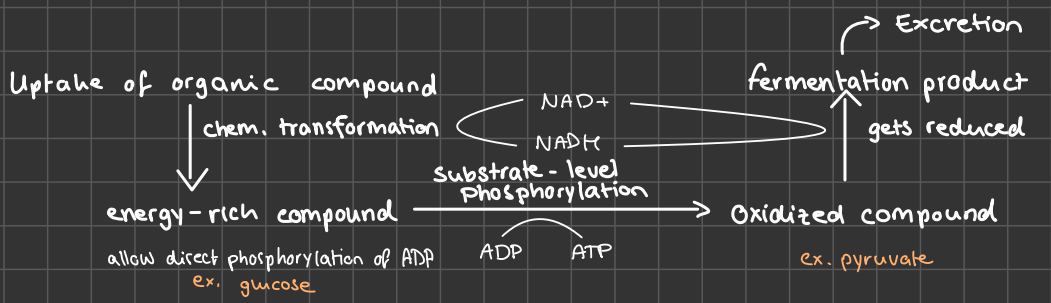
ex.: $\Delta E^{0'} = +820\,mV - -414\,mV = 1234\,mV = 1.234\,V$

$\Rightarrow \Delta G^{0'} = -2 \cdot 96.5\,kJ/mol^{-1} V^{-1} \cdot 1.234\,V = -238\,kJ\,mol^{-1} \Rightarrow -238\,kJ/mol$

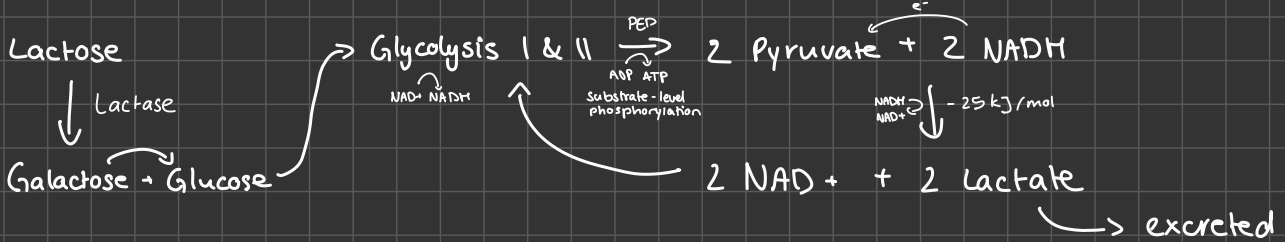
Chemoorganotrophs



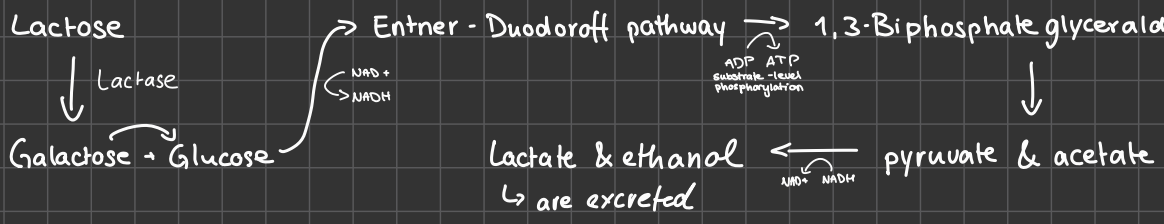
General fermentation cycle



Homofermentative Lactic acid fermentation



Heterofermentative Lactic acid fermentation



Alcohol fermentation

Glucose

↓ Stage 1 & 2

PEP

↓ Substrate-level phosphorylation (ADP → ATP)

2 Pyruvate + 2 NADH

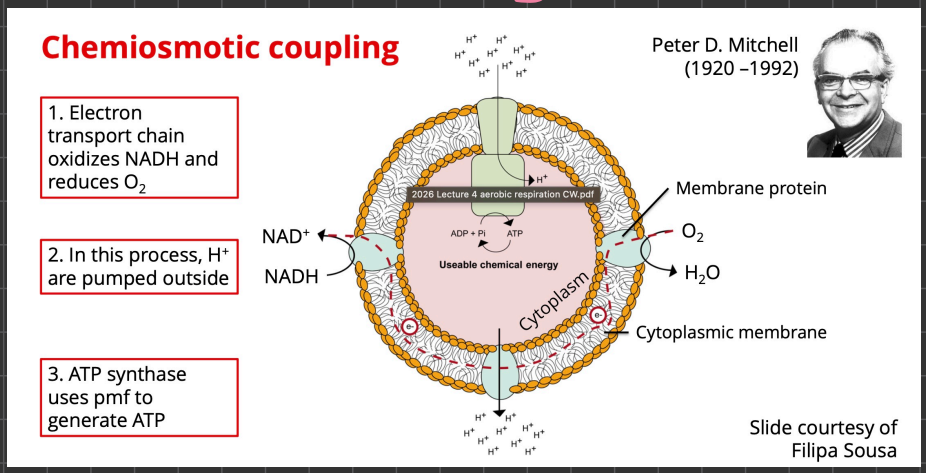
↓ Pyruvate decarboxylase
↳ produce CO_2 by chopping it off pyruvate

2 acetaldehyde + 2 CO_2
↳ very toxic

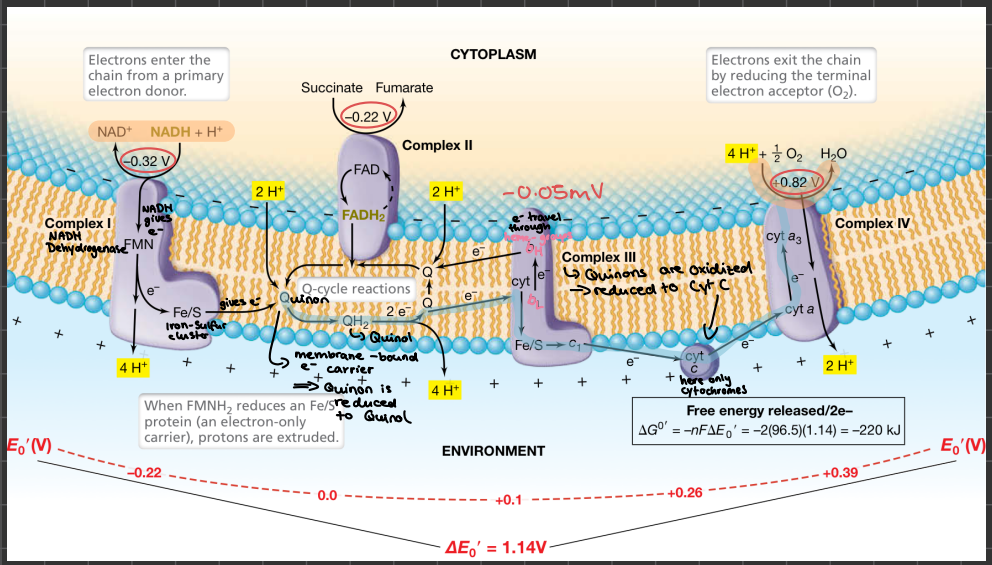
↓ Alcohol dehydrogenase
↳ reduces acetaldehyde

2 ethanol + 2 CO_2 ⟶ released to environment
↳ fermentation products

Chemiosmotic coupling



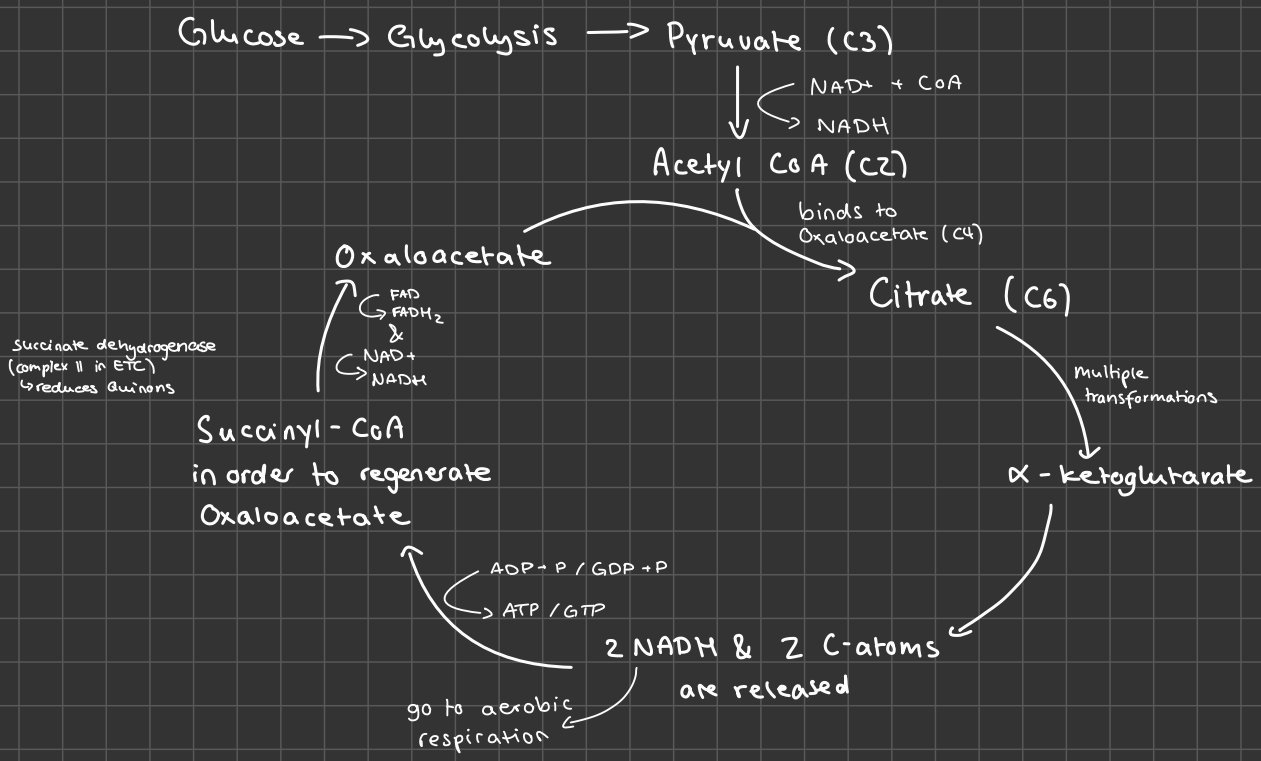
Aerobic respiration



Free energy released / 2 e^-

$\Delta G^{0\prime} = -nF\Delta E_0{}' = -2\,(96.5)(1.14) = -220$ kJ

Citric acid cycle / TCA cycle



Overall energetic balance

Glycolysis : Glucose → 2 Pyruvate + 2 ATP + 2 NADH

- Substrate level phosphorylation: 2 ADP + P → 2 ATP
- Oxidative phosphorylation: 2 NADH → 6 ATP
- } 8 ATP
- 2 Pyruvate → CAC
- 2 NADH → Complex I

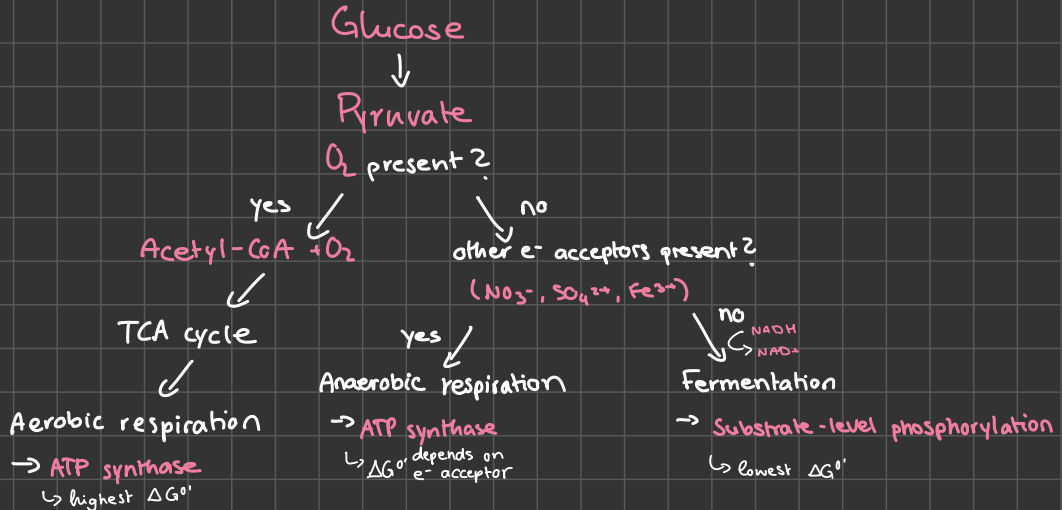
CAC : Pyruvate + 4 NAD+ + GDP + FAD → 3 CO_2 + 4 NADH + $FADH_2$ + GTP/ATP

- Substrate level phosphorylation: ADP/GDP + P → ATP/GTP
- Oxidative phosphorylation: 4 NADH → 12 ATP
- Oxidative phosphorylation: 1 $FADH_2$ → 2 ATP
- } 2x 15 ATP
- 4 NADH → Complex I
- $FADH_2$ → Complex II

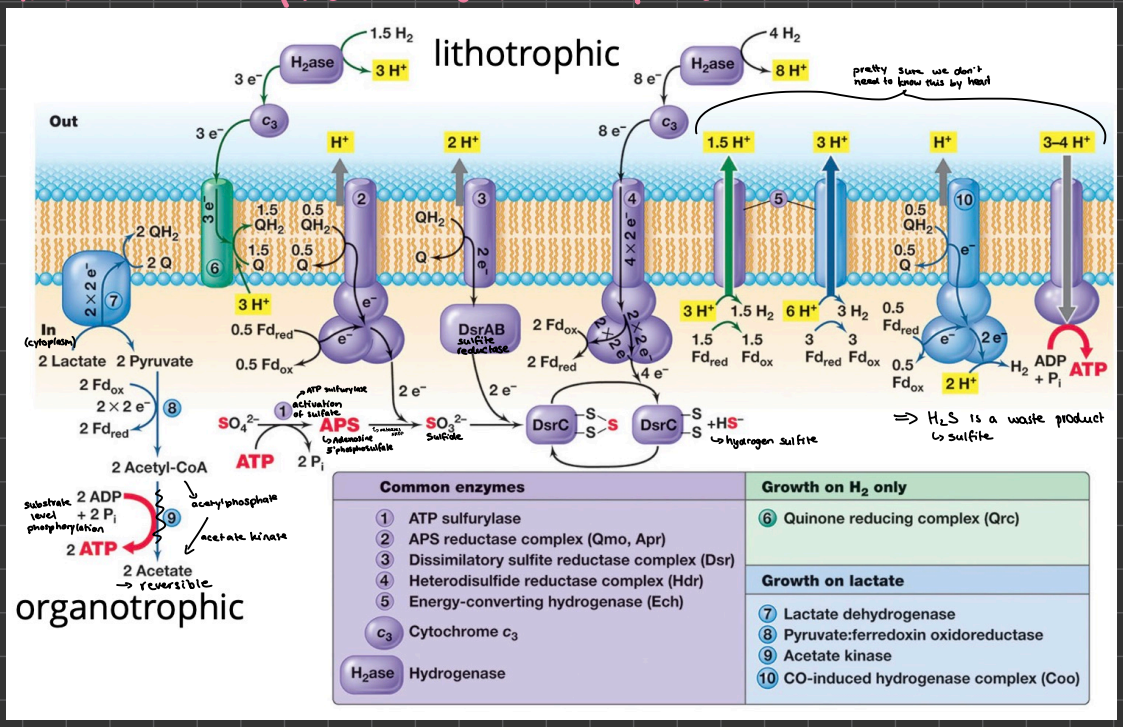
Glycolysis + CAC → 38 ATP per Glucose

Not all energy is harvested – some is released as heat ⇒ reaction can go forward

Decision chart : fermentation or fermentation

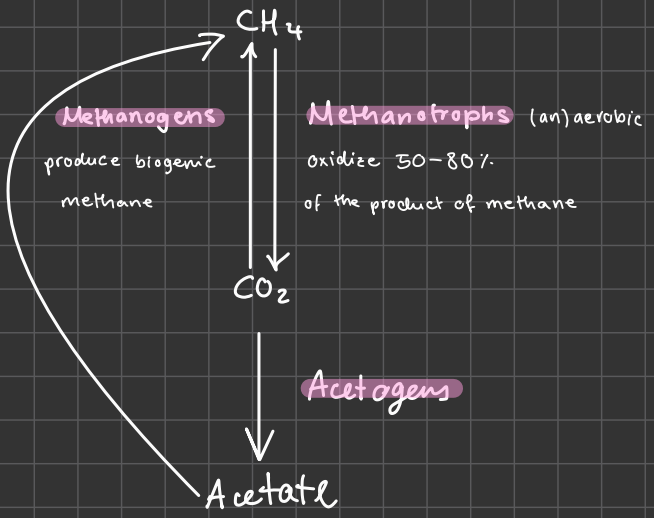


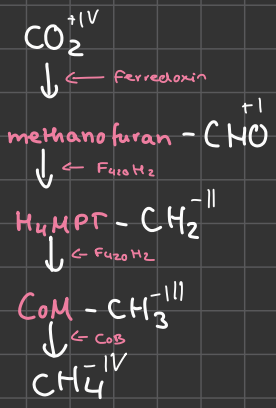
Anaerobic respiration with sulfate



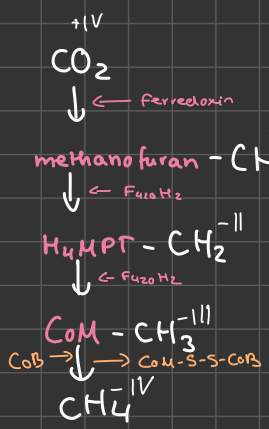
Lecture 6.

Methanogenisis VS Methanotrophy





Hydrogenotrophic methanogenesis



3 Types of methanogens

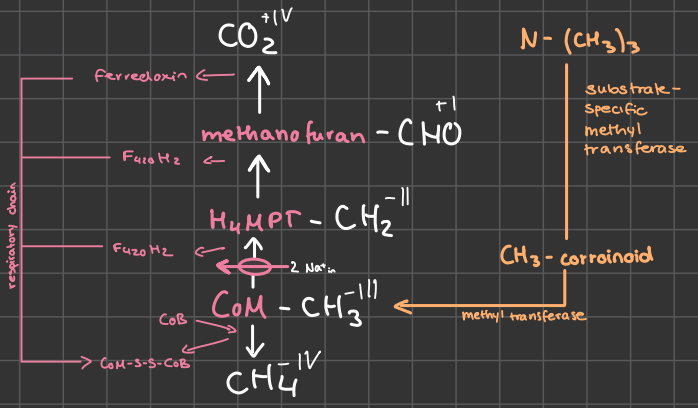
- 2 Hydrogenases are key to delivering e^- from H_2 to redox carriers

$$H_2 + F_{420} \xrightarrow{\text{hydrogenase}} F_{420}H_2$$

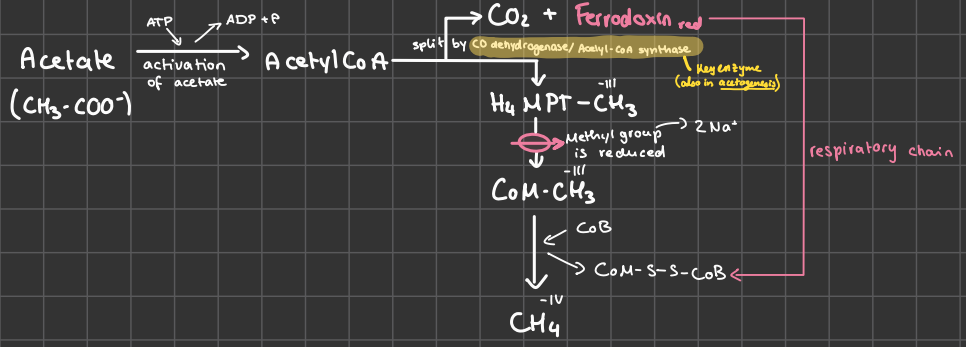
- Bifurcation: e^- go 2 different ways
  - 1 goes to reduce CoM-S-S-CoB → CoM-SH & CoB-SH → stops metabolism
  - 1 goes to reduce ferredoxin$_{ox}$ → ferredoxin$_{red}$

↳ flavins are used to give 1 e^- at a time

Methylotrophic methanogenesis

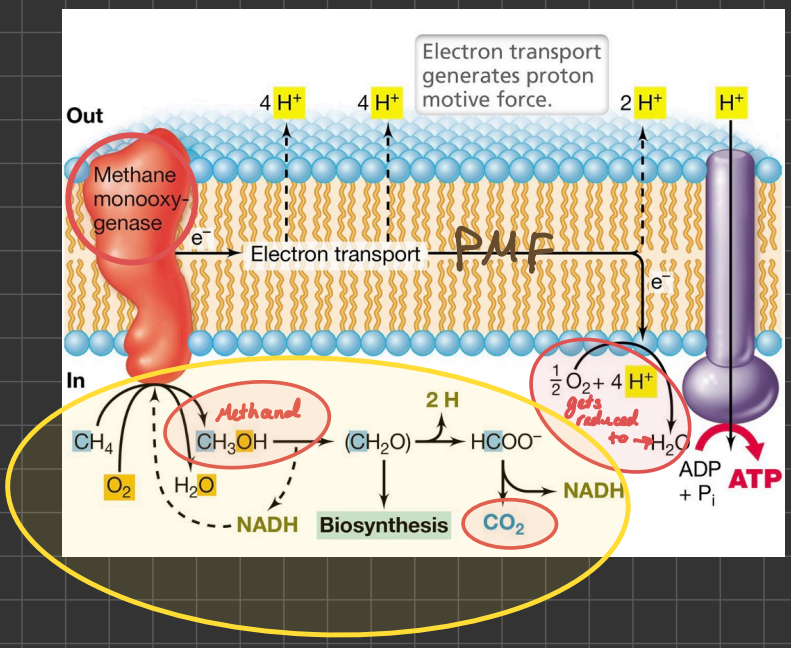


Acetoclastic methanogenesis



2 types of methanotrophs / methane oxidisers

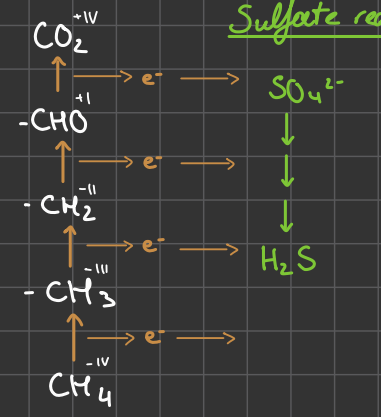
Aerobic Methanotrophy



Anaerobic methanotrophy

ANME

Sulfate reducer

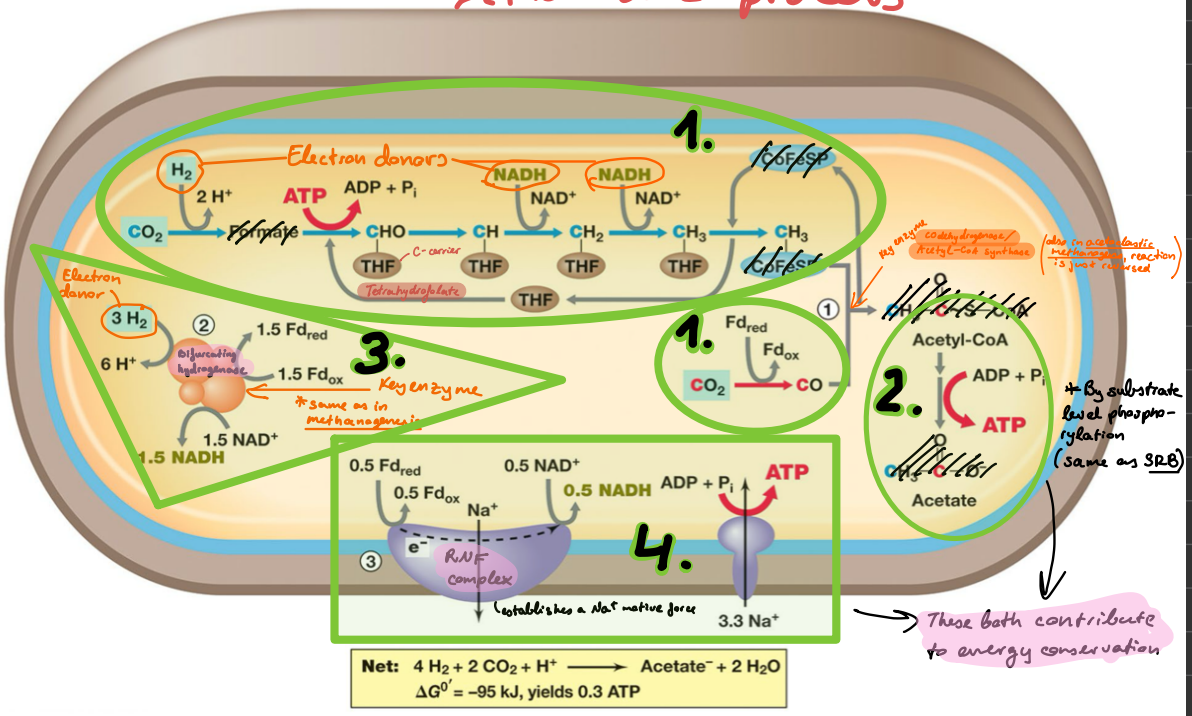


From this, electrons make PMF, from which $O_2 \rightarrow H_2O$ & ATP synthesis

Acetogenesis

Wood - Ljungdahl

→ Anaerobic process



Net: $4\ H_2 + 2\ CO_2 + H^+ \longrightarrow Acetate^- + 2\ H_2O$

$\Delta G^{0\prime} = -95$ kJ, yields 0.3 ATP

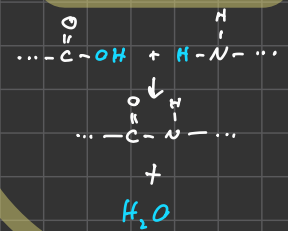
Department of Microbiology

Notes:

- First part same as methanogenesis only thing diff is the electron carrier
  - ↳ need xtra ATP to bind it

Lecture 7.

Peptide bond formation



Amino acid biosynthesis

(How ammonium can be put into aminoacids ! Only way how!)

(From TCA cycle)

α-ketoglutarate

N_2 —Nitrogen fixation→ NH_4^+

NO_3 —Assimilatory nitrate reduction→ NH_4^+

Transaminase

Glutamate

+ NH_4^+

Transaminase

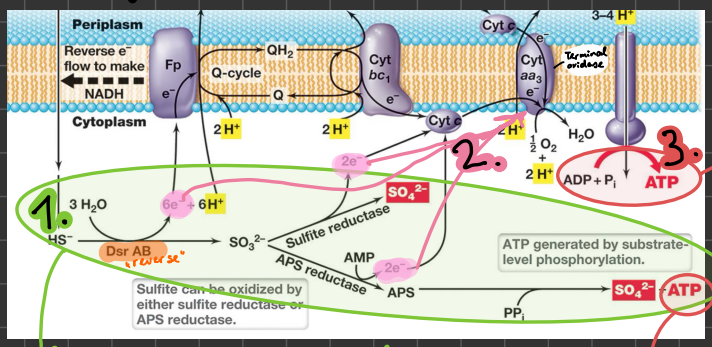
Glutamine

→ Donate ammonium to other aminoacids



Lecture 8.

Sulfite oxidation

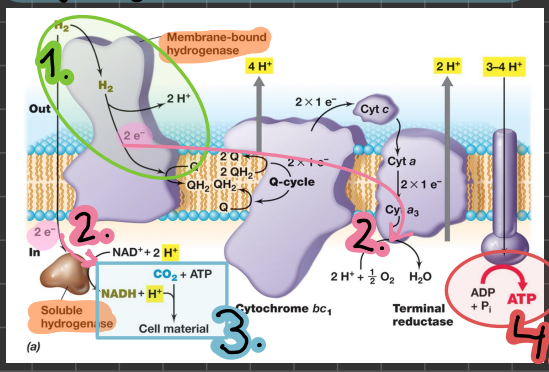


ATP from electron level phosphorylation

Pathway is the same as sulfate reduction, just reversed

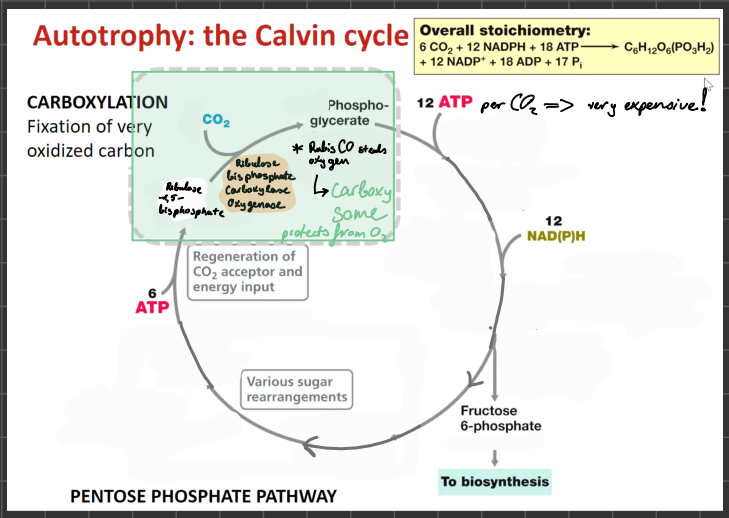
ATP from substrate-level phosphorylation

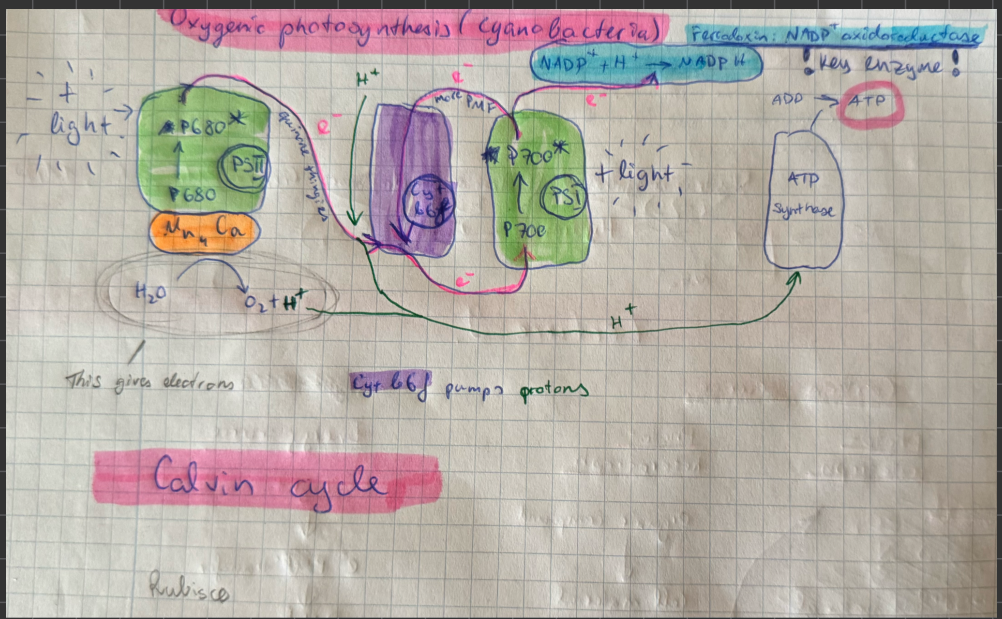
Hydrogen oxidation



* Used by Knallgas (the tube worm bacteria)

Lecture 9.





Lecture 9

Carbon source

Photo-autotroph

Photo-heterotroph

Organic compound

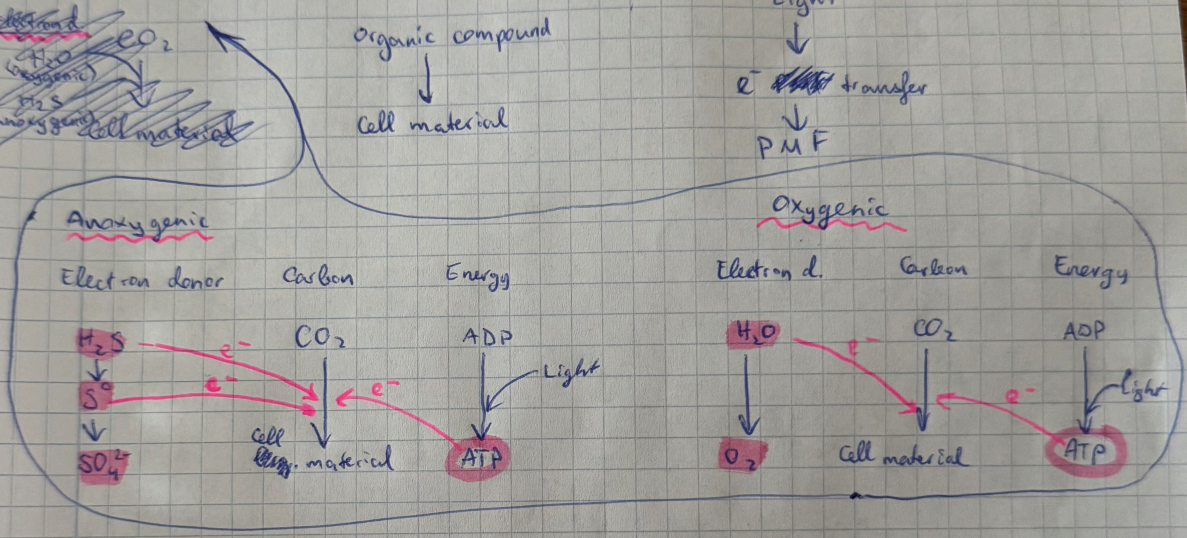
Cell material

Energy source

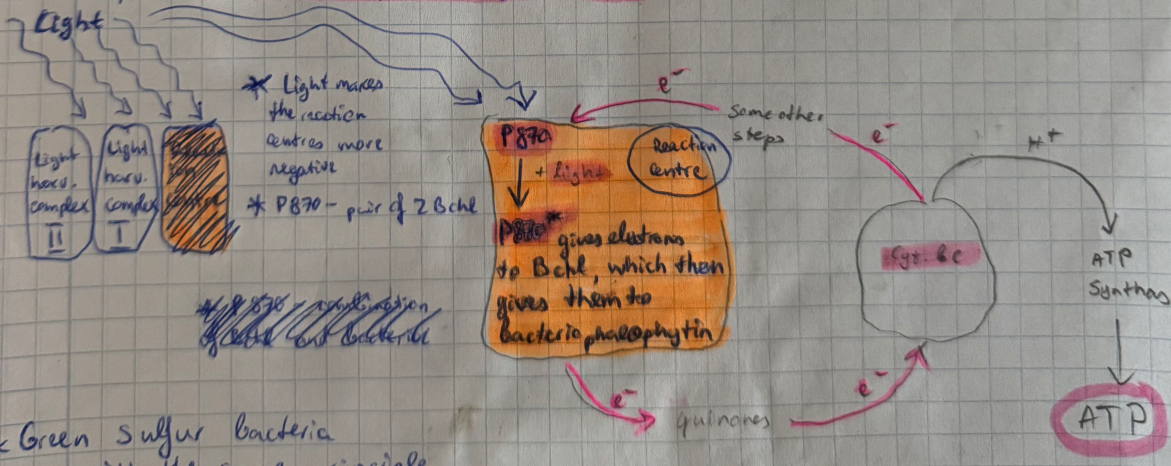
Light

e^- transfer

PMF



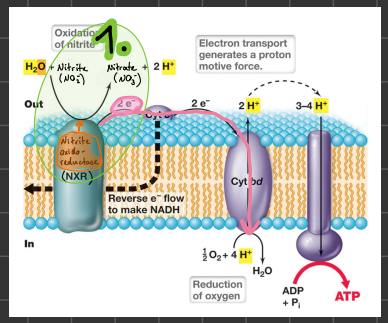
Purple bacteria photosynthesis



* Green sulfur bacteria work with the same principle, but diff pigments and diff P___.

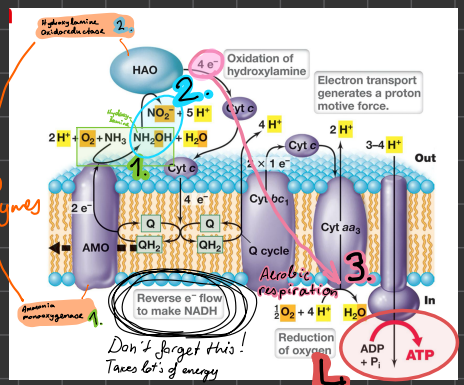
Nitrogen cycle

Nitrite oxidation



NO_2^-

Ammonium oxidation



Key enzymes

Aerobic respiration

Don't forget this! Takes lot's of energy

NO_3^-

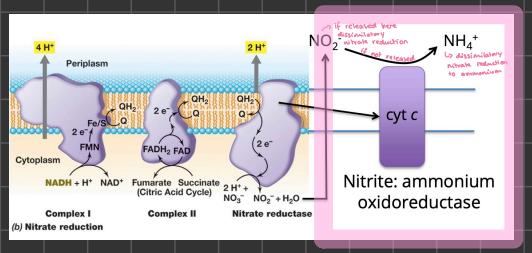
Organic Nitrogen

Ammonification

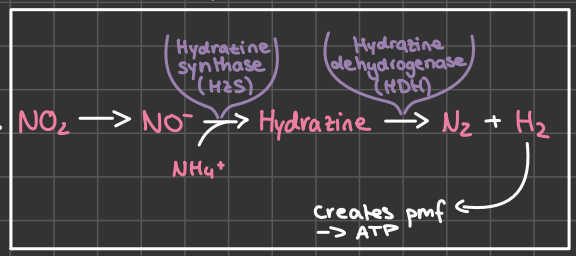
NH_3

Oxic / Anoxic

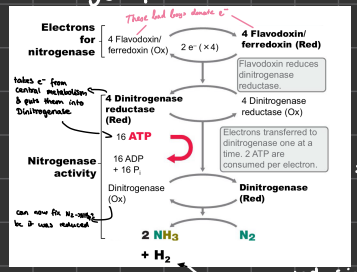
Dissimilatory nitrate reduction (to ammonium)



Anammox reaction



Nitrogen fixation



- Fe Mo Cofactor is specific to Nitrogenase
  - ↳ molybdenum ion inside
  - => cells need it in environment if they have nitrogenase

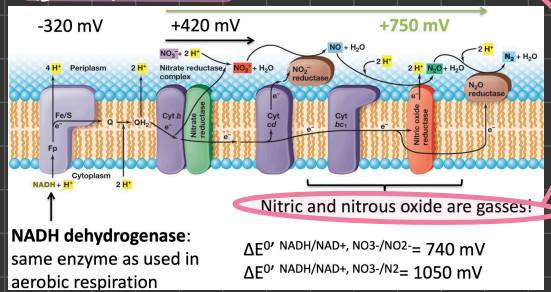
unwanted side product

NO_2^-

NO
N_2O

N_2

Dinitrification



NADH dehydrogenase: same enzyme as used in aerobic respiration

$\Delta E^{0\prime}$ NADH/NAD+, NO3-/NO2- = 740 mV

$\Delta E^{0\prime}$ NADH/NAD+, NO3-/N2 = 1050 mV