Life detection on Europa from a lander: metabolic signatures

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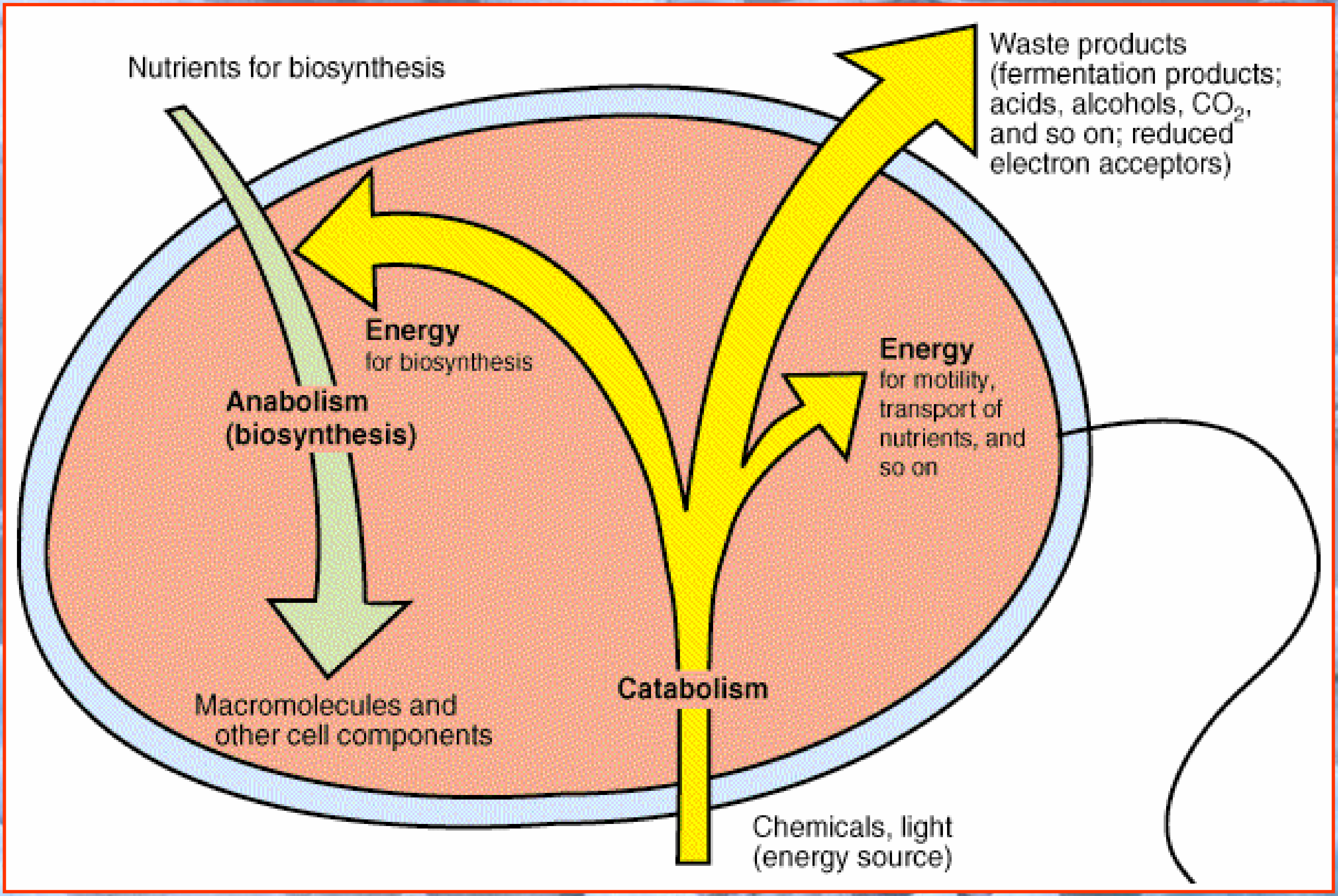
Starting Hypothesis

- **If Life exists on Europa**
  - **Living Entities are small-sized and not visible from an Orbiter**
  - **Living Entities are organized like Cells and have properties similar to living Cells on Earth**
  - **These Cell-like Entities carry out Carbon Chemistry in liquid Water**

How to detect microbial Cells from an Orbiter

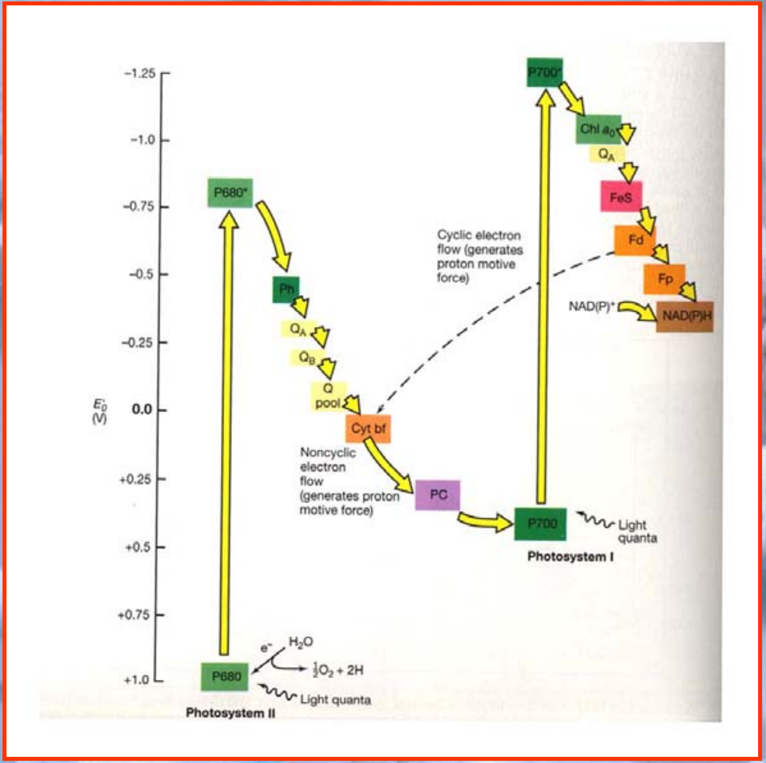
- We cannot look at them
- We cannot measure their metabolic activity
- We can search for Life Macromolecules, but there is a serious detection limit problem: a single cell dry weight is about 10^{-12} g.
- But we can search for metabolic signatures

Cell Life on Earth



The best example

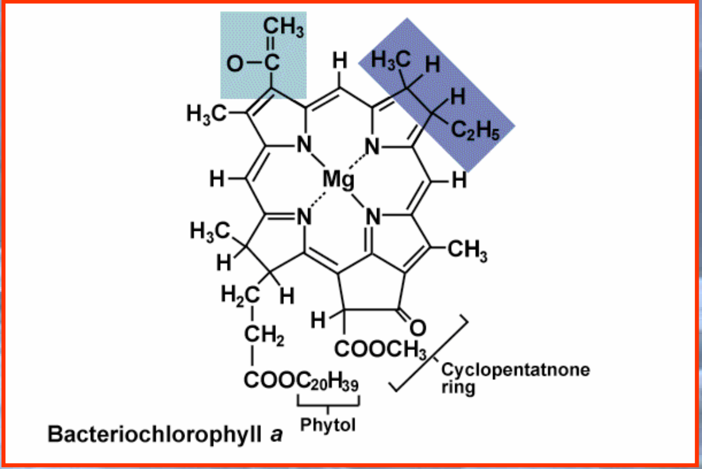
- **To fix carbon dioxide via the Calvin cycle, oxygenic photosynthetic organisms need to reduce it into carbohydrates**
- **The reducing power (electrons from Hydrogen) comes from photolysis of water**
- **This photolysis also produces O_2, which accumulated in Earth 's atmosphere**



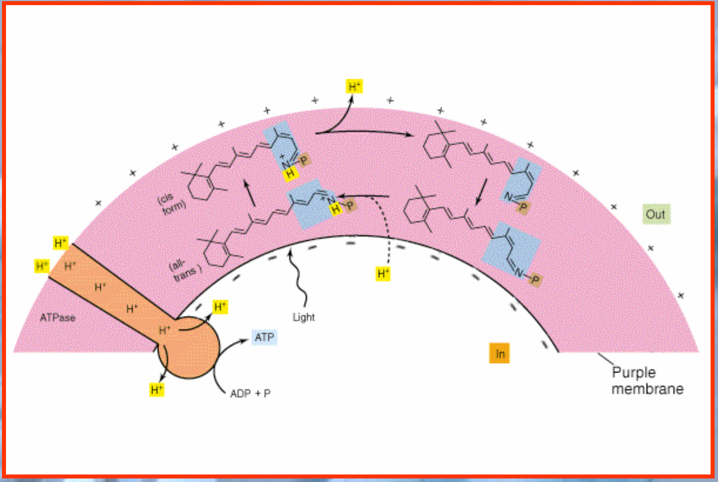
Diversity of metabolisms involved in energy production

- **Phototrophy**
- **Chemotrophy**
  - **Aerobic respiration**
    - **Organic or inorganic electron donnors**
  - **Anaerobic respiration**
    - **Organic or inorganic electron donnors**
    - **Organic or inorganic electron acceptors**
  - **Fermentation of organic compounds**

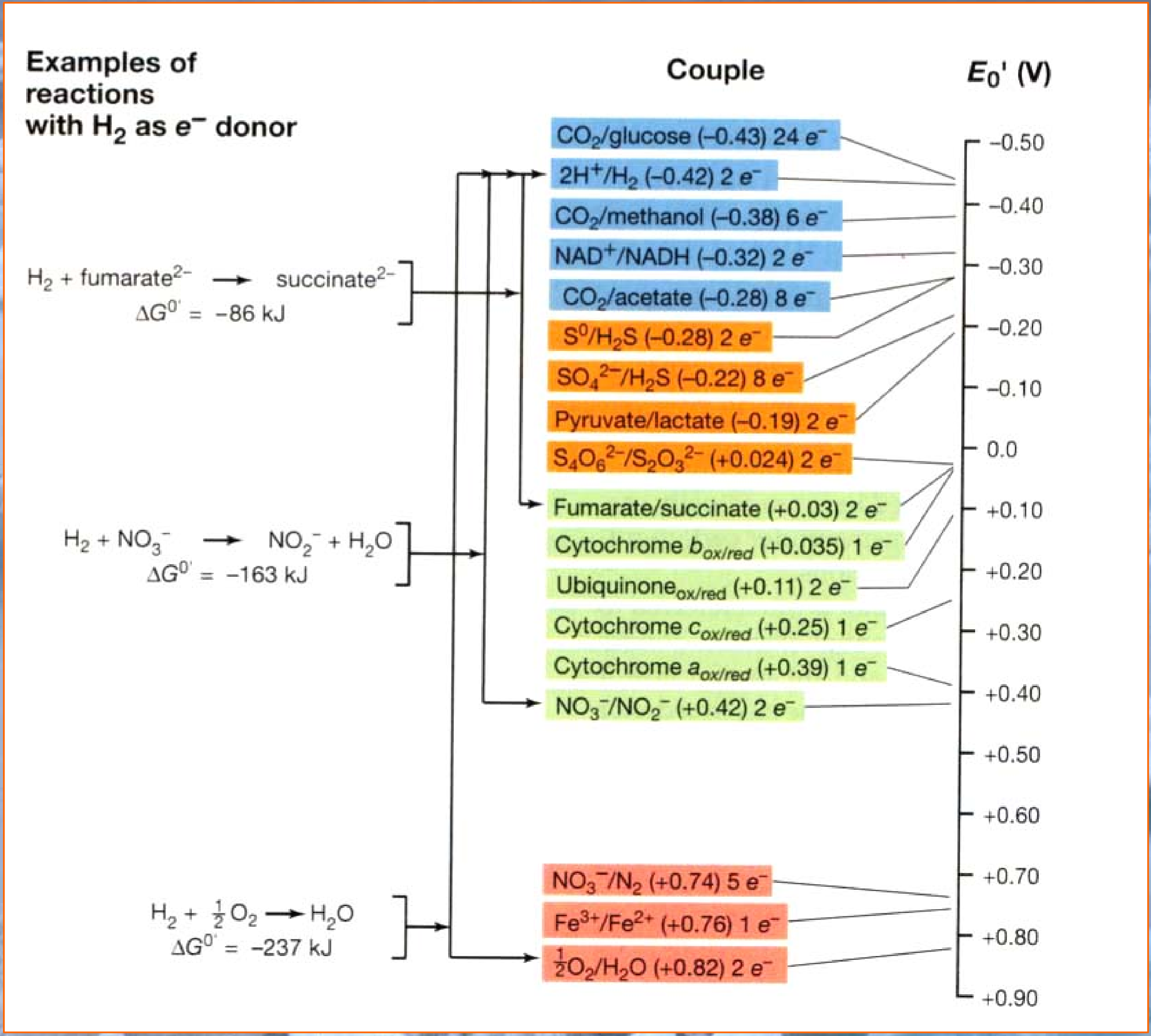
Phototrophy



- Oxygenic photosynthesis
  - O_2 detection
- Anoxygenic photosynthesis
- Bacteriorhodopsin-like processes
- In all cases: pigments



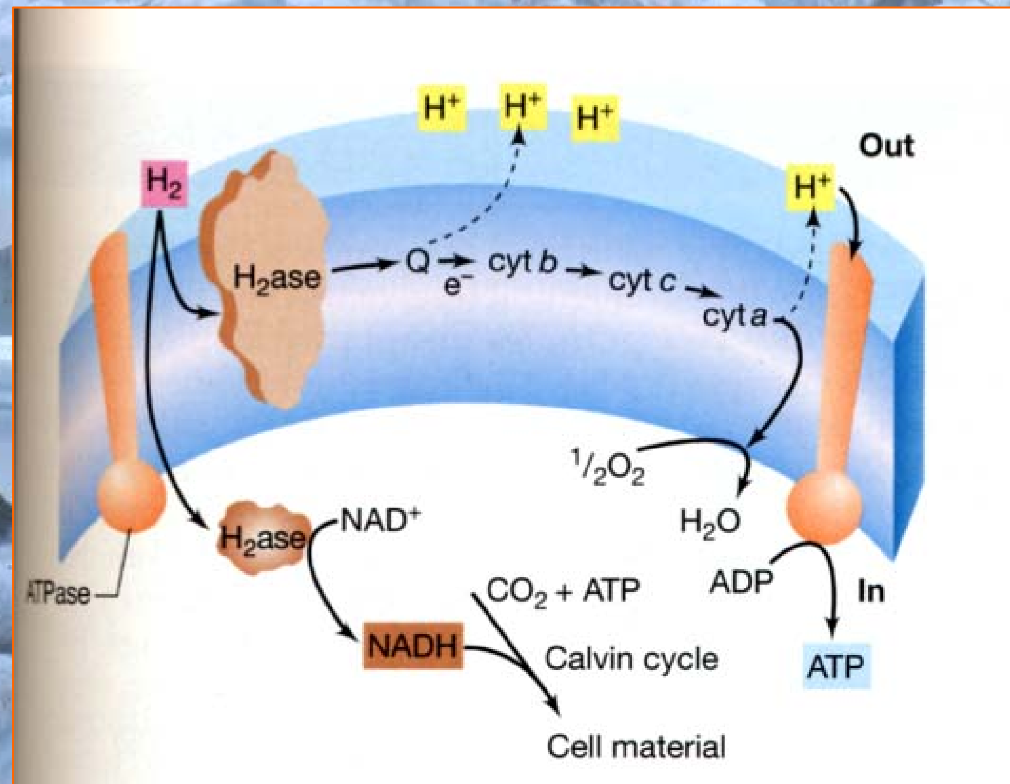
Respirations



Hydrogen oxidation

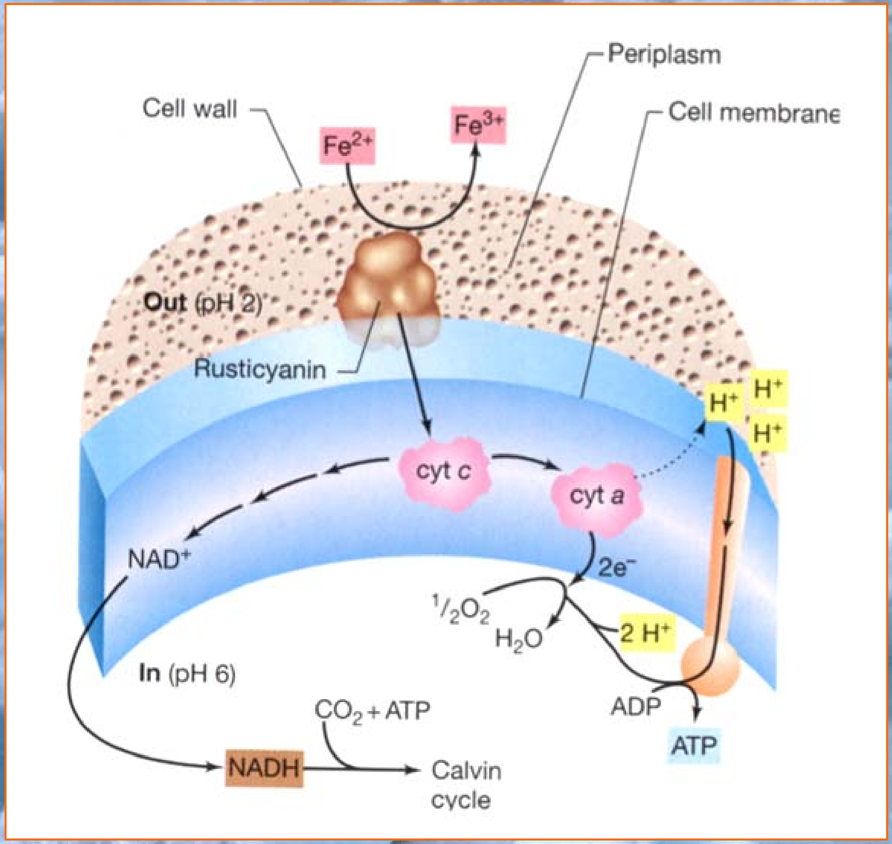
$H_2 + 1/2\ O_2 \Rightarrow H_2O$

$\Delta G^{0}{}' = -237\ kJ$



Fe ++ oxidation

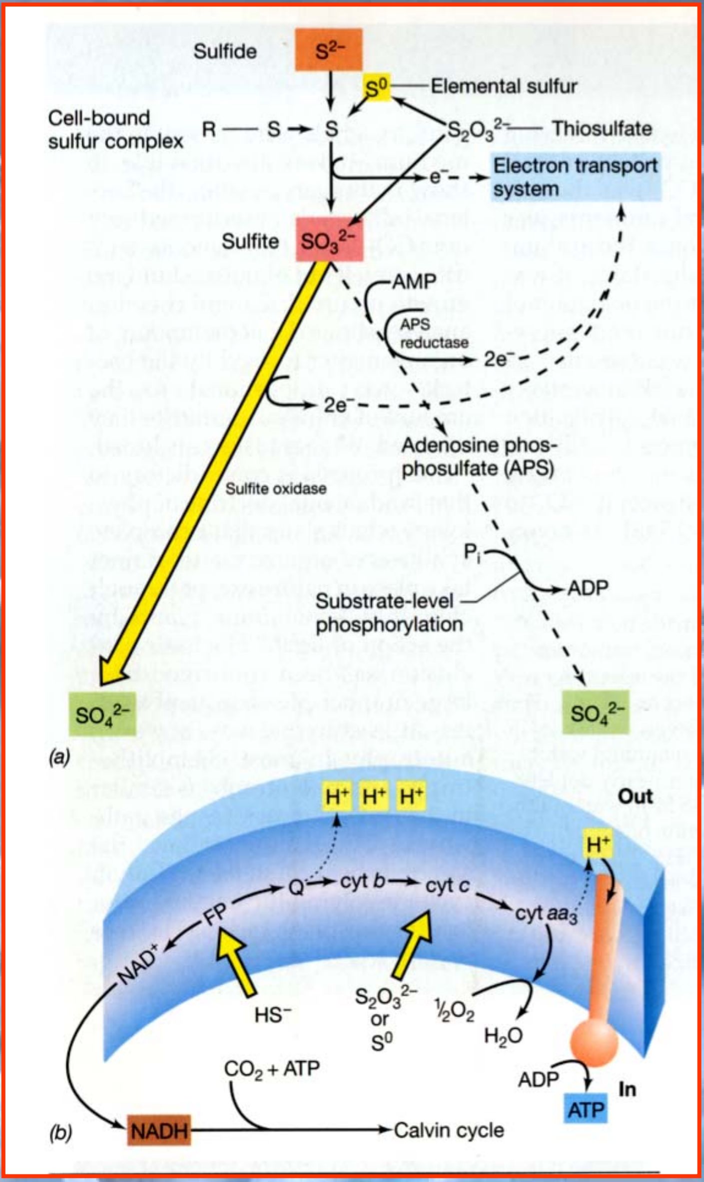
$2Fe^{++} + 1/2O_2 + 2H^+ \Rightarrow 2Fe^{+++} + H_2O$



Non soluble iron hydroxide

$FeCO_3 + 10\ H_2O \Rightarrow 4\ Fe(OH)_3 + 3\ HCO_3 + 3H^+$

Oxidation of reduced sulphur compounds



$H_2S + 2O_2 \Rightarrow SO_4^{--} + 2\ H^+$

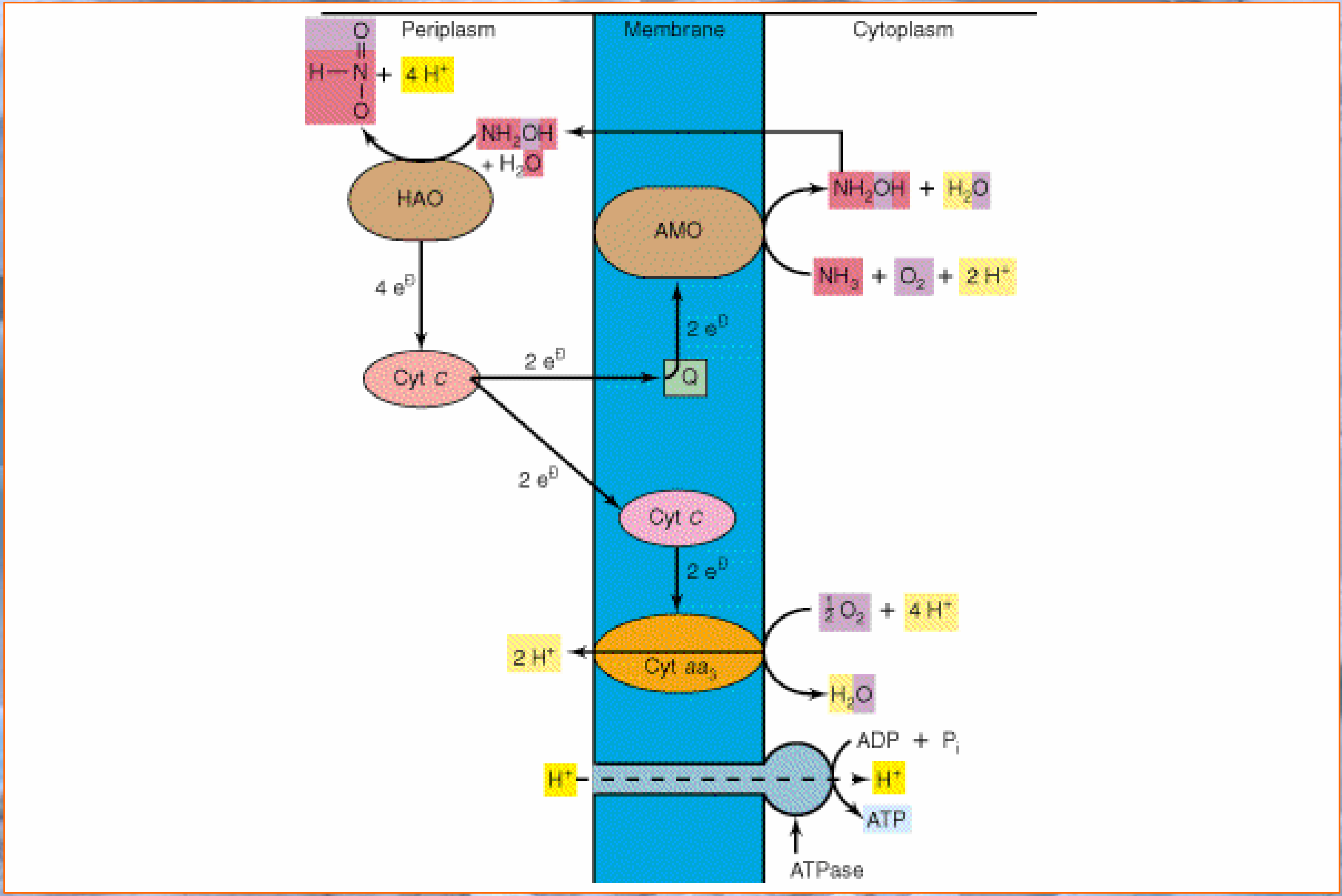
$HS^- + 1/2O_2 + H^+ \Rightarrow S° + H_2O$

$S° + H_2O + 1/2O_2 \Rightarrow SO_4^{--} + 2\ H^+$

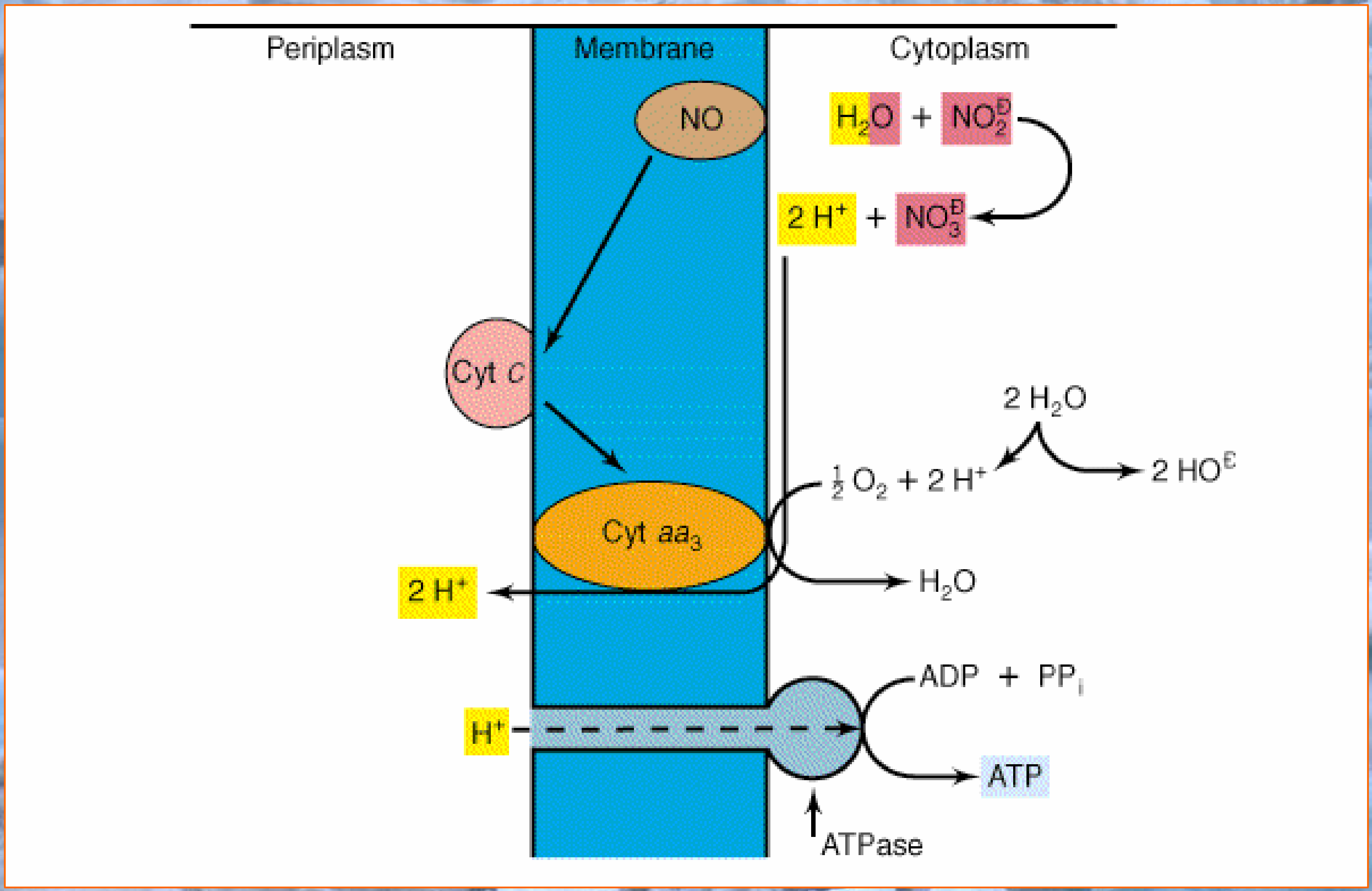
$S_2O_3^{--} + H_2O + 2O_2 \Rightarrow 2SO_4^{--} + 2\ H^+$

Environment becomes acidic

Ammonium oxidation=>Nitrite

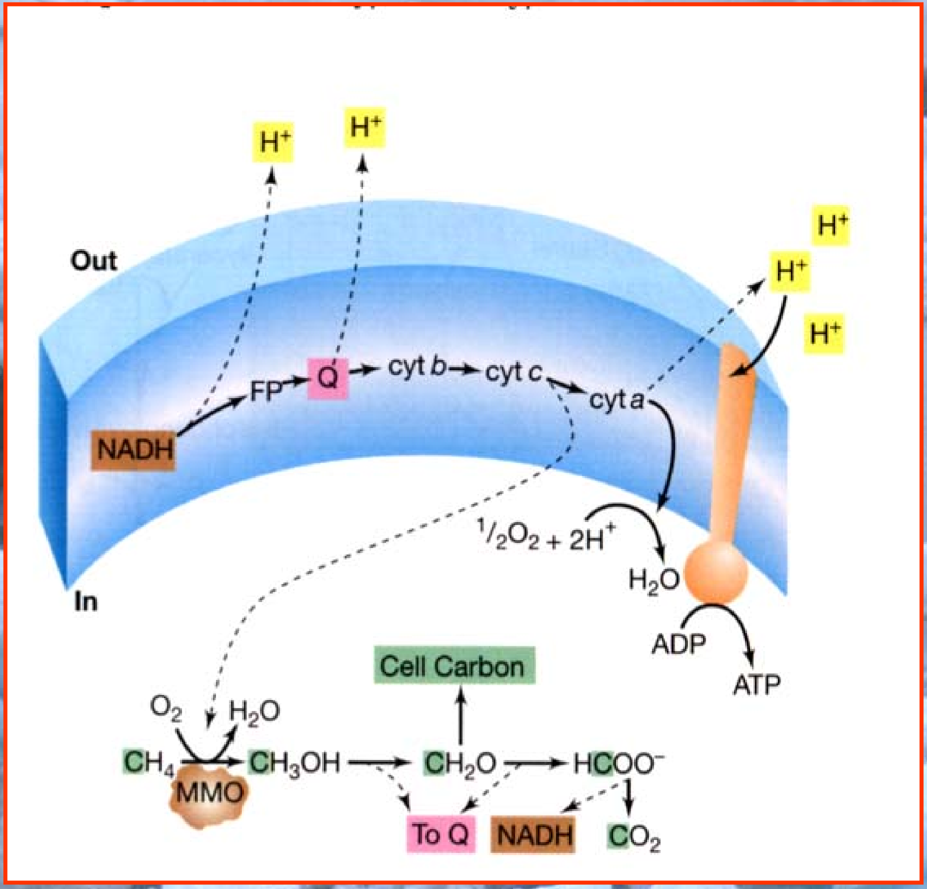


Nitrite Oxidation=>Nitrate

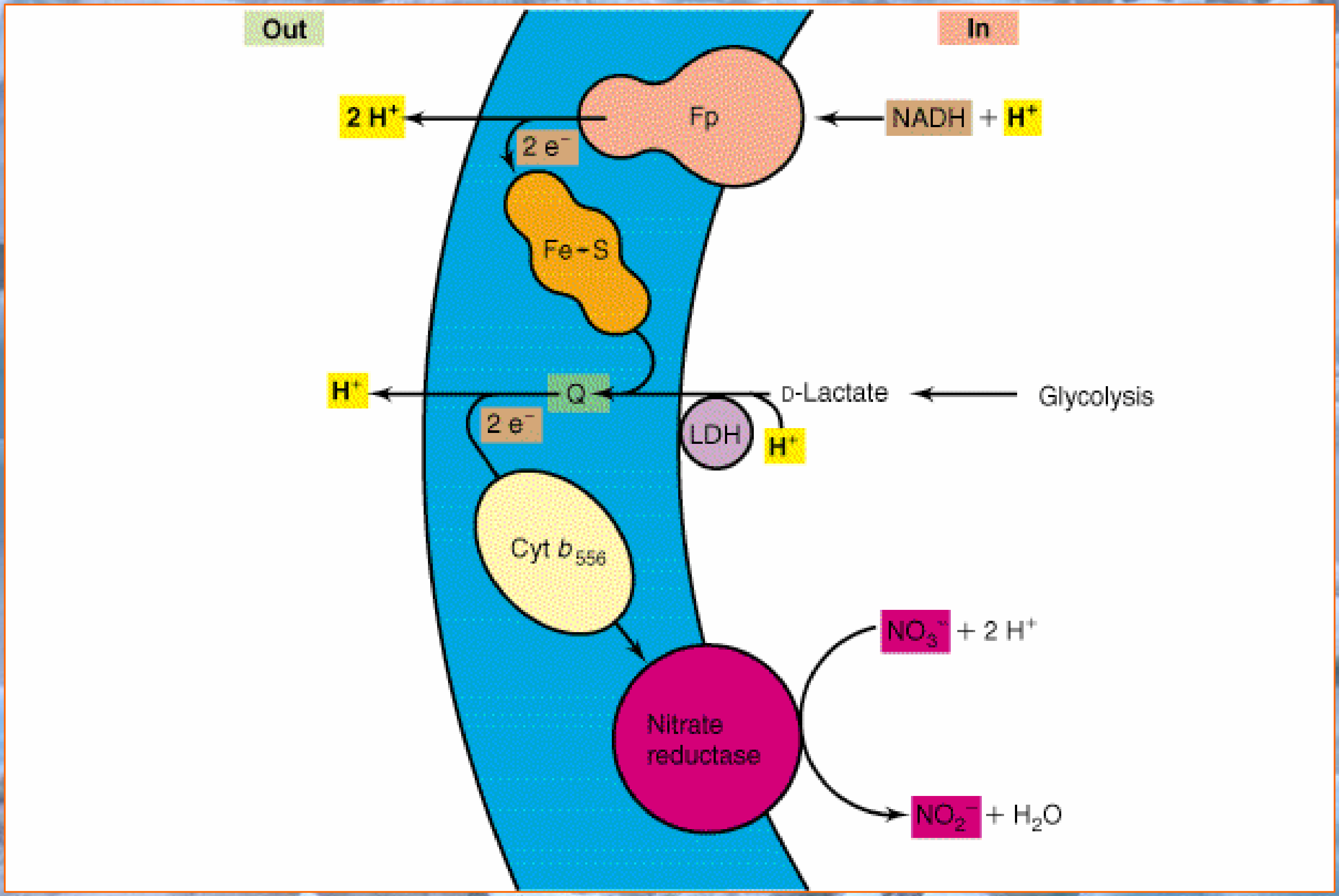


Methane & C_1 compounds oxidation

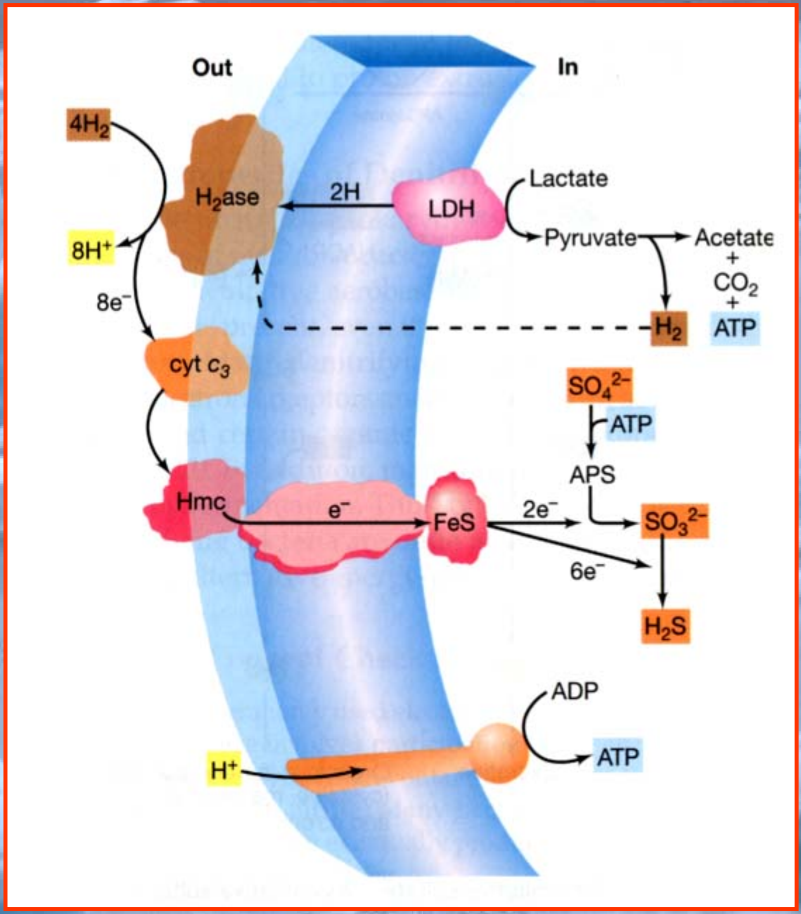
$CH_4 \Rightarrow CH_3OH \Rightarrow CH_2O \Rightarrow HCOO^- \Rightarrow CO_2$



Nitrate respiration=>NO, N_2O,NO_2, N_2



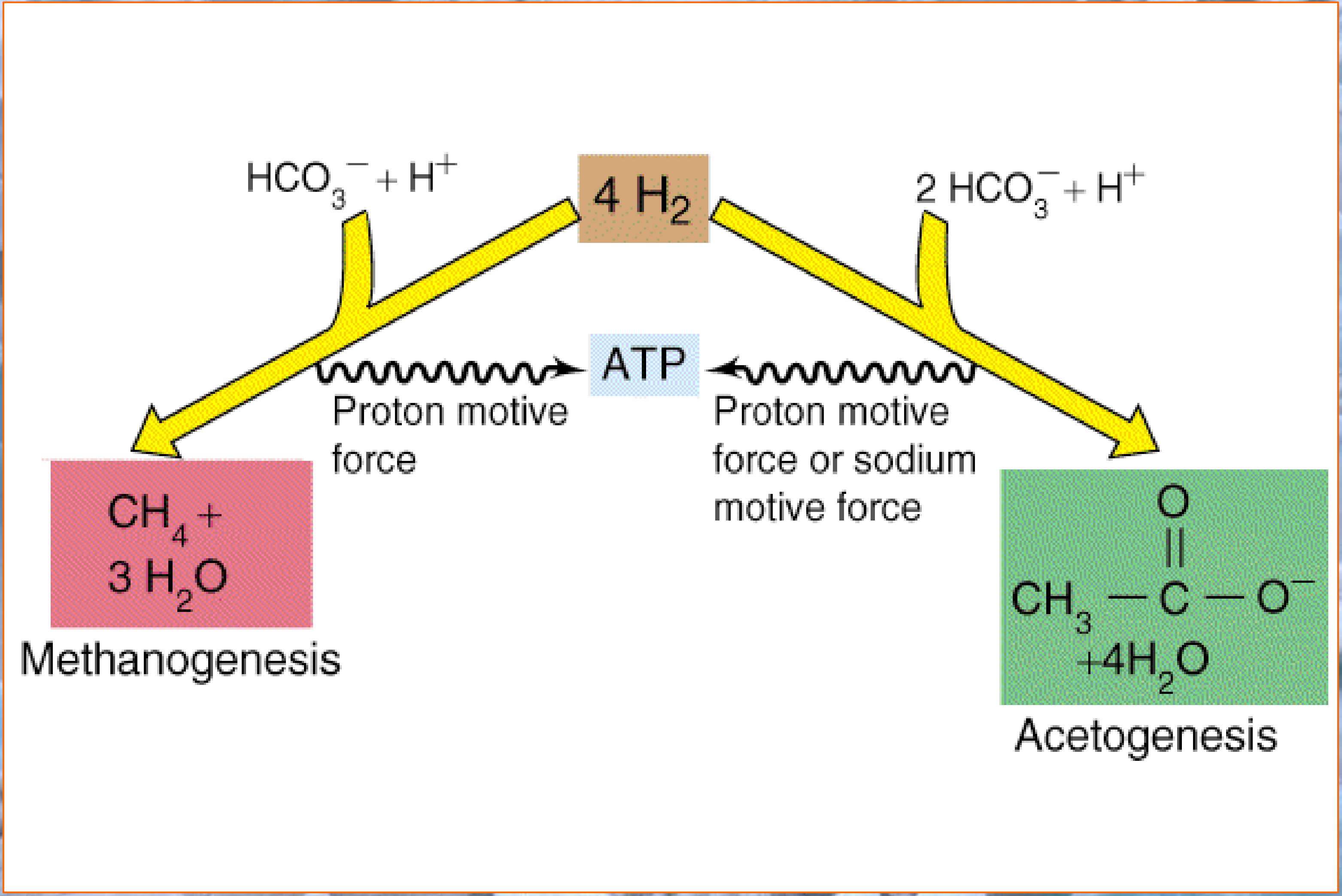
Sulphate reduction=> H_2S



$4\ H_2 + SO_4^{--} + H^+ \Rightarrow HS^- + 4\ H_2O$

$CH_3COO^- + SO_4^{--} + 3\ H^+ \Rightarrow 2\ CO_2 + H_2S + 2\ H_2O$

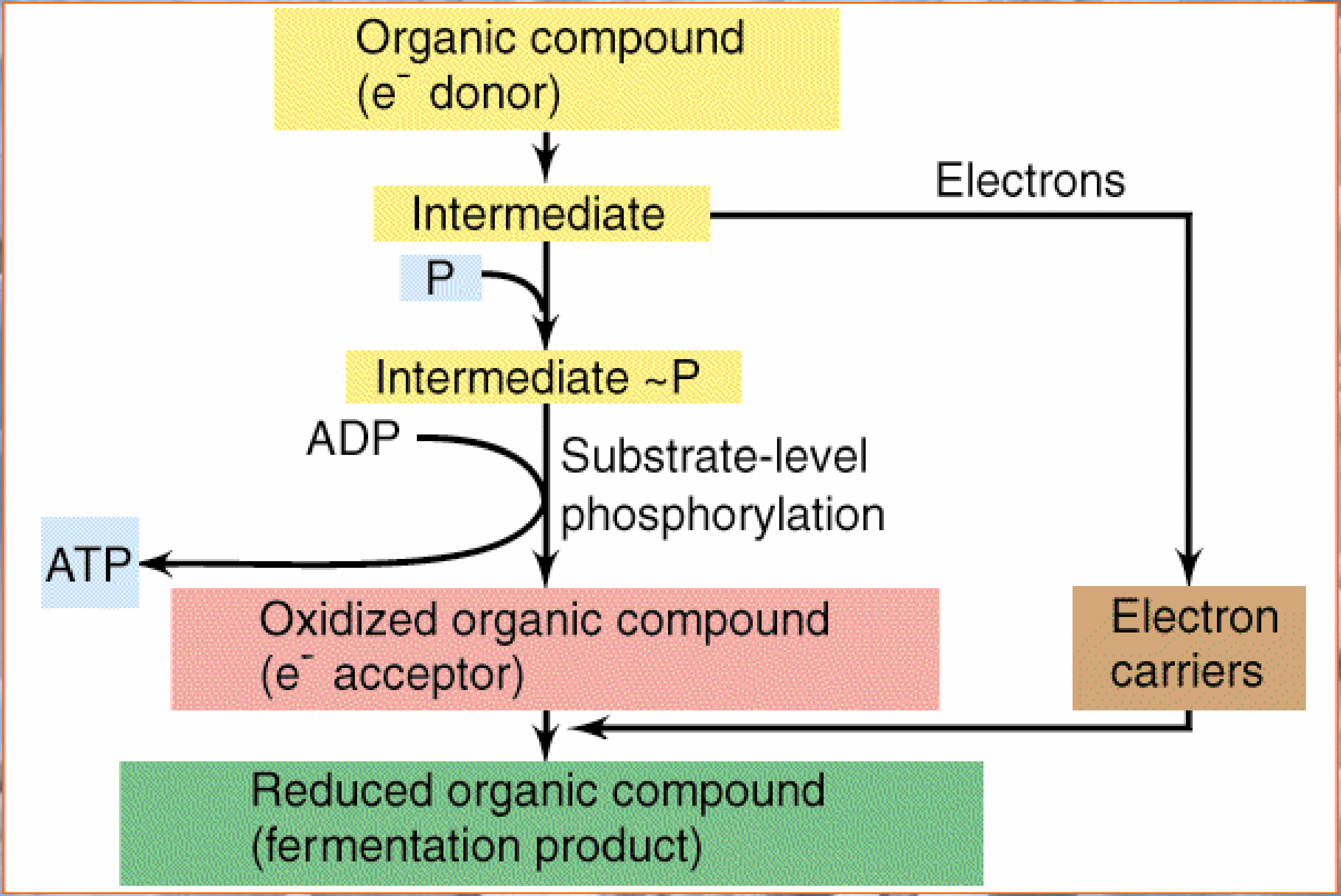
CO_2: electron acceptor



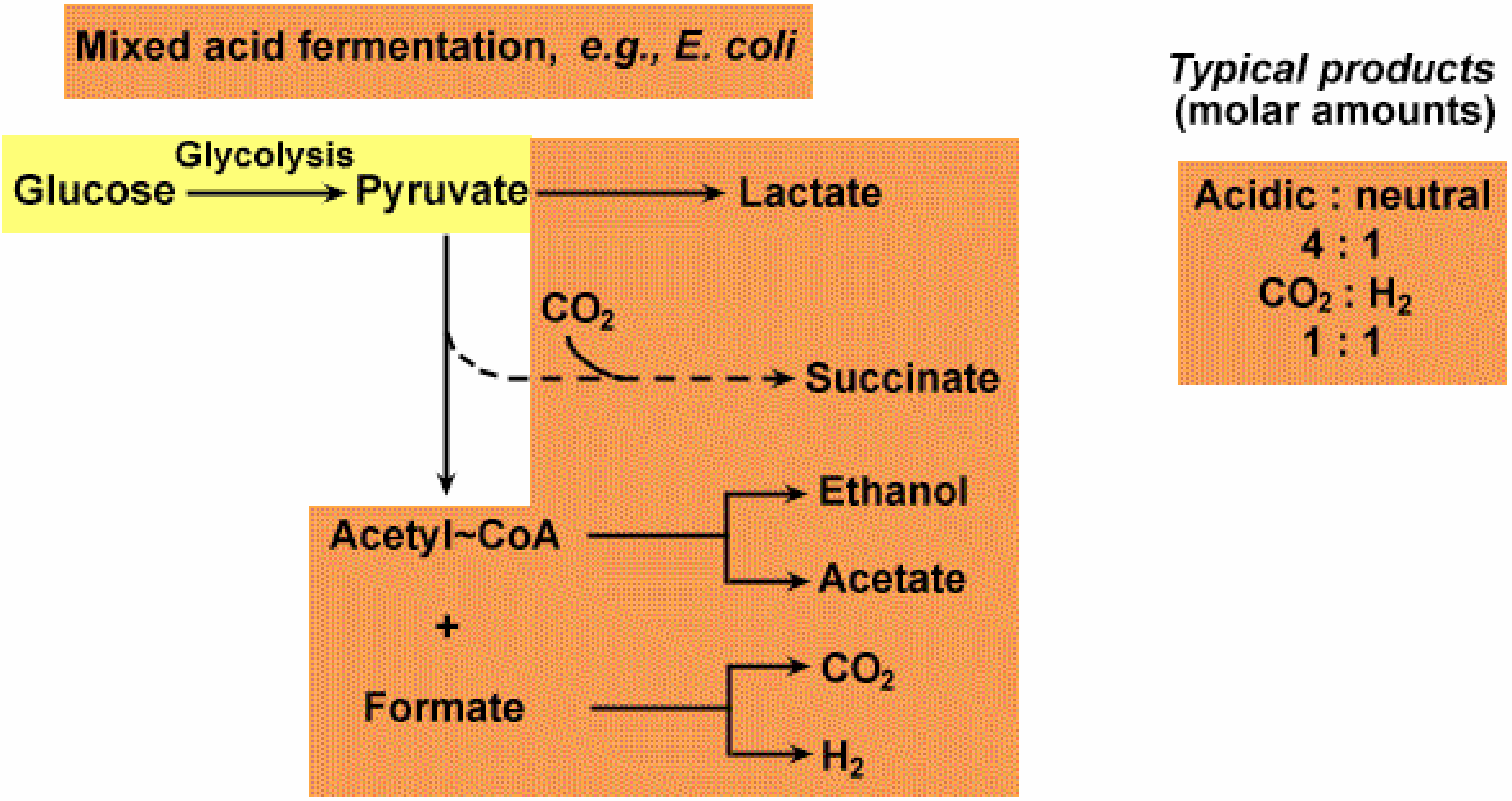
Other electron acceptors

- Chlorate (ClO_3^-) => Chloride
- Mn^{4+} => Mn^{2+}
- Fe^{3+} => Fe^{2+}
- Selenate => Selenite
- Arsenate => Arsenite
- DMSO => DMS
- Fumarate => Succinate

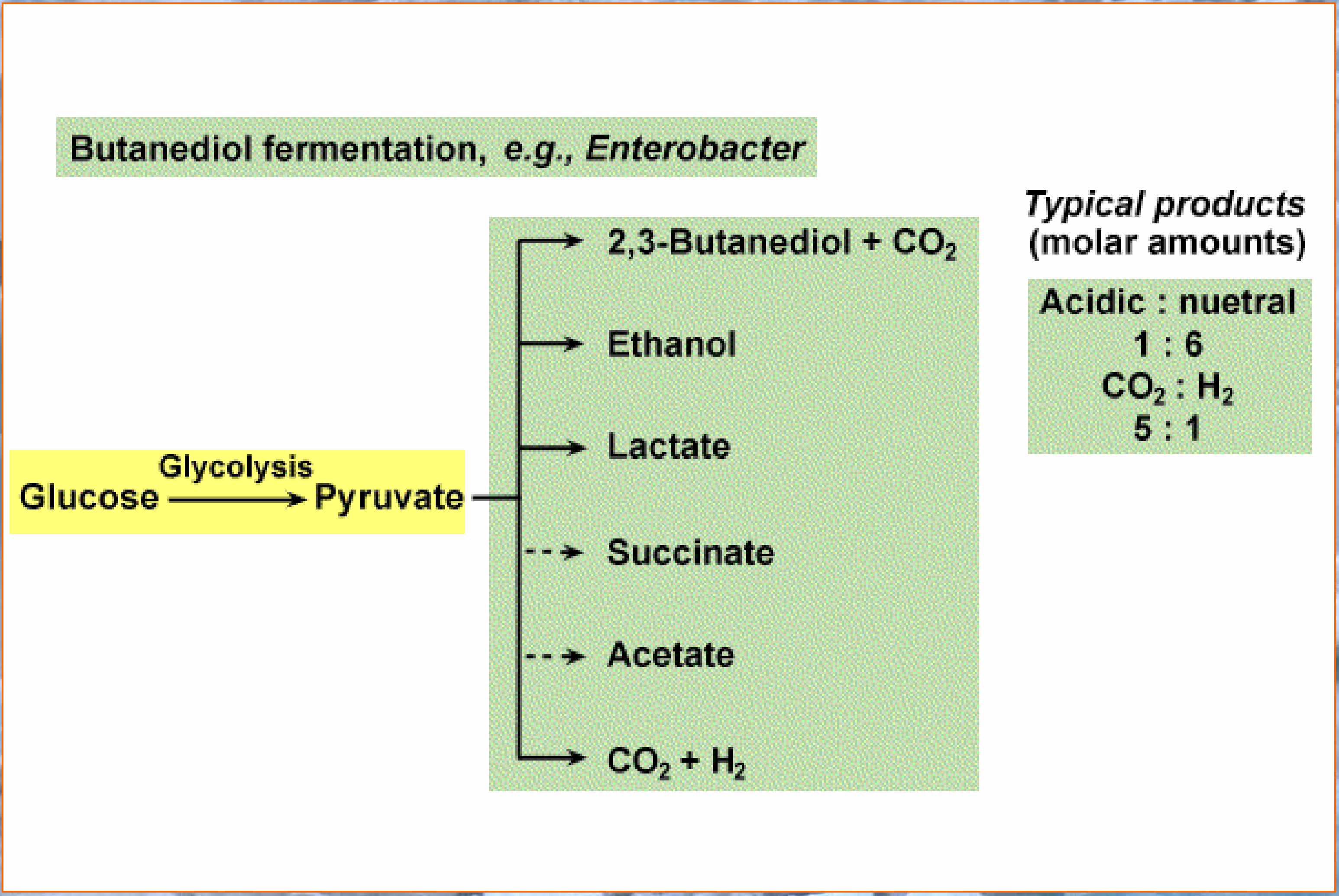
Fermentations



Fermentation products (1)



Fermentation products(2)



Conclusions (1)

There is a variety of compounds that cells (prokaryotic) may use to obtain energy.

This energy is used by cells to build macromolecules and biomass.

If the amount of energy produced by unit of substrate is low, then the amount of biomass produced may be undetectable.

But the quantity of metabolic products may be high.

Conclusions (2)

Some metabolic products are volatile and may accumulate in the atmosphere:
H_2, CO_2, CH_4, O_2, N_2, NO, N_2O, H_2S, organics, etc.

Some others may accumulate in the liquid phase, dissolved (nitrate, nitrite) or not (iron hydroxide), or change the pH of the environment (sulphuric acid).

Detection of concentration anomalies of such compounds may indicate the existence of life-mediated chemical reactions.