Lecture #10 – 9/26 – Dr. Hirsh

Image from Molecular Motors page – ATP synthase machine – 6 lobes, H\(^+\) drives ATP synthesis as it falls through from inter-membrane space to the inner cristae space of the mitochondrion.

From this chapter – realize what comes in, what goes out; what parts of the cell are involved in which processes.

There is a relatively small yield of energy from Glycolysis. More energy yield from Krebs as ATP and energy equivalents (NADH, FADH\(_2\)).

Form ATP by “burning” NADH through respiration (oxidative phosphorylation).

This is a redox reaction with NADH as an intermediate; reduced A (AH\(_2\)) has a higher energy level than reduced B (BH\(_2\)) – therefore we have a source of energy for proton pumping.

We need to get energy out of the process in small steps.

The final products: Oxygen accepts electrons and H\(^+\) to form water; ADP couples with P\(_i\) to form ATP by burning glucose in a most efficient way, using O\(_2\), to form CO\(_2\).

What do we do if there’s no oxygen? Fermentation!

Glycolysis doesn’t need oxygen but produces NADH

Can’t oxidize NADH without oxygen...

Pyruvate + NADH + H\(^+\) \(\rightarrow\) Lactate + NAD\(^+\)

Brain tissue cannot perform fermentation!

Another kind of fermentation – alcoholic fermentation

Pyruvate \(\rightarrow\) CO\(_2\) + Acetaldehyde

Acetaldehyde + NADH + H\(^+\) \(\rightarrow\) Ethanol + NAD\(^+\)
Lactic Acid Fermentation:
Allows Glycolysis to proceed w/o O₂

Alcohol Fermentation

Glycolysis occurs in the cytosol; 1 glucose yields 2 pyruvate, 2 NADH, 2 ATP

In the mitochondrion matrix,
   2 Pyruvates yield 2 CO₂ and 2 NADH and 2 Acetyl CoA at the pyruvate dehydrogenase complex
   2 Acetyl CoA enter the Krebs (Citric Acid) cycle, yield 6 NADH, 2 FADH₂, 2 ATP

In the inner mitochondrial membrane
   Each NADH from the mitochondrial matrix yields 3 ATP
   Each FADH₂ yields 2 ATP
   Each NADH from the cellular cytosol yields 2 ATP (has to be transported across the mitochondrial membranes)

For a net of 36 ATP for one mole of glucose.
Glucose metabolism connects to intermediate metabolism pathways

Example: Fatty acids may be broken down to yield Acetyl CoA; if there is a surplus of ATP in the cell, acetyl CoA is utilized to manufacture fats.

Example: alpha keto Glutarate may be converted into Aspartate by the addition of an amine group

Feedback can change the activity of pathways

A --------> B  (A stimulates the production of B)

A --------| B  (A represses the production of B)

Often sequential cascades:

A ---> B ----> C  (all positive)

A ----| B ------| C  (repressing a repressor)

Note outcomes of both above are the same!  2 negatives = 1 positive here.

Examples:

In Glycolysis, the enzyme that adds a second phosphate onto Fructose 6 Phosphate, Phosphofructokinase is stimulated by ADP and AMP, but repressed by ATP and Citrate.

Regulation often occurs at the beginning of a pathway, so there’s no waste of energy.

Often the final product of a pathway represses the first step of that pathway.

In the Krebs cycle,

Excessive Citrate stimulates the conversion of acetyl CoA into fatty acids.

ATP and NADH inhibit the conversion of acetyl CoA into citrate
Isocitrate dehydrogenase is inhibited by NADH and ATP and activated by NAD+ and ADP

Chapter 8 – Photosynthesis

Reversal of glucose oxidation!

All of oxygen in earth’s atmosphere comes from photosynthesis. Early on from cyanobacteria. Anaerobic organisms are poisoned by oxygen; other organisms evolved to use oxygen.

Early (1940’s) radioactive tracer experiment used $^{18}\text{O}$

Where does $\text{O}_2$ come from? $\text{CO}_2$ or $\text{H}_2\text{O}$?

Use radioactive $\text{CO}_2 \rightarrow$ get regular $\text{O}_2$ from plants
Use radioactive $\text{H}_2\text{O} \rightarrow$ radioactive $\text{O}_2$

Therefore the proper equation for photosynthesis must be:

$6\text{CO}_2 + 12 \text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O}$

Two pathways of photosynthesis

Light reaction – driven by light, yield ATP and reduced electron carrier [NADPH]; splits water into $\text{H}^+$ and $\text{O}_2$.

Calvin-Benson cycle: “Dark” reactions (don’t require light). Uses ATP, NADPH, $\text{H}^+$, $\text{CO}_2$ – yields sugars (reduced carbon).

Photosynthesis overview

Thylakoid membranes – contains chlorophyll complex, splits water, makes ATP

Rest of reactions occur in the stroma (carbon fixation)

Wave properties of light

$\lambda$ = wavelength = distance between troughs.
Velocity is constant in the same medium = $c$
Frequency = $\nu$

$\nu = \frac{c}{\lambda}$

Energy = $E = h \nu$, where $h =$ Planck’s constant
Therefore $E = \frac{hc}{\lambda}$, implying $E$ is inversely proportional to the wavelength.

Wavelengths
400 nm = border of UV light
700 nm = border of red – Infra-red light

Visible light is between the above; photosynthesis systems interact with visible spectrum
Atom absorbs light, electron goes from ground state to excited state

Can decay -> fluorescence! Decay is not perfect -> slightly longer wavelength given off than accepted

Photons absorbed, $E$ is transferred to other molecules to do work.

Pigments = planar molecules that can absorb photons at different wavelengths

Chlorophyll a and b absorb near infra-red and blue. Other visible wavelengths captured by the other photopigments except for green (500 nm).

Photopigments transfer the captured energy to chlorophyll (fluorescence resonance transfer)

Figure – Action spectrum for photosynthesis shows a gap in the yellow-green

Figure – Chlorophyll a has a Porphyrin ring structure – similar structure to heme. The long carbon tail helps hold the molecule into membranes.
Excited electrons captured from chlorophyll act as a reducing agent; they can take an oxidized electron carrier and reduce it.

This electron’s ultimate source is water – water is oxidized by P680 complex in the light reaction by Photosystem II; the electron is promoted to a higher energy level. This electron then goes through an electron transport chain, synthesizing ATP, and ending at a low energy state.
Photosystem I’s P700 complex promotes this electron again to an energy level where it reduces Ferredoxin (Fd) Fd then reduces NADP+ to NADPH and H+.

Cyclic electron flow

This occurs in the Photosystem I. The P700 electron is excited; reduces Fd; then goes down an electron chain to yield ATP and is returned to the P700 complex it began from. This drives protons from one side of the thylakoid membrane to the other, thus driving ATP synthesis. This is sufficiently powerful to maintain a 4 unit pH difference across the thylakoid membrane!