Honors Biology – Unit 2 – Chapter 5b
"THE WORKING CELL"

1. 3 types of energy: kinetic energy, potential energy, chemical energy

2. first law of thermodynamics: conservation of energy

3. second law of thermdynamics: entropy

4. exergonic vs. endergonic reactions

5. structure of ATP and ADP, the ATP cycle

6. 3 types of cellular work: chemical work, mechanical work, transport work

Honors Biology – Unit 2 – Chapter 6
"HOW CELLS HARVEST CHEMICAL ENERGY"

1. the energy cycle: photosynthesis and cellular respiration

2. respiration vs. cellular respiration

3. structure of a mitochondrion, surface area

4. overall chemical reaction for cellular respiration

5. glycolysis: 1 glucose (6 C atoms) → 2 ATP + 2 NADH + 2 pyruvate (3 C each)

6. Krebs cycle: 2 pyruvate → 6 CO_2 + 6 NADH + 2 $FADH_2$ + 2 ATP

7. electron transport chain: 6 O_2 + 8 NADH + 2 $FADH_2$ → 6 H_2O + 28 ATP

8. the true purpose of breathing oxygen, effect of cyanide

9. alcohol fermentation, lactic acid fermentation

Honors Biology – Unit 2 – Chapter 7
"PHOTOSYNTHESIS: USING LIGHT TO MAKE FOOD"

1. the energy cycle: photosynthesis and cellular respiration
2. structure of a leaf
3. structure of a chloroplast, surface area
4. overall chemical reaction for photosynthesis
5. why plants are green: reflection and absorption
6. accessory pigments and their functions: carotene, xanthophyll, anthocyanin
7. light reactions: $H_2O \rightarrow O_2$ + hydrogens + electrons
8. NADPH: the taxicab from the light reactions to the dark reactions
9. dark reactions: 6 CO_2 + hydrogens (from NADPH) → glucose

Honors Biology – Chapters 5b, 6, & 7 Word Roots
"CELLULAR ENERGETICS"

aero- = air (*aerobic:* using oxygen)

an- = not (*anaerobic:* not using oxygen)

auto- = self; **-troph** = food (*autotroph:* an organism that makes its own food, thereby sustaining itself without eating other organisms or their molecules)

chemi- = chemical (*chemiosmosis:* the production of ATP using the energy of hydrogen ion gradients across membranes to phosphorylate ADP)

chloro- = green; **-phyll** = leaf (*chlorophyll:* a green pigment located within the chloroplasts of plants, algae, and certain prokaryotes)

de- = without; **-hydro** = water (*dehydrogenase:* an enzyme that removes water when catalyzing a chemical reaction)

electro- = electricity; **magnet-** = magnetic (*electromagnetic spectrum:* the entire spectrum of radiation)

endo- = inner, within (*endergonic reaction:* an energy-requiring chemical reaction that yields products with more potential energy than the reactants)

exo- = outer (*exergonic reaction:* an energy-releasing chemical reaction in which the reactants contain more potential energy than the products)

glyco- = sweet; **-lysis** = split (*glycolysis:* the multistep chemical breakdown of a molecule of glucose into two molecules of pyruvate)

kinet- = movement (*kinetic energy:* the energy of motion)

meso- = middle (*mesophyll:* the middle layer of tissue inside a leaf)

photo- = light (*photoautotroph:* an organism that obtains energy from sunlight and carbon from CO2 by photosynthesis; *photon:* a fixed quantity of light energy); **-synthesis** = put together or combine (*photosynthesis:* the process by which autotrophs use light energy to make sugars and other organic food molecules from carbon dioxide and water)

therm- = heat (*thermodynamics:* the study of the energy transformations that occur in a collection of matter)

thylaco- = sac or pouch (*thylakoid:* one of a number of disk-shaped membranous sacs inside a chloroplast)

PROPERTY OF:

HONORS BIOLOGY – UNIT 2 – CHAPTERS 5b – 7 NOTES

CELLULAR ENERGETICS

Chemical Reactions

- Endergonic Reaction = a "building up" reaction; requires energy; not spontaneous; anabolic
  - EX: sugar becomes starch (building up, anabolic, endergonic)
  - EX: 2 monosaccharides become 1 disaccharide (building up, anabolic, endergonic)
  - EX: 3 hydrocarbon chains form a triglyceride (building up, anabolic, endergonic)
  - EX: PHOTOSYNTHESIS (building up, anabolic, endergonic)
    "building" sugars out of CO_2 and H_2O
- Exergonic Reaction = a "breaking down" reaction; produces energy; spontaneous; catabolic
  - EX: a lipid is digested (breaking down, catabolic, exergonic)
  - EX: a polypeptide is broken down (breaking down, catabolic, exergonic)
  - EX: CELLULAR RESPIRATION (breaking down, catabolic, exergonic)
    "breaking down" sugars into CO_2 and H_2O

Energy

- Energy molecule is ATP (adenosine tri-phosphate)
- When ATP is "used", it becomes ADP (adenosine di-phosphate) and P (phosphate)
- The breakdown of ATP into ADP and P releases energy which the cell uses to do work
- In the mitochondrion, ADP and P are joined together, forming ATP
- This is how the mitochondrion makes "energy" (but it really makes ATP, not ENERGY!!!)
- ATP is used for 3 main types of work inside of cells
  - EX: transport work (active transport; moving chemicals up their concentration gradient)
  - EX: mechanical work (the ability to move; usually requires a contractile protein)
  - EX: chemical work (helps an anabolic reaction, which requires energy)
- Energy coupling = when an anabolic reaction is helped by a molecule of ATP
- ATP can be cycled: When it is used, it breaks into ADP + P.
  When it needs to be regenerated, the ADP + P can join to form ATP.
- Analogy: If ATP is like a dollar bill, then ADP is 75 cents and P is a quarter

Photosynthesis – Overview

- ultimate source of energy for photosynthesis = the sun
- chloroplast = organelle in a plant cell that performs photosynthesis
- chemical formula: $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$
  (reactants) (products)
- products: glucose and oxygen
- reactants: carbon dioxide and water
- light reactions: $H_2O \rightarrow O_2$ (oxygen gas is created)
- dark reactions: $CO_2 \rightarrow C_6H_{12}O_6$ (glucose is created)
- So how do the extra hydrogens get from the light reactions to the dark reactions?…

Pigments

- chlorophyll = a green pigment in the chloroplast that absorbs light energy from the sun
- accessory pigments = other pigments that help chlorophyll absorb light energy
  - EX: carotene = orange (carrots)
  - EX: xanthophyll = yellow (yellow pepper)
  - EX: anthocyanin = red (red pepper)
- Reflection/Absorption: The color that you see is reflected off the object.
  All other colors are absorbed.
  white = all the colors are reflected (none are absorbed)
  black = all the colors are absorbed (none are reflected)

Photosynthesis – Light Reactions

- hydrolysis reaction = when a water molecule is split into 3 parts using light energy
- 3 products:
  1. O_2 (oxygen gas)
  2. H+ (hydrogen ions)
  3. e- (electrons)
- oxygen gas is released into the atmosphere
- H+ and e- join a molecule called NADPH
- NADPH = an "electron carrier' – carries H+ and e- to the dark reactions (like a taxicab!)
- a little bit of ATP is made in the light reactions (stores the light energy from the sun)

Photosynthesis – Dark Reactions

- overall reaction:
  CO_2 + hydrogens (from the light reactions) → glucose ($C_6H_{12}O_6$)
- also called the "Calvin Cycle"
- requires 6 CO_2's to make one glucose… WHY?
  HINT: How many carbon atoms are found in each glucose? _____
- Key Players:
  1. ATP = made in the light reactions; used in the dark reactions; provides energy!
  2. Rubisco = the main enzyme in the dark reactions; helps convert CO_2 to $C_6H_{12}O_6$
  3. NADPH = electron carrier; transports electrons and hydrogens from the light reactions to the dark reactions

Energy Flow in Photosynthesis

- BEGINNING: light energy from the sun
- MIDDLE: ATP (temporary energy storage)
- END: covalent bonds in glucose (final energy storage)

Cellular Respiration
- a process in which a cell breaks down glucose for energy
- complete opposite of photosynthesis
- chemical formula: $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$
- reactants: glucose and oxygen
- products: carbon dioxide and water
- 3 parts to respiration: glycolysis, Krebs cycle, electron transport chain (ETC)

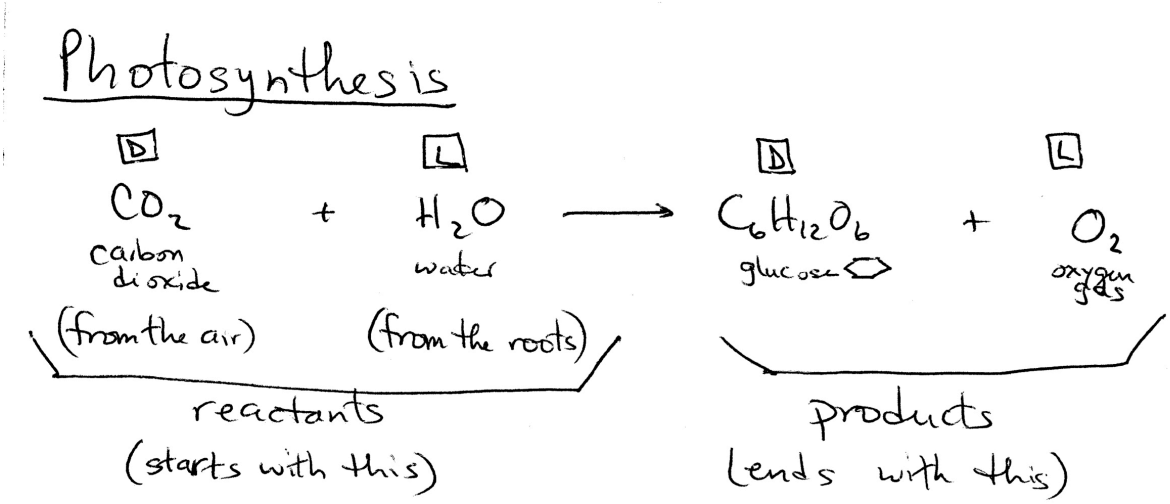
Glycolysis
- "glucose-splitting"
- occurs in the cytoplasm
- 10 steps and 10 enzymes are involved
- STARTS with: 1 glucose
- ENDS with: 2 ATP, 2 NADH, 2 pyruvate (3 carbons each)
- Phosphofructokinase (PFK) = enzyme the begins the process of glycolysis; inhibited by ATP

Krebs Cycle
- breakdown of pyruvate into CO_2
- H's are stored in NADH and $FADH_2$
- this is a cyclic process
- 9 steps and 9 enzymes
- located in the mitochondrion
- STARTS with: 2 pyruvates
- ENDS with: 6 CO_2, 6NADH, 2 $FADH_2$, 2 ATP

Electron Transport Chain
- located on the inner, folded surface of the mitochondrion
- more folds = more surface area = more ATP
- H's get removed from NADH and $FADH_2$
- H's and e-'s get combined with O_2 to form H_2O
- opposite of the light reactions in photosynthesis
- OXYGEN IS THE FINAL ELECTRON ACCEPTOR!
- Why is oxygen necessary?
- STARTS with: O_2, NADH, $FADH_2$
- ENDS with: H_2O, 28 ATP
- Note: The number of ATP produced in the ETC is an estimate.

Fermentation
- aerobic = with oxygen
- anaerobic = without oxygen
- fermentation occurs only in anaerobic conditions
- only produces 2 ATP (technically during glycolysis)
- purpose is to use up the NADH from glycolysis to regenerate NAD
- lactic acid fermentation: produces 2 lactic acids (causes muscles to burn)
- alcohol fermentation: products 2 alcohols and 2 CO_2's (occurs in yeast – bread)

OVERVIEW OF PHOTOSYNTHESIS



2 stages of photosynthesis:

1. Light Reactions
2. Dark Reactions

Light Reactions

$H_2O \rightarrow O_2$ } Where did the hydrogens go?

Dark Reactions

$CO_2 \rightarrow C_6H_{12}O_6$ } Where did the hydrogens come from?

LIGHT REACTIONS / DARK REACTIONS REVIEW

Light Reactions

- called a "hydrolysis" reaction
  - water cutting or splitting
- requires energy from the sun

H_2O (water splits into 3 parts using sunlight as energy)
- ① H^+ = hydrogen ions
- ② e^- = electrons

} go to the dark reactions with the help of a chemical called NADPH

- ③ O_2 = oxygen gas ⟹ goes into the air (atmosphere)

NADPH = nicotinamide adenine dinucleotide Phosphate hydrogen

NADPH is an "electron carrier" - it brings the hydrogens from the light reactions to the dark reactions

NADPH is like a taxi!

The energy from sunlight is saved in the form of ATP!

Dark Reactions

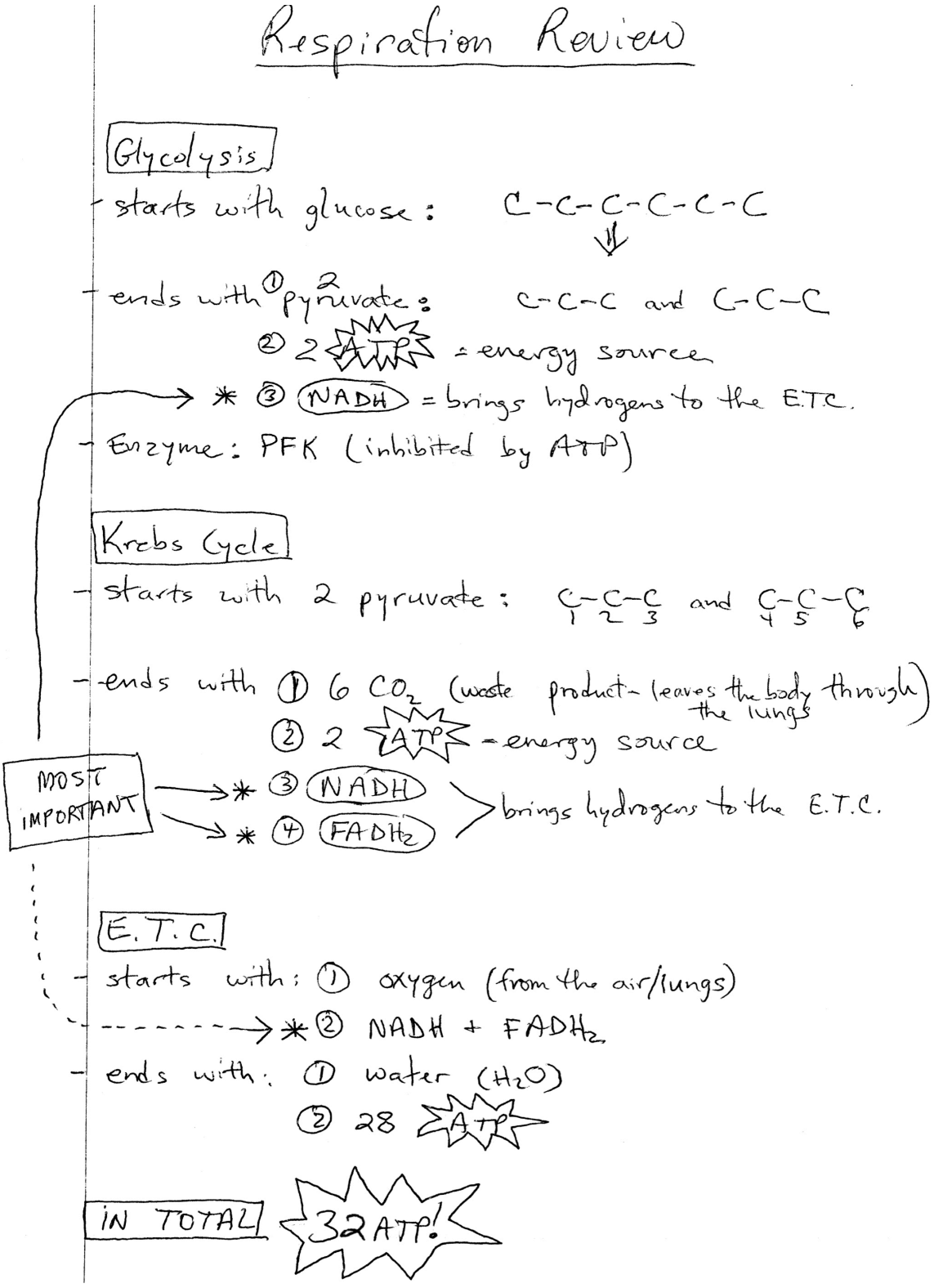
- called the "Calvin Cycle"

$6CO_2$ + hydrogens from NADPH ⟶ $C_6H_{12}O_6$ (glucose)

3 key players in the Dark Reactions

① ATP = gives energy to build sugars
② Rubisco = the main enzyme for the dark reactions
③ NADPH = brings the hydrogens and electrons from the light reactions to the dark reactions

OVERVIEW OF CELLULAR RESPIRATION



CELLULAR RESPIRATION / GLYCOLYSIS REVIEW

Cellular Respiration

#1 #2 #3

Mitochondrion #3 is the best – it has the most surface area!

Goal of respiration: 32 ATP

$C_6H_{12}O_6$ + O_2 → CO_2 + H_2O

glucose, oxygen gas — reactants (starts with)

carbon dioxide, water — products (ends with)

opposite formula of photosynthesis

3 stages:
1. Glycolysis
2. Krebs Cycle
3. Electron Transport Chain (ETC)

1 Glycolysis

Glucose splitting/cutting

C-C-C-C-C-C glucose

↑ Splits here

C-C-C C-C-C 2 pyruvates

pyruvate has 3 carbons (it is half of a glucose)

2 other things are made in glycolysis:

2 ATP

and

VIP 2 NADH } carries hydrogens and electrons to the ETC

KREBS CYCLE / ELECTRON TRANSPORT CHAIN REVIEW

② Krebs Cycle

C-C-C C-C-C 2 pyruvates

splits splits

CO_2 CO_2 CO_2 CO_2 CO_2 CO_2 6 CO_2

3 other things are made in the Krebs Cycle:

2 ATP

and

VIP 6 NADH

and

VIP 2 $FADH_2$

} carries hydrogens and electrons to the ETC

③ ETC

breathe in oxygen (O_2) and it combines with hydrogens to form H_2O

H's come from: 8 NADH and 2 $FADH_2$

"Oxygen is the final electron acceptor."
(oxygen receives the hydrogens and the electrons)

This process produces:

28 ATP

PHOSPHOFRUCTOKINASE / FERMENTATION REVIEW

Phosphofructokinase - "PFK"

PFK is the enzyme that controls glycolysis and all of cellular respiration

Glucose fits into the active site:

"LOCK + KEY FIT"

ATP can <u>inhibit</u> PFK and stop cellular respiration.

Fermentation

aerobic → oxygen → Glycolysis = 2, Krebs Cycle = 2, ETC = 28 } 32 ATP

anaerobic → no oxygen → Glycolysis = 2, Fermentation = 0 } 2 ATP

2 types of fermentation:

① Lactic Acid Fermentation:

- occurs in your muscles - produces the burning feeling
- starts with 2 pyruvates
- ends with lactic acids

② Alcohol Fermentation:

- occurs in yeast (EX: bread, beer)
- starts with 2 pyruvates
- ends with alcohols and CO_2
- CO_2 is what causes bubbles in beer and bread to rise