Chpt 4: Pond Scum to Jet Fuel, p.64-68

what do you think of when we say respiration?

breathing

inhaling O2, exhaling CO2

cellular respiration is related but there is more

cellular respiration is process by which food E molecules (glucose) are broken down to release chemical E (ATP)

E stored in chemical bonds of glucose is released within cell to do work

it is **decomposition rx**

$C_6H_{12}O_6 + 6\ O_2 \text{---------} > 6\ CO_2 + 6\ H_2O + E$

process is opposite of photosynthesis, but the steps do not go backwards

who does photosynthesis?

plants, blue-green bacteria, plant-like protists, anything w/chlorophyll

who does cellular respiration? all living organisms

both autotrophs & heterotrophs

Cellular Respiration

the **glucose molecule** is loaded w/E
there is **too much E** to be released all at once, it would explode the cell
so E is **put into smaller packets: ATP's**

breakdown of glucose involves oxidation/ reduction reactions

oxidation: removal of e- from molecule resulting in decreasing amount E in molecule

reduction: addition of e- to molecule resulting in increasing E in molecule, reduces charge of molecule (more neg)

2 main types of cellular respiration

1-aerobic CR-------->requires O2 to proceed

2-anaerobic CR---->occurs in absence of O2

aerobic cellular respiration has 3 stages

1-glycolysis
2-Krebs cycle
3-ETS: electron transport system

glycolysis takes place in **cytoplasm** of cells
Krebs cycle & ETS occurs in mitochondria

mitochondria: powerhouse of cell
it releases E stored in chemical bonds of glucose & puts into ATP molecule
mitochondria varies from cell to cell
some cells: 10-20 mitochondria
muscle cells: 1000's mito

mitochondria have inner & outer membrane structure
inner folds called cristae
enzymes are embedded in membrane

Krebs cycle & ETS occur on cristae

why have inner folds?why not just have outer membrane? what do inner folds do for mito?

Glycolysis: 1st stage cell respiration

3 things happen

1-glucose breaks into 2 pieces (pyruvate)

2-make ATP

3-reduce NAD+---------->NADH

C6H12O6-------->2 PGAL---------->2 pyruvate

(3 C) (3C)

for each molecule of glucose, **we need 2 ATP to start process**

for each molecule of glucose, **we make 4 ATPs,** thus **net gain is 2 ATP**

for each molecule of glucose we **make 2 NADH**

if O2 is present------>go to Krebs cycle

Krebs cycle: also called **citric acid cycle**
all CO_2 is produced here
NAD+ & FAD are reduced to NADH & FADH2
some ATP is produced

by the **end of glycolysis,** we made pyruvate
pyruvate must now be **transported** from cytoplasm to **mitochondria**
pyruvate is converted to acetic acid (2C) & CO_2 is released
then acetic acid combines w/coenzyme A to help transport it into mitochondria
acetic acid + CoA-------->acetyl CoA
acetyl CoA now enters Krebs cycle

Krebs cycle

- acetyl CoA combines w/oxaloacetate (4C) forming citric acid (6C)
- CoA is released to be used again to transport another pyruvate to Krebs cycle
- citric acid is then changed from one molecule to another in a cycle
- along the way, 2 CO_2 are released, 3 NADH are produced, 1 $FADH_2$ is produced, 1 ATP is produced
- the **citric acid cycle turns once for each pyruvate**

at **end of Krebs cycle w/ 1 molecule glucose**

6 CO_2 are released

8 NADH's are produced

2 $FADH_2$ are produced

2 ATP are produced

Electron Transport System

series of oxid/reduct rx passing e- along & E is given off

each NADH---------->makes 3 ATP's

each $FADH_2$---------->makes 2 ATP's

O_2 is final acceptor molecule at end of ETS makes H_2O

math

glycolysis----------> ? ATP's

2 NADH----------> ? ATP's

Krebs----------> ? ATP's

8 NADH----------> ? ATP's

2 FADH2----------> ? ATP's

?? ATP's

1 molecule glucose yields 36 ATP's
(the NADH from glycolysis yields only 2 b/c it takes 1 ATP to get the NADH from the cytoplasm to the mitochondrion)

Cellular Respiration is actually a relatively **inefficient process,** it is 34-38% efficient, we get about 34% of the E stored in glucose the rest is used as heat

so how can we get along with such an inefficient process?

it is actually pretty efficient considering we gain only about 25% energy from gasoline

Anaerobic Cellular Respiration
release of E in absence of O2
2 main pathways
1-alcoholic fermentation
2-lactic acid fermentation

alcoholic fermentation
glycolysis same as for aerobic CR
glucose---->pyruvate---->ethanol + CO_2
only 2 ATP's are made
we use this process to our advantage
yeast and bacteria do alcoholic fermentation: important for alcohol industries and baking

Lactic acid fermentation

animal cells cannot do alcoholic fermentation

but **in absence of O2, can do lactic acid fermentation for short time**

glycolysis is same

glucose---->pyruvate---->lactic acid

only produces 2 ATP

So when do we do this?

humans doing strenuous exercise can go into O2 debt

exercise requires continuous supply of O2 which is delivered by cardiovascular sys

in a well-conditioned athlete: CV sys can keep up w/O2 demand

however, if we push muscles to keep going & CV sys cannot keep up, our muscles can shift to lactic acid fermentation

but **lactic acid builds up in muscle tissue creating an acidic environment**, so enzymes can't work

eventually this causes cramping and muscle fatigue, finally body says stop, collapses, we breathe heavily, bringing in lots of O2, once O2 is delivered, cells do aerobic CR, lactic acid is removed & taken to liver where it is broken down

this can take 24-36 hours

Living organisms can be defined by what kind of CR they can do

-facultative anaerobes

can do aerobic or anaerobic CR depending on O2 availability

most bacteria fit here

-obligate aerobes: must do aerobic CR for

most part, plants & animals fit in this category as multicellular organisms

our brain cells can only do aerobic CR, must have O2 to the brain

however, our muscle cells can do both aerobic CR lactic acid fermentation

-obligate anaerobes

some bacteria are actually poisoned by O2, so they can only do anaerobic CR

Photosynthesis & Cellular Respiration

opposite processes
raw materials for one are products of other
both processes give C skeletons used in biosynthesis
animals rely on plants for photosynthesis
nonphotosynthetic plant cells rely on photosyn plant cells

Evolution of Cellular Respiration

glycolysis evolved first

no oxygen needed here
first prokaryotic cells evolved this process and gained 2 ATP for E, not much E produced but these are simple cells
oldest bacteria are 3.5 bill yrs old
blue-green bacteria arose and began capturing sunlight E, producing O2

as life became more complex and multicellular, more E was needed, more complex systems evolved, Krebs cycle, ETS

Glycolysis, Krebs cycle, & ETS work best with breakdown of carbohydrates
however, sometimes we may not have carbs for E, what can we do?

Protein & Fat metabolism

we can also use Krebs cycle to get E from fats & proteins if necessary

fats--->FA--->acetyl CoA---->Krebs cycle

proteins--->AA--->---->4 C acids--->Krebs cycle