Cellular Respiration

How do living things use
chemical reactions to get energy from food?

Version November 2017

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How do we get our energy from food?

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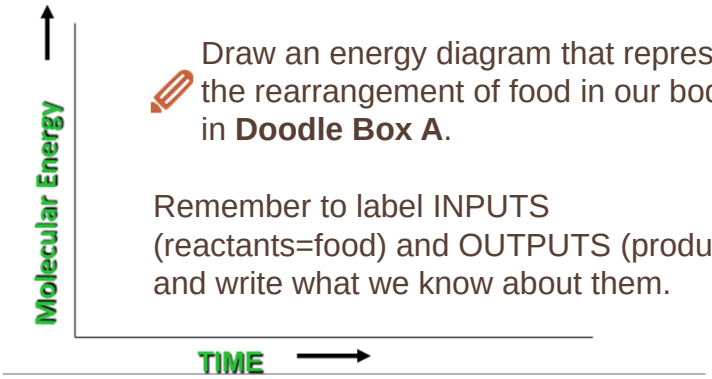
The connection between food and energy…

We've figured out that we somehow get energy from food… and that it has to do with chemical reactions where matter is rearranged.



Draw an energy diagram that represents the rearrangement of food in our bodies in **Doodle Box A**.

Remember to label INPUTS (reactants=food) and OUTPUTS (products), and write what we know about them.

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The chemical reaction inside of us…

We know that we get energy from food through some kind of chemical reaction.

We know the reaction has different reactants and products (molecules are rearranged) and that energy is released.

But **what are the reactants and products?**
What atoms are they made up of?
What do we know or wonder about the specific reaction in our bodies?

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How do we get the energy from food?

Hmmm.
How do we actually get energy from food?

Energy

Let's explore a bit more.

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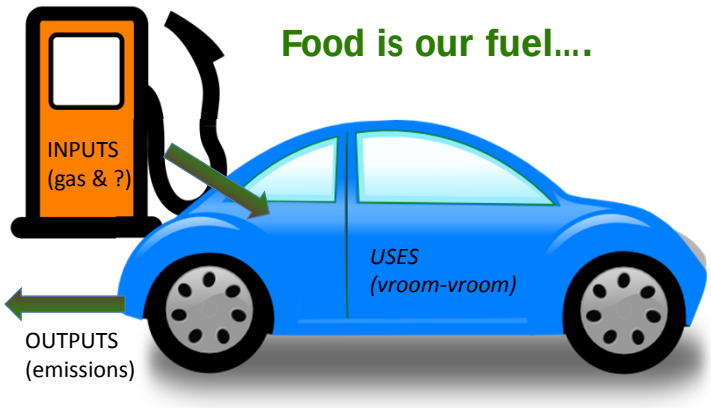
Food is our fuel….



How does a car get energy from it's fuel?

What's the reaction?
(Or at least, what is the reaction called?)

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Food is essentially our fuel.

We talk about:

- "Burning calories"
- "Burning carbs"
- "Burning Fat"

But we are still trying to figure out: How do we get energy from food?

Does this help?

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Let's see what burning (oxidizing) food looks like!

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What makes something a fuel?

What do these substances have in common in terms of energy?

What do they have in common in terms of matter?

Record your ideas in **Doodle Box E**.

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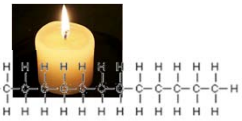
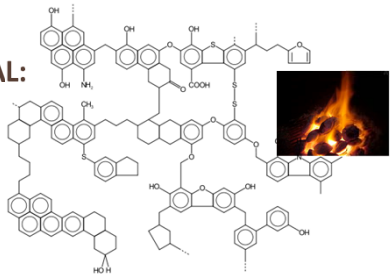
What makes something a fuel?

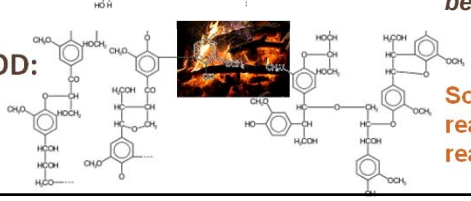
Paraffin (WAX):



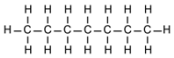
COAL:



WOOD:



Heptane (gasoline)



Propane Fuel

Methane (natural gas)

Lots of Carbon-Hydrogen-Oxygen!

What else do these fuels need in order to burn (release their energy)? What is the other reactant when something burns?

O_2

What else do WE need to take in besides our fuel (food!)?

O_2!

So O_2 is definitely one of the reactants in our energy- releasing reactions.

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What exactly is burning?

ENERGY

FUEL

What other reactant do we need again? Record in **Doodle Box F.**

Following the conservation of matter, what are the likely products? Record in **Doodle F.** (Do you see any products when stuff burns?)

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What exactly is burning?

ENERGY

FUEL + O_2

$CO_2 + H_2O$

Record this definition for burning in **Doodle F.**

Carbon fuel (C, H, some O) + O_2 → $CO_2 + H_2O$ + ENERGY

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What happens when we eat food?

Carbon fuel (C, H, some O) + O_2 → CO_2 + H_2O

ENERGY

13

How does our definition of fuel and burning fit our understanding of what might be happening with carbs, proteins and fats in our body?

Write your ideas in **Doodle Box G**.

What questions do we still have? Record these in **Doodle Box G** too.

Be prepared to share out to the class.

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Class Driving Question

What is the reaction in our cells and how in the body is it the same as and different from burning?

Write this question in **Doodle Box H**.

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Investigation:

What is the connection between increased energy demand (exercise) and a the rate of burning (output of CO_2)?

Burning for Energy

We've seen that we produce more CO_2 when we exercise.

So there's a connection between exercise and the rate of the reaction that gives us energy.

But is there a connection between exercise and matter? What happens to our mass when we exercise?

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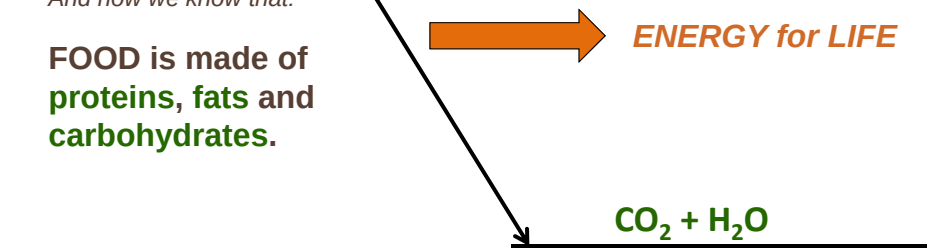
What we've figured out so far…

FOOD + O_2

And now we know that:

FOOD is made of proteins, fats and carbohydrates.



Let's try to narrow it down. Which of these molecules provide our energy? In other words, which is our "fuel"?

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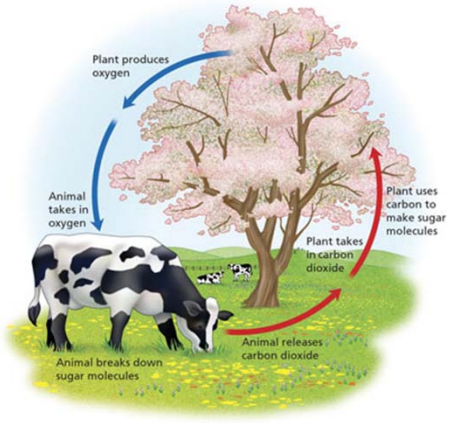

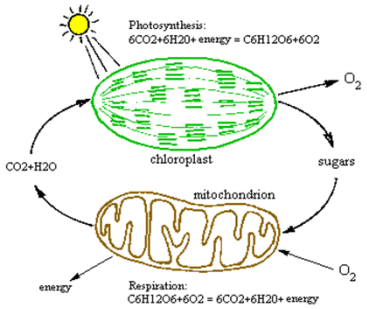

Figure 16 - With the photosynthesis, the solar energy is cumulated by the chloroplasts as sugar molecules. With the glycolysis and the respiration, made by mitochondria, the energy is liberated and supplied to the cell for its biochemical processes.

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Let's step back…

What happens to that hamburger or veggie burger after we eat it ?

What is the burger made of ?

Recall what we know about the components of food.

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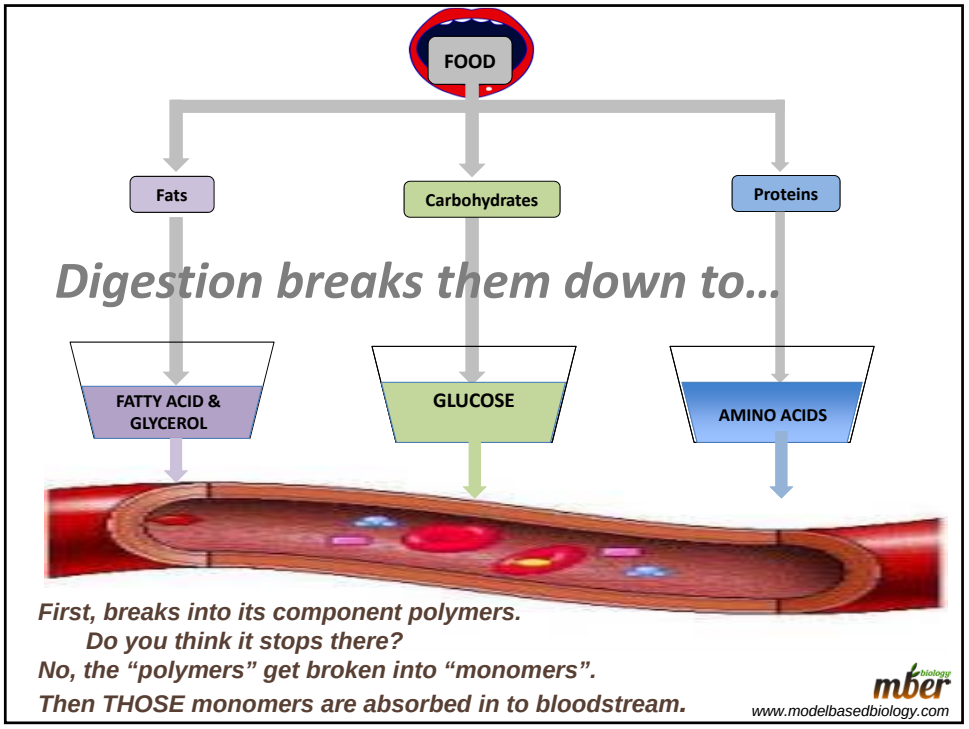
FOOD
Fats
Carbohydrates
Proteins
Digestion breaks them down to…
FATTY ACID & GLYCEROL
GLUCOSE
AMINO ACIDS
First, breaks into its component polymers.
Do you think it stops there?
No, the "polymers" get broken into "monomers".
Then THOSE monomers are absorbed in to bloodstream.
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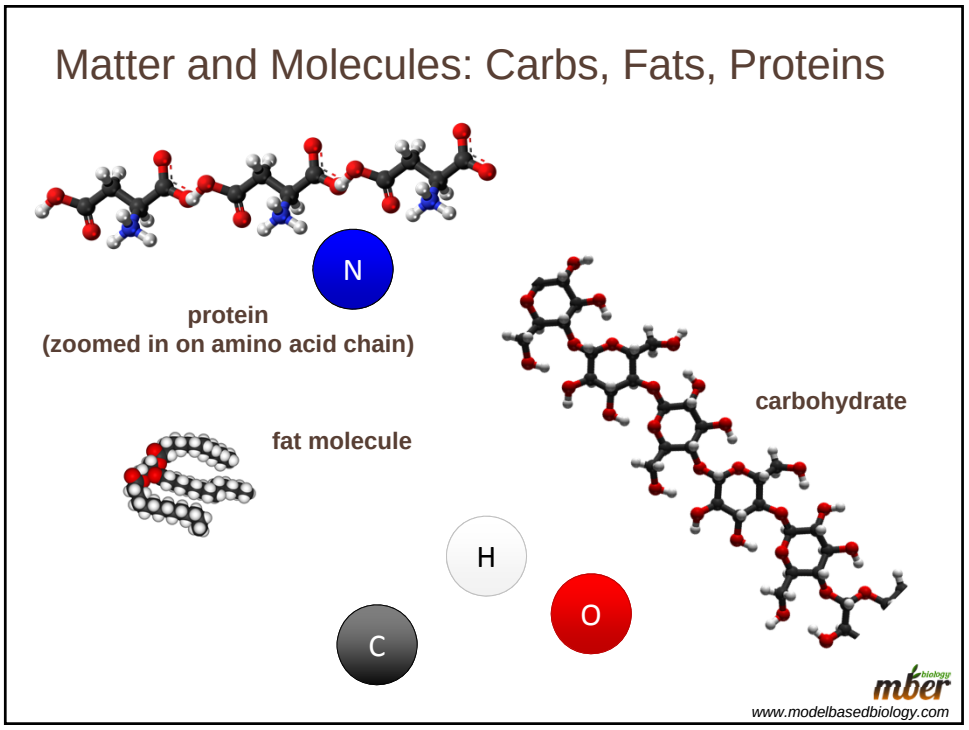
Matter and Molecules: Carbs, Fats, Proteins
N
protein
(zoomed in on amino acid chain)
fat molecule
carbohydrate
H
O
C
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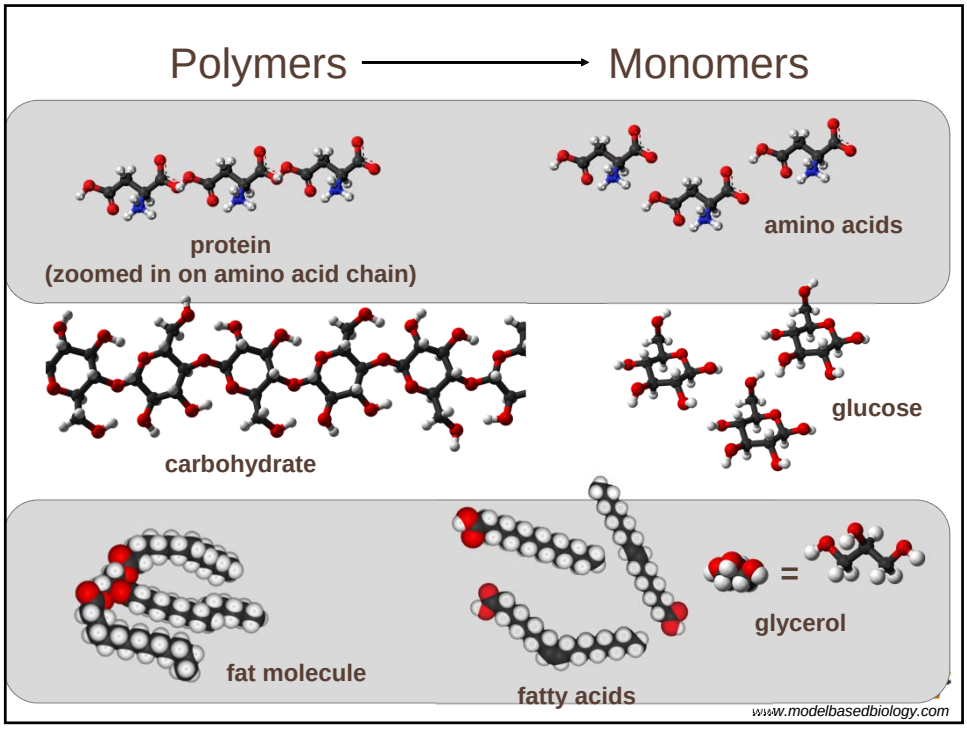
Polymers
Monomers
protein
(zoomed in on amino acid chain)
amino acids
carbohydrate
glucose
fat molecule
fatty acids
=
glycerol
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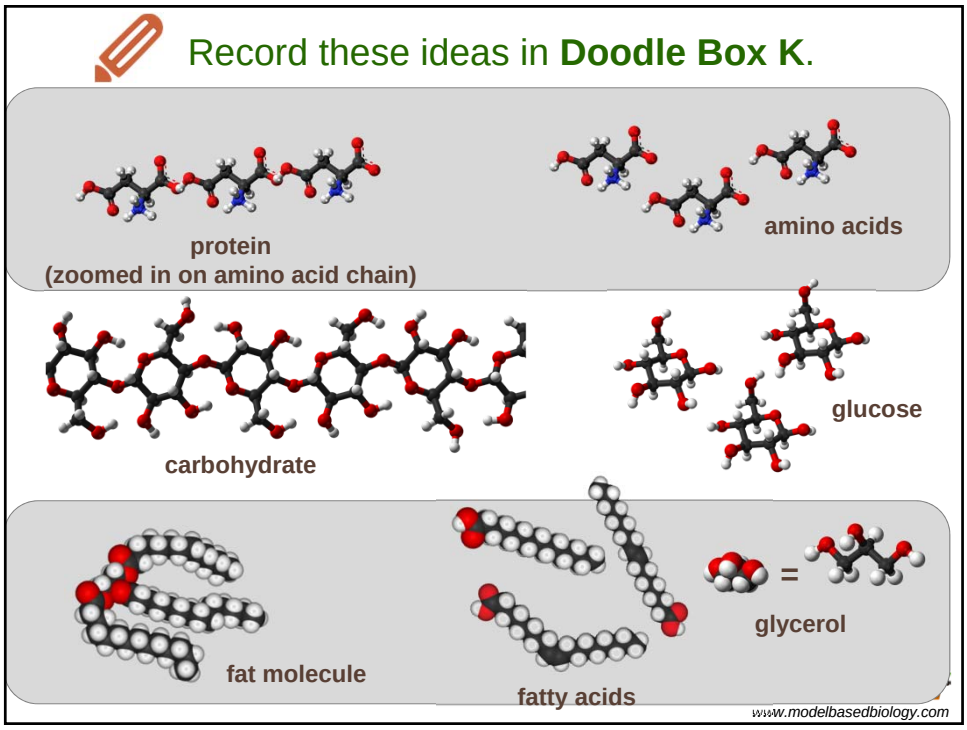
Record these ideas in **Doodle Box K**.
protein
(zoomed in on amino acid chain)
amino acids
carbohydrate
glucose
fat molecule
fatty acids
=
glycerol
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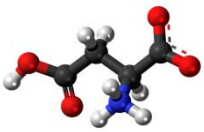
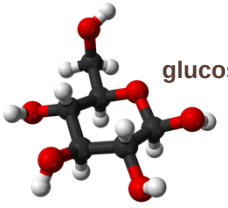
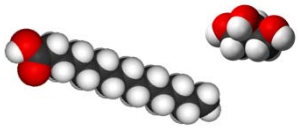


amino acids



glucose



fatty acids + glycerol

Which monomer is the fuel?

Which one (or ones) do you think is our fuel? Why?

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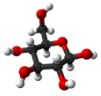
What's the carbon-containing fuel?



glucose

Our bodies work to supply **GLUCOSE** to all of our cells, every minute of every day!

- People who have difficulty regulating the amount of glucose in their blood and the amount that gets into the cells have a condition called diabetes.
- Our brains in particular require a very consistent supply of glucose.
- Muscles have a need for lots of glucose all at once, so they store it right in the tissue. They even store extra oxygen which makes them red!

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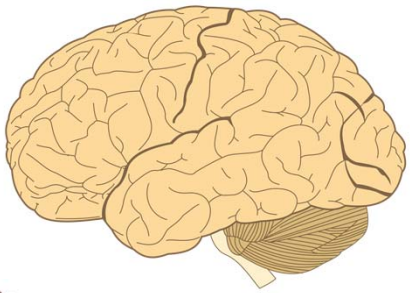
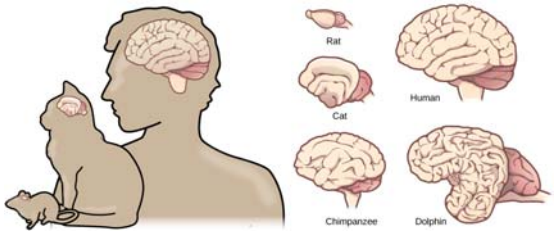
The importance of glucose…

Our brains use about 50% of the energy we require each and every day!

The evolution of increased blood supply and delivery of glucose to our brains is thought to be a key step in human evolution.

The Human Brain





It allowed our brains to become larger than most mammals (but we burn more energy!)

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The importance of glucose…

When we exercise, we don't eat as we do it. We also don't have to eat right before we exercise…

So where is the fuel coming from in that moment when we are running, jumping, or swinging a bat?

Complete the reading about glucose and exercise and answer the questions at the end.

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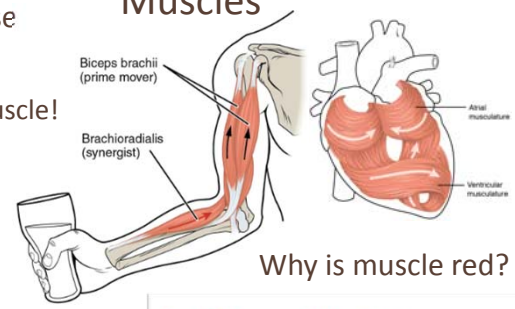
The importance of glucose…

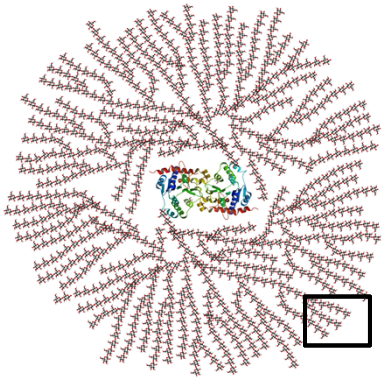
When we exercise, our muscles and heart (a muscle!) increase their "demand" for glucose.

We actually **store glucose** in muscle!

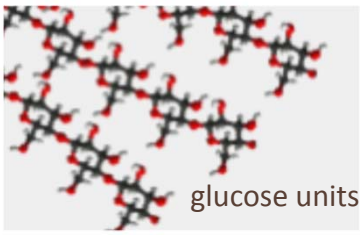
Muscles



Why is muscle red?



Glycogen



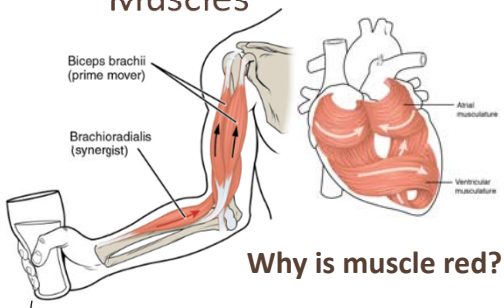
glucose units!

The importance of glucose…

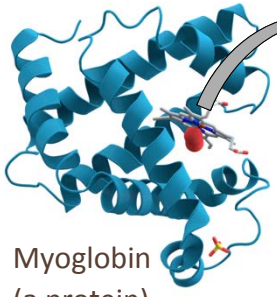
When we exercise, our muscles and heart (a muscle!) increase their "demand" for glucose.

We store oxygen in muscle too!

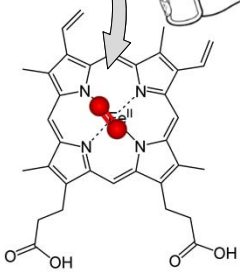
Muscles



Why is muscle red?



Myoglobin
(a protein)



An iron group "holds" the oxygen.

This is the same structure is seen in blood cells that carry oxygen! (hemoglobin protein)

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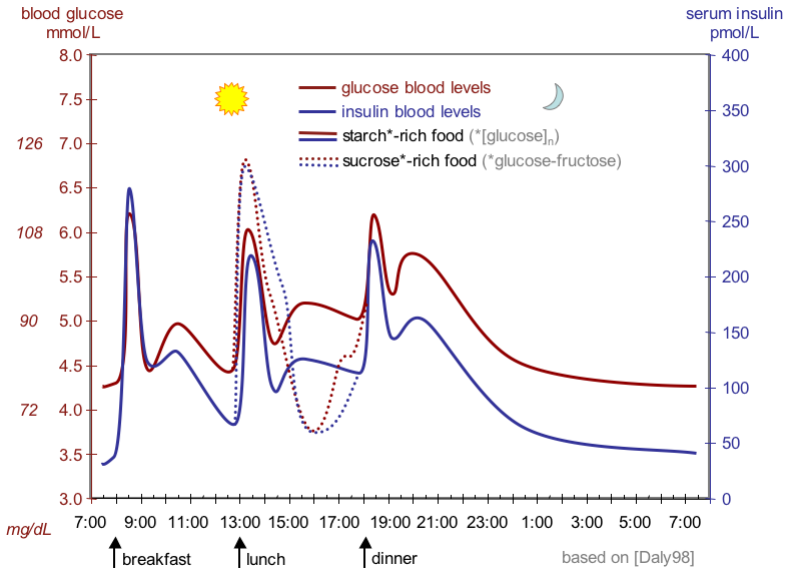
The importance of glucose…



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We have a reaction!

"Cellular Respiration"

$C_6H_{12}O_6 + 6\,O_2$

Glucose and Oxygen

→ ***ENERGY for LIFE***

$6\,CO_2 + 6\,H_2O$

Carbon Dioxide and Water

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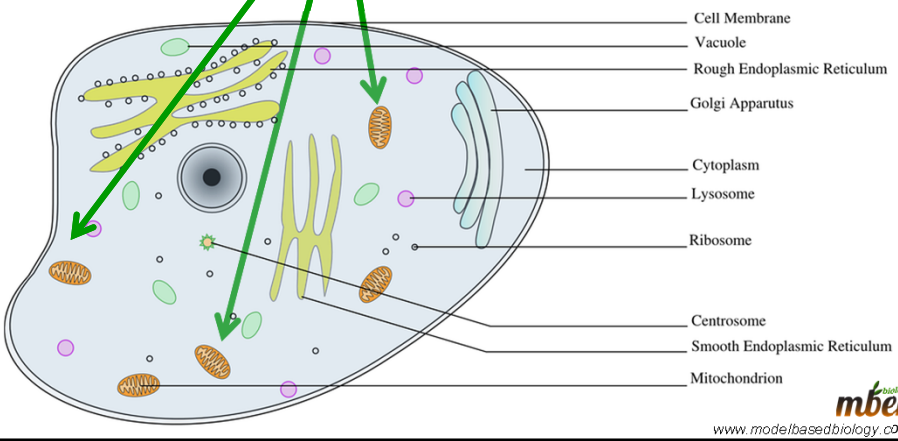
Where does cellular respiration happen?

In our cells,
in the **MITOCHONDRIA.**

Nearly all cells have mitochondria, but muscle cells have tons of mitochondria (so they can use all of that glucose and oxygen they are storing)!



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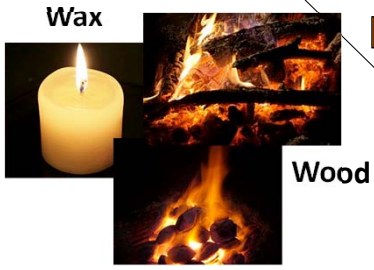
Burning gives a lot of energy!

CARBON FUEL + O_2



LOTS OF ENERGY!

$CO_2 + H_2O$

What form does the energy take in burning?
(What evidence do we have for energy?)

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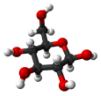
Burning FOOD gives a lot of energy!

$C_6H_{12}O_6 + O_2$



glucose

LOTS OF ENERGY!

$CO_2 + H_2O$

The calories from glucose in a bowl of cereal is the same type of energy as we saw in the burning gummy bear demonstration!

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Burning FOOD gives a lot of energy!

If we think that carbs give us this much energy, what's the problem if this is happening inside our cells?

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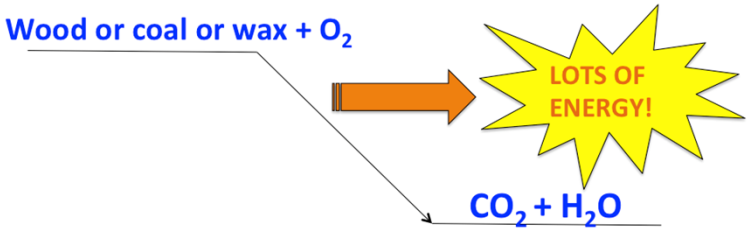
What is the problem with having a reaction like this happen in a cell?

In combustion reactions, the fuel molecules are rearranged all at once, in one big step, so all of the energy is released at once!



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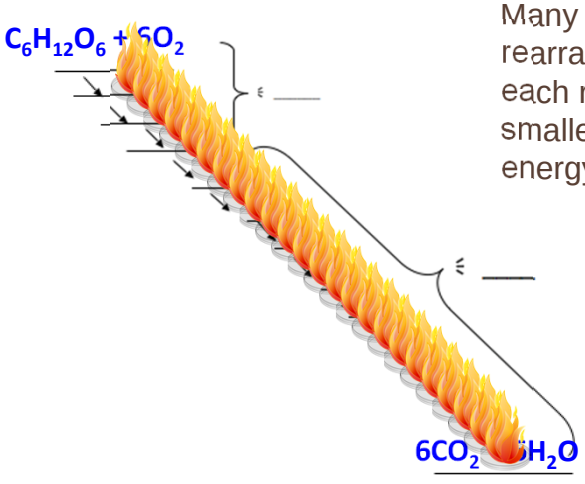
Break it up!



Many small rearrangements, each releasing a smaller amount of energy!

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But wait…

The energy from burning fuel is released as heat and light.

Can cells use HEAT to do the work of life?

Some helps heat our bodies, yet most is lost to the environment.

BUT cells can't use heat to do work.

How can a cell move energy from the mitochondria to where it's needed??

These problems are solved by a little molecule called

ATP

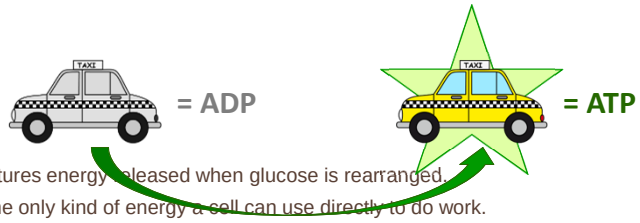
Adenosine Triphosphate

Think of it as the transport molecule for energy in the cell!

ATP transports usable energy inside the cell!

ATP is a molecule that starts as ADP.

When it comes in contact with an energy-releasing reaction, it gets energized and transforms into ATP.

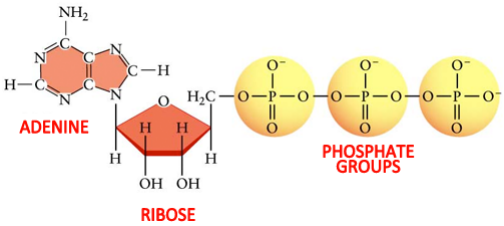


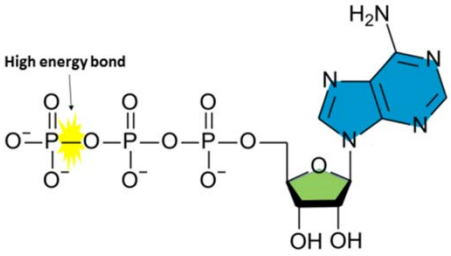
ATP captures energy released when glucose is rearranged.

This is the only kind of energy a cell can use directly to do work.

ATP moves the energy from mitochondria to wherever it may be needed in the cell.

ATP Structure



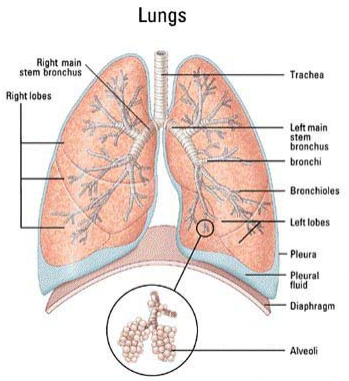


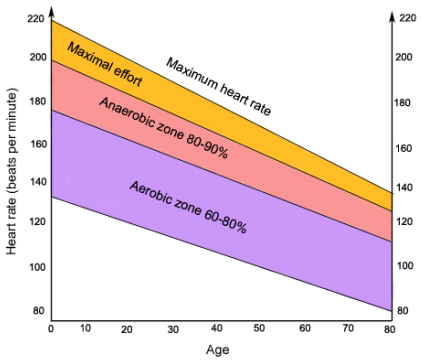
Remember:

- Releasing energy from food is a multi-step process. Each step re-arranges the atoms, creates new molecules and releases some energy.

You are not responsible for knowing the enzymes involved in all of the step and the intermediate molecules that are built.

Anaerobic vs. Aerobic

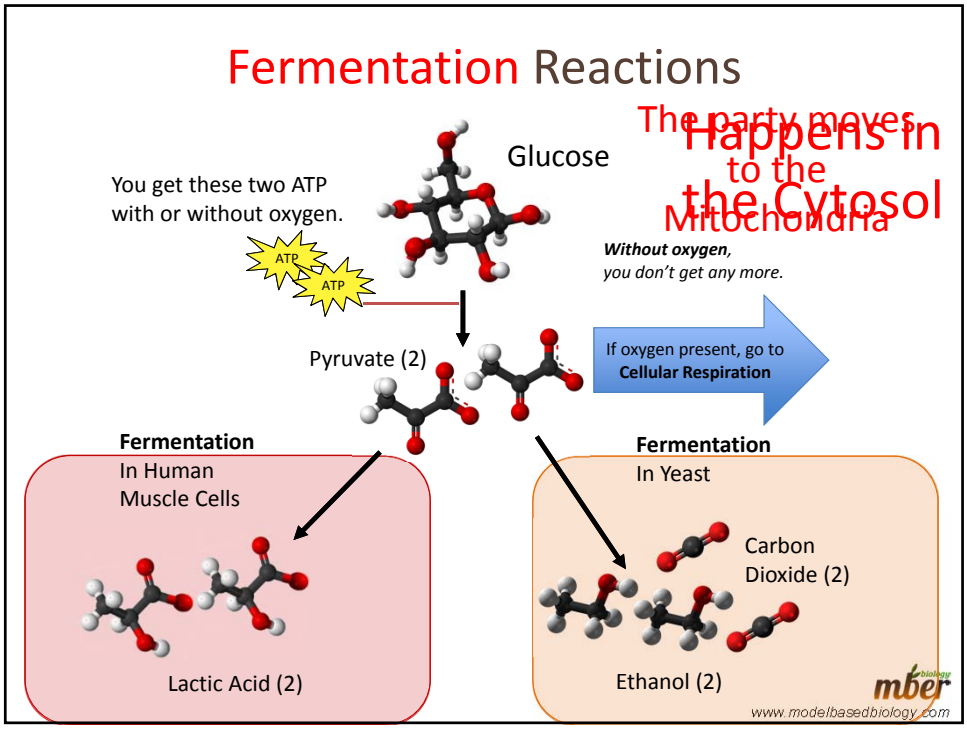




Oxygen is the key…but what's the difference?

Some living things get usable energy from food (matter) without oxygen at all.

They were likely the first to evolve. They can live of this relatively low ATP output. We still have the ability to do this, but this is just part of the equation. (and a step in the process you DO have to know)


Fermentation Reactions
The party moves to the Mitochondria
Happens in the Cytosol
Glucose
You get these two ATP with or without oxygen.
ATP
ATP
Without oxygen, you don't get any more.
Pyruvate (2)
If oxygen present, go to Cellular Respiration
Fermentation In Human Muscle Cells
Lactic Acid (2)
Fermentation In Yeast
Carbon Dioxide (2)
Ethanol (2)
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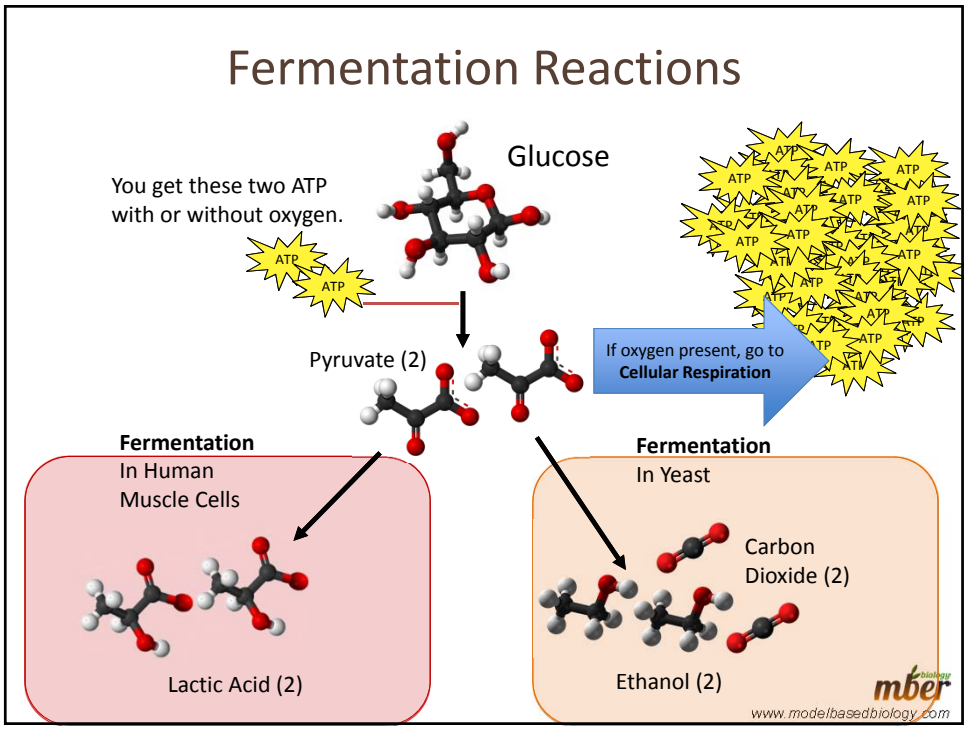
Fermentation Reactions
Glucose
You get these two ATP with or without oxygen.
ATP
ATP
Pyruvate (2)
If oxygen present, go to Cellular Respiration
Fermentation In Human Muscle Cells
Lactic Acid (2)
Fermentation In Yeast
Carbon Dioxide (2)
Ethanol (2)
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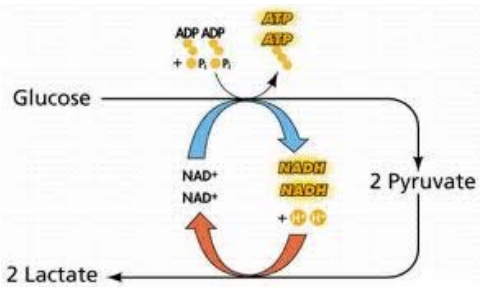
Fermentation Types

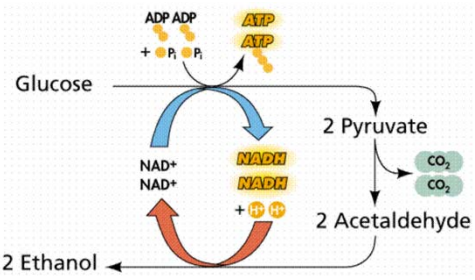
Lactic Acid Fermentation



Produces a 3-carbon compound called LACTIC ACID.

Fermentation Types

Alcoholic Fermentation



Produces a 2-carbon compound called ETHYL ALCOHOL.

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- Fermentation is an anaerobic process – happens in the absence of oxygen
- Cellular Reparation is an aerobic process – requires oxygen

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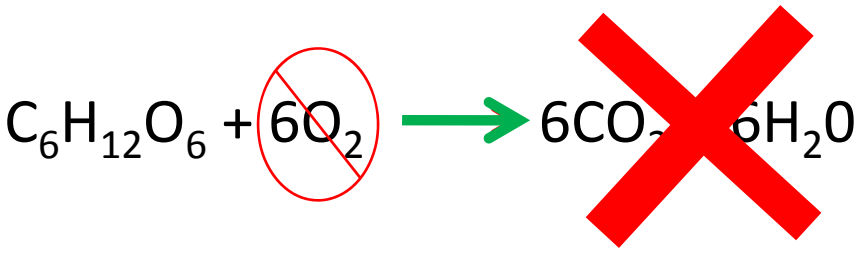
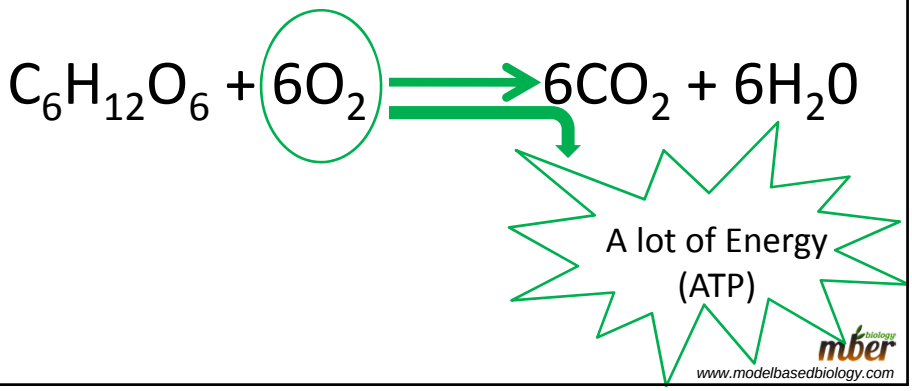
OK…Now What?

If you don't have enough oxygen, aerobic respiration can't occur, but fermentation can.

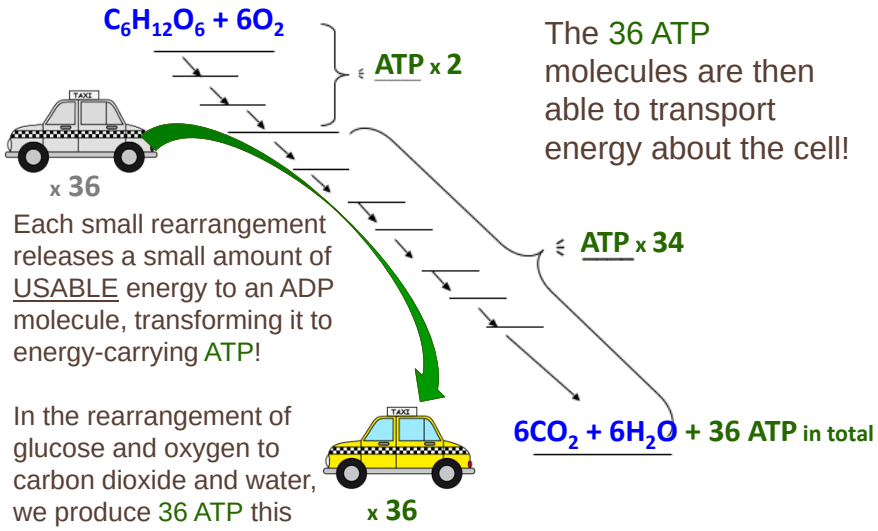


OK…Now What?

If you have oxygen, aerobic respiration can occur.



ATP "captures" the energy from the burning of glucose!



The 36 ATP molecules are then able to transport energy about the cell!

Each small rearrangement releases a small amount of USABLE energy to an ADP molecule, transforming it to energy-carrying ATP!

In the rearrangement of glucose and oxygen to carbon dioxide and water, we produce 36 ATP this way.

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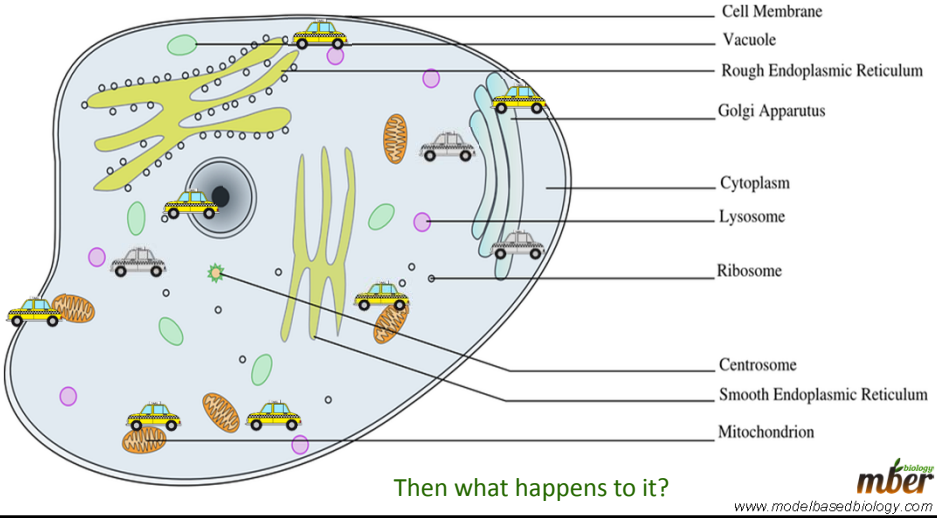
ATP transports usable energy inside the cell.

ADP is continually being made into ATP in our mitochondria. ATP then delivers energy to other parts of the cell to do "work".



Then what happens to it?

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ADP→ATP … ATP→ADP

When the energy in ATP is used to do work, it returns to being ADP.

In this way, more ADP is ready to pick up energy and become ATP once again. It's a cycle!

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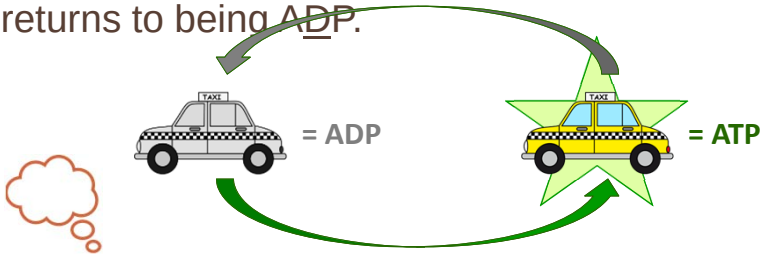
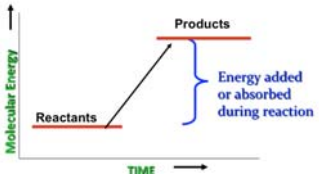
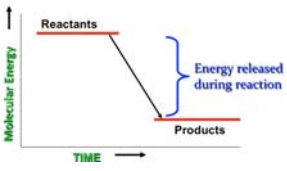
ADP→ATP … ATP→ADP

When the energy in ATP is used to do work, it returns to being ADP.



Hmmm, so how do these two processes, indicated by the arrows, relate to our energy diagram and our understanding of chemical reactions?





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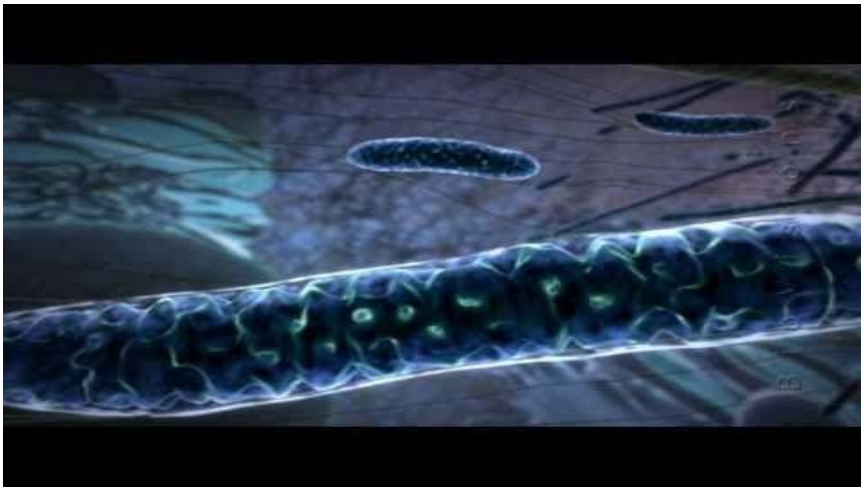
Watching ATP being made



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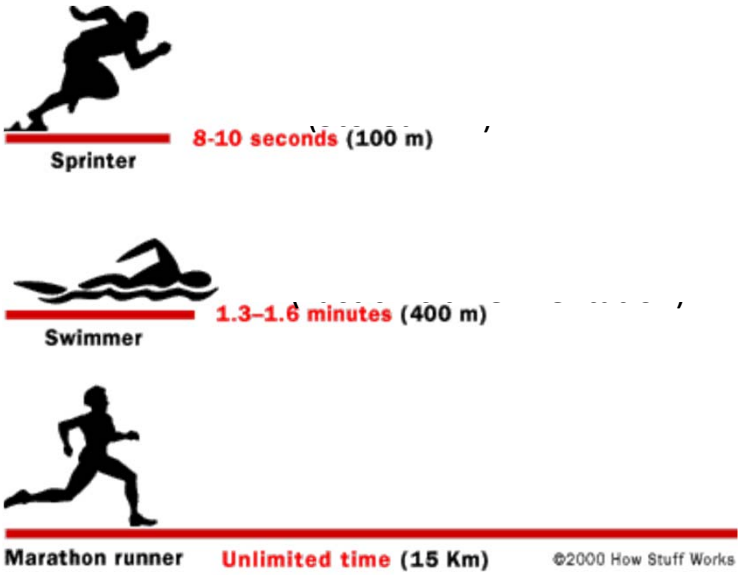

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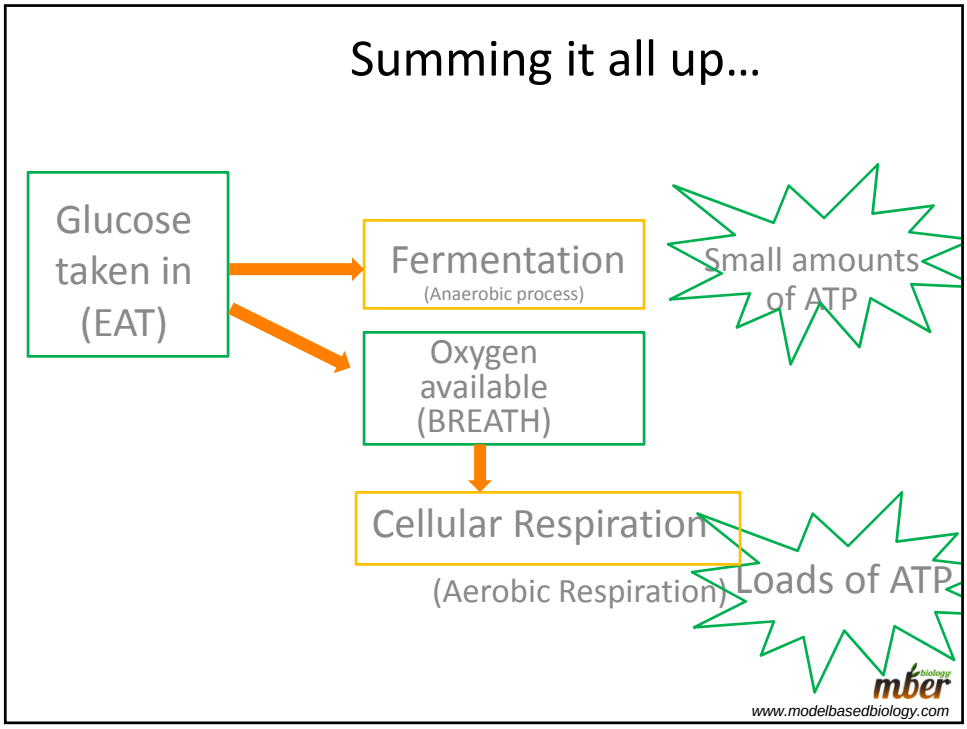
Summing it all up…
Glucose taken in (EAT)
Fermentation
(Anaerobic process)
Small amounts of ATP
Oxygen available (BREATH)
Cellular Respiration
(Aerobic Respiration)
Loads of ATP
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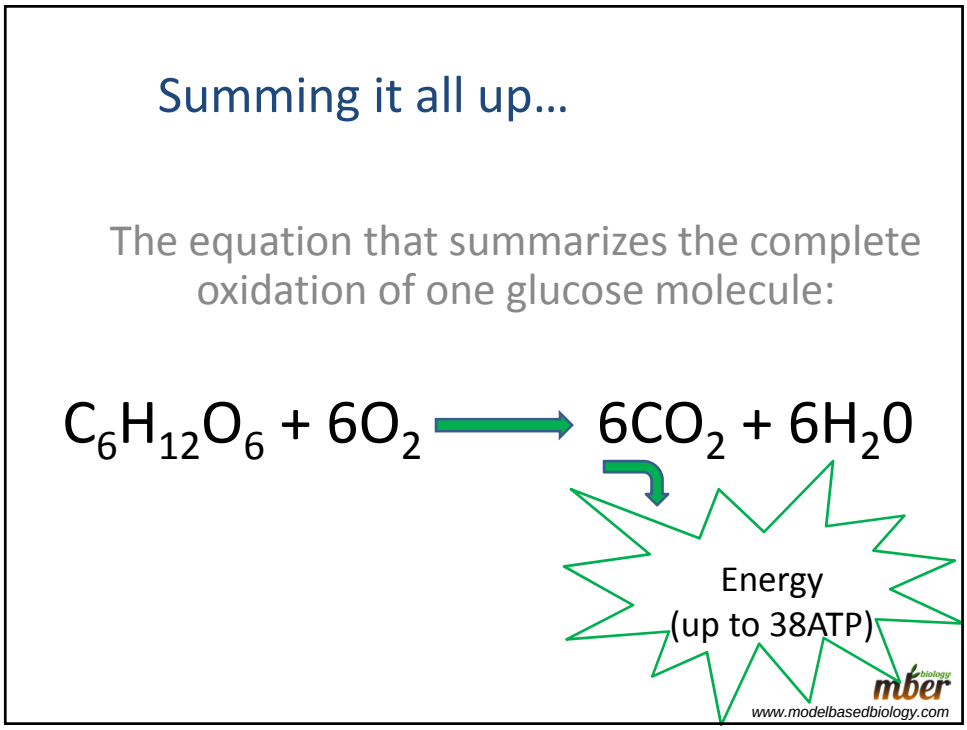
Summing it all up…
The equation that summarizes the complete oxidation of one glucose molecule:
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_20$
Energy (up to 38ATP)
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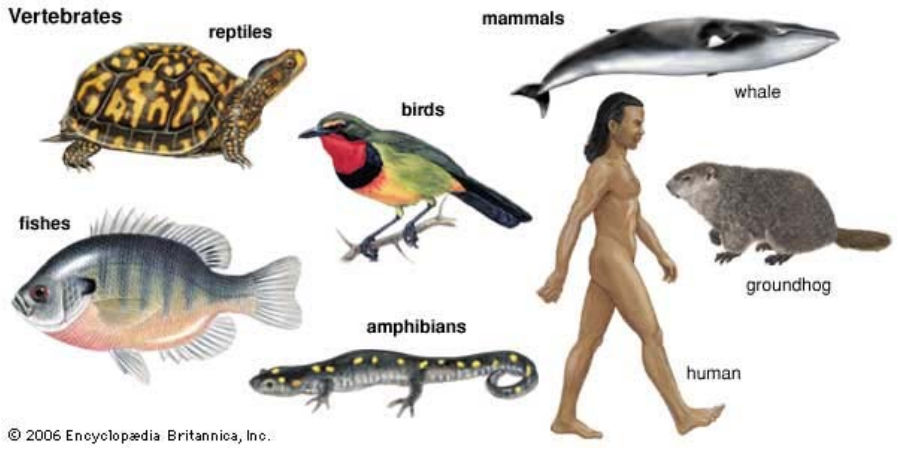
How do animals get oxygen to their cells?

A circulatory & respiratory system



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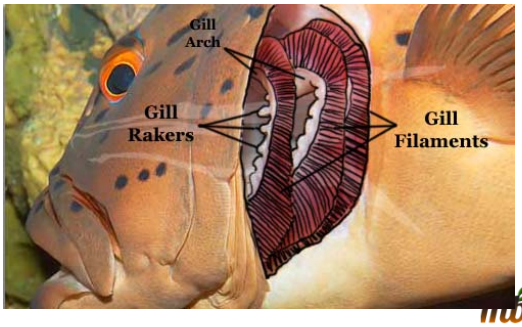
Oxygen Uptake



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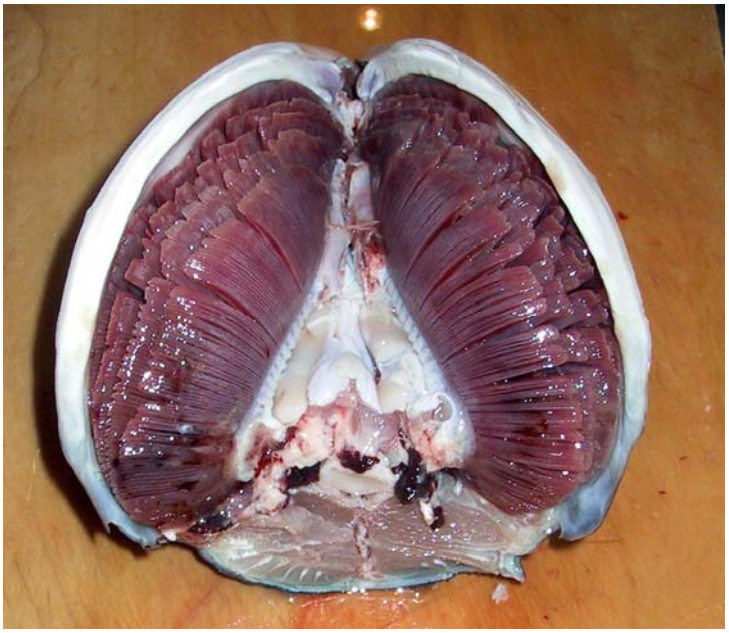

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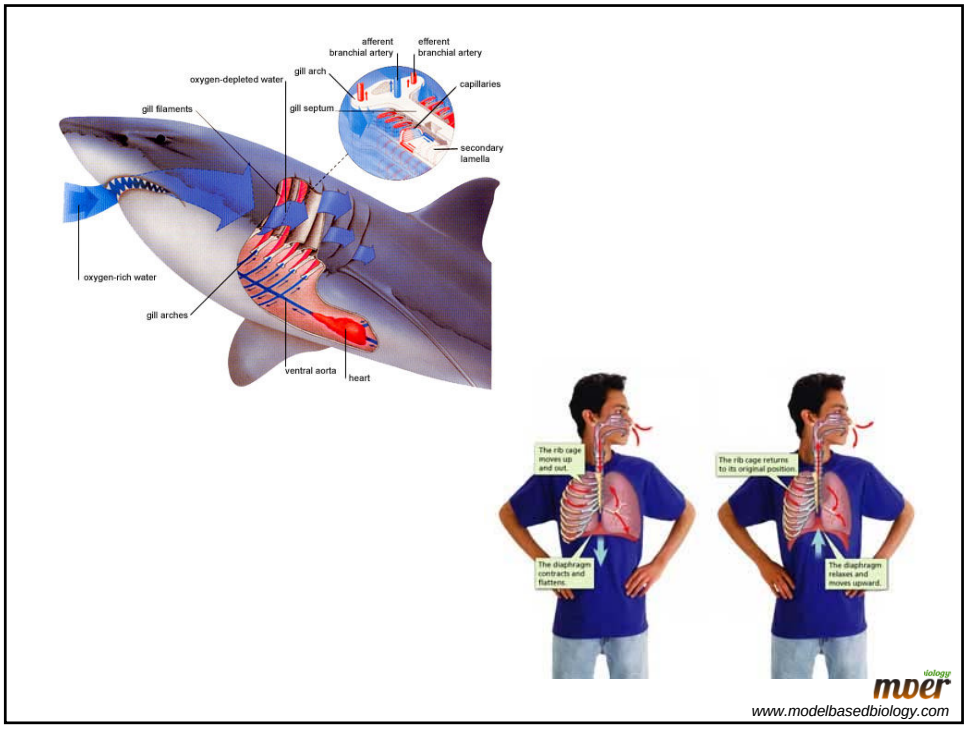
afferent branchial artery
efferent branchial artery
oxygen-depleted water
gill arch
capillaries
gill filaments
gill septum
secondary lamella
oxygen-rich water
gill arches
ventral aorta
heart
The rib cage moves up and out.
The diaphragm contracts and flattens.
The rib cage returns to its original position.
The diaphragm relaxes and moves upward.
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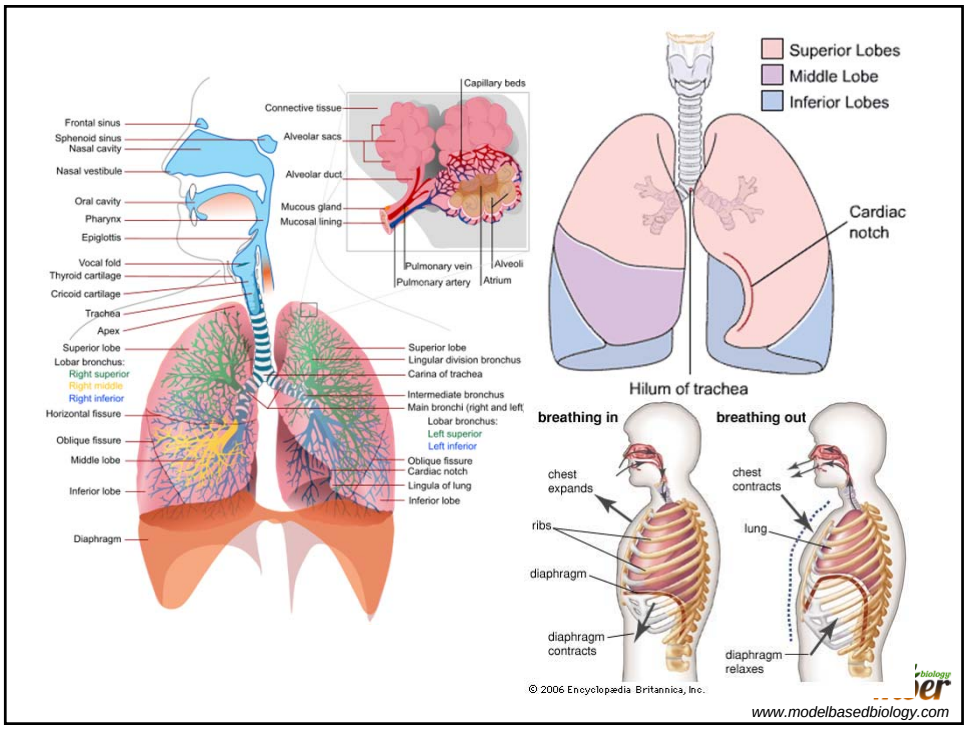
Frontal sinus
Sphenoid sinus
Nasal cavity
Nasal vestibule
Oral cavity
Pharynx
Epiglottis
Vocal fold
Thyroid cartilage
Cricoid cartilage
Trachea
Apex
Superior lobe
Lobar bronchus:
Right superior
Right middle
Right inferior
Horizontal fissure
Oblique fissure
Middle lobe
Inferior lobe
Diaphragm
Connective tissue
Alveolar sacs
Alveolar duct
Mucous gland
Mucosal lining
Capillary beds
Pulmonary vein
Pulmonary artery
Alveoli
Atrium
Superior lobe
Lingular division bronchus
Carina of trachea
Intermediate bronchus
Main bronchi (right and left)
Lobar bronchus:
Left superior
Left inferior
Oblique fissure
Cardiac notch
Lingula of lung
Inferior lobe
Superior Lobes
Middle Lobe
Inferior Lobes
Cardiac notch
Hilum of trachea
breathing in
breathing out
chest expands
ribs
diaphragm
diaphragm contracts
chest contracts
lung
diaphragm relaxes
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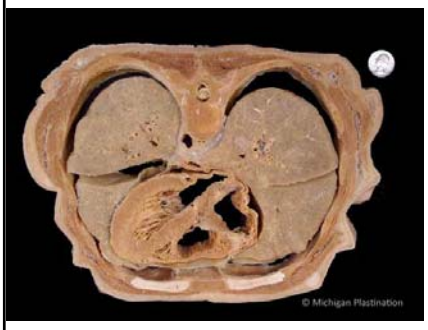
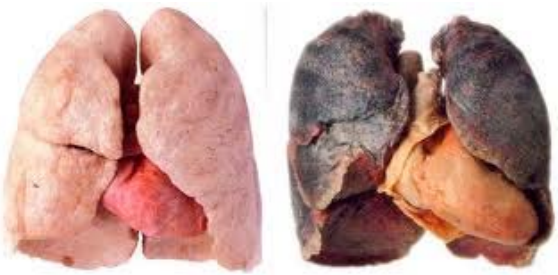


Oxygen Uptake



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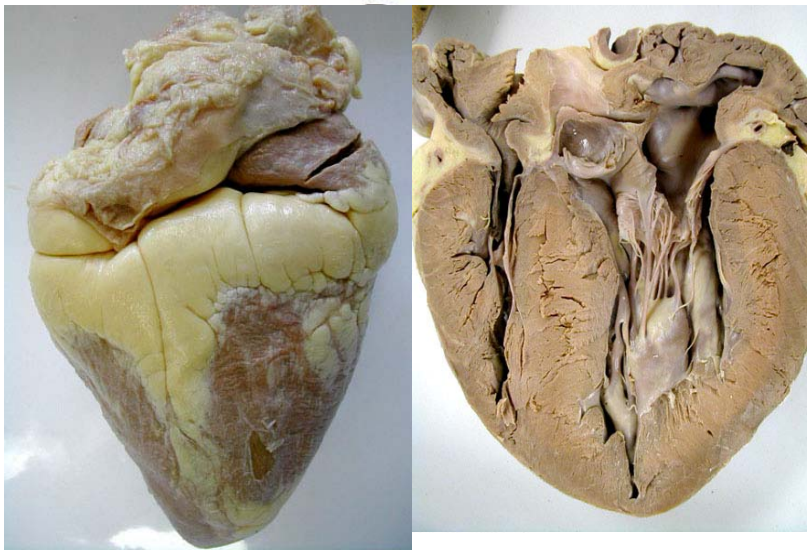

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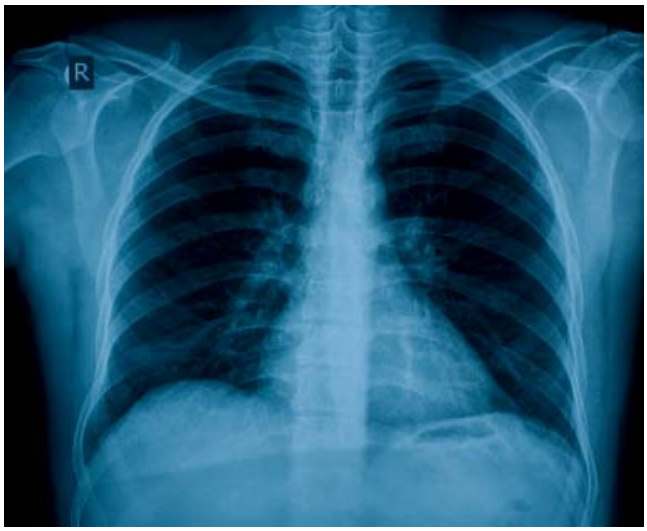

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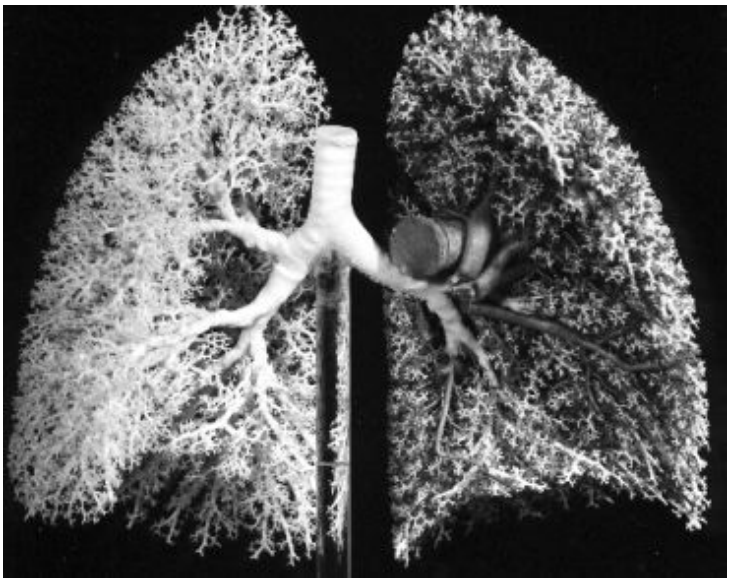
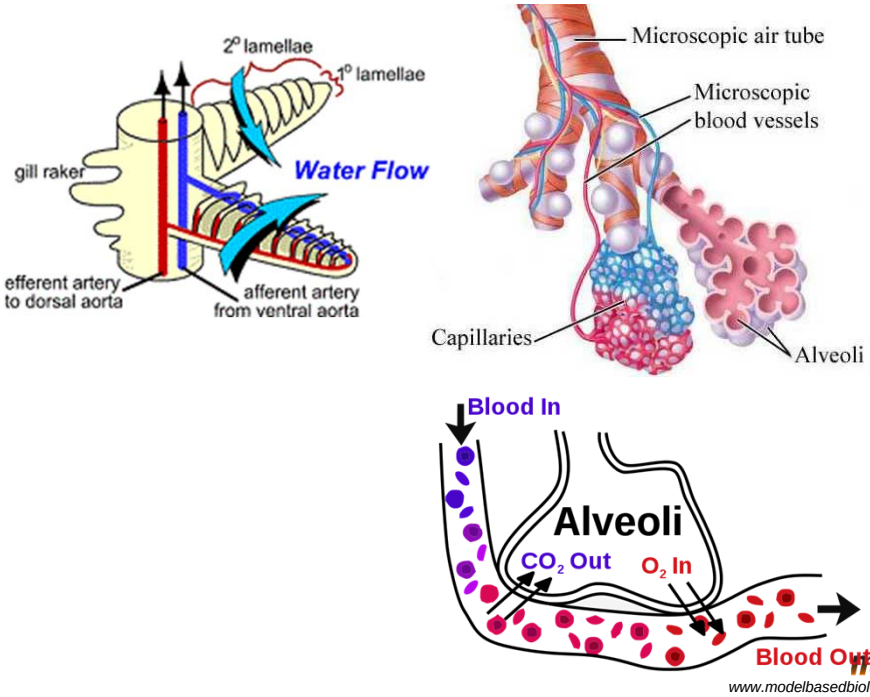
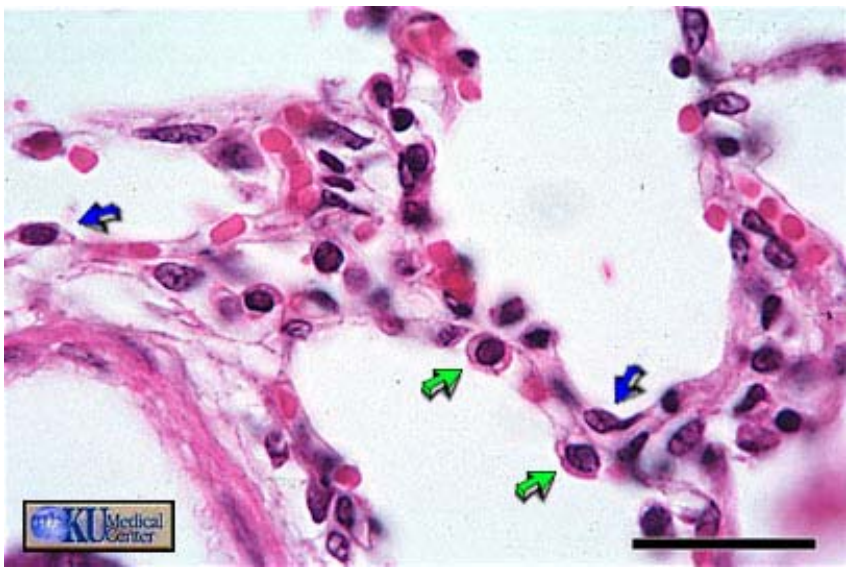
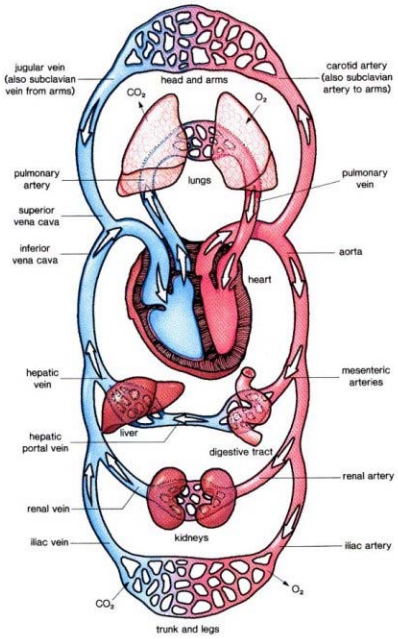
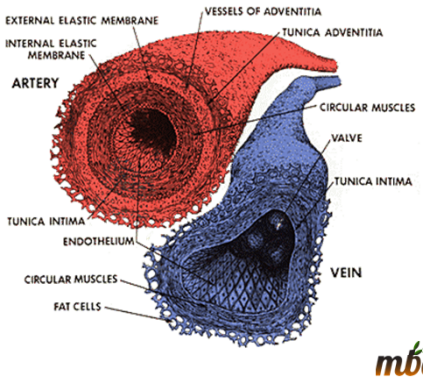


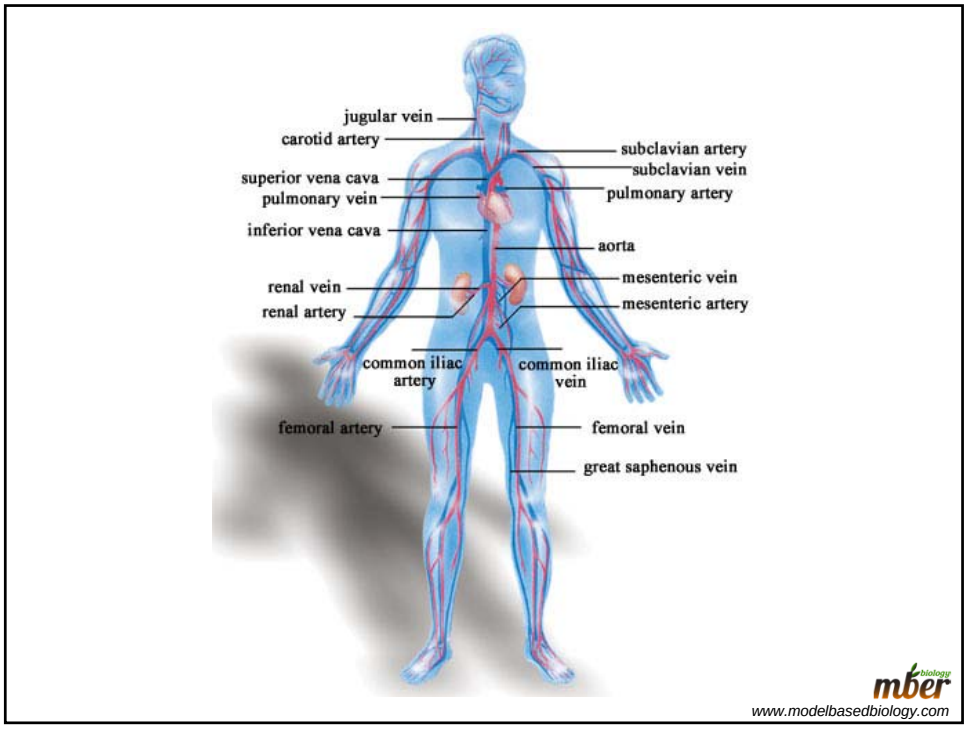




Circulation






jugular vein
carotid artery
superior vena cava
pulmonary vein
inferior vena cava
renal vein
renal artery
common iliac artery
femoral artery
subclavian artery
subclavian vein
pulmonary artery
aorta
mesenteric vein
mesenteric artery
common iliac vein
femoral vein
great saphenous vein
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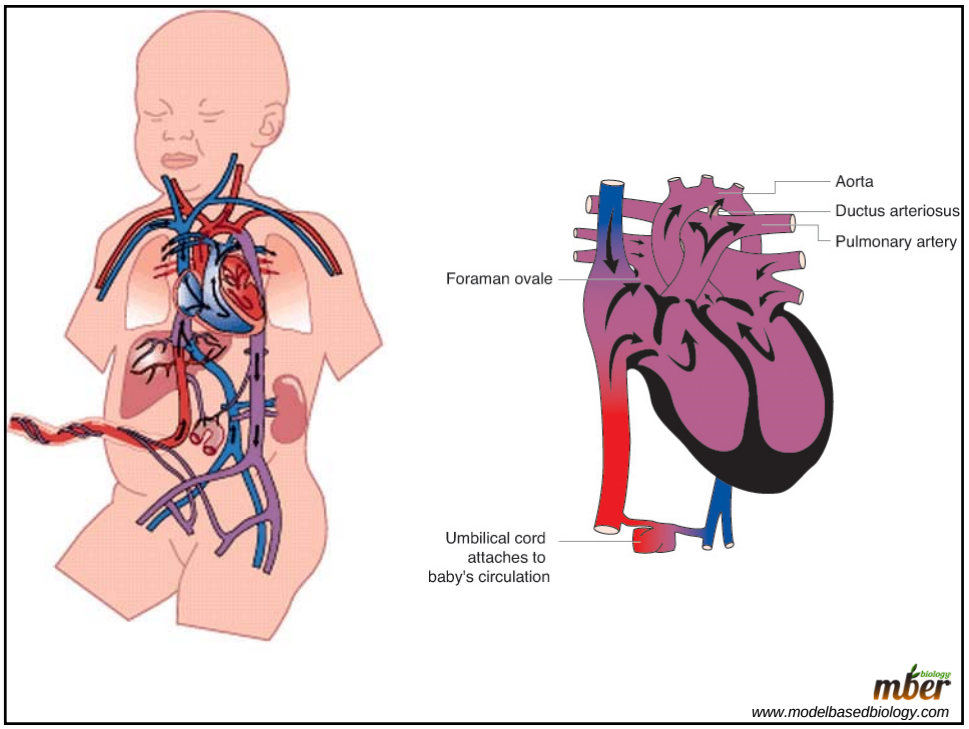
Aorta
Ductus arteriosus
Pulmonary artery
Foraman ovale
Umbilical cord attaches to baby's circulation
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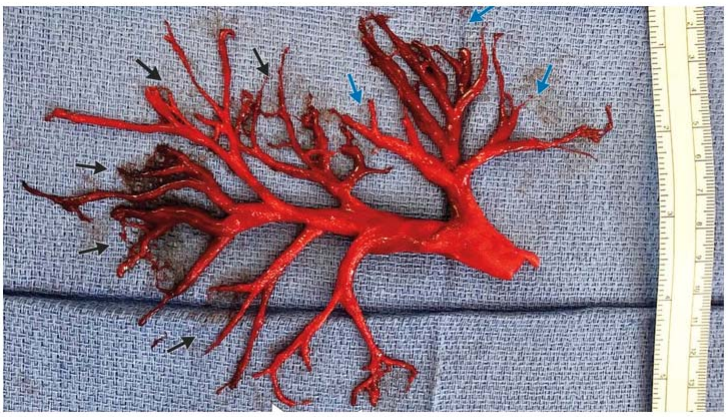
The Atlantic

HEALTH

Doctors Aren't Sure How This Even Came Out of a Patient

Somehow, a man coughed up an intact blood clot shaped like a lung passage.

HALEY WEISS DEC 6, 2018



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