THE WATER MOLECULE

structural formula

ball-and-stick model

space-filling model

Water molecules are covalent. Electrons are shared.

Water molecules are polar.

Hydrogen ions are protons, H+.
Hydroxide ions are OH-.
Hydronium ions are H_3O.

Out of 55,000,000 (55 million) water molecules, you will find only one ion.

(There are about 470,000,000,000,000,000,000 water molecules in one drop of water.)

Carbon wants to make 4 bonds.

ball and stick model of methane

ethane and butane

Simplyfing how we draw carbon chains

Carbon can make double bonds (and even triple bonds).

A fatty acid is a chain of carbons with -COOH at one end.

LIPIDS (part 1: triglycerides)

FATTY ACID

GLYCEROL

TRIGLYCERIDE

TRIGLYCERIDES
DIGLYCERIDES
MONOGLYCERIDES

What kind of fatty acids might be attached to glycerol?

_____ acid has only ___ carbon atoms. It is found in coconuts and palms. Palmitic acid has ___ carbon atoms.

These fatty acids all have ___ carbons:
1) _____ acid has ___ double bonds and is found in abundance in _____.
2) _____ acid has ___ double bond and is found in abundance in _____.
3) _____ acid has ___ double bonds and is found in abundance in _____ and _____.
4) _____ (ALA) has ___ double bonds and is found in _____ and _____.

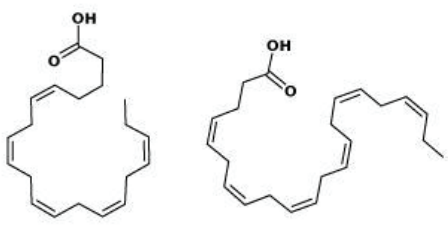
Our bodies can make some fatty acids. Others must come from our diet and are called _____.

PHOSPHATE is PO_4
It carries an electrical charge of -3 because it has three unhappy oxygen atoms. Oxygen always wants two bonds. One of these oxygens is lucky— it has a double bond. The others have an empty place where they need a bond.

A PHOSPHOLIPID is made of a phosphate group, a glycerol "hanger" and two fatty acids.

Additional fact: Carbon can form rings.

CHOLESTEROL is a natural body substance, very necessary for proper functioning of cells.



In a polar substance (like water) phospholipids form a bilayer with the hydrophobic tails pointing to the inside.

Phospholipids will form a sphere. This is the basic structure of all membranes.

An empty phospholipid sphere is called a liposome. "Lipo" is Greek for "fat," and "soma" is Greek for "body."

Liposomes form basic cell parts such as:

VACUOLES: empty "bubbles" filled with water or air

VESICLES: "storage bags" used to transport things around the cell

LYSOSOMES: vesicles that are acidic inside and contain digestive enyzmes

MEMBRANES (part 2)

The phospholipid bilayer membrane separates the inside from the outside. However, cells need to bring things in and send things out. There are many methods for getting things in and out, depending on the size and the chemical properties of those things. Some ways require energy and some don't.

PASSIVE TRANSPORT

Does not require energy.

1) SIMPLE DIFFUSION

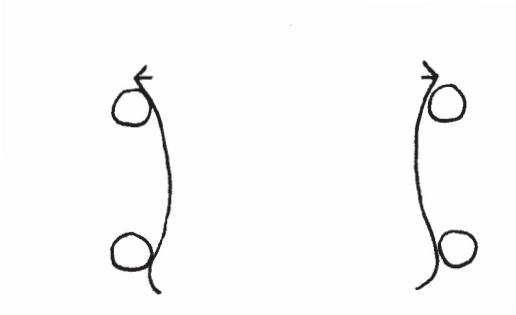
Very small, non-polar molecules, such as oxygen and carbon dioxide can go right through the membrane.

Small lipids can also diffuse because they get along so well with the fatty acid tails in the middle layer.

2) FACILITATED DIFFUSION (facil = to make easier)

Molecules that are polar or electrically charged can't use simple diffiusion; they must use channel proteins.

A) Aquaporins (for water)



Center of tube is tiny and will allow only 1 water molecule through at a time. However, 1 million water molecules get through every second!

B) Ion channels

Types of gates: light, temperature, pressure, voltage, binding of messenger molecules

ACTIVE TRANSPORT

Uses energy (often from ATP or NADH)

1) PUMPS

Use energy to push molecules across the membrane against the "concentration gradient."

Types of energy: ATP, NADH carrying high-energy electrons

2) ENDOCYTOSIS (when particles are brought inside)

3) EXOCYTOSIS (when particles are sent out)

MEMBRANES (part 3)

(the “Fluid Mosaic Model”)

The phospholipid bilayer membrane is a busy place. Not only does it have many channels and pumps, it also has lots of gadgets for sending and receiving messages. Also present are “ID tags” called MHC 1. Every cell in the body has these MHC 1 tags on them so that immune system cells know they belong to the body.

This model is called “fluid” because everything can move around. The word “mosaic” is an art term used to describe a picture made from many small colored tiles. Recent research has revealed that some things in the membrane stay in place more than expected, but this model still seems to be valid, nonetheless.

Vocab to know:

1) ***Integral membrane proteins*** are attached to the membrane. They can be on one side, or all the way through.
2) ***Transmembrane proteins*** go all the way through from one side to the other.
3) There are two words that both means “sugar.” ***Glyco*** is from Greek, and ***sacchar*** is from Latin.
4) ***Oligo*** means “few.”

PROTEINS (part 1)

The biggest difference between proteins and lipids is the presence of nitrogen, N. Nitrogen is number 7 on the Periodic Table, so it has 5 electrons in its outer shell. This means it wants to make 3 bonds (5+3=8).

The nitrogen atom:

The basic unit of all proteins is the AMINO ACID:

LEFT-HANDED AMINO ACID

RIGHT-HANDED AMINO ACID

"Handedness" is called ***chirality.*** "Chiro" is Greek for "hand."

Living things are made of left-handed amino acids only!

PROTEINS (part 2)

A protein is a chain of amino acids. Amino acids are attached by a ***peptide bond***. When you see the root word "pep," think "protein." (Ex: the enyzme "pepsin" digests protein)

To form a peptide bond, we can use the same attachment method that we used for making triglycerides. We will use ***dehydration synthesis***.

amino acid | dipeptide | tripeptide | polypeptide (poly=many)

There are only 20 amino acids (all left-handed, of course). The R group determines the chemical characteristics. R groups can be hydrophililc or hydrophobic (or neutral), and they can carry an electrical charge (or not).

PROTEINS (part 3)

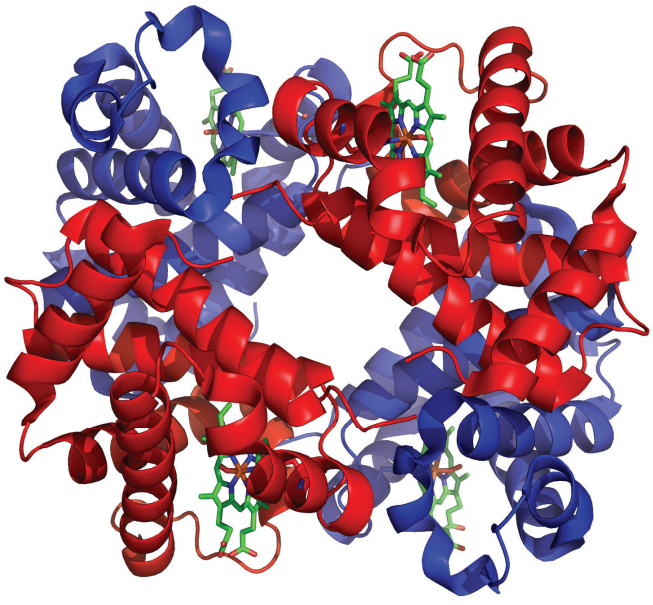
The PRIMARY structure of a protein is the sequence of amino acids in the chain.

The SECONDARY structure of a protein is either an alpha helix or a beta sheet.

The TERTIARY structure of a protein is the way it folds up into a unique 3D shape.

Hydrophobic aminos try to hide in the center. Sometimes atoms of other elements (like zinc) are incorporated into the shape.

The QUATERNARY structure is when two or more proteins bond together to form a final protein shape. Hemoglobin is made of four tertiary structures.



PROTEINS (part 4)

Proteins are the building blocks of numerous “gadgets” in and around cells.

EMBEDDED GADGETS in the plasma membrane

CABLES

Microtubules

Intermediate filaments

Microfilaments

“SCISSORS” and “STAPLERS” (enzymes)	“VEHICLES” transportation around the body	TAGS mark invaders for destruction by immune cells
A and B are called “substrates.”	MOTOR PROTEINS: --Kinesins --Dyneins ALBUMIN Acts like boat (or taxi)	They go by three names: --gamma globulins --immunoglobulins --antibodies All three are correct-- you choose.

CARBOHYDRATES

MONOSACCHARIDES are simple sugars

GLUCOSE FRUCTOSE GALACTOSE

DISACCHARIDES are “double” sugars made of two simple sugars

POLYSACCHARIDES are long strings of simple sugars (up to 4,000 units long!)

1) Starch

Plants make starches and store them in seeds and roots: wheat, rice, corn, beans, potatoes, beets, carrots, etc.

2) Cellulose

Plants make cellulose and use it for their tough cell walls. We eat it as fiber (leaves and stems).

3) Glycogen

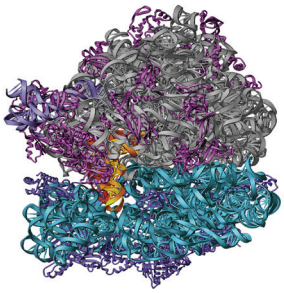
Our bodies make glycogen as a way to store glucose in the liver and in muscles.

The hormone Insulin signals the body to turn glucose into glycogen. Adrenaline does the opposite.

HOW PROTEINS ARE MADE (part 1: Translation)

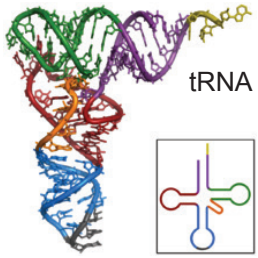
RIBOSOMES are the “factories” that make proteins. They are the smallest organelle in a cell.

(NOTE: They are NOT protein gadgets. They are made primarily of RNA with only a few bits of protein mixed in.)



ribosome

Image of ribosome from the Center for Molecular Biology of RNA, Univ. of CA Santa Cruz, ma.ucsc.edu/rnacenter



“TRNA-Phe yeast 1ehz” by Yikrazuul - https://commons.wikimedia.org/wiki/File:TRNA-Phe_yeast_1ehz.png#/media/File:TRNA-Phe_yeast_1ehz.png

1) All pieces are separate until a mRNA snaps onto a small subunit. (There are special molecules that cause the mRNA to stick.)

2) The two subunits snap together.

3) tRNAs start bringing amino acids to the ribosome, and they are added one by one to the growing protein chain.

4) When the protein is finished, all parts separate.

5) After the polypeptide is done it gets folded, often with help from chaperone proteins.

Floating nearby are millions of transfer RNAs (tRNAs) holding amino acids.

HOW PROTEINS ARE MADE (part 2: RNA)

RNA is **ribonucleic acid**. The individual units of RNA are called **nucleotides**.
A nucleotide is made of three pieces: a ribose, a phosphate, and a "base."

Ribose is a simple sugar but has only 5 carbons.

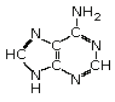
Phosphate is PO_4. This is the "acid."

Bases contain nitrogen. There are 5 types.

A NUCLEOTIDE
is a ribose, a phosphate and a base.

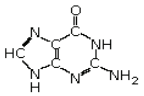
There are 5 kinds of bases. Three of them are in both RNA and DNA.

Found in RNA and DNA.



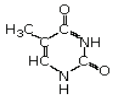
Adenine

Cytosine



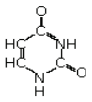
Guanine

DNA only



Thymine

RNA only



Uracil

RNA is a long chain of nucleotides. The bases in RNA are A, C, G and U.

We could draw RNA showing the riboses, the phosphates and the bases.

Or we can short-cut and draw it like this:

To make it even simpler we can draw it like this:

Each set of 3 nucleotides forms a unit called a CODON. (64 possible codons)

tRNA has an anticodon that matches up with a codon during translation in a ribosome.

RNA is found in more than one place in a cell.

1) _____ (messenger RNA) is a copy of a section of DNA and is used to make _____.

2) _____ (transfer RNA) is used as a taxi for _____ _____.

3) _____(ribosomal RNA) is folded up to make _____.

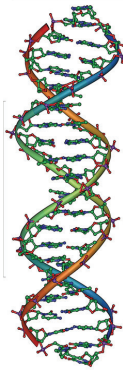
4) _____ (microRNA) are very short pieces of RNA used to regulate gene expression.

HOW PROTEINS ARE MADE (part 3: Transcription)

DNA contains all the information a cell will ever need. DNA is so important that it can never leave the protection of the nucleus. Therefore, when information is needed outside the nucleus, a mRNA copy of that section of DNA is created and sent out.

The nucleus is made of TWO bilayers of phospholipids. It has a double-thick membrane.

DNA



DNA is similar to RNA. It is made of nucleotides.

These are the DIFFERENCES:

1)

2)

3)

4)

A protein gadget called **RNA polymerase** acts as both a scissor (or maybe zipper) and a stapler. It unzips the DNA and then staples nucleotides together to match one of the strands of the DNA. (Notice which strand is being copied.)

The mRNA that leaves the polymerase is not ready for immediate use.
There are "filler" pieces called ***introns*** that must be snipped out.
Also, a special cap must be put on the 5' end, and a poly(A) tail on the 3'.

The introns are cut out by a machine made of RNA called a ***spliceosome***.

After the introns are gone, the mRNA is ready to leave the nucleus.

PROKARYOTES (part 1)

- For every 1 human cell in your body, you have 10 bacteria cells.
- There are two types of prokaryotes: BACTERIA and ARCHAEA. (Archaea used to be classified as bacteria. They tend to be the "extremophiles" who survive in harsh conditions.)
- Prokaryotes do not have a true nucleus. They have a clump of DNA but it does not have an envelope around it.

ANATOMY of a "basic" BACTERIA

NOTE: The "cillin" antibiotics interfere with the enzyme robot that does the cross-linking. Without these links, the cell wall is too weak and the bacteria falls apart.

MORPHOLOGY (means "shape") (SIZE: 1 to 3 μm)

coccus (cocci) | diplococcus | bacillus (bacilli) | vibrio

streptococcus | staphylococcus | spirillum (spirilli) | spirochete

FIMBRIAE *(fim-bree-eye)* are little "hairs" that allow the bacteria to stick to surfaces. They are more common in Gram negatives.

PILI *(pie-lie)* are similar to fimbriae (some people think the names are interchangeable) but are longer, and thicker. They are used to move (like rock climbers use grappling hooks). A "sex plius" is very long and can grab another bacteria and "reel it in" until they touch. Then DNA can be shared.

PROKARYOTES (part 2)

MOTILITY (means “movement”)

Bacteria sometimes have “tails” called flagella that are made of microtubules. (“Flagella” means “whip.”)

Some bacteria can glide using a sugary slime.
They can also use pili as grappling hooks to pull forward.

Spirochetes have an inner flagellum.

CLASSIFICATION by pathologists (“Patho” means “disease.”)

The Gram stain is used to find out what kind of cell wall the bacteria has so right kind of antibiotic can be prescribed.

GRAM positive (+) GRAM negative (-)

(Gram staining is named after Danish scientist Hans Christian Gram.)

CAPSULES (the “slime layer”)

Capsules keep them from drying out and from being eaten by immune cells.

ARCHAEA

- Used to be classified as bacteria
  (They have their own kingdom now.)
- Most of them live in extreme environments like the bottom of the ocean or in hot mineral springs. However, a few species live in our intestines where they produce methane gas.
- None of them are pathogens.
  (They won’t make you sick.)
- Coccus, bacillus and spirillum shapes
- Some have flagella

Archaea look and act very much like bacteria.

Differences between bacteria and archaea:

1)

2)

3)

4)

5)

ATP and GLYCOLYSIS

What does it mean to be alive? We just looked at bacteria, which are definitely alive. But what about viruses? Are they alive? Viruses are also part of our microbiome.

To be alive, an organism must:

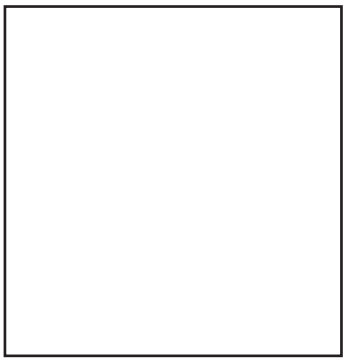
1)

2)

3)

4)

5)



A virus is basically a piece of DNA or RNA inside a protein shell sometimes with a lipid membrane.

HOW DO LIVING CELLS USE ENERGY?

Most cellular processes are powered by **ATP** (adenosine triphosphate). ATP acts like a rechargeable battery.

GLYCOLYSIS means “breaking glucose”

Glucose is a like a stick of dynamite, full of potential energy. It must be disassembled little by little so the energy is released slowly, not all at once.

What is NADH?

SPERM and MITOCHONDRIA

The sperm cell is the smallest human cell. It has half the normal amount of DNA and has very few organelles.

MITOCHONDRIA are often called the "powerhouses" of the cell because they make lots of ATPs.

Mitochondrial DNA (mtDNA) is inherited primarily from the mother. The egg cell will donate thousands of mitochondria compared to the sperm's one hundred or so. This fact makes mtDNA useful for researching ancestry.

Most genes are for tRNA, some are for protein gadgets found in the Electron Transport Chain, and some are for ribosomal RNA.

A "gene" is a strip of DNA (or several strips spliced together) that code for a particular protein.

The Electron Transport Chain (ETC) is an assembly line of machines that will turn ADP back into ATP.

KREBS CYCLE and ELECTRON TRANSPORT CHAIN

In the mitochondrial matrix, pyruvates are cut apart to make acetyl-CoA's, which are then sent to the Krebs Cycle.

The Krebs Cycle breaks apart the remaining carbon bonds and uses the energy to recharge "taxi" molecules NADH and FADH2. These taxis then go over to the E.T.C.

The end result of all these processes is that one molecule of glucose can yield up to 36 ATPs. CO_2 and H_2O are given off as wastes.

1) The PRE-KREBS step happens as the pyruvate crosses the inner membrane (into the matrix)

An enzyme "scissor" snips off one carbon. This carbon has two oxygens attached to it, so the carbon goes sailing off as CO_2.

NADH is a "taxi" for high-energy electrons. One taxi gains two electrons in this step.

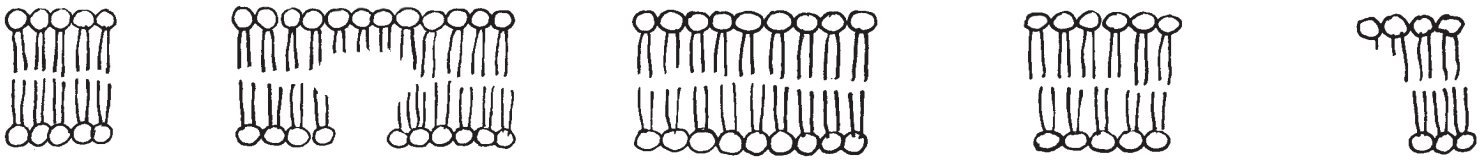
An enzyme "stapler" adds a piece called **coenzyme A** to the remaining 2-carbon molecule (which is called acetyl). CoA is actually a very large molecule.

2) The KREBS CYCLE finishes the "burning" of glucose

This cycle is also called the Citric Acid Cycle

3) The Electron Transport Chain (ETC)

The ETC is an elaborate system of protein gadgets. There are 3 pumps, several shuttles, and a motor at the end. The goal? ATPs!

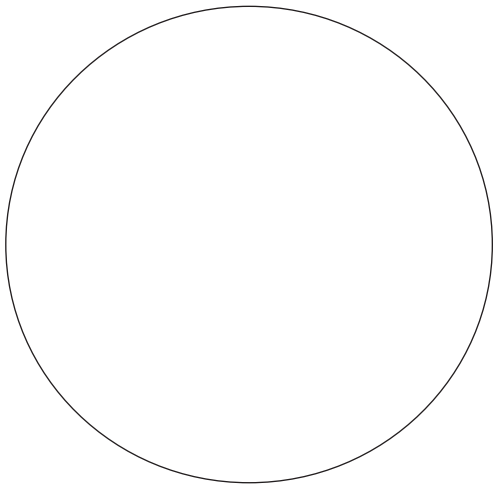


Since this process requires O_2 and it results in phosphates being put back on, we can call it **oxidative phosphorylation**.

THE OVUM and FERTILIZATION

The ovum (egg) is the largest human cell at about 200 microns (the length of a paramecium).

MEIOSIS

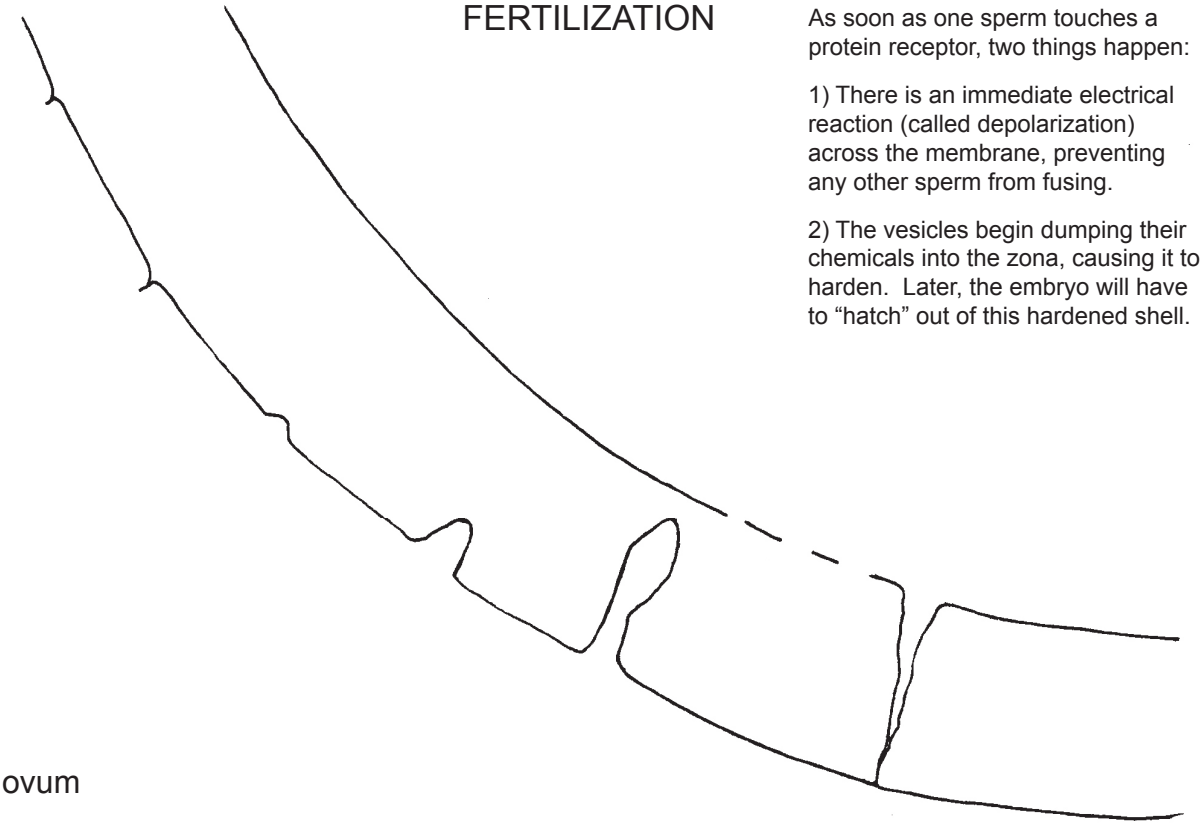


FERTILIZATION

As soon as one sperm touches a protein receptor, two things happen:

1) There is an immediate electrical reaction (called depolarization) across the membrane, preventing any other sperm from fusing.

2) The vesicles begin dumping their chemicals into the zona, causing it to harden. Later, the embryo will have to “hatch” out of this hardened shell.



CLOSE-UP of ovum

THE ZYGOTE

When the sperm nucleus fuses with the ovum nucleus, a zyote is formed. This cell is **totipotent** and is capable of turning into any type of cell, including not only body cells, but also placenta cells or umbilical cord cells.

_____ for receiving messages

_____ for taking in large molecules such as proteins or fats.

_____
- Holds the cell's shape
- Provides "roads" for motor proteins.

_____
- The location of the Krebs Cycle and the Electron Transport Chain (which makes lots of ATPs).

_____
- Is an identification tag showing that the cell is "self" and not an invader.

_____
- Makes microtubules and will form the spindle during mitosis.

_____
- DNA when it looks like spaghetti

_____
- Is a thick clump of DNA that makes ribosomes

_____
- Makes phospholipids to be used in membrane and vesicles
- Stores calcium
- Makes steroid hormones

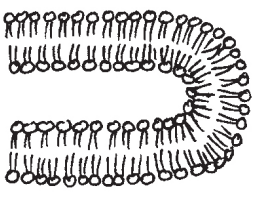
_____
- Contain several dozen types of digestive enzymes that can break down proteins, fats, sugars and nucleic acids into individual units that can be used by the cell to build cell parts. (Without lysosomes, cellular garbage builds up and poisons the cell.)

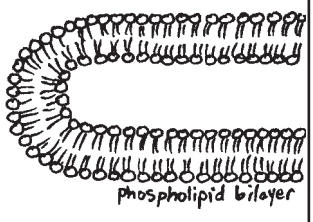
_____
- Make proteins

_____
- Has ribosomes stuck to it. The ribosomes feed polypeptides into it. The ER wraps them in membrane to form a vesicle. The vesicle will likely go to a Golgi body to be labeled for delivery.

_____
- Break long chain fatty acids into medium length chains that get delivered to the mitochondria (where they will then be turned into acetyl-CoA's).
- Neutralize toxins (ex: alcohol) and free radicals by transferring dangerous H atoms to O_2 molecules, making H_2O_2 (hydrogen peroxide). Another enzyme neutralizes the H_2O_2. Liver cells contain many peroxisomes.

NUCLEAR PORES





GOLGI BODIES

Golgi bodies add sugar tags that act like address labels so vesicles get delivered to the correct place in or out of the cell.

MITOSIS

Mitosis is the process where body cells (somatic cells) duplicate themselves in order to make new cells. Don't confuse mitosis with meiosis (the process that produces gametes) or with binary fission (how prokaryotes split in half).

A CENTROSOME is made of two CENTRIOLES surrounded by a blob of protein goo.

The centrosomes form a spindle of microtubules. The pairs of chromosomes are lined up in the middle of the spindle. The microtubules will then contract and pull the pairs apart.

THE CELL CYCLE

INTERPHASE is when cell is not actively in mitosis.

Gap 0 = cell is resting
Gap 1 = organelles duplicated
S phase = DNA replicated
Gap2 = enzymes are made

PROPHASE

Chromatin condenses into chromosomes, and nuclear envelope begins to dissolve.

METAPHASE

Chromosomes line up in the middle.

(Think META---MIDDLE)

ANAPHASE

Chromosomes pulled apart

(ANA = opposite)
(Or visualize letter A)

TELOPHASE

Chromosomes are far away and nuclear envelope begins to form again.

(TELO = far; "telescope")

CYTOKINESIS
cell movement

The cell splits (cleaves) in half.

DNA REPLICATION

The zygote is a human cell but it is not any particular cell. To become a specific type of cell, such as a skin cell or a muscle cell, all the non-skin or non-muscle DNA must be permanently zippered shut. There are three main ways that DNA can be silenced.

1) DNA methylation

Methyl:

This is the most permanent form of locking away information.
Enzymes put methyl tags (CH_3) on cytosines in the areas that are to be locked.

2) Histone modification

The histone spools on which DNA is wound can control whether a gene is expressed or not.
("Expressed" means that the information is being used and proteins are being made.)

3) Micro RNAs (miRNA)

Micro RNAs are non-coding RNAs whose sole purpose is to mess up RNA. When a miRNA attaches, that portion of the RNA becomes unusable. Thus, gene expression is blocked.