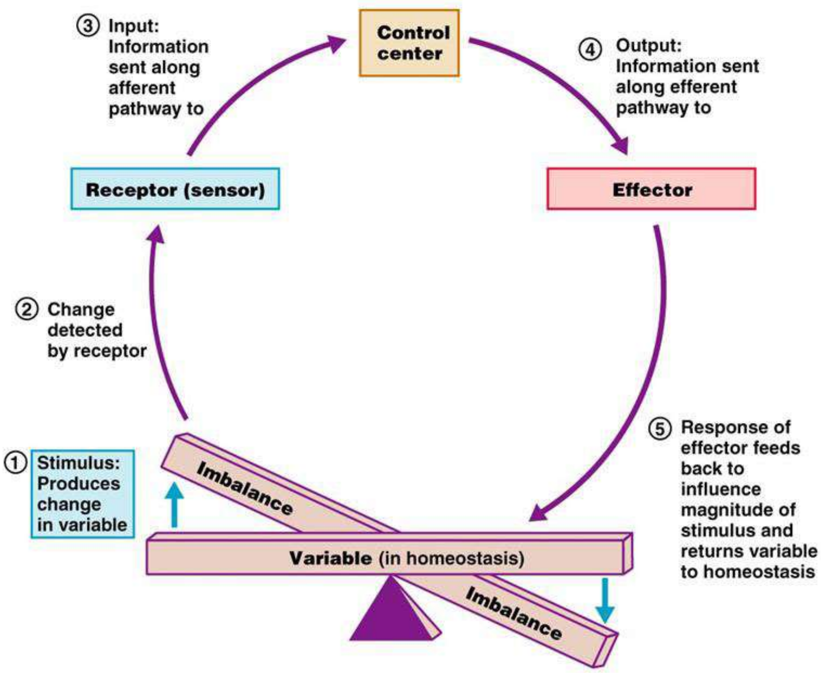
Biology EOC Review Session 2: Wednesday May 31, 2017

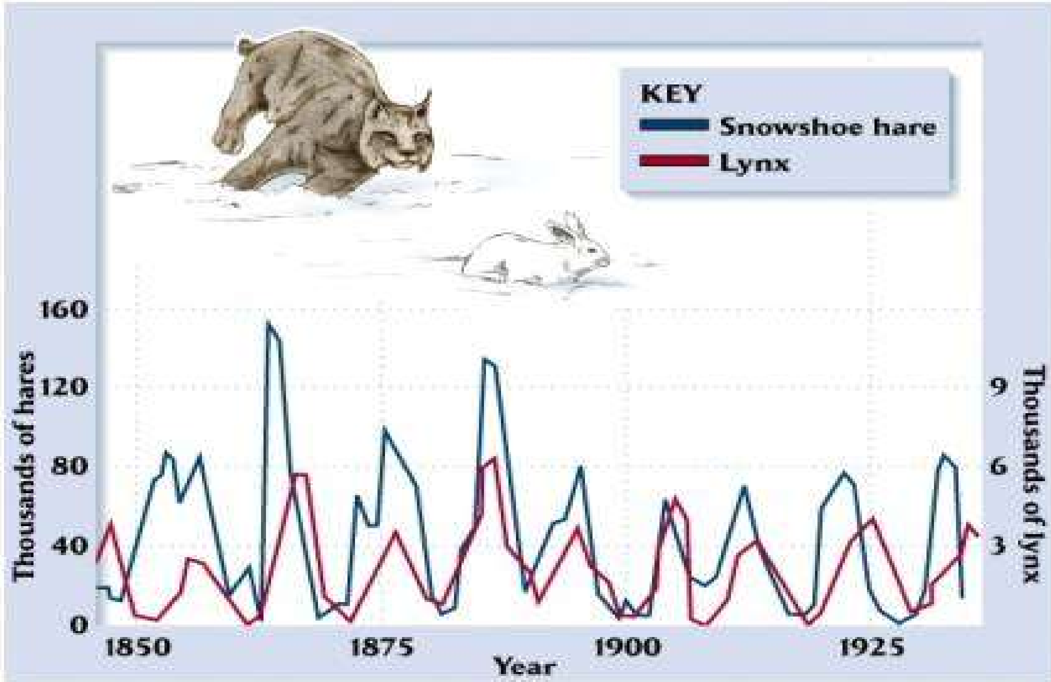
Positive and Negative Feedback Loops

Biological systems operate on a mechanism of **inputs and outputs**, each caused by and causing a certain event.



A feedback loop is a biological occurrence wherein the output of a system **amplifies the system** (positive feedback) or **inhibits the system** (negative feedback). Feedback loops are important because they allow living organisms to **maintain homeostasis**. *Homeostasis* is the mechanism that enables us to keep our internal environment relatively constant – not too hot, or too cold, not too hungry or tired. The level of energy that an organism needs to maintain homeostasis depends on the type of organism, as well as the environment it inhabits. For example, a cold-blooded fish keeps its temperature at the same level as the water around it, and so doesn't need to control its internal temperature. Compare this to a warm-blooded whale in the same environment: it needs to keep its body temperature higher than that of the water around it, and so it will expend more energy in temperature regulation.

Feedback loops can also occur to a larger degree: at the ecosystem level, a form of homeostasis is maintained. A good example of this is in the cycle of predator and prey populations: a boom in prey population will mean more food for predators, which will increase predator numbers. This will then lead to over predation, and the prey population will again decline. The predator population will decline in response, releasing the pressure on the prey population and allowing it to bounce back. See figure 1. Another example is what is known as the "evolutionary arms race," wherein a predator and its prey are continually trying to out compete each other. One such relationship is that of nectarivorous birds and the flowers on which they feed. The birds evolve long beaks to gain access to the nectar within the flower. In response, the flower develops a longer and longer trumpet-like shape, in an attempt at preventing the bird from getting to the nectar. The bird responds by developing an even longer beak. And so it continues.



The graph to the left is showing the two populations in **dynamic equilibrium.** The two species are interrelated in that the main food source for Lynx are snowshoe hair, when the population of hair decrease so do the Lynx keeping the populations in check

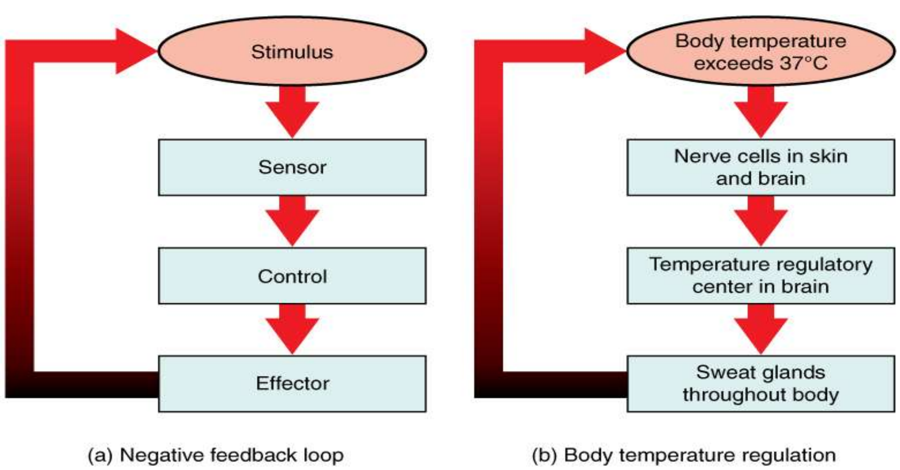
Figure 1: The population trends of predator and prey.

Negative Feedback Loops

A negative feedback loop occurs in biology when the product of a reaction leads to a decrease in that reaction. In this way, a negative feedback loop brings a system closer to a target of stability or homeostasis. Negative feedback loops are responsible for the stabilization of a system, and ensure the maintenance of a steady, stable state. The response of the regulating mechanism is opposite to the output of the event.

Example 1: Temperature Regulation

Temperature regulation in humans occurs constantly. Normal human body temperature is approximately 98.6°F. When body temperature rises above this, two mechanisms kick in the body begins to sweat, and vasodilation occurs to allow more of the blood surface area to be exposed to the cooler external environment. As the sweat cools, it causes evaporative cooling, while the blood vessels cause convective cooling. Normal temperature is regained. Should these cooling mechanisms continue, the body will become cold. The mechanisms which then kick in are the formation of goose bumps, and vasoconstriction. Goosebumps in other mammals raise the hair or fur, allowing more heat to be retained. In humans, they tighten the surrounding skin, reducing (slightly) the surface area from which to lose heat. Vasoconstriction ensures that only a small surface area of the veins is exposed to the cooler outside temperature, retaining heat. Normal temperature is regained.



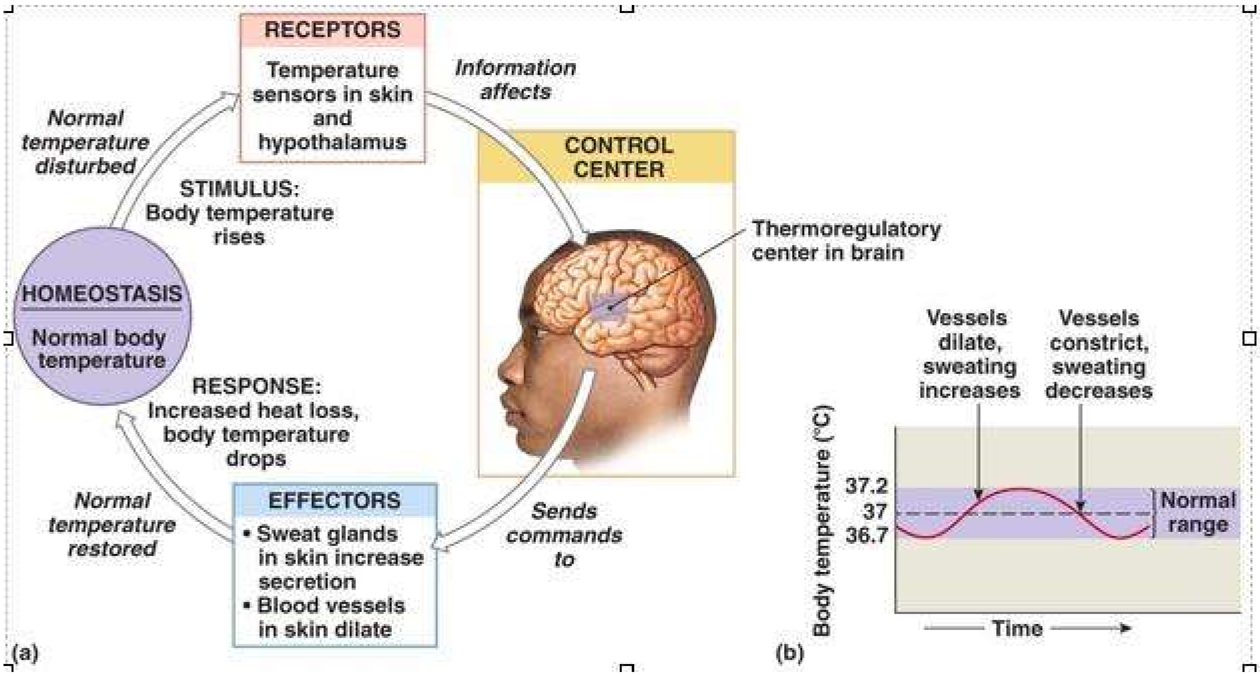
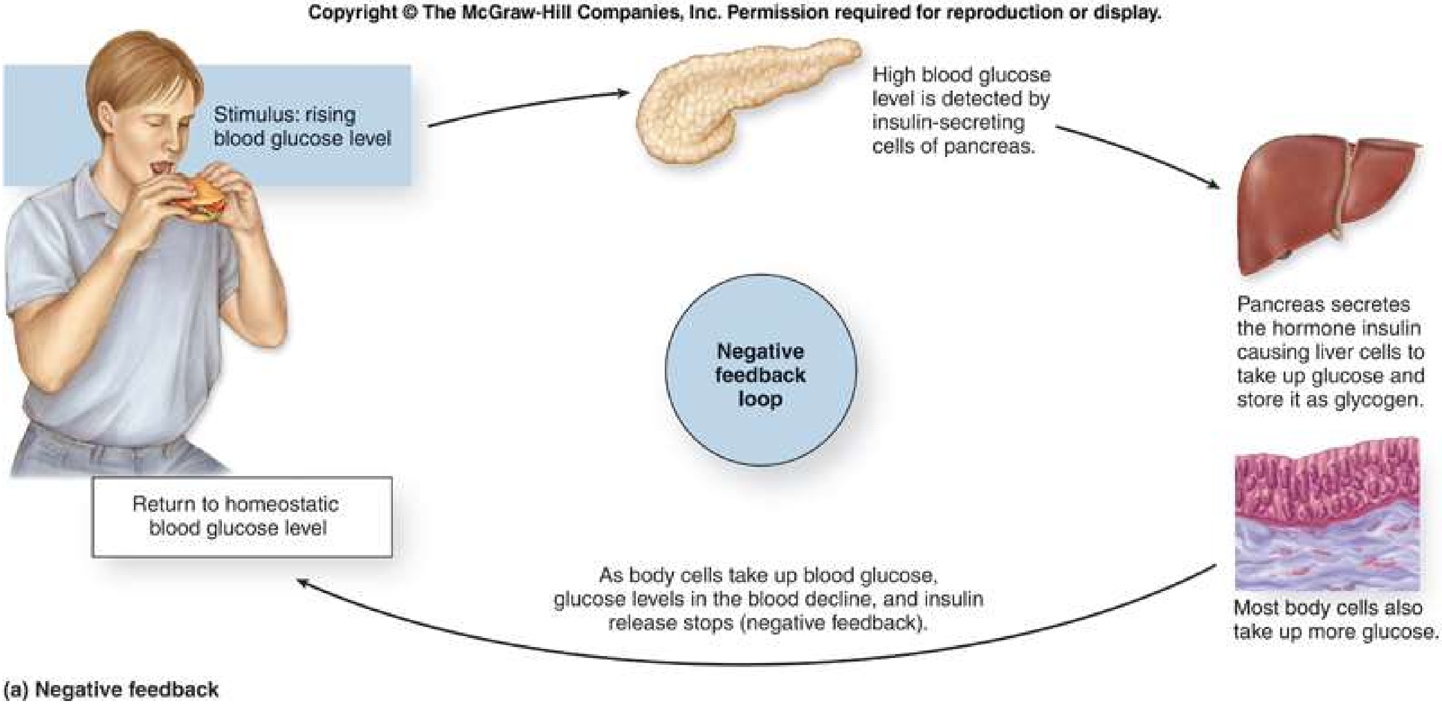


Figure 5: The process of temperature regulation in humans is a negative feedback loop.



Positive Feedback Loops

A positive feedback loop occurs in nature when the product of a reaction leads to an **increase in that reaction**. If we look at a system in homeostasis, a positive feedback loop moves a **system further away from the target of equilibrium.** It does this by **amplifying the effects** of a product or event and occurs when something needs to happen quickly.

Example 1: Childbirth

When labor begins, the baby's head is pushed downwards and results in increased pressure on the cervix. This stimulates receptor cells to send a chemical signal to the brain, allowing the release of oxytocin. This oxytocin diffuses to the cervix via the blood, where it stimulated further contractions. These contractions stimulate further oxytocin release until the baby is born.

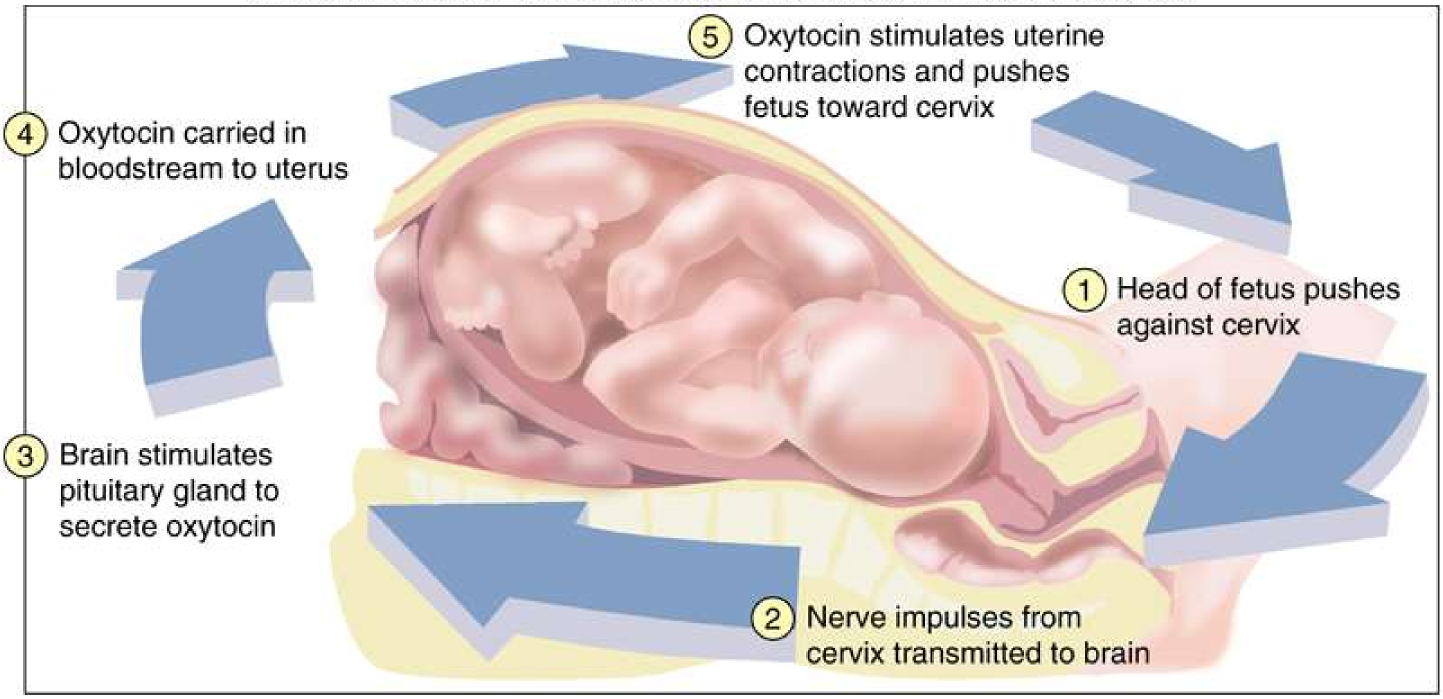
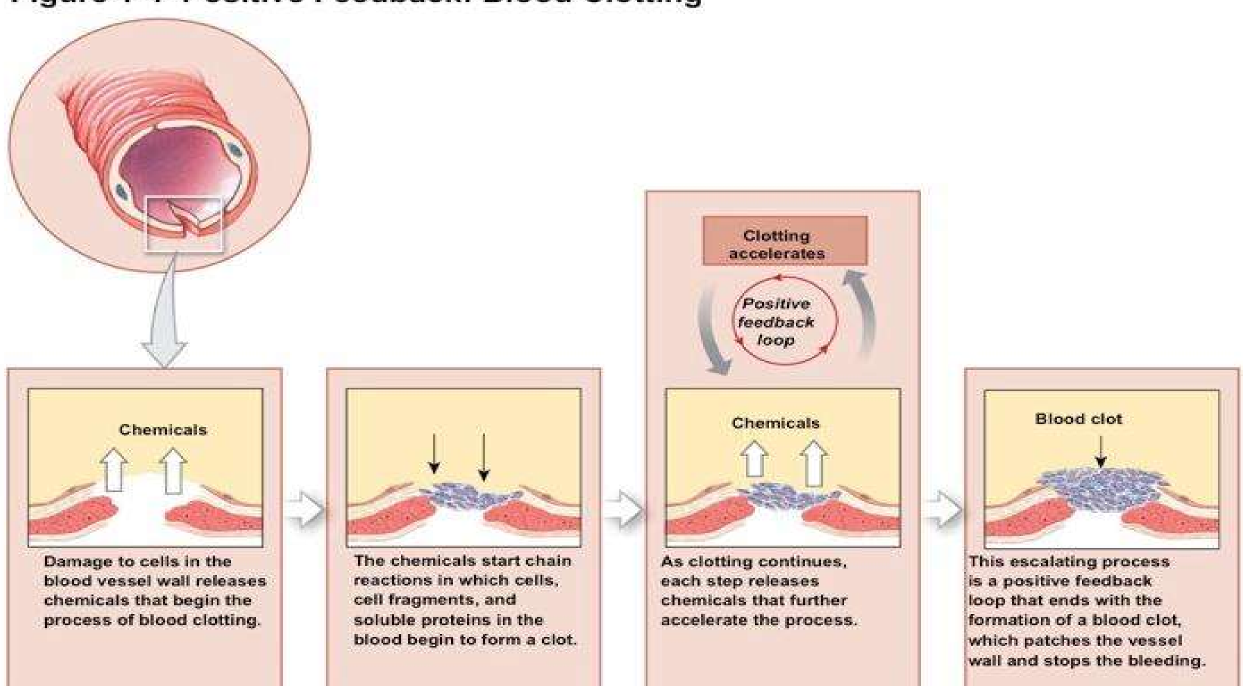


Figure 3: The contractions experienced in childbirth come about as a result of a positive feedback loop.

Example 3: Blood Clotting
When tissue is torn or injured, a chemical is released. This chemical causes platelets in the blood to activate. Once these platelets have activated, they release a chemical which signals more platelets to activate, until the wound is clotted.

Figure 1-4 Positive Feedback: Blood Clotting



Positive vs. Negative Feedback
The key difference between positive and negative feedback is their response to change: positive feedback amplifies change while negative feedback reduces change. This means that positive feedback will result in more of a product: more apples, more contractions, or more clotting platelets. Negative feedback will result in less of a product: less heat, less pressure, or less salt. Positive feedback moves away from a target point while negative feedback moves towards a target.

Why is Feedback Important?
Without feedback, homeostasis cannot occur. This means that an organism loses the ability to self-regulate its body. Negative feedback mechanisms are more common in homeostasis, but positive feedback loops are also important. Changes in feedback loops can lead to various issues, including diabetes mellitus.

Photosynthesis: Overview: The Process That Feeds the Biosphere

Life on Earth is solar powered.
The chloroplasts of plants use a process called photosynthesis to capture light energy from the sun and convert it to chemical energy stored in sugars and other organic molecules.

Plants and other autotrophs are the producers of the biosphere.

Photosynthesis nourishes almost all the living world directly or indirectly.
All organisms use organic compounds for energy and for carbon skeletons.
Organisms obtain organic compounds by one of two major modes: autotrophic nutrition or heterotrophic nutrition.

Autotrophs produce their organic molecules from CO_2 and other inorganic raw materials obtained from the environment.

Autotrophs are the ultimate sources of organic compounds for all heterotrophic organisms.
Autotrophs are the *producers* of the biosphere.
Autotrophs can be separated by the source of energy that drives their metabolism.
*Photo*autotrophs use light as a source of energy to synthesize organic compounds.
Photosynthesis occurs in plants, algae, some other protists, and some prokaryotes.
*Chemo*autotrophs harvest energy from oxidizing inorganic substances, such as sulfur and ammonia.
Chemoautotrophy is unique to prokaryotes.

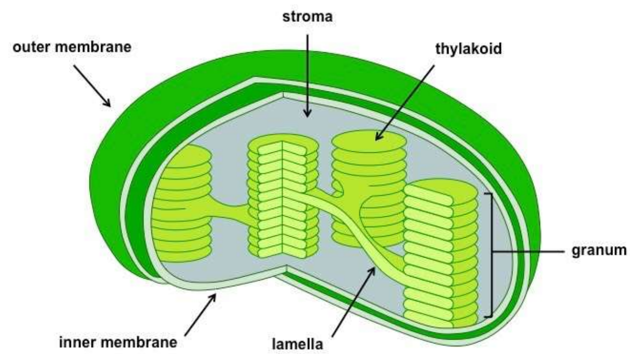
Heterotrophs live on organic compounds produced by other organisms.

These organisms are the *consumers* of the biosphere.
The most obvious type of heterotrophs feeds on other organisms.
Animals feed this way.
Other heterotrophs decompose and feed on dead organisms or on organic litter, like feces and fallen leaves.
Most fungi and many prokaryotes get their nourishment this way.
Almost all heterotrophs are completely dependent on photoautotrophs for food and for oxygen, a by-product of photosynthesis.

Parts of a Plant

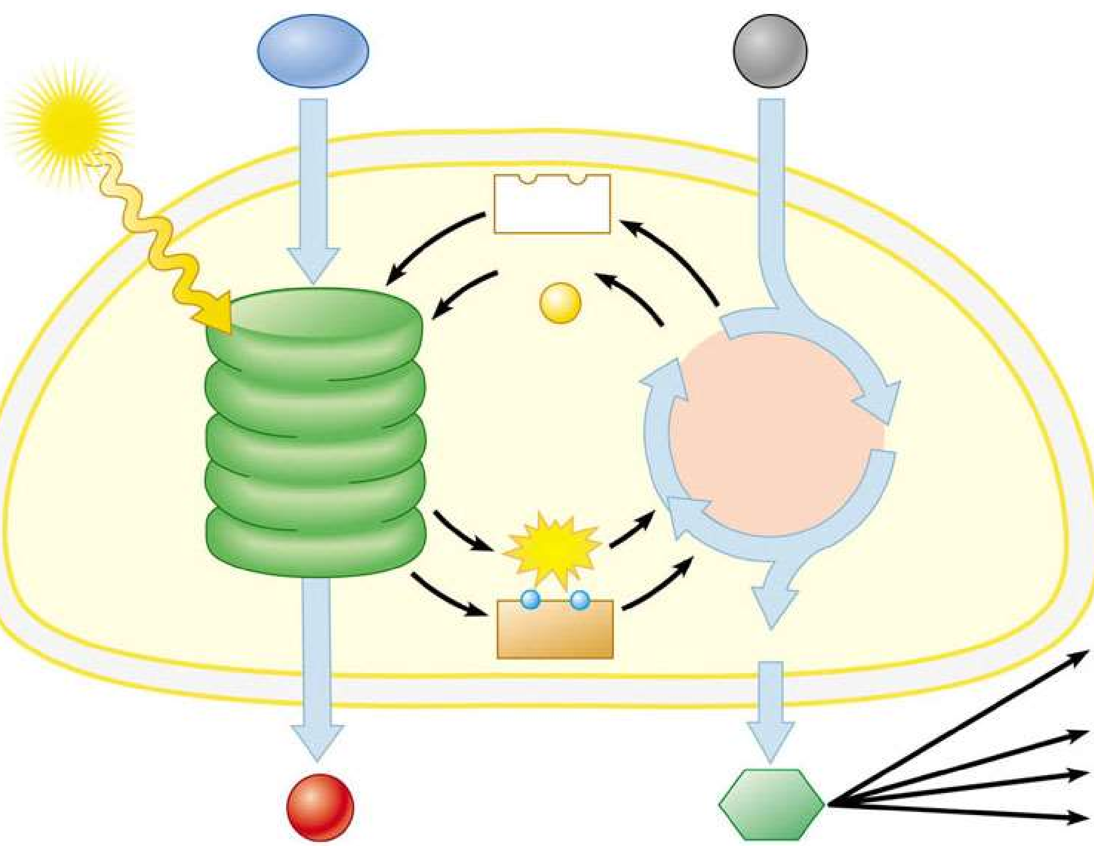
All green parts of a plant have chloroplasts. However, the leaves are the major site of photosynthesis for most plants.
The color of a leaf comes from **chlorophyll,** the green pigment in the chloroplasts.
Chlorophyll plays an important role in the absorption of light energy during photosynthesis.
Chloroplasts are found mainly in **mesophyll** cells forming the tissues in the interior of the leaf.
O_2 exits and CO_2 enters the leaf through microscopic pores called **stomata** in the leaf.
Each chloroplast has two membranes around a central aqueous space, the **stroma.**
In the stroma is an elaborate system of interconnected membranous sacs, the **thylakoids.**
The interior of the thylakoids forms another compartment, the *thylakoid space.*
Thylakoids may be stacked into columns called *grana.*

Chlorophyll is located in the thylakoids.



Photosynthetic prokaryotes lack chloroplasts. their photosynthetic membranes arise from infolded regions of the plasma membranes, folded in a manner similar to the thylakoid membranes of chloroplasts.

The equation describing the process of photosynthesis is:
$6CO_2 + 12H_2O + \text{light energy} \longrightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$



Vocabulary

Chloroplast
Carbon Dioxide
Sunlight
Thylakoid
Granum
ADP
ATP
Calvin Cycle
Light Reactions
Glucose
Sucrose
Fructose
Other sugars
NADPH
H_2O
Stroma
NADP+
O_2
Carbon Fixing

Water appears on both sides of the equation because 12 molecules of water are consumed, and 6 molecules are newly formed during photosynthesis.
We can simplify the equation by showing only the net consumption of water:

$$6CO_2 + 6H_2O + \textbf{light energy} \longrightarrow C_6H_{12}O_6 + 6O_2$$

The overall chemical change during photosynthesis is the reverse of cellular respiration.
One of the first clues to the mechanism of photosynthesis came from the discovery that the O_2 given off by plants comes from H_2O, not CO_2.

Photosynthesis is a redox reaction. (reduction oxidation = means it involves the transfer of electrons)
Water is split and electrons transferred with H^+ from water to CO_2, reducing it to sugar.
Because the electrons increase in potential energy as they move from water to sugar, the process requires energy. The energy boost is provided by light.

Here is a preview of the two stages of photosynthesis.

Photosynthesis is **two processes**, each with multiple stages.

The **light reactions** *(photo)* convert solar energy to chemical energy.
The **Calvin cycle** *(synthesis)* uses energy from the light reactions to incorporate CO_2 from the atmosphere and fixes it into sugar.

Light Reactions

In the light reactions, light energy absorbed by chlorophyll in the **thylakoids** drives the transfer of electrons and hydrogen from water to **$NADP^+$** (*nicotinamide adenine dinucleotide phosphate*), forming NADPH.
NADPH, an electron acceptor, provides reducing power via energized electrons to the Calvin cycle.
Water is split in the process, and O_2 is released as a by-product.
The light reaction also generates ATP using **chemiosmosis**, in a process called **photophosphorylation.**
Thus light energy is initially converted to chemical energy in the form of two compounds: NADPH and ATP.

The Calvin Cycle

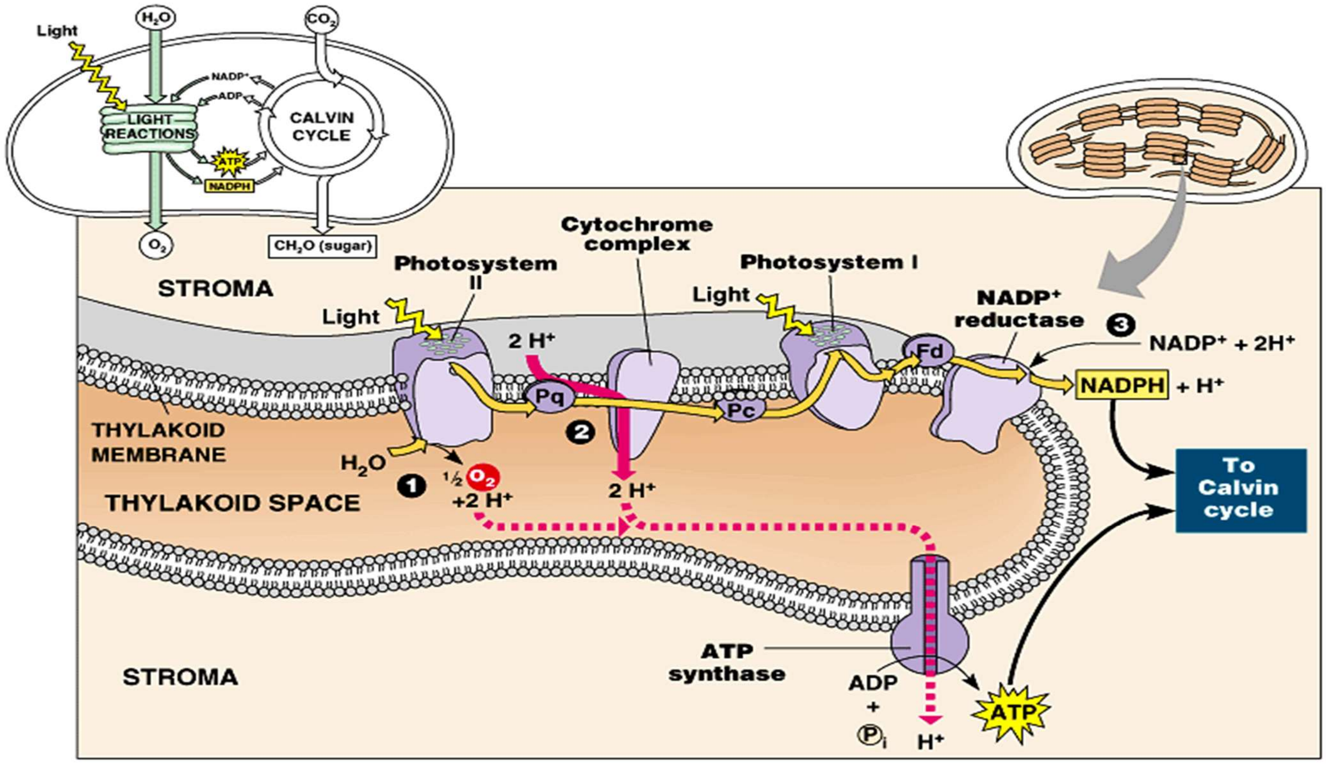
The Calvin cycle is named for Melvin Calvin who, with his colleagues, worked out many of its steps in the 1940s.
The cycle begins with the incorporation of CO_2 into organic molecules, a process known as **carbon fixation.**
The fixed carbon is reduced with electrons provided by NADPH. ATP from the light reactions also powers parts of the Calvin cycle. Thus, it is the Calvin cycle that makes sugar, but only with the help of ATP and NADPH from the light reactions.
The metabolic steps of the Calvin cycle are sometimes referred to as the light-independent reactions, because none of the steps requires light *directly.* Nevertheless, the Calvin cycle in most plants occurs during daylight, because that is when the light reactions can provide the NADPH and ATP the Calvin cycle requires.

While the light reactions occur at the thylakoids, the Calvin cycle occurs in the stroma.

The thylakoids convert ***light energy*** into the chemical energy of **ATP and NADPH.**
Light is a form of electromagnetic radiation.
Chlorophyll *a*, the dominant pigment, **absorbs best in the red and violet-blue wavelengths** and least in the green.
Other pigments with different structures have different absorption spectra.
Collectively, these photosynthetic pigments determine an overall **action spectrum** for photosynthesis.
Only chlorophyll *a* participates directly in the light reaction, but accessory photosynthetic pigments absorb light and transfer energy to chlorophyll *a*.
Chlorophyll *b*, with a slightly different structure than chlorophyll *a*, has a slightly different absorption spectrum and funnels the energy from these wavelengths to chlorophyll *a*.

Carotenoids can funnel the energy from other wavelengths to chlorophyll *a* and also participate in *photoprotection* against excessive light.

In the thylakoid membrane, chlorophyll is organized along with proteins and smaller organic molecules into **photosystems.**



A photosystem is composed of a reaction center surrounded by a light-harvesting complex.
Each **light-harvesting complex** consists of pigment molecules (which may include chlorophyll *a*, chlorophyll *b*, and carotenoid molecules) bound to particular proteins.
There are two types of photosystems in the thylakoid membrane.
Photosystem I (PS I) has a reaction center chlorophyll *a* that has an absorption peak at 700 nm.
Photosystem II (PS II) has a reaction center chlorophyll *a* that has an absorption peak at 680 nm.

Chloroplasts and Mitochondria
Chloroplasts and mitochondria generate ATP by the same mechanism: **chemiosmosis**.
In both organelles, an electron transport chain pumps protons across a membrane as electrons are passed along a series of increasingly electronegative carriers.
ATP synthase molecules harness the proton-motive force to generate ATP as H^+ diffuses back across the membrane.
Some of the electron carriers, including the cytochromes, are very similar in chloroplasts and mitochondria.
The ATP synthase complexes of the two organelles are also very similar.

Cellulose, the main ingredient of cell walls, is the most abundant organic molecule in the plant, and probably on the surface of the planet.
Plants also store excess sugar by synthesis of starch.
Starch is stored in chloroplasts and in storage cells in roots, tubers, seeds, and fruits.
Heterotrophs, including humans, may completely or partially consume plants for fuel and raw materials.
On a global scale, photosynthesis is the most important process on Earth.
It is responsible for the presence of oxygen in our atmosphere.
Each year, photosynthesis synthesizes 160 billion metric tons of carbohydrate.

CELLULAR RESPIRATION

DEFINITION The process in a cell's mitochondria when food (sugar) is broken down using oxygen to produce energy (ATP).

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6\ H_2O + ATP\ (32\text{-}38)\ energy$$

STAGES OF CELLULAR RESPIRATION

1. Glycolysis

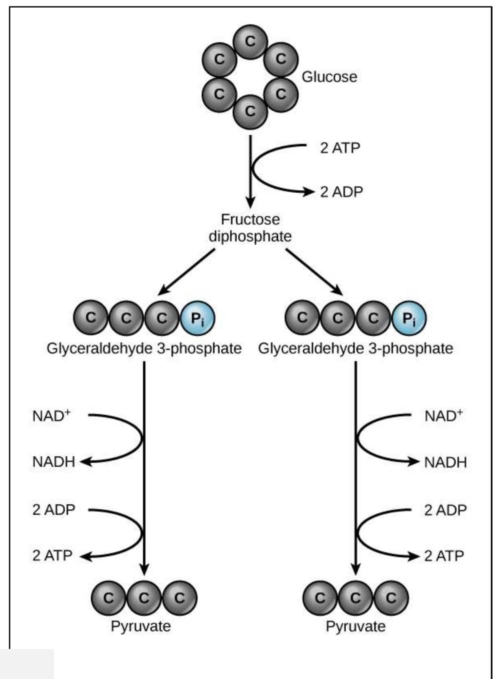
2. Krebs Cycle

3. Electron Transport Chain

All living things undergo cell respiration, even plants!

AEROBIC VS. ANAEROBIC Aerobic •With oxygen •Includes: • Krebs Cycle • Electron Transport Chain Lasts indefinitely Activities: distance running, distance swimming Anaerobic •

Without oxygen FERMENTATION Includes: •Glycolysis Lasts for 30-40 seconds Activities: 100-meter run, football, weight lifting Both Provide the cell with energy (ATP) Use glucose



GLYCOLYSIS "splitting of sugar"

LOCATION: CYTOPLASM •Anaerobic: NO oxygen required

Chemical Reactions break down glucose into

2 pyruvic acid molecules

2 ATP

2NADH

KREBS CYCLE (A.K.A. CITRIC ACID)

LOCATION: Mitochondria •Aerobic:

REQUIRES oxygen •Finishes breaking sugar down to CO_2 is released into the atmosphere to be used again in photosynthesis

KREBS CYCLE produces

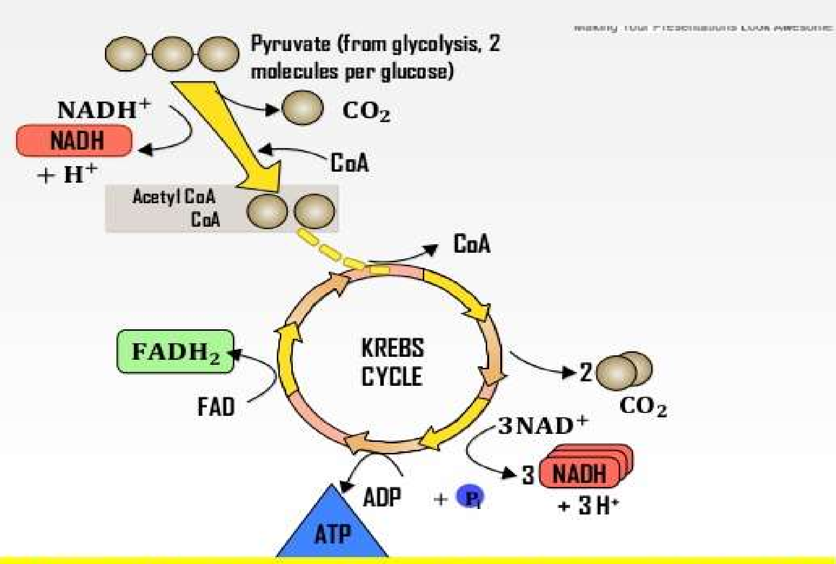
6 CO_2,

8NADH.

2FADH2,

2ATP

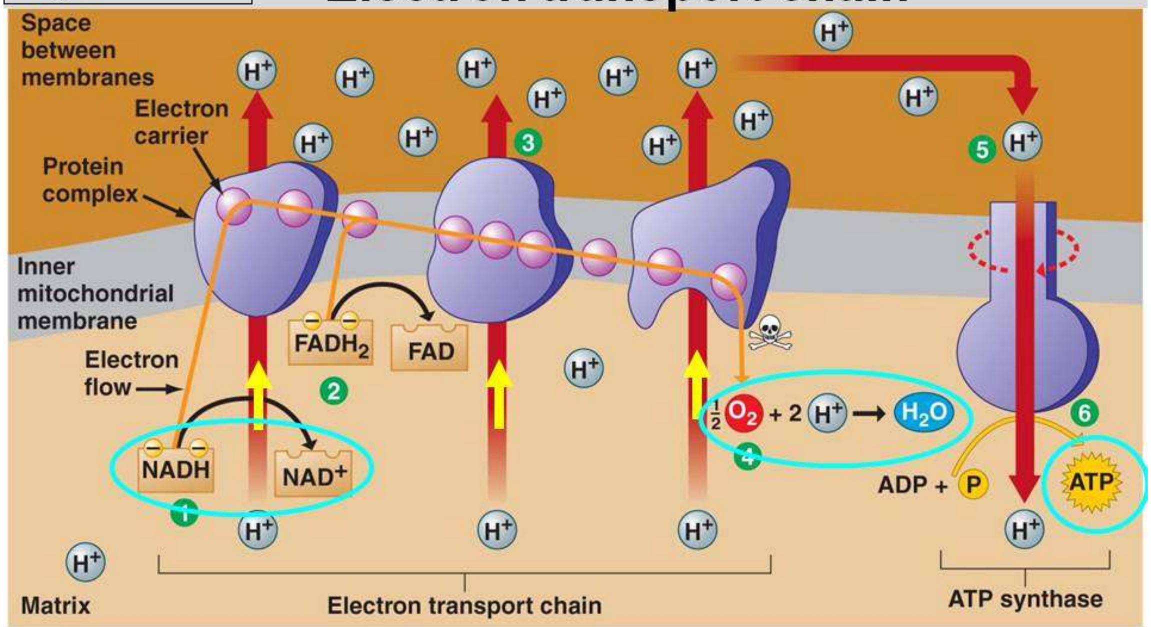
For each pyruvate the Kreb's cycle turns on time



ELECTRON TRANSPORT CHAIN LOCATION: Inner Mitochondria Membrane Aerobic: REQUIRES oxygen •Uses electron carriers to make many ATP •Makes the majority of the cell's ATP •Produces about 34 ATP

ELECTRON TRANSPORT CHAIN uses the high energy electron carriers **FADH2 and NADH** – (from glycolysis and Kreb's) to transfer electron to the ETC in order to make the most ATP

Figure 6.11 **Electron transport chain**



4-5 is sometimes called chemi-osmosis, kinetic energy of H^+ flowing back through ATP synthase powers the synthesis of ATP from ADP (also called oxidative phosphorylation in your book)

2 NADH from Glycolysis and 8 NADH from Kreb's cycle come over to the ETC. Also have 2 $FADH_2$ from Kreb's to power the production of H+ ions being pumped into the IMS and then these H+ ions are used to power ATP synthase to make ATP from ADP

FERMENTATION

Anaerobic: NO oxygen present

2 types: Lactic Acid • Ethanol

LACTIC ACID FERMENTATION

Pyruvic acid + NADH ⟶ lactic acid + NAD+

Produced in muscles during rapid exercise when no oxygen is available

Produces soreness Cheese, yogurt, buttermilk, sour cream, pickles sauerkraut

ALCOHOLIC FERMENTATION

Pyruvic acid + NADH ⟶ alcohol + CO2 + NAD+

Yeasts and microorganisms

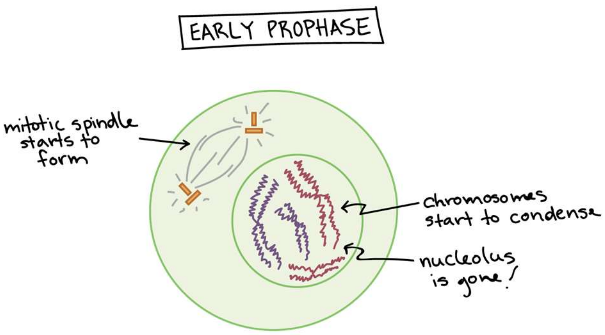
Gives off bubbles of carbon dioxide •Bread dough

MITOSIS

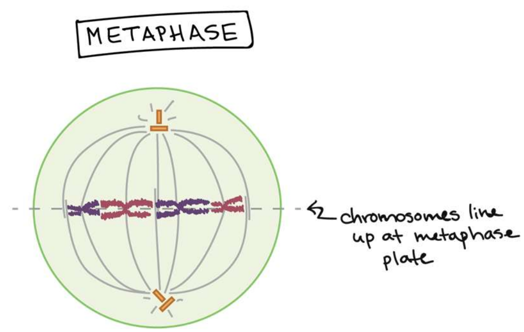
It is a form of asexual reproduction. Mitosis is a type of cell division in which one cell (the parent cell) divides to produce two new cells (the daughters) that are genetically identical to itself. In the context of the cell cycle, mitosis is the part of the division process in which the DNA of the cell's nucleus is split into two equal sets of chromosomes.

The great majority of the cell divisions that happen in your body involve mitosis. During development and growth, mitosis populates an organism's body with cells, and throughout an organism's life, it replaces old, worn-out cells with new ones. For single-celled eukaryotes like yeast, mitotic divisions are actually a form of reproduction, adding new individuals to the population.

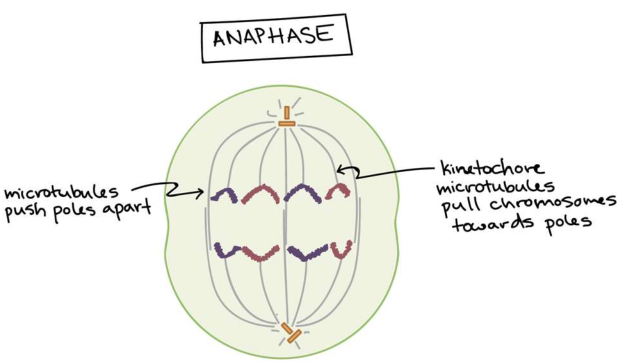
In all of these cases, the "goal" of mitosis is to make sure that each daughter cell gets a perfect, full set of chromosomes. Cells with too few or too many chromosomes usually don't function well: they may not survive, or they may even cause cancer. So, when cells undergo mitosis, they don't just divide their DNA at random and toss it into piles for the two daughter cells. Instead, they split up their duplicated chromosomes in a carefully organized series of steps. You can remember the order of the phases with the famous mnemonic **Pee on the MAT or PMAT**. But don't get too hung up on names – what's most important to understand is what's happening at each stage, and why it's important for the division of the chromosomes.



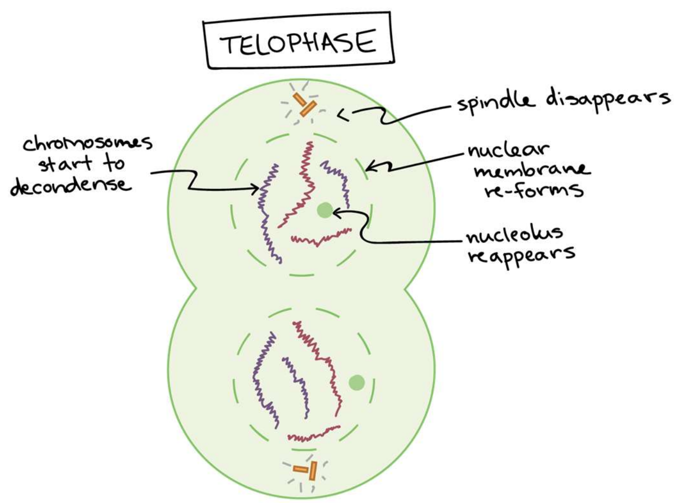
Prophase: -Nucleus breaks down
-Centrioles move towards opposite poles
-Spindle fibers develop
-Chromatin condenses in chromosomes



Metaphase: -Chromosomes line up at the Metaphase plate
-spindle fibers attach at the centromere



Anaphase: -Sister chromatids are pulled to opposite sides of the cell at the centromere.
-cell elongates, becomes egg-like.



Telophase: -cell starts to pinch, (cell cleavage)
-nucleus reforms
-chromosomes start to unravel into chromatin & nucleolus reappears