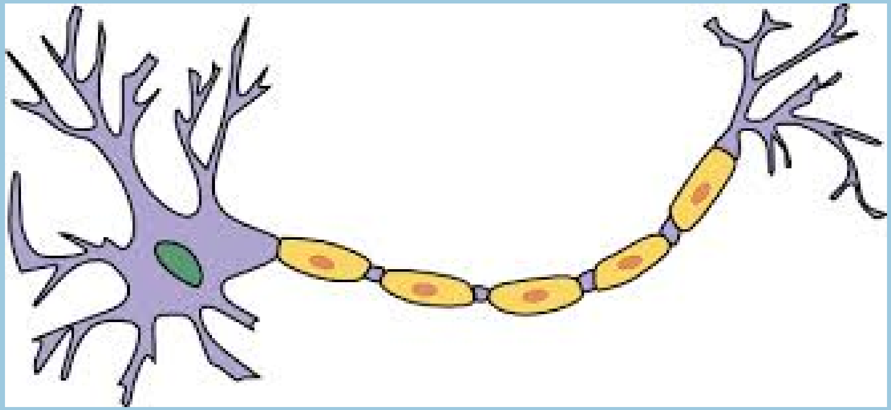
Summer Assignment: Living Systems, Part 2

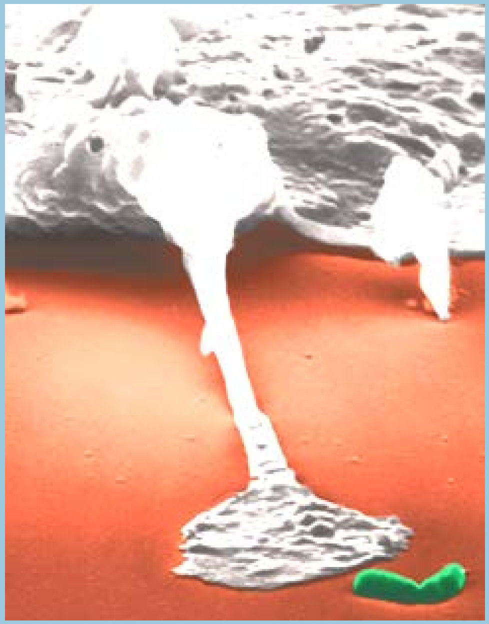
In the AP Biology curriculum, this section on human body systems focuses on the immune, endocrine and nervous systems, with a big emphasis on communication. Some other systems are included in certain places.

Read through the material and look at the pictures in this presentation. Wherever you see the icon, there is a question to answer (35 questions total). Write your answers on the Word document provided (AP Bio Summer Assignment 2017 Questions). You are welcome to use online or other resources to help you with the questions. This is due during the week of Sept. 18th - exact date TBA.

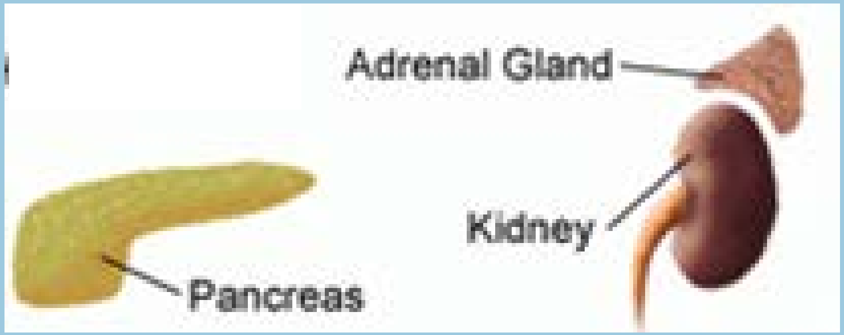
A



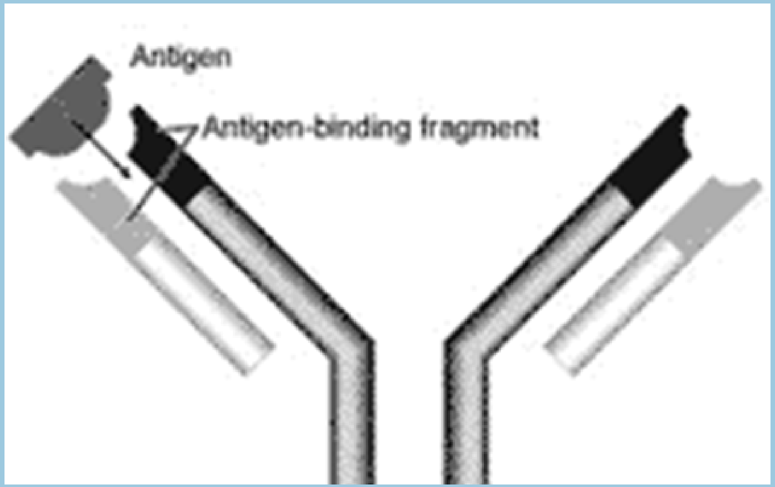
B



C


Adrenal Gland
Kidney
Pancreas

D


Antigen
Antigen-binding fragment

First Question!

1. Look at the pictures on the previous slide and see if you can identify them by matching each picture with the best terms or descriptions below. Each picture matches to 2 items below.

1. Antibody (a type of protein)
2. A white blood cell carrying on phagocytosis
3. A nerve cell or neuron
4. One part of this picture is responsible for producing insulin and another produces adrenalin
5. Includes an axon and dendrites
6. One part of this picture filters the body's blood and produces urine
7. The cell will engulf the bacterium
8. Will bind to a molecule with a complementary shape

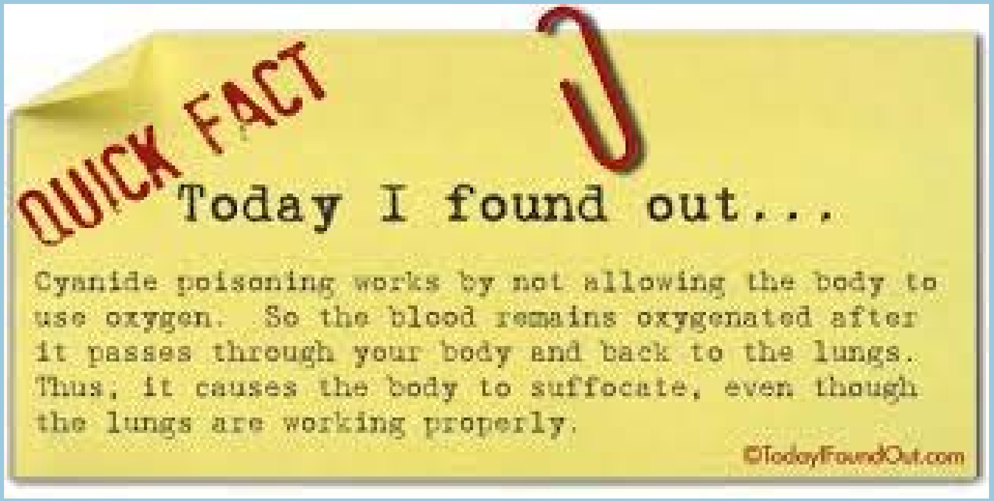
(Picture A matches to # _____ and # _____, etc.)

Remember that the Living Systems, Part 1 presentation stressed the importance of organisms maintaining their **dynamic homeostasis**. Unfortunately, there are many reasons why it can be difficult to maintain this homeostasis…

Homeostasis Can Be Disrupted in Many Ways

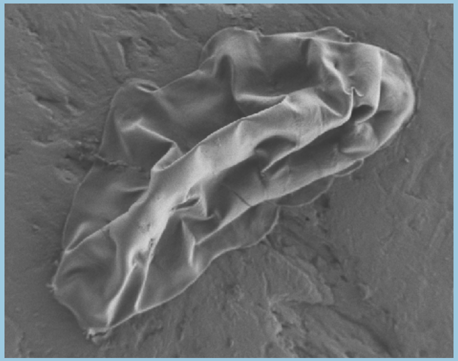
- **Biological systems are affected by disruptions to their dynamic homeostasis.**
- Disruptions at the molecular and cellular levels affect the health of the organism. Examples of disruptions and their effects include:
  - Dehydration
  - Immunological responses to pathogens, toxins and allergens
  - Physiological responses to toxic substances
    - There are many toxic substances which can potentially harm a cell or organism. Here are 2 examples:

Botulism is a rare but serious paralytic illness caused by a nerve toxin that is produced by the bacterium *Clostridium botulinum*.

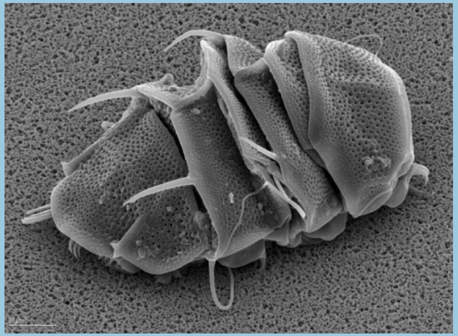


Cyanide works by blocking the electron transport chain that is an important part of aerobic cell respiration. Fun times!

Dehydration – from Water Bears to Humans

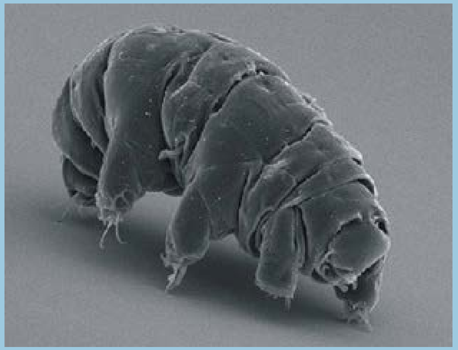


- **Water bears (tardigrades)** are tiny microscopic animals that live in mosses, lichens, and liverworts. A few species live on plants in fresh water. They have eight legs with four claws on each and short, stout bodies in the shape of a cylinder.
- Water bears have developed an interesting way to survive if the moss they live in dries up. It is called an "anhydrobiotic state." Because they need moisture to live, if a moss dries up, the water bear becomes inactive, almost like a state of hibernation. It also mostly dries up. Then, when the moss becomes wet again, so does the water bear. It revives, and goes on with its life.



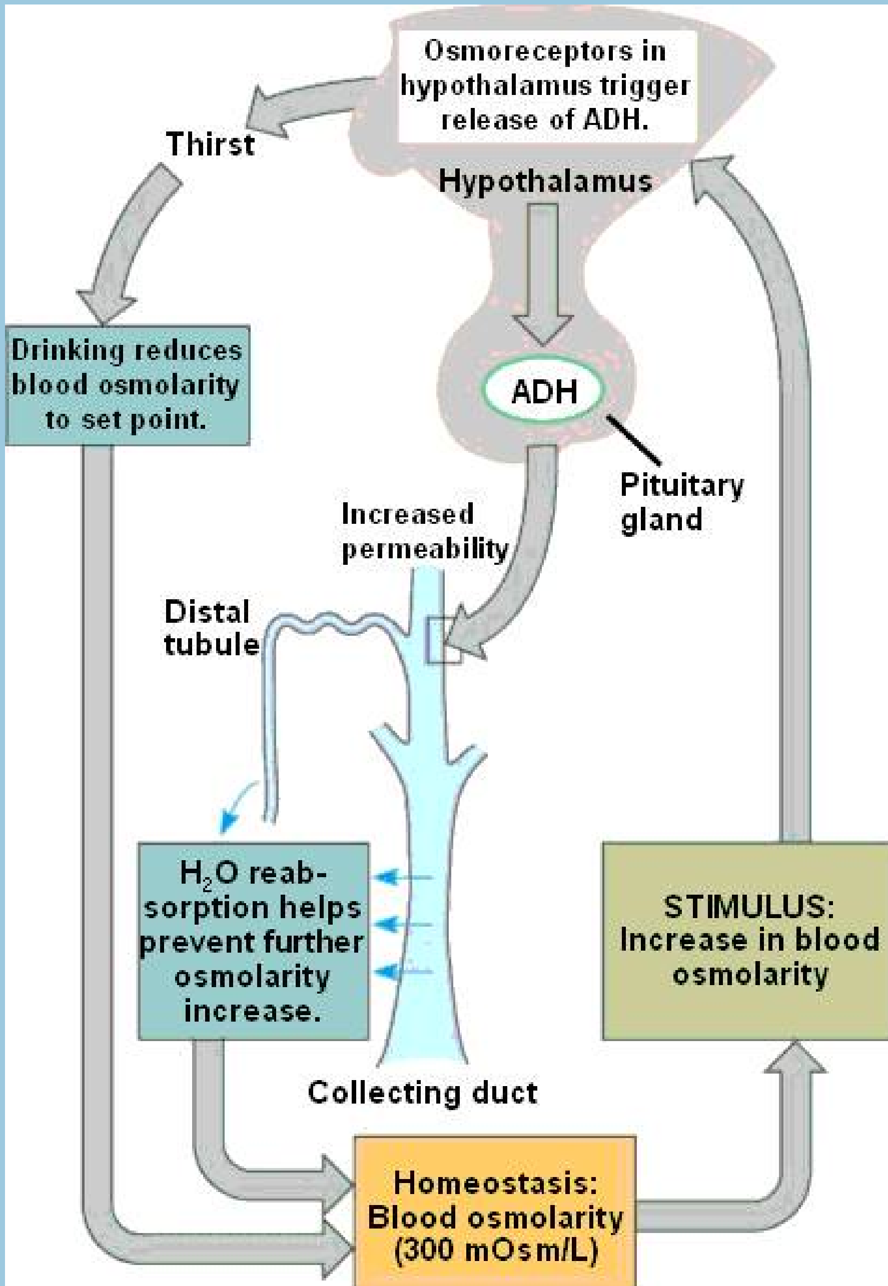
- Sometimes, water bears can be in a state of anhydrobiosis for many years.
- Check out these 4 quick videos:

http://tardigrades.bio.unc.edu/movies/



2. Why might tardigrades be called extremophiles? What other organisms have you heard called extremophiles (2 or more)?

Dehydration – from Water Bears to Humans



- Compared to water bears, we may not have a dramatic way of maintaining water balance, but we do have an effective one:
- Our bodies produce a hormone called **a**nti**d**iuretic **h**ormone (ADH).
- ADH is produced in the brain and released from the pituitary gland into the bloodstream. It enhances fluid retention by **causing the kidneys to reabsorb more water**.
- The pituitary is stimulated to release ADH *when receptors detect an increase in blood osmolarity (increase in solute concentration in the blood).* **This also stimulates increased thirst.**

3. What is the effect of increased thirst?

4. Is this an example of positive or negative feedback? Explain.

Chemical Defenses of the Immune System

- **Plants** and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
  - Most people don't think of a plant as having an immune system – but plants get diseases too and they need to be able to defend themselves against pathogens and respond to infections.
  - Because we rely on plants for our food, it is really important that we study the pathogens that infect plants and understand how they respond. If you are really interested in this topic, you could even major in plant pathology someday ☺
- A plant's 1st line of defense is its <u>physical barriers</u>. Stems and leaves are covered by a **waxy cuticle**, which helps prevent fungi and bacteria from entering the plant's tissues.
- Plants also have **chemical defenses**. For example, plantains produce a chemical, called *iridoid glycoside*, which inhibits the growth of fungi.

5. Plant pathogens include which of the following:
a. viruses   b. bacteria   c. fungi
d. protists   e. all of the above

Molecular Recognition and More

- Plant pathogens induce the host plant to activate various chemical defense responses. Many of the pathogens' molecules – called **elicitors** – trigger plant defenses.
- If a plant has a **receptor protein** on its cell surfaces, the protein will bind to the elicitor. After binding, a **signal transduction pathway** is set in motion. The overall effects are both local, causing a response near the site of infection, and systemic, causing a response in parts of the plant that are distant from the site of infection.
- Receptor proteins and elicitor bonding is **specific** and relies on molecular recognition.
- Other diverse examples of plant defenses include:
  - Plants may produce pathogenesis-related proteins (**PR proteins**). One type is **chitinase**, an enzyme which breaks down the cell walls of fungi.
  - Phytoalexins, which serve as a natural antibiotic, are produced within hours of an infection by plant cells near the infection site.
  - Plants have a way of *isolating damaged areas* so that a pathogen does not spread. Cells around the site of infection undergo **apoptosis** depriving the pathogen of nutrients from the surrounding cells.

6. If chitinase is a PR protein that breaks down fungal cell walls, the cell walls of fungi must contain what complex carbohydrate? (You could look up examples of complex carbohydrates.)

A Few Familiar Ideas

7. Look up apoptosis – What happens during the process? Explain how it could help the plant, as described on the previous slide.

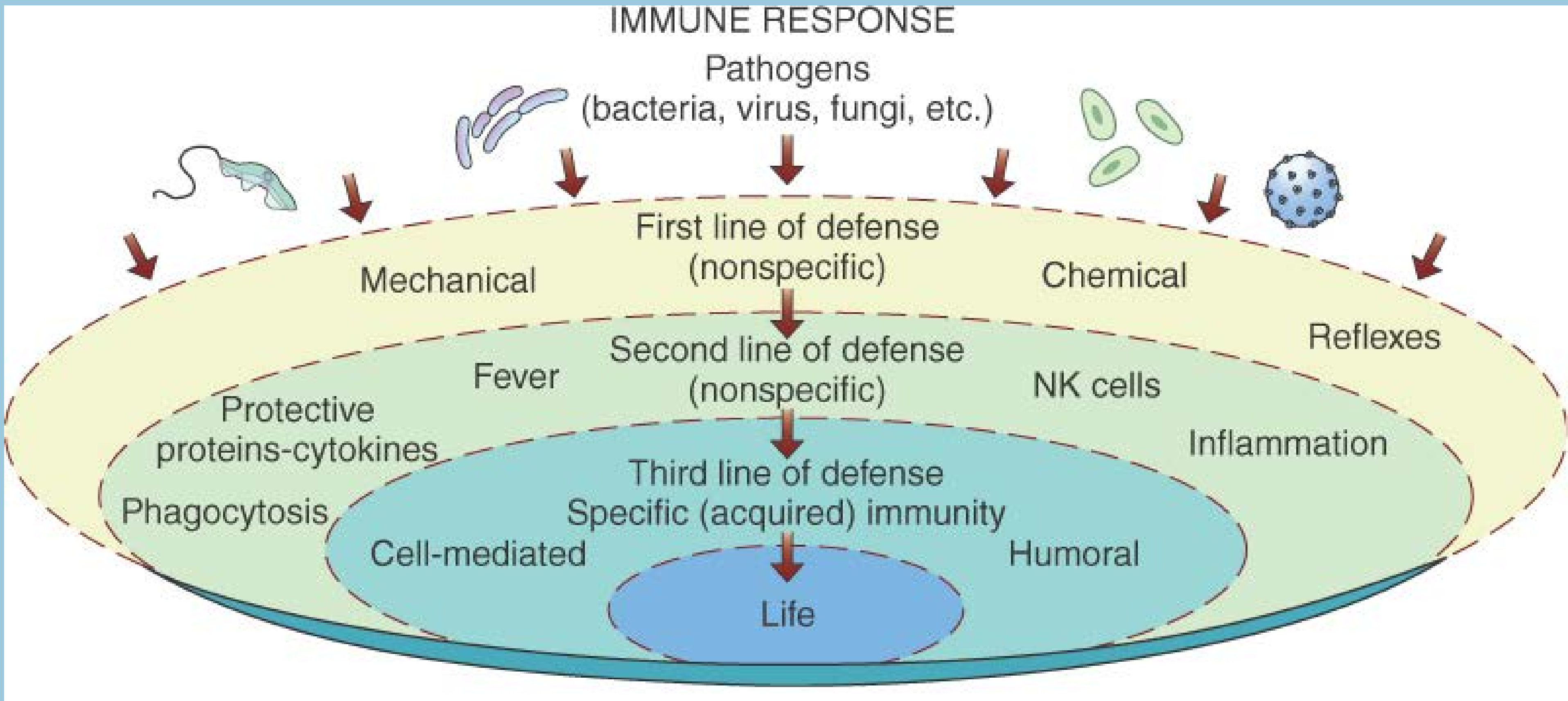
- As one last example, plants have a way to become resistant to viruses: They use RNAi (RNA interference) to break down mRNA preventing the production of the protein that would normally be produced.
- **8. If they use RNAi, the plant cells must have enzymes that will respond to the viral genome. What would the plant cell be doing to the viral RNA?**

- Plasmodesmata are gaps between plant cells that allow material to be transported from cell to cell. In this case, the molecules involved in the RNA interference spread rapidly through the plant via the plasmodesmata, providing systemic resistance.

Chemical Defenses of the Immune System

- Plants and animals have a variety of chemical defenses against infections that affect dynamic homeostasis.
- In animals, such as humans, there are 2 lines of nonspecific defense. Non-specific defenses are mechanisms that fight against all types of pathogens; they do not distinguish among pathogens. These defenses include chemical defenses (and a few others that are more physical than chemical).
  - The **1st Line of Defense** includes the **skin** covering the whole body and **mucous membranes** of the digestive and respiratory tracts.
  - Secretions from the skin and mucous membranes are chemical defenses and include **mucous traps, lysozyme, and chemicals that provide an unfriendly acidic environment.**
  - Intact skin is not normally penetrated by bacteria or viruses, but even minor minute abrasions (tiny cuts or scrapes) allow a route of entrance into the body, so it is helpful to have chemical defenses present as well.

Chemical Defenses - Animals



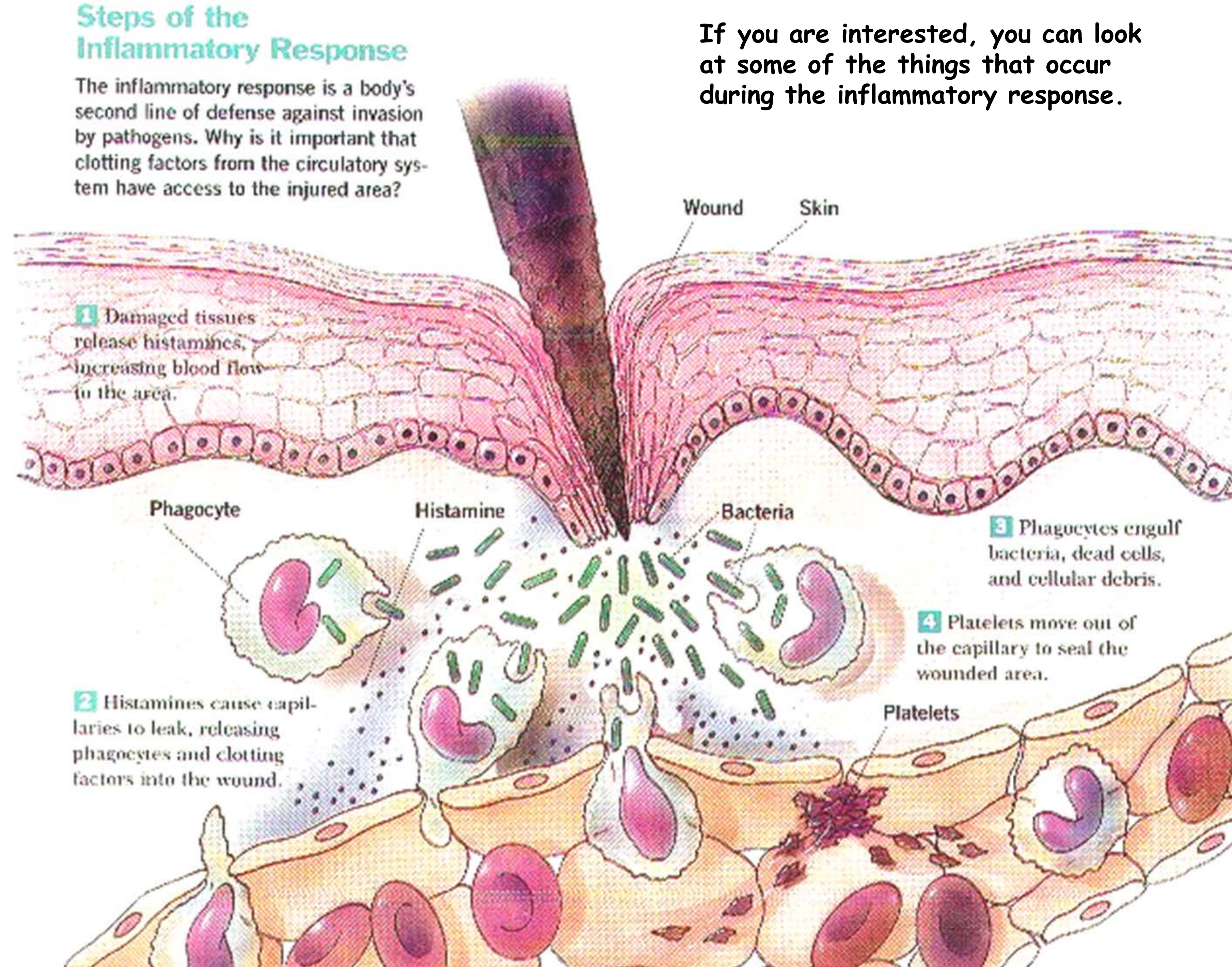
Chemical Defenses (& a Few Other Types) In Animals

- If the pathogens succeed in getting through the 1st line of defense, there are a variety of 2nd line defenses, including:
  - **Phagocytes**, a type of white blood cells that engulf pathogens by phagocytosis
  - **Eosinophils**, another type of white blood cells, which attach to larger parasites, such as blood flukes, and discharge deadly enzymes against the outer surfaces of the parasite
  - **Antimicrobial proteins**
  - **Interferons**, which are secreted by virus-infected cells to inhibit viral reproduction
  - **Natural Killer (NK) Cells** (sounds scary!), which kill virus-infected cells and abnormal cells that could become tumors. They often attack the abnormal cell membranes causing them to burst open (lysis).
  - **Inflammatory response**, a series of responses that often occurs in response to wound or injury – see next slide
  - **Fever**

9. What effects do you associate with the inflammatory response? (If you have a wound or injury that is inflamed, how would you describe the way it feels or appears?)

10. What effect might a fever have on invading pathogens? (Think about what heat can do to an organism and its molecules.)

If you are interested, you can look at some of the things that occur during the inflammatory response.



A Variety of Immune Systems

- **In summary, plants, invertebrates and vertebrates have multiple, nonspecific immune responses. Examples include:**
  - Invertebrate immune systems have nonspecific response mechanisms, but they lack pathogen-specific defense responses.
  - Plant defenses against pathogens include molecular recognition systems with systemic responses; infection triggers chemical responses that destroy infected and adjacent cells, thus localizing the effects.
  - Vertebrate immune systems have nonspecific and non-heritable defense mechanisms against pathogens.

http://highered.mheducation.com/sites/0072495855/student_view0/chapter24/animation__the_immune_response.html

An Example of Immunity in Invertebrates

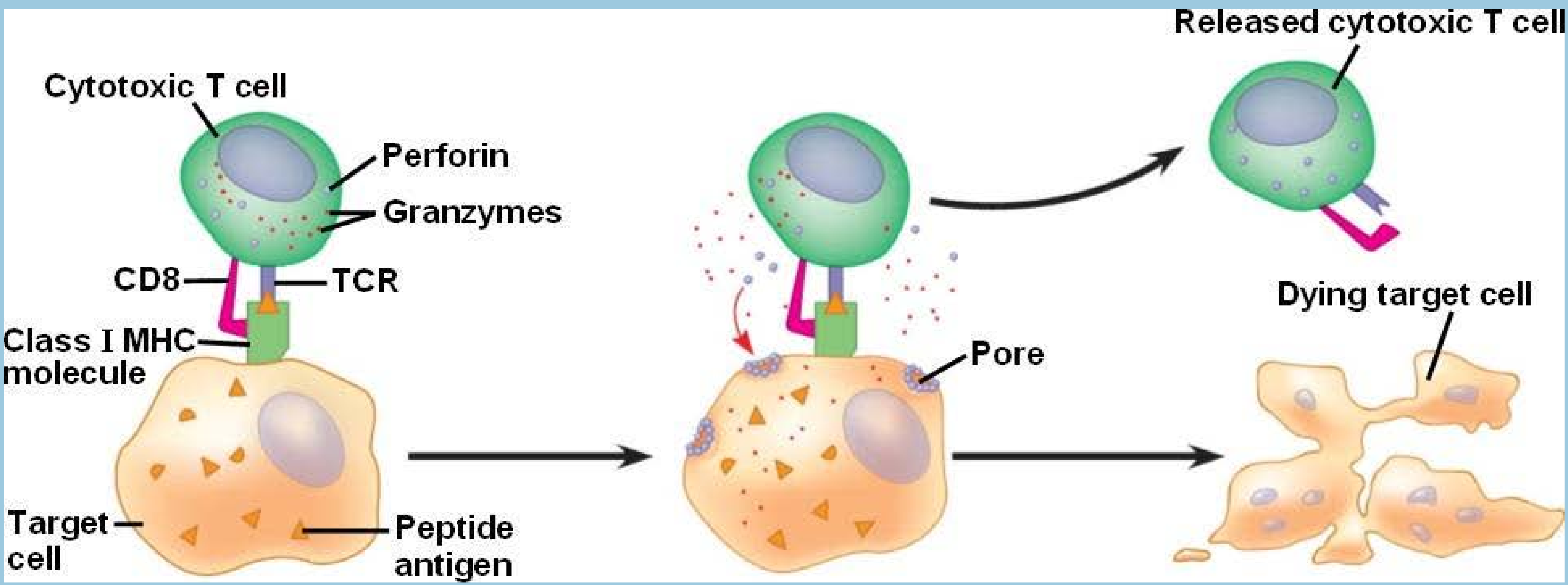
- Pathogens can infect **invertebrates** too, even very simple organisms like worms! Invertebrates also have **physical to prevent pathogens from entering.** Little is known about their defense mechanisms, but it has been shown that some invertebrates can **distinguish self from non-self** – a very important concept in immunity – because an organism has to be able to determine which cells belong to itself and which cells are foreign.

- For example, scientists have researched how **earthworms** react when they are exposed to another organism's tissues during the process of tissue grafting (think of this as a skin graft, or even an organ transplant.)

- **What did they find?** Earthworms attack foreign cells after a tissue graft! In fact, some have also shown an **immunological memory** (another important concept): If the same earthworm received a second tissue graft, the earthworm will **recognize and quickly attack foreign cells** from the same tissue donor. The immunological memory allows the earthworm to have a faster reaction the second time around.

Mammalian Immune Systems (Including Us!)

- Mammals use specific immune responses triggered by natural or artificial agents that disrupt dynamic homeostasis.
  - The mammalian immune system includes two types of specific responses: **cell-mediated and humoral**.
    - In the cell-mediated response, **cytotoxic T cells**, a type of lymphocytic white blood cell, "target" intracellular pathogens when antigens are displayed on the outside of the cells.



11. Describe what the cytotoxic T cell is doing to the target cell.

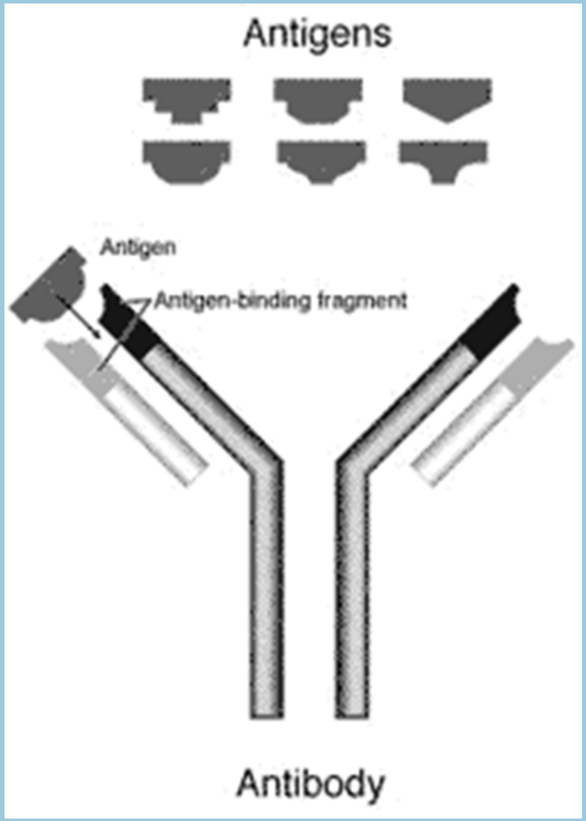
Mammalian Immune Systems (Con't)

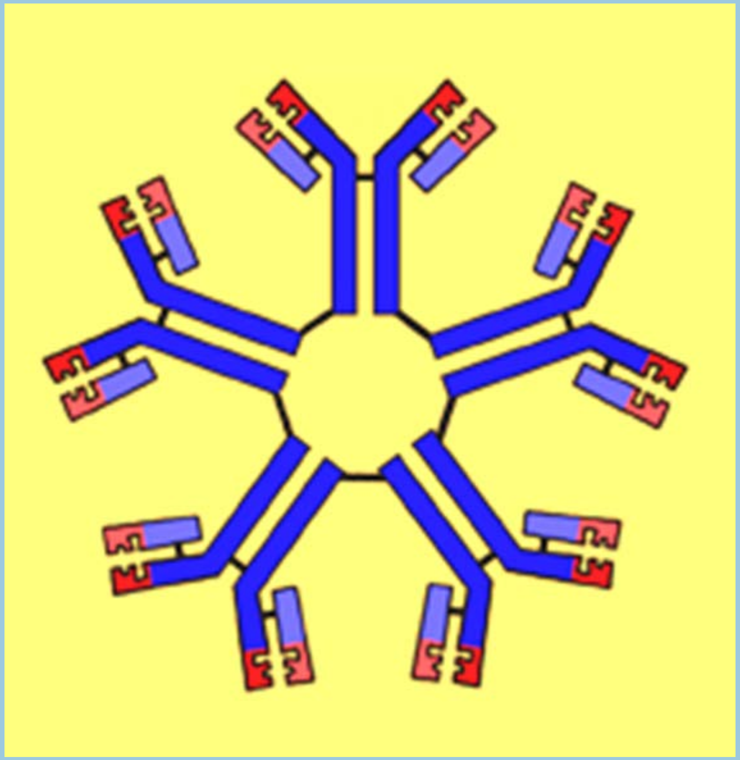
- Mammals use specific immune responses triggered by natural or artificial agents that disrupt dynamic homeostasis.
  - The mammalian immune system includes two types of specific responses: **cell-mediated and humoral**.
    - In the humoral response, **B cells**, a type of lymphocytic white blood cell, **produce antibodies against specific antigens**.
      - An antigen is a foreign molecules that elicits one of the specific immune responses (The word antigen comes from "antibody generator.")
      - Antigens are usually proteins or carbohydrates, often located on the surface of an invading cell
    - Antigens are recognized by antibodies to the antigen.
    - Antibodies are proteins produced by B cells, and each antibody is specific to a particular antigen.
      - An antibody for one antigen will not bind to another antigen.
      - See the next slide

12. Normally, antigens alert the immune system to the presence of foreign cells that could be harmful. However, sometimes a non-self molecule that is generally harmless will bind to mast cells, causing the release of histamines and subsequent inflammation. The non-self molecule may come from food or the environment (for example, on the surface of a pollen grain). This type of reaction is called an ____________________.

Antigen-Antibody Specificity

- An antibody is usually a Y-shaped protein. Sometimes antibodies work together in groups.

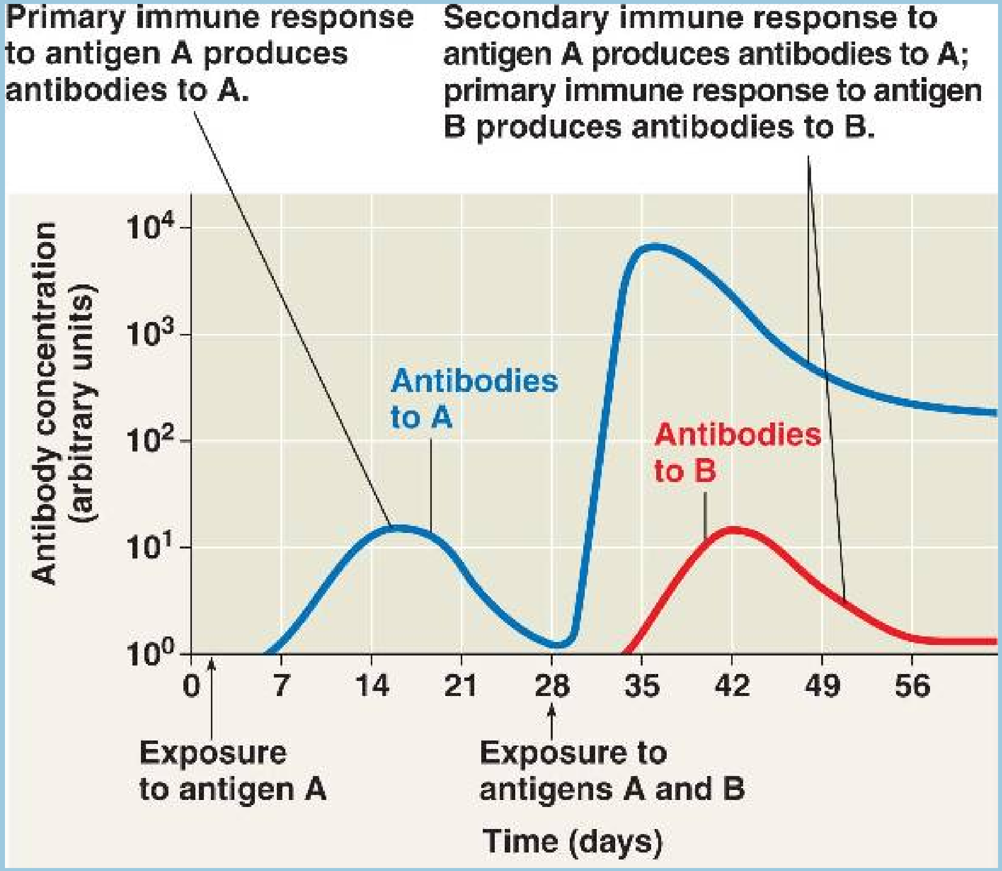




13. What does it meant to say that antibodies and antigens display specificity? (What do you notice about their shapes/structures?)

Immunological Memory

- A second exposure to an antigen results in a more rapid and enhanced immune response.



14. If a person received the flu vaccine this year, their immune system started producing antibodies to that particular strain of flu virus. Those antibodies are present in their bloodstream. Later, if a sick friend sneezes around them and they come in contact with the flu virus, they will have a secondary immune response. How would you describe their immune response (both in time and intensity)?

Immune System as an Example of Cell Communication

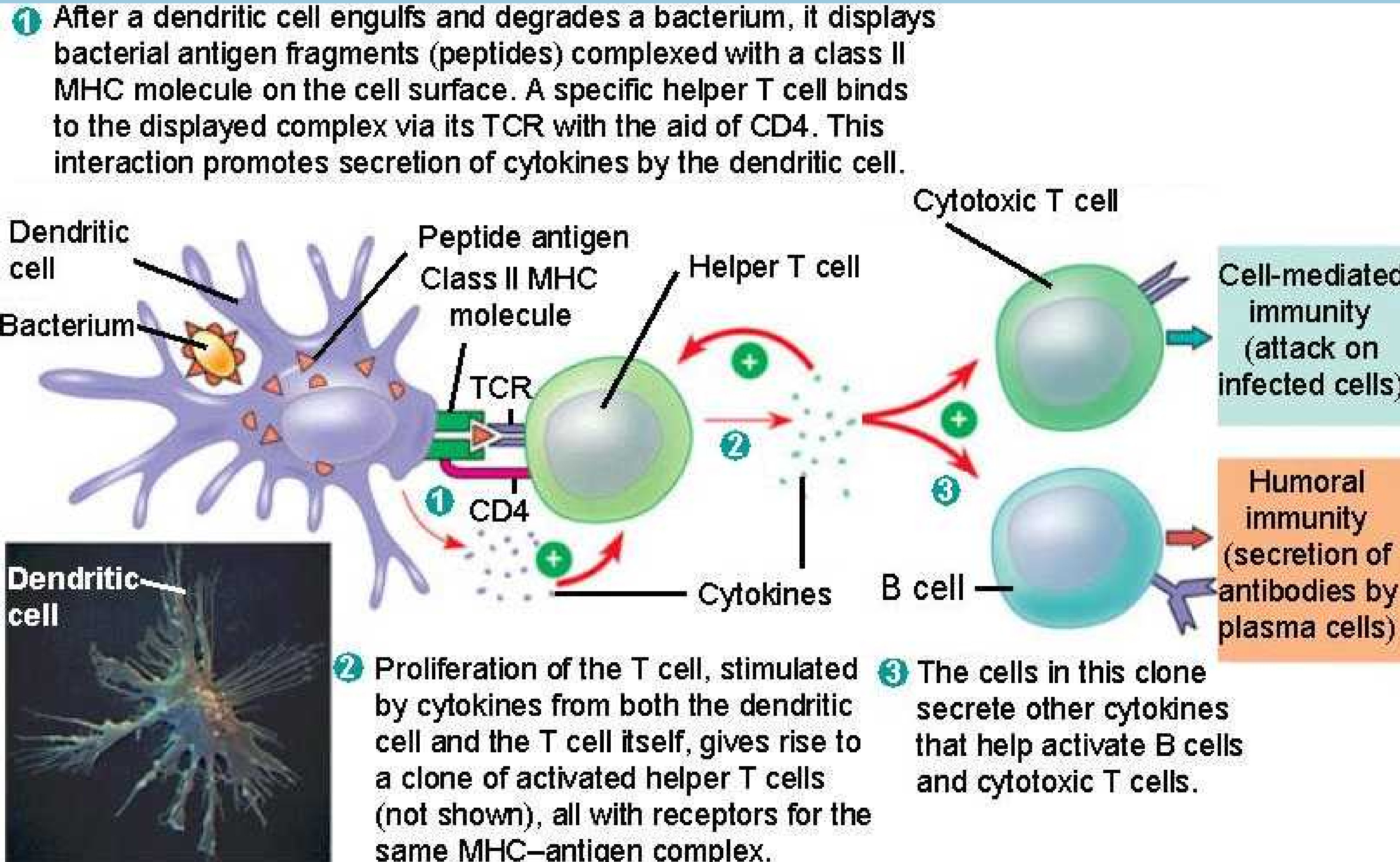
- **Cells communicate with each other through direct contact with other cells or from a distance via chemical signaling.**
- Cells communicate by cell-to-cell contact. Examples include:
  - Immune cells interact by cell-cell contact
  - Antigen-presenting cells (APCs)
  - Helper T-cells and killer T-cells

- On the next slide, there is a diagram that illustrates all 3 of these examples in one scenario. There is a lot going on in the picture, but take a look and see if you can make sense of it.
- The main idea is that there is a type of immune cell, known as a dendritic cell, that has engulfed a bacterium. This sets off a series of other responses.

15. One function of the dendritic cell is to serve as an antigen-presenting cell (APC) that will alert helper T-cells. What is it presenting or displaying on its surface for the helper T-cells to detect?

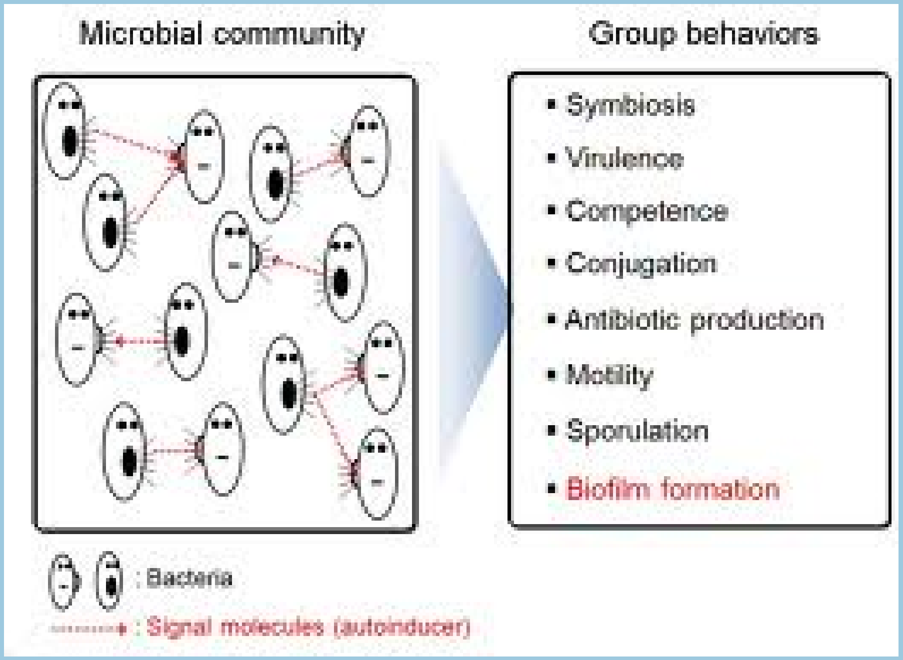
16. Cytokines are an important chemical signal in the immune system. What is one function of the cytokines in this scenario?

Interaction Between Immune System Cells



Cell Communication

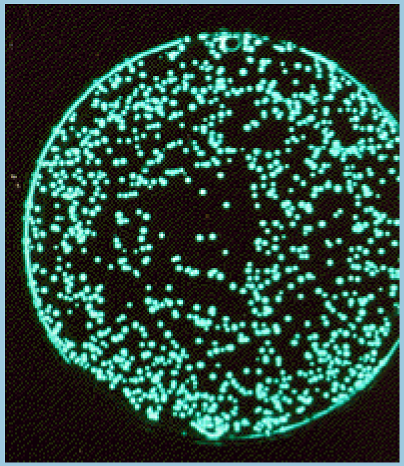
- Cells communicate over short distances by using local regulators that target cells in the vicinity of the emitting cell. Examples include:
  - Neurotransmitters
  - Plant immune response
  - Morphogens in embryonic development
  - Quorum sensing in bacteria

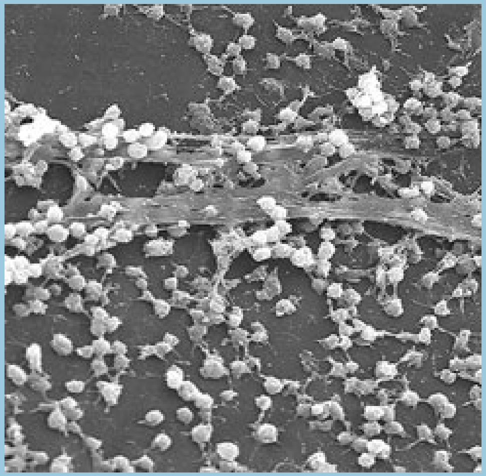


17. By looking at these cartoons, why do you suppose quorum sensing is important in bacteria?

Quorum Sensing in Bacteria

- You have seen bacteria growing in colonies on petri plates, but did you know that those bacteria were communicating with each other? Bacteria release chemical substances that are sensed by other bacteria of the same species.
  - Sometimes the signals tell other bacteria that they can undergo **conjugation**, which enables them to share genetic information.
  - Other times, they monitor their **population's density** by assessing how much chemical signal has accumulated. If the population becomes dense enough, it may be able to accomplish certain functions, such as forming a **biofilm.**
  - Here's some information about biofilms: http://www.biofilm.montana.edu/biofilm-basics-section-1.html & here's a picture on right:
  - In **bioluminescent bacteria**, the ability to glow requires a critical concentration of a chemical produced by the bacteria. At low densities, there is not enough of the chemical to cause the bacteria to glow.

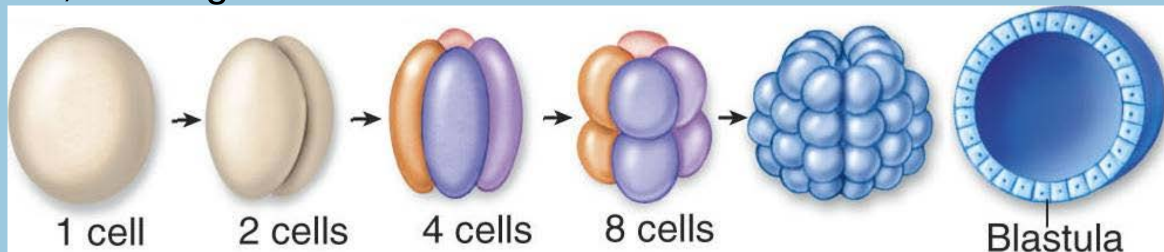




18. What is an example of a surprising (and maybe unfortunate) place biofilms are found?

Morphogens in Embryonic Development

- Remember that after fertilization, the **zygote** (1 cell-stage) begins to undergo many **mitotic cell divisions**, forming a ball of cells.



- At first the cells are undifferentiated and appear about the same. Eventually those cells will **differentiate** and become **specialized** for their future functions. Some cells differentiate into the cells and tissue that will become the brain, others will become the heart, others will become the limbs, etc.

- An important factor in determining cell type is the **position** of the cell within the embryo. Some of the information about the cells' position is relayed by morphogens.

- A **morphogen** is a chemical signal, which diffuses from one group of cells to the surrounding cells. Depending on the concentration of the morphogen, the target cells will develop in certain ways.

(a) **5 weeks.** Limb buds, eyes, the heart, the liver, and rudiments of all other organs have started to develop in the embryo, which is only about 1 cm long.

(b) **14 weeks.** Growth and development of the offspring, now called a fetus, continue during the second trimester. This fetus is about 6 cm long.

19. An example of a case in which Information about position is very important is the development of the hand because there is a specific position and direction for each finger. Therefore, morphogens play a key role in this process. True or False?

The Endocrine System

- Signals released by one cell type can travel long distances to **target cells** of another cell type.
- Endocrine signals are produced by endocrine cells that release **signaling molecules**, which are specific and can travel long distances through the blood to reach all parts of the body. There are many **hormones** and a few examples include:
  - Insulin
  - Human growth hormone
  - Thyroid hormones
  - Testosterone
  - Estrogen
- A **hormone** is a specific molecule that is synthesized and secreted by a group of specialized cells (usually referred to as an **endocrine gland**) and travels to another area of the body, where it elicits specific biological responses from select target cells

20. Sometimes people wonder why hormones only affect their target cells and not any of the other cells they come in contact with as they travel through the bloodstream. What do you suppose a target cell has that allows it receive a signal from a specific hormone? (Think back to the cell signaling diagrams you looked at in Part 1.)

Examples of Hormone Functions

- Hormones have many functions and are especially important in helping an organism **maintain homeostasis, coordinate body functions/communication and regulate body functions** such as growth, development, reproduction, and others.

- The pancreas produces important hormones (proteins) that regulate the blood glucose level, **glucagon & insulin.**

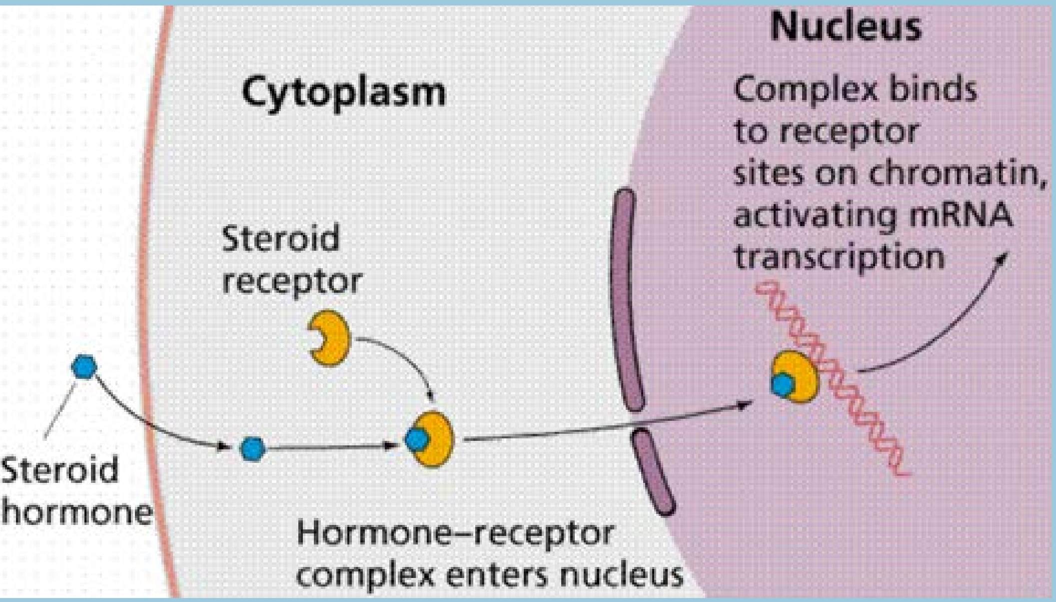
- The pituitary gland secretes **human growth hormone**, a protein which promotes growth (such as bone growth) and secretes growth factors.

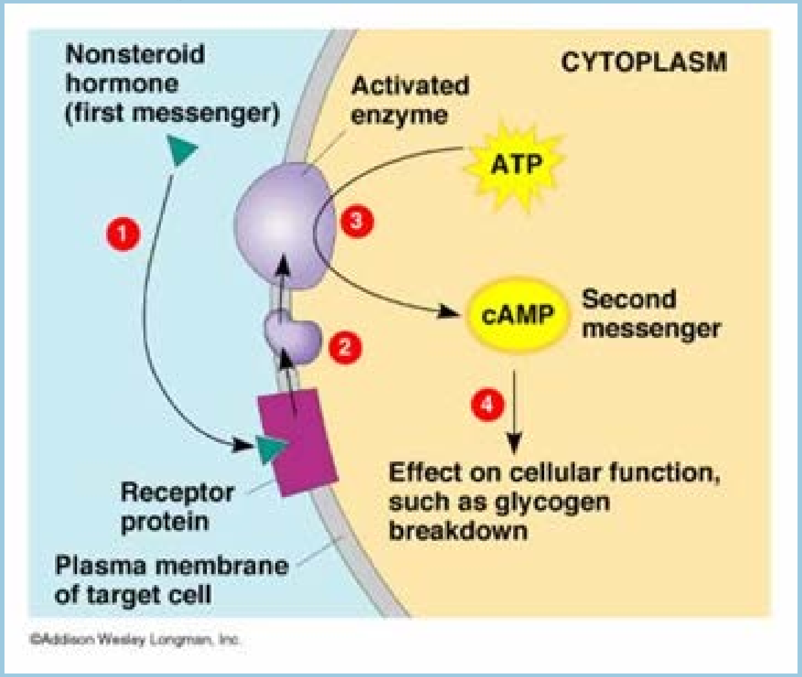
- The thyroid gland produces **thyroid hormones** (proteins containing iodine), which regulate development and help maintain homeostasis (blood pressure, metabolism, etc.)

- The testes produce **testosterone** and the **ovaries** produce **estrogen** and progesterone. These sex hormones are steroid hormones and regulate the reproductive system and secondary sex characteristics

21. If someone has the condition hyperthyroidism, what does that indicate about their thyroid activity level? How about hypothyroidism?

Steroid vs. Protein Hormones





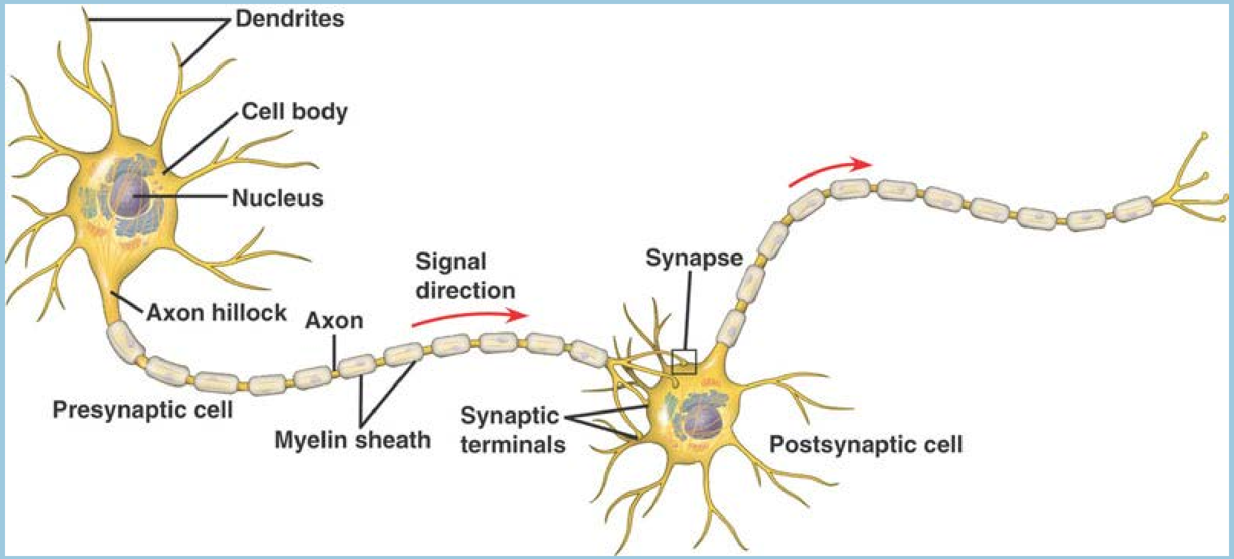
22. What is the first difference you notice about the way the steroid hormone interacts with the cell? (Think about what is happening to the steroid compared to the protein hormone at the cell membrane.)

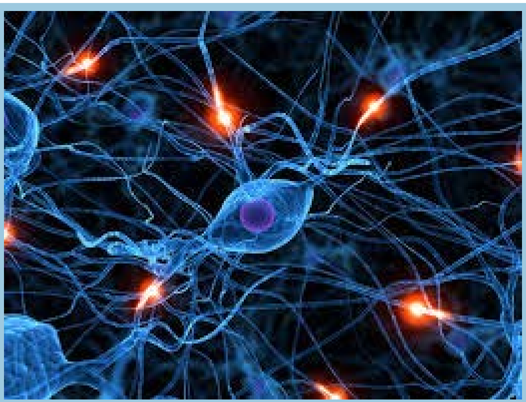
23. What cell response is the steroid causing? What cell response is the protein hormone causing?

24. Because the protein hormone cannot enter the cell, it relies on receptor proteins in the membrane and ________________ messengers inside the cell.

Nervous Systems

- **Animals have nervous systems that detect external and internal signals, transmit and integrate information, and produce responses.**
  - The neuron is the basic structure of the nervous system that *reflects function*.

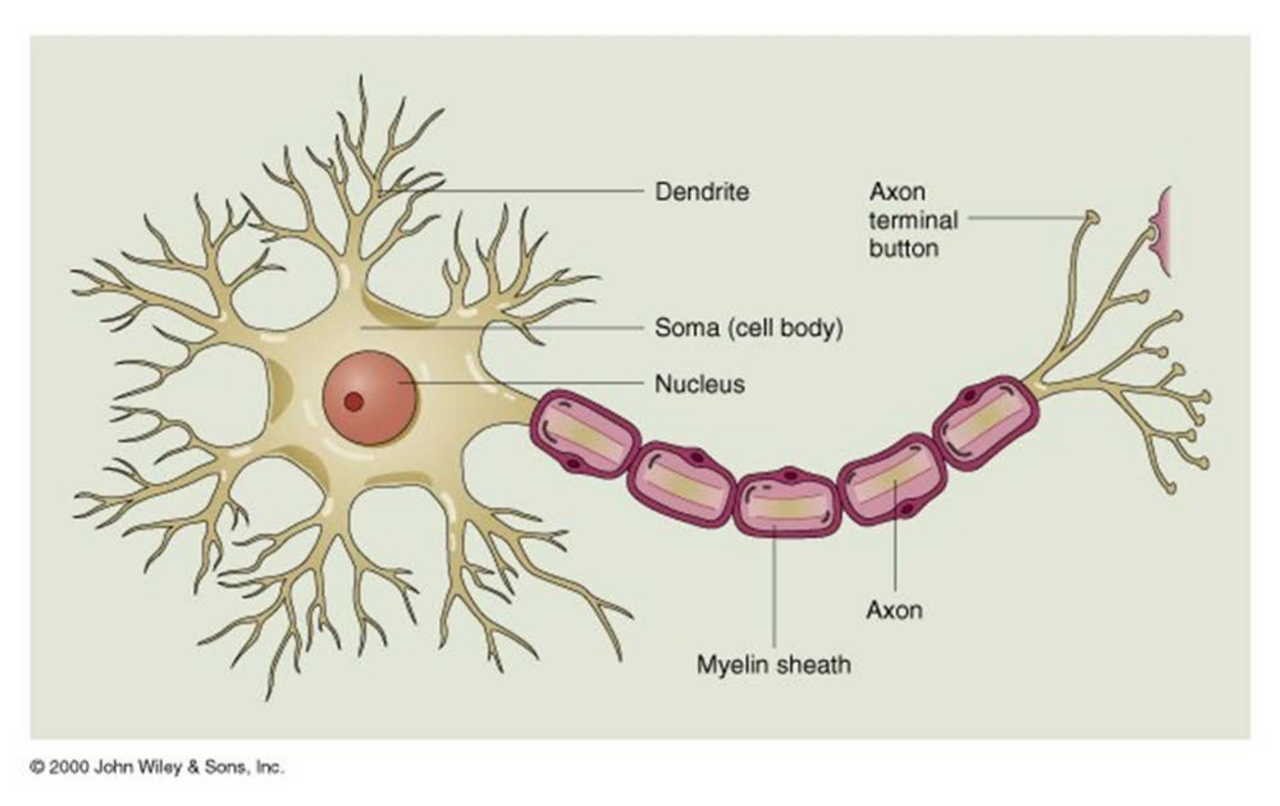




25. The concept that structure reflects function is an important one in biology. How does the structure of a neuron help it accomplish its function?

Neuron Structure

– A typical neuron has a cell body, axon and dendrites. Many axons have a myelin sheath that acts as an electrical insulator.
– The structure of the neuron allows for the detection, generation, transmission and integration of signal information.
– Schwann cells, which form the myelin sheath, are separated by gaps of unsheathed axon over which the impulse travels as the signal propagates along the neuron.



Some neurons will send their signal to an effector cell or tissue, such as the muscle tissue shown here. The nervous signal may cause the muscle to contract or relax. This is how your muscles help you to move and respond to stimuli.

Myelin & Nerve Impulse Transmission

- On the last slide, the **myelin sheath** was described as an electrical insulator. It is composed of many layers of Schwann cells rolled around the axon. Because of all the cell membranes, it is like a jelly-roll of lipids wrapped around sections of the long axon. But what is its purpose? How does it affect the rate of nerve impulse transmission? Make a prediction and then look at the animation on the site below.

http://www.wiley.com/college/jenkins/0470227583/animations/ch12/nerve3a/screen_3_2.swf

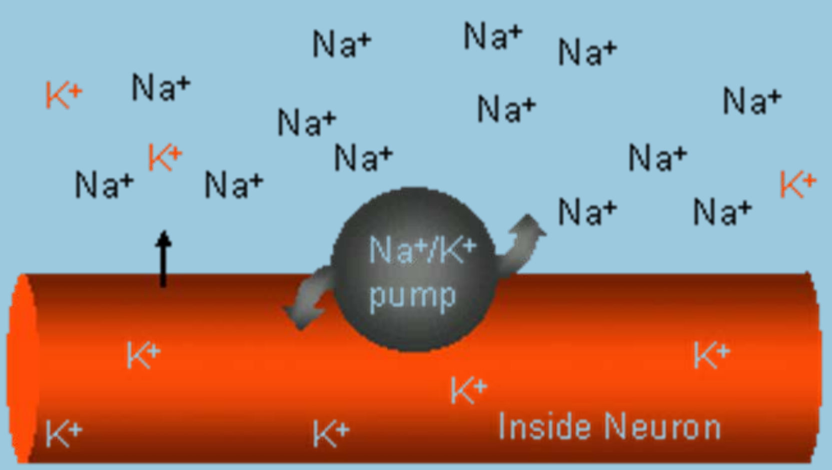
- **26. What is the effect of myelination on the speed of nerve impulse transmission?**

- **27. Multiple sclerosis (MS) involves an abnormal response of the body's immune system directed against the central nervous system (CNS), which is made up of the brain, spinal cord and optic nerves. Within the CNS, the immune system attacks myelin as well as the nerve fibers themselves. How might this affect someone suffering from MS?**

Nerve Impulse Transmission

http://highered.mheducation.com/sites/0072495855/student_view0/chapter14/animation__the_nerve_impulse.html

- **Action potentials** propagate impulses along neurons. (Action potential is the term used to describe the *wave-like transmission of a nerve impulse along a neuron*.)
- There are various steps that occur as part of an action potential:
  - Membranes of neurons are polarized by the establishment of electrical potentials across the membranes.
  - In response to a stimulus, Na+ and K+ gated channels sequentially open and cause the membrane to become locally depolarized.
  - Na+/K+ pumps, powered by ATP, work to maintain membrane potential.
- All cells have **membrane potential** (difference in charge across the membrane). Generally, there is a more (-) charge inside cell.
- In its **resting state**, a neuron is not actively sending or receiving an impulse and there is a high concentration of Na^+ (sodium ions) outside the axon and a high concentration of K^+ (potassium ions) inside the axon.

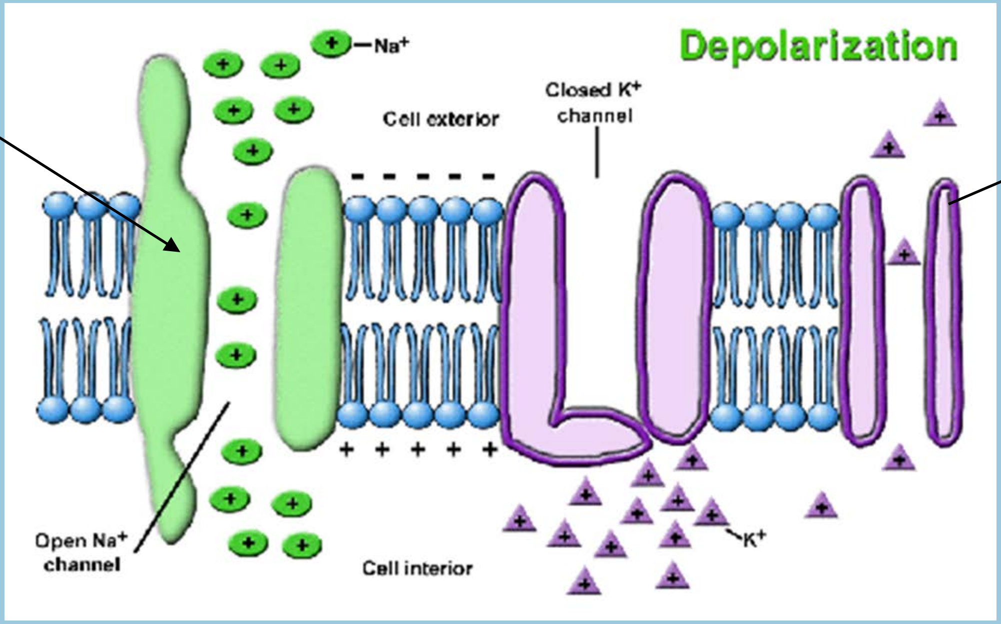


28. The Na^+/K^+ pump helps maintain this balance. This pump is an example of ________________ transport. (active or passive?)

Changes to Membrane Potential

- During the first phase of an action potential, **depolarization** (a change in polarity) occurs as Na^+ ion gated channels open. This causes Na^+ ions to rush into cell.
  - The cell becomes more (+) inside
  - This diagram is showing movement across the membrane of the neuron's axon.

Transport protein



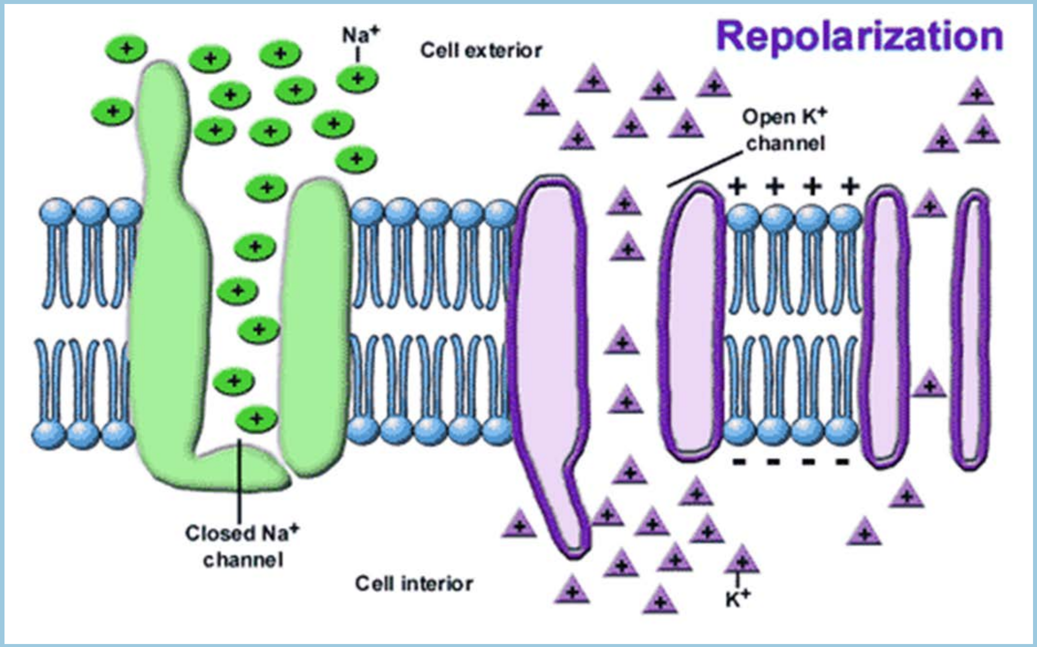
Transport protein

29. What do the blue structures in this diagram represent? How about the green & purple structures?

30. What is happening in this diagram?

More Changes to Membrane Potential

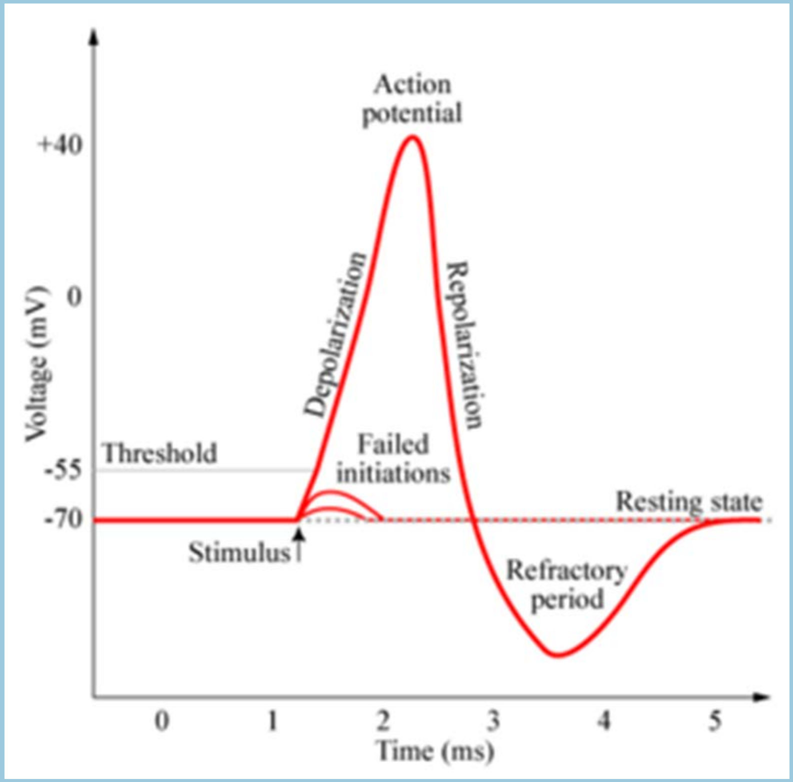
- During the second phase of an action potential, **repolarization** occurs as Na^+ ion channels close and K^+ channels open
  - K^+ ions rush out; cell becomes more (-) again
  - But ions are not in their normal locations



31. What is happening in this diagram?

Returning to Normal

- During the third phase, the refractory period, the neuron re-establishes the location of the ions using the sodium-potassium pump. The cell returns to its resting potential.



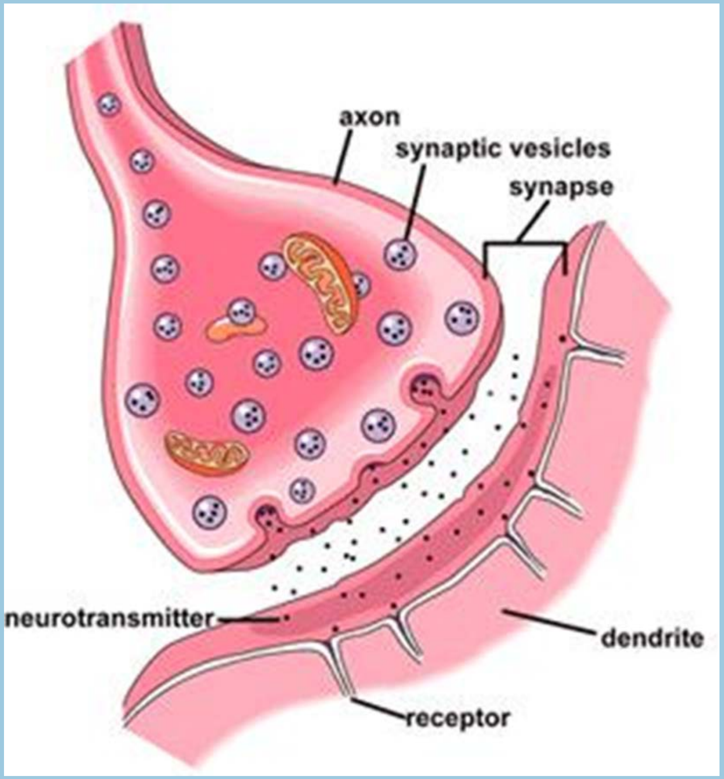
32. What is the role of the stimulus in this graph?

33. What happens to the membrane potential (in terms of voltage) as the action potential progresses through depolarization and repolarization?

Neurotransmitters

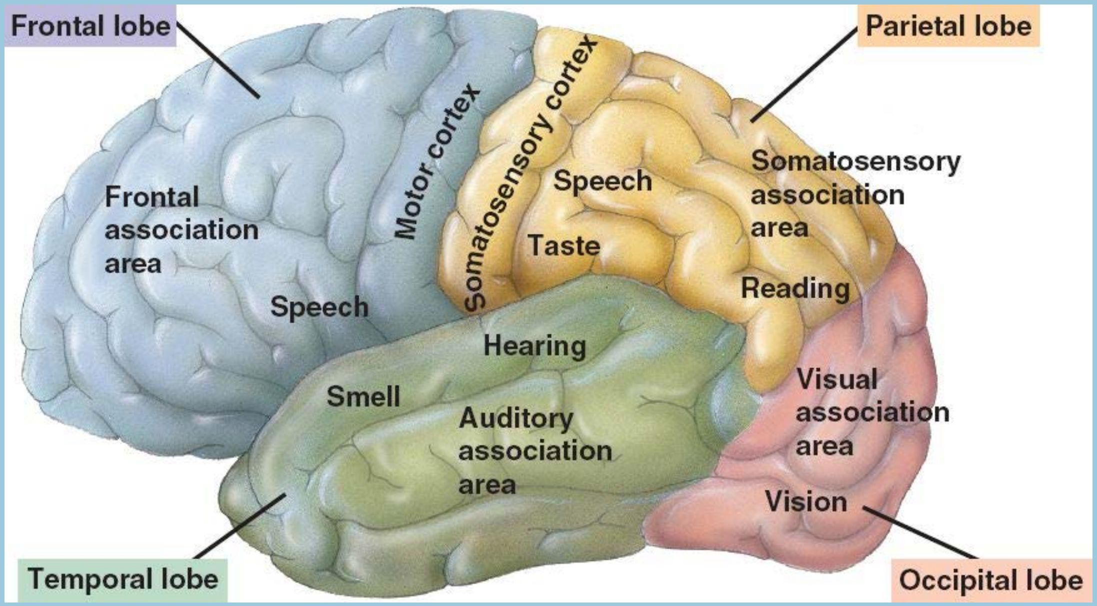
- Transmission of information **between neurons** occurs **across synapses**.
  - In most animals, transmission across synapses involves chemical messengers called **neurotransmitters**. Examples of neurotransmitters include:
    - Acetylcholine
    - Epinephrine
    - Norepinephrine
    - Dopamine
    - Serotonin
    - GABA
  - Transmission of information along neurons and synapses results in a response.
  - The response can be stimulatory or inhibitory.

34. Choose 3 of the neurotransmitters above. Use the Internet to find out their functions and summarize here.



The Brain

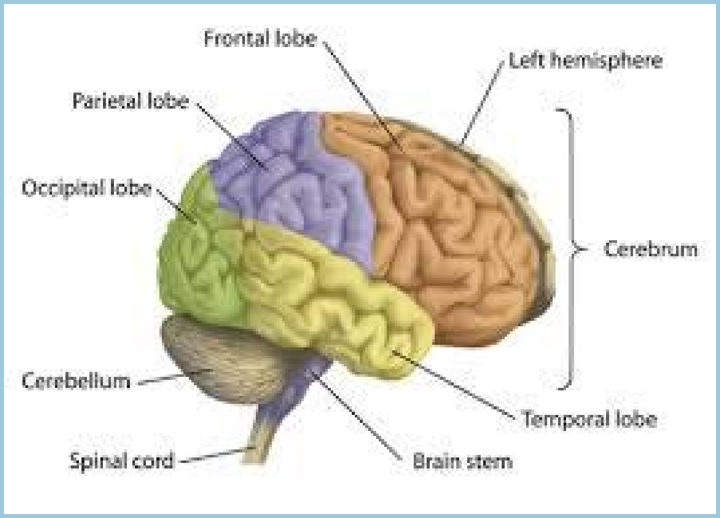
- Different regions of the vertebrate brain have different functions. Examples include:
  - Vision,
  - Hearing
  - Muscle movement
  - Abstract thought and emotions
  - Neuro-hormone production



The Brain (con't)

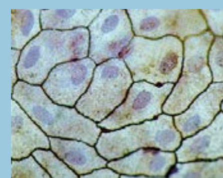
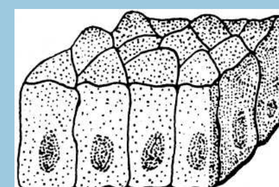
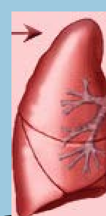
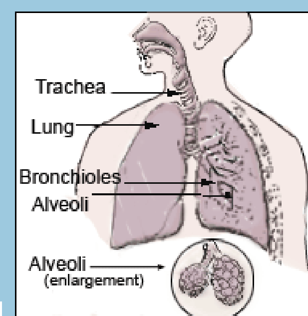
- The brain can also be divided into these regions:
  - Forebrain (cerebrum), midbrain (brainstem) and hindbrain (cerebellum)
  - Right and left cerebral hemispheres in humans

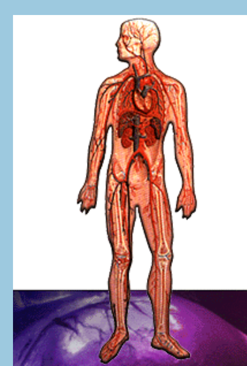
- The cerebrum controls voluntary activities, receives and interprets sensory information
- The cerebellum coordinates muscle activity
- The brainstem controls involuntary activities (breathing, swallowing, heartbeat, etc.)
- The hypothalamus regulates homeostasis, secretes hormones and regulates the pituitary gland



To Sum Up, Think About the Levels of Organization

(Macromolecules make up cells, cells make up tissues, etc.)

- Macromolecules 
- Cells 
- Tissues  
- Organs 
- Organ Systems 

- Organism 

35. It has often been said of the human body that the whole is greater than the sum of its parts. Give one example of how various parts of the human body work together for a higher-level function. Your example could be from this self-study, but does not have to be.

Survival Guide

- Check out the Survival Guide posted with the summer assignment. What are 2 strategies you plan to use during AP Bio this year?

And now you are finished….until we see you in class ☺

Enjoy the rest of your summer!