Chemistry, Neurons, and The Endocrine System…

To truly understand animal behavior, you really need to know how the nervous system works. And to understand how the nervous system works, you really need to start with some basic chemistry and cell biology. So here we go….

## Introductory Chemistry

Living things are made up of parts. If you take apart the parts, you get more parts. Eventually, you get down to the very tiniest of parts (which, by the way, also have parts). Anything that takes up space and has mass (which is like weight) is called matter. In biology, a good place to start when talking about matter is with atoms (which are very, very, very small).

An atom is made up of subatomic particles. The subatomic particles are called protons, neutrons and electrons. Protons have a +1 charge, electrons have a -1 charge, and neutrons are neutral and have no charge. The protons and neutrons are located in the center of the atom (a region called the nucleus). The electrons spin around the nucleus. The electrons are located at different distances from the nucleus. These distances are called energy levels and the space in which the electrons are held are called orbitals. Each orbital can hold two electrons in it. A total of 2 electrons can be held at the first energy level because there is one orbital. Eight electrons can be held in the second and third energy level because there are four orbitals in each. Different atoms have different numbers of protons, electrons and neutrons. **For the most part, it is the protons and electrons that we need to pay attention to. Here is a picture of two different atoms (Fig 1.1a).**

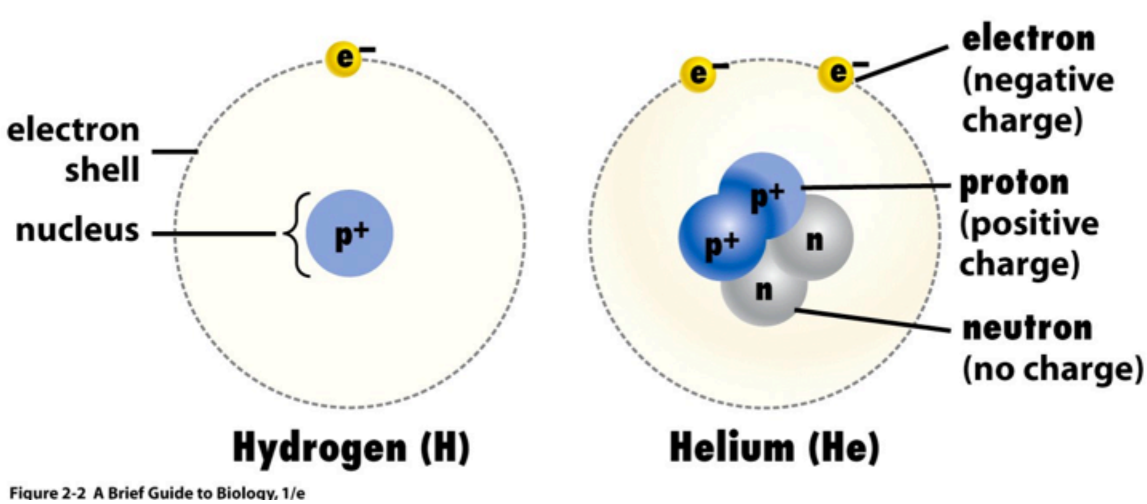


**Figure 1.1a**

In a balanced, normal atom, the number of protons is equal to the number of electrons (we will see in a minute that this can change). So, in the picture above, the hydrogen atom has 1 proton and can attract 1 electron (one positive thing can attract one negative thing). In the picture below, more protons can attract more electrons. As electrons are added, they are added in such a way as to fill up the lower energy level first. In other words, before an electron can be placed in the second energy level, the first energy level must be filled first.

In the picture below, look at an **oxygen** atom and a **nitrogen** atom (Fig 1.2a). The oxygen has eight protons and eight electrons (2 in the first energy level and 6 in the second energy level). There are also neutrons (not pictured), but they are generally not important in how the atom functions so we don't need to worry about them at the moment. Notice that the nitrogen atom has seven protons and seven electrons. These first three atoms are very common in living things. Also important and very common are **Carbon, Sodium, Chlorine** and **Phosphorous** (especially carbon). Figure 1.2a shows the most common atoms in living organisms. For this class, you really need to know the **Sodium, Chlorine and Potassium** Figure 1.2b atoms.

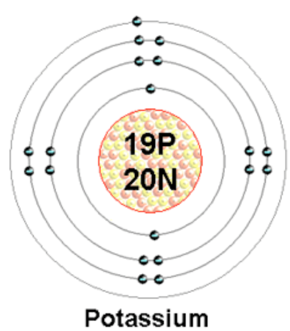


**Figure 1.2b**

I should mention that these models of atoms are inaccurate in how they place atoms in a particular spot. In reality, we believe that the atoms move around the nucleus in sort of a "cloud" of probability as to where the electrons might be during specific times. We won't worry about this, however, and we will just stick with the oversimplified models above.

# *Ions*

**Ions** are atoms that have gained or lost electrons. Notice in Fig 1.3a that the only difference between the sodium atom and the sodium ion is that the sodium atom is missing an electron. When this electron is lost (in a minute, you will find out what causes that to happen) the sodium atom becomes a sodium ion. Because the sodium ion has 1 more proton than electrons, we symbolize it as Na+, implying that it has an electrical charge.

Chlorine atoms can also form ions. In Fig 1.3a you can see that when a Sodium atom (Na) loses its electron, it moves over to the chlorine atom which then turns into a Chloride ion. When the sodium loses an electron (and becomes a sodium ion) and when the chlorine atoms gains an electron (and becomes a chloride ion), they become attracted to each other (because one is positively charged and one is negatively charged). When they stick together, they form an ionic bond. This then becomes NaCl which is a molecule better known as table salt. Ions such as **Potassium, Sodium and Chloride** are VERY important in understanding how the nervous system works so you really need to know these ions well. Potassium (represented by the letter K) is also a positively charge ion. They are also important "electrolytes" (such as those found in Gatorade) because they can help the nervous system to work better if you are low on salt.

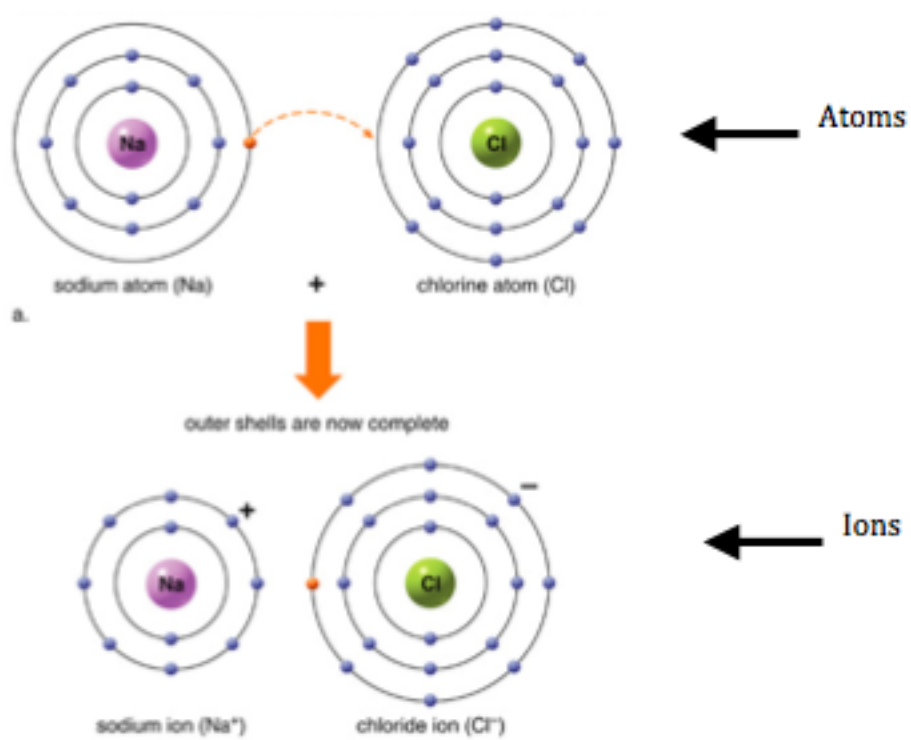


Figure 1.3a

It just so happens that all atoms are most stable when their outer electron shell is either filled with electrons or is empty. If I attached a wing onto each side of my car and then drove really fast down the road, I might be able to actually fly (for a very short distance). But if I attach a wing to ONLY ONE SIDE of my car then it would be very unbalanced and I would generate lift on only one side. The atom kind of works that way. There are two main ways that an atom can reach this balance. One is that the two atoms can share electrons (a covalent bond...see below). The other is that one atom can "steal" an electron away from another atom. This makes both atoms turn into ions (again, ions are atoms that have either gained or lost electrons). In the picture above, you should notice that the Chlorine has stripped the Sodium of one of its electrons:

Now, the Sodium will have +1 positive charge and the chloride ion will have a -1 negative charge (because it now has 18 electrons and 17 protons). Because the $Na^+$ is positive and the Chloride ($Cl^-$) is negative, the two are attracted to each other and form an ionic bond.

****** This section is not terribly important to this class; read it twice and make sure you get the basic idea of covalent bonds*****

**Chemical Bonds**

Individual atoms are often unstable by themselves. In order for an atom to be "balanced", an atom's outer electron shell (or valence shell) must be filled with electrons. This can be achieved in several ways. An atom can gain or lose electrons (which forms the ions we just talked about). Or, two or more atoms can share electrons. When two atoms are connected, they become a molecule. Chemical bonds hold the two atoms together. In this class, chemical bonds can be divided into four basic types:
1) **Ionic bonds** - these form between ions (see example above)
2) **Covalent Bonds**- bonds that form when two atoms share electrons
3) **Hydrogen Bonds**- weak bonds that form when a molecule has slightly positive and/or negative regions.
4) **van der Waal interactions** – Even non-polar covalent bonds will occasionally have slightly positive and negative regions every now and then. This results in very weak bonds (similar to those of hydrogen bonds) called van der Waal interactions. We won't talk about these very much.

## *Covalent Bonds*

One way that atoms can become balanced is to share electrons. For example, take a look at a hydrogen atom. It has 1 proton and therefore can attract one electron in the first energy level. But for the atom to be stable, it would need to have two electrons in the first energy level (because remember, the atom is most stable when the outer energy shell is either full of electrons or completely empty). So, if TWO hydrogen atoms were to get together (each needs one electron and each has one electron) they could each share their electron (Figure 1.5a). This would mean that some of the time the two electrons would be around one hydrogen and other times they would be around the other hydrogen. This forms a covalent bond. This is a very strong chemical bond and you will pretty much see this every day for the rest of your life. Well, at least this semester.

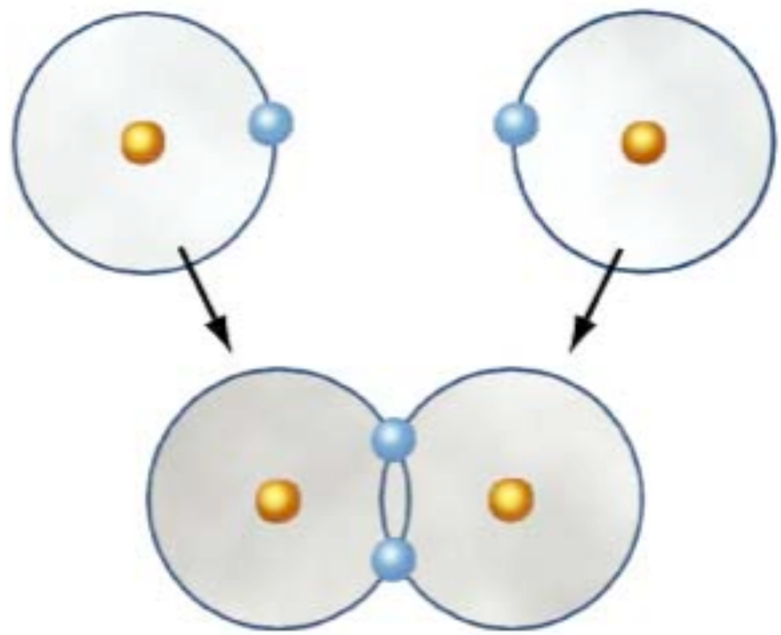

**Figure 1.5a**

## *Hydrogen Bonds*

Now remember that a COVALENT bond forms when two or more atoms share electrons. Well, sometimes they don't share the electrons equally. Instead, one of the atoms pulls the electrons with more force. It's kind of like a tug-of-war match between Arnold Schwarzerneger and a little kid. Now also remember that the electrons are negative. So, if one atom (the "Arnold atom") pulls the electrons slightly more towards it, then it will become slightly negative. And the other atom (the little kid) will become slightly positive. This type of covalent bond (when electrons are shared unequally) is called a polar covalent bond. Figure 1.7a is an example of several water molecules. The arrow shows that the molecule has a slightly positive and slightly negative region. Notice that the hydrogen bond is between the two adjacent water molecules. That is because the slightly positive regions of one water molecule are attracted to the slightly negative regions of another water molecule. I say slightly negative because it is not a full +1 or -1 charge; in order for that to occur it would have to pick up or lose one or more electrons (which would make it an ion). Hydrogen bonds can form between other molecules; water is just one very good example!

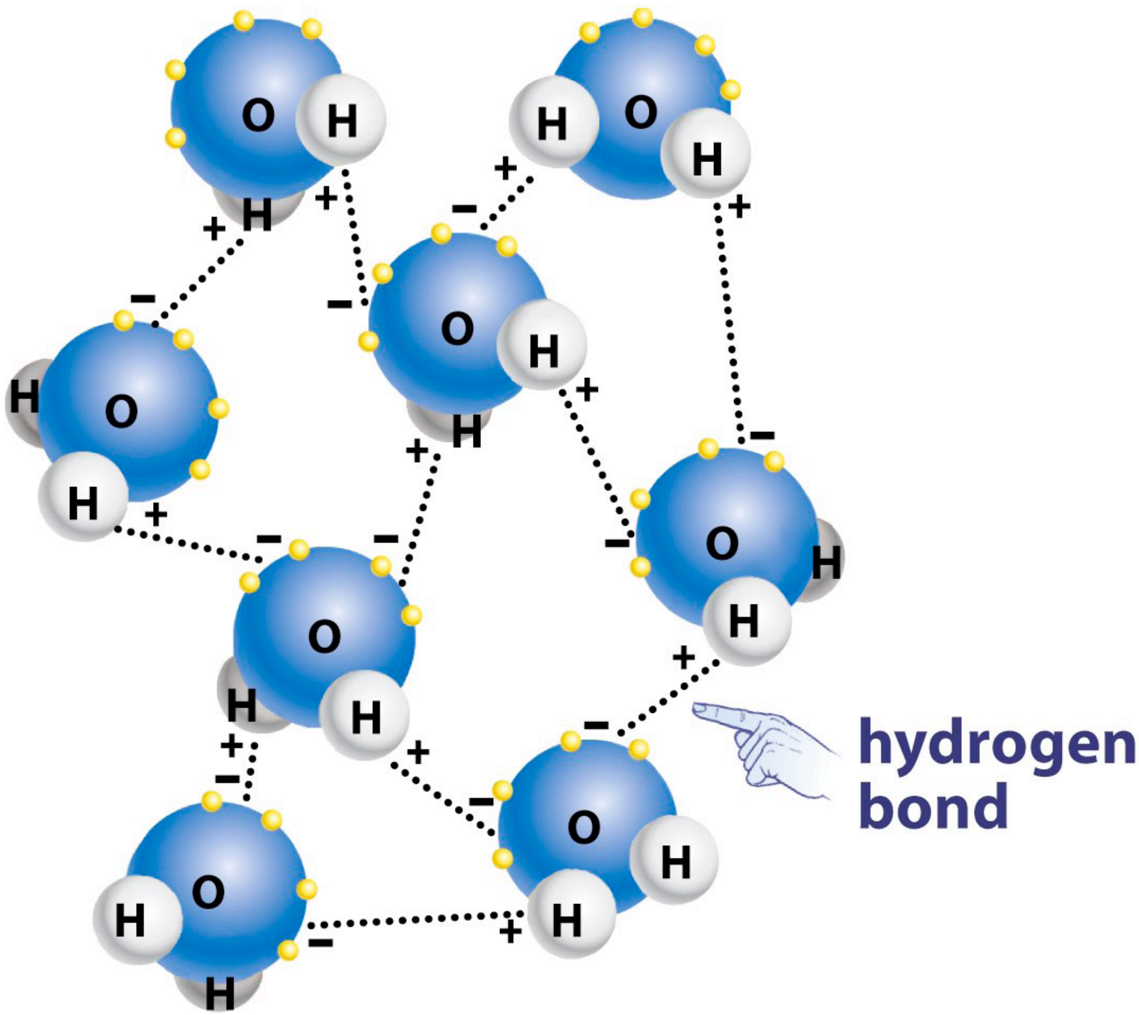


Figure 2-11 A Brief Guide to Biology, 1/e


***Figure 1.7a***

In living organisms, smaller molecules are often attached to each other to make larger molecules. These “smaller” molecules are sometimes called **monomers,** and the larger molecules made from these monomers are called **polymers**. When naming and identifying molecules, it is important to recognize certain features of the molecule. For example, one part of a molecule is often very reactive or will combine with other molecules. The parts of specific regions of a molecule that are important are often called **“functional groups”.** The functional groups are important because they are the parts that often determine how a molecule functions or interacts with other molecules. There are several functional groups that are important in biology. Make sure you can recognize and name the various functional groups illustrated below, and also be able to tell what types of molecules often have them (Figure 1.8a).

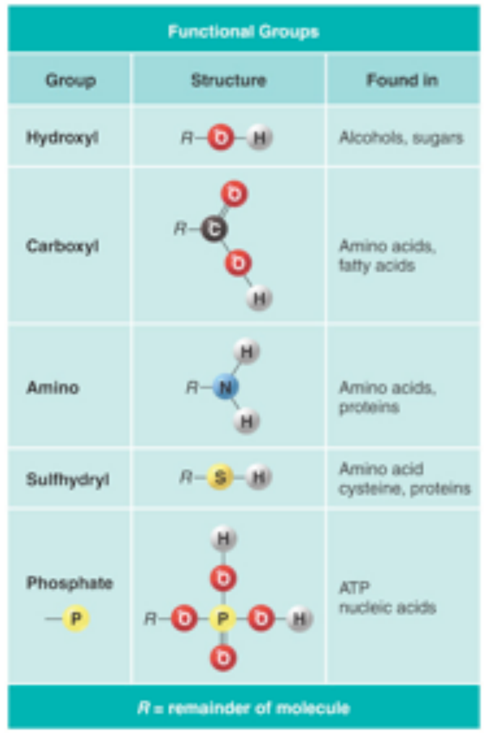


*Figure 1.8a*

## *Macromolecules*

There are four types of macromolecules (i.e., big molecules) that we commonly deal with in this class. They are carbohydrates, lipids, proteins, and nucleic acids. In this class, we will really only worry about two for now. Those a proteins and lipids.

**Lipids** are macromolecules that are made almost entirely of carbon and hydrogen. THEY DO NOT have the ratio of carbon:hydrogren:oxygen as found in carbohydrates. Lipids are a very diverse group of macromolecules and include **steroids, fats**, and **phospholipids.** Below is an example of a steroid called **cholesterol (Figure 1.9a).**

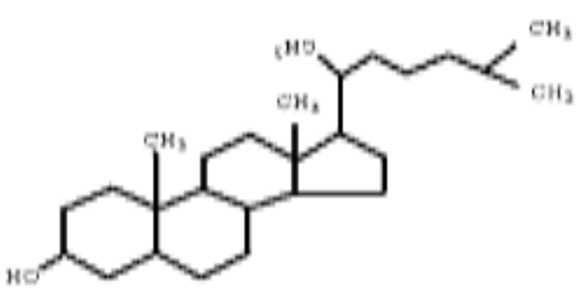

**Figure 1.9a**

This is a typical fat molecule (Figure 1.9b)

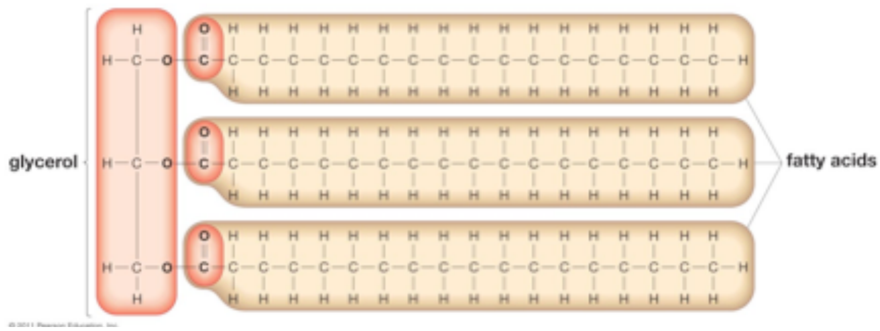


**Figure 1.9b**

This is a phospholipid which is important in cell membranes such as those that surround neurons.  Phospholipids help regulate what can move in and out of a cell (Figure 1.9c)

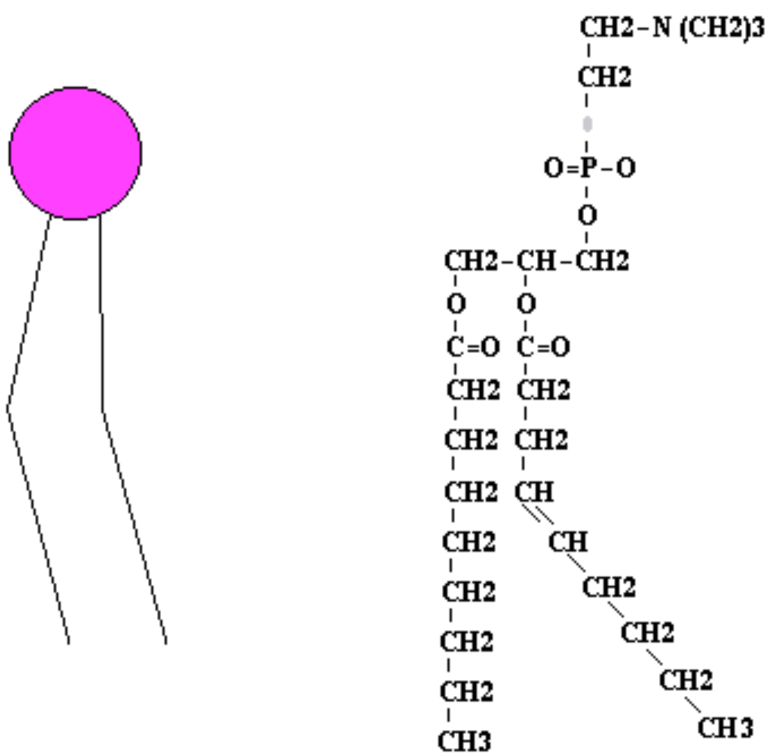

**Figure 1.9c**

**Proteins**

The next group of macromolecules that are important in biology are **proteins**. Proteins are very important molecules in biology. Proteins are made out of smaller units (monomers) called **amino acids.** Here are two different amino acids (Figure 1.10a):

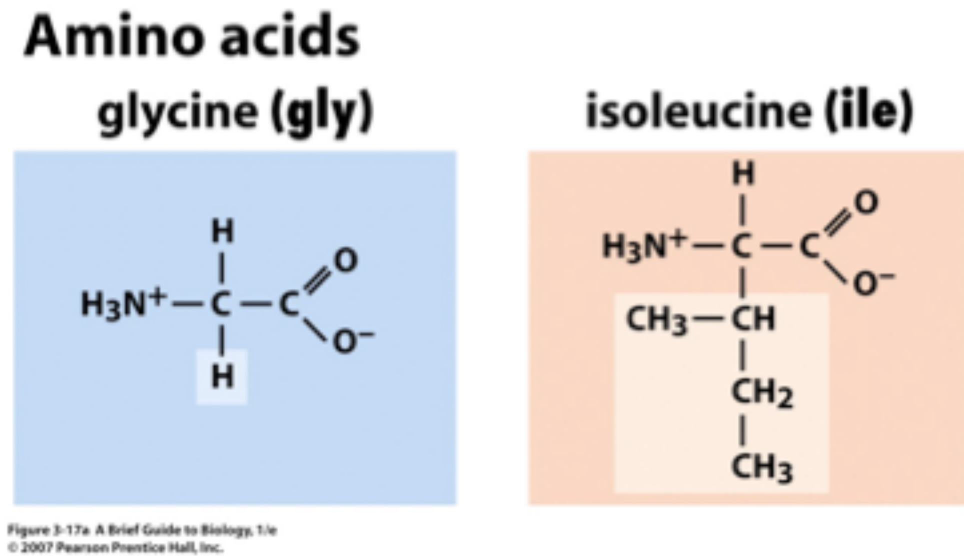


**Figure 1.10a**

You should note the "amino group" (which is the nitrogen and the two hydrogens) and what is called the **carboxylic group** (the carbon with the double bonded oxygen and oxygen with a negative charge (or, a hydrogen atom attached). These are two of the functional groups that you learned about earlier. All amino acids have these two main parts. What makes one amino acid different from another is the shaded region. You will notice that in the picture above, the amino acid glycine has a “H” in the shaded region whereas the amino acid isoleucine has a four carbon attachment. This shaded region is often referred to as the “R” group and again, it is what makes one amino acid different from another amino acid. The “R group” in chemistry is a term used to describe the side chain that is attached to a “core” part of a molecule. The “core part” is generally the same but the “R group” varies from molecule to molecule.

There are twenty amino acids found in living organisms. They all have different "R" groups but the other two parts remain the same. You do not need to memorize what *each* of the twenty amino acids looks like, BUT, you should be able to recognize the difference between a lipid, a carbohydrate, and an amino acid.

The next thing is to hook these amino acids together. This is a very common chemical reaction in biology called **"dehydration synthesis" (Figure 1.11a).** It basically means what it sounds like: we are going to "lose" or dehydrate out the water between two amino acids:

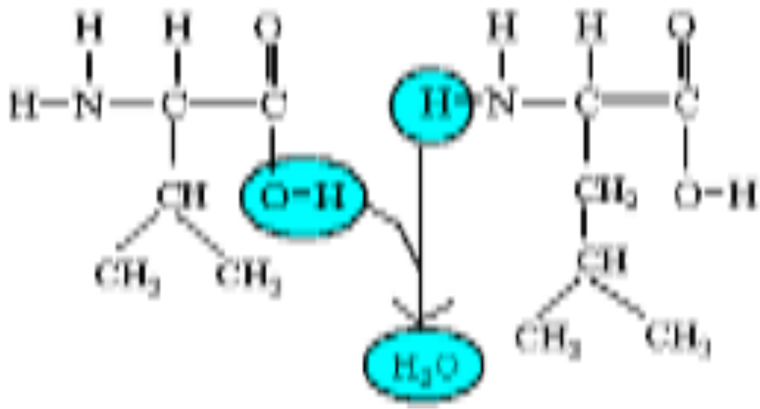


***Figure 1.11a***

This does not usually happen on its own in living systems. Right now, just pretend it's magic. Later we will learn how this happens. Since we are here, the opposite reaction, hydrolysis, can also occur. In Hydrolysis, we basically split a bigger molecule into smaller molecules by adding water between them.

After dehydration synthesis is done, you are left with two amino acids hooked together by a covalent bond. We have a special name for this covalent bond which is only used when it's between two amino acids. We call it a **peptide bond.**

A peptide bond connects two adjacent amino acids (Figure 1.12a). Dehydration synthesis is not only used to hook amino acids together. It is a very common reaction that we will see over and over again in the building of many macromolecules. I just introduce it here because it is one of the first times we see the reaction taking place. Actually, the hooking of the fatty acids to the glycerol (back at the lipids section) is another place where dehydration synthesis takes place.

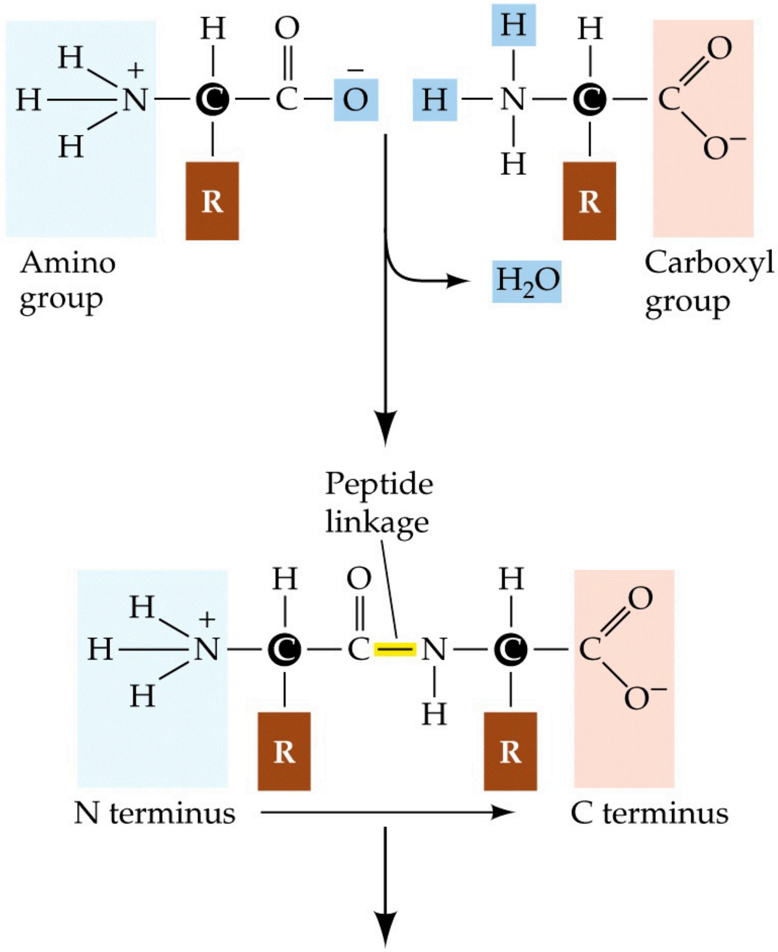



**Figure 1.12a**

Now, if you hook a whole bunch of amino acids together in a big long chain, the chain will fold up and eventually form a **polypeptide chain.** This will continue to fold up with more and more complexity until you end up with a functional three dimensional protein (Figure 1.13a)

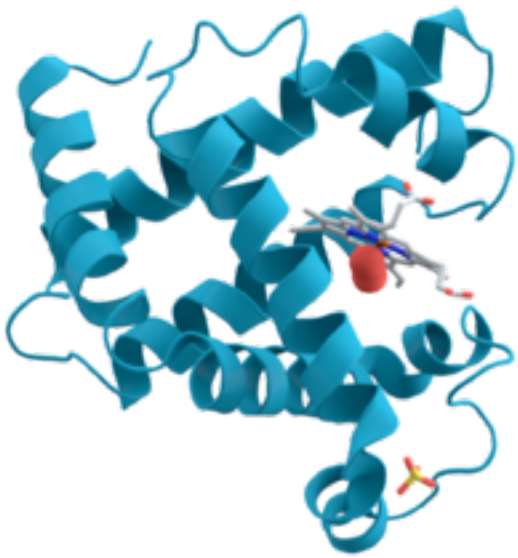

**Figure 1.13a**

Proteins are very important. They do all sorts of things. They primarily are important as enzymes and basically control your entire metabolism. In this class, we will mainly be concerned with how proteins affect our nervous system. Proteins are important as regulators in neurons (in terms of allowing Sodium and Potassium to entire or exit neurons) and also as neurotransmitters.

## Cell Membranes and What can move in and out of a cell (or Neuron!)

Earlier when we learned about the organelles in a cell, we talked about the cell membrane or plasma membrane and how it is important in all cells in regulating what moves in and out of a cell. You might also remember (from week one) that one of the properties of life is that all things must maintain homeostasis. **Homeostasis** is a kind of balancing act and it means that, in order for something to stay alive, it must stay within certain boundaries. Since the outside world is changing all the time, living things must be able to control how they change (in other words, they cannot just change with every change in the environment). Once again, cell membranes help maintain homeostasis by allowing cells to control what is going on inside of a cell while the outside might be changing drastically.

Recall from last week that we talked about **solutions.** Remember that a **solution** is made up of a **solute** (the stuff that gets dissolved) and the **solvent** (the thing that does the dissolving which is usually water). Cells are complex solutions which have a great deal of water in them (the solvent) and many different solutes (such as glucose, salts, proteins, etc.).

You may also remember that I told you that the cell membrane is

**Selectively Permeable**. This means it is selective in terms of what types of molecules move in and out of the cell. We will learn about the structure of a cell membrane later on; but first, a little lesson about concentration differences.

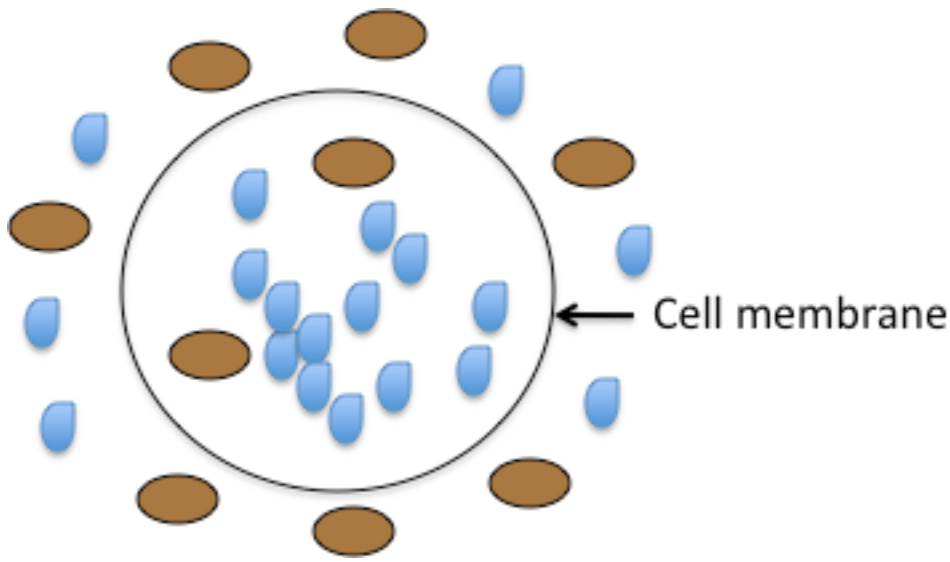


**Figure 1.14a**

Let's just say for a moment that the glucose (in brown) is not able to move back and forth across the cell membrane BUT that water (in blue) CAN (Figure 1.14a). If there is more water inside the cell than outside, which direction will water move? Will water move into the cell, out of the cell, or both? Well, your first response is probably that it will move out of the cell. That is partially true, but it will actually move both directions. If one water molecule can move out of the cell, than another one can move in. BUT, the OVERALL movement (in other words, most of the water molecules or the net movement) will be moving out of the cell until an equilibrium is reached. At that point, the movement of water in the cell will equal the rate of movement out of the cell. This point is called the **dynamic equilibrium** of the reaction.

Because the concentration of different chemicals is important in trying to figure out which way molecules will move, we have special names to describe the concentrations in and out of a cell. These terms are based on the concentration of the solute (not the solvent). So, if the inside of a cell has 10% salt and the outside of the cell has 2% salt, then we say the inside the cell is **hyperosmotic** (has more solute) to the outside. We could also say that, in this same case, the outside of the cell is **hyposmotic** (has less solute) to the inside. The other term, **isosmotic**, is used to refer to situations that have equal concentrations of solute. In figure 1.15a, there are three examples illustrating this. The large black circles represent the cell membrane of a cell. In these cases, the solute is glucose.

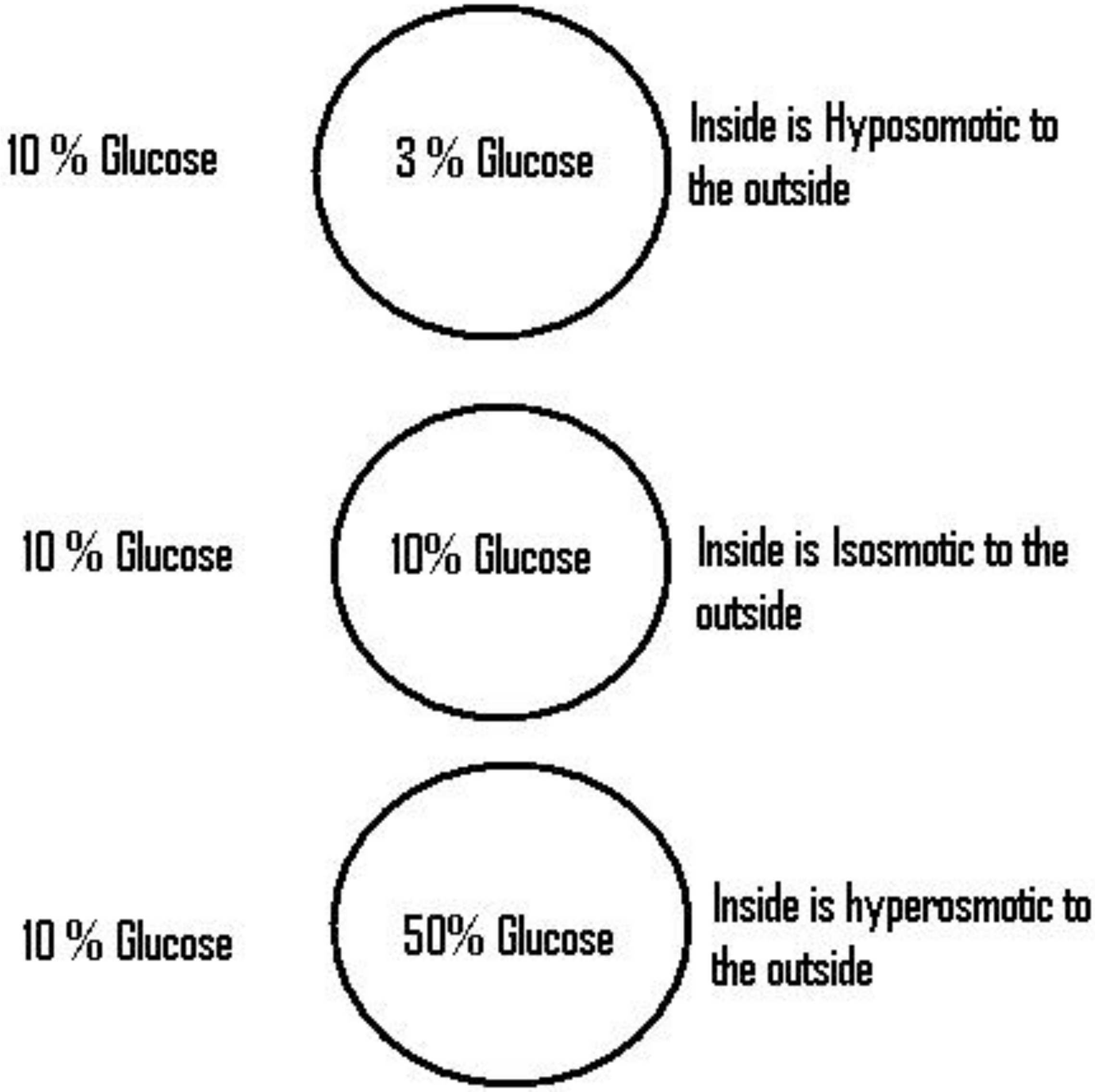


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**Figure 1.15a**

Figure 1.16a is commonly referred to as the “fluid-mosaic” model of the cell membrane. Most scientists believe this is what a cell membrane is like (however, studies in the past five years suggest that this view might be changing).

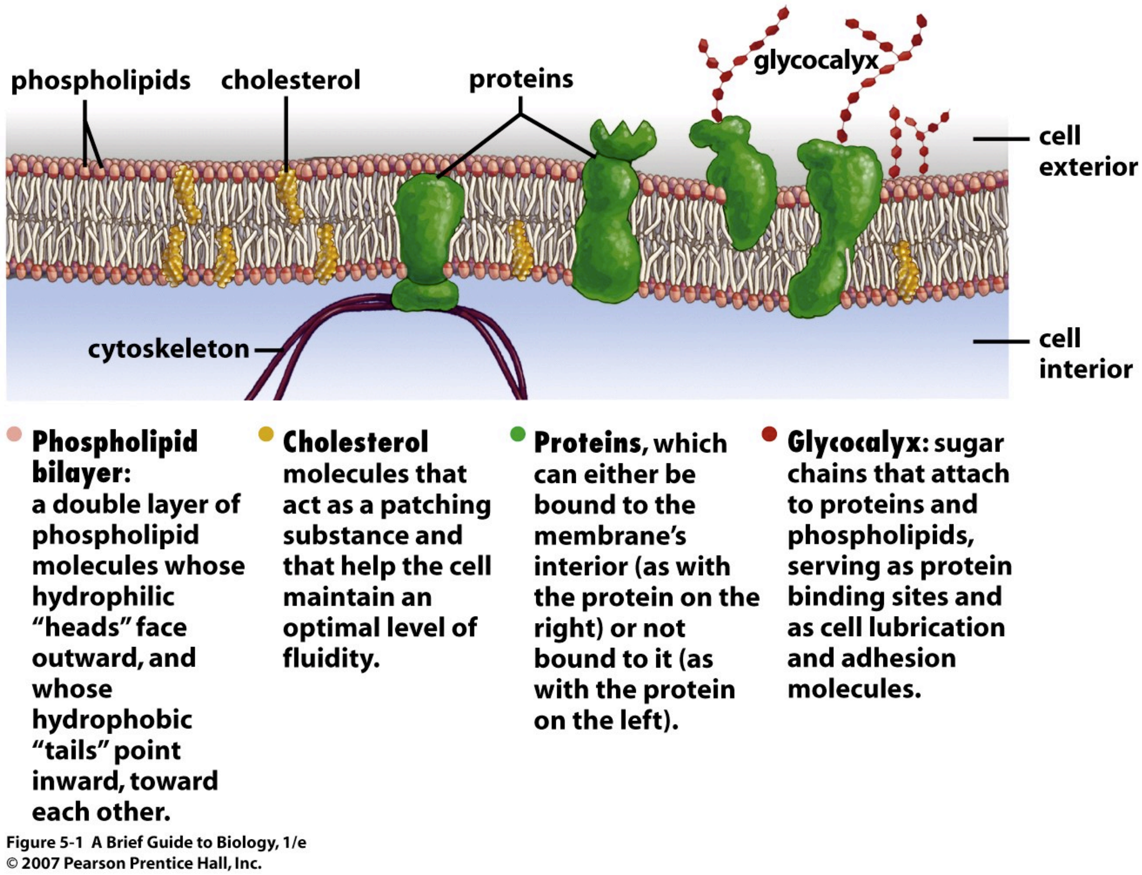



**Figure 1.16a**

There are several parts to a cell membrane (and we will cover those shortly). The main part of the cell membrane, however, are the molecules called phospholipids. As their name implies, they are lipid molecules (made up mostly of carbon and hydrogen) with a phosphate attached to them. Specifically, we call the lipid part the **"tails"** and the phosphate part the **"head"** of the phospholipid. Figure 1.17a shows a chemical drawing of what a phospholipid looks like.

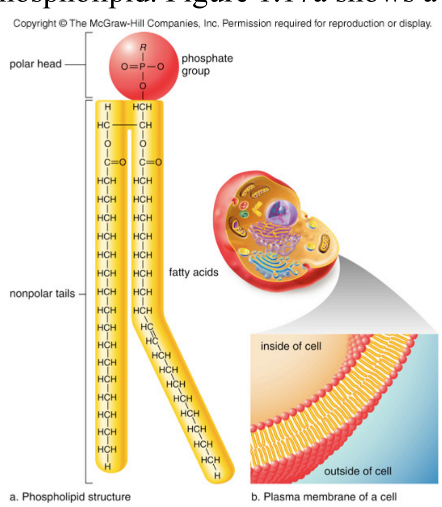



**Figure 1.17a**

If you remember back to week two, when we discussed the properties of molecules like lipids, we said that carbon and hydrogen (the main components of lipids) form non-polar covalent bonds. This means that they share the electrons equally between the atoms which results in no slightly negative or slightly positive parts on a lipid. Also, you should remember that water can only bind to things with electrical charges. So, water does not stick to lipids (or does not "mix" with lipids) very well. Because of these properties, the phosphate head of a phospholipid (which does have an electrical charge) can mix with water and the carbon-hydrogen tails of a phospholipid cannot. We then apply the terms **"hydrophilic"** to the heads of a phospholipid (because they "love" water so to speak) and **"hydrophobic"** to the tails of a phospholipid (because they are "afraid" of water). Of course, they are molecules so they don't really think about being afraid….these are just terms we use to describe how the molecules seem to react. Also, when you mix a bunch of phospholipids together in water, they will naturally arrange themselves so that water is only touching the phosphate heads. They thus form what is called the **"phospoplipid bilayer"**. In Figure 1.18a you can see the details of the phospholipid bilayer of a cell membrane. You should also note the hydrophilic and hydrophobic regions of the phospholipids.

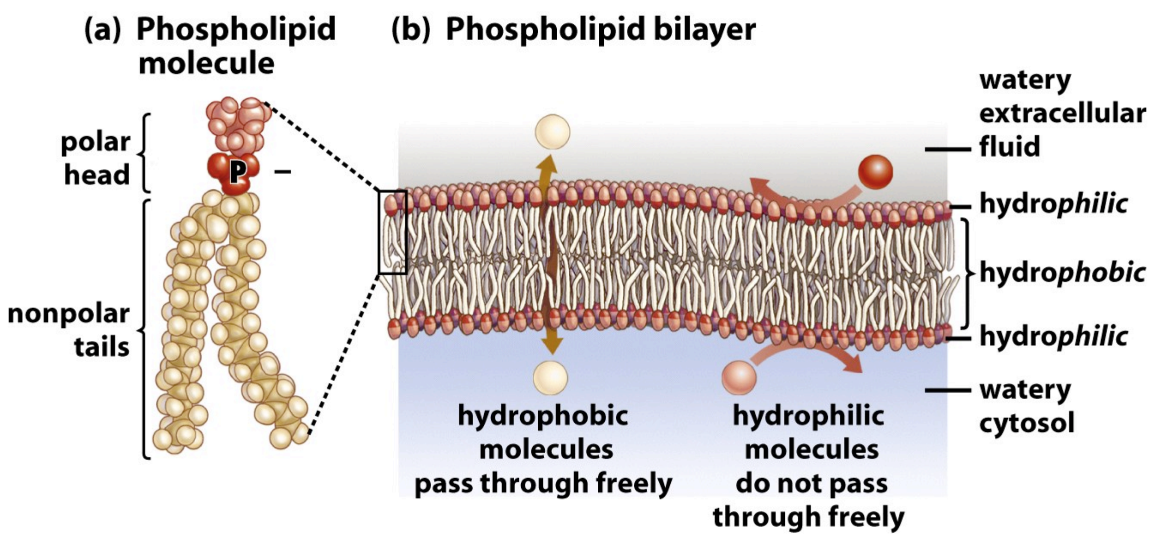





**Figure 1.18a**

The cell membrane contains other parts in addition to the phospholipids. For example, there are cholesterol molecules in the cell membrane that help keep it fluid like. Some animals have a lot of cholesterol in their cell membranes and it actually acts like a type of anti-freeze and keeps the cell membrane very fluid even in freezing cold weather. There are also several types of protein molecules that you can see embedded in the membrane. Some of these proteins act as channels or tunnels and they allow certain molecules to pass through. Others act as recognition proteins. These proteins are very important for your immune system because they can allow your body to recognize certain cells. Also, these recognition proteins are often very important in how different drugs work. Some cells have certain recognition proteins that allow certain drugs to bind to them that eventually affect the inside working of the cells.

## *How do things get in and out of a cell?*

**Passive transport:**

**Passive transport** is the movement of molecules that goes along with the concentration gradients. So, if you have a high concentration of water on the outside of a cell and a low concentration of water on the inside of the cell, you would expect water to move BOTH directions: in and out of the cell. BUT, you would expect the OVERALL movement of water to move INSIDE the cell. This would be passive transport because the overall movement of water is going with the flow. It is kind of like the water is going downhill. Think of a rock on the edge of a hill; the rock would naturally (or passively) roll down the hill.

**Active transport:**

**Active transport** is the movement of molecules that move AGAINST the concentration gradient. For example, let us say you have a high concentration of glucose on the inside of the cell and a low concentration of glucose on the outside of the cell BUT THE GOAL is to move even more glucose INSIDE the cell. This is like moving UPHILL. Just like a rock does not roll uphill on it’s own, energy will be required for active transport.

Let’s take a closer look now at PASSIVE TRANSPORT:

Take a look at this simple picture of a cell membrane (Figure 1.19a):

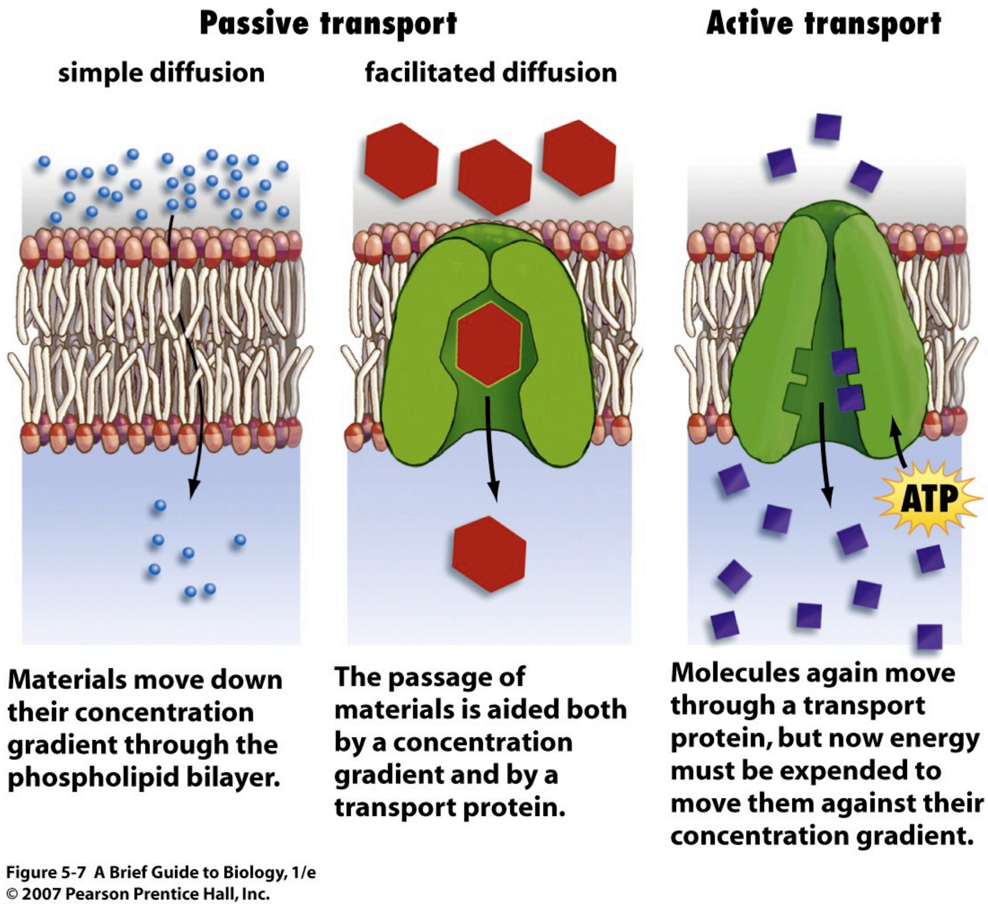



**Figure 1.19a**

Some molecules can go straight across the cell membrane. The only molecules that can do that are either non-polar molecules (such as cholesterol and carbon dioxide) and very small polar molecules (such as water). This is called **simple diffusion**. Simple diffusion is also used when describing any molecules moving from high to low concentration (not necessarily needing to cross a membrane). Sometimes (such as in your lab book), the term **dialysis** is used to specifically describe diffusion across a selectively permeable membrane. Now, if it is specifically water that is moving across the cell membrane, we call that specific type of simple diffusion, **osmosis**. Remember, osmosis only refers to the passive diffusion of water. Therefore, if you are studying by osmosis you are only sucking water into your head, not facts and knowledge! These (simple diffusion, dialysis, and osmosis) are types of passive transport.

Other molecules that are either big and polar (such as glucose) or are charged (such as ions) cannot go across the cell membrane. The reasons for this is that water molecules form hydrogen bonds with these types of molecules and these keep them from moving very much. Therefore, they usually don't develop enough kinetic energy (energy in motion) to move across the cell membrane. So, molecules such as glucose or Na+ (a sodium ion) or K+ (a potassium ion) must enter or leave the cell through a special protein (See Figure 1.19a above). This is called **facilitated diffusion.** Facilitate diffusion is also a type of passive transport. This is very important in understanding the resting and action potentials of neurons!

So far, the type of movements we have described are for regularly sized molecules. But if you want to move something REALLY big inside or outside of a cell (such as a bacteria or a virus or large protein), then we have another system. **Endocytosis** and **Exocytosis.** In these, the membrane can fold in and surround the object. It eventually pinches off and encloses the item in a type of internal sac. **Figure 1.20a** depicts what EXOCYTOSIS would look like (the movement of something out of the cell):

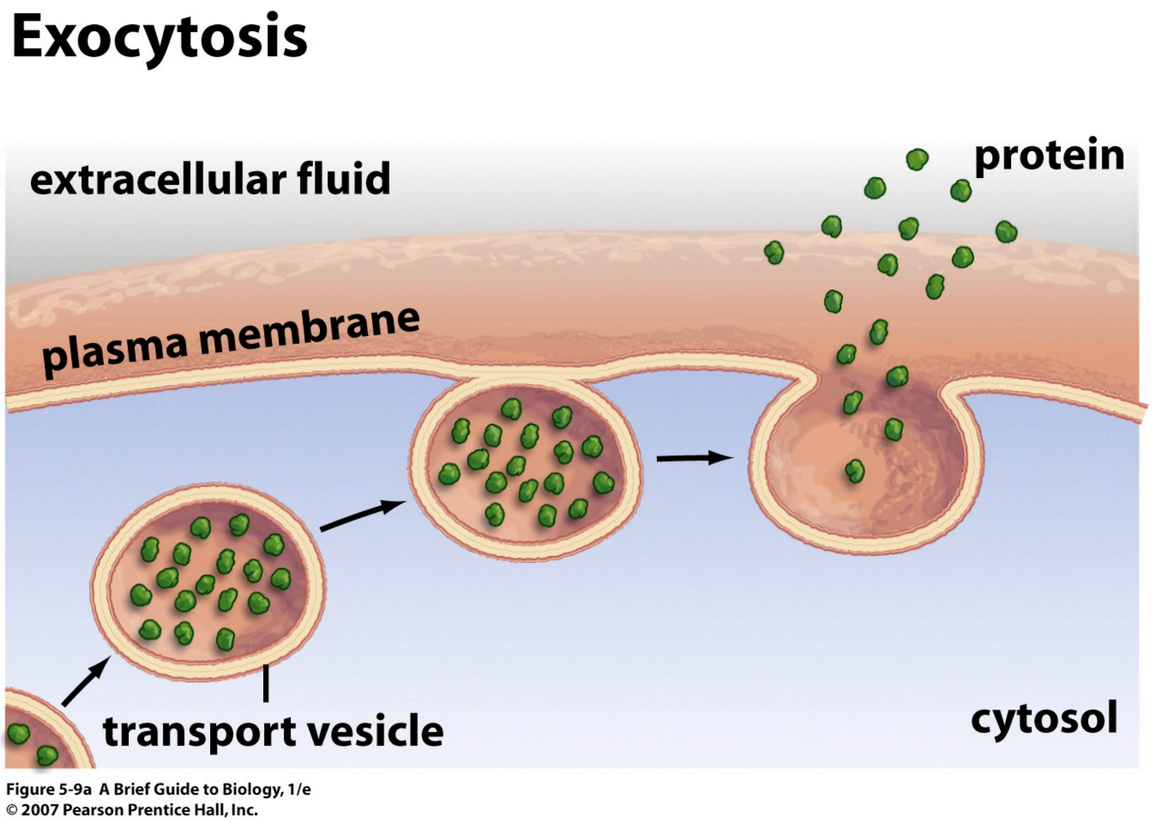



**Figure 1.20a**

Endocytosis would look similar but in reverse. Instead, cells or large molecules or groups of molecules enter the cell as it folds inward. Often, there are receptors on the surface of the cell-membrane that help this happen. Endo and Exocytosis are both active types of transport. A summary of the different types of transport are demonstrated in the

******* That is the end of the read twice section! ********

*Nervous system*:

Now that you know some basic chemistry and cell biology, we are ready to examine how neurons work! The nervous system is both complex in many respects, but also very simple in other respects. The main important functional part of the nervous system are specialized cells called neurons. Neurons are cells but are very weird looking cells for the most part: They have four main regions: Dendrites (which are the receptive ends), Soma or body (where the nucleus is), axon (generally the long part that delivers the electrical signal), and the synaptic terminal (which ends at a muscle, gland, or another neuron) (Figure 1.20b).

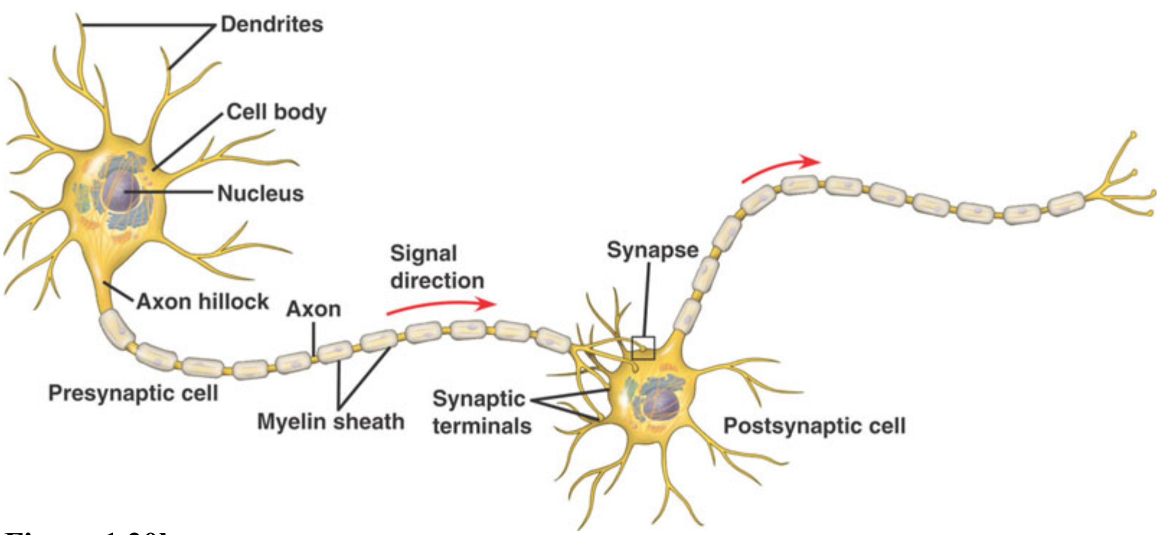



**Figure 1.20b**

There are basically three types of neurons: motor, sensory, and interneurons. **Motor neurons** take information from your brain out to your muscles and glands in your body. **Sensory neurons** take information from your skin and elsewhere and bring it back to your spinal cord and brain. **Interneurons** are the most abundant and they are between motor and sensory neurons.

The next thing that I need to talk about briefly is neuron physiology (in other words, how it works). If you were to take a voltmeter (a device that measures voltage…you can use one, for example, to test whether a battery is good or not) and measure the voltage across the cell membrane, you would find that the inside of the neuron is slightly negative compared to the outside. This occurs when the neuron is not firing. We call this the **resting potential** of the neuron. Now if you were to stimulate the neuron, it would quickly change from negative to positive and then it would return to normal. This quick change in the voltage of the neuron is called the **action potential**.

This is how it works. First, in the cell membrane of the neuron are specialized proteins that pump Na+ ions out of the cell and K+ ions into the cell. These are called sodium-potassium pumps. They pump 3 Na+ ions OUT for every 2 K+ they pump in. Second there are another set of proteins that act as channels that allow K+ ions to flow OUT of the cell (the **net** flow is out because of the concentration difference…but again, K+ can really flow both in and out). Third, there are Na+ channels that are CLOSED during the resting potential. This means that Na+ cannot flow into the cell. The result is this, there is a protein pump that is constantly pumping K+ in and Na+ out. The K+ channels allows positive ions to flow out of the cell but because the Na+ channel is closed, no positive ions are flowing back in. If positive ions are flowing out and are not being replaced, the inside of the cell becomes negative (and that is why the neuron is negative during the resting potential). When the neuron is stimulated by touch, pressure, heat, vibration, or another neuron, Na+ channels quickly open and Na+ comes rushing into the cell. This rush of Na+ causes the inside of the cell to become slightly positive which is what happens during an action potential (Figure 1.21a – Resting Potential).

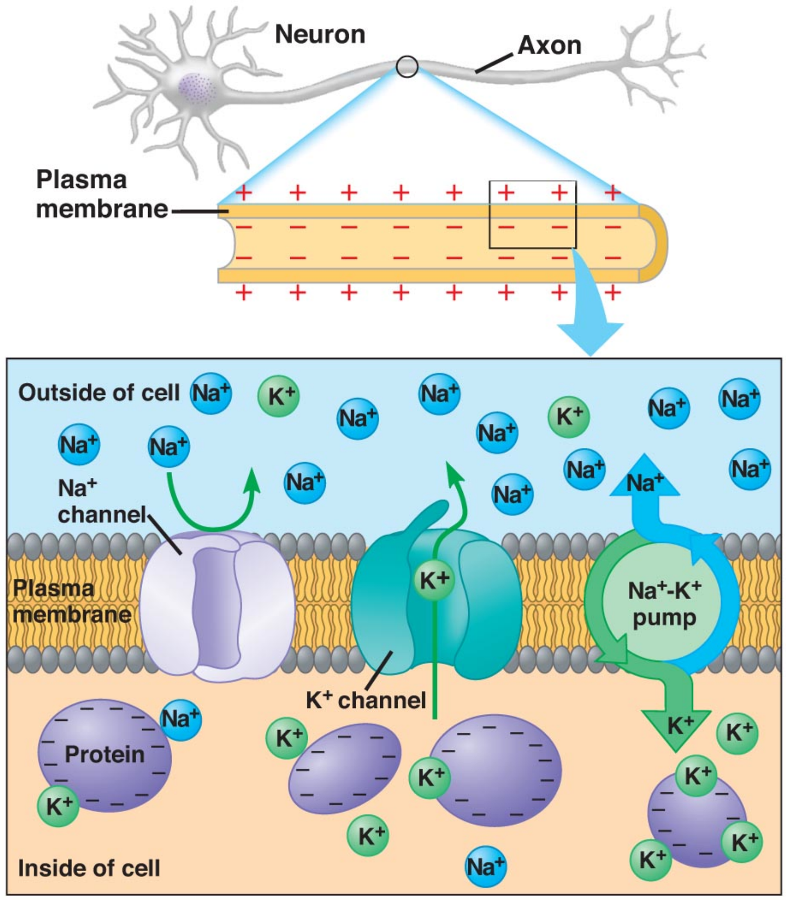




**Figure 1.21a (Resting Potential)**

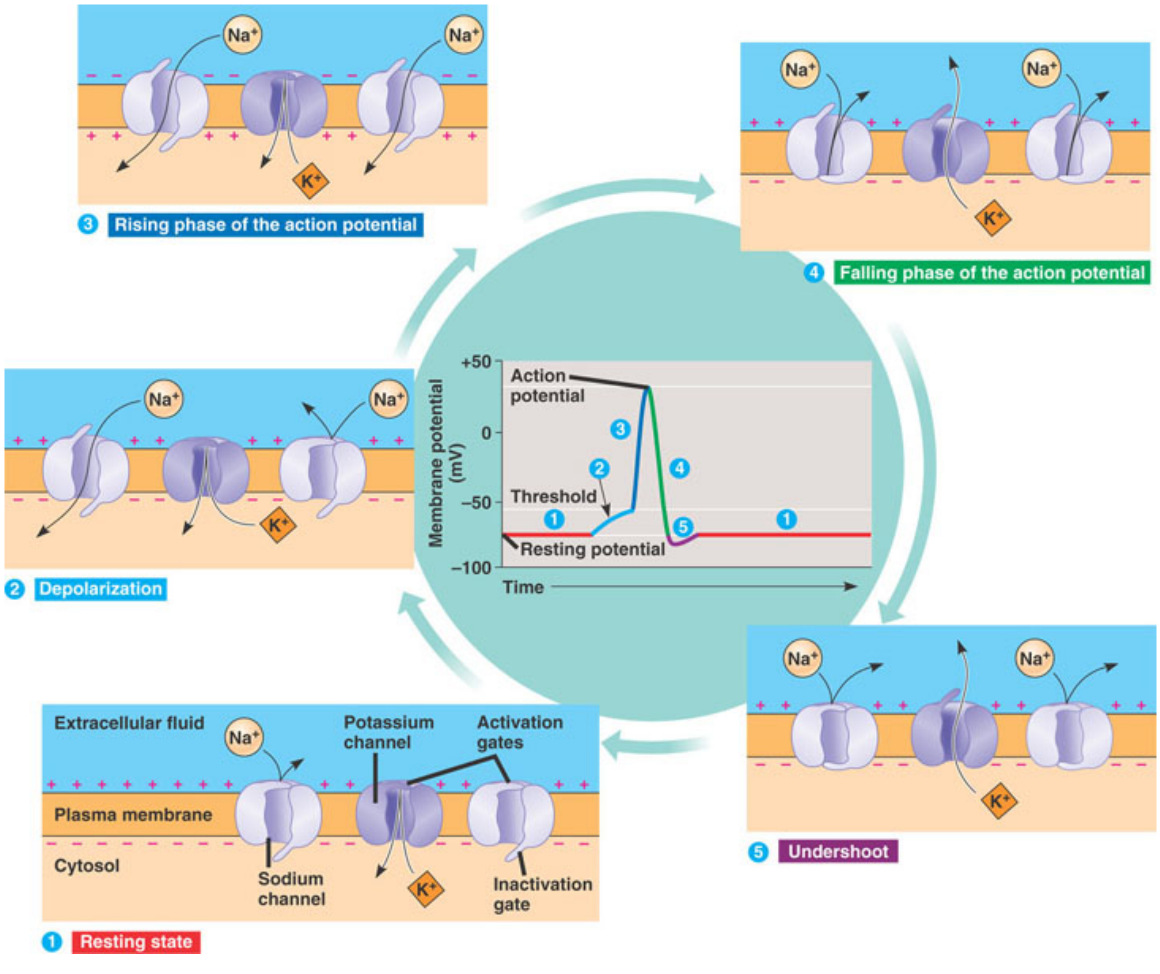



**Figure 1.21b (Action Potential)**

The action potential starts at the dendrite and quickly moves through the soma and down the axon towards the synaptic terminal. When the action potential reaches the synaptic terminal, it causes small vesicles containing **neurotransmitters** to fuse with the cell membrane of the neuron. This result is exocytosis of the neurotransmitters (if you can't remember what exocytosis is, look back to the week on cell membranes!). These neurotransmitters cross over a tiny distance (called the synaptic cleft) and fuse to receptors on another neuron (or muscle or gland). If it is a muscle at the end of the synaptic terminal, it will contract. If it is another neuron, it can cause an action potential in the next neuron. This is how two neurons communicate (Figure 1.22a)!

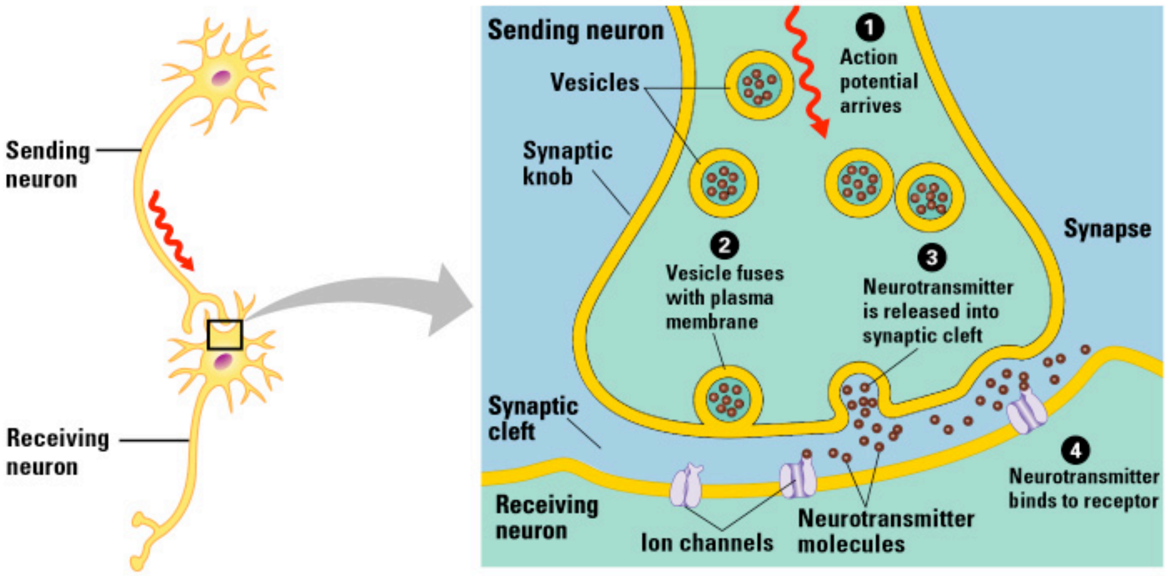
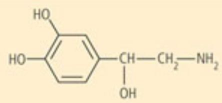
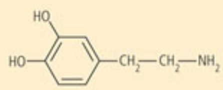
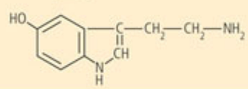



**Figure 1.22a**

There are more than 100 different neurotransmitters that have been indentified. Some of these neurons are excitatory in nature (in other words, they help cause action potentials in the next neuron) while others are inhibitory and therefore tend to inhibit the next neuron from firing. Some neurotransmitters are excitatory in one part of the part while they are inhibitory in other parts of the body. Synapses that result in excitatory actions are called EPSP's (Excitatory Post Synaptic Potentials). Synapses that result in inhibitory actions are called IPSP's (Inhibitory Post Synaptic Potentials). Make sure you know the following chart below related to different types of neurotransmitters (Table 1.1a)

**Table 1.1a – Examples of Neurotransmitters**

**Table 48.1 Major Neurotransmitters**

| Neurotransmitter | Structure | Functional Class | Secretion Sites |
|---|---|---|---|
| **Acetylcholine** | $H_3C—\overset{O}{\overset{\Vert}{C}}—O—CH_2—CH_2—N^+—[CH_3]_3$ | Excitatory to vertebrate skeletal muscles; excitatory or inhibitory at other sites | CNS; PNS; vertebrate neuromuscular junction |
| **Biogenic Amines** | | | |
| Norepinephrine |  | Excitatory or inhibitory | CNS; PNS |
| Dopamine |  | Generally excitatory; may be inhibitory at some sites | CNS; PNS |
| Serotonin |  | Generally inhibitory | CNS |
| **Amino Acids** | | | |
| GABA (gamma aminobutyric acid) | $H_2N—CH_2—CH_2—CH_2—COOH$ | Inhibitory | CNS; invertebrate neuromuscular junction |
| Glycine | $H_2N—CH_2—COOH$ | Inhibitory | CNS |
| Glutamate | $H_2N—\underset{COOH}{CH}—CH_2—CH_2—COOH$ | Excitatory | CNS; invertebrate neuromuscular junction |
| Aspartate | $H_2N—\underset{COOH}{CH}—CH_2—COOH$ | Excitatory | CNS |
| **Neuropeptides** (a very diverse group, only two of which are shown) | | | |
| Substance P | Arg—Pro—Lys—Pro—Gln—Gln—Phe—Phe—Gly—Leu—Met | Excitatory | CNS; PNS |
| Met-enkephalin (an endorphin) | Tyr—Gly—Gly—Phe—Met | Generally inhibitory | CNS |

Now on to the brain. Although there are other cells that make up the nervous system, these neurons are where most of the action occurs. Your brain (and spinal cord) are basically made up of billions of neurons. Again, there are other cells that hold these neurons together and help clean them and such, but the neurons are by the far the most important. Everything you see, hear, smell, touch and feel is coded by sequences of neurons that are either turned on (action potentials) or off (remaining at the resting potential state). In fact, every memory you have and everything you have learned is also mysteriously stored in combinations of neurons that you are somehow able to turn on (generate action potentials in) or turnoff (resting potentials).

**Brain Structure:**

Below is a picture of the human brain. It is primarily made up of many, many neurons. The neurons in certain regions are important for certain functions. Below the picture is a list of the functions of the regions I want you to learn (if you can get your brain to do that!) (Figure 1.23a):

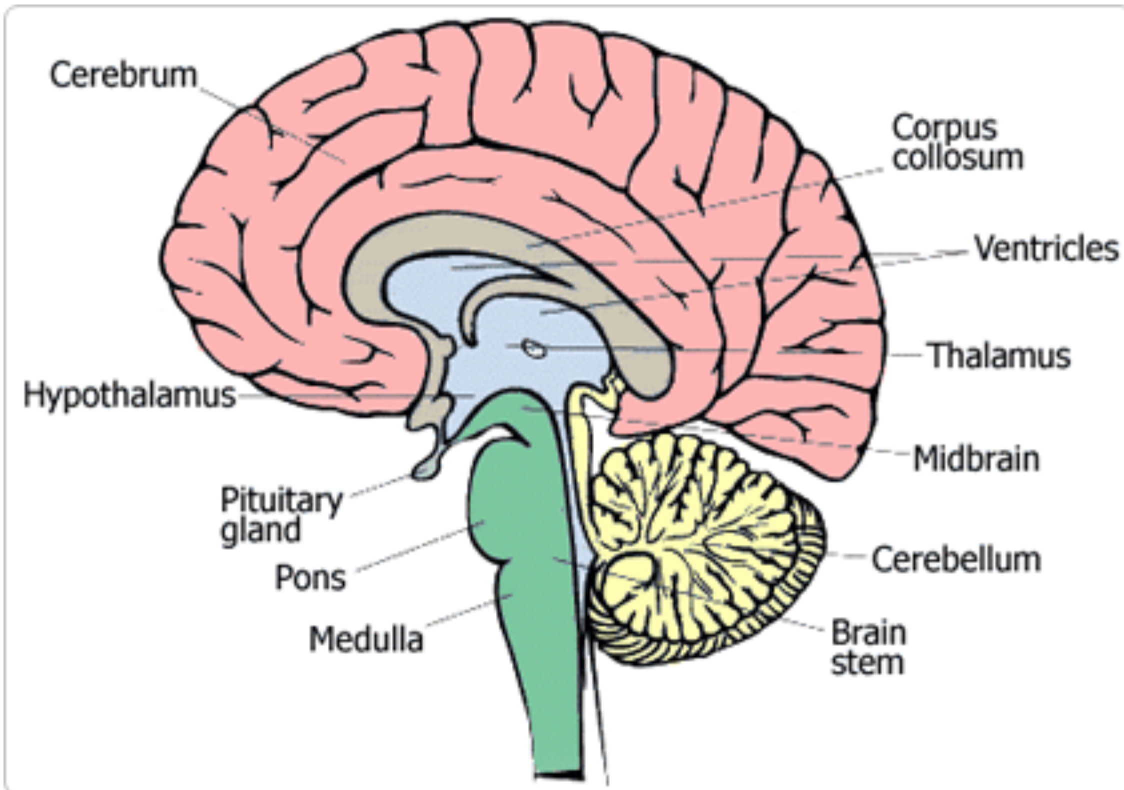



**Figure 1.23a**

*Cerebrum* – The cerebrum is the largest part of the human brain. It is important for all of your cognitive functions such as thinking, your ability to speak languages, art, and math and analytical skills.

*Thalamus* – You can think of the thalamus as a kind of filter. The neurons in this region are important for filtering out both important sensory and motor relays. For example, you are constantly being bombarded with sensory information from your skin. Your clothes are touching your skin, wind is blowing through your hair, etc. That information first goes to your thalamus where it is stopped and prevented from continuing on to your cerebrum (so that you are unaware of it).

*Hypothalamus* – The hypothalamus controls many of our emotional states such as anger, fear, and our sex drive. It connects to a special gland called the pituitary gland which is major component of the endocrine system (which we talk about next week).

*Pons* – the pons is located between the midbrain and the medulla oblongata and is important in controlling involuntary breathing.

*Medulla oblongata* – This very important region of the brain controls many of our automatic functions such as heart rate, blood pressure, respiration (in conjunction with the pons) and digestive activities.

*Cerebellum* – The cerebellum is located in the back part of the brain. It is important for coordinating body movements. This is seen most in people that perform martial arts and dancing and other situations that require complex and coordinated body movements.

We could go on and on and ON about the nervous system and the brain. We will stop there, however, because there are so many other things to do.

## Endocrine

The endocrine system, like the nervous system, is important for maintaining homeostasis. When it gets hot outside, your body can sense the heat and it responds by sweating to cool itself down. The nervous system works very quickly (almost instantaneously!) The endocrine system on the other hand generally works much, much slower. Think of it this way…let's say your house is on fire. What do you do? Hopefully you pick up the phone and call the fire department. That would be an appropriate response for the nervous system. The endocrine system on the other hand would respond by sitting down and writing a letter to the fire department "dear fire department…" In this example, you would not want the endocrine system in charge. But there are other examples when you would. First, let's look at the basic components of the endocrine system.

Certain organs and certain cells in your body secrete important molecules called hormones. Hormones are chemicals that are secreted by one group of cells that travel in the blood stream and target other cells. These cells then respond by doing something (some secrete other hormones) (Figure 1.24a).

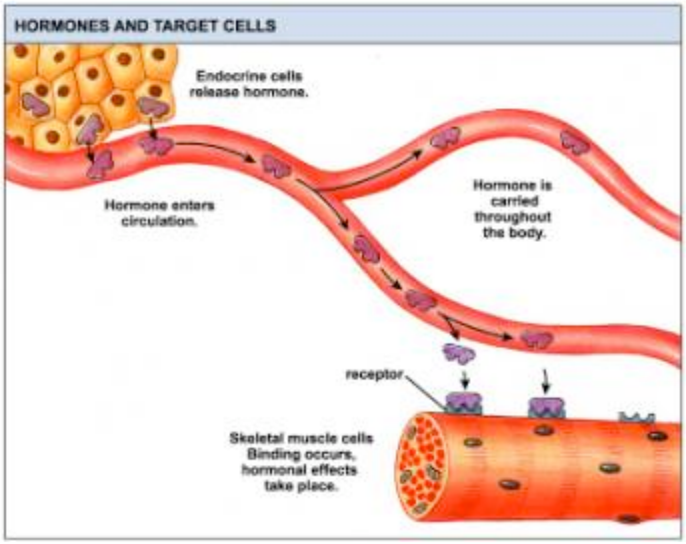



**Figure 1.24a**

There are many endocrine glands and organs in the body that secrete various chemicals. Let's start with the tiny little gland called the pituitary gland. Don't be fooled; even though it is small it does a whole bunch of stuff. The pituitary gland sits just below the hypothalamus. The pituitary gland can be divided into two regions: the anterior and posterior pituitary gland. Below is a picture (Figure 1.25a) of the pituitary gland and the hormones it secretes; below the picture I have added a table of the hormones and their basic functions. I purposely left one or two out (you do not need to know the ones I left out!) (Table 1.2a)

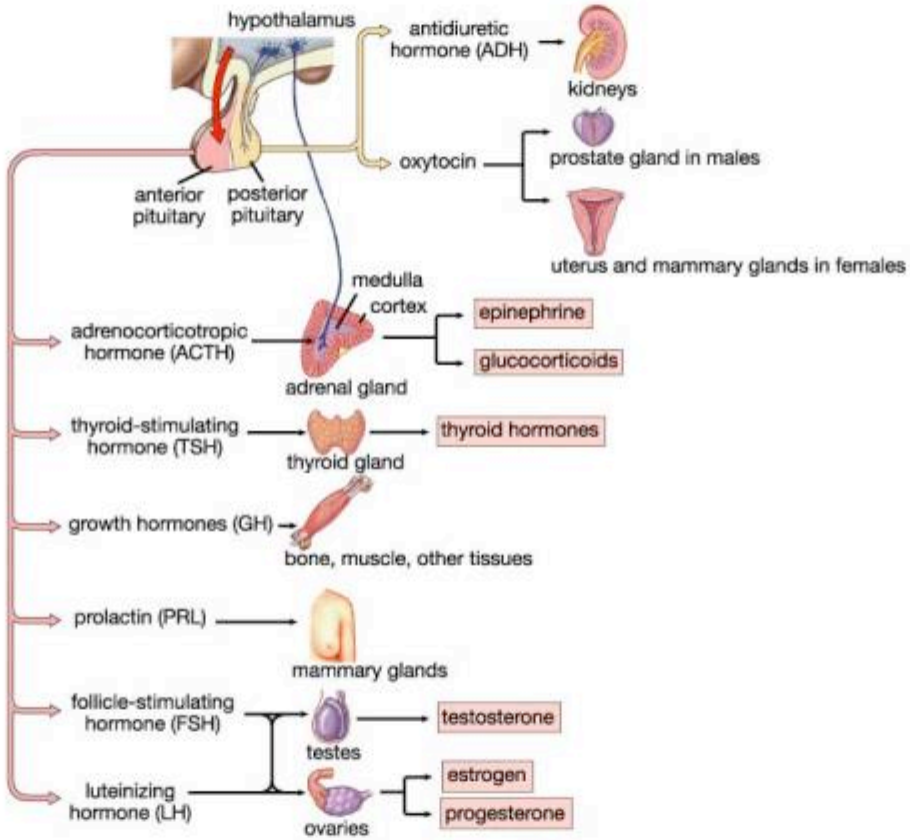

hypothalamus
antidiuretic hormone (ADH)
kidneys
oxytocin
prostate gland in males
uterus and mammary glands in females
anterior pituitary
posterior pituitary
medulla
cortex
adrenocorticotropic hormone (ACTH)
epinephrine
glucocorticoids
adrenal gland
thyroid-stimulating hormone (TSH)
thyroid hormones
thyroid gland
growth hormones (GH)
bone, muscle, other tissues
prolactin (PRL)
mammary glands
follicle-stimulating hormone (FSH)
testosterone
testes
luteinizing hormone (LH)
estrogen
progesterone
ovaries

**Figure 1.25a**

**Table 1.2a**

| Region | Hormone | Target/Function |
|---|---|---|
| Posterior | Antidiuretic Horomone (ADH) | Targets the collecting ducts in the kidneys. Causes you to retain water |
| | Oxytocin | Females – smooth muscle contraction in the uterus during childbirth<br>Males – Increases contractions in prostate |
| Anterior | Follicle Stimulating Hormone (FSH) | Males-promotes sperm development<br>Females-promotes egg development and stimulates ovary to release estrogen |
| | Thyroid Stimulating Hormone (TSH) | Causes the thyroid gland to release a hormone called "Thyroid hormone" |
| | Growth-Hormone (GH) | Targets most cells in the body and causes them grow and divide |
| | Prolactin (PRL) | Females – stimulates development of the mammary glands and their production of milk.<br>Males – no major function |
| | Luteinizing Hormone (LH) | Female- causes ovulation; stimulates ovaries to produce estrogen and progesterone.<br>Male- stimulates testes to produce testosterone. |

In addition to the pituitary gland there are several other glands that are important parts of the endocrine system (Figure 1.26a). We will learn just a few of them. They are the thyroid gland, the pineal gland, the pancreas the testes and the ovaries.

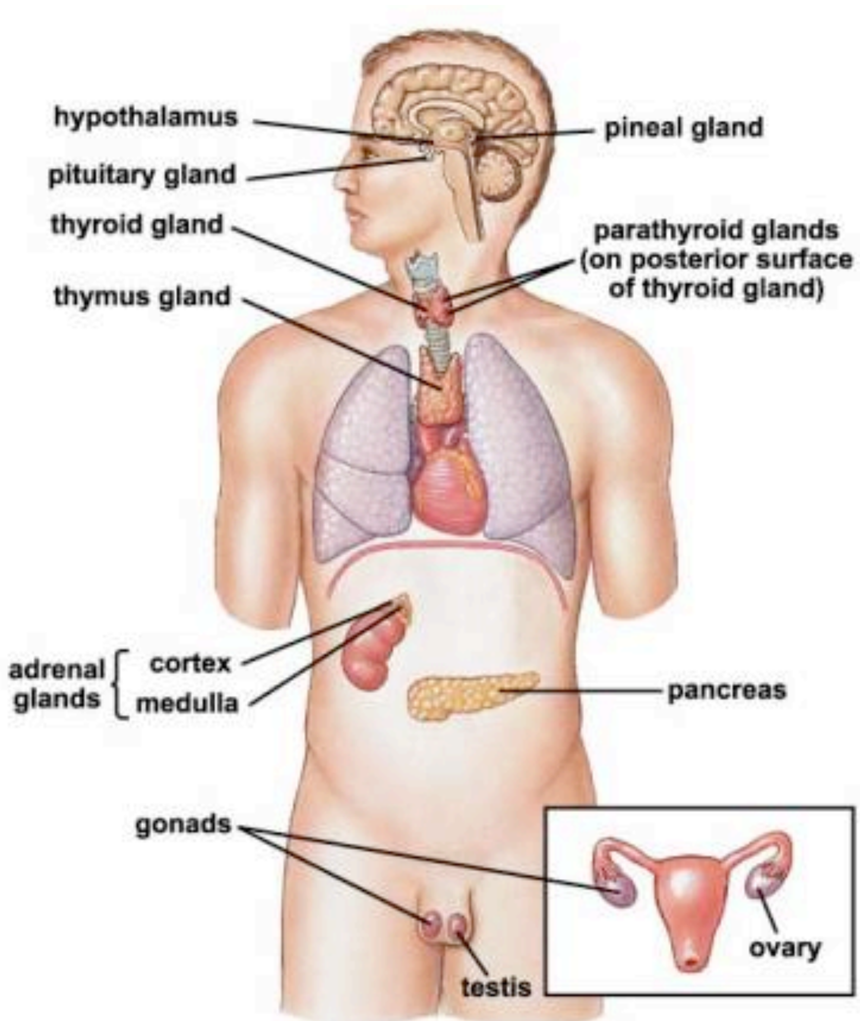



**Figure 1.26a**

The pineal gland is located near the center of the brain. It secretes a hormone called melatonin. Melatonin is a hormone that is important for regulating a persons sleep cycle. Your body normally gets used to secreting a particular amount of melatonin on a regular cycle. You may have heard of or have experienced the feeling of "jet lag". Jet lag occurs because it takes several days for your body to adjust to the new time of day in terms of knowing when to secrete high levels of melatonin to make you sleepy.

The thyroid gland sits on top of your trachea near in your throat region. The thyroid gland secretes Thyroid hormone when it is stimulated by Thryoid Stimulating Hormone (released by the Anterior Pituitary Gland). Thyroid Hormone targets nearly every cell in the body and causes an increase in metabolism. Therefore, high levels of Thyroid Hormone causes a person to burn more energy.

The Pancreas is a very important organ in the body for both digestion and endocrine function.  The Pancreas is located near the first part of your small intestines.  The pancreas secretes two important hormones.  First, insulin is secreted when your blood sugar is too high.  Insulin causes an uptake of glucose from the blood and causes your body to either use the glucose for cellular respiration or to store it as glycogen.  Second, the pancreas also secretes the hormone called glucagon.  When your blood sugar is too low, the secretion of glucagon causes your cells to stop using up glucose and to start breaking down excess glycogen into glucose.  Insulin and glucagon work together to help maintain the homeostasis of blood sugar.

The next two endocrine organs I want you to know are the testes and the ovary.  The testes primarily secrete testosterone and the ovaries primarily secrete estrogen and progesterone.  These hormones have very large effects on an animals behavior and we will discuss some examples of these in class.

We will also talk more about the nervous system, brain functions and endocrine system in class as well.   Make sure you are very familiar with this reading assignment BEFORE class!