Summaries of Human Systems

“SLIC MEN R RED”

Skeletal
Lymphatic
*Immune
Circulatory
Muscular
*Endocrine
*Nervous
Respiratory
Reproductive
*Excretory
Digestive

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(Source of the “SLIC MEN R RED” mnemonic device is Michael J. Lazaroff)
Nervous System

The nervous system consists of two types of cells. Nerve cells are called neurons. Various support cells are associated with the neurons, most typically, Schwann cells. The parts of a neuron include the dendrite which receives the impulse (from another nerve cell or from a sensory organ), the cell body (numbers of which side-by-side form gray matter) where the nucleus is found, and the axon which carries the impulse away from the cell. Wrapped around the axon are the Schwann cells, and the spaces/junctions between Schwann cells are called nodes of Ranvier. Collectively, the Schwann cells make up the myelin sheath (numbers of which side-by-side form white matter).

Schwann cells wrap around the axon (like the camp food, “pigs in a blanket”). Having an intact myelin sheath and nodes of Ranvier are critical to proper travel of the nerve impulse. Diseases which destroy the myelin sheath (demyelinating disorders) can cause paralysis or other problems. Schwann cells are analogous to the insulation on electrical wires, and just as electrical wires short out if there’s a problem with the insulation, so also, neurons cannot function properly without intact myelin sheaths.

The nervous system has three basic functions:

1. **sensory neurons** receive information from the sensory receptors,
2. **interneurons** transfer and interpret impulses, and
3. **motor neurons** send appropriate impulses/instructions to the muscles and glands.

A nerve impulse is an electrical charge that travels down the cell membrane of a neuron’s dendrite and/or axon through the action of the Na-K pump. Ordinarily, the inside of a neuron’s cell membrane is negatively-charged while the outside is positively-charged. When sodium and potassium ions change places, this reverses the inner and outer charges causing the nerve impulse to travel down the membrane. A nerve impulse is “all-or-none:” it either goes or not, and there’s no halfway. However, a neuron needs a **threshold stimulus**, the minimum level of stimulus needed, to trigger the Na-K pump to go and the impulse to travel. A neuron cannot immediately fire again; it needs time for the sodium and potassium to return to their places and everything to return to normal. This time is called the **refractory period**.
A junction between two nerve cells or a nerve and a muscle cell is called a **synapse**. In a synapse, various chemicals are used to transfer the impulse across the gap to the next cell. These are collectively known as **neurotransmitters**, and include such chemicals as dopamine (brain levels of which are low in Parkinson’s disease), serotonin, and acetylcholine (levels of which are low in myasthenia gravis).

The nervous system can be subdivided several ways depending on if one is looking at function or location:

<table>
<thead>
<tr>
<th>In terms of function,</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Somatic NS</strong></td>
<td><strong>Autonomic NS</strong></td>
</tr>
<tr>
<td>voluntary muscles and reflexes</td>
<td>visceral/smooth and cardiac muscle</td>
</tr>
<tr>
<td></td>
<td>Sympathetic NS</td>
</tr>
<tr>
<td></td>
<td>Parasympathetic NS</td>
</tr>
<tr>
<td></td>
<td>increases energy expenditure</td>
</tr>
<tr>
<td></td>
<td>prepares for action</td>
</tr>
<tr>
<td></td>
<td>decreases energy expenditure</td>
</tr>
<tr>
<td></td>
<td>gains stored energy</td>
</tr>
<tr>
<td>These have the opposite effects on the same organs</td>
<td></td>
</tr>
</tbody>
</table>

---OR---

<table>
<thead>
<tr>
<th>In terms of location,</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Peripheral NS</strong></td>
<td><strong>Central NS (CNS)</strong></td>
</tr>
<tr>
<td>sensory and motor neurons</td>
<td>interneurons: brain and spine</td>
</tr>
<tr>
<td>covered with three membranes, the meninges</td>
<td></td>
</tr>
<tr>
<td>inflammation of these is called meningitis</td>
<td></td>
</tr>
<tr>
<td>brain has gray matter on outside and white in center</td>
<td></td>
</tr>
<tr>
<td>spine has white matter on outside and gray in center</td>
<td></td>
</tr>
</tbody>
</table>

Most body organs/systems are enervated by both sympathetic and parasympathetic nerves, and these have opposite effects on the various organs. For example, the sympathetic NS prepares for action by increasing heart and respiration rates by telling the liver to release stored glycogen as sugar, and by decreasing digestive processes. Conversely, the parasympathetic NS stores energy by slowing heart and respiration rates, by telling the liver to store up sugar as glycogen, and by increasing digestive processes.

A light-sensitive organ that we are only beginning to understand is the **pineal gland**. This organ manufactures melatonin in response to darkness, thus the shorter the day (like in winter) the more melatonin is secreted. In many animals, the pineal gland is located just under the skin somewhere on the head, and is directly stimulated by light. Some lizards even have a third eye! In humans, the pineal gland is inside the skull and it is thought that it receives its stimuli from nerves from the eyes. Some people make too much melatonin in the winter, making them sleepy and/or depressed. This is called **seasonal affective disorder** (SAD) and is treated by having the person spend a certain number of hours each day in front of bright lights. There is also a drop in melatonin production at puberty, and it is thought that these may be related. Studies have been done on blind girls (with a form of blindness in which no impulses can travel down the optic nerve and reach the brain and pineal gland), which showed that these girls tended to have higher levels of melatonin for a longer time, resulting in a delay in the onset of puberty.
Endocrine System

The nervous system sends electrical messages to control and coordinate the body. The endocrine system has a similar job, but uses chemicals to “communicate”. These chemicals are known as **hormones**. A hormone is a specific messenger molecule synthesized and secreted by a group of specialized cells called an **endocrine gland**. These glands are **ductless**, which means that their secretions (hormones) are released directly into the bloodstream and travel to elsewhere in the body to **target organs**, upon which they act. Note that this is in contrast to our digestive glands, which have ducts for releasing the digestive enzymes.

**Pheromones** are also communication chemicals, but are used to send signals to other members of the same species. Queen bees, ants, and naked mole rats exert control of their respective colonies via pheromones. One common use for pheromones is as attractants in mating. Pheromones are widely studied in insects and are the basis for some kinds of Japanese beetle and gypsy moth traps. While pheromones have not been so widely studied in humans, some interesting studies have been done in recent years on pheromonal control of menstrual cycles in women. It has been found that pheromones in male sweat and/or sweat from another “dominant” female will both influence/regulate the cycles of women when smeared on their upper lip, just below the nose. Also, there is evidence that continued reception of a given man’s pheromone(s) by a woman in the weeks just after ovulation/fertilization can significantly increase the chances of successful implantation of the new baby in her uterus. Pheromones are also used for things like territorial markers (urine) and alarm signals.

Each hormone’s shape is specific and can be recognized by the corresponding target cells. The binding sites on the target cells are called **hormone receptors**. Many hormones come in antagonistic pairs that have opposite effects on the target organs. For example, **insulin** and **glucagon** have opposite effects on the liver’s control of blood sugar level. Insulin lowers the blood sugar level by instructing the liver to take glucose out of circulation and store it, while glucagon instructs the liver to release some of its stored supply to raise the blood sugar level. Much hormonal regulation depends on **feedback loops** to maintain balance and homeostasis.

There are three general classes (groups) of hormones. These are classified by chemical structure, not function.

- **steroid hormones** including **prostaglandins** which function especially in a variety of female functions (aspirin inhibits synthesis of prostaglandins, some of which cause “cramps”) and the sex hormones all of which are lipids made from cholesterol,
- **amino acid derivatives** (like epinephrine) which are derived from amino acids, especially tyrosine, and
- **peptide hormones** (like insulin) which is the most numerous/diverse group of hormones.
The major human endocrine glands include:

1. the **hypothalamus** and **pituitary gland**
   The pituitary gland is called the “master gland” but it is under the control of the hypothalamus. Together, they control many other endocrine functions. They secrete a number of hormones, especially several which are important to the female menstrual cycle, pregnancy, birth, and lactation (milk production). These include **follicle-stimulating hormone (FSH)**, which stimulates development and maturation of a follicle in one of a woman’s ovaries, and **leutinizing hormone (LH)**, which causes the bursting of that follicle (= ovulation) and the formation of a **corpus luteum** from the remains of the follicle. There are a number of other hypothalamus and pituitary hormones which affect various target organs. One non-sex hormone secreted by the posterior pituitary is **antidiuretic hormone** or ADH. This hormone helps prevent excess water excretion by the kidneys. Ethanol inhibits the release of ADH and can, thus, cause excessive water loss. That’s also part of the reason why a group of college students who go out for pizza and a pitcher of beer need to make frequent trips to the restrooms. **Diuretics** are chemicals which interfere with the production of or action of ADH so the kidneys secrete more water. Thus diuretics are often prescribed for people with high blood pressure, in an attempt to decrease blood volume.

   Another group of non-sex hormones that many people have heard of is the **endorphins**, which belong to the category of chemicals known as **opiates** and serve to deaden our pain receptors. Endorphins, which are chemically related to morphine, are produced in response to pain. The natural response to rub an injured area, such as a pinched finger, helps to release endorphins in that area. People who exercise a lot and push their bodies “until it hurts” thereby stimulate the production of endorphins. It is thought that some people who constantly over-exercise and push themselves too much may actually be addicted to their own endorphins which that severe exercise regime releases.

2. the **thyroid gland**
   Thyroid hormones regulate metabolism, therefore body temperature and weight. The thyroid hormones contain iodine, which the thyroid needs in order to manufacture these hormones. If a person lacks iodine in his/her diet, the thyroid cannot make the hormones, causing a deficiency. In response to the body’s feedback loops calling for more thyroid hormones, the thyroid gland then enlarges to attempt to compensate (The body’s plan here is if it’s bigger it can make more, but that doesn’t help if there isn’t enough iodine.). This disorder is called **goiter**. Dietary sources of iodine include any “ocean foods” because ocean-dwelling organisms tend to accumulate iodine from the seawater, and would include foods like ocean fish (tuna) and seaweeds like kelp. Because of this, people who live near the ocean do not have as much of a problem with goiter as people who live inland and don’t have access to these foods. To help alleviate this problem in our country, our government began a program encouraging salt refiners to add iodine to salt, and encouraging people to choose to consume this **iodized salt**.
3. the pancreas
This organ has two functions. It serves as a ducted gland, secreting digestive enzymes into the small intestine. The pancreas also serves as a ductless gland in that the islets of Langerhans secrete insulin and glucagon to regulate the blood sugar level. The islet cells secrete glucagon, which tells the liver to take carbohydrate out of storage to raise a low blood sugar level. The islet cells secrete insulin to tell the liver to take excess glucose out of circulation to lower a blood sugar level that’s too high. If a person’s body does not make enough insulin (and/or there is a reduced response of the target cells in the liver), the blood sugar rises, perhaps out of control, and we say that the person has diabetes mellitus.

4. the adrenal glands
These sit on top of the kidneys. They consist of two parts, the outer cortex and the inner medulla. The medulla secretes epinephrine (= adrenaline) and other similar hormones in response to stressors such as fright, anger, caffeine, or low blood sugar. The cortex secretes corticosteroids such as cortisone. Corticosteroids are well-known as being anti-inflammatory, thus are prescribed for a number of conditions. However, these are powerful regulators that should be used with caution. Medicinal doses are typically higher than what your body would produce naturally, thus the person’s normal feedback loops suppress natural secretion, and it is necessary to gradually taper off the dosage to trigger the adrenal glands to begin producing on their own again. Because the corticosteroids suppress the immune system, their use can lead to increased susceptibility to infections.

5. the gonads or sex organs
In addition to producing gametes, the female ovaries and male testes (singular = testis) also secrete hormones. Therefore, these hormones are called sex hormones. The secretion of sex hormones by the gonads is controlled by pituitary gland hormones such as FSH and LH. While both sexes make some of each of the hormones, typically male testes secrete primarily androgens including testosterone. Female ovaries make estrogen and progesterone in varying amounts depending on where in her cycle a woman is. In a pregnant woman, the baby’s placenta also secretes hormones to maintain the pregnancy.

6. the pineal gland
This gland is located near the center of the brain in humans, and is stimulated by nerves from the eyes. In some other animals, the pineal gland is closer to the skin and directly stimulated by light (some lizards even have a third eye). The pineal gland secreted melatonin at night when it’s dark, thus secretes more in winter when the nights are longer. Melatonin promotes sleep (makes you feel sleepy). In some animals, melatonin affects skin pigmentation. Because melatonin production is affected by the amount of light to which a person is exposed, this is tied to circadian rhythm (having an activity cycle of about 24 hours), annual cycles, and biological clock functions. SAD or seasonal affective disorder (syndrome) is a disorder in which too much melatonin is produced, especially during the long nights of winter, causing profound depression, oversleeping, weight gain, tiredness, and sadness. Treatment consists of exposure to bright lights for several hours each day to inhibit melatonin production.
Immune System

An animal’s immune system protects its body from intruders: bacteria, viruses, parasites, cancer cells, etc. An immune system is present in several animal groups, especially within the vertebrates. Animals have both non-specific and specific defense mechanisms to fight invaders. We will focus on the human immune system.

Non-specific defense mechanisms work against a wide variety of invaders. These defense mechanisms include the barrier formed by our skin; chemicals in perspiration, skin oil, saliva, tears, etc.; the hairs in our nostrils; the ciliary escalator (the cilia and mucus that clean out dust and debris from our lungs and trachea) in our respiratory tracts; the inflammatory response which is the dilation of blood vessels and accumulation of WBCs at the site of an injury (the signs of which are that the area is red, hot, and swollen); and fever, a raised body temperature to inhibit the growth of pathogens.

Specific defense mechanisms are effective against specific pathogens. This involves various WBCs called lymphocytes or leukocytes. There are several kinds of WBCs involved in the immune system, all of which originate in the bone marrow. Leukemia is a cancer of the bone marrow, thus it typically is treated by killing all of the person’s bone marrow. Unfortunately, this leaves the person with no immune system, so (s)he must be extremely careful during that time to avoid all possible pathogens. There are two main types of specific defense mechanisms involved in the immune system.

<table>
<thead>
<tr>
<th>The humoral immune system consists of B-cells which originate in the Bone marrow and stay there to develop.</th>
<th>The cell-mediated immune system consists of T-cells which originate in the bone marrow, but go to the Thymus to finish their development. The thymus is the major gland of our immune system. It is composed of two soft pinkish-gray lobes lying in a bib-like fashion just below the thyroid gland and above the heart. To a very large extent, the health of the thymus determines the health of the immune system. Individuals who get frequent infections or suffer from chronic infections typically have impaired thymus activity. Also, people affected with hayfever, allergies, migraine headaches, and rheumatoid arthritis may have altered thymus function.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-cells can produce antibodies, but need exposure to foreign antigens to do so. These antigens are cell surface oligosaccharides and proteins which the cell uses as “ID tags”. Antibodies are proteins in blood plasma and lymph to fight bacteria and viruses in body fluids. All daughter cells of a B-cell will be able to produce the same antibodies as the mother cell. Antibodies bind to certain parts of an antigen to mark it for destruction (by the T-cells).</td>
<td>T-cells are highly-specialized cells in the blood and lymph to fight bacteria, viruses, fungi, protozoans, cancer, etc. within host cells and react against foreign matter such as organ transplants. There are three kinds of T-cells. Cytotoxic T-cells directly kill invaders. Helper T-cells aid B and other T-cells to do their jobs, and HIV lives in and kills them. Suppressor T-cells suppress the activities of B- and other T-cells so they don’t overreact. Allergy injections are supposed to increase the number of suppressor T-cells to make the person less sensitive to allergens.</td>
</tr>
</tbody>
</table>
Immunity is the ability to “remember” foreign substance previously encountered and react again, promptly. There are two kinds of immunity: active immunity, when the body is stimulated to produce its own antibodies, and passive immunity, where the antibodies come from outside the person’s body. Active immunity is usually permanent, and can be induced due to actual illness or vaccination. Passive immunity is not permanent because the antibodies are introduced from outside the body, thus the B-cells never “learn” how to make them. An example of passive immunity includes antibodies passed across the placenta and in milk from a mother to her baby. The antibodies are proteins must be replaced if the immunity is to continue.

A vaccination is a weakened or inactive form of a pathogen given to enable the immune system to respond and produce immunity to it. The first vaccination was when Edward Jenner purposely gave people cowpox, a mild disease, because he had figured out that could prevent them from getting smallpox, a very serious disease.

AIDS stands for Acquired ImmunoDeficiency Syndrome. The Human Immunodeficiency Virus (HIV) virus, that is the cause of AIDS, lives in and kills helper T-cells. With fewer helper T-cells, the person’s immune system can’t form any new antibodies against any new invaders, thus people with AIDS usually die from some secondary infection or unusual form of cancer. The HIV virus is transmitted by direct blood-to-blood contact, such as in sexual contact where there is a tear in the tissue (more likely if anal tissue, not designed for this type of activity, is involved) or sharing the same needle to inject drugs intravenously (which usually also injects some of the first person’s blood into the second person’s arm. There have also been cases of young hemophiliac boys contracting HIV from blood transfusions and babies born with HIV (it can cross the placenta). The HIV virus is not spread via saliva nor skin contact. When a person has an AIDS test, what actually is being tested is the presence of anti-HIV antibodies that would indicate that the person has been exposed to the virus.

In an autoimmune response, the immune system turns against the “self”, developing antibodies against its own antigens and destroying its own cells. For example, in myasthenia gravis, antibodies block, alter, or destroy the receptors for acetylcholine at the neuromuscular synapse which prevents the muscle contraction from occurring. These antibodies are produced by the body's own immune system.

Interferon is a substance produced by virus-infected cells to “warn” neighboring cells thereby helping them to resist the virus.
In cancer cells, genetic changes cause changes in the cell-surface antigens such that the person’s immune system (hopefully) no longer recognizes them as “self” and destroys them. However, if the immune system is stressed and not functioning properly, a cancer cell may multiply before the immune system has a chance to kill it.

Allergy is an abnormal overreaction to a specific environmental antigen called an allergen. In an allergic reaction, antibodies bond to mast cells (instead of the antigens) which then produce histamine which attaches to other cells, such as those in the nose or skin, to cause an allergic reaction. An antihistamine is a chemical which competes with histamine for receptor sites on the nose/skin cells. Some people are concerned about this because the histamine is still present in the person’s body. More recently, mast cell inhibitors, such as cromolyn sodium (NasalCrom®), have been developed that stop the mast cells from even making histamine to begin with.
Humoral (antibody-mediated) immune response

- Antigen (1st exposure)
  - Engulfed by Macrophage (APC)
  - Stimulates Helper T cell
- Free antigens directly activate B cell
  - Stimulates Helper T cell
  - Gives rise to Memory helper T cell
    - Stimulates Plasma cells
      - Secrete Antibodies
        - Defend against extracellular pathogens by binding to antigens and making the pathogens easier targets for phagocytes and complement.
- Macrophage (APC) stimulates Helper T cell
  - Stimulates Cytotoxic T cell
  - Stimulates Memory T cells
  - Stimulates Active cytotoxic T cells

Cell-mediated immune response

- Antigens displayed by infected cells activate Cytotoxic T cell
  - Stimulates Memory T cells
  - Gives rise to Active cytotoxic T cells

- Helper T cell
  - Stimulates Memory B cells
  - Stimulates Memory T cells

- Memory helper T cell
  - Stimulates Antigen (2nd exposure)
- Memory B cells
  - Secrete Antibodies
- Memory T cells
  - Secrete Cytotoxic T cells

Defend against intracellular pathogens and cancer by binding to and lysing the infected cells or cancer cells.
Excretory/Urinary System

As animals perform their various metabolic processes, protein and nucleic acid, both of which contain nitrogen, are broken down. While some of the nitrogen is used to manufacture new nitrogen-containing molecules, much of it cannot be used for this purpose and must be disposed of as waste. Typically, the first nitrogen-containing molecule that forms is ammonia (NH₃, which is very water-soluble, forming NH₄OH, a strong base. In some way, this ammonia must be gotten rid of before it raises the pH of the body fluids. Because ammonia is so water-soluble, aquatic animals often can get rid of it just by diffusion into the surrounding water. That’s one reason why the water in an aquarium gets “bad” and needs to be changed, and why not changing the water could kill the fish. However, ammonia doesn’t readily go from body fluids into air, so terrestrial animals need other ways of getting rid of nitrogenous wastes.

The two most common substances used by terrestrial animals to get rid of excess nitrogen are urea and uric acid. Many animal species that aren’t terribly concerned about water-loss, including humans, convert the ammonia to urea, which is water-soluble and excreted in a water-based solution. Other organisms such as birds, insects, or lizards, especially if they live in an arid area, must conserve water whenever possible, thus convert the NH₃ to uric acid. Uric acid is not water-soluble, thus can be excreted with little, if any, water with it. This is the white goo in bird droppings. While the major portion of human nitrogenous waste is in the form of urea, humans typically excrete some uric acid, too.

Gout is a disorder in which humans start to accumulate more than the usual amount of uric acid (caused by either the body manufacturing excess uric acid or the kidneys not excreting enough of it) and since it’s not water-soluble, it gets stored in the body, frequently in toe joints, causing pain and deformation of the joints involved as well as the formation of kidney stones.

Some insects, notably blowfly larvae (larvae of those shiny green or blue flies) excrete their nitrogenous wastes as allantoin. Allantoin is known to be a “cell-proliferant,” thus is used to help wounds to heal. For hundreds of years, people have recognized that the presence of blowfly larvae in a gangrenous wound actually helped it to heal better. From about the turn of the century until the invention of a lot of synthetic drugs, blowfly larvae were raised aseptically, and used to treat severe wounds. It has been found that the fly larvae only eat dead, gangrenous tissue, leaving the live, healthy tissue, and since their nitrogenous waste is allantoin, that stimulates the wound to heal, usually with less scaring. In this procedure, small, sterile larvae are introduced into the wound and, if needed, traded for other small ones when they get big.
The Kidney and the Nephron

We excrete nitrogenous wastes via our kidneys. Our kidneys are located on either side of the spine, just up under the bottom ribs. They are well supplied with blood via the renal artery and renal vein. Urine made in the kidney collects in the renal pelvis within the kidney, then flows down the ureter to the bladder where it is stored until voided. From the bladder, the urine flows to the outside via the urethra, (which in the male also serves as part of the reproductive tract).

The kidney is composed of an outer layer, the cortex, and an inner core, the medulla. The kidney consists of repeating units (tubules) called nephrons. The “tops” of the nephrons make up or are in the cortex, while their long tubule portions make up the medulla. To the right is a diagram of an individual nephron. Each nephron has a closely associated blood supply. Blood comes in at the glomerulus and transfers water and solutes to the nephron at Bowman’s capsule. In the proximal tubule, water and some “good” molecules are absorbed back into the body, while a few other, unwanted molecules/ions are added to the urine. Then, the filtrate goes down the loop of Henle (in the medulla) where more water is removed (back into the bloodstream) on the way “down”, but the “up” side is impervious to water. Some NaCl (salt) is removed from the filtrate at this point to adjust the amount in the fluid which surrounds the tubule. Capillaries wind around and exchange materials with the tubule. In the distal tubule, more water and some “good” solutes are removed from the urine, while some more unwanted molecules are put in. From there, the urine flows down a collecting duct which gathers urine from several nephrons. As the collecting duct goes back through the medulla, more water is removed from the urine. The collecting ducts eventually end up at the renal pelvis which collects the urine from all of them. The area where the collecting ducts enter the renal pelvis is a common area for formation of kidney stones, often giving them a “staghorn” shape.

Antidiuretic hormone (ADH) from the pituitary is one factor influencing urine production. ADH promotes water retention by the kidneys, and its secretion is regulated by a negative feedback loop involving blood water and salt balances. ADH helps the kidney tubules reabsorb water to concentrate the urine. When the blood water level is too high (when you’ve been drinking a lot of liquids), this acts as a negative feedback to inhibit the secretion of ADH so more water is released. Ethanol also inhibits secretion of ADH, so a person who consumes a lot of alcoholic beverages could excrete too much water (and maybe even become dehydrated). Many diuretics work by interfering with ADH production, thus increasing the volume of urine produced. These diuretic effects are one reason why a person drinking beer (alcohol) or coffee (caffeine) needs to urinate more frequently.

When a person’s kidneys cease functioning, due to illness or other causes, renal dialysis can be used on a short-term basis to filter the person’s blood. This is not a perfect process; it can’t do everything a person’s kidneys can. Typically a person is put on renal dialysis as a temporary measure to extend the person’s life until a kidney transplant can be found.
Diseases and disorders of the excretory system include:

- **Nephritis** is an inflammation of the glomeruli, due to a number of possible causes, including things like strep throat. Symptoms include bloody urine, scant urine output, and edema (swelling/puffiness). Another, more severe form, is due to an autoimmune attack on the glomeruli. Other types of nephritis affect the tubules.

- **Nephrosis** also affects the glomeruli, and is characterized by excretion of abnormally large amounts of protein (often causing “foamy” urine) and generalized edema (water retention/swelling) throughout the whole body, especially noted as “puffy” eyelids. Because these people’s kidneys often do not handle sodium properly, a low-salt diet is usually prescribed.

- **Most urinary tract infections** (UTIs) are caused by Gram negative bacteria such as *E. coli*.

- There are a variety of types of **kidney stones** depending on what conditions caused their formation. Often, as the stone is passed down the ureter, the person experiences much pain, and the affected kidney may even temporarily become nonfunctional. Stones may be broken up by ultrasound so they can be passed more easily, but large stones may have to be surgically removed. Calcium stones might be caused by anything from a parathyroid gland problem to too much vitamin D to some forms of cancer to a genetic predisposition.
From Blood Filtrate to Urine: A Closer Look

In this section we concentrate on how the filtrate becomes urine as it flows through the mammalian nephron and collecting duct. The circled numbers correspond to the numbers in FIGURE 44.22, page 946.

Fig 44-22. The nephron and collecting duct: regional functions of the transport epithelium. The numbered regions in this diagram are keyed to the circled numbers in the text discussion of kidney function.

1 **Proximal tubule.** One of the most important functions of the proximal tubule is reabsorption of most of the NaCl (salt) and water from the huge initial filtrate volume. Salt in the filtrate diffuses into the cells of the transport epithelium, and the membranes of the cells actively transport Na\(^+\) into the interstitial fluid. This transfer of positive charge is balanced by the passive transport of Cl\(^-\) out of the tubule. As salt moves from the filtrate to the interstitial fluid, water follows by osmosis. The exterior side of the epithelium has a much smaller surface area than the side facing the lumen, which minimizes leakage of salt and water back into the tubule. Instead, the salt and water now diffuse from the interstitial fluid into the peritubular capillaries.

2 **Descending limb of the loop of Henle.** Reabsorption of water continues as the filtrate moves into the descending limb of the loop of Henle. Here the transport epithelium is freely permeable to water but not very permeable to salt and other small solutes. Filtrate moving downward from the cortex to the medulla within the descending limb of the loop of Henle continues to lose water to interstitial fluid of greater and greater osmolarity. As water departs by osmosis, the solute concentration of the filtrate increases.

3 **Ascending limb of the loop of Henle.** In contrast to the descending limb, the transport epithelium of the ascending limb is permeable to salt but not to water. The ascending limb actually has two specialized regions: a thin segment near the loop tip and a thick segment adjacent to the distal tubule. As filtrate ascends in the thin segment, NaCl, which became concentrated in the descending limb, diffuses out of the permeable tubule into the interstitial fluid. This movement of salt adds to the high osmolarity of the interstitial fluid in the medulla. The exodus of salt from the filtrate continues in the thick segment of the ascending limb, but here the epithelium actively transports NaCl into the interstitial fluid. By losing salt without giving up water, the filtrate becomes progressively more dilute as it moves up to the cortex in the ascending limb of the loop.

4 **Distal tubule.** The distal tubule is another important site of secretion and reabsorption. It plays a key role in regulating the K\(^+\) and NaCl concentration of body fluids by varying the amount of the K\(^+\) that is secreted into the filtrate and the amount of NaCl reabsorbed from the filtrate. Like the proximal tubule, the distal tubule also contributes to pH regulation, by the controlled secretion of H\(^+\) and reabsorption of bicarbonate (HCO\(_3^-\)).

5 **Collecting duct.** The collecting duct carries the filtrate through the medulla to the renal pelvis which is drained by the ureter.
Diverse excretory systems are variations on a tubular theme

Non-human excretory systems:

- Flatworms have an excretory system called **protonephridia**, consisting of a branching network of dead-end tubules.
  - These are capped by a flame bulb with a tuft of cilia that draws water and solutes from the interstitial fluid, through the flame bulb, and into the tubule system.
- The urine in the tubules exits through openings called nephridiopores.
  - Excreted urine is very dilute in freshwater flatworms.
  - Apparently, the tubules reabsorb most solutes before the urine exits the body.
  - In these freshwater flatworms, the major function of the flame-bulb system is osmoregulation, while most metabolic wastes diffuse across the body surface or are excreted into the gastrovascular cavity.
  - However, in some parasitic flatworms, protonephridia mainly dispose of nitrogenous wastes.
  - Protonephridia are also found in rotifers, some annelids, larval mollusks, and lancelets.
- **Metanephridium**, another tubular excretory system, consists of internal openings that collect body fluids from the coelom through a ciliated funnel, the nephrostome, and release the fluid through the nephridiopore.
  - Found in most annelids, each segment of a worm has a pair of metanephridia.
- An earthworm’s metanephridia have both excretory and osmoregulatory functions.
  - As urine moves along the tubule, the transport epithelium bordering the lumen reabsorbs most solutes and returns them to the blood in the capillaries.
  - Nitrogenous wastes remain in the tubule and are dumped outside.
  - Because earthworms experience a net uptake of water from damp soil, their metanephridia balances water influx by producing dilute urine.
- Insects and other terrestrial arthropods have organs called **Malpighian tubules** that remove nitrogenous wastes and also function in osmoregulation.
  - These open into the digestive system and dead-end at tips that are immersed in the hemolymph.
- The transport epithelium lining the tubules secretes certain solutes, including nitrogenous wastes, from the hemolymph into the lumen of the tubule.
  - Water follows the solutes into the tubule by osmosis, and the fluid then passes back to the rectum, where most of the solutes are pumped back into the hemolymph.
  - Water again follows the solutes, and the nitrogenous wastes, primarily insoluble uric acid, are eliminated along with the feces.
  - This system is highly effective in conserving water and is one of several key adaptations contributing to the tremendous success of insects on land.
Reproductive System

Animals’ reproductive systems can be divided into the internal reproductive organs and the external genitalia. The **gonads** are the actual organs that produce the **gametes**. In the male, **testes** (singular = testis) produce sperm, and in the female, **ovaries** make eggs.

In most animals, individuals are either definite males or definite females. However, in some species, individual organisms are both male and female. **Hermaphroditism** is when one organism has both sexes. Earthworms and garden snails always have both male and female organs, and when, for example, two earthworms mate, they fertilize each other. A special variation on the theme is **sequential hermaphroditism**, in which an organism changes sex during its life. If an organism is female first and later changes to male, that organism is **protogynous**, and if the organism is male first and changes to female, it is said to be **protandrous**. In different species, sequential hermaphroditism can be influenced by the organism’s age or size or by various environmental/climatic factors.

While most higher animals reproduce sexually, there are some species in which the females can, under certain conditions, produce offspring without mating. **Parthenogenesis** is the ability of an unfertilized egg to develop and hatch. This seems to be especially prevalent among insects. Some of the giant walkingsticks at the Zoo are females who, without mating, lay eggs that hatch into more females generation after generation. Other insects, like some aphids, have complicated life cycles that involve sexually-reproducing generations alternating with parthenogenically produced generations. In honeybees, fertilized eggs turn into females (workers and queens), while unfertilized eggs, which are only produced in the spring, turn into males.

In sexual reproduction, there must be some way of getting the sperm to the egg. Since sperm and eggs are designed to be in a watery environment, aquatic animals can make use of the water in which they live, but terrestrial animals must, in some way, provide the wet environment needed for the sperm to swim to the egg. There are, thus, two major mechanisms of fertilization. In **external fertilization**, used by many aquatic invertebrates, eggs and sperm are simultaneously shed into the water, and the sperm swim through the water to fertilize the egg. In **internal fertilization**, the eggs are fertilized within the reproductive tract of the female, and then are covered with eggshells and/or remain within the body of the female during their development.

In species with external fertilization, at an appropriate developmental stage, the eggs hatch, and the new young simply swim away. However, females of species with internal fertilization must, at some point, expel the growing young. There are three general ways of doing this:

- **Oviparous** organisms, like chickens and turtles, lay eggs that continue to develop after being laid, and hatch later.
- **Viviparous** organisms, like humans and kangaroos, are live-bearing. The developing young spend proportionately more time within the female’s reproductive tract, portions of which are specially-modified for this purpose. Young are later released to survive on their own.
- **Ooviviparous** organisms, like guppies, garter snakes, and Madagascar hissing roaches, have eggs (with shells) that hatch as they are laid, making it look like “live birth.”

A discussion of the human male and female reproductive systems follows.

(clipart edited from Corel Presentations 8)
Male Reproductive System

The male reproductive system is illustrated to the right. Sperm are produced in the testes located in the scrotum. Normal body temperature is too hot thus is lethal to sperm so the testes are outside of the abdominal cavity where the temperature is about 2°C (3.6°F) lower. Note also that a woman’s body temperature is lowest around the time of ovulation to help insure sperm live longer to reach the egg. If a man takes too many long, very hot baths, this can reduce his sperm count. Undescended testes (testes are supposed to descend before birth) will cause sterility because their environment is too warm for sperm viability unless the problem can be surgically corrected.

From there, sperm are transferred to the epididymis, coiled tubules also found within the scrotum, that store sperm and are the site of their final maturation.

In ejaculation, sperm are forced up into the vas deferens (plural = vasa deferentia). From the epididymis, the vas deferens goes up, around the front of, over the top of, and behind the bladder. A vasectomy is a fairly simple, outpatient operation that involves making a small slit in each scrotum, cutting the vasa deferentia near where they begin, and tying off the cut ends to prevent sperm from leaving the scrotum. Because this is a relatively non-invasive procedure (as compared to doing the same to a woman’s oviducts), this is a popular method of permanent birth control once a couple has had all the children they desire. Couples should carefully weigh their options, because this (and the corresponding female procedure) is not designed to be a reversible operation.

The ends of the vasa deferentia, behind and slightly under the bladder, are called the ejaculatory ducts. The seminal vesicles are also located behind the bladder. Their secretions are about 60% of the total volume of the semen (= sperm and associated fluid) and contain mucus, amino acids, fructose as the main energy source for the sperm, and prostaglandins to stimulate female uterine contractions to move the semen up into the uterus. The seminal vesicles empty into the ejaculatory ducts. The ejaculatory ducts then empty into the urethra (which, in males, also empties the urinary bladder).

The initial segment of the urethra is surrounded by the prostate gland (note spelling!). The prostate is the largest of the accessory glands and puts its secretions directly into the urethra. These secretions are alkaline to buffer any residual urine, which tends to be acidic, and the acidity of the woman’s vagina. The prostate needs a lot of zinc to function properly, and insufficient dietary zinc (as well as other causes) can lead to enlargement which potentially can constrict the urethra to the point of interfering with urination. Mild cases of prostate hypertrophy can often be treated by adding supplemental zinc to the man’s diet, but severe cases require surgical removal of portions of the prostate. This surgery, if not done very carefully can lead to problems with urination or sexual performance.

The bulbourethral glands or Cowper’s glands are the third of the accessory structures. These are a small pair of glands along the urethra below the prostate. Their fluid is secreted just before emission of the semen,
Thus it is thought that this fluid may serve as a lubricant for inserting the penis into the vagina, but because the volume of these secretions is very small, people are not totally sure of this function.

The urethra goes through the **penis**. In humans, the penis contains three cylinders of spongy, **erectile tissue**. During arousal, these become filled with blood from the arteries that supply them and the pressure seals off the veins that drain these areas causing an **erection**, which is necessary for insertion of the penis into the woman’s vagina. In a number of other animals, the penis also has a bone, the **baculum**, which helps to stiffen it. The head of the penis, the **glans penis**, is very sensitive to stimulation. In humans, as in other mammals, the glans is covered by the foreskin or **prepuce**, which may have been removed by **circumcision**. Medically, circumcision is not a necessity, but rather a cultural “tradition”. Males who have not been circumcised need to keep the area between the glans and the prepuce clean so bacteria and/or yeasts don’t start to grow on accumulated secretions, etc. there. There is some evidence that uncircumcised males who do not keep the glans/prepuce area clean are slightly more prone to penile cancer.

**Female Reproductive System**

The female reproductive system is illustrated to the right. “**Eggs**” are produced in the **ovaries**, but remember from our discussion of **meiosis**, that these are not true eggs, yet, and will never complete meiosis and become such unless/until first fertilized by a sperm. Within the ovary, a **follicle** consists of one precursor egg cell surrounded by special cells to nourish and protect it. A human female typically has about 400,000 follicles/potential eggs, all formed before birth. Only several hundred of these “eggs” will actually ever be released during her reproductive years. Normally, in humans, after the onset of puberty, due to the stimulation of **follicle-stimulating hormone** (FSH) one “egg” per cycle matures and is released from its ovary. **Ovulation** is the release of a mature “egg” due to the stimulation of **leutenizing hormone** (L.H), which then stimulates the remaining follicle cells to turn into a **corpus luteum** which then secretes **progesterone** to prepare the uterus for possible implantation. If an egg is not fertilized and does not implant, the corpus luteum disintegrates and when it stops producing progesterone, the lining of the uterus breaks down and is shed.

Each “egg” is released into the abdominal cavity near the opening of one of the **oviducts** or **Fallopian tubes**. Cilia in the oviduct set up currents that draw the egg in. If sperm are present in the oviduct (if the couple has recently had intercourse), the egg will be fertilized near the far end of the Fallopian tube, will quickly finish meiosis, and the embryo will start to divide and grow as it travels to the uterus. The trip down the Fallopian tube takes about a week as the cilia in the tube propel the unfertilized “egg” or the embryo down to the **uterus**. At this point, if she had intercourse near the time of ovulation, the woman has no idea whether an unfertilized “egg” or a new baby is travelling down that tube. During this time, progesterone secreted by the corpus luteum has been stimulating the **endometrium**, the lining of the uterus, to thicken in preparation for possible implantation, and when a growing embryo finally reaches the uterus, it will implant in this nutritious environment and begin to secrete its own hormones to maintain the endometrium. If the “egg” was not...
fertilized, it dies and disintegrates, and as the corpus luteum also disintegrates, its progesterone production falls, and the unneeded, built-up endometrium is shed.

The uterus has thick, muscular walls and is very small. In a nulliparous woman, the uterus is only about 7 cm long by 4 to 5 cm wide, but it can expand to hold a 4 kg baby. The lining of the uterus is called the endometrium, and has a rich capillary supply to bring food to any embryo that might implant there.

The bottom end of the uterus is called the cervix. The cervix secretes mucus, the consistency of which varies with the stages in her menstrual cycle. At ovulation, this cervical mucus is clear, runny, and conducive to sperm. Post-ovulation, the mucus gets thick and pasty to block sperm. Enough of this mucus is produced that it is possible for a woman to touch a finger to the opening of her vagina and obtain some of it. If she does this on a daily basis, she can use the information thus gained, along with daily temperature records, to tell where in her cycle she is. If a woman becomes pregnant, the cervical mucus forms a plug to seal off the uterus and protect the developing baby, and any medical procedure which involves removal of that plug carries the risk of introducing pathogens into the nearly-sterile uterine environment.

The vagina is a relatively-thin-walled chamber. It serves as a repository for sperm (it is where the penis is inserted), and also serves as the birth canal. Note that, unlike the male, the female has separate opening for the urinary tract and reproductive system. These openings are covered externally by two sets of skin folds. The thinner, inner folds are the labia minora and the thicker, outer ones are the labia majora. The labia minora contain erectile tissue like that in the penis, thus change shape when the woman is sexually aroused. The opening around the genital area is called the vestibule. There is a membrane called the hymen that partially covers the opening of the vagina. This is torn by the woman’s first sexual intercourse (or sometimes other causes like injury or some kinds of vigorous physical activity). In women, the openings of the vagina and urethra are susceptible to bacterial infections if fecal bacteria are wiped towards them. Thus, while parents who are toilet-training a toddler usually wipe her from back to front, thus “imprinting” that sensation as feeling “right” to her, it is important, rather, that that little girls be taught to wipe themselves from the front to the back to help prevent vaginal and bladder infections. Older girls and women who were taught the wrong way need to make a conscious effort to change their habits.

At the anterior end of the labia, under the pubic bone, is the clitoris, the female equivalent of the penis. This small structure contains erectile tissue and many nerve endings in a sensitive glans within a prepuce which totally encloses the glans.

**Reproductive Physiology, Conception, Prenatal Development**

The reproductive cycles of sexually-reproducing animals are influenced by a number of hormones, including follicle-stimulating hormone, leutinizing hormone, estrogen, testosterone, and progesterone, produced by the animals’ bodies. Additionally, reproductive cycles are influenced by environmental factors such as day length. Since the hormone melatonin is only secreted in the dark, animals’ bodies produce more melatonin in winter months when there is less daylight. Melatonin (or lack thereof) produces a number of physiological changes, including regulation of fertility in many species. In humans, melatonin levels drop 75% just before puberty, and it has been noted that blind girls whose brains/pineal glands do not receive light from their eyes have delayed onset of puberty. In many other species, melatonin controls sexual receptivity. For example, ewes only are receptive in fall/winter so the lambs will be born in spring and have all summer to grow. Typically, special sex pheromones are emitted to convey information about receptivity to members of the opposite sex or to regulate sexual cycles of other members of the same species.
Sperm production in males is under the control of **follicle-stimulating hormone** (FSH) and **leutinizing hormone** (LH). LH stimulates production of androgens (including **testosterone**) by the testes, while FSH stimulates the testes to produce sperm. As in females, production of FSH and LH are under the control of **gonadotropin releasing hormone** (GnRH) produced by the hypothalamus. Via a negative feedback loop, androgens control levels of GnRH, FSH, and LH. Additionally, androgens are responsible for development of the male reproductive organs during embryonic development, development of secondary sexual characteristics (beard, deeper voice) and behaviors (singing in birds), and production of sperm. Also via negative feedback loops, FSH and LH control production of GnRH. In human males, it appears that blood levels of all these hormones remain fairly constant, but in males of many other mammal species, blood levels of these hormones vary seasonally (hinting at involvement of melatonin in some way).

Thus, in a number of species of mammals, such as goats, deer, camels, and sheep, due to environmental and hormonal cues, the male periodically goes into **rut**, a periodic sexual excitement in the male that is analogous to estrous in the female. Billy goats (bucks) in rut stink worse that they do at other times. Buck deer are more likely to use their antlers to engage in sexual competition with other males. People who work with camels know that male camels in rut become more unpredictable, meaner than usual, and harder to work with and control.

In most species of mammals, the female has either an **estrous cycle** or a **menstrual cycle**. An estrous cycle is also called “being in heat” because the female’s body temperature rises a little. However, more pronounced than changes in temperature are noticeable behavioral changes. If the female does not become pregnant, the endometrium is reabsorbed and (usually) there is no “bleeding”. In species in which the female has a menstrual cycle, the unused endometrium is shed and voided from the body as the **menstrual flow**. Note that while this term was derived in the context of human females who happen to cycle in about the same length of time as a lunar month, it is also applied to other species whose cycles are not one month long. Most other species have cycles that are shorter or longer than a month, and in some species, the timing of ovulation and female receptivity is so tied to environmental cues (light, temperature, etc.) that they only cycle and mate at one or two specific times of the year. Human females are somewhat unusual because the females of most species are only receptive around the time of ovulation (release of a fertile egg). A human female is more receptive around the time of ovulation, but that is not the only time she is receptive. Human females generally are receptive to sexual activity throughout their cycles.

The average menstrual cycle in humans ranges about 20 to 40 days in length, with a statistical average of about 28 to 29 days. Some women experience regular cycles, while others are quite irregular. Much is understood about the hormones involved in the female cycle, but we are only beginning to understand the role of **pheromones**. It is well-known that the cycles of college women living in a dorm situation frequently adjust such that many of the women “have their periods” at the same time as each other. It has been shown experimentally that when perspiration from one woman is dissolved in alcohol and applied above the upper lip of other females (several times a week), their cycles all adjust to coincide with hers. There is also experimental evidence that frequent exposure (several times a week) to male perspiration (therefore, pheromones) can regulate a female’s cycle, causing irregular, short, or long cycles to become more regular and closer to the 28 to 29 day average. This would make sense evolutionarily because it would increase a woman’s chances of conceiving if she was in a situation where she had frequent contact with a stable, supportive mate who could provide her and her child with enough food to survive (at a time when she would be more vulnerable and less able to gather food herself, yet need more than usual).

By convention, the first day of a woman’s period is considered to be day 1 of her cycle. The first 3 to 7 days are generally the **menstrual flow phase**, and during this time, all hormones involved are at low levels. There are five hormones involved in controlling the female cycle. These are **gonadotropin releasing hormone** (GnRH) secreted by the hypothalamus, **follicle-stimulating hormone** (FSH) and **leutinizing hormone** (LH).
secreted by the pituitary gland, and **estrogen** and **progesterone** secreted by the ovaries. The following diagrams and explanation show how levels of these hormones and the changes they induce vary throughout a woman’s cycle.
The first half of a woman’s cycle is the **proliferative phase** (**follicular phase**), during which the endometrium starts to thicken. The pituitary secretes FSH which causes (usually one) follicle to mature and the ovaries to secrete estrogen. The ovarian estrogen secretion gradually increases until just prior to ovulation. This gradually suppresses secretion of FSH and stimulates the hypothalamus to secrete a larger amount of GnRH which, in turn, triggers the pituitary to secrete a burst of LH, causing **ovulation**. During the proliferative phase, a woman’s body temperature is low, perhaps as low as 98.0°F (36.7°C) or less. Sometimes there is a slight rise near the end of the phase during the pre-ovulatory burst of LH before it dips again at ovulation. Throughout this phase, the cervical mucus becomes progressively clearer and thinner.

On about day 14 of an average 28-day cycle, **ovulation**, the rupture of the follicle and release of the egg, occurs in response to the surge of LH. LH stimulates the remaining follicle cells to form a **corpus luteum** after ovulation. Often at ovulation there is a sharp drop in the woman’s body temperature and her cervical mucus becomes very thin and clear and forms “threads”. Interestingly, both the low body temperature and the condition of the mucus are designed to prolong the life of and aid in the mobility of sperm to increase the chances that the egg being released will be fertilized.

The second half of the cycle is called the **secretory phase** in the uterus and the **luteal phase** in the ovaries. The endometrium continues to build up due to the secretion of progesterone (and estrogen) by the corpus luteum, and this prepares the uterus for a possible pregnancy. In case an egg has been fertilized, the growing embryo needs a warmer environment to do well, so the body temperature rises to 98.6°F (37.0°C) or higher. The cervical mucus becomes thick and paste-like, blocking any more sperm from entering the uterus.

If an egg is not fertilized, as the corpus luteum deteriorates at the end of a cycle, both estrogen and progesterone levels go very low. In a pregnancy, implantation triggers hormone production that keeps the corpus luteum secreting estrogen and progesterone for a while, but without that, the corpus luteum disintegrates and stops secreting these hormones. At this time, all of the hormone levels are low and...
decreasing. This frequently causes the mood swings and other symptoms of premenstrual syndrome (PMS), but PMS is also affected by diet, and large amounts of salt, sugar, yeast, and/or caffeine can make things worse.

Throughout this discussion, the roles of the five hormones that influence a woman’s menstrual cycle have been mentioned, but their interactions are quite complex and involve both positive and negative feedback loops. Reiterating the previous discussion specifically from the point of view of the female hormone cycle will hopefully aid in better understanding the roles played by these hormones.

Click on the animation below to view a presentation on the female hormone cycle (452 KB file).

1. GnRH from the hypothalamus stimulates the pituitary to produce FSH.
2. During the first part of pre-ovulatory phase, the pituitary secretes low levels of FSH.
3. FSH stimulates growth and maturation of a follicle.
4. As the follicle grows and matures, it secretes estrogen in increasing amounts.
5. The rising levels of estrogen exert negative feedback on the pituitary to gradually lower the levels of FSH.
6. However, estrogen exerts a positive feedback effect on the hypothalamus.
7. Thus, just before ovulation, the hypothalamus secretes a larger amount of releasing hormone which causes the pituitary to secrete a burst of LH.
8. The effect of this burst of LH on the mature follicle causes it to rupture, release the egg, and start to form a corpus luteum.
9. After ovulation, LH stimulates the corpus luteum to secrete progesterone and estrogen to prepare the uterus for implantation.
10. The rising/high levels of the estrogen-progesterone combination in the blood exert a negative feedback effect on the hypothalamus and pituitary, causing levels of LH to decrease.
11. As LH decreases, the corpus luteum starts to disintegrate.
12. Unless an embryo has implanted, near the end of the post-ovulatory phase, without the stimulation of LH, the corpus luteum stops producing estrogen and progesterone. Thus the endometrium is no longer maintained and begins to deteriorate and is shed.
13. Thus, around the time a woman’s period starts, all five hormones are at their lowest levels.
14. However with the low estrogen and progesterone levels, the hypothalamus can now begin again to secrete GnRH so the cycle starts over.

15. If an egg was fertilized, it begins to divide as it travels down the Fallopian tube, and the blastocyst that reaches the uterus is about 100 cells in size and ready to implant in the endometrium.

16. If implantation is successful, the outer embryonic membrane, the chorion secretes human chorionic gonadotropin (HCG) which maintains the corpus luteum during the first trimester of pregnancy. Excess HCG is excreted in the woman’s urine, thus many pregnancy tests test for the presence of HCG in urine.

17. During the second trimester, the placenta starts to secrete progesterone and stops HCG production. Because of the lack of HCG, the corpus luteum, which is no longer needed, degenerates. The endometrium is maintained by the hormones secreted by the placenta.

Copulation in most species of animals is preceded by various courtship rituals which help insure that the most genetically fit individuals pass on their genes.

If the woman is just pre-ovulation or at ovulation, conception, the start of a new person, of pregnancy, may occur. Interestingly, there are some things a couple can do to increase their chances of having a baby of a given sex. It has been found that sperm which contain an X chromosome tend to live longer than Y sperm, so having intercourse a couple days prior to ovulation increases the chances of a girl baby. On the other hand, Y sperm swim faster than X sperm, so having intercourse right at ovulation can increase the chances of a boy baby. As previously mentioned, at the time of ovulation, a woman’s body temperature and cervical mucus are “right” to help sperm survive. The contractions caused by orgasm and the prostaglandins in semen help propel sperm up into the uterus, and from there, up the Fallopian tubes. An egg is fertilized near the end of the Fallopian tube, then finishes meiosis, the nuclei unite, and the embryo starts dividing as it begins to travel to the uterus.

Recent work on human pheromones has turned up some interesting effects they may have on pregnancy. It is not unusual in our busy society, for a couple who desire a baby to keep track of where the woman is in her cycle, and plan to have intercourse “at the right time,” yet, despite no physical problems, many of these couples still fail to conceive. Recent work on human pheromones suggests that this is not enough. Apparently the woman’s body may need continued exposure to the man’s pheromones, such as would be acheived by the close contact during coitus, several times a week during the last two weeks of her cycle to make implantation more likely. Again, evolutionarily, this would make sense in terms of signaling the presence of a pair-bonded male who could provide her and her developing child with enough food to survive the pregnancy. It would, then, make sense that lack of continued pheromonal stimulation (as in when the couple go back to their busy schedule until next month at the appointed time or in a “one night stand”) would signal the absence of a male that could mean increased hardship and lower chances of survival if pregnancy were to result. However, in the interest of passing on one’s genes, evolutionarily, the possibility of pregnancy is not totally ruled out, just diminished.

If an egg is fertilized, fertilization occurs in the far end of the Fallopian tube near the ovary, and as the embryo travels down the tube, cell division starts. By the time it reaches the uterus (about a week later), it is a “hollow ball” or blastocyst, which has about 100 cells. The embryo, specifically the placenta, starts producing hormones which prevent the corpus luteum from disintegrating, and hormones from the corpus luteum maintain the endometrium until the placenta is large enough to secrete more hormones on its own. Note that whereas contraceptives, as their name suggests, prevent conception (union of egg and sperm to form a new person), intrauterine devices (IUDs) as well as “morning after” pills and some other drugs, including Depo-Provera, work to prevent implantation of the week-old, genetically-unique, growing embryo thereby causing it to die, and thus are abortifacients.
When the embryo implants in the endometrium, it starts to form the placenta. A human placenta attains the size of a dinner plate. The placenta serves as the site of transfer of nutrients and wastes between the maternal and fetal blood, and when large enough, it secretes hormones to maintain the endometrium, thus the pregnancy. Keep in mind that the two blood supplies do not come into contact with each other, but chemicals can be passed back and forth.

In the first trimester (the first three months) of pregnancy, most organogenesis, development of body organs occurs. The baby’s heart starts beating at about four weeks (when the mother’s first period is about two weeks late and she’s beginning to suspect she might be pregnant). Because so much critical growth and development takes place in the first few weeks before she even knows she’s pregnant, it is very important that she be well nourished (including vitamin supplements if needed, especially folic acid to prevent neural tube defects) before she even tries to get pregnant. By the end of the eighth week (when her second period is two weeks overdue) all of the major body structures and organs of an adult are present in at least rudimentary form, so the embryo is now called a fetus. The rest of the time during pregnancy is mostly just growth. Note that because of organogenesis, the first trimester is the time when the growing baby is the most sensitive to adverse effects of drugs like alcohol, tobacco, and caffeine, viruses like German measles, and lack of necessary nutrients such as folacin. During the first trimester, the placenta secretes HCG to maintain the corpus luteum which continues to secrete the estrogen and especially progesterone needed to maintain the endometrium. The cervical plug forms to protect the growing baby from “foreign invaders”, and the woman’s breasts begin to enlarge in preparation for lactation, or nursing. The level of HCG is so high in the blood that some is excreted in the urine. Most pregnancy tests look for the presence of HCG in urine. As the sex organs begin to develop, the embryo starts with rudimentary forms of both male and female systems, and only one set continues to develop while the other atrophies. Also the initial development of external genitalia is similar and it can be difficult to tell the sex of a baby early on.

In the second trimester growth occurs. The baby is very active, and eventually these movements can be felt by the mother. The baby can hear by the fourth month, and when born recognizes not only mom’s voice, but also dad’s voice (if he’s around) and/or any other frequently-heard, familiar sounds, perhaps including things like any musical instruments the mother plays, etc. During this trimester, HCG production declines and the corpus luteum stops producing progesterone as it deteriorates. As this is happening, the placenta takes over and begins to secrete progesterone itself to maintain the endometrium.

The third trimester is a time of rapid growth. The baby tends to move less just because the uterus has become so crowded. Estrogen levels in the mother’s blood reach their highest in the last weeks of pregnancy, and as this increases, it triggers the formation of oxytocin receptors in the uterus. Late in pregnancy, fetal cells produce increasing amounts of oxytocin, another hormone, as does the pituitary. Oxytocin is a powerful smooth muscle stimulant, and due to the receptors which have formed in the uterus, causes uterine contractions. The high estrogen levels also stimulate the placenta to make prostaglandins (similar to those that cause “cramps”) that also stimulate contractions. The hormonal induction of labor is a positive feedback loop. Oxytocin and the prostaglandins cause uterine contractions that, in turn, stimulate the release of more oxytocin and prostaglandins. This is partially due to pressure of the baby’s head against the cervix that both dilates the cervix and acts on cervical nerve endings to stimulate the production of oxytocin, which causes stronger contractions that cause the baby’s head to be pressed more strongly against the cervix, etc.

There are three stages in the birth process, including:

1. The dilation of the cervix, which lasts from the onset of labor until the cervix reaches its full diameter of about 10 cm, and is the longest stage, often lasting 6 to 12 hr or longer,
2. the **expulsion stage**, the time (about 20 min to 1 hr) from full dilation until delivery, during which, strong contractions about 1 min each occur every 2 to 3 min, and the mother feels an increasing urge to push until the baby is forced down, into the vagina, and out, and
3. the **delivery of the placenta** which usually occurs within 15 min of the delivery of the baby.

After the baby is born, the umbilical cord is clamped and cut, often before the placenta is delivered. When the baby is born, much of his/her blood is still circulating in the placenta, and as (s)he begins to breathe, that blood is naturally brought back into the body, aided by the pulsating of the umbilical cord. For optimum health of the baby, it is important that as much of the baby’s blood as possible be out of the placenta and into the baby’s body before the cord is cut, thus the person doing this should wait until the cord stops pulsating before clamping and cutting it. Many medical staff people try to rush through this procedure and cut the cord too soon.

After birth, decreasing progesterone and estrogen and increasing oxytocin help reduce the uterus to its normal size. It has been found that laying the baby on the mother’s abdomen immediately after birth will stimulate the production of oxytocin, helping shrink the uterus faster. The baby’s sucking on the mother’s nipples stimulates nerve endings that also stimulate the production of oxytocin, so immediate **postpartum** nursing can also help return uterus to proper size.

The hormones oxytocin and **prolactin** trigger the production of milk. While these are present initially in quantities sufficient to begin **lactation**, the baby’s sucking triggers further release of these hormones, in yet another positive feedback loop. At first, **colostrum** is produced. This nutrient-rich substance contains lots of antibodies, etc. important to the baby’s health for the first few days and it’s very important that the baby have the benefit of this nutrition. Also, nursing is important in the bonding process, and for that reason, too, it’s very important to let a baby nurse immediately after birth. There is evidence that human babies imprint on the smell of their mothers’ nipples. Instinctively, when a newborn is first trying to nurse, (s)he will turn his/her mouth toward anything that brushes his/her cheek. Frequently, in hospital setting, well-meaning nurses trying to “help” can actually distract and confuse the baby by touching the baby’s face, thus making it harder for the baby to find the nipple. In contrast, brushing the baby’s cheek with the nipple will cause the baby to turn toward it. About 2 to 3 days after the birth, the mother’s real milk will begin to be produced. This is a specially-designed food source that exactly matches the nutritional needs of a baby, thus every effort should be made to make use of mother’s milk rather than artificial substitutes which often are nutritionally lacking.

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**Digestive System**

Most animals have one of three main types of diets: they are either **carnivores**, **herbivores**, or **omnivores**. Most humans fall into the last category. In humans, herbivores are usually called vegetarians. Strict vegetarians who consume no animal products, whatsoever, are called **vegans**. Some people are **lacto-ovo-vegetarians**, meaning that they also eat dairy products and eggs.

**Digestion** is the process of breaking down food into molecules small enough for the body to absorb. Proteins, carbohydrates, and fat in our diets must be broken down and later, reassembled in forms useful to our body.
The path of food through the human digestive system includes the following organs and structures:
(clipart edited from Corel Presentations 8)

1. the **mouth**, which includes:
   - the **teeth**, which grind food to increase the surface area
   - the **saliva**, which includes **mucin**, a lubricant; **buffers** to neutralize acidic foods, **antibacterial agents**, and **amylase**, which converts starch to maltose
   - the **tongue** which tastes and manipulates the food

2. the **pharynx**, which in humans, leads to both the **trachea** and the **esophagus**. While food is being swallowed, the **epiglottis** blocks the trachea and the **uvula** blocks off the nose.

3. the **esophagus**, which is the tube from the pharynx to the stomach. Food is moved along the esophagus by **peristalsis**, wave-like contractions of the muscles in the walls of the esophagus. The lining of the esophagus secretes **mucus** to lubricate the ball of food. There are **sphincter muscles** (rings of constricting muscles) at the top and bottom of the esophagus.
4. the stomach is a J-shaped, expandable sack, normally on the left side of the upper abdomen. Several muscle layers surround the stomach, serving to churn food. The stomach can expand to hold about 2 L of food (= 1/2 gal). The stomach contains hydrochloric acid (HCl) strong enough to dissolve metal (pH about 1.5 to 3, usually around 2), which kills bacteria and helps denature the proteins in our food, making them more vulnerable to attack by pepsin. The stomach secretes mucus to protect itself from being digested by its own acid and enzymes. The stomach also manufactures pepsin, an enzyme to digest protein. The average person secretes about 400 mL of gastric juice per meal, containing 50 to 300 µg pepsin/mL. For an average of around 200 µg/mL × 400 mL of gastric juice, this would be 80 mg (or 0.080 g) pepsin/meal. For HCl with a concentration of around 6.08 g/L × 400 mL, this would be 2.4 g/meal. Consumption of antacids does just what their name suggests: they drastically change the pH of the stomach contents, interfering with pepsin’s ability to digest protein. Here is more background on pepsin and the effects of antacids. Here is a photograph of results of an experiment we perform to study pepsin’s ability to digest the protein in egg white, and a summary of the contents of each of these test tubes.

<table>
<thead>
<tr>
<th>Tube No.</th>
<th>Distilled Water</th>
<th>0.5% Baking Soda</th>
<th>0.8% Hydrochloric Acid</th>
<th>1% Pepsin Solution</th>
<th>Other Info/Ingredients (@ body temp unless noted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 mL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5 mL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5 mL</td>
<td>5 mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5 mL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5 mL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>5 mL</td>
<td>5 mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>5 mL</td>
<td>5 mL* boiled pepsin soln.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>5 mL</td>
<td></td>
<td></td>
<td>5 mL @ room temp</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>5 mL</td>
<td></td>
<td></td>
<td>5 mL § 5 mL mixture w/ Tums</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>5 mL</td>
<td></td>
<td></td>
<td>5 mL § 5 mL mixture w/ Rolaids</td>
<td></td>
</tr>
</tbody>
</table>

§ For # 9 and 10, 100 mL of HCl was mixed with one “dose” of antacid. 5 mL of that was used.

**Conclusion:** OTC antacids interfere with pepsin’s ability to digest protein.
5. the **cardiac sphincter** (which, officially is not considered to be a true sphincter), which closes off the top end of the stomach and the **pyloric sphincter**, which closes off the bottom

6. the **small intestine**, which has a length of about 6 m. The surface of the small intestine is wrinkled and convoluted to produce a greater surface area for absorption. The total surface area is about 600 m² (about the size of baseball diamond). Most enzymatic digestion occurs here. The secretions of the small intestine include amylase maltase, sucrase, lactase, etc. to digest carbohydrates and lipase to digest fats. Several other associated organs secrete chemicals into the small intestine to aid in digestion: the **pancreas** secretes enzymes like trypsin, chymotrypsin, and alkali solutions like bicarbonate as buffers and the **liver** and **gall bladder** make and secrete **bile**. Bile contains no enzymes, but salts to emulsify fat so it can be digested.

   the sections of the small intestine include:
   - the **duodenum**, the first portion
   - the **jejunum**, the second portion
   - the **ileum**, the third portion

7. the valve between the small and large intestines, which is the **ileocecal valve**, a sphincter that separates the two

8. the **large intestine or colon**, which begins with a blind pouch called the **cecum**. In humans, this terminates in the appendix, a finger-like extension which may function in the immune system. The large intestine functions to re-absorb (resorb) water and in the further absorption of nutrients. The bacterial flora of the large intestine includes such things as **Escherichia coli**, **Acidophilus spp.**, and other bacteria, as well as **Candida** yeast (a fungus). These bacteria produce methane (CH₄), hydrogen sulfide (H₂S), and other gases as they ferment their food. Occasionally, some of this gas is released as **flatus**. As these bacteria digest/ferment left-over food, they secrete beneficial chemicals such as vitamin K, biotin (a B vitamin), and some amino acids, and are our main source of some of these nutrients.

9. the **rectum** is the terminal portion of the large intestine and functions for storage of the **feces**, the wastes of the digestive tract, until these are eliminated. The external opening at the end of the rectum is called the **anus**. The anus has two sphincters, one voluntary and one involuntary. The pressure of the feces on the involuntary sphincter causes the urge to defecate and the voluntary sphincter controls whether a person defecates or not.

**Belching** is when swallowed gas moves up the esophagus and is released from the mouth and/or nose. Some people, whose larynx had to be removed, have learned to purposely swallow air and control its release to enable them to talk.

**Vomiting** is an important reflex to protect from harmful substances. Illnesses like flu, extreme pain (anywhere in the body: migraine, kidney stones. . .), and other stressful conditions can trigger the emptying of the stomach contents.

**Hiatal hernia** is caused in part by failure of the cardiac sphincter to close properly allowing stomach acid to enter and burn the esophagus.

An **ulcer** is when the gastric secretions eat through stomach (gastric ulcer) or intestinal wall (duodenal ulcer).

**Diarrhea** is having very loose, watery feces and **constipation** is having larger, harder, nearly dry feces. Getting enough fiber is importance to proper intestinal functioning because it holds water in the feces. If feces are too dry and hard, they will pass through the digestive tract with difficulty, possibly leading to diverticulosis or diverticulitis. Also, due to the increased transit time, there is more time for bacteria to
ferment the left-overs and secrete increased amounts of carcinogenic byproducts, thereby increasing the person’s chances of colon cancer.

Here’s an interesting wordstem “trivia”: carni is also the rootword for carnival. Many people in the Catholic church traditionally fast during Lent, which begins on Ash Wednesday. Thus, the custom developed of eating up any meat and meat products such as lard left in the house on the Tuesday before, called Shrove Tuesday in English, but in French, Mardi Gras, or “Fat Tuesday”. For many people, this developed into a time to get together with family and friends for one last party before the somber season of Lent. In some places, such as New Orleans, this meat-eating party was expanded into a grand celebration--carnival--one last time to eat meat (and do other things) for a while.

Circulatory System

All animals must exchange materials with their environment, including nutrients and wastes, O₂, CO₂, etc., thus need a system that will do this. The more complex the organism, the more complex this system must be. Arthropods, like insects and spiders, have an open circulatory system, in which the blood is pumped forward by the heart, but then flows through the body cavity, directly bathing the internal organs. Vertebrates, like humans, have a closed circulatory system in which the blood stays in the circulatory system as it circulates, and chemicals are exchanged by diffusion. Our system is also called our cardiovascular system, and is composed of our heart plus our arteries and veins. In a person’s heart, the atria (plural of atrium) receive blood from the veins and the ventricles send blood to the arteries. As the arteries become more finely divided, they are called arterioles. The finest divisions of our vascular system are called capillaries. As the vessels get larger again, the smallest are called venules which join and enlarge to form veins. Note that the distinction between arteries and veins is by direction of blood flow, not oxygen content. Veins carry blood toward the heart and arteries carry it away from the heart. Because of this, not all arteries carry oxygenated blood. The two major exceptions, in which arteries are carrying deoxygenated blood are the pulmonary artery which carries deoxygenated blood from the heart to the lungs (to pick up oxygen there) and the umbilical arteries which carry deoxygenated blood away from the baby’s body to the placenta (to pick up oxygen there). We have double circulation: we have a separate pulmonary circuit to the lungs and a systemic circuit to the body.

This illustration is orientated as thought you were looking at this heart in another person standing in front of you. The path of blood flow in a human, then, is as follows:
1. The superior (a) and inferior (b) vena cava are the main veins that receive blood from the body. The superior vena cava drains the head and arms, and the inferior vena cava drains the lower body.

2. The right atrium receives blood from the body via the vena cavae. The atria are on the top in the heart.

3. The blood then passes through the right atrioventricular valve, which is forced shut when the ventricles contract, preventing blood from reentering the atrium.

4. The blood goes into the right ventricle (note that it has a thinner wall; it only pumps to lungs). The ventricles are on the bottom of the heart.

5. The right semilunar valve marks the beginning of the artery. Again, it is supposed to close to prevent blood from flowing back into the ventricle.

6. The pulmonary artery or pulmonary trunk is the main artery taking deoxygenated blood to the lungs.

7. Blood goes to the right and left lungs, where capillaries are in close contact with the thin-walled alveoli so the blood can release CO$_2$ and pick up O$_2$.

8. From the lungs, the pulmonary vein carries oxygenated blood back into the heart.

9. The left atrium receives oxygenated blood from the lungs.

10. The blood passes through the left atrioventricular valve.

11. The blood enters the left ventricle. Note the thickened wall; the left ventricle must pump blood throughout the whole body.

12. The blood passes through the left semilunar valve at the beginning of the aorta.

13. The aorta is the main artery to the body. One of the first arteries to branch off is the coronary artery, which supplies blood to the heart muscle itself so it can pump. The coronary artery goes around the heart like a crown. A blockage of the coronary artery or one of its branches is very serious because this can cause portions of the heart to die if they don’t get nutrients and oxygen. This is a coronary heart attack. From the capillaries in the heart muscle, the blood flows back through the coronary vein, which lies on top of the artery.

14. The aorta divides into arteries to distribute blood to the body.

15. Small arteries are called arterioles.

16. The smallest vessels are the capillaries.

17. These join again to form venules, the smallest of the veins.

18. These, in turn, join to form the larger veins, which carry the blood back to the superior and inferior vena cava.
The atrioventricular and semilunar valves prevent backflow as the heart contracts. Defects in any of these that allow some blood to leak backwards cause distinctive sounds through a stethoscope, thus are called heart murmurs.

The sinoatrial node controls the heart beat. This natural pacemaker is located in the upper wall of the right atrium, and is composed of muscle tissue that sends electrical impulses to the rest of both atria to contract. The impulse then spreads to the ventricles, causing them to contract. The heart cycle involves three phases:

1. The atria contract and force blood into the ventricles. If the atria don’t contract, this is called atrial fibrillation and pooled blood in the atria can begin to clot. When the atria start beating normally again, these clots may be sent throughout the person’s system. If one of these clots lodges in an arteriole somewhere, it could cause a stroke, heart attack, or similar problem. As blood is pushed into the ventricles, when the A-V valves close, the ventricular walls vibrate a little causing the first sound of the heart beat, the “lubb” sound.

2. The ventricles contract and force blood into the arteries. This is called systole and the systolic blood pressure (BP) is the higher of the two numbers, when the heart is actively contracting and putting pressure on the blood. When the semilunar valves snap shut, this causes the second sound of the heart beat, the “dup.”

3. The heart relaxes and blood flows into the atria and ventricles. This is called diastole. The diastolic BP is the lower of the two numbers, when the heart is relaxed, and so, is a measure of how much pressure the arteries, themselves, are putting on the blood. Clogged arteries are less elastic, so the blood is under more pressure, thus more likely to cause the arteries to burst.

The rate of contraction is the heart rate. A baby’s heart starts beating when it is about four weeks old (the mother’s period is two weeks late, and she’s just beginning to suspect she might be pregnant). A newborn’s heart rate is around 135 to 140 beats per minute (bpm). By age 15 to 30, the rate decreases to about 65-75 bpm, then speeds up slightly as the person ages. The pulse is a wave of contraction of the artery walls (which roughly corresponds to the heart rate) as blood is forced into the arteries. Pulse is usually measured using the radial artery (the one along the radius). To find your pulse, rest your right arm in the palm of your left hand. Curl the fingers of your left hand up around the thumb side of your right wrist. Place several fingers of your left hand along and just to the outside (thumb side) of the tendon that runs along your wrist. With gentle pressure, you should be able to feel your pulse.
Blood pressure is maximum during systole, when the heart is pushing, and minimum during diastole, when the heart is relaxed. In a living person, the blood pressure doesn’t go to zero because the thick, elastic artery walls exert pressure on the blood. A sphygmomanometer is the instrument used to determine BP. The artery used to determine BP is the brachial artery, which runs down the upper arm, splitting into the radial and ulnar arteries near the elbow. The cuff of the sphygmomanometer is wrapped around the arm just above the elbow and pumped up to block off blood flow (the pressure exerted by the cuff is higher than the systolic pressure). The pressure in the cuff is gradually decreased, and when it equals the person’s systolic pressure, the heart can force blood under the cuff, and a sound is heard as the pulses of blood surge under the cuff. As the pressure in the cuff is lowered, when it equals the diastolic pressure, blood can flow freely, so the sound disappears (not enough pressure is exerted by cuff to restrict blood flow). Thus, by listening for the first sound, and when the sound becomes faint, while watching the pressure indicator on the sphygmomanometer, it is possible to determine someone’s blood pressure.

Typically, when you go to the doctor’s office, one of the first things that is done to you is that someone (a nurse?) takes your blood pressure. I have frequently had the experience that when I ask what the results were, I initially get the answer “It’s OK.” Here’s a tip: you, not they, are in charge of your health. The only way you can educate yourself to how your body works is to keep re-asking the question until you get a real answer. You need to know the actual numbers to be able to evaluate if things have changed or are good or bad. Be persistent and eventually they’ll tell you what your BP is.

A neonate’s BP is around 80/45 mm Hg meaning that the systolic pressure is equivalent to air pressure that will support a column of mercury 80 millimeters high in a barometer, and the diastolic is equivalent to the air pressure that will support a column of mercury 45 millimeters high. For adults in their 20s, 120/80 mm Hg is considered average for a male and 115/75 mm Hg for a female, thus the accepted average is said to be 120/80 mm Hg. With age, the arteries become less elastic (due in part to undesirable lipid deposits in their walls), so the BP rises. Hypertension is when the BP is too high. There are two ways this could happen: either the systolic pressure is greater than 145 to 160 mm Hg and/or the diastolic is greater than 90 to 100. Major contributing factors include the amounts of salt, cholesterol (and other lipids), and sugar in one’s diet and the amount of exercise the person gets. Frequently, diuretics are prescribed to try to remove water from the person’s blood, thus lowering the blood volume and hopefully thereby, the BP. However, many diuretics also remove potassium (and other beneficial minerals?) from the person’s system, and if serum potassium levels are not carefully monitored and go to low, this could cause a heart attack!

A thrombus is a blood clot (platelets and fibrin) which forms within a vessel and blocks the blood flow. These can result from surgery or from conditions like atrial fibrillation. An embolus is a moving thrombus which may “get stuck” somewhere. If thrombi or emboli lodge in an artery supplying blood to the heart, this can cause a coronary embolism or heart attack or myocardial infarction. If one of these becomes lodged in an artery in the lungs, it is also a life-threatening pulmonary embolism, and if in the brain, a cerebral (or cerebellar) embolism or stroke or cerebrovascular accident (CVA).
A **hemorrhage** is bleeding, especially profuse, and can be severe if internal.

A **hematoma** is a local swelling or tumor filled with blood; a bruise, especially a large one. Sometimes, if the injury is extensive, it can calcify as it heals, leading to a hard lump (which may need to be surgically removed).

**Hemorrhoids** are dilated or **varicose veins** in the anal area. Typically, these are caused not enough fiber in diet causing the feces to be very hard so the person has to strain to pass them. Increasing the amount of fiber in one’s diet can help prevent hemorrhoids and possibly aid in healing mild cases. Because vitamin C is necessary for collagen synthesis, it is necessary for strong capillary walls (one of the first signs of a vitamin C deficiency is easy bruising), so that and the bioflavonoid **rutin** (found in buckwheat) have proven useful for strengthening blood vessels and preventing/treating hemorrhoids and other varicose veins.

**Edema** is an accumulation of fluid (plasma) within tissues and/or the lymph system. There are many possible causes of edema from injury, to too much salt, to improperly functioning kidneys, to lack of exercise, to female hormonal changes, to a number of other possible causes. If in doubt, see a doctor.

Much like a heat pump for your house or your refrigerator coils, your cardiovascular system is also involved in **countercurrent heating/cooling** of your body. Arteries and veins lying near each other in your extremities, but flowing in opposite directions can absorb heat from each other as needed. When your core temperature is too high, the arteries carry heat to the extremities to be dissipated. As the blood returns via the veins, any excess heat still in the blood is transferred to the arterial blood and sent to the extremities, again. When your core temperature is too low, as the blood flows out in the arteries to nourish the extremities, its heat is transferred to the venous blood and sent back into the body to keep it warm.

In **Raynaud’s Phenomenon**, when the person (more common in women than men) gets cold, spasms in the tiny arteriole muscles cause the circulation in portions of the fingers or toes to completely “turn off,” and that portion of the finger/toe turns completely white. As the person warms up and circulation is restored, initially these areas of the fingers/toes will be cyanotic (blue), then will be flushed and red, before returning to normal. The Merck Manual suggests that there may be a relationship between migraine headaches and Raynaud’s. Diagnosis is confirmed by testing the blood pressure in not only the brachial artery, but also the radial and ulnar arteries, and using tiny cuffs made of Velcro® and aquarium tubing, each finger, both when the person is comfortably warm and when the person’s hands have been soaking in ice water. People with Raynaud’s need to make sure to wear warm mittens and heavy socks in winter weather, and since much heat is lost from our heads, wearing a scarf or hat can actually help to keep the person’s whole body warm and lessen the chances of a Raynaud’s episode in the fingers/toes!

Hardening of the arteries is also called **arteriosclerosis**, a generic term for a number of diseases in which the artery walls become thickened and lose elasticity. One special form of this is **atherosclerosis** which is a build-up of lipids on the inside of blood vessels. Major risk factors for atherosclerosis include hypertension, elevated serum lipids, elevated LDL (low-density lipoproteins, the bad guys) and lowered HDL (high-density lipoproteins, the good guys), smoking, diabetes, obesity, male sex, and family history. Female hormones offer protection against accumulation of arterial **plaque**, so usually, premenopausal women do not have as many problems with this as men do. However, after menopause, lipids will start to accumulate. I once hear a statistic that the average 55-year-old woman has a build-up equivalent to the average 18-year-old man.
Respiratory System

Each cell in an animal’s body must receive O\textsubscript{2} and give off CO\textsubscript{2}. This is easier for smaller organisms. In the vertebrates, the blood carries O\textsubscript{2} and CO\textsubscript{2} to and from the cells, but these gases must also be exchanged with the outside air or water. In insects, the tracheal system takes air directly to the organs and O\textsubscript{2} is usually not carried in the blood. Mammals and some other vertebrates have lungs to exchange air. However, the lungs are ventilated differently in different groups of vertebrates. For example, a frog opens its nostrils and expands the floor of its mouth to draw air into its mouth. Then it closes its nostrils and uses the floor of its mouth to push O\textsubscript{2} into its lungs. Mammals are unique in possessing a diaphragm to pull O\textsubscript{2} into the lungs. As the diaphragm contracts and the rib cage rises, a negative pressure is created in the chest cavity causing the lungs to expand and air to be drawn in.

(clipart edited from Corel Presentations 8)

1. Air first passes into the nostrils where it is filtered by the nasal hairs and warmed and humidified in the nasal cavity and sinuses.
2. From there, the air passes through the pharynx, which is shared with the digestive tract. Many students have trouble with the pronunciation of this word. It is pronounced “fair--inks,” and you need to learn how to correctly pronounce it.
3. Air next passes through the larynx, (pronounced as above, but with an “l”) also called the Adam’s apple, voice box, or vocal cords. The vocal cords are under tension, and a change in tension causes a change in pitch as air passes over them and they vibrate. An inflammation of the larynx is called laryngitis.
4. The larynx is situated at the top end of the trachea, through which the air passes next. The trachea has rings of cartilage, like the rings in a vacuum cleaner hose, for support. The lining of the trachea is pseudostratified.
ciliated columnar epithelium which brushes debris up and out. This epithelial tissue is destroyed by smoking, but can regenerate if the person stops smoking.

5. The trachea divides at its bottom end into two bronchi (sing. = bronchus), one to each lung. Recall that the mucus in the bronchi serves to trap and coat dust particles so they don’t scratch or infect the delicate tissues in the lungs.

6. The bronchi divide in the lungs into smaller branches called bronchioles. In humans, the lungs are not symmetrical because the heart, while located in the center of the chest (thorax), leans slightly to the left. Thus the right lung has three lobes (sections) and the left lung has two.

7. The tiniest bronchioles branch to the alveoli (sing. = alveolus) which are tiny, multi-lobed air sacs made of simple squamous cells. Having this thin wall enables air exchange with the equally-thin-walled capillaries of the circulatory system. In order to function properly, the alveoli must always stay moist. Special cells in the alveoli secrete a substance called a surfactant which reduces the surface tension of water, thereby enabling it to better coat the cells of the alveoli to keep them moist and keep them from sticking to each other when the person exhales. The ability to secrete this chemical doesn’t develop until around the eighth or ninth month of pregnancy, so there frequently is a problem in premature babies with the lack of surfactant causing the alveoli to stick together when the baby exhales. Then, when the baby inhales again, the stuck alveolar cells tear away from their neighbors. Scar tissue forms at these sites, thus the damage is permanent, and the person’s lungs lose some of their elasticity and ability to expand fully. A current “hot” area of research is searching for a suitable replacement surfactant that could be placed into the lungs of premature babies to prevent this damage.

The usual volume of air inhaled/exhaled in one breath is called the tidal volume. The average tidal volume for an adult human is around 500 mL of air. The maximum volume that can be exhaled during forced breathing (as in the “breathing machines” people are given after surgery) is called the vital capacity. For young adult male humans, this amounts to around 4 to 5 L of air, and the average for females is slightly lower.

As mentioned when we were discussing muscles, the diaphragm is unique in that control of its operation can be either voluntary or involuntary. Normally, control is involuntary, and we don’t have to think about breathing. The breathing center in the medulla of the brainstem responds to O₂ and CO₂ content in the blood when adjusting the breathing rate. We also have the ability, somewhat, to control breathing voluntarily, and a classic example of this is holding one’s breath while swimming.

Related to this, I have heard that it is physiologically impossible for a person to hold his/her breath until (s)he suffocates. Generally, as CO₂ builds up, a point is reached where the person just can’t hold his/her breath any longer. If the person would pass out, control would immediately return to involuntary, and (s)he would automatically start breathing normally. Parents, do not give in to a child who tries to do this to control you! I have seen advice that says to “ignore” and not react to this type of behavior. One thing that might not occur to you when you are upset with a child’s behavior is that it would be pretty difficult for the child to hold his/her breath while being gently, lovingly tickled or if enticed into a conversation about some other, interesting topic.

To get air to all the cells of the body, in mammals, hemoglobin in the RBCs carries O₂ to everywhere in the body. However, hemoglobin has a greater affinity for carbon monoxide (CO), and does not readily release it. Thus a victim of CO poisoning, is usually put on supplemental oxygen to make sure the remaining hemoglobin gets all it can carry. Also, because of this, it takes a long time to recover from CO poisoning. Some other organisms have hemocyanin in their blood (this has Cu rather than Fe in a porphyrin ring). This is typical of many insects with greenish or Bluish blood. Most insects, however, do not depend on their blood to take oxygen to their tissues, but rather, their tracheal system allows air to go directly to the body organs.
Knowing CPR (cardiopulmonary resuscitation), or at least mouth-to-mouth can prepare you to save someone’s life, and the Heimlich maneuver (developed by a doctor here in Cincinnati) can help save someone’s life if (s)he is choking. If you have never had CPR training, you might wish to check with the Red Cross for their class schedule.

Diseases and disorders of the respiratory tract include:

**Hiccups**
are spasms of the diaphragm thought to be caused by not enough CO\(_2\) in the body. Thus, hiccups are frequently cured by breathing into a paper bag.

**Rhinitis**
is an inflammation of the mucus membrane in the nose, due to a common cold, allergies, etc.

**Pharyngitis**
is a sore throat, which could be due to a viral infection such as the common cold or flu or a bacteria infection such as *Streptococcus pyogenes*.

**Laryngitis**
is an inflammation of the vocal cords in which the person partially or totally loses his/her voice.

**Bronchitis**
is an inflammation of the bronchi, causing them to over-secrete mucus, which in turn, causes coughing to get it up.

**Pneumonia** and **tuberculosis**
infect the lungs.

**Empyema**
is an infection, similar to pneumonia, in the chest cavity outside of the lungs.

**Pleurisy**
is an infection of the pleural membranes lining the inside of the chest cavity and coating the lungs. Normally these membranes are very slippery, aiding in breathing, but when they become infected, they don’t slide over each other as well, and breathing becomes painful.

**Asthma**
is an allergic reaction that causes constriction of the bronchiole muscles, thereby reducing the air passages, thus the amount of air that can get to the alveoli. Interestingly, many of the treatments for asthma are similar to treatments used for hypoglycemia. That and the fact that diabetics rarely also have asthma have led some authors to suggest that asthma may be related to hypoglycemia, and that a hypoglycemia diet may aid in alleviation of asthma symptoms.

**Emphysema**
is a progressive loss of elasticity in the lungs due to rupture of some alveolar walls, coalescing of alveoli, and formation of scar tissue.

**Lung cancer**
has been shown to be more common in people who smoke cigarettes and/or who are constantly forced to inhale someone else’s side stream smoke. A number of pamphlets from the American Cancer Society and biology textbooks have featured pictures that show what smoking can do to a person’s lungs. Typically, there is a photograph of a robust, healthy, pink lung next to a photograph of a shrivled, diseased, blackened lung from a smoker. Similarly, people who work around substances like asbestos fibers, coal dust, flour dust, or dry, crumbled, dusty bird droppings for much of their lives, frequently show signs of lung diseases caused by these substances.