DISCLAIMER - This presentation was prepared using draft rules. There may be some changes in the final copy of the rules. The rules which will be in your Coaches Manual and Student Manuals will be the official rules.

**BE SURE TO CHECK THE 2015 EVENT RULES for EVENT PARAMETERS and TOPICS FOR EACH COMPETITION LEVEL**

**TRAINING MATERIALS:**

- **Training Power Point** presents an overview of material in the training handout
- **Training Handout** presents introductory topic content information for the event
- **Sample Tournament** has sample problems with key
- **Event Supervisor Guide** has event preparation tips, setup needs and scoring tips
- **Internet Resource & Training Materials** are available on the Science Olympiad website at [www.soinc.org](http://www.soinc.org) under Event Information.
- **A Biology-Earth Science CD, an Anatomy/A&P CD** as well as the **Division B and Division C Test Packets** are available from SO store at [www.soinc.org](http://www.soinc.org)

**BASIC ANATOMY AND PHYSIOLOGY**

- Cardiovascular System (*new for B&C*)
- Immune System (*new for Div. B*)
- Integumentary System
- Major Diseases
- Treatment and prevention of diseases

**PROCESS SKILLS** - observations, inferences, predictions, calculations, data analysis, and conclusions.
Cardiovascular System

Components of the Cardiovascular System

- consists of the heart plus all the blood vessels
- transports blood to all parts of the body in two 'circulations': pulmonary (lungs) & systemic (the rest of the body)
- responsible for the flow of blood, nutrients, oxygen and other gases, and hormones to and from cells
- about 2,000 gallons (7,572 liters) of blood travel daily through about 60,000 miles (96,560 kilometers) of blood vessels
- average adult has 5 to 6 quarts (4.7 to 5.6 liters) of blood, which is made up of plasma, red blood cells, white blood cells and platelets
- In addition to blood, it moves lymph, which is a clear fluid that helps rid the body of unwanted material
ANATOMY OF THE HEART

- The heart is a muscular organ a little larger than your fist weighing between 7 and 15 ounces (200 to 425 grams).
- It pumps blood through the blood vessels by repeated, rhythmic contractions. The average heart beats 100,000 times per day pumping about 2,000 gallons (7,571 liters) of blood.
- The average human heart beating at 72 BPM (beats per minute), will beat approximately 2.5 billion times during a lifetime of 66 years.
- The heart is usually situated in the middle of the thorax with the largest part of the heart slightly offset to the left underneath the breastbone or sternum and is surrounded by the lungs.
- The sac enclosing the heart is known as the pericardium.
- The right side of the heart is the pulmonary circuit pump.
- Pumps blood through the lungs, where CO$_2$ is unloaded and O$_2$ is picked up.
- The left side of the heart is the systemic circuit pump.
- Pumps blood to the tissues, delivering O$_2$ and nutrients and picking up CO$_2$ and wastes.
• **Right Atrium:** It collects deoxygenated blood returning from the body (through the vena cava) and then forces it into the right ventricle through the tricuspid valve.

• **Left Atrium:** It collects oxygenated blood returning from the lungs and then forces it into the left ventricle through the mitral valve.

• **The atrioventricular (AV) valves (Mitral & Tricuspid Valves)** prevent flow from the ventricles back into the atria.

• **Right Ventricle:** It collects deoxygenated blood from the right atrium and then forces it into the lungs through the pulmonary valve.

• **Left Ventricle:** It is the largest and the strongest chamber in the heart. It pushes blood through the aortic valve and into the body.

• **The pulmonary and aortic valves** prevent back flow from the pulmonary trunk into the right ventricle and from the aorta into the left ventricle.

• **Cardiac muscle cells** are joined by gap junctions that permit action potentials to be conducted from cell to cell.

• The **myocardium** also contains specialized muscle cells that constitute the conducting system of the heart, initiating the cardiac action potentials and speeding their spread through the heart.

• **Aorta:** It is the largest artery and carries oxygenated blood from the heart to the rest of the body.

• **Superior Vena Cava:** Deoxygenated blood from the upper parts of the body returns to the heart through the superior vena cava.

• **Inferior Vena Cava:** Deoxygenated blood from the lower parts of the body returns to the heart through the inferior vena cava.

• **Pulmonary Veins:** They carry oxygenated blood from the lungs back to the heart.

• **Pulmonary Arteries:** They carry blood from the heart to the lungs to pick up oxygen.
ELECTRICAL SYSTEM OF THE HEART

1. **Sinoatrial Node (SA Node)** - Pacemaker of the heart
2. **Intra-atrial Pathway** - carries electricity through atria
3. **Internodal Pathway** - carries electricity through atria
4. **Atrioventricular Node (AV Node)** - Back up pacemaker. Slows conduction
5. **Bundle of His** - last part of conduction in atria
6. **Right Bundle Branch** - carry electricity through R. Ventricle
7. **Purkinje Fibers** - distribute electrical energy to the myocardium
8. **Left Bundle Branch** - carries electricity through L. Ventricle

HEARTBEAT COORDINATION

- Cardiac muscle cells must undergo action potentials for contraction to occur.
  - The rapid depolarization of the action potential in atrial and ventricular cells (other than those in the conducting system) is due mainly to a positive feedback increase in sodium permeability.
  - Following the initial rapid depolarization, the membrane remains depolarized (the plateau phase) almost the entire duration of the contraction because of prolonged entry of calcium into the cell through slow plasma-membrane channels.
- The SA node generates the current that leads to depolarization of all other cardiac muscle cells.
  - The SA node manifests a pacemaker potential, which brings its membrane potential to threshold and initiates an action potential.
  - The impulse spreads from the SA node throughout both atria and to the AV node, where a small delay occurs. The impulse then passes in turn into the bundle of His, right and left bundle branches, Purkinje fibers, and nonconducting-system ventricular fibers.
- Calcium, mainly released from the sarcoplasmic reticulum (SR), functions as the excitation-contraction coupler in cardiac muscle, as in skeletal muscle, by combining with troponin.
  - The major signal for calcium release from the SR is calcium entering through voltage-gated calcium channels in the plasma membrane during the action potential.
  - The amount of calcium released does not usually saturate all troponin binding sites, and so the number of active cross bridges can be increased if cytosolic calcium is increased still further.
- Cardiac muscle cannot undergo summation of contractions because it has a very long refractory period.
**Electrocardiogram (ECG or EKG)** = record of spread of electrical activity through the heart

- **P wave** = caused by atrial depolarization (contraction)
- **QRS complex** = caused by ventricular depolarization (contraction) and atrial relaxation
- **T wave** = caused by ventricular repolarization (relaxation)

**ECG** = useful in diagnosing abnormal heart rates, arrhythmias, & damage of heart muscle
MECHANICAL EVENTS OF THE CARDIAC CYCLE

- The cardiac cycle is divided into systole (ventricular contraction) and diastole (ventricular relaxation).
  - At the onset of systole, ventricular pressure rapidly exceeds atrial pressure, and the AV valves close. The aortic and pulmonary valves are not yet open, however, and so no ejection occurs during this isovolumetric ventricular contraction.
  - When ventricular pressures exceed aortic and pulmonary trunk pressures, the aortic and pulmonary valves open, and ventricular ejection of blood occurs.
  - When the ventricles relax at the beginning of diastole, the ventricular pressures fall significantly below those in the aorta and pulmonary trunk, and the aortic and pulmonary valves close. Because AV valves are also still closed, no change in ventricular volume occurs during this isovolumetric ventricular relaxation.
  - When ventricular pressures fall below the pressures in the right and the left atria, the AV valves open, and the ventricular filling phase of diastole begins.
  - Filling occurs very rapidly at first so that atrial contraction, which occurs at the very end of diastole, usually adds only a small amount of additional blood to the ventricles.
- The amount of blood in the ventricles just before systole is the end diastolic volume. The volume remaining after ejection is the end-systolic volume, and the volume ejected is the stroke volume.
- Pressure changes in the systemic and pulmonary circulations have similar patterns but the pulmonary pressures are much lower.
- The first heart sound is due to the closing of the AV valves, and the second to the closing of the aortic and pulmonary valves.
THE CARDIAC OUTPUT

- The cardiac output is the volume of blood pumped by each ventricle and equals the product of heart rate and stroke volume.
  1. Heart rate is increased by stimulation of the sympathetic nerves to the heart and by epinephrine; it is decreased by stimulation of the parasympathetic nerves to the heart.
  2. Stroke volume is increased by an increase in end-diastolic volume (the Frank-Starling mechanism) and by an increase in contractility due to sympathetic-nerve stimulation or to epinephrine.

Inherent rates for each of the three pacemaker sites

Sinus Node: 60 to 100 beats per minute
AV Junction: 40 to 60 beats per minute
Ventricles: 20 to 40 beats per minute

Relevant Formulas

*Stroke volume (SV) = milliliters of blood pumped per beat*

*Heart rate (HR) = number of beats per minute*

*Cardiac output (CO) = heart rate times stroke volume*

\[
CO = HR \times SV
\]

*Pulse pressure (PP) = the difference between systolic pressure (SP) and diastolic pressure (DP)*

\[
PP = SP - DP
\]

*Mean Arterial Pressure (MAP) (2 equations):*

  Formula 1: \[ MAP = \text{diastolic pressure} + \frac{1}{3} \text{pulse pressure} \]
  Formula 2: \[ MAP = \frac{2}{3} \text{diastolic pressure} + \frac{1}{3} \text{systolic pressure} \]

Mean arterial pressure, the primary regulated variable in the cardiovascular system, equals the product of cardiac output and total peripheral resistance. The factors that determine cardiac output and total peripheral resistance are complex and include venous pressure, inspiration, stroke volume, and nervous activity.
Flow of Blood through the Body:

vena cava → right atrium → tricuspid valve → right ventricle → pulmonary valve → pulmonary artery → pulmonary capillary bed → pulmonary veins → left atrium → bicuspid (mitrial valve) → left ventricle → aortic valve → aorta → arteries → arterioles → tissue capillaries → venules → veins → vena cava

PRESSURE, FLOW, & RESISTANCE

• The cardiovascular system consists of two circuits: the pulmonary circulation, from the right ventricle to the lungs and then to the left atrium; and the systemic circulation, from the left ventricle to all peripheral organs and tissues and then to the right atrium.
• Arteries carry blood away from the heart, and veins carry blood toward the heart.
• In the systemic circuit, the large artery leaving the left heart is the aorta, and the large veins emptying into the right heart are the superior vena cava and inferior vena cava. The analogous vessels in the pulmonary circulation are the pulmonary trunk and the four pulmonary veins.
• The microcirculation consists of the vessels between arteries and veins: the arterioles, capillaries, and venules.
• Flow between two points in the cardiovascular system is directly proportional to the pressure difference between the points and inversely proportional to the resistance: \( F = \frac{P}{R} \)
• Resistance is directly proportional to the viscosity of a fluid and to the length of the tube. It is inversely proportional to the fourth power of the tube's radius, which is the major variable controlling changes in resistance.
**THE VASCULAR SYSTEM**

**Blood Vessels**

**Arteries** – largest vessels – carry blood from the heart.

**Arterioles** – smaller version of arteries, carry blood to the capillaries

**Capillaries** – smallest vessels, one cell thick, transfer materials to and from blood

**Venules** – small version of veins, carry blood from capillaries to veins

**Veins** – carry blood back to heart, have valves to stop backflow
ARTERIES
- The arteries function as low-resistance conduits and as pressure reservoirs for maintaining blood flow to the tissues during ventricular relaxation.
- The difference between maximal arterial pressure (systolic pressure) and minimal arterial pressure (diastolic pressure) during a cardiac cycle is the pulse pressure.
- Mean arterial pressure can be estimated as diastolic pressure plus one-third pulse pressure.

ARTERIOLES
- Arterioles, the dominant site of resistance to flow in the vascular system, play major roles in determining mean arterial pressure and in distributing flows to the various organs and tissues.
- Arteriolar resistance is determined by local factors and by reflex neural and hormonal input.
  - Local factors that change with the degree of metabolic activity cause the arteriolar vasodilation and increased flow of active hyperemia.
  - Flow autoregulation, a change in resistance that maintains flow constant in the face of a change in arterial blood pressure, is due to local metabolic factors and to arteriolar myogenic responses to stretch.
  - The sympathetic nerves are the only innervation of most arterioles and cause vasoconstriction via alpha-adrenergic receptors. In certain cases noncholinergic, non-adrenergic neurons that release nitric oxide or other noncholinergic vasodilators also innervate blood vessels.
  - Epinephrine causes vasoconstriction or vasodilation, depending on the proportion of alpha- and beta-adrenergic receptors in the organ.
  - Angiotensin II and vasopressin cause vasoconstriction.
  - Some chemical inputs act by stimulating endothelial cells to release vasodilator or vasoconstrictor paracrine agents, which then act on adjacent smooth muscle. These paracrine agents include the vasodilators nitric oxide (endothelium-derived relaxing factor) and prostacyclin, and the vasoconstrictor endothelin-1.
- Arteriolar control in specific organs varies considerably, including influences from metabolic factors, physical forces, autoregulation, and sympathetic nerves.
**CAPILLARIES**

- Capillaries are the site of exchange of nutrients and waste products between blood and tissues.
- Blood flows through the capillaries more slowly than in any other part of the vascular system because of the huge cross-sectional area of the capillaries.
- Capillary blood flow is determined by the resistance of the arterioles supplying the capillaries and by the number of open precapillary sphincters.
- Diffusion is the mechanism by which nutrients and metabolic end-products exchange between capillary plasma and interstitial fluid.
  - Lipid-soluble substances move across the entire endothelial wall, whereas ions and polar molecules move through water-filled intercellular clefts or fused-vesicle channels.
  - Plasma proteins move across most capillaries only very slowly, either by diffusion through water-filled channels or by vesicle transport.
  - The diffusion gradient for a substance across capillaries arises as a result of cell utilization production of the substance. Increased metabolism increases the diffusion gradient and increases the rate of diffusion.
- Bulk flow of protein-free plasma or interstitial fluid across capillaries determines the distribution of extracellular fluid between these two fluid compartments.
  - Filtration from plasma to interstitial fluid is favored by the hydrostatic pressure difference between the capillary and the interstitial fluid. Absorption from interstitial fluid to plasma is favored by the plasma protein concentration difference between the plasma and the interstitial fluid.
  - Filtration and absorption do not change the concentrations of crystalloids in the plasma and interstitial fluid because these substances move together with water.
  - There is normally a small excess of filtration over absorption.

**VEINS**

Veins serve as low-resistance conduits for venous return.
Veins are very compliant and contain most of the blood in the vascular system.
Their diameters are reflexively altered by sympathetically-mediated vasoconstriction so as to maintain venous pressure and venous return.
The skeletal-muscle pump and respiratory pump increase venous pressure locally and enhance venous return. Venous valves permit the pressure to produce only flow toward the heart.

**Blood – Functions**

- Transportation:
  - oxygen & carbon dioxide
  - nutrients
  - waste products (metabolic wastes, excessive water, & ions)
- Regulation - hormones & heat (to regulate body temperature)
- Protection - clotting mechanism protects against blood loss & leucocytes provide immunity against infection.
LYMPH VESSELS AND LYMPH CIRCULATION

- Lymph vessels are thin walled, valved structures that carry lymph.
- Lymph is not under pressure and is propelled in a passive fashion.
- Fluid that leaks from the vascular system is returned to general circulation via lymphatic vessels.
- Lymph vessels act as a reservoir for plasma and other substances including cells that leaked from the vascular system.
- The lymphatic system provides a one-way route for movement of interstitial fluid to the cardiovascular system.
- Lymph returns the excess fluid filtered from the blood vessel capillaries, as well as the protein that leaks out of the blood vessel capillaries.
- Lymph flow is driven mainly by contraction of smooth muscle in the lymphatic vessels but also by the skeletal-muscle pump and the respiratory pump.

**LYMPH CIRCULATION**

Interstitial fluid → **Lymph** → Lymph capillary → Afferent lymph vessel → Lymph node → Efferent lymph vessel → Lymph trunk → Lymph duct {Right lymphatic duct and Thoracic duct (left side)} → Subclavian vein (right and left) → **Blood** → Interstitial fluid
CARDIOVASCULAR PATTERNS

HEMORRHAGE AND OTHER CAUSES OF HYPOTENSION

• Hypotension can be caused by loss of body fluids, by strong emotion, and by liberation of vasodilator chemicals.
• Shock is any situation in which blood flow to the tissues is low enough to cause damage to them.

THE UPRIGHT POSTURE

• In the upright posture, gravity acting upon unbroken columns of blood reduces venous return by increasing vascular pressures in the veins and capillaries in the limbs.
• The increased venous pressure distends the veins, causing venous pooling, and the increased capillary pressure causes increased filtration out of the capillaries.
• These effects are minimized by contraction of the skeletal muscles in the legs.

EXERCISE

• The changes are due to active hyperemia in the exercising skeletal muscles and heart, to increased sympathetic outflow to the heart, arterioles, and veins, and to decreased parasympathetic outflow to the heart.
• The increase in cardiac output depends not only on the autonomic influences on the heart but on factors that help increase venous return.
Training can increase a person's maximal oxygen consumption by increasing maximal stroke volume and hence cardiac output.

Exercise decreases the risk of atherosclerosis; it decreases BP or causes a slower rise in BP.

Exercise decreases LDLs, decreases cholesterol, and increases HDLs.

**HYPERTENSION**

- Hypertension is usually due to increased total peripheral resistance resulting from increased arteriolar vasoconstriction.
- More than 95 percent of hypertension is termed primary in that the cause of the increased arteriolar vasoconstriction is unknown.

**HEART FAILURE**

- Heart failure can occur as a result of diastolic dysfunction or systolic dysfunction; in both cases cardiac output becomes inadequate.
- This leads to fluid retention by the kidneys and formation of edema because of increased capillary pressure.
- Pulmonary edema can occur when the left ventricle fails.

**CORONARY ARTERY DISEASE**

- Insufficient coronary blood flow can cause damage to the heart.
- Acute death from a heart attack is usually due to ventricular fibrillation.
- The major cause of reduced coronary blood flow is atherosclerosis, an occlusive disease of arteries.
- Persons may suffer intermittent attacks of angina pectoris without actually suffering a heart attack at the time of the pain.
- Atherosclerosis can also cause strokes and symptoms of inadequate blood flow in other areas.

**DISORDERS OF THE VASCULAR SYSTEM**

- **Arteriosclerosis** - a general term describing any hardening (and loss of elasticity) of medium or large arteries
- **Atherosclerosis** - Common form of arteriosclerosis-cholesterol, lipid, calcium deposits in the walls of the arteries
- **High Cholesterol** - elevated level of cholesterol. can cause deposits on walls of blood vessels Increases risk of Coronary Heart Disease
- **high blood pressure** – hypertension
- **Stroke** - Sudden loss of neurological function caused by vascular injury to the brain
- **Myocardial Infarction** - loss of living heart muscle as a result of coronary occlusion
- **Congestive Heart Failure** - the heart's function as a pump is inadequate to deliver oxygen rich blood to the body due to weaken heart muscle, stiffening of heart muscle or deseases that demand oxygen beyond the capacity of the heart to deliver oxygen-rich blood. It is treated with medications like ACE inhibitors, beta blockers, and diuretics as well as lifestyle changes. Surgery may also be used.
- **Atrial Fibrillation** - Irregular and often rapid beats of the atria. Treatment involves medications to slow heart rate, restore and maintain normal rhythm, and prevent clot formation
- **Bradyarrhythmia** – slowness of heart rate, usually fewer than 60 beats per minute in resting adults. Treatment vary based on the underlying cause of the condition. They may include medications, pacemaker, surgery, or even in severe cases a heart transplant
- **Tachycardia** – rapid resting heart rate, more than 100 beats per minute. Treatment varies based on underlying causes may include lifestyle changes, medications to slow heart, surgery for pacemaker or defibrillator
IMMUNE SYSTEM

The body’s defense against:

- disease causing organisms or infectious agents
- malfunctioning cells or abnormal body cells as cancer
- foreign cells or particles

Basic Immunity

- Depends on the ability of the immune system to distinguish between *self* and *non-self* molecules
- *Self* molecules are those components of an organism's body that can be distinguished from foreign substances by the immune system
  - *Autoimmunity* is an immune reaction against self molecules (causes various diseases)
- *Non-self* molecules are those recognized as foreign molecules
  - One class of non-self molecules are called *antigens* (short for *antibody generators*) and are defined as substances that bind to specific immune receptors and elicit an immune response

Immune System Components:

- **specific cells** - lymphocytes, macrophages, etc., originate from precursor cells in the bone marrow and patrol tissues by circulating in either the blood or lymphatics, migrating into connective tissue or collecting in immune organs
- **lymphatic organs** - thymus, spleen, tonsils, lymph nodes
- **diffuse lymphatic tissue** - collections of lymphocytes and other immune cells dispersed in the lining of the digestive and respiratory tracts and in the skin
Organs of the Lymphatic System Aid Immunity

Lymph Nodes
- Small (1-25 mm) round structures found at points along lymphatic vessels that have fibrous connective tissue capsule with incoming and outgoing lymphatic vessels
- Each nodule contains sinus filled with lymphocytes and macrophages
- They occur in regions: auxiliary nodes in armpits and inguinal nodes in groin
- Occur singly or in groups of nodules:
  - **Tonsils** are located in back of mouth on either side
  - **Adenoids** on posterior wall above border of soft palate
  - **Peyer’s patches** found within intestinal wall

Spleen
- Located in upper left abdominal cavity just beneath diaphragm.
- Structure similar to lymph node; outer connective tissue divides organ into lobules with sinuses filled with blood
- Blood vessels of spleen can expand so spleen functions as blood reservoir making blood available in times of low pressure or oxygen need
- **Red pulp** containing RBCs, lymphocytes, and macrophages; functions to remove bacteria and worn-out red blood cells
- **White pulp** contains mostly lymphocytes
- Both help to purify the blood

Thymus
- Located along trachea behind sternum in upper thorax
- Larger in children; disappears in old age
- Divided into lobules where T lymphocytes mature
- Interior (medulla) of lobule secretes thymosin thought to aid T cells to mature

Red Bone Marrow
- Site of origin of all types of blood cells
- Five types of white blood cells (WBCs) function in immunity
- Stem cells continuously divide to produce cells that differentiate into various blood cells
- Most bones of children have red blood marrow
- In adult, red marrow is found in the skull, sternum, ribs, clavicle, spinal column, femur, and humerus
- Red blood marrow has network of connective tissue where reticular cells produce reticular fibers; these plus stem cells fill sinuses; differentiated blood cells enter bloodstream at these sinuses

Immune tissue associated with various organs:
- **GALT**—gut-associated lymphatic tissue; comprised of lymphoid tissue (lymph nodules) in the intestinal wall containing lymphocytes, plasma cells and macrophages.
• The digestive tract is a very important part of the immune system and the intestine possesses the largest mass of lymphoid tissue in the body.
Lymphoid tissue in the gut comprises the following:

- **Tonsils** (Waldeyer's ring)
- **Adenoids** (Pharyngeal tonsils)
- **Peyer's patches** – lymphoid follicles in wall of small intestine
- Lymphoid aggregates in the appendix and large intestine
- Lymphoid tissue accumulating with age in the stomach
- Small lymphoid aggregates in the esophagus
- Diffusely distributed lymphoid cells and plasma cells in lining of the gut

**MALT**—*mucosa-associated* lymphatic tissue; lymphoid tissue associated with the mucosa of the female reproductive tract, respiratory tract, etc.

**SALT**—*skin-associated* lymphatic tissue; lymphoid tissue associated with the dermis of the skin.

**Plan of Protection – Immunity** is the ability to defend against infectious agents, foreign cells and abnormal cells eg. cancerous cells

- **1st Line of defense** – Block entry
- **2nd Line of Defense** – Fight Local Infections
- **3rd Line of Defense** – Combat Major Infections

**Nonspecific and Specific Defense Systems** - work together to coordinate their responses

**Nonspecific (Innate) Response** - responds quickly, fights all invaders and consists of:

- **First line of defense** – intact skin and mucosae and secretions of skin and mucous membranes prevent entry of microorganisms
- **Second line of defense** – phagocytic white blood cells, antimicrobial proteins, and other cells
- Inflammation response process is key
- Inhibit invaders from spreading throughout the body

**Specific Response (Adaptive) Response** - takes longer to react, works on specific types of invaders which it identifies and targets for destruction

- **Third line of defense** – mounts attack against particular foreign substances
- Lymphocytes and Antibodies
- Works in conjunction with the nonspecific or innate system

**Nonspecific (Innate) Response – fight all invaders**

- **First line of defense** – Non specific barriers to block entry
  - Skin provides an impervious barrier – physical or mechanical barrier
  - Mucous membranes line the entrances of the body and produce mucus which traps foreign particles and directs them out of the body – physical or mechanical barrier
  - Nasal hairs trap dirt and dust while microscopic cilia line some mucous membranes helping to trap foreign particles
  - Gastric juice, vaginal secretions and urine are acidic fluids which provide protection
  - Natural flora (harmless bacteria) in the intestine and vagina prevent pathogens from growing
  - Tears, saliva and sweat possess some anti-bacterial properties
  - Cerumen or ear wax protects the ear canal by trapping dirt and dust particles
**Second line of defense** – Fight local infection with Inflammation Process
- Begins as soon as the first line of defense is violated
- The response is a non-specific, immediate, maximal response to the presence of any foreign organism or substance and involves no immunological memory
- **Phagocytosis** is an important feature of cellular innate immunity performed by cells called 'phagocytes' that engulf, or eat, pathogens or particles
- **Phagocytes** – types of immune cells involved in phagocytosis - Produced throughout life by the bone marrow
- **Scavengers** – remove dead cells and microorganisms
- **Complement proteins** activate other proteins in a domino fashion resulting in a cascade of reactions which attract phagocytes to the site of the invasion, bind to the surface of microbes to insure WBC’s can phagocytize the microbe and produce holes in the bacterial cell walls and membranes
- The **Inflammation Process** releases *histamines* causing redness, pain, swelling, and heat
Phagocytes and their Relatives

**Neutrophils** - kill bacteria  
- 60% of WBCs  
- ‘Patrol tissues’ as they squeeze out of the capillaries  
- Large numbers are released during infections  
- Short lived – die after digesting bacteria  
- Dead neutrophils make up a large proportion of pus

**Monocytes** – are chief phagocytes found in the blood  
- Made in bone marrow as monocytes and the circulate in the blood for 1-2 days before being called macrophages once they reach organs.

**Macrophages** - Found in the organs, not the blood  
- Larger than neutrophils and long lived - involved in phagocytosis, release interferon and interleukin (which stimulates production of cells of the Specific Defense System)  
- Macrophages also act as scavengers, ridding the body of worn-out cells and other debris by ingesting cellular debris, foreign material, bacteria and fungi  
- Versatile cells that reside within tissues and produce a wide array of chemicals including enzymes, complement proteins, and regulatory factors such as interleukin 1  
- **Antigen-presenting cells** that activate the adaptive immune system they display antigens from the pathogens to the lymphocytes.

**Basophils** – are capable of ingesting foreign particles and produce heparin and histamine and which induce inflammation, are often associated with asthma and allergies

**Mast cells** reside in connective tissues and mucous membranes, and regulate the inflammatory response. They are most often associated with allergy and anaphylaxis: for example, they release histamine – this is why anti-histamines help allergic reactions

**Dendritic cells** are phagocytes in tissues that are in contact with the external environment  
- Located mainly in the skin, nose, lungs, stomach, and intestines (are in no way connected to the nervous system)  
- Dendritic cells serve as a link between the innate and adaptive immune systems, as they present antigens to T cells, one of the key cell types of the adaptive immune system

**Eosinophils** – weakly phagocytic of pathogens kill parasitic worms

**NK cells (natural killer)** - used to combat tumor cells or virus-infected cells  
- A class of lymphocytes which attack and induce cells to kill themselves (self-induced apoptosis)  
- **They complement both specific and nonspecific defenses**  
- May also attack some tumor cells  
- Also secrete interferons, proteins produced by virus infected cells which binds to receptors of non-infected cells, causing these cells to produce a substance that will interfere with viral reproduction and activate macrophages and other immune cells
Most infections never make it past the first and second level of defense.
Specific (Adaptive) Response – work on specific types of invaders which it identifies and targets for destruction - takes longer to react

- The response is directed at specific targets and is not restricted to initial site of invasion/infection
- Lag time occurs between exposure and maximal response
- The adaptive immune system allows for a stronger immune response as well as immunological memory, where each pathogen is "remembered" by its signature antigen
- **Antigens** are proteins or carbohydrate chain of a glycoprotein within a plasma membrane which the body recognizes as “nonself”
- The specific immune response is antigen-specific and requires the recognition of specific “non-self” antigens during a process called **antigen presentation**
- Antigen specificity allows for the generation of responses that are tailored to specific pathogens or pathogen-infected cells
- The ability to mount these tailored responses is maintained in the body by **memory cells**
- Should a pathogen infect the body more than once, these specific memory cells are used to quickly eliminate

**Third line of defense** – mounts attack against particular foreign substances antigens throughout the body
Components of the Specific Defense System

- Identify, destroy, remember
- **Cellular components** – B cells and T cells - lymphocytes which are white blood cells
- **Humoral (antibody-mediated response)** defends against extracellular pathogens by binding to antigens and making them easier targets for phagocytes and complement proteins
- **Cell mediated immune response** – defends against intracellular pathogens and cancer by binding to and lyzing the infected cells or cancer cells

**Humoral or antibody-mediated response** – termed anti-body mediated because B cells produce antibodies and Humoral because antibodies are released into the bloodstream

- **B cells** - are produced and mature in the bone marrow – they possess a protein on the B cells outer surface known as the B cell receptor (BCR) which allows them to bind to a specific antigen
  - **Plasma B cells** also known as plasma cells, plasmocytes, and effector B cells– they produce antibodies
  - **Memory B cells** – ready for the next invasion
- B cell comes into contact with antigen on microbe
- it attaches to the antigen and becomes an antigen-presenting B cell with antigen-MHC complex
- Helper T cell that binds to the complex
- Helper T secretes interleukin that stimulates mitosis in B cells so they multiply
- Some B cells mature into **plasma cells** and other become **memory cells**
- The **plasma cells** produce **antibodies** also called **immunoglobins** – proteins which attach to the antigens
- Antibodies can clump microbes for destruction, mark microbes for destruction by phagocytes, activate complement proteins that rupture/lyse microbe cell membranes or infected host cells

**Antibody Targets and Functions**

- **Complement fixation**: Foreign cells are tagged for destruction by phagocytes and complement fixation Immune complex formation exposes a complement binding site on the C region of the Ig and Complement fixation results in cell lysis.
- **Neutralization**: immune complex formation blocks specific sites on virus or toxin & prohibit binding to tissues (antibodies block active sites on viruses and bacterial toxins so they can no longer bind to receptor cites on tissue cells and cause injury)
- **Agglutination**: cells are cross-linked by immune complexes & clump together
- **Precipitation**: soluble molecules (such as toxins) are cross-linked, become insoluble, & precipitate out of the solution
- **Inflammation & phagocytosis** prompted by debris
Antigen-Antibody Complex – Functions

IgA
Antibodies are dimmers – contain two Y shaped structures. Found in mucosal areas, such as the gut, respiratory tract and urogenital tract. Also found in saliva, tears, and breast milk. They attack microbes and prevent colonization by pathogens before they reach the blood stream so it is most important antibody in local immunity.

IgD
Functions mainly as an antigen receptor on B cells that have not been exposed to antigens. It has been shown to activate basophils and mast cells to produce antimicrobial factors.

IgG
In its four forms, provides the majority of antibody-based immunity against invading pathogens. It makes up about 75% of all human antibodies and is the body’s major defense against bacteria. The only antibody capable of crossing the placenta to give passive immunity to fetus. It is the most versatile of antibodies because it carries out functions of the other antibodies as well.

IgE
Binds to allergens and triggers histamine release from mast cells and basophils, and is involved in allergy. Also protects against parasitic worms.

IgM
Expressed on the surface of B cells and in a secreted form with very high avidity. Eliminates pathogens in the early stages of B cell mediated (humoral) immunity before there is sufficient IgG.

Human Antibody Classes (Isotopes) & Their Functions
• **Memory B cells** are stimulated to multiply but do not differentiate into plasma cells; they provide the immune system with long-lasting memory.
**Cell-mediated immune response (within the cell)** - does not involve antibodies but rather involves the activation of phagocytes, antigen-specific cytotoxic T-lymphocytes, and the release of various cytokines in response to an antigen

- **T cells** – are produced in bone marrow but mature in the thymus gland. T cells contribute to immune defenses in two major ways: some direct and regulate immune responses; others directly attack infected or cancerous cells.

  - **Helper T cells** – assist other white blood cells in the immunologic process including maturation of B cells into plasma cells and memory B cells and activation of T cells and macrophages.
  - **Cytotoxic T cells** – sometimes called killer T cells destroy virally infected cells and tumor cells and play a role in transplant rejection.
  - **Memory T cells** – antigen-specific T cells that persist long-term after an infection has been resolved that will provide memory of past infection and earlier defense for new infection.
  - **Regulatory T cells** – formally called suppressor T cells maintain balance by shutting down T-cell mediated immunity toward the end of an immune reaction – they are a self check built into the immune system to prevent excessive reactions. They play a key role in prevent autoimmunity.

- **Antigens** are proteins or carbohydrate chain of a glycolprotein within in plasma membrane that the body recognizes as **nonself**

- The antigens on the cell membrane of the target or invader cell are recognized.

- MHC (a protein marker on body’s cell) binds to the antigen of the foreign cell forming an MHC complex.

- The MHC complex alerts the T cells about an invasion, macrophage, virgin B cell or cell infected by a microbe that displays the antigen on its membrane.

- The MHC complex activates the T cell receptor and the T cell secretes cytokines.

- The cytokines spur the production of more T cells.

- Some T cells mature into **Cytotoxic T cells** which attack and destroy cells infested with viruses or cancerous cells.

- **Cytotoxic T cells** or **Killer T cells (NKT)** share the properties of both T cells and natural killer (NK) cells. They are T cells with some of the cell-surface molecules of NK cells. The kills cancer cells, cells that are infected (particularly with viruses), or cells that are damaged in other ways. -They have storage granules containing perforin and granzymes (proteins which perforates the cell membrane of the cell to be destroyed allowing water & salts to enter and rupture the cell). They and are implicated in disease progression of asthma and in protecting against some autoimmune diseases, graft rejection, and malignant tumors.
• Other T cells mature into **Helper T cells** which regulate immunity by increasing the response of other immune cells

• **Helper T cells** secrete **cytokines** (messenger molecules) when exposed to antigens that causes more Helper T cells to be cloned, B cells to make antibodies and macrophages to destroy cells by phagocytosis

• AID’s virus attacks to Helper T cells so it inactivates the immune system

• **Regulatory T cells** will shut down T-cell mediated immunity when things are under control

• **Memory T** cells persist sometimes for life and protect in case of re-infection

**Primary and Secondary Immunity**

**Primary Immunity** – When first exposed to an antigen, the body usually takes several days to respond and build up a large supply of antibodies. The number of antibodies will peak and then begin to decline.

**Secondary Immunity** – The production of Memory B or T Cells allows the cell to recognize the antigen much quicker if it is introduced again so the body will often be able to destroy the invading antigen before its numbers become great enough to initiate symptoms. Memory B cells rapidly divide and develop into plasma cells and the antibody levels in the body rise quickly and reach greater numbers. Active immunity lasts as long as clones of memory B and memory T cells are present.
Sources of Specific Immunity – resistance to a disease causing organism or harmful substance

- **Inborn Immunity** – Immunity for certain diseases is inherited
- **Acquired Immunity** – immunity can be acquired through infection or artificially by medical intervention

### Naturally acquired
- **Active Exposure** – infection; contact with pathogen
- **Passive Exposure** – antibodies pass from mother to fetus via placenta; or to infant in her milk

### Artificially acquired
- **Active Exposure** – injection of causative agent that has been weakened or killed such as a vaccine and you develop your own antibodies – Immunity is long lived
- **Passive Exposure** – injection of protective gamma globulin serum containing antibodies that were developed by someone else’s immune system – This immunity is short-lived but immediate so it prevents full infection from developing in patients just exposed to serious agents when there is not time to develop active immunity from immunization

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Result of an initial immunization and a booster injection
- **Passive Exposure** - injection of protective gamma globulin serum containing antibodies that were developed by someone else’s immune system - This immunity is short-lived but immediate so it prevents full infection from developing in patients just exposed to serious agents when there is not time to develop active immunity from immunization
Role of Antibiotics and Antivirals

- **Antibiotics or antibacterials** – group of medications used to kill bacteria by preventing them from dividing.
  There is concern about the extensive use of antibiotics resulting in resistant forms of bacteria and “superbugs”.
- **Antivirals** – group of medications used to treat viral infections but they cannot destroy the virus. Rather they inhibit the virus from reproducing and developing.

Cultured Antibodies

- **Monoclonal antibodies** – cloning of many copies of the same antibody which can be useful in fighting diseases because they can be designed specifically to only target a certain antigen, such as one that is found on cancer cells.

Immunity Disorders - the Immune System can be under productive when it fails to recognize abnormal cells as cancerous cells or it can be over protective and cause other types of difficulties

- **Allergies** – hypersensitivity of the immune system to relatively harmless environmental antigens - the immune system reacts to an outside substance that it normally would ignore - allergy types (food, dust, mold, seasonal), symptoms and signs (skin rash, itching, red bumps, sneezing).

- **Asthma** - an obstructive pulmonary disorder characterized by recurring spasms of muscles in bronchial walls accompanied by edema and mucus production which make breathing difficult - it causes the airways of the lungs to swell and narrow, leading to wheezing, shortness of breath, chest tightness, and coughing.
  *Extrinsic, or allergic asthma*, is more common (90% of all cases) and typically develops in childhood
  *Intrinsic asthma* represents about 10% of all cases. It usually develops after the age of 30 and is not typically associated with allergies.
  Treatment – inhaler with medications as albuterol to open airways

- **Autoimmune Disorder** - a condition that occurs when the immune system mistakenly attacks and destroys healthy body tissue - more than 80 different types - the immune system can’t tell the difference between healthy body tissue and antigens. The result is an immune response that destroys normal body tissues. This response is a hypersensitivity reaction similar to the response in allergic conditions - Examples of autoimmune (or immune-related) disorders include Addison's disease, Celiac disease - (gluten-sensitive enteropathy), Graves disease, Hashimoto's thyroiditis, Multiple sclerosis, Myasthenia gravis, Pernicious anemia, Rheumatoid arthritis, Systemic lupus erythematosus, Type I diabetes
- **AIDS** - *(acquired immune deficiency syndrome)* is the final stage of HIV disease, which causes severe damage to the immune system—caused by infection with **human immunodeficiency virus (HIV)**. HIV infects vital cells in the human immune system such as helper T cells, macrophages, and dendrite cells.

- **Tissue Rejection – Foreign MHC Proteins** - human immune system is designed to attack anything it doesn't recognize—white blood cells recognize the body's tissues by looking for a set of antigens on the surface of each cell.
  - The most important of these make up the **major histocompatibility complex (MHC)**.
  - Self-antigens - Major-histocompatibility complex (MHC) protein markers - Two groups
    - Class I MHC markers – displayed on all cells except RBCs
    - Class II MHC markers – displayed on mature B-cells, some T-cells, and antigen-presenting cell
  - When your immune system finds cells in your body that don't show the right MHC proteins (foreign MHC proteins), it tries to destroy them—Doctors test the MHC of potential organ donors to find the best match.

- **Blood typing problems** – ABO System
  The surface membranes of RBCs carry proteins that act as antigens in some recipients.
  - **Type A** blood has A antigens only.
  - **Type B** blood has B antigens only.
  - **Type AB** blood has both A and B antigens present.
  - **Type O** blood lacks both A and B antigens.
  - Blood plasma contains antibodies to the blood types not present.
  - Exposure to foreign blood antigens results in agglutination or clumping of RBCs, prevents circulation of blood, and the RBCs burst.

- **Rh System problems**
  - Another important antigen used in matching blood types.
  - Persons with Rh factor on RBC membrane are Rh positive; Rh negative lack the Rh factor protein.
  - Rh negative individuals do not automatically have antibodies to Rh factor but develop immunity when exposed to it.
  - **Hemolytic disease of the newborn (HDN)** can occur when mother is Rh negative and baby is Rh positive.
    - Mother is not exposed to infants blood unless baby's RBCs leak across placenta; otherwise mother is only "inoculated" with small amount of baby's blood (and Rh protein) at birth.
    - Mother builds up antibodies that are small enough to pass placenta and can destroy baby's RBC; mother receives a booster at each baby's birth; therefore danger to successive infants grows.
    - Problem is solved by giving the mother anti-Rh antibodies, usually after baby's birth, that attack any of baby's RBCs left in mother's blood before mother can produce antibodies.
The Integumentary System

The integumentary system consists of the skin, hair, nails, the subcutaneous tissue below the skin, and assorted glands.

Functions of the Integumentary System
- Protection against injury and infection
- Regulates body temperature
- Sensory perception
- Regulates water loss
- Chemical synthesis

Protection – covers and protects the entire body against injury and infection

Physical barriers - continuity of the skin and hardness of keratinized cells
- Due to the skin’s physical characteristics such as the keratinized cells and waterproofing properties of the glycolipids.
- Keratin helps waterproof the skin and protects from abrasions and bacteria
- Glycolipids prevent diffusion of water and water-soluble substances between cells
- Continuity prevents bacterial invasion
- Substances that are able to penetrate the skin:
  - Lipid-soluble substances (i.e., oxygen, carbon dioxide, steroids, and fat-soluble vitamins)
  - Oleoresins of certain plants (ex. poison ivy and poison oak)
  - Organic solvents (ex. acetone, dry cleaning fluid, and paint thinner)
  - Salts of heavy metals (ex. lead, mercury, and nickel)
  - Topical medications as motion sickness patch
- Penetration enhancers

Chemical barriers - (skin secretion and melanin)
- Skin secretions such as sebum, human defensins (antimicrobial peptides), acid mantle of the skin retards bacteria growth and/or kills them
- Melanin provides protection from UV damage
• Skin secretions (acid mantle)
• Low pH and sebum slow bacterial growth on skin surface
• Human defensin – natural antibiotic
• Cathelicidins – proteins that prevent Strep A infection in wounded skin
• Melanin – chemical pigment that prevents UV damage

**Biological Barriers**
• Langerhans’ cells, macrophages, and DNA
• Langerhans’ cells in epidermis present antigens to lymphocytes
• Dermal macrophages (2nd line of defense) – attack bacteria and viruses that have penetrated the epidermis
• Langerhan’s cells and macrophages present in the skin helps activate the body’s immune system.
• DNA structure – the electrons in DNA absorb UV radiation and converts it to heat

**Temperature regulation**
• Production of copious amounts of sweat to dissipate heat
• When body temperature rises and is hotter than the external environment the blood vessels in the dermal area dilates and sweat glands are stimulated into activity.
• Evaporation of the sweat from skin’s surface helps dissipate heat from the body.
• Constriction of dermal blood vessels to retain heat
• When it is cold outside, the dermal blood vessels constrict and pull the blood away from the skin and keeps it close to the body core to protect crucial internal organs.

**Cutaneous Sensations** - cutaneous sensory receptors (see - nervous system)
• Meissner’s corpuscles: light touch
• Merkel discs: light touch
• Pascinian receptors – lies in deeper dermis/hypodermis & detect deep pressure contacts
• Hair root plexus: sensations from movement of hairs
• Hair follicle receptors – movement across the surface of the skin
• Bare nerve endings: painful stimuli (chemicals, heat, cold)

**Excretion/Absorption**
• Elimination of nitrogen-containing wastes (ammonia, urea, uric acid), sodium chloride, and water. It regulates water loss

**Metabolic Functions**
• Synthesis of Vitamin D – increases calcium absorption in the body
• Vitamin D is a fat-soluble vitamin that may be absorbed from the intestines or may be produced by the skin when the skin is exposed to ultraviolet light (particularly sunlight). It is converted to its active form by the body in 2 steps, occurring first in the liver and completed in the kidneys. In its active form, vitamin D acts as a hormone to regulate calcium absorption from the intestine and to regulate levels of calcium and phosphate in the bones. Vitamin D deficiency causes Rickets
• When the body is deficient in vitamin D, it is unable to properly regulate calcium and phosphate levels. If the blood levels of these minerals becomes low, the other body hormones may stimulate release of calcium and phosphate from the bones to the bloodstream.
• Chemical conversion of many substances
• Blood Reservoir – preferential shunting of blood as needed
Types of Membranes - thin sheet-like structures that protect parts of the body

Serous Membranes
- Line body cavities that have no opening to the outside
- Secrete a watery fluid called serous fluid that lubricates surfaces.

Mucous Membranes
- Line cavities and tubes that open to the outside

Synovial Membranes
- Form the inner lining of joint cavities
- Secrete a thick fluid called synovial fluid

Cutaneous Membrane – also known as skin
Characteristics of Skin

- The integument covers the entire body and is the largest organ ~ 2 meters and heaviest organ 16% of body mass of the body.
- Composed of the epidermis and dermis
- Pliable, yet durable
- Thickness: 1.5 to 6.0 mm

Types of Skin

**Thin** - 1-2 mm on most of the body and 0.5 mm in eyelids
- Hairy
- Covers all parts of the body *except* palms of hands and soles of feet
- Thin epidermis and lacks stratum lucidum
- Lacks dermal papillae
- Has more sebaceous glands
- Fewer sweat glands, sensory receptors than thick skin

**Thick** - up to 6 mm thick on palms of hands and soles of feet
- Hairless
- Covers palms of hands and soles of feet
- Thick epidermis and a distinct stratum lucidum
- Epidermal ridges are present due to well-developed, numerous dermal papillae.
- Lacks sebaceous glands, has more sweat glands
- Sense receptors are also more densely packed.
**Epidermis**

**Types of Cells**

**Keratinocytes**
- 90% of epidermal cells are keratinized
- contains keratin (fibrous protein)
- protects and waterproofs the skin

**Melanocytes**
- 8% of the epidermal cells
- produces melanin
- contributes to skin color and absorbs UV light

**Langerhans cells**
- Arise from red bone marrow and migrate to the epidermis
- Constitute small portion of epidermal cells
- Participate in immune responses
- Easily damaged by UV light

**Merkel cells**
- Least numerous of the epidermal cells
- Found in the deepest layer of the epidermis
- Along with tactile discs, they function in sensation of touch
Layers of epidermis

**Stratum corneum**
- 25-30 layers of dead flat keratinocytes
- Shed continuously and replaced by cells from the deeper strata
- Serves as a water, microbe, injury barrier

**Stratum lucidum**
- Present only in thick skin
- 3-5 layers of clear, flat, dead keratinocytes
- Dense packed intermediate filaments
- Thick plasma membranes

**Stratum granulosum**
- Located above the stratum spinosum
- 3-5 layers of flattened keratinocytes undergoing apoptosis
- Organelles begin to disintegrate becomes non-living cells
- Marks the transition between deeper metabolically active strata and the dead cells of the superficial strata.
- Contains lamellar granules
- Secretes lipid-rich secretion that acts as a water sealant

**Stratum spinosum**
- Located above the stratum basale
- 8-10 layers of keratinocytes
- Some cells retain their ability for cell division
- Cells have spinelike projections (bundles of filaments of the cytoskeleton) tightly joins cells to each other.
- Provides skin both strength and flexibility

**Stratum basale**
- Also referred to as stratum germinatum because this is where new cells are formed
- Deepest layer of the epidermis
- Single row of cuboidal or columnar keratinocytes

Growth of epidermis

- Newly formed cells in the stratum basale undergo keratinazation as they are pushed to the surface.
- They accumulate more keratin during the process
- Then they undergo apoptosis
- Eventually they slough off and are replaced
- The process takes about 4 weeks
- Rate of cell division in the stratum basale increases during injury
**Dermis**
- Second deepest part of the skin
- Blood vessels, nerves, glands and hair follicles are embedded here
- Composed mainly of connective tissues (collagen and elastic fibers)
- Collagen fibers make up 70% of the dermis and give structural toughness and strength. Elastin fibers are loosely arranged in all directions and give elasticity to the skin
- Has two layers – Papillary Layer and Epidermal layer.

**Papillary layer**
- Superficial portion of the dermis
- Consist of areolar connective tissue containing elastic fiber
- Surface area is increased due to projections called dermal papillae which contains capillaries or tactile receptors
- Epidermal ridges conforms to the dermal papillae

**Reticular layer**
- Deeper portion of the dermis
- Consist of dense irregular connective tissue containing collagen/elastic fibers
- Provides skin with strength and elasticity
- Contains hair follicles, nerves, sebaceous and sudoriferous glands

**Hypodermis** – (subcutaneous) Attaches the skin to underlying organs and tissues
- Not part of the skin - lies below the dermis
- Contains connective tissue and adipose tissues (subcutaneous fat) for insulation
- Infants and elderly have less of this than adults and are therefore more sensitive to cold

**Skin Appearances**
- Epidermis appears translucent when there is little melanin or carotene
- **White skin** appears pink to red depending on amount and oxygen content of blood moving in the capillaries of the dermis.
- **Albinism** is an inherited trait where a person can’t produce melanin. The have melanocytes but are unable to make tyrosinase (the enzyme which initiates melanin production) so melanin is missing in their hair, eyes, and skin.
- Skin color as diagnostic clues for medical conditions
  - Cyanotic (cyan = blue) Ex: someone who has stopped breathing and the skin appears bluish
  - Jaundice (jaund = yellow) - Buildup of bilirubin (yellow pigment) in the blood gives a yellowish appearance of eyes and skin indicating liver disease. Bilirubin is produced when red blood cells get old and are broken down by the body. Normally it is processed in the liver and then deposited in the intestine so it can come out in the stool.
  - Erythema (ery = red) - Engorgement of capillaries in the dermis indicating skin injury, infection, heat exposure, inflammation, allergies, emotional state, hypertension
  - Pallor - paleness, emotional state, anemia, low blood pressure
  - Bronzing - Addison’s disease, adrenal cortex
- **Bruising** (hematoma) - escaped blood has clotted; hematomas, deficiency in Vitamin C or hemophilia
- **Leathery skin** - overexposure, clumping of elastin fibers; depressed immune system; can alter DNA to cause skin cancer
- **Photosensitivity** - to antibiotics & antihistamines

**Skin Color** – genetic factors, environmental factors and volume of blood

**Skin Pigments** - three pigments are responsible for skin color: melanin, carotene, hemoglobin

**Melanin**
- Located mostly in epidermis
- Number of melanocytes are about the same in all races
- Difference in skin color is due to the amount of pigment that melanocytes produce and disperse to keratinocytes.
- Freckles are caused by the accumulation of melanin in patches
- Liver spots are also caused by the accumulation of melanin
- Melanocytes synthesize melanin from an amino acid called tyrosine along with an enzyme called tyrosinase. All this occurs in the melanosome which is an organelle in the melanocyte.
- Two types of melanin: eumelanin which is brownish black and pheomelanin which is reddish yellow
- Fair-skinned people have more pheomelanin and dark skinned people have more eumelanin

**Environmental Factors**
- UV light increases enzymatic activity in the melanosomes and leads to increased melanin production.
- A tan is achieved because the amount of melanin has increased as well as the darkness of the melanin. (Eumelanin provides protection from UV exposure while pheomelanin tends to break down with too much UV exposure)
- The melanin provides protection from the UV radiation but prolonged exposure may cause skin cancer.

**Carotene** (carot = carrot)
- Yellow-orange pigment
- Precursor for Vitamin A which is used to make pigments needed for vision
- Found in stratum corneum and fatty areas of dermis and hypodermis layer
**Hemoglobin**
- Oxygen-carrying pigment in red blood cells

**Skin Markings** - skin is marked by many lines, creases and ridges

- **friction ridges**: markings on fingertips characteristic of primates
- allow us to manipulate objects more easily - *fingerprints* are friction ridge skin impressions
- **flexion lines**: on flexor surfaces of digits, palms, wrists, elbows etc skin is tightly bound to deep fascia at these points
- **freckles**: flat melanized patches vary with heredity or exposure to sun
- **moles**: elevated patch of melanized skin, of the with hair mostly harmless, beauty marks

**Aging**

- Beginning in our 20s, the effects of aging begin to be visible in the skin.
- Stem cell activity declines: skin thin, repair difficult
- Epidermal dendritic cells decrease: reduced immune response
- Vitamin D3 production declines: calcium absorption declines and brittle bones
- Glandular activity declines: skin dries, body can overheat
- Blood supply to dermis declines: tend to feel cold
- Hair follicles die or produce thinner hair
- Dermis thins and becomes less elastic – wrinkles
- Sex characteristics fade: fat deposits spread out, hair patterns change
- Genetically programmed chronologic aging causes biochemical changes in collagen connective tissues that give skin its firmness and elasticity.
- The genetic program for each person is different, so the loss of skin firmness and elasticity occurs at different rates and different times in one individual as compared with another.
- As skin becomes less elastic, it also becomes drier.
- Underlying fat padding begins to disappear.
- With loss of underlying support by fat padding and connective tissues, the skin begins to sag. It looks less supple and wrinkles form.
- The skin may be itchy with increased dryness. A cut may heal more slowly.

**Derivatives of skin** - during embryonic development thousands of small groups of epidermal cells from stratum basale push down into dermis to form hair follicles and glands
Skin receptors:

Your skin and deeper tissues contain millions of sensory receptors. Most of your touch receptors sit close to your skin’s surface.

Light touch

- **Meissner's corpuscles** are enclosed in a capsule of connective tissue
- They react to light touch and are located in the skin of your palms, soles, lips, eyelids, external genitals and nipples
- These areas of your body are particularly sensitive

Heavy pressure

- **Pacinian corpuscles** sense pressure and vibration changes deep in your skin.
- Every square centimeter of your skin contains around 14 pressure receptors

Pain

- skin receptors register pain
- pain receptors are the most numerous
- each square centimeter of your skin contains around 200 pain receptors

Temperature

- Skin receptors register warmth and cold
- Each square centimeter of your skin contains 6 receptors for cold and 1 receptor for warmth
- **Cold receptors** start to perceive cold sensations when the surface of the skin drops below 95 ° F. They are most stimulated when the surface of the skin is at 77 ° F and are no longer stimulated when the surface of the skin drops below 41 ° F. This is why your feet or hands start to go numb when they are submerged in icy water for a long period of time.
- **Hot receptors** start to perceive hot sensations when the surface of the skin rises above 86 ° F and are most stimulated at 113 ° F. Beyond 113 ° F, pain receptors take over to avoid damage being done to the skin and underlying tissues.
- **Thermoreceptors** are found all over the body, but cold receptors are found in greater density than heat receptors – most of the time our environment is colder than our body temperature
- The highest concentration of thermoreceptors can be found in the face and ears so your nose and ears always get colder faster than the rest of your body on a chilly winter day
Accessory Structures of the Skin

Hair

Anatomy of Hair Follicle

**Shaft:** portion of hair that projects from skin surface
- Straight hair has a round shaft
- Curly hair is oval

**Root:** portion of hair deep to the shaft penetrating the dermis
- Has **3 layers:**
  - **Medulla:** contains pigment granules and air spaces
  - **Cortex:** middle layer
    - in dark hair contains pigment
    - in gray or white hair contains air bubbles
  - **Cuticle:** outer layer
    - heavily keratinized cells that lie like shingles

**Base of the hair follicle**
- **Bulb:** houses the papilla which contains the blood vessels that nourishes the growing hair follicle.
- **Matrix:** responsible for hair growth and produces new hair

**Arrector pili: smooth muscle**
- Extends from the dermis to the side of hair follicle.
- Hair grows at an angle to the surface of the skin
- Arrector pili muscles contract and pulls hair straight causing **goose bumps.**

**Hair root plexus** - dendrites of neurons which are sensitive to touch

Important Features and Texture
- Roughly 5 million hairs cover the body of an average individual
- About 100,000 are on the scalp
- Almost every part of body is covered with hair except palms of hands, soles of feet, sides of fingers and toes, lips and parts of genitals.
- Hair shafts differ in size, shape, and color. In the eyebrows they are short and stiff while on the scalp they are longer and more flexible. Over the rest of the body they are fine and nearly invisible
- Oval shaped hair shafts produce wavy hair, flat or ribbon-like hair shafts produce curly or kinky hair, and round hair shafts produce straight hair.
The Hair Growth Cycle

- Hair follicles grow in repeated cycles.
- One cycle can be broken down into three phases.
  1. **Anagen** - Growth Phase
  2. **Catagen** – Transitional Phase
  3. **Telogen** - Resting Phase
- Each hair passes through the phases independent of the neighboring hairs

**Anagen Phase** - Growth Phase

- Approximately 85% of all hairs are in the growing phase at any one time. The Anagen phase or growth phase can vary from two to six years. Hair grows approximately 10cm per year and any individual hair is unlikely to grow more than one meter long. Each hair on your body grows from its own individual hair follicle. Inside the follicle, new hair cells form at the root of the hair shaft. As the cells form, they push older cells out of the follicle. As they are pushed out, the cells die and become the hair we see.
- A follicle will produce new cells for a certain period of time depending on where it is located on your body. This period is called the growth phase.

**Catagen Phase** - Transitional Phase

- At the end of the Anagen Phase the hairs enters into a Catagen Phase which lasts about one or two weeks, during the Catagen Phase the hair follicle shrinks to about 1/6 of the normal length.
- The lower part is destroyed and the dermal papilla breaks away to rest below.

**Telogen Phase** - Resting Phase

- The Resting Phase follows the Catagen Phase and normally lasts about 5-6 weeks. During this time the hair does not grow but stays attached to the follicle while the dermal papilla stays in a resting phase below. Approximately 10-15 percent of all hairs are in this phase at any one time.
- When the hair follicle enters the **Resting Phase**, the hair shaft breaks, so the existing hair falls out and a new hair takes its place. Therefore, the length of time that the hair is able to spend growing during the growth phase controls the maximum length of the hair.
- The cells that make the hairs on your arms are programmed to stop growing every couple of months, so the hair on your arms stays short. The hair follicles on your head, on the other hand, are programmed to let hair grow for years at a time, so the hair can grow very long.
- Animals that shed have hair follicles that synchronize their rest phase so that all of the follicles enter the rest phase at once.
- Some factors that affect the rate of growth and replacement of hair are illness, diet, stress, gender, radiation therapy, and medication.
- At the end of the Telogen phase the hair follicle re-enters the Anagen Phase. The dermal papilla and the base of the follicle join together again and a new hair begins to form. If the old hair has not already been shed the new hair pushes the old one out and the growth cycle starts all over again.
Functions of Hair

- Hair on the head protects scalp from injury and sunlight
- Eyelashes and eyebrows protect eyes
- Nostril and ear hairs protect from foreign particles
- Help in sensing light touch due to the touch receptors associated with the hair root plexuses.

Hair Color

- Hair color is due to amount and type of melanin in the keratinized cells.
- Melanocytes in the matrix of the bulb synthesizes melanin.
- Melanin passes into the cortex and medulla of the hair.
- **Dark hair** contains true melanin
- **Blond and red hair** have variants of melanin in which there is iron/sulfur.
- **Gray hair results from** a decline in tyrosinase (enzyme which initiates melanin production).
- **White hair** results from the accumulation of air bubbles in the medullary shaft.

Skin Glands

**Sudoriferous - sweat glands (sudori = sweat) (ferous = bearing)**

- 3-4 million glands in your body empties onto the skin thru pores or into hair follicles
- Two main types of sweat glands
  - **Eccrine sweat glands**
    - Secretes cooling sweat
    - Secretes directly onto the skin
    - Began to function soon after birth
    - Sweat is composed of 98 percent water and two percent dissolved salts and nitrogenous wastes, such as urea and uric acid
    - Helps regulate body temperature/aids in waste removal
  - **Appocrine sweat glands**
    - Stimulated during emotional stress/excitement
    - Secretes into hair follicle
    - Begins to function at puberty
    - Slightly more viscous than eccrine secretions
    - Composed of the same components as eccrine sweat plus
      - lipids and proteins.
      - Referred to as “cold sweat”.

**Sebaceous - oil glands (sebace = grease)**

- They are mostly connected to hair follicles.
- Sebaceous glands are embedded in the dermis over most of the body.
- Absent in the palms and soles.
- Vary in size, shape and numbers in other areas of the body.
- Secrete an oily substance called sebum, which lubricates the hair and skin
- Mixture of fats, cholesterol, proteins, inorganic salts, pheromones.
- Coats surface of hair
- Prevents excessive evaporation of water from skin
• Keeps skin soft and pliable
• Inhibits growth of some bacteria.
• Sebaceous gland activity increases with puberty, due to the male and female hormone activity
• Accumulation of sebum in the ducts = white pimples – if the sebum darkens -black heads form
• **Acne** - inflammation of sebaceous gland ducts

**Ceruminous** - modified sweat glands of the external ear that produce ear wax (cer = wax)

• Open directly onto the surface of the external auditory canal (ear canal) or into ducts of sebaceous glands.
• Earwax is the combination of secretion of ceruminous and sebaceous glands.
• Earwax and the hair combine to provide a sticky barrier against foreign items.

**Nails**

• Made of tightly packed, hard, keratinized epidermal cells
• Consist of:
  **Nail body**: portion of the nail that is visible
  • Free edge: part that extends past the distal end of the digit
  • Nail root: portion buried in a fold of skin
  **Lunula**: means little moon
  • Crescent shaped area of the nail
  **Hyponychium**: secures the nail to the fingertip
  • Thickened stratum corneum
  **Eponychium or cuticle**: narrow band of epidermis
  • Growth of nails is in the nail matrix.
• Nail cells multiply under the skin. Each cell keeps dividing and creating more cells. The new cells push the old cells above the skin surface.
• Once the nail cells are out on the surface, they are pushed from below by new nail cells, towards your finger or toe. However, once they come out they lose the ability to multiply. They become dead cells.
• **Functions of the nails:**
  o Grasping objects
  o Manipulating objects
  o Protects ends of digits from trauma
  o Scratching

**Imbalances of Homeostasis**

**Skin Imbalances** - The skin can develop >1000 different ailments. the most common skin disorders result from allergies or infections less common are burns and skin cancers

**Skin lesions** – any measurable variation from normal structure of the skin
  • **Elevated lesions** – cast a shadow outside the edges as warts, plaque, blister
  • **Flat lesions** – do not cast a shadow as a scab, elevated lesion with pus, hive
  • **Depressed lesions** – cast a shadow within their edges as lacerations, ulcers, fissures

**Infections**
  • **Viral** - eg. cold sores, herpes simplex especially around lips and oral mucosa
  • **Warts** – benign neoplasms caused by papillomavirus (HPV)
  • **Fungal** - eg. athletes foot, Tinea
  • **Bacterial**- eg. boils and carbuncles inflammation of hair follicle and sebaceous glands especially on face or dorsal side of neck, impetigo *Streptococcus* infection

**Contact dermatitis** is a condition in which the skin becomes red, sore, or inflamed after direct contact with a substance. There are two kinds of contact dermatitis: **irritant or allergies**

**Irritant dermatitis** is the most common type. It's caused by contact with acids, alkaline materials such as soaps and detergents, fabric softeners, solvents, or other chemicals. The reaction usually looks like a burn.

Other irritants may include:

  • Cement
  • Hair dyes
  • Long-term exposure to wet diapers
  • Pesticides or weed killers
  • Rubber gloves
  • Shampoos
**Allergic contact dermatitis** is caused by exposure to a substance or material to which you have become extra sensitive or allergic.

Common allergens include:

- Adhesives, including those used for false eyelashes or toupees
- Antibiotics such as neomycin rubbed on the surface of the skin
- Balsam of Peru (used in many personal products and cosmetics, as well as in many foods and drinks)
- Fabrics and clothing
- Fragrances in perfumes, cosmetics, soaps, and moisturizers
- Nail polish, hair dyes, and permanent wave solutions
- Nickel or other metals (found in jewelry, watch straps, metal zips, bra hooks, buttons, pocketknives, lipstick holders, and powder compacts)
- Poison ivy, poison oak, poison sumac, and other plants
- Rubber or latex gloves or shoes

**Treatment**

- Washing with lots of water to remove any traces of the irritant that may remain on the skin
- Avoid further exposure to known irritants or allergens
- Anti-itch (antipruritic) or drying lotions may be recommended to reduce other symptoms
- Corticosteroid skin creams or ointments may reduce inflammation
- Corticosteroid pills or a corticosteroid shot from the doctor may be needed in severe cases

**Genetic Diseases**

- **Psoriasis**
  - chronic, noninfectious skin disease
  - skin becomes dry and scaly, often with pustules and many varieties
  - cycle of skin cell production increases by 3-4x’s normal
  - stratum corneum gets thick as dead cells accumulate
  - seems to be a genetic component
  - often triggered by trauma, infection, hormonal changes or stress

- **Vitiligo** – a autoimmune pigmentation disorder where melanocytes in the epidermis are destroyed eg Michael Jackson
Burns - too much sunlight or heat - categorized by degree of penetration of skin layer

- **1st degree burns**
  o skin is inflamed, red - surface layer of skin is shed

- **2nd degree burns**
  o deeper injury - blisters form as fluid builds up beneath outer layers of epidermis

- **3rd degree burns**
  o full thickness of skin is destroyed - sometimes even subcutaneous tissues results in ulcerating wounds
  o typically results in catastrophic loss of fluids:
    ▪ dehydration
    ▪ electrolyte imbalances
    ▪ also highly susceptible to infections
    ▪ slow recovery (from cells of hair follicles if they survive; otherwise must heal from margins of wound)
    ▪ may require: autografts, cadaver skin, pig skin
    ▪ prognosis may depend on extent of damage

- **A fourth-degree burn** additionally involves injury to deeper tissues, such as muscle or bone

“rule of 9’s”- extend of burn damage estimated by
- head, arms ~9% of skin surface
- front and back of torso, each leg ~18% of skin surface
- groin ~1% of skin surface
Skin Cancer

- Cells have a built-in mechanism that causes contact inhibition. Healthy cells stop growing when they come in contact with one another. In damaged cells, contact inhibition is lost and therefore the cells continue to grow until they start lumping up on one another.
- Cancer cells do not exhibit contact inhibition.
- Excessive or chronic exposure UV radiation, x-rays or radiation’ chemicals or physical trauma are predisposing factors to cancer.
- most forms progress slowly and are easily treated but a few are deadly

**Basal Cell Carcinoma**
- least malignant
- most common -78% of all skin cancers
- stratum basale can’t form keratin
- lose boundary layer between epidermis and dermis
- results in tissue erosion and ulceration
- 99% of these cancers are fully cured

**Squamous Cell Carcinoma** -20% of all skin cancers
- cancer of the cells in stratum spinosum
- arise from squamous cells of the epidermis
- usually induced by sun
- cells grow rapidly and grow into the lymphatic tissues
- hardened small red growth
- spreads rapidly if not removed
- good chance of recovery if detected and treated early

**Malignant Melanoma**
- cancer of pigment cells = melanocytes
- rare ~1% of skin cancers
- deadly, poor chance of cure once it develops
- often begins with moles
- spreads rapidly
- early detection and treatment is the key to survival