Dr. Rubin's Mini Medical School for High School Students
Session 1

1.1 Introduction to Mini Med School

Student Expectations and TA's

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Mini- Medical School
The first Mini-Med School was held at the University of Colorado in 1990 with the goal of enhancing the Medical School's reputation with its surrounding community. Currently, most Mini-Med schools function as public education programs. More than 80 medical schools, universities, research institutions, and hospitals in the United States now offer programs called Mini Medical School. These programs are primarily developed for adult learners with no prior educational requirements and serve as public relations and educational projects.

What is Dr. Rubin's Mini Medical School for High School Students Program?
It is an educational program to encourage and help students learn if they want to become a medical doctor and if so, help make that a reality. The program is designed to take the word Mini literally and provide an experience that gives students, both at the high school and college level, a sense of the knowledge and experience that a real medical student pursues. Classes contain lectures, interactive conversations, case presentations, and projects that complement the lectures like casting and suturing. As a student, you are assigned to a group with 3 other students who share your interests and background. Several teaching assistants are available to help you learn and experience the material presented. Do not be afraid to ask questions. Your group will also have its own set of tools just like those found in the typical doctors black bag. With your tools you will examine your fellow group members and manikins. Like all doctors, you are expected to work with your teammates, helping each other and examine each other with respect. Though this program, you will get a firm understanding of a medical school education, the way physicians operate and the knowledge that will help you enter the medical fiels should you choose to further pursue this career choice.

Remember, if you have problems or cannot attend a session, contact Dr. Rubin.
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1.2 Brief History of Medicine in the U.S.

From Heroic Medicine to Scientific Medicine to Modern Medicine

"Bloodletting Over the Centuries" by Gilbert R. Seigworth, M.D.

Bloodletting is a procedure that was performed to help alleviate the ills of mankind. For an operation with a 3,000-year history, bloodletting has attracted little attention in recent historic accounts of medicine. Bloodletting began with the Egyptians of the River Nile one thousand years B.C., and the tradition spread to the Greeks and Romans; its popularity continued throughout the Middle Ages. It reached its zenith during the beginning of the nineteenth century, but had virtually died as a therapeutic tool by the end of that century.

The custom of bloodletting as practiced over the centuries might seem repulsive to the modern practitioner of medicine. However, the physician and his treatment must be judged in the light of the contemporary theory of disease. Primitive man looked on disease as a curse cast on him by an evil spirit; his treatment consisted of driving out the demon that possessed him. Neolithic man of the late Stone Age used flint tools for trepanning the skull as a method for releasing the demon; the logic of the treatment was sound, but the premise on which it was based was wrong. The premise was that the evil spirit of disease was contained within the skull and could be drawn out. In much the same way as trepanning allowed demons to escape from the head, bloodletting was supposed to facilitate the release of evil spirits from elsewhere in the body. Later use of bloodletting in hypertension, apoplexy, dropsy, and nervous disorders had a more physiologic explanation.

The story of bloodletting is intertwined in the mysterious fabric of medical lore; it originated from magic and religious ceremonies. The physician and priest were one and the same since disease was thought to be caused by supernatural causes. Witch doctors and sorcerers were called on to drive out the evil spirits and demons. Bloodletting was a method for cleansing the body of ill-defined impurities and excess fluid. The early instruments included thorns, pointed sticks and bones, sharp pieces of flint or shell, and even sharply pointed shark's teeth. Miniature bow and arrow devices for bloodletting have been found in South America and New Guinea. A small bloodletting instrument resembling a crossbow was once used in Greece and Malta. Wall paintings dating from 1400 B.C. depict the use of leeches for drawing blood from human beings.

Four body humors

Prior to the time of Hippocrates (460 to 377 B.C.), all illness was attributed to one disease with variable symptoms. Careful clinical observations by Hippocrates led to the recognition of specific disease states with identifying symptoms. It was during this time that the concept of body humors developed. The four fluid substances of the body were blood, phlegm, yellow bile, and black bile. Health depended on the proper balance of these humors. Bloodletting was, therefore, a method used for adjusting one of the four body humors to proper balance. This clinical concept led to the decline in the doctrine of evil spirits in disease.

It was thought that blood carried the vital force of the body and was the seat of the soul; body

weakness and insanity were ascribed to a defect in this vital fluid. Blood spurting from fallen gladiators was drunk with the hope that it would transfer strength to the recipient. Caspar Bartholin, M.D., (1655 to 1738) described an epileptic girl at Breslau who drank the blood of a cat. The girl, so the report goes, became endowed with the characteristics of a cat. She climbed on the roofs of houses and imitated the manner of a cat by jumping, scratching, and howling. Not content with that, she would sit for hours gazing into a hole in the floor.

Barber-surgeons develop

Surgery during the four centuries from 1100 to 1500 A.D. was a very crude business. The barber-surgeon developed during these years after a church edict by the Council of Tours in 1163 A.D. prevented monks and priests from continuing the custom of bloodletting. The council said, "The church abhors bloodletting." The barbers began to lance veins and abscesses as well as perform amputations of arms and legs. The red-and-white barber pole designated a barber who did surgery as well as haircutting. The educated physicians avoided surgery during these years. This was to set the stage for later conflict when surgery became a respectable method of treatment. The Barber-Surgeon Company existed officially in England until 1744. However, barbers and surgeons had a clear separation of function for many years before that. The transition of surgery from disrespect to prominence was led by the French master barber-surgeon Ambroise Paré (1510 to 1590), who is considered the father of surgery.

Astrology played an important role in the physician's practice during the fourteenth and fifteenth centuries. Bloodletting as well as surgery in general was regulated by the signs of the zodiac, and the planets had to be in a proper relationship. A phlebotomy table (1480 A.D.) spelled out the relationship of every part of the body to the signs of the zodiac. Bloodletting was performed at specific times for specific parts of the body.[1]

Indications for venesection

Venesection was the most common method of general bloodletting. The specific indications have varied over the years. The following translation from Old English is advice given by Ambroise Paré in a 1634 text.[2]

> But blood is let by opening a vein for five respects: the first to lessen the abundance of blood, as in plethoric bodies, and those troubled with plentitude. The second is for diversion, or revulsion, as when a vein of the right arm is opened to stay the bleeding of the left nostril. The third is to allure or draw down, as when the vein is opened in the ankle to draw down the menstrual flow in women. The fourth is for alteration or introduction of another quality, as when in sharp fevers we open a vein to breathe out that blood which is heated in vessels, and cooling the residue which remains behind. The fifth is to prevent imminent disease, as in the spring and autumn we draw blood by opening a vein in such as are subject to spitting of blood, quinsy, pleurisy, falling sickness, apoplexy, madness, gout, or in such as are wounded, for to prevent the inflammation which is to be feared. Before bloodletting, if there be any excrement in the guts, they

> shall be evacuated by a gentle clyster, or suppository, lest the mesenteric veins should thence draw unto them any impurity.

In the early nineteenth century adults with good health from the country districts of England were bled as regularly as they went to market;[3] this was considered to be preventive medicine. In earlier times specific veins were described as heart veins, breast veins, and head veins. Buchan's[4] DOMESTIC MEDICINE discussed this in the 1784 edition. Buchan realized that since systemic blood made a full circuit, little significance should be placed on the site chosen for venesection. The median basilic vein was the site most frequently used.

The term antiphlogistic means to counteract inflammation. Redness, heat, and swelling were considered the abnormal responses to be treated. With infection, the formation of laudable pus was thought to be an essential part of healing. It was not appreciated that these responses represented an attempt by the body to counteract bacterial infection; this discovery came later. Our current efforts to treat cancer without understanding the underlying etiologic factors will someday no doubt appear just as illogical. Bloodletting counteracted the redness, heat, and swelling by relieving the vascular congestion. The following quotation comes from Watson and Condie's[5] PRACTICE OF PHYSIC in 1858.

> The main object of general blood letting is to diminish the whole quantity of blood in the system, and thus to lessen the force of the heart's action. The object of local bleeding is, in most instances, that of emptying the gorged and loaded capillaries of the inflammed part. Sometimes the blood is thus taken directly from the turgid vessels themselves; more often, I fancy, topical bloodletting produces its effect by diverting the flow of blood from the affected part, and giving it a new direction, and so indirectly relieving the inflammatory congestion.

Watson goes on to state, "I cannot too strongly inculcate the precept that in order to extinguish or check acute inflammation, you must above all bleed early." An indication for bleeding in acute inflammation was a hard pulse of 90 to 120 beats per minute, which was measured by the resistance that the pulse of the artery made to the pressure of the examiner's fingers. Rapid bleeding by venesection with the patient standing was advised. It was surmised that the early onset of faintness and softness of pulse was beneficial. Slow bleeding with the patient supine led to more blood loss before the soft pulse and faintness developed, which was thought to be undesirable. Blood losses averaged 16 to 30 oz. Sufficient bleeding had occurred when the fever subsided, the pulse had become soft, or suppuration had developed.

Variations of the concept of body balance persisted until the end of the nineteenth century. Most physicians of that century believed that illness was due to either an excess or deficiency of some body product. Cathartics were used to reduce an over-excited nervous system by cleansing the bowels. Diuretics were used to restore systemic balance. Tonics were used to stimulate a depressed nervous system. Bloodletting allowed the physician to reduce body fluids and decrease body temperature. The febrile patient with a full pulse, red skin, and agitated state could be rendered pale and cool. The physician concluded that this represented clinical improvement.

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The Flexner Report and the Standardization of American Medical Education

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If the sick are to reap the full benefit of recent progress in medicine, a more uniformly arduous and expensive medical education is demanded. Abraham Flexner[1]

MEDICAL EDUCATION IN THE UNITED STATES TODAY IS STRIKingly standardized and demanding. It was not always so. Prior to the widespread implementation of educational reforms,medical training was highly variable and frequently inadequate.It was not until the early decades of the 20th century that a "uniformly arduous and expensive" system of medical education was instituted nationally. In the 19th century, most medical education in the United States was administered through 1 of 3 basic systems: an apprenticeship system, inwhich students received hands-on instruction from a local practitioner; a proprietary school system, in which groups of students attended a course of lectures from physicians who owned the medical college; or a university system, in which students received some combination of didactic and clinical training at university affiliated lecture halls and hospitals. These medical schools taught diverse types of medicine, such as scientific, osteopathic, homeopathic, chiropractic, eclectic, physiomedical, botanical, and Thomsonian.[2] In addition, wealthy and industrious medical students supplemented their education with clinical and laboratory training in the hospitals and universities of Europe, primarily in England, Scotland, France, and Germany. Because of the heterogeneity of educational experiences and the paucity of licensing examinations, physicians in America at the turn of the 20th century varied tremendously in their medical knowledge, therapeutic philosophies, and aptitudes for healing the sick.[3,4] Throughout the second half of the 19th century, the American Medical Association (AMA) lobbied for the standardization of American medical education. These efforts were largely unsuccessful, both because political traditions in America dissuaded national regulation of professions and because the American public and much of the medical profession were not convinced that any particular brand of medical education was significantly superior to any other. "The great mass of the public," declared the medical educator John Shaw Billings in 1891, "know little and care less about the details of professional education . . . . The popular feeling is that in a free country every one should have the right to follow any occupation he likes, and employ for any purpose any one whom he selects, and that each party must take the consequences."[5] However, by the turn of the 20th century, a series of scientific breakthroughs had altered the values held by the public and the medical profession: clinical and laboratory research had exposed the irrationality of "heroic" treatments (such as blistering, bleeding, and purging) and had proven the therapeutic efficacy and rational scientific basis of modern practices, such as antiseptic surgery, vaccination, and public sanitation. Most of the public and virtually all physicians now believed in the superiority of scientific medicine.[2] Educators at leading US medical schools now contended that the path toward mastering the analytical skills required to practice scientific medicine lay not with the memorization of accepted truths but with the systematic application of the scientific method throughout medical training. They asserted that students should spend most of their time at medical school actively engaged in laboratory experimentation and hands-on care at the bedside.[3] The AMA sought to eliminate schools that failed to adopt this rigorous brand of systematized, experiential medical education."It is to be hoped that with higher standards universally applied their number will soon be adequately reduced, and that only the fittest will survive," the editors of *JAMA* declared in 1901.[6] In 1904, theAMAcreated the Council on Medical Education (CME) to promote the restructuring of US medical education. At its first annual conference,the CME outlined its 2 major reform initiatives: standardization of preliminary education requirements for entry into medical school and national implementation of an "ideal" medical curriculum, consisting of 2 years of training in laboratory sciences followed by 2 years of clinical rotations in a teaching hospital.[7] In 1908, the CME planned to undertake a survey of medical education in the United States to promote the organization's reformist agenda and to hasten the elimination of medical schools that failed to adopt the CME's standards. The CME requested the Carnegie Foundation for the Advancement of Teaching to lead the undertaking. Carnegie Foundation president Henry Pritchett, a staunch advocate of medical school reform, chose the schoolmaster and educational theorist Abraham Flexner to head the survey.[8,9] Over the course of 18 months, Flexner visited all 155 US medical schools. He examined 5 principle areas at each school: entrance requirements, size and training of the faculty, size of endowment and tuition, quality of laboratories, and availability of a teaching hospital whose physicians and surgeons would serve as clinical teachers. Flexner's report showed that although most of the nation's medical schools claimed to adhere to progressive, scientific principles of medical education, only a very few had the financial resources, laboratory and hospital

facilities, and highly skilled teaching staff necessary to apply this demanding form of education. Flexner noted, "We have indeed in America medical practitioners not inferior to the best elsewhere; but there is probably no other country in the world in which there is so great a distance and so fatal a difference between the best, the average, and the worst." He maintained that to standardize the quality of all medical schools to that of America's "best" schools, the nation must stop wasting its social and economic resources on financially strapped commercial schools that were unable to provide the costly, time consuming, economically unprofitable ideal standard of medical education being offered at the leading US medical schools: "The point now to aim at is the development of the requisite number of properly supported institutions and the speedy demise of all others."[1] For decades, physicians had promoted medical education reform as a means to increase professional status. Flexner's unique contribution was to promote educational reform as a public health measure. He argued that the business ethic that governed proprietary medical schools was incompatible with the progressive academic values necessary for socially useful medical education. "Such exploitation of medical education," Flexner declared, "is strangely inconsistent with the social aspects of medical practice. The overwhelming importance of preventive medicine, sanitation, and public health indicates that in modern life the medical profession is an organ differentiated by society for its highest purposes, not a business to be exploited."[1] He maintained that the state government is the proper instrument for regulating medical education, because social welfare is inextricably linked to the quality of the nation's physicians: "The right of the state to deal with the entire subject in its own interest can assuredly not be gainsaid. The physician is a social instrument."[1]

In the 1910s, state licensing boards began to force medical schools across the United States to implement heightened admission standards and stricter curriculum requirements.[10] In 1912, a group of licensing boards formed the Federation of State Medical Boards, which voluntarily agreed to base its accreditation policies on academic standards determined by the AMA's CME. Consequently, the CME's decisions "came to have the force of law."[11] During these same years, philanthropic foundations began making large contributions to promote medical research and education at a select group of leading medical universities.[12,13] By the 1930s, the combined efforts of state licensing boards, philanthropic foundations, and the AMA's CME resulted in the eradication of America's proprietary medical colleges and the standardization of the laboratory- and hospital-based research medical university model that Flexner advocated in his report.[3] Although these reforms raised the quality of medical education in the United States, it concurrently caused a disproportionate reduction in the number of physicians serving disadvantaged communities: most small, rural medical colleges and all but 2 African American medical colleges were forced to close, leaving in their wake impoverished areas with far too few physicians.[11,14] Furthermore, the increased entrance requirements and extended course of study now required to become a physician promoted "professional elitism" and inhibited the economically underprivileged from pursuing careers in medicine.[15]

Medical schools continue to struggle to overcome these untoward effects of the standardization of American medical education.[16,17] To the present day, all accredited US medical schools strive to apply Flexner's "uniformly arduous and expensive" brand of medical education, though the rising costs of health care have forced many schools to make curricular compromises and to form corporate alliances as they attempt to balance academic ideals with economic and social responsibilities.[18-21]

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1.3 Introduction to the patient

Physician Professionalism

The medical student must be committed to carrying out professional responsibilities, adhering to ethical practices and demonstrating sensitivity to diverse patient populations. Student Doctors are expected to demonstrate the following:

- Honesty
- Compassion for patients
- Respect for patient's privacy, dignity, and diversity of culture, ethnicity, religion and sexual orientation
- Integrity, reliability and dependability in all interactions with patients and their families, professional colleagues and peers
- The ability to maintain confidentiality
- Altruistic behavior by prioritizing the patient's well being above the student's own self interest
- The knowledge of how to obtain informed consent
- The skills to advocate for improvements in the access of healthcare for everyone
- The understanding that medicine is a team effort involving the contributions of many health care disciplines

The Black Bag (The Tools)

a. Ophalmoscope
b. Otoscope
c. Pen Light
d. Stethoscope
e. Hammer
f. Tuning Fork
g. Blood Pressure Cuff
h. Watch
i. Thermometer

History and Physical Exam

History Taking Skills (Approach to the patient)

Engage the patient with friendly conversation.
Chief Complaint
Good Health Till…
Characteristics of complaint.. How often, intensity, location….
What affects the complaint? Food, light, position, heat, medication…

Past History
Past Surgeries
Social History
Medications
Allergies
Review of Systems
Optional: Birth History, Immunizations, Past Pregnancy, etc.

The Exam:
Vital Signs: Respirations, Pulse, Temperature, Blood Pressure

General Appearance: Well Developed, Well Nourished, Age, Race (White, Black, Hispanic, Indian, etc) Distress/ No Apparent Distress
Skin: Rash - location, type (erythema, purpura, peticheal, papule, bolus), size, shape
Scars - location, draw, size
Moles – location, size, shape, color, thickness
Head: Normal, Traumatic, Fontanel – soft, depressed, full, tender
Eyes: sclera, pupils - equal, reactive to light, red reflex
Fundus – vessels, optic nerve, cataract
Ears: external- tender to touch, red, swollen,
Internal - tympanic membrane landmarks, bulky, full, redness. Mobility
Nose: patent, swollen, discharge – clear, white, yellow, green
Throat: pharynx – red, lesions, swollen
tonsils – red, puss, swollen, touching, enlarged, ulcers, pus
tongue – lesions, color
Neck: ROM, lymph nodes and where, tender or non-tender
Lungs: clear, rales, rhonchi, wheezing, crackles, location and equal
Heart: rhythm
rate
murmur - grade 1 to 5
holosystolic, mid systolic, end systolic, location of murmur, S1, S2 split,
Abdomen: soft, bowel sounds, liver, spleen, mass, location of tenderness
Pelvis: lymph nodes, pain, hernia
Genitalia: male- testicular, penile, urethra
female- labia, breast mass, tenderness, color of skin, texture
Comment on tanner stage
Extremities: arms, joints, flexibility, symmetry, bow, toe in or out, mobility, knee integrity
Neuro: cranial nerves 1 – 12 exam, memory, orientation to time, place and person, reflexes

List any test that may have been done prior to your seeing the patient.

Then formulate a list of possible diagnosis called the differential diagnosis and make a summary with your opinion.

Then list your approach and treatment plan for the patient. It may include further testing, trial on a medication, careful watching and then conclude with a follow-up plan or conclusion. Students over the first 2 years of school must learn the art of interviewing patients and then examining the patient appropriately.

1.4 Vital Signs

How to measure and what they mean

Vital signs are indicators of one's overall health. They offer clues to diseases and help us evaluate a patient's progress towards recovery. Vital signs should be taken at rest. Any abnormal measurement should be repeated to verify the finding. The most common vital signs measured are body temperature, heart rate, respiration rate, and blood pressure.

Temperature

Temperature is a good indicator of infectious or inflammatory diseases. A patient's temperature can be measured at any body part, i.e., skin, mouth, rectum, or even the armpit. However, due to the ease and speed, most clinics measure a patient's temperature in the ear using a tympanic thermometer. Normal ear temperatures range from 97 to 100 degrees F (Fahrenheit), the average being 98.6 F. A rise in body temperature above 101.5 F or below 96.0 F is associated with clinical disease.

Heart Rate

Heart rate is a good indicator of cardiac function or fluid status. You can measure a pulse anywhere there is an artery (wrist, arm, neck, knee, foot or head). Most clinics use the radial artery in the wrist, but the carotid artery in the neck is also commonly used in emergency conditions. Normal resting heart rates vary with age from 120 - 160 beats per minute for an infant to 60 – 100 beats per minute for an adult. Resting heart rates of more than 180 bpm or less than 50 bpm are associated with clinical disease in adults.

Respiratory Rate

Respiratory rate is a good indicator of lung function or neurologic status. The normal resting respiratory rate will vary from 40 – 60 breaths per minute for an infant to 12 to 20 breaths per minute for an adult. A respiratory rate of 40 or more is associated with clinical disease in adults.

Blood Pressure

Blood pressure is a good indicator of cardiac muscle function, peripheral vascular resistance, kidney function, and neurologic status. Blood pressure measures the force circulating blood on the walls of the arteries. Blood pressure can be measured in any extremity or by a catheter placed in an artery. Most clinics measure the left brachial artery blood pressure. The average blood pressure is 120 millimeters of mercury systolic, over 80 millimeters of mercury diastolic, otherwise indicated as 120/80. A resting systolic blood pressure of over 130 is considered mildly elevated; over 180 needs immediate treatment. A resting diastolic blood pressure over 90 is considered mildly elevated; over 100 may require treatment. Blood pressure is the hardest vital sign to measure and takes a lot of practice to master.

A discussion on vital signs is included with the class hands on experience handout. However, your class will learn how to measure a blood pressure as a group and then have a second chance during the group project time during which you will also do a heart rate, respiratory rate and measure a temperature. * Refer to the experience 1 handout for details on how to measure each vital sign.

1.5 Histology

Cell types, tissues and organs

Histology

1. A tissue is an aggregation of similar cells that perform a specific set of functions. The body is composed of over 25 kinds of tissues, classified as epithelial tissue, connective tissue, muscle tissue and nervous tissue.

2. The standard tissue stain is composed of hematoxylin and eosin. Most slides use this stain refered to as H & E stain.

- The hematoxylin stains nucleic acids (plus calcium deposits and bacteria) blue.
- The eosin stains most proteins (actually, arginine and lysine) pink.
- Clear areas represent water, carbohydrate, lipid, or gas.

Epithelial Tissue:
(1) covers the body and organ surfaces, lines body cavities and lumina.
(2) forms various glands.
(3) functions for protection, absorption, excretion and secretion.

Epithelia tissue is avascular (without blood vessels), has an inner surface bound by a basement membrane and is composed of tightly packed cells.

Classification by describing the layers of cells and the shape of the cells:
Layers: simple or single, stratified (two or more layers), or pseudostratified (one layer, looks like more because there are multiple layers of nucleoli)
Shape: squamous (flat), cuboidal, columnar, or transitional (both flat and cuboidal)
Outer layer (epidermal layer) may contain a protein called keratin which functions to waterproof the layer

Examples of epithelium:
Alveoli (air sacs) in lungs – simple squamous
Salivary ducts in mouth – simple cuboidal
Lining of the digestive tract – simple columnar
Areas of the respiratory tract – simple ciliated columnar
Epidermis of the skin – stratified squamous keratinized
Pancrease – stratified cuboidal

Lining of the urinary bladder – transitional

Connective Tissue

Supports and binds other tissues, stores nutrients and/or manufactures protective and regulatory materials. It is composed of a matrix containing secreted organic materials of varying composition that binds widely separated cells of a tissue.

Type	Cells	Matrix	Function	Location
Loose (areolar)	Fibroblasts Mast cells	Collagenous fibers and elastin	Binding Protection Nourishment	Deep to skin Around muscles, Vessels and organs
Dense Fibrous	Fibroblasts	Densely packed collagenous fibers	Strong Flexibility	Tendon Ligament
Elastic	Fibroblasts	Elastin fibers	Flexibility Distensibility	Arteries, Larynx Trachea and Bronchi
Reticular	Phagocytes	Reticular fibers In a jellylike matrix	Phagocytic	Liver, Spleen, Lymph nodes and Bone Marrow
Adipose	Adipocytes	Fat:very little matrix	Stores lipids	Hypodermis and around organs
Cartilage Hyaline Fibrocartilage Elastic	Chondrocytes	Collagenous fibers Elastin (for elastic cartilage)	Support Strength Flexibility	Joints, Trachea Nose, Ear and Larynx
Bone Spongy bone Compact bone	Osetocytes	Collagenous fibers And Calcium carbonate	Strength And Support	Bones
Blood	Erythrocytes Leukocytes Thrombocytes	Plasma	Conduction of nutrients and wastes	Circulatory System (arteries, veins, heart, etc)

Muscle Tissues

There are 3 different muscle tissues:

- **Skeletal muscle**, as its name implies, is the muscle attached to the skeleton. It is also called **striated muscle**. The contraction of skeletal muscle is under voluntary control.
- **Smooth muscle** is found in the walls of all the hollow organs of the body (except the heart). Its contraction reduces the size of these structures. Thus it:
    - regulates the flow of blood in the arteries
    - moves your breakfast along through your gastrointestinal tract
    - expels urine from your urinary bladder
    - sends babies out into the world from the uterus
    - regulates the flow of air through the lungs

The contraction of smooth muscle is generally **not** under voluntary control.

- **Heart muscle** — also called **cardiac muscle** — makes up the wall of the heart. Throughout life, it contracts some 70 times per minute pumping about 5 liters of blood each minute.

Skeletal Muscle

Skeletal muscle is made up of thousands of cylindrical muscle fibers. The fibers are bound together by connective tissue through which run blood vessels and nerves.

Each muscle fibers contains:

- an array of **myofibrils** that are stacked lengthwise and run the entire length of the fiber.
- **mitochondria**
- an extensive **endoplasmic reticulum**
- **many nuclei**.

The multiple nuclei arise from the fact that each muscle fiber develops from the fusion of many cells (called **myoblasts**).

Because a muscle fiber is not a single cell, its parts are often given special names such as

- **sarcolemma** for plasma membrane
- **sarcoplasmic reticulum** for endoplasmic reticulum
- **sarcosome** for mitochondrion
- **sarcoplasm** for cytoplasm

Seen from the side under the microscope, skeletal muscle fibers show a pattern of cross banding, which gives rise to the other name: **striated muscle**.

The striated appearance of the muscle fiber is created by a pattern of alternating

- dark **A bands** and
- light **I bands**.

- The A bands are bisected by the **H zone**
- The I bands are bisected by the **Z line**.

Each myofibril is made up of arrays of parallel **filaments**.

- The **thick filaments** have a diameter of about 15 nm. They are composed of the protein **myosin**.
- The **thin filaments** have a diameter of about 5 nm. They are composed chiefly of the protein **actin** along with smaller amounts of two other proteins:
    - **troponin** and

- **tropomyosin**.

The entire array of thick and thin filaments between the Z lines is called a **sarcomere**. Shortening of the sarcomeres in a myofibril produces the shortening of the myofibril and, in turn, of the muscle fiber of which it is a part.

Smooth Muscle

Smooth muscle is made of single, spindle-shaped cells. It gets its name because no striations are visible in them. Nonetheless, each smooth muscle cell contains **thick** (myosin) and **thin** (actin) filaments that slide against each other to produce contraction of the cell. The thick and thin filaments are anchored near the plasma membrane.

Smooth muscle (like cardiac muscle) does not depend on motor neurons to be stimulated. However, motor neurons (of the autonomic system) reach smooth muscle and can stimulate it — or relax it — depending on the neurotransmitter they release (e.g. noradrenaline or nitric oxide).

Smooth muscle can also be made to contract:

- by other substances released in the vicinity (paracrine stimulation)
  - Example: release of **histamine** causes contraction of the smooth muscle lining our air passages (triggering an attack of **asthma**)
- by hormones circulating in the blood
  - Example: oxytocin reaching the uterus stimulates it to contract to begin childbirth.

The contraction of smooth muscle tends to be slower than that of striated muscle.

Cardiac Muscle

Cardiac or heart muscle resembles skeletal muscle in some ways: it is striated and each cell contains sarcomeres with sliding filaments of actin and myosin.

However, cardiac muscle has a number of unique features that reflect its function of pumping blood.

- The myofibrils of each cell (and cardiac muscle is made of single cells — each with a single nucleus) are branched.
- The branches interlock with those of adjacent fibers by adherens junctions. These strong junctions enable the heart to contract forcefully without ripping the fibers apart.
- The action potential that triggers the heartbeat is generated within the heart itself. Motor nerves (of the autonomic nervous system) do run to the heart, but their effect is simply to modulate — increase or decrease — the intrinsic rate and the strength of the heartbeat. Even if the nerves are destroyed (as they are in a transplanted heart), the heart continues to beat.

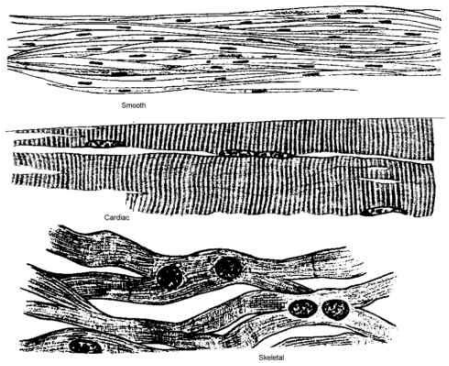
- The action potential that drives contraction of the heart passes from fiber to fiber through gap junctions.
    - Significance: All the fibers contract in a synchronous wave that sweeps from the atria down through the ventricles and pumps blood out of the heart. Anything that interferes with this synchronous wave (such as damage to part of the heart muscle from a heart attack) may cause the fibers of the heart to beat at random — called **fibrillation**. Fibrillation is the ultimate cause of most deaths and its reversal is the function of defibrillators that are part of the equipment in ambulances, hospital emergency rooms, and — recently — even on U.S. air lines.
- The **refractory period** in heart muscle is **longer** than the period it takes for the muscle to contract (systole) and relax (diastole). Thus **tetanus** is not possible (a good thing, too!).
- Cardiac muscle has a much richer supply of mitochondria than skeletal muscle. This reflects its greater dependence on cellular respiration for ATP.
- Cardiac muscle has little glycogen and gets little benefit from glycolysis when the supply of oxygen is limited.

Thus anything that interrupts the flow of oxygenated blood to the heart leads quickly to damage — even death — of the affected part. This is what happens in heart attacks.

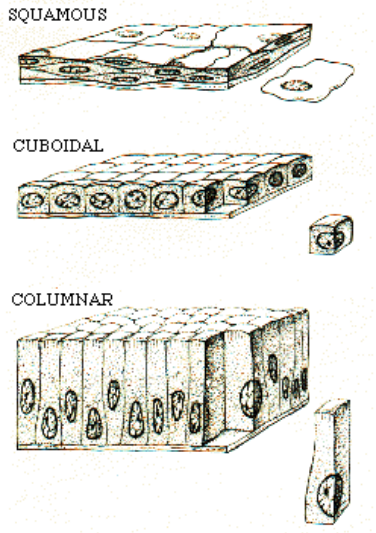
Smooth Muscle

Skeletal Muscle

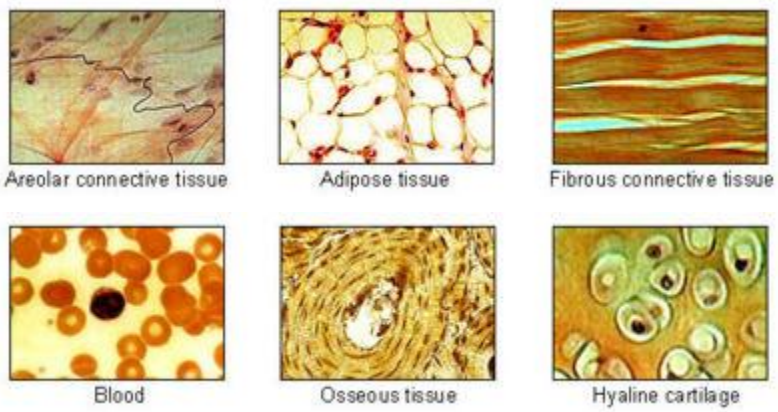
Cardiac Muscle



Epithelial Tissues



Connective Tissues



1.6 Human Anatomy

Review of Systems

Gross Dissection Video

We will later dissect lamb organs to better understand anatomy and the process of dissection. There is a separate handout for the dissection.

The approach to study anatomy can be sectional, as with dissection, or can be by system, as when we study the nervous system. We will use a system approach in our handout but we will experience a sectional approach when we watch dissections. Anatomy is largely a descriptive science. We must first understand some basic terms before we can understand anatomy.

Basic Anatomical Terms

Term of Reference	Meaning	Opposing Term	Meaning
Superior Cranial	Toward the head	Inferior Caudal	Toward the feet (tail)
Anterior Ventral	Toward the front	Posterior Dorsal	Toward the back
Medial	Toward the midline of the body	Lateral	Toward the side of the body
Internal Deep	Away from the surface of the body	External Superficial	Toward the surface of the body
Proximal	Toward the main mass of the body	Distal	Away from the main mass of the body
Palmar	Dorsum of the hand	Plantar	Dorsum of the feet
Supine	Lay abdomen up	Prone	Lay abdomen down
Visceral	Related to the internal organs	Parietal	Related to the body walls
Afferent	Carry in toward	Efferent	Carry away from

The body can be divided into sections based on the plane of dissection.

Median	Divides right/left halves
Sagittal/longitudinal	Divides right/left parts
Frontal/coronal	Divides anterior/posterior
Transverse/horizontal/ cross section	Divides superior/inferior parts

Cavities of the body: spaces that separate support and protect organs.

Posterior (Dorsal) Cavities:

Cranial (brain and skull)

Vertebral (spine)

Anterior (Ventral) Cavities:

Thoracic (contains 2 pleural or lung sacs and the pericardial or heart sac)

Abdominopelvic (contains the digestive and reproductive organs)

In the thoracic cavity, the area called the mediastinum, which contains the heart and surrounding tissues, separates the pleural sacs. The diaphragm separates the thoracic from the abdominopelvic cavities.

Membranes made of connective tissue line the body cavities. The two types of membranes are **mucous membranes** (thick and viscous lubricant) and s**erous membranes** (watery lubricant).

Skeletal System

Humans are born with 300 bones. By the time a human matures to adulthood, many bones fuse and at that time there are 206 separately identified bones. The skeletal system consists of these bones, the joints between them, and the cartilage and ligaments that hold them together.

The skeletal system has five main functions:

1. Support.
2. Protection (like protecting the internal organs or the brain).
3. Production of blood cells.
4. Storage (for mineral salts like calcium and fat).
5. Movement (bones allow the appendages to be flexible).

There are different types of bones:

Long bones: found in the appendages

Periosteum

Epiphysis

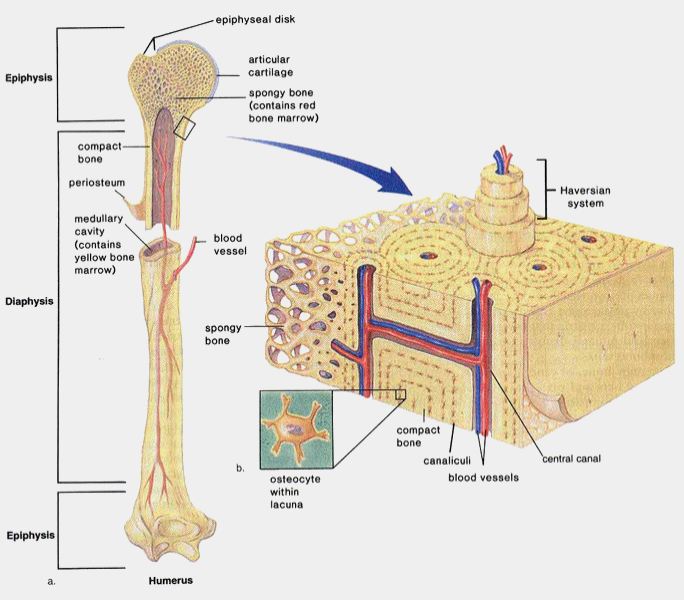
Diaphysis

Short Bones: found in confined spaces like the carpals in a hand

Flat Bones: found in the skull and ribs

Irregular Bones: vertebrae

There is spongy bone and compact bone based on the density of the bone matrix as seen in this diagram.



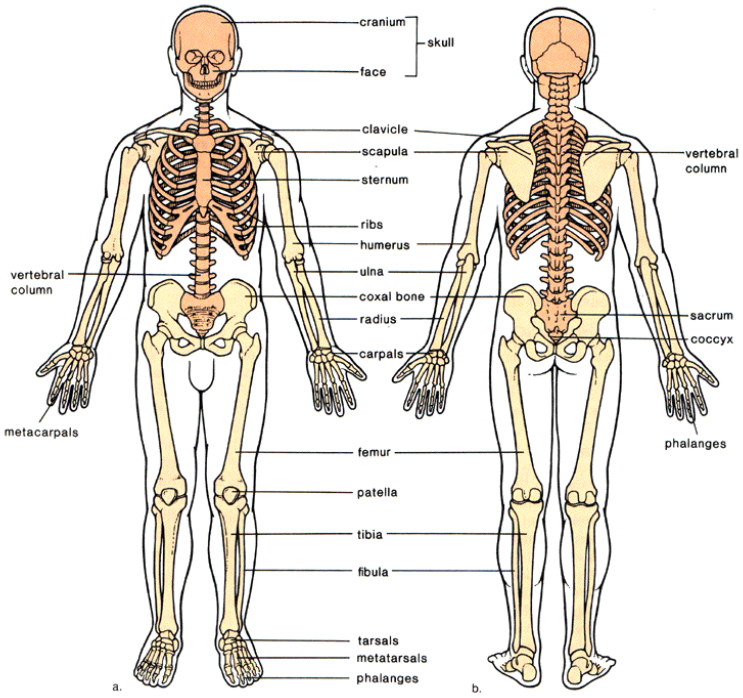
The skeleton can be divided into two parts: **axial** and **appendicular**

The Axial Skeleton (skull, hyoid bone, vertebral column, and the thoracic cage).

(1) The skull is made of 8 cranial and 14 facial bones.
(2) The hyoid bone is a unique U-shaped bone located above the voice box in the neck. It is the only bone in the body that does not connect to another bone. It anchors the tongue and attaches to muscles associated with swallowing.
(3) The vertebral column extends from the bottom of the skull all the way to the pelvis. It is made up of a long series of small bones known as vertebrae separated by small pads of fibrocartilage called intervertebral disks. The vertebral column is divided into five regions: cervical (7), thoracic (12), lumbar (5), sacral (4-5 fused), and coccygeal (4-5 fused).
(4) Thoracic Cage is a protective shell to the heart and lungs made of ribs and a sternum.
A. Ribs- There are twelve pairs of ribs that connect to the vertebrae. Seven are true ribs and articulate directly to the sternum. Three are false ribs and are joined indirectly through costal cartilage. Two are floating ribs and do not attach to the sternum at all.
B. Sternum- There are three distinct parts of the sternum known as the manubrium, body, and xiphoid process. Of interest, the body is made up of 3 parts that fused with growth about every 7 years. The last part is not fully fused until about 21 years of age.

Appendicular Skeleton (the pectoral girdle, upper limbs, pelvic girdle, and lower limbs)

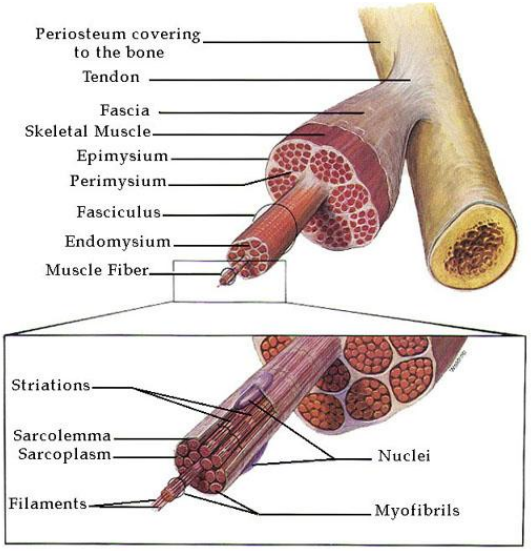
(1) The pectoral girdle is made up of two clavicles and two scapulae.
(2) The upper limb includes the humerus, radius, ulna, carpals, metacarpals, and phalanges.
(3) The pelvic girdle is made up of two hipbones as well as the sacrum and coccyx.
(4) The lower limbs include the femur, tibia, fibula, tarsals, metatarsals, and phalanges.



Muscular System

Connective Tissue Wrappings

Each muscle fiber (cell) is wrapped in a thin, delicate layer of connective tissue called **endomysium**. Many muscle fibers are bundled together into groups called **fascicles**. Each fascicle is wrapped in a second layer of connective tissue made of collagen called **perimysium**. Many fascicles are bundled together to form a **skeletal muscle**. Each skeletal muscle is covered by a third layer of dense, fibrous connective tissue called **epimysium**. Each skeletal muscle is then covered by a fourth, very tough fibrous layer of connective tissue called **deep fascia**. The deep fascia may extend past the length of the muscle (**tendon** or **aponeuroses)**, and attach that muscle to a bone, cartilage or muscle.



SKELETAL MUSCLE ACTIONS

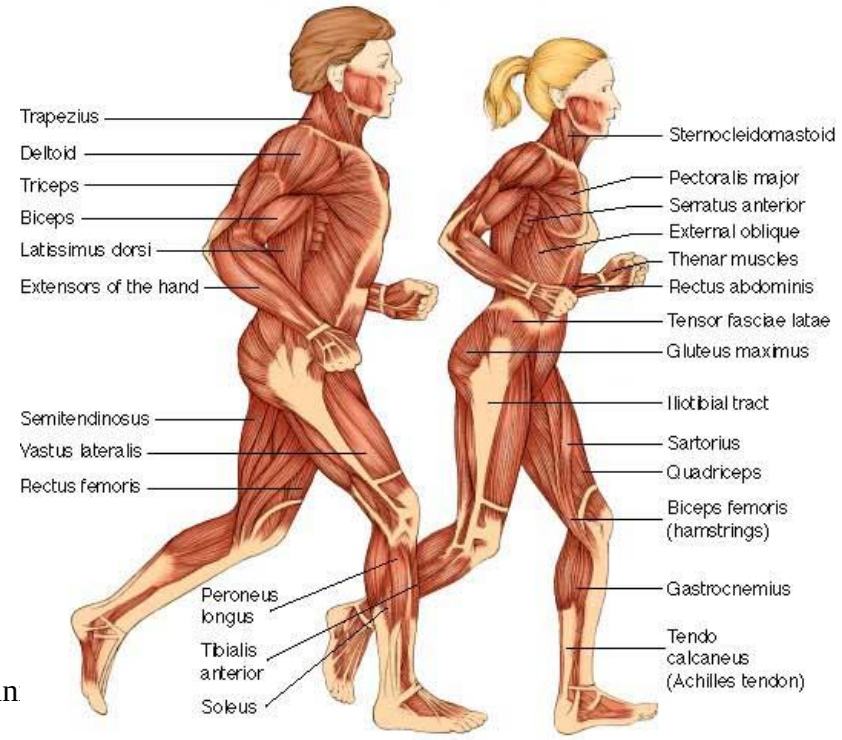
A. **Introduction**: Skeletal muscles generate a great variety of body movements. The action of a muscle primarily depends upon the joint associated with it and the manner in which the muscle is attached on either side of that joint.

B. **Origin and Insertion:** Skeletal muscles are usually attached to a fixed body part and a movable body part.
   1. The **origin** of a muscle is its immovable (fixed) end.
   2. The **insertion** of a muscle is the movable end of a muscle.
   *When a muscle contracts and shortens, its insertion is pulled toward its origin.

C. **Skeletal Muscle Actions**:
   1. **Flexion** = decreasing the angle between 2 bones
      a. Dorsiflexion = decreasing the angle between the foot and shin
      b. Plantar flexion = pointing toes
   2. **Extension** = increasing the angle between 2 bones
   3. **Abduction** = moving a body part away from the midline
   4. **Adduction** = moving a body part toward the midline
   5. **Circumduction** = movement in a circular (cone-shaped) motion
   6. **Rotation** = turning movement of a bone about its long axis
   7. **Supination** = thumbs up
   8. **Pronation** = thumbs down
   9. **Inversion** = sole of foot in
   10 **Eversion** = sole of foot out
   11. **Elevation** = lifting a body part
   12. **Depression** = returning a body part to pre-elevated position

NAMING SKELETAL MUSCLES

CHARACTERISTIC	EXAMPLES	EXAMPLES IN HUMANS
Direction of fascicles relative to midline	rectus = parallel transverse = perpendicular oblique = at 45° angle	Rectus abdominis Transversus abdominis External Oblique
Location (i.e. the bone or body part that a muscle covers)	frontal bone tibia	Frontalis Tibialis Anterior
Relative Size	maximus = largest longus = longest brevis = shortest	Gluteus maximus Palmaris longus Peroneus longus
Number of Origins (Heads)	biceps = 2 origins triceps = 3 origins	Biceps brachii Triceps brachii
Shape	deltoid = triangle trapezius = trapezoid serratus = saw-toothed orbicularis = circular	Deltoid Trapezius Serratus anterior Orbicularis oris
Location of Origin and/or Insertion	origin = sternum insertion = mastoid process	Sternocleidomastoid
Action of Muscle	flexion extension adduction	Flexor carpi radialis Extensor digitorum Adductor longus



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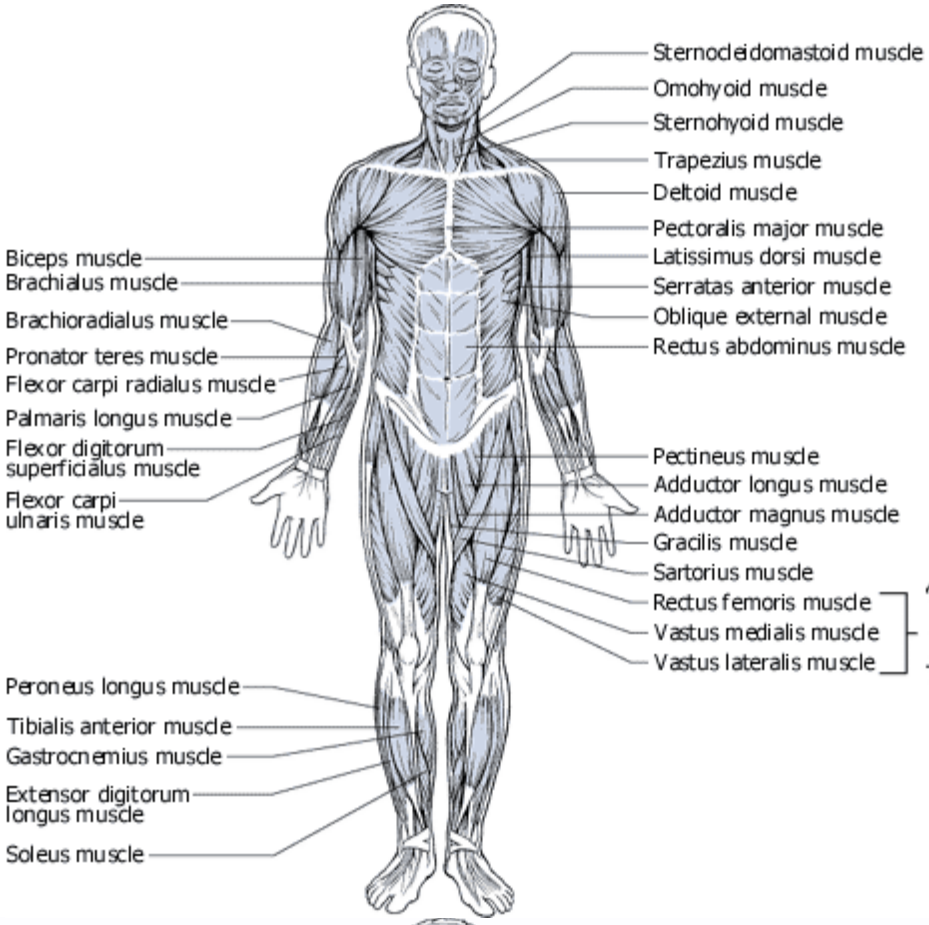
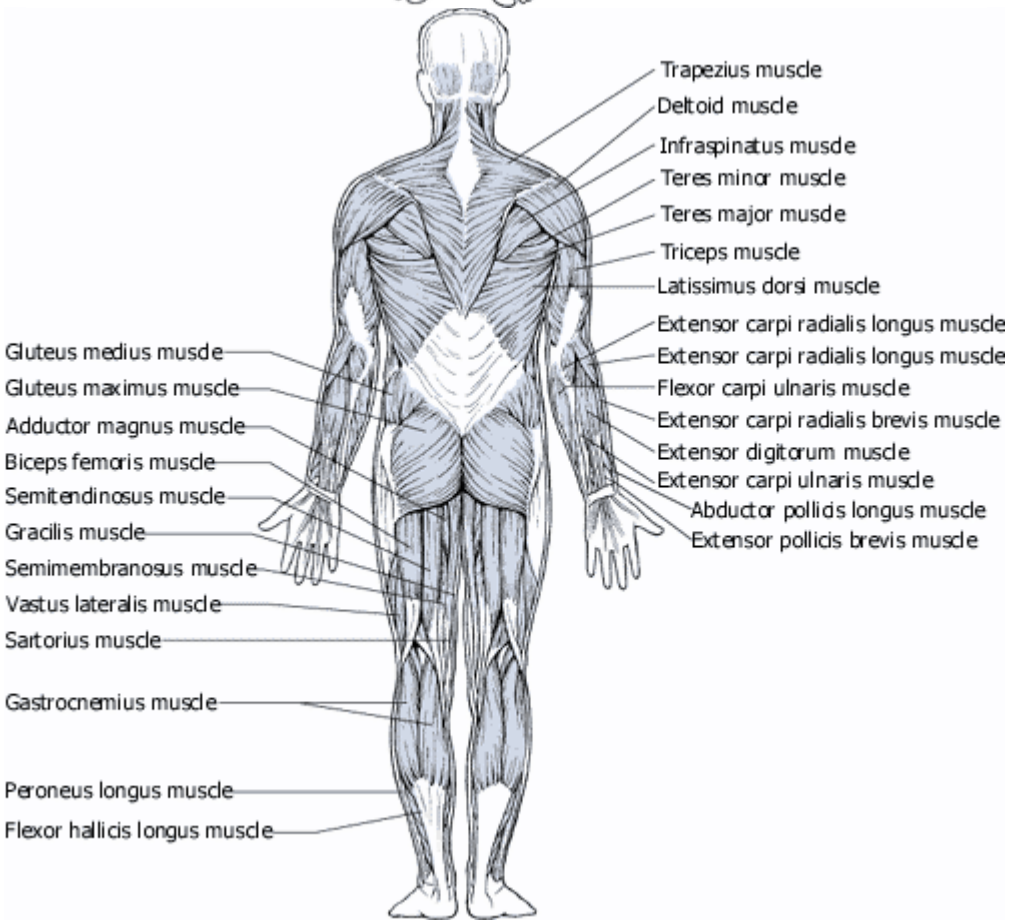
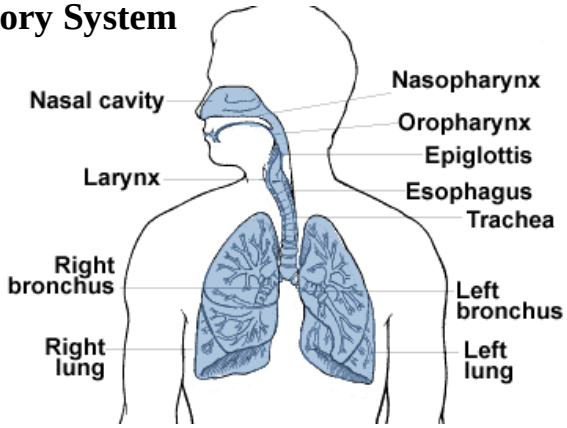

Sternocleidomastoid muscle
Omohyoid muscle
Sternohyoid muscle
Trapezius muscle
Deltoid muscle
Pectoralis major muscle
Latissimus dorsi muscle
Serratas anterior muscle
Oblique external muscle
Rectus abdominus muscle
Biceps muscle
Brachialus muscle
Brachioradialus muscle
Pronator teres muscle
Flexor carpi radialus muscle
Palmaris longus muscle
Flexor digitorum superficialus muscle
Flexor carpi ulnaris muscle
Pectineus muscle
Adductor longus muscle
Adductor magnus muscle
Gracilis muscle
Sartorius muscle
Rectus femoris muscle
Vastus medialis muscle
Vastus lateralis muscle
Quadriceps
Peroneus longus muscle
Tibialis anterior muscle
Gastrocnemius muscle
Extensor digitorum longus muscle
Soleus muscle


Trapezius muscle
Deltoid muscle
Infraspinatus musde
Teres minor muscle
Teres major musde
Triceps muscle
Latissimus dorsi muscle
Extensor carpi radialis longus muscle
Extensor carpi radialis longus muscle
Flexor carpi ulnaris muscle
Extensor carpi radialis brevis muscle
Extensor digitorum muscle
Extensor carpi ulnaris muscle
Abductor pollicis longus muscle
Extensor pollicis brevis muscle
Gluteus medius musde
Gluteus maximus muscle
Adductor magnus muscle
Biceps femoris muscle
Semitendinosus muscle
Gracilis muscle
Semimembranosus muscle
Vastus lateralis muscle
Sartorius muscle
Gastrocnemius muscle
Peroneus longus muscle
Flexor hallicis longus muscle

Respiratory System



The respiratory system is composed of:

1. The nose
2. Nasal cavity
3. Pharynx
4. Larynx
5. Trachea
6. Bronchi and bronchioles
7. Alveolar tissue of the lungs.

.

Divided into two parts:

Upper Respiratory Tract: the air passages of the nose, nasal cavities, pharynx, larynx and upper trachea (parts outside of the rib cage).

Lower Respiratory Tract: lower trachea, bronchi, bronchioles and the lungs

How does air travel in the system?
Air enters through the nose or mouth. Then air proceeds to the pharynx where both food and air can pass. When food is swallowed, a flap of cartilage called the epiglottis, presses down and covers the opening to the air passage. Air then moves through the larynx or voice box at the upper end of the trachea through the trachea and then to either the right or left bronchi and then the bronchioles into the lung tissue itself, ending at the alveolar sacs.

Specific Descriptions:

The Nose: There are 3 chonae, inferior, middle and superior which function to filter heat and moisten the air. When air enters through the mouth, much less filtering is done.

The Larynx (Voice Box or Adam's Apple)**:** This is where your voice originates. Inside there are two highly elastic folds of tissue (ligaments) called the vocal cords. Air rushing through the voice box causes the vocal cords to vibrate producing sound waves.

The Trachea: The walls of the trachea are made up of C-Shaped rings of tough flexible cartilage. These rings of cartilage protect the trachea, make it flexible, and keep it from collapsing or over expanding. The cells that line the trachea produce mucus; the mucus helps to capture things still in the air (dust and microorganisms), and is swept out of the air passageway by tiny cilia. The trachea divides into two branches, the right and left bronchi. The first branches are called the bronchioles. The bronchioles then end in air space sacs called alveoli where gas exchange between the atmosphere and the blood occurs.

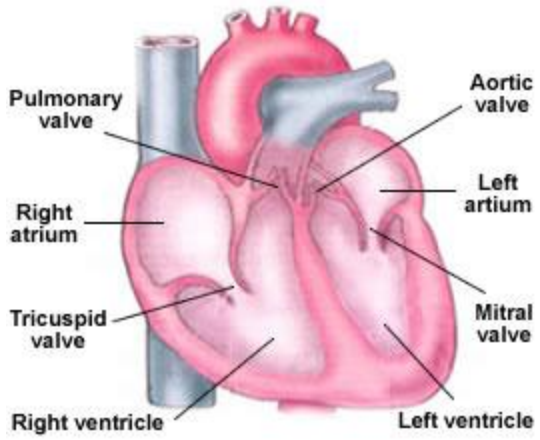
The Lungs: There are 2 lungs located in the thoracic cavity, the right and the left. The right lung has 3 lobes, the upper, middle and the lower. The left lung has 2 lobes, the upper and the lower. The pleura membranes line the rib cage and a membrane called the parietal membrane covers the lungs. These membranes secrete mucus, which decreases friction from the movement of the lungs during breathing. Throughout the lung tissue are groups of alveoli which look like bunches of grapes. These sacs attach to the ends of the bronchioles and represent the location where gas exchange occurs in the lungs.

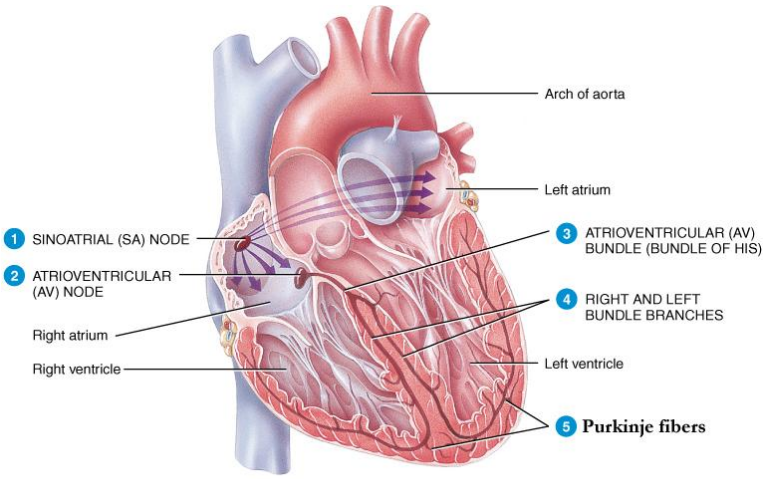
Cardiovascular System

The heart has three layers of tissue:

1. Epicardium – serous membrane that lubricates.
2. Myocardium – cardiac muscle and connective tissues that contract.
3. Endocardium – epithial membrane that strengthens the inner lining.

The heart is basically 2 pumps combined, the right and the left side, each with atrial chambers that collect blood and then inject it to their respective ventricles for pumping out into the body. The right side pumps blood into the lungs. The left side pumps blood into the rest of the body. The two sides of the heart are separated by septums. The interatrial septum is thin and membranous. The interventricular septum is thick and muscular.





Anterior view of frontal section

Valves: Each cardiac valve is secured by tendons called chordae tendons, which attach to small muscles called papillary muscles

Tricuspid valve: between the right atria and ventricle and obviously tricuspid
Mitral valve: between the left atria and ventricle and not so obviously bicuspid
Pulmonary valve: between the right ventricle and the pulmonary artery
Aortic valve: between the left ventricle and the aorta

Conduction System
Sinoatrial node (SA node) - pacer of the heart (posterior wall of the right atrium)
Atrioventricular node (AV node) – substation (interatrial septum)
Atrioventicular Bundle- connect the AV node to the purkinje fiber (ventricular septum)
Purkinje fibers – final conduction myofibrils in the ventricles
Parasympathic – decrease heart rate
Sympathic – increase heart rate

The vessels of the body consist of arteries, arterioles, veins, venules, capillaries and lymphatic vessels (not discussed here).

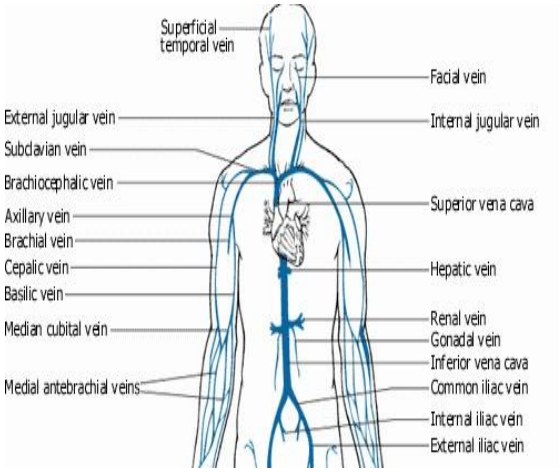
Walls of vessels:

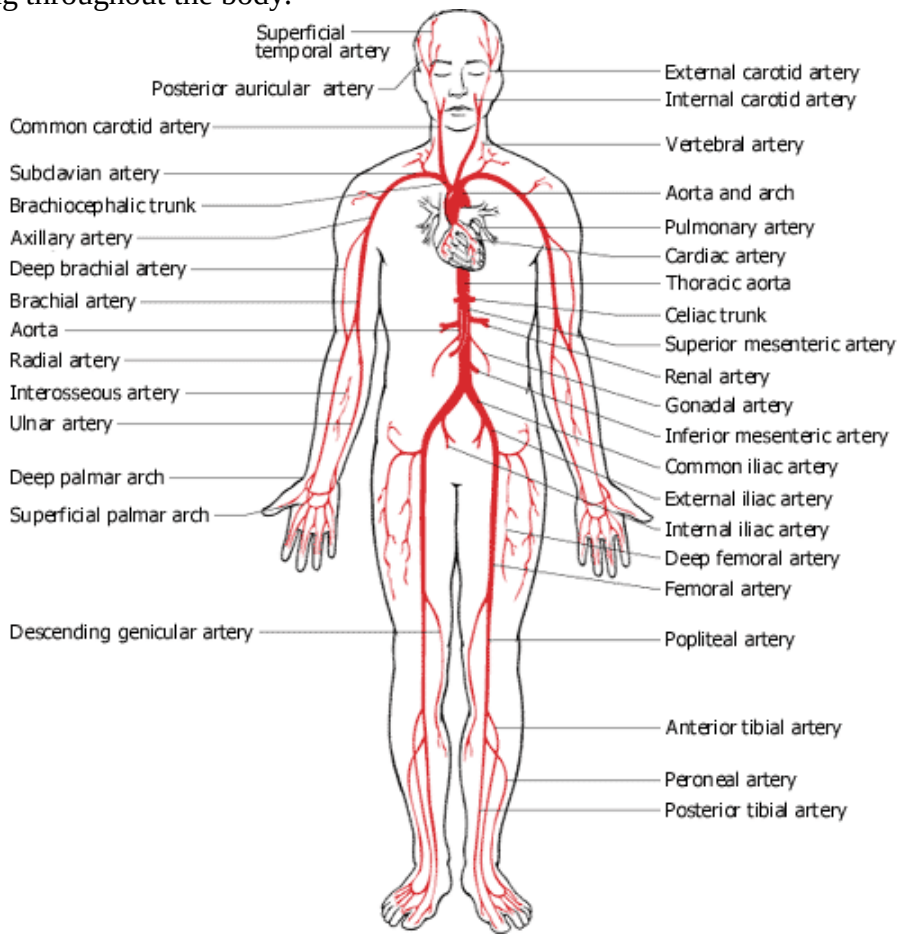
1. Tunica interna: thin layer of squamous cells called endothelium
2. Tunica media: mixed muscle and elastic fibers
3. Tunica externa: elastic and collagenus fibers

Arteries: carry blood away from the heart, lumen relatively large for vessel.
Arterioles: carry blood away from the heart, lumen relatively narrow with large tunica media which serve to help regulate blood flow.
Veins: carry blood to the heart, very large diameter, valves present
Venules: carry blood to the heart, thin small veins, valves present.
Cappillaries: exchange vessel composed only of a tunica interna (thin squamous epithelium) allowing for exchange of fluids and gases (like in the lung).

Major Vessels:
Aortic Arch and Descending Aorta – Biggest Artery
Superior and Inferior Vena Cava – Biggest Vein

See the diagram below for the names of important arteries. Most veins will follow a similar distribution. In veins, the flow of blood is reversed, in other words, arteries take blood away from the heart to the body parts but veins take blood to the heart, away from the body tissues. Veins converge in the end at the **Vena Cava** before entering the heart, whereas all blood leave the heat from the **Aorta** before distributing throughout the body.

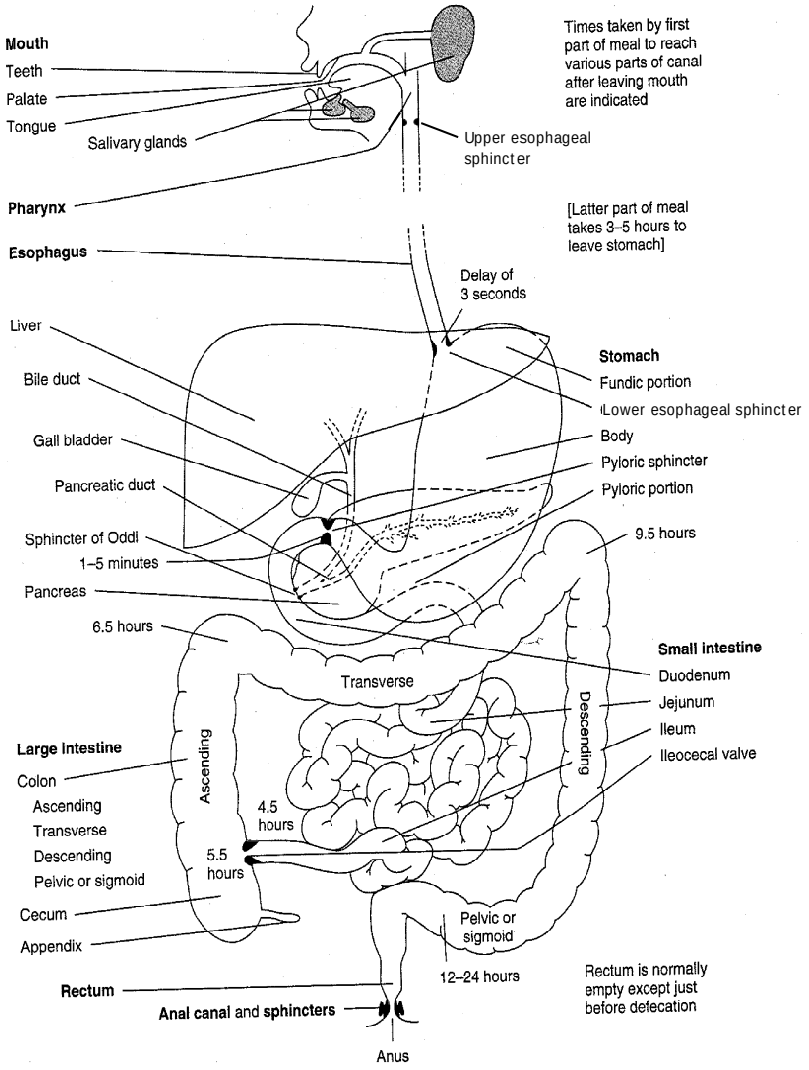




Digestive System

Digestion begins at the mouth and ends with the anus. The digestive system has the following functions:

1. To ingest food.
2. Digest food to small molecules that can cross plasma membranes.
3. Absorb nutrient molecules.
4. Eliminate indigestible wastes.



I am sure all of you are familiar with the digestive process. In short, you chew food in the mouth where digestion begins with saliva breaking down starches. Then when you swallow, food travels down the oropharynx, passing a closed epiglottis (so that you do not get food into your lung) into the esophagus. Here peristalses takes over as the method of mechanically processing food, and with the aid of the lower esophageal valve, food ends up in the stomach. In the stomach, the food is in contact with gastric juices that include pepsin (an enzyme to digest proteins), hydrochloric acid to break down connective tissue in meat, and mucus to protect the lining of the stomach. Food exits the stomach via the pyloric valve, and then enters the duodenum where bile from the liver emulsifies the fats and enzymes from the pancreas, help digest carbohydrates, fats and proteins further. Food then moves into the small intestines (duodenum, jejunum and ileum) to the large intestine at the ileocecal valve (by the appendix, a vestigious structure). The digestion process is now over. The food waste now passes through the ascending, transverse, descending and sigmoid colon where water and other essential chemicals like bile are absorbed for recycling and the stool is stored. Finally, when the body is ready to defecate, stool is pushed into the rectum (a large muscle) and released from the body.

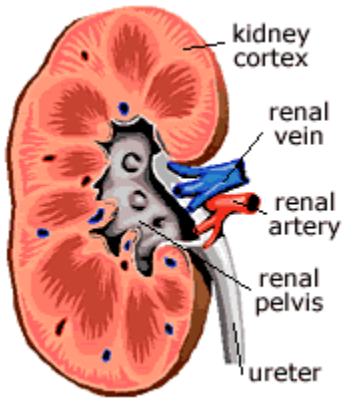
Urinary System

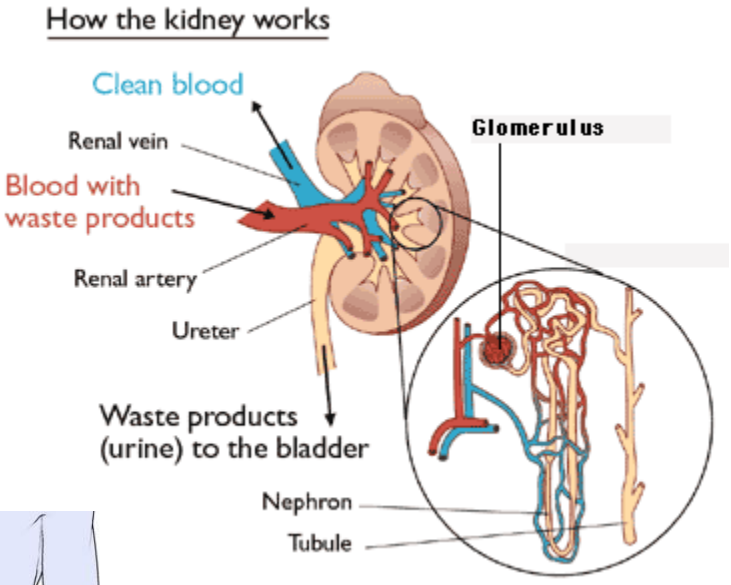
The primary functions of the urinary system are carried out by the kidneys:
1. The kidneys excrete nitrogenous wastes, such as urea, uric acid, creatinine, and ammonium.
2. The kidneys maintain blood volume by regulating the amount of water excreted.
3. The kidneys monitor blood composition by regulating electrolyte excretion. Sodium is the most significant, but potassium, bicarbonate, and calcium are also important.
4. The kidneys monitor blood pH chiefly by regulating the excretion of certain ions, such as hydrogen.
5. The kidneys help maintain blood pressure by secreting an enzyme called rennin.
6. The kidneys help maintain red blood cell production by secreting a hormone called erythropoietin.

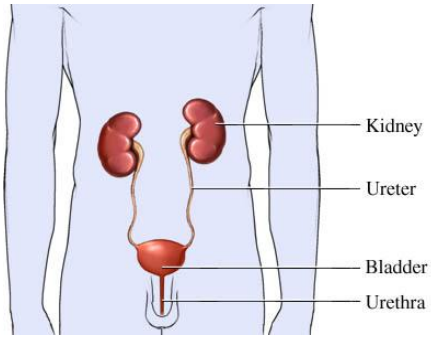
The parts of the urinary system are shown in the diagrams below. As the blood passes through the kidney **nephrons**, waste products and unneeded water are collected and turned into urine. The urine is gathered in an area called the renal pelvis. From here it drains into the bladder down a tube called the ureter. There are 2 ureters - one from each kidney. The two ureters insert into the bladder where urine is held. Then, when you are ready, the urine is excreted through a urethral valve out the urethra and out of your body.

Urination is a complex process that is not well understood. Control of urine appears to depend on the relative position of the bladder, its neck and relation to other pelvic structures. Enuresis (urine leakage) is very common in children and adults.

Inside the kidney, the blood is filtered through very small networks of tubes called **nephrons**.







Endocrine System

Introduction

The endocrine system along with the nervous system runs the body in a controlled and coordinated manner. The main functions of the endocrine system are the production of secondary sexual characters, reproduction, and growth.

There are two types of glands:

1. Exocrine glands release their secretions along ducts into spaces within the body, for example, the salivary glands release saliva in the mouth.
2. Endocrine glands do not have ducts and release their secretions (hormones) directly into the blood stream.

Pineal Gland: A midline structure in the brain, the pineal gland is responsible for the production of melatonin, which has a role in regulating the circadian rhythm. Melatonin is a derivative of the amino acid tryptophan.

Hypothalamus and Pituitary: A pea sized, pituitary gland is located just below the brain and releases more than 8 hormones, many of which control other endocrine glands. The pituitary in turn is controlled by the hypothalamus. Some examples of pituitary hormones are:

Growth hormone: Stimulates growth during childhood and adolescence.

Thyroid stimulating hormone: Stimulates the release of thyroid hormone by the thyroid gland.

Adrenocorticosteroid hormone: Stimulates release of glucocorticoid hormones by adrenals.

Follicle-stimulating hormone: Stimulates release of estrogen in ovaries, stimulates sperm production in testes and stimulates egg maturation in ovaries.

Luteinizing hormone: Stimulates ovulation and progesterone production in ovaries and testosterone production in testes.

Antidiuretic hormone (ADH): Acts on kidneys to reduce volume of urine released.

Thyroid and parathyroid: The butterfly shaped thyroid gland is present in front of the neck, on the trachea and just below the larynx. It releases three hormones; triiodothyroxine, thyroxine (together known as thyroid hormone), and calcitonin. **Thyroid hormone** is called the body's accelerator as it speeds up the metabolic rate. It also promotes growth during childhood and adolescence, and maintains the normal function of the heart and nervous system. **Calcitonin**, the third hormone, helps control the calcium levels of blood. Parathyroid glands are four in number, embedded in the posterior aspect of the thyroid gland. They release **parathyroid** hormone, which raises the calcium levels in the blood by breaking down the bones, by increasing the uptake of calcium from digested food, and by increasing the resorption of calcium into the blood via the kidneys.

Adrenal Glands: They are present on top of the kidneys, one on each side.

They produce the corticosteroids, epinephrine (adrenaline) and, norepinephrine (noradrenaline). Adrenaline and noradrenaline are helpful in "fight or flight" situations when there is a crisis i.e. to stay or run in a crisis situation.

Pancreas: Lies horizontally below the stomach, it has a head, neck and a tail.

The pancreas is both an exocrine and an endocrine gland. Most of the pancrease (90%) produces digestive juices, and the remaining cells (Islets of Langerhans) produce glucagon and insulin. These hormones ensure a stable level of glucose in the blood by having an opposing effect.

Ovaries: Two ovaries lie on either side of the uterus and are the primary female sex organs. They store the eggs (releases one mature ovum each month between puberty and menopause) and release two sex hormones, estrogen and progesterone that maintain the reproductive system and prepare the body for pregnancy when needed.

Testes: Two, oval shaped testes, lie in the scrotum. They are the primary sex organs for men and have two functions- manufacturing of sperm throughout the reproductive life, and the production of the male sex hormone called androgen.

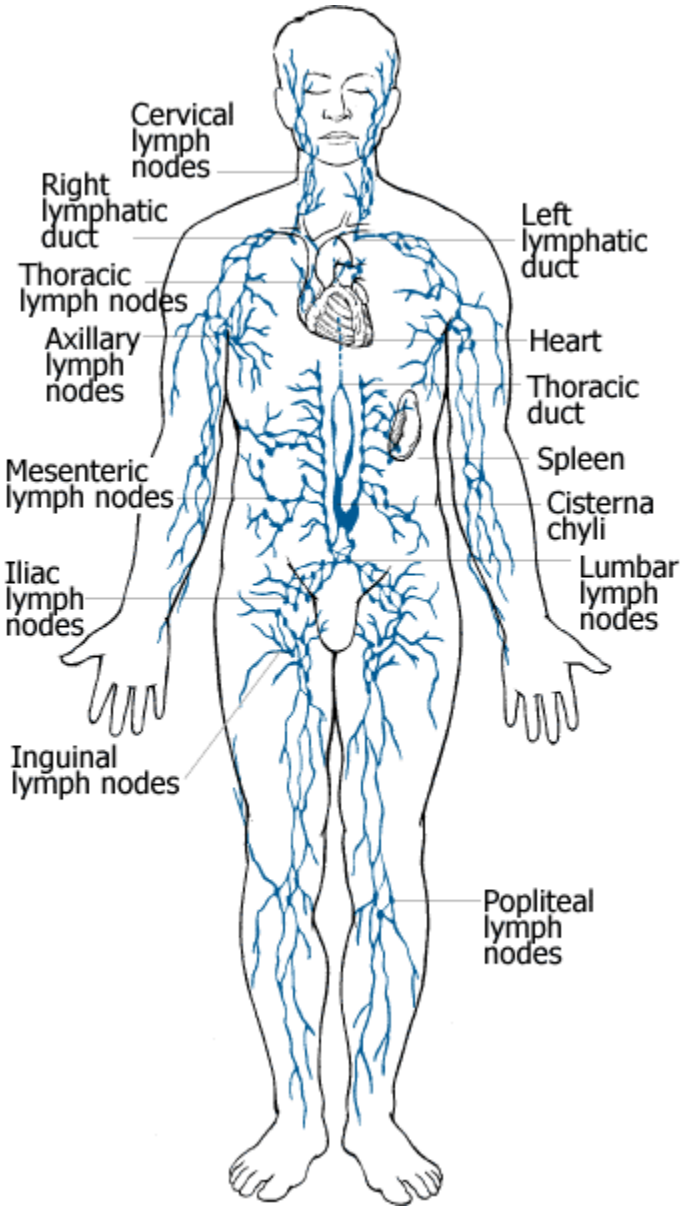
Lymphatic System

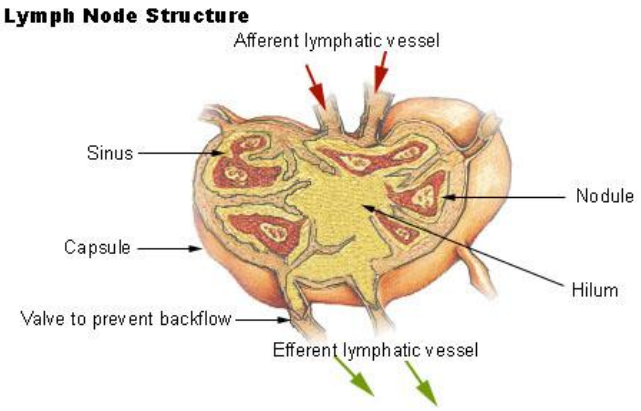
The lymphatic system is a network of very fine vessels or tubes called lymphatics that drain lymph from all over the body. Lymph is composed of water, protein molecules, salts, glucose, urea, lymphocytes, and other substances.

Lymphatic vessels are found in every part of the body except the central nervous system. The major parts of the system are the bone marrow, spleen, thymus gland, lymph nodes, and the tonsils. Other organs, including the heart, lungs, intestines, liver, and skin also contain lymphatic tissue.

Lymph nodes are round or kidney-shaped, and range in size from very tiny to 1 inch in diameter. They are usually found in groups in different places throughout the body, including the neck, armpit, chest, abdomen, pelvis, and groin. About two thirds of all lymph nodes and lymphatic tissue are within or near the gastrointestinal tract.

Lymphocytes are white blood cells in the lymph nodes that help the body fight infection by producing antibodies that destroy foreign matter such as bacteria or viruses. Two types are T-cells and B-cells. Some lymphocytes become stimulated and enlarged when they encounter foreign substances; these are called immunoblasts.





The major lymphatic vessel is the thoracic duct (dilated part is called Cisterna chyli as seen in the diagram), which begins near the lower part of the spine and collects lymph from the lower limbs, pelvis, abdomen, and lower chest. It runs up through the chest and empties into the blood through a large vein near the left side of the neck. The right lymphatic duct collects lymph from the right side of the neck, chest, and arm, and empties into a large vein near the right side of the neck.

1.7 Neuroscience

Central Nervous System - brain and spinal cord
Peripheral Nervous System

General Facts

The nervous system functions are:

1. Respond to internal and external stimuli
2. Transmit information to and away from the Central Nervous System (CNS).
3. Interpret the information
4. Assimilate experiences in memory and learning
5. Initiate muscle contraction and glandular secretion
6. Program behavior

The brain constitutes 2% of bodily mass (about 3 pounds in the average adult) but consumes 20% of bodily oxygen and glucose at rest. Neurons in the brain synthesize ATP almost exclusively from glucose via aerobic respiration. When the activity of neurons and neuroglia increases in any region of the brain, blood flow to that area of activity increases. Since glucose is not stored in the brain, this organ must receive a continuous supply of it. This is why brain death occurs when a patient is resuscitated and too much time has passed.

There are two types of cells in the nervous system.

1. **Neurons**:

Neurons are specialized cells that conduct electrochemical impulses composed of a cell body with dendrites that receive the impulse and an axon that then travels a distance ending in an axon terminal. The axon is often wrapped or insulated by an myelin sheath generated by the membrane of an accessory cell called the Schwann cell. The area where each Schwann cell ends and another Schwann cell begins is called a node of Ranvier. This area plays an

important role in the transmission of the electrochemical impulses of the neuron. The axon terminals secrete neurotransmitter chemicals to the next neuron's dendrites in an area call the synapse.

There are 3 types of neurons:
Sensory Neurons: composed of nerve cells that detect smell, sight, touch, taste and sound
Interneurons: composed of cells found only in the CNS that interact with other neurons
Motor Neurons: composed of nerve cells that stimulate muscles and glands

2. **Neuroglia:**

Neuroglia are specialized cells that function to support the nervous system.
They do not transmit impulses.

There are 4 types of neuroglia in the CNS:
astrocytes (support neuron functions like help make new connections between cells)
ependymal cells (produce spinal fluid)
oligodendrites (myelin producing cells that cover many cells)
microglia (phagocytes that clean debris)

There are 2 types in the Peripheral Nervous System (PNS): Satellite cells, Schwann cells

Synapse and Neurotransmitters
A synapse is a special junction through which impulses travel from one neuron to another or to an end organ like a muscle or gland. The initial neuron that is stimulated creates an electic potential via a Na and K shift that travels down its axon. This translates into an electrical impulse that ends at the axon terminal. The axon terminal releases a neurotransmitter chemical, which in turn crosses the synapse and binds to the next neuron's dentrites. This causes either another electic potential impluse or it decreases the chance of the neuron from having another electric potential impulse. The neurotransmitter is released and is either reabosrbed or degraded.

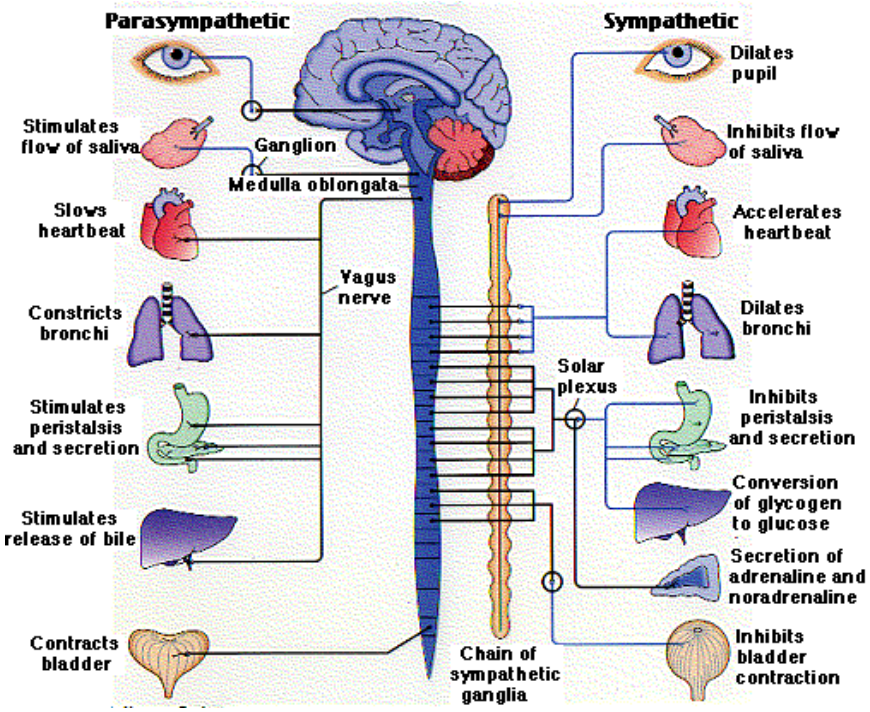
There are over 200 known neruotransmitters synthesized and secreted by the brain. Examples are: acetylcholine, epinephrine, norepinephrine, dopamine and gama-aminobutyric acid.

From a structural view, the nervous system can be divided into 2 parts:

1. Central Nervous System (CNS): Bran and Spinal Cord which contain gray matter (cell bodies, dendrites, unmyelinated axons, and neuroglia) and white matter (myelinated axons).
2. Peripheral Nervous System (PNS): Cranial Nerves and Spinal Nerves, which contain plexuses (networks of nerves) and ganglia (clusters of cell bodies).

From a functional view, the nervous system can be divide into 3 systems:

1. Autonomic Nervous System (ANS): speeds up or slows down body activities automatically.
2. Sensory -Somatic Nervous System: receives information about the environment and also interacts with the environment in a voluntary manner.



Anatomy of the Brain and Spinal Cord

Please note that you may find that different texts use different terms to describe the same structure in the brain. For example the cerebrum may be called the telecephalon. These texts are using the embryological terms rather than the typical anatomical terms. Often these terms describe regions of the brain rather than specific structures. For our purpose, we will only use anatomical terms.

The Meninges

Three connective tissues cover the CNS (brain and spinal cord). From outer to inner layer, they are:

1. **Dura mater**: protective layer pressed against the interior surface of the cranium or vertebrae.
2. **Arachnoid**: avascular membrane, have cobweb like trabeculae that look like spiders (thus named arachnoid) that cross the subarachnoid space to become the pia mater. The subarachnoid space contains cerebral spinal fluid.
3. **Pia mater**: vascular membrane adherent to the brain and spinal cord.

The Cerebrum and its lobes:

Frontal Lobe: Cognitive functions like planning, organizing, problem solving, selective attention, personality and a variety of "higher cognitive functions" including behavior and emotions.

Parietal Lobe: Contains the primary sensory cortex that controls cutaneous and muscular sensations. In addition, there are some additional functions which are located depending on the person's dominant side. For example, the dominant parietal lobe will control spoken and written language. Remember, the dominant side of your brain is opposite to your dominant hand.

Occipital Lobe: Processes visual information. It is mainly responsible for visual reception, but it also contains association areas that help in the visual recognition of shapes and colors.
Temporal Lobe: Processes sensory information like smells and tastes and helps retain short-term memories from these senses.

Superficially, the two cerebral hemispheres are separated by a rather deep **longitudinal fissure** but are connected by a deep corpus callosum. The **central sulcus** separates the **frontal lobe** from the **parietal lobe**. Immediately anterior to the central sulcus is the **precentral gyrus**. A gyrus is a convoluted ridge. The precentral gyrus is the primary motor area of the cerebral cortex. Immediately posterior to the central sulcus is the **postcentral gyrus**. It is the primary somatosensory area of the cerebral cortex. The **lateral cerebral sulcus** separates the **frontal lobe** from the **temporal lobe**. The **parieto-occipital** sulcus separates the parietal from the **occipital lobe**.

The Brainstem
This is the lower extension of the brain where it connects to the spinal cord. Neurological functions located in the brainstem include those necessary for survival (breathing, digestion, heart rate, blood pressure) and for arousal (being awake and alert). Most of the cranial nerves come from the brainstem. The brainstem is the pathway for all fiber tracts passing up and down from the peripheral nerves and spinal cord to the cerebrum and cerebellum. A detailed description of the brainstem describing all of its parts and functions is beyond our class time constraints. Many of the regions of the brainstem have regional names as well as structural names. Here is a brief outline.

Structure	Function
Thalamus	A pair of relays for sensory information (except smell) to the cerebral cortex.
Hypothalamus	Several neuclei which regulate viseral activies like temperature, heart rate, and water/ electrolyte balance.
Epithalmamus (Pineal Gland)	A gland that secretes Melatonin sets the body's clock, helps with sleep cycle and may play a role with puberty.
Superior Colliculi	Visual reflexes.
Inferior Colliculi	Auditory reflexes.
Cerebral Peduncles	Coordinating motor and sensory reflexes.
Pons	Relay station for nerve fibers from one area of the brain to another area of the brain.
Cerebellum	Two hemispheres that involuntarily coordinate body movements.
Medulla Oblongata	Primarily nerve tracts that connect the spinal cord to the brain.

Cerebral Spinal Fluid (CSF) and Ventricles
CSF is produced by the choriod epithelial cells of the lateral, third and fourth ventricles (Choroid Plexuses). It is composed of water, sodium chloride, magnesium, potassium, calcium, glucose and proteins. The CSF produced by the choriod plexuses passes through the ventricular system to exit the fourth ventricle through the foramina of Luschka and Magendie, and enters the

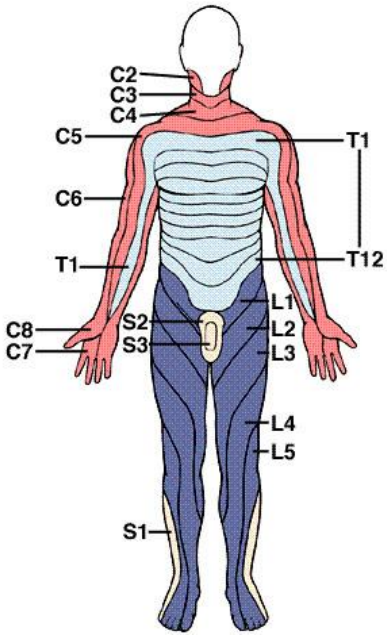
subarachnoid space, circulates around the brain and spinal cord and reenters the vascular system through the arachnoid villi that extend into the superior sagittal sinus. About 330 to 380ml of CSF enters the venous circulation per day. This provides the buoyancy necessary to prevent the weight of the brain from crushing nerve roots and blood vessels against the internal surface of the skull. The movement of CSF is influenced by two major factors, pressure gradient between the points of production (choroid plexuses), and the points of transfer into the venous system (arachnoid villi), and movement by pure mechanical means – the gentle movement of the brain during normal activities, and the pulsations of the numerous arteries found in the subarachnoid space.

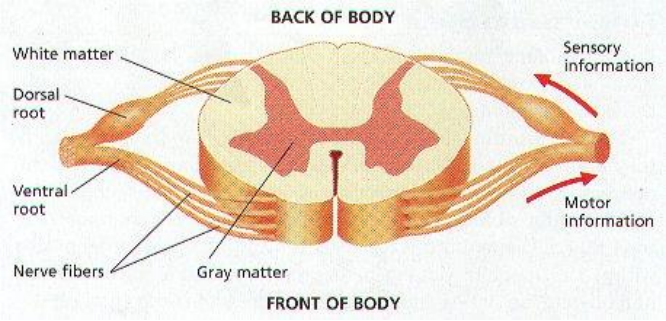
CRANIAL NERVES

There are 12 cranial nerves. These are nerves that inervate the brain directly rather than go through the spinal cord and brain stem. They are:

Cranial Nerve:	**Major Functions:**
I Olfactory	smell
II Optic	vision
III Oculomotor	eyelid and eyeball movement
IV Trochlear	innervates superior oblique turns eye downward and laterally
V Trigeminal	chewing face & mouth touch & pain
VI Abducens	turns eye laterally
VII Facial	controls most facial expressions secretion of tears & saliva taste
VII Vestibulocochlear (auditory)	hearing equillibrium sensation
IX Glossopharyngeal	taste senses carotid blood pressure
X Vagus	senses aortic blood pressure slows heart rate stimulates digestive organs taste
XI Spinal Accessory	controls trapezius & sternocleidomastoid controls swallowing movements
XII Hypoglossal	controls tongue movements

Diagram of Dermatomes below)





The Spinal Cord

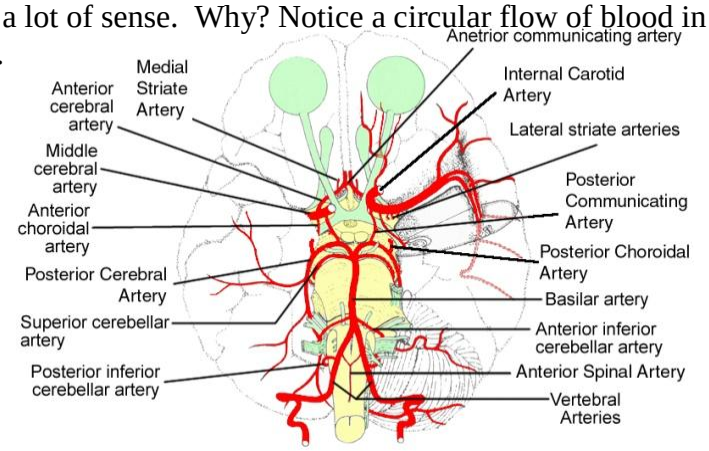
There are 31 pairs of spinal nerves that arise along the spinal cord. These are "mixed" nerves because each contain both sensory and motor axons. However, within the spinal column, all the **sensory axons** pass into the **dorsal root ganglion** where their cell bodies are located and then on into the spinal cord itself, and all the **motor axons** pass into the **ventral roots** before uniting with the sensory axons to form the mixed nerves.The spinal cord has several functions. First, it sends information (nerve impulses) from a large part of the peripheral nervous system up into the brain. Signals then arising in the motor areas of the brain travel back down the cord and end in motor neurons. Second, the spinal cord also acts as a minor coordinating center responsible for some simple reflexes like the withdrawal reflex. Impulses reaching the spinal cord from the left side of the body eventually pass over to tracts running up to the right side of the brain and vice versa. In some cases, this crossing over occurs as soon as the impulses enter the cord. In other cases, it does not take place until the tracts enter the brain itself.

Specific areas of the body reflect sensory innervation to specifie spinal nerves. Each specific area is called a dermatome. Spinal problems can be located based on sensations lossed or increased at specific dermatomes. See the diagram on the previous page on the right.

The Blood Circulation to the Brain

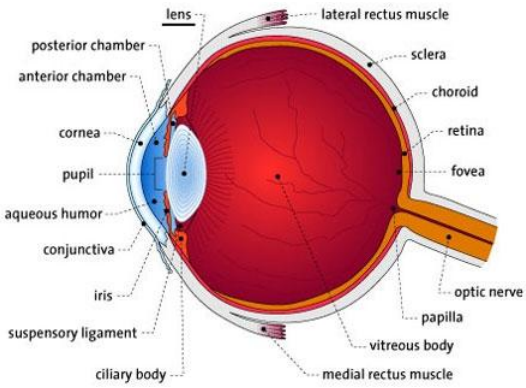
There is a **blood-brain barrier**. In the brain, tight junctions join the endothelial cells in a capillary so there is no space between endothelial cells from which substances can enter them. Surrounding endothelial cells are neuroglial cells known as **astrocytes**, which release chemicals that control which substances are able to enter the brain. Nonpolar substances such as O_2, CO_2, alcohols, and most anesthetics can diffuse across the barrier. Water and ions, urea and creatine traverse the blood-brain barrier via channels. Glucose, which is polar, crosses the blood-brain barrier via active transport. Proteins and most antibiotics cannot cross.

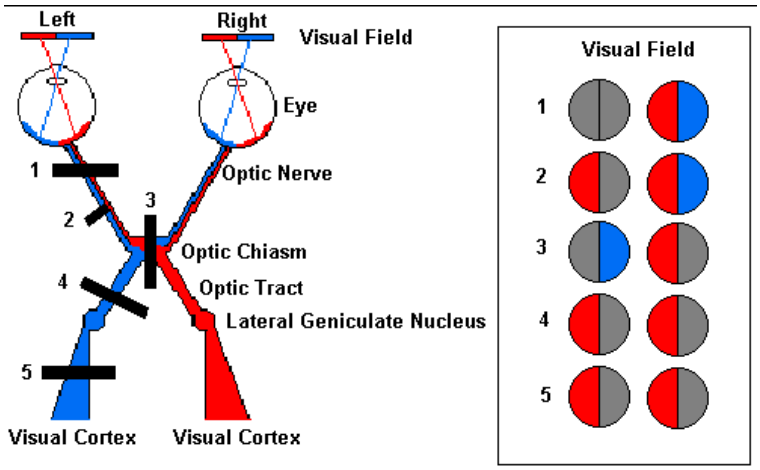
There are numerous blood vessels in the brain. It is important for the brain to have blood flow all of the time, as it is very dependent on oxygen and glucose, and it does not have any ability to store or make its own energy. Thus, you may reason that the following diagram of artieres to the brain in fact makes a lot of sense. Why? Notice a circular flow of blood in the diagram called the Circle of Willis.



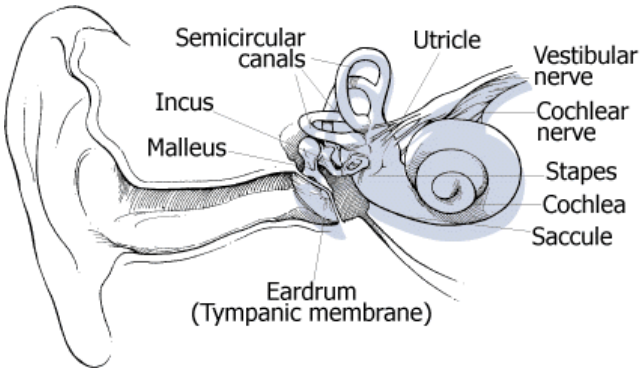
Special Sensory Organs: Eye, Ear, Nose and Tongue

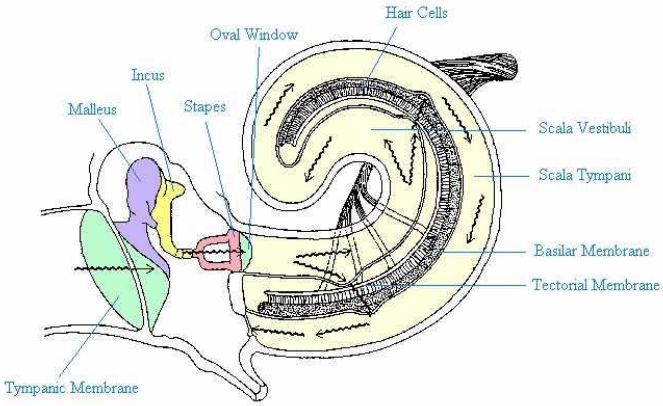
The Eye:



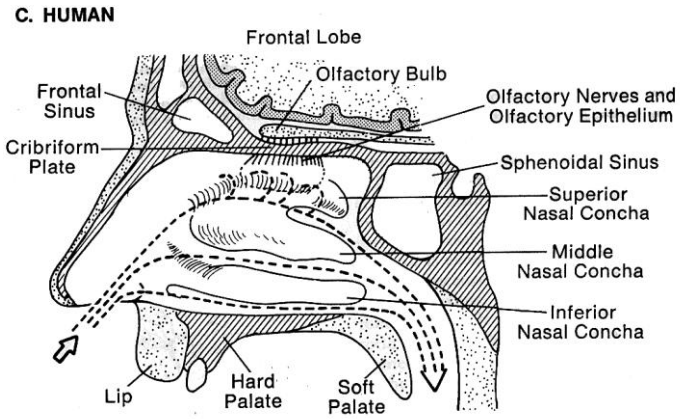


The Ear:





The Nose:



The Tongue:

1.8-1 Experience 1: Taking Vital Signs

Measure Vital Signs: practice BP and measure the rest

* Pulse * Temperature
* Respiration * Blood Pressure

* Refer to Experience 1 handout.

1.8-2 Experience 2: Gross Dissection

Dissect Kidney, Heart, Eye and Brain

We are not able to perform a real human cadaver dissection. We will dissect organs from a lamb to get a good idea of the experience a med students have during the anatomy lab.

1.9 Biochemistry/ Cell Biology

Carbohydrates, Lipids, Proteins, Nucleic Acids
Clinical Case Correlation: The Urea Cycle

Medical schools are changing and in the near future, will most likely require biochemistry as a prerequisite. Medical biochemistry is important for the understanding of metabolic diseases and nutrition. I present an overview of the basic elements of biochemistry. The memorization of biochemical pathways is beyond our needs. However, we will discuss the metabolic pathway in class and review a defect in the urea cycle to demonstrate the clinical relevance of biochemistry.

Carbohydrates: CH_2O , monosaccharides, polysaccharides

Carbohydrates always have a 1:2:1 ratio of carbon, hydrogen, and oxygen.

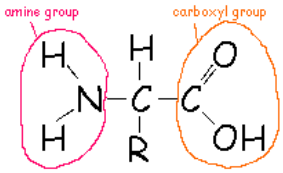
The monomers of carbohydrates are called monosaccharides or simple sugars. They are usually ring-like and are composed of five or six carbons. They are either a polyhydroxy aldehyde or a polyhydroxy ketone, which means they have more than one hydroxide group (-OH) and one carbonyl group (C=O). Some common monosaccharides are glucose, fructose, and galactose.

Polysaccharides are carbohydrates that are composed of thousands of monomers. The main important polysaccharides are:
1. Starches: Plants store their energy as starch using photosynthesis. We eat plants, breaking down the starch into its monomers.
2. Cellulose: The cell walls around plants are composed of cellulose. Cellulose is a very important structural component of plants.
3. Glycogen: Animals store energy as glycogen in the liver.

Carbohydrates are a major energy source for living organisms. Mitochondria break down carbohydrates and use the chemical reaction as an energy source.

Proteins: amino acids

Amino acids are the monomers of proteins. The basic parts of an amino acid are an amine group, a carboxylic group, and a side chain, all attached to an alpha-carbon (central carbon).



The bond between two amino acids is called a peptide bond.

There are only 20 kinds of amino acids found in nature, 8 of which can be produced by humans and are referred to as non-essential amino acids. The rest we have to obtain by eating, and these are called essential amino acids.

There are three levels of structure in the formation of a protein: the primary, secondary, and tertiary structures.

The primary structure is simply the sequence of amino acids. The secondary structure is formed by the hydrogen bonds that are formed between the amino acids. There are two kinds of hydrogen bonding between amino acids, and therefore two kinds of secondary structure. When the hydrogen bonds are intrachain, meaning they are within the same polypeptide chain, they form a helical structure called the alpha-helix. On the other hand, interchain hydrogen bonding (H-bonding among two different polypeptide chains) produce a stable structure called a pleated sheet (or a beta sheet). The tertiary structure refers to the overall shape of the protein: either long and narrow, or globular. The tertiary structure is determined by many different kinds of interactions, such as hydrogen bonding, ionic bonds, and covalent bonds.

There are two kinds of proteins, and they both serve different purposes:
- fibrous proteins: They usually provide structure and are usually long and thin. Examples include muscles, hair, cartilage, veins, ducts, and other structures.
- globular proteins: The name describes their structure. These proteins usually do things other than structure, like transport oxygen and nutrients, fight invasions by foreign objects, help maintain homeostasis in the body, transport electrons, and catalyze reactions that would take too long in their absence. Most hormones are proteins.

Enzymes are very important globular proteins. Enzymes are biological catalysts. A catalyst is a substance that lowers the activation energy needed to make a reaction run. The catalyst is not altered during the reaction in any way. Enzymes are essential to life.

Each enzyme is reaction-specific. An enzyme can only catalyze one type of reaction, but it can catalyze it forwards and backwards. Also, it is reusable, since it doesn't get altered in the reaction.

Enzymes are said to be working according to the lock-and-key theory, pictured below:

Sometimes, a molecule that is not a substrate goes into the active site of the enzyme, disabling it from catalyzing reactions. This molecule is called an inhibitor. Many inhibitors are neurotransmitters that control impulses.

In summary, proteins are very important. They provide structure, and also function as organic catalysts. They can also be used to store energy. They are produced by the ribosomes in our cells.

Lipids: fatty acids and glycerol

Lipids are also very important to structure, function, and they store energy. There are four kinds of lipids according to their molecular structure. Here are their common uses:
- fats: oils, animal fat, etc.
- phospholipids: cell membrane structure
- waxes: waterproof coatings on leaves, fruit, feathers, skins of animals
- steroids: cholesterol, sex hormones, bile acids

1.Fats: A fat is composed of glycerol and long chains of carboxylic acids called fatty acids. They are generally referred to as triglycerides. Triglycerides can be decomposed by adding NaOH.

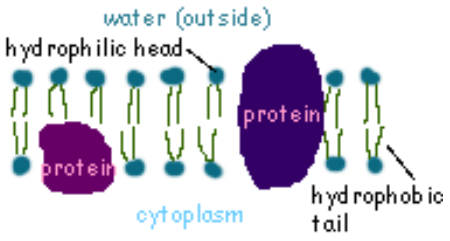
Fatty acids are saturated if there are no double bonds in their chain, unsaturated if there is one double bond, and polyunsaturated if there is more than one double bond. Saturated fatty acids tend to be solid. On the other hand, unsaturated fats are liquid at room temperature because they have a double bond, their shape is bent and they can't form layers as well.

2. Phospholipids: cell membrane structure

Phospholipids are similar to triglycerides, only the phospholipid has two fatty acid tails and one phosphate group "head." The head is polar and therefore hydrophilic. The tail is nonpolar and is hydrophobic. Because of this, phospholipids can form phospholipid bilayers and vesicles.

According to the fluid mosaic model, our cell membranes are composed of phospholipid bilayers through which small molecules like water and air can diffuse through. For bigger molecules, there are large proteins embedded into the membrane to passively and actively support transport of these materials.

Here is a simple diagram of the cell membrane:



3. Waxes: waterproof coatings on leaves, fruit, feathers, skins of animals. Waxes contain monohydroxy alcohols instead of glycerol (which has three hydroxyl groups). They are solids with low melting points and are used as waterproof both in nature and commerically.

4. Steroids: Steroids are separated into four groups:
- cholesterol: It is found on the cell membrane, and according to the fluid mosaic model, it keeps the membrane moving.
- adrenocorticoid hormones (ADH): This hormone is found in the kidney and regulates water retention.

- sex hormones: Some include the testosterone which gives secondary male characteristics. There are various female hormones like estrogen.
- bile acids: Bile acids emulsify, or break down, fats in the intestines so they are easier to digest.

Nucleic Acids

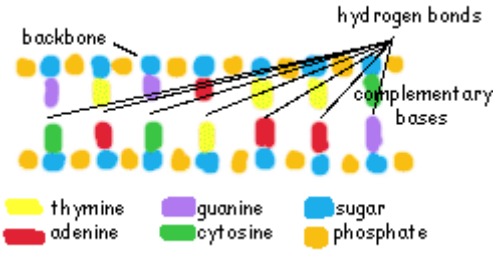
In order for life to go on for generations, organisms need to transmit genetic material to the next generation. Somehow this information needs to be stored somewhere and be easy to duplicate during reproduction.

Nucleotides are the monomers of nucleic acids. They are made up of three parts: a pentose sugar, a nitrogenous base, and a phosphate group:

There are five different kinds of nitrogenous bases. In DNA there are adenine (A), thymine (T), cytosine (C), and guanine (G). In RNA there is no thymine; instead, there is uracil (U).

The order of these different nucleotides store the genetic code in the structure of DNA and RNA.

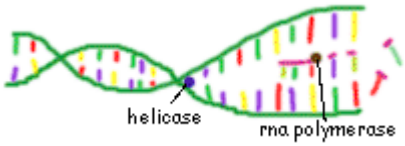
In DNA and RNA, the nucleotides bond together at the phosphate group and the sugar, so the "backbone" is a chain of alternating phosphate and sugar. Branching off from the sugar is a nitrogenous base.



DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) can be easily copied because one type of nitrogenous base only has one complement: adenine always pairs up with thymine (or uracil in RNA), and guanine always pairs up with cytosine. It is a practical way of storing the information.

A gene is a segment of DNA that codes for a molecule, usually a protein.

DNA has a double helix shape, meaning there are two strands, and they're twirled together like a helix. I'm sure you all know what DNA looks like. The instructions for making a protein are coded into the DNA by the order of its nitrogenous bases. First, helicase "unzips" the DNA and then enzymes start building an mRNA (messenger RNA) molecule according to the DNA's order of bases:



After the mRNA is made, it leaves the nucleus and travels out to the cytoplasm, where it finds a ribosome. On an mRNA, a set of three nitrogenous bases that code for a specific amino acid is called a codon. The codons determine the primary structure of the protein.

There is also a type of RNA called a tRNA (transfer RNA). This RNA has an anticodon (three nitrogenous bases that are complementary to the codon on mRNA) that codes for the same amino acid. Its job is to find the amino acid that the genetic code asks for, and bring it to the ribosomes.

The ribosome's job is to build peptide bonds connecting the amino acids to form a polypeptide. It uses the information on mRNA and the amino acids that tRNA brings to build a polypeptide.

Cell Biology
The Cell components:

Plasma Membrane

Diffusion: passive movement from high to low concentration
Osmosis: passive movement of water through a semi-permeable membrane
Facilitated Transport: proteins in the membrane allow passage of otherwise restricted molecules
Active Transport: energy (ATP) is used to cross a molecule across a concentration

Gradient
Endocytosis, Phagocytosis, Pinocytosis: Mechanical processes by which the cell membrane brings material into the cell
Exocytosis: Process by which the cell releases molecules from the cell

Cytoplasm: fluid matrix in the cell, primarily water and dissolved substances like proteins, O_2, CO_2, glucose, ATP and ions.

Ribosomes: the protein factories within a cell, responsible for translation of DNA and building proteins by mRNA

Organelles: a subcellular structure with a specific function found in the cytoplasm of a cell

Nucleus: contains Chromosomes (DNA, 23 pairs in humans – 46 in total)
Nucleolus: found in the nucleus, is a site where ribosomes are made
Endoplasmic Reticulum: membranous network continuous with the cell and nuclear membranes. Rough ER has ribosomes attached and produces proteins for use outside the cell. Smooth ER does not have ribosomes but functions for steroid synthesis, intracellular transport, and detoxification.
Golgi apparatus: Stacked membrane and vessels that package proteins from the rough ER.
Mitochondria: Oval structures with membrane folds called cristae that produce ATP through the Krebs cycle and oxidative phosphorylation.
Lysosomes: Vesicles filled with enzymes that break down worn cellular components or engulfed particles.
Secretory vesicles: Membrane bound sacs which store proteins for secretion.
Microtubules/ Microfilaments: Long protein fibers that function in cell support and movement.
Centrioles: Two short rods composed of microtubules located near the nucleus during cell division that are involved in the movement of chromososmes.

Replication: process in which DNA makes an identical copy of itself prior to cell division.

Transcription: process of making mRNA from a DNA template in the nucleus

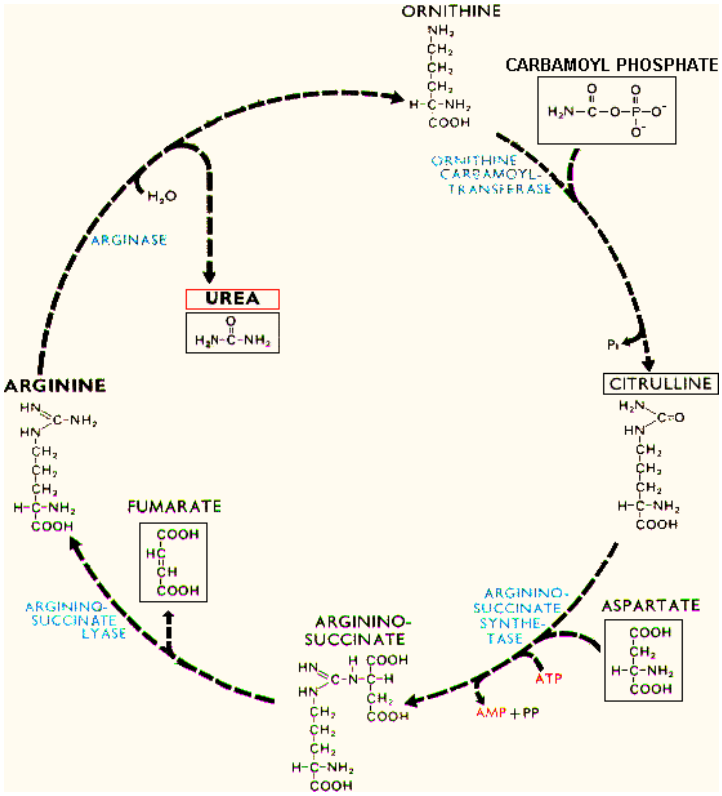
Translation: process of taking the mRNA made in the nucleus, getting it to a ribosome in the cytoplasm and then making a protein (as discussed above).

Cell Division:

Mitosis: normal cell division where the body cells need to produce more cells for growth or for replacement. The result is two identical cells with the same chromosome content as the parent.

Meiosis: sex cell (gamete) formation where the sex cells (sperm or ova) are formed and the resulting cells have half the chromosome content as the parent (46 chromosomes divide into 23 per resulting cell).

The Urea Cycle:



We will go over a clinical case in class showing why knowing the urea cycle is important.

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