ANATOMY AND PHYSIOLOGY

CHEMISTRY OF LIFE

A. WATER

1. About 65% of the human body is water.
2. An acid dissociates into hydrogen ions in water.
3. A base dissociates into hydroxyl ions in water.
4. pH is a numerical scale showing the degree of acidity or alkalinity.

B. ORGANIC COMPOUNDS

1. The carbohydrate molecules are the monosaccharides, disaccharides, and polysaccharides. They are a source of energy.
2. Lipids are insoluble in water. Triglycerides consist of three fatty acids bonded to one glycerol molecule. They store large amounts of energy.
3. Proteins consist of amino acid building blocks. Their primary structure is the sequence of amino acids in a polypeptide. Biological functions of proteins include structure, regulation, transport, contraction, and catalysis.
4. Nucleic acids consist of nucleotide building blocks. DNA is the heredity material of cells. DNA directs the synthesis of RNA, which directs the synthesis of proteins.

TISSUES

A. EPITHELIUM

1. Epithelial tissues cover the free surfaces of the body. Their shapes are squamous, cuboidal, and columnar. Epithelium can be simple or stratified.

B. CONNECTIVE TISSUE

1. Connective tissue consists of cells suspended in an intercellular material or matrix. Collagen, elastin, and reticular fibers are in the matrix.
2. Areolar or loose connective tissue has a variety of specialized cells such as fibroblasts.
3. Dense fibrous connective tissue has a compact arrangement of collagen fibers.
4. Cartilage has chondrocytes in lacunae in the matrix. Subtypes are hyaline, fibrocartilage, and elastic.
5. Bone has osteocytes arranged in a Haversian system.
6. Adipose tissue stores fat.
7. Blood has erythrocytes, leukocytes, and thrombocytes suspended in the plasma.

C. MUSCLE TISSUE

1. The cells of muscle tissue can contract.
2. Skeletal muscle tissue is striated, multinucleated, attaches to bones, and produces movement.
3. Visceral muscle tissue composes all internal organs except the heart. It is smooth and the cells have one nucleus each.
4. Cardiac muscle tissue is striated with intercalated disks. Each cell has one nucleus.

D. NERVE TISSUE

1. The neuron is the cell that sends a signal. The signal travels from the dendrites to cell body to axon.
2. Glial cells protect and support neurons.

THE SKIN

A. FUNCTIONS

1. The functions of the skin are protection, sensory reception, regulation of body temperature, vitamin D synthesis, and identification.

B. STRUCTURE

1. The sublayers of the epidermis are the stratum corneum (outermost), stratum lucidum, stratum granulosum, stratum spinosum, and stratum basale (deepest).
2. The specialized structures of the dermis are collagen and elastin fibers, arteries and veins, neurons and receptors, sweat glands and sebaceous glands, and erector pili muscles.
3. The skin and accessory structures compose the integumentary system.

C. MEMBRANES

1. The skin is the cutaneous membrane.
2. Mucous membranes line body cavities contiguous with the external environment.
3. Serous membranes line body cavities sealed off from the external environment.
4. Synovial membranes line joint capsules.

THE SKELETAL SYSTEM

A. FUNCTIONS

1. The skeletal system consists of 206 countable bones. The functions are protection, support, movement, mineral storage, and hemopoiesis.

B. GROWTH AND DEVELOPMENT

Bones can be long, short, flat, irregular, sesamoid.

1. Bones grow in diameter by the activity of osteoblasts.
2. Bones grow longitudinally at the epiphyseal plate.

C. GROSS ANATOMY OF A LONG BONE

1. The structures of the long bone are the epiphysis, diaphysis, metaphysis, medullary cavity, compact bone, cancellous bone, endosteum, periosteum, and articular cartilage.

D. AXIAL SKELETON

1. This branch consists of the skull, hyoid bone, vertebral column, and thoracic cage.
2. The bones of the skull are the frontal, temporal (2), parietal (2), occipital, ethmoid, sphenoid, maxillae (2), zygomatic (2), nasal (2), lacrimal (2), palatine (2), inferior nasal conchae (2), vomer, and mandible.
3. The vertebral column consists of four curvatures: cervical, thoracic, lumbar, and pelvic.
4. The thoracic cage consists of the sternum and 12 pairs of ribs.

E. APPENDICULAR SKELETON

1. This branch consists of the pectoral girdle, arm bones, pelvic girdle, and leg bones.
2. The pectoral girdle consists of the scapulae and clavicles.
3. Bones in each arm are the humerus, radius, ulna, carpals (8), metacarpals (5), and phalanges (14).
4. The two os coxa make up the pelvic girdle.
5. Bones in each leg are the femur, patella, tibia, fibula, tarsals (7), metatarsals (5), and phalanges (14).

F. ARTICULATIONS

1. The synarthroses are the immovable joints.
2. The amphiarthroses are the slightly movable joints.
3. The diarthroses are the freely movable joints.

THE SKELETAL MUSCLES

A. FUNCTIONS

1. Skeletal muscles produce movement, generate heat, and maintain posture.

B. STRUCTURE OF A SKELETAL MUSCLE / MUSCLE CONTRACTION

1. Fibers are skeletal muscle cells.
2. The epimysium, perimysium, and endomysium are levels of connective tissue in the muscle.
3. Myofibrils are the organelles of the muscle cell. They are a series of sarcomeres. The contractile proteins actin and myosin are organized in the sarcomere.
4. When signaled by the nervous system, a skeletal muscle contracts by the collective shortening of sarcomeres.

C. PATTERNS OF MUSCLE CONTRACTION

1. Tonus produces tautness without movement.
2. Muscle responses can be isometric or isotonic.
3. Isotonic responses can be graphed as simple twitches, summation, tetanus, and fatigue.

D. MOTIONS

1. By pulling on bones, skeletal muscles produce the motions of flexion, extension, abduction, adduction, rotation, dorsiflexion, and plantar flexion.
2. Muscles produce motions by working in groups and are prime movers as well as antagonists and synergists.

E. NAMING OF SKELETAL MUSCLES

1. Muscles are named by the characteristics of location, number of attachments, direction of fibers, shape/size, and action.

THE NERVOUS SYSTEM

A. DIVISIONS OF THE NERVOUS SYSTEM

1. The central nervous system consists of the brain and spinal cord. The peripheral nervous system consists of the 12 pairs of cranial nerves and 31 pairs of spinal nerves.

B. NEURON/GLIAL CELL

1. The neuron sends signals. Its parts are the dendrites, cell body, axon, myelin sheath, nodes of Ranvier, and neurilemma.
2. Neurons can be sensory, motor, or interneurons. They are separated by synapses.
3. Glial cells protect and support neurons.

C. NERVE IMPULSE / SYNAPTIC TRANSMISSION

1. The nerve impulse is electrical, traveling from the dendrites to the cell body to the axon.
2. The signal at the synapse is chemical (neurotransmitter).

D. REFLEX ARC

1. The reflex arc is a simple neural pathway connecting receptors to an effector. Its five parts are activated in the order: receptor-sensory neuron-interneuron-motor neuron-effector.

E. CENTRAL NERVOUS SYSTEM

1. The hindbrain consists of the medulla oblongata, pons, cerebellum, and fourth ventricle.
2. The midbrain consists of the cerebral peduncles, corpora quadrigemina, and cerebral aqueduct.
3. The lower forebrain consists of the third ventricle, thalamus, and hypothalamus.
4. The higher forebrain (cerebrum) includes the cerebral cortex (outer layer) with lobes that are: frontal, parietal, temporal, occipital. It has an inner core of white matter, including the corpus callosum which connects the two cerebral hemispheres. A lateral ventricle is found in each hemisphere.
5. The spinal cord consists of white matter columns and gray matter horns.

F. PERIPHERAL NERVOUS SYSTEM

1. The 12 pairs of cranial nerves are: olfactory, optic, oculomotor, trochlear, trigeminal, abducens, facial, vestibulocochlear, glossopharyngeal, vagus, spinal accessory, hypoglossal.
2. The five groups of spinal nerves are: cervical (8), thoracic (12), lumbar (5), sacral (5), and coccygeal (1).
3. The autonomic nervous system, part of the PNS, controls the motor function of internal organs and glands. Its sympathetic and parasympathetic branches have opposing actions. The sympathetic branch dominates during "fight or flight."

THE SENSE ORGANS

A. RECEPTORS

1. Receptors detect environmental changes. Examples are chemoreceptors, proprioceptors, photoreceptors, and mechanoreceptors.

B. EYE / PHYSIOLOGY OF VISION

1. Associated structures supporting the eye are the orbit, extrinsic muscles, palpebra, and the lacrimal apparatus.
2. The eye consists of the sclera, cornea, choroid coat, ciliary body, suspensory ligaments, iris and pupil, retina, lens, aqueous humor, and vitreous body. The lens changes convexity for objects at varying distances.
3. For vision, light passes through the: cornea – aqueous humor – lens – vitreous body – retina. The retina contains cones for color vision and rods for dim light.

ANATOMY AND PHYSIOLOGY

C. EAR/PHYSIOLOGY OF HEARING AND EQUILIBRIUM

1. External ear – the pinna and external auditory meatus.
2. Middle ear – the tympanic membrane, malleus, incus, stapes, and eustachian tube.
3. Inner ear – the cochlea, vestibule, and semicircular canals.
4. For hearing, the vibration passes through the: pinna – external auditory meatus – tympanic membrane – malleus – incus – stapes – oval window – vestibular canal – tympanic canal – round window. The cochlear duct in the cochlea has the hair cell receptors for hearing.
5. The vestibule, with its saccule and utricle, functions for static equilibrium.
6. The semicircular canals function for dynamic equilibrium.

THE ENDOCRINE SYSTEM

A. HORMONE ACTION

1. An endocrine gland secretes a hormone into the bloodstream that signals a target organ.

B. PITUITARY GLAND

1. The hypothalamus controls the anterior lobe through releasing factors.
2. The anterior lobe secretes the growth hormone (GH), in addition to ACTH, TSH, FSH, LH, and ICSH. GH stimulates the increased use of amino acids. The other five hormones are tropic hormones that stimulate other endocrine glands.
3. The posterior lobe secretes ADH, which signals the nephron tubules of the kidney to reabsorb water. It also secretes oxytocin, which signals the uterus to contract during labor.

C. THYROID GLAND

1. The thyroid gland secretes the thyroid hormone, which increases metabolism. It also secretes thyrocalcitonin, which decreases the concentration of calcium in the blood.

D. PARATHYROID GLANDS

1. Four parathyroids secrete PTH. It increases the concentration of calcium in the blood.

E. ADRENAL GLANDS

1. The adrenal cortex secretes the glucocorticoids which promote gluconeogenesis. It also secretes the mineralocorticoids, including aldosterone, which increases the reabsorption of sodium.
2. The adrenal medulla secretes epinephrine and norepinephrine. They produce an effect similar to the "fight or flight" responses of the sympathetic nervous system.

F. PANCREAS

1. The islets of Langerhans secrete insulin and glucagon. Insulin decreases the concentration of glucose in the blood. Glucagon increases the concentration of glucose in the blood.

G. GONADS

1. The reproductive organs secrete testosterone, estrogen, and progesterone. Testosterone has a masculinizing effect. Estrogen stimulates the development of the uterus and vagina. Progesterone stimulates the development of primary and secondary female characteristics.

CIRCULATORY SYSTEM

A. FUNCTIONS

1. The heart pumps blood through blood vessels to cells, serving their needs of metabolism. This system also stabilizes pH of the extracellular fluid, transports hormones, and establishes immunity.

B. BLOOD

1. The hematocrit is the percentage of blood that is cellular by volume.
2. Erythrocytes transport oxygen and carbon dioxide. They contain the pigment hemoglobin.
3. Leukocytes fight infection. There are five kinds: neutrophil, basophil, eosinophil, lymphocyte, and monocyte.
4. Thrombocytes initiate blood clotting.
5. The plasma is the liquid part of the blood.
6. The four blood types are A, B, AB, and O.

C. HEART STRUCTURE AND FUNCTION

1. The heart, encased in the pericardium, has four pumping chambers: two atria and two ventricles.
2. Its associated blood vessels transporting blood are the superior and inferior vena cava, pulmonary trunk, pulmonary veins, and aorta.
3. Its two pairs of valves are the AV and semilunar. They prevent the backflow of blood.
4. Its conduction system signals heart regions in the order: SA node – AV node – AV bundle – Purkinje fibers.
5. The cardiac cycle has the alternating events of systole and diastole. The blood pumped per minute is measured by the cardiac output.
6. The ECG is the recording of the electrical activity of the heart.

D. BLOOD VESSELS: STRUCTURE AND FUNCTION

1. Arteries transport blood away from the heart. They are elastic and contractile, with a pulsatile pressure (systolic/diastolic).
2. Veins transport blood toward the heart. They lack a pulse.
3. Capillaries are microscopic exchange vessels.
4. To supply a body region by the systemic or pulmonary circulation, blood flows through this sequence of blood vessels: arteries – arterioles – capillaries – venules – veins.
5. Major arteries are the: aorta, left subclavian and left common carotid, brachiocephalic, right common carotid and right subclavian, axillary (2), brachial (2), radial (2), ulnar (2), celiac, superior mesenteric, renal, inferior mesenteric, femoral (2), popliteal (2), anterior popliteal (2), and posterior popliteal (2).
6. Major pairs of veins are the: superior and inferior vena cava, internal and external jugular, brachiocephalic, subclavian, axillary, cephalic, basilic, brachial, anterior and posterior tibial, popliteal, femoral, external and internal iliac, common iliac, dorsal venous arch, and great saphenous.

E. LYMPHATIC SYSTEM

1. This system returns lymph to the circulatory system. Lymph is derived from tissue fluid not recaptured around systemic capillaries.

THE RESPIRATORY SYSTEM

A. ANATOMY/RESPIRATORY TRACT

1. Inhaled air passes through the structures of the tract in the order: nose – pharynx – larynx – trachea – primary bronchus – secondary bronchus – bronchioles – alveolar ducts – alveoli.
2. Each lung resides in an intrapleural cavity.

B. BREATHING/PHYSIOLOGY

1. Inhalation occurs when the pressure in the lungs drops below atmospheric pressure.
2. Exhalation occurs when the pressure in the lungs increases above atmospheric pressure.
3. Measurable air volumes include: TV, ERV, IRV, VC.
4. A center in the medulla controls breathing.

C. EXTERNAL RESPIRATION

1. By this process oxygen diffuses from the alveoli into the blood. Carbon dioxide diffuses in the other direction.

D. INTERNAL RESPIRATION

1. By this process oxygen diffuses from the blood into the tissue cells. Carbon dioxide diffuses in the other direction.

THE DIGESTIVE SYSTEM

A. ANATOMY/DIGESTIVE TRACT AND ACCESSORY STRUCTURES

1. Food passes through the structures of the tract in the following order: oral cavity – pharynx – esophagus – stomach – small intestine – large intestine – rectum. Accessory structures include the pancreas, liver, and gallbladder.

B. PHYSIOLOGY OF DIGESTION

1. By physical digestion food undergoes a physical change.
2. By chemical digestion, hydrolysis changes: polysaccharides into disaccharides into monosaccharides, proteins into amino acids, and triglycerides into fatty acids and glycerol. This is completed in the small intestine.
3. Motility and secretion are controlled by hormones such as gastrin, enterogastrone, secretin, and CCP.
4. Absorption occurs in the small intestine. Monosaccharides, amino acids, glycerol, fatty acids, vitamins, and minerals pass from the digestive tract into the blood. Most of these are transported to the liver by the hepatic portal system.
5. Reabsorption occurs in the large intestine. Fluids secreted for digestion are returned to the blood.

THE URINARY SYSTEM

A. ANATOMY

1. Each kidney consists of a capsule, cortex, and medulla with renal pyramids. Renal columns alternate with the pyramids. The papilla of each pyramid projects into a calyx. All calyces converge into a pelvis.
2. A ureter extends from the pelvis of the kidney to the urinary bladder. A urethra drains the bladder.
3. Each kidney consists of nephrons, microscopic units. The nephron consists of the renal corpuscle (Bowman's capsule and glomerulus) and several regions of tubules. Peritubular capillaries surround the tubules.

B. RENAL PHYSIOLOGY

1. Filtration is the passage of most substances from blood plasma in the glomerulus into the Bowman's capsule.
2. Reabsorption is the selective return of substances from the tubules of the nephrons into the blood of the peritubular capillaries. Aldosterone controls sodium reabsorption. Water reabsorption can be obligatory or facultative. The hypothalamus controls the facultative part through the secretion of ADH.
3. The kidneys control blood pressure by producing angiotensin through renin secretion.
4. By secretion, some substances are transported from the blood in the peritubular capillaries into the ends of nephrons.

THE REPRODUCTIVE SYSTEM

A. MALE REPRODUCTIVE SYSTEM

1. In the testis, seminiferous tubules produce sperm cells. Interstitial cells produce testosterone.
2. Sperm cells pass from the seminiferous tubules through the male reproductive tract in the order: rete testis – epididymis – vas deferens – common ejaculatory duct – urethra.
3. Glands adding seminal fluid to the tract are the seminal vesicles, prostate gland, and Cowper's gland.
4. The external genitalia are the penis and scrotum.

B. FEMALE REPRODUCTIVE SYSTEM

1. The ovary is attached to the broad ligament. It stores sex cells and produces estrogen and progesterone.
2. The oviduct curves over the ovary and enters the uterus. The oviduct receives sex cells from ovulation and is the site of fertilization.
3. The uterus has three layers. It is the site of prenatal development.
4. The vagina is the organ of copulation.
5. The external genitalia are the labia majora, labia minora, clitoris, posterior fourchette, vestibule, and mons pubis.

C. FEMALE REPRODUCTIVE CYCLE

1. The concentrations of FSH, LH, estrogen, and progesterone fluctuate during this cycle. FSH increases early in the cycle, beginning the follicular phase. LH peaks during ovulation, starting the luteal phase. The corpus luteum secretes increased levels of progesterone.

DEVELOPMENT

A. EMBRYONIC DEVELOPMENT

1. Fertilization produces a zygote. Cleavage and cell division of the zygote produce the embryo (first two months). Morphogenesis and cell differentiation produce the early embryo. These two processes produce the layers of ectoderm, mesoderm, and endoderm.

B. FETAL DEVELOPMENT

1. Refinements of morphogenesis and differentiation produce the fetus over the last seven months.

C. PARTURITION

1. Parturition is the process of birth. Oxytocin signals the uterus for labor.

D. POSTNATAL DEVELOPMENT

1. The stages of postnatal development are the child, adolescent, and adult.

BIOLOGY

CELLULAR BIOLOGY

A. ORGANELLES

1. **Mitochondria** – membrane-enclosed – energy-producing reactions
2. **Chloroplasts** – plants – photosynthesis
3. **Lysosomes** – storage for digestive enzymes
4. **Endoplasmic reticulum** (ER) – protein and lipid synthesis – rough ER has ribosomes attached
5. **Ribosomes** – particles composed of ribonucleic acid (RNA) – protein synthesis
6. **Golgi apparatus** – stores, modifies, and packages secretory products
7. **Peroxisomes** – contain oxidative enzymes
8. **Vacuoles** – fluid-filled spaces – storage
9. **Cell wall** – plants – protection and support
10. **Centriole, centrosome** – animal cells – cell division
11. **Cilia, flagella** – locomotion and ingestion
12. **Nucleolus** – in nucleus – ribosome synthesis

TISSUES

A. PLANT TISSUES

1. **Epidermis** – protection – increases absorption in root, reduces H_2O loss in stem, leaf (stomata)
2. **Parenchyma** – food and H_2O storage
3. **Sclerenchyma** – support
4. **Chlorenchyma** – photosynthesis
5. **Vascular system** – transport of fluid (xylem – upward, phloem – downward)
6. **Meristem** – growth

B. ANIMAL TISSUES

1. **Epithelial**: protection (covering body); secretion (lining internal organs)
2. **Muscle**:
   a. **Skeletal** – voluntary
   b. **Smooth** – involuntary
   c. **Cardiac** – pumping blood
3. **Connective**:
   a. **Binding** – holding tissues, organs together (tendons, ligaments, organ coverings)
   b. **Bone** – support, protection (skeleton)
   c. **Adipose** – fat storage, insulation, cushioning (under skin, around organs)
   d. **Cartilage** – reduction of friction, support (ends of bone, parts of nose, ears)
4. **Nerve**:
   a. **brain** – impulse interpretation, mental activity
   b. **spinal cord, nerves, ganglions** – carrying impulses
5. **Blood**: blood cells, vessels, heart – carrying materials to and from cells, fighting infection, clotting

EXCHANGE BETWEEN CELL AND ENVIRONMENT

A. DIFFUSION – migration of molecules or ions, result of random movements, concentration-dependent

B. OSMOSIS – tendency of a solution to move to equilibrium – going from an area of higher concentration to an area of lower concentration

1. **Isotonic medium** – same solute concentration as cell
2. **Hypertonic medium** – higher solute concentration than cell: cell loses H_2O (shrinks)
3. **Hypotonic medium** – has lower solute concentration than cell: cell gains H_2O (expands)

C. ACTIVE TRANSPORT – movement against a concentration gradient, energy-requiring.

D. ENDOCYTOSIS – active – cell encloses material (includes phagocytosis of solid particles)

E. EXOCYTOSIS – cell discharges vacuole-enclosed material

METABOLIC AND ENERGY-PRODUCING PATHWAYS

A. ENZYME – protein catalyst speeds reaction by lowering energy of activation

1. **Substrate** – molecule on which enzyme acts
2. **Coenzyme** – binds briefly to enzymes, activates and assists enzymes
3. **ATP** – adenosine triphosphate; energy released when bonds are hydrolyzed
4. **NAD** – nicotinamide adenine dinucleotide; part of electron transport system

B. PHOTOSYNTHESIS – chloroplasts – $6CO_2 + 6H_2O \rightarrow$ (light, chlorophyll) $\rightarrow C_6H_{12}O_6 + 6O_2$

C. CELLULAR RESPIRATION – generates ATP

1. **Glycolysis** – initial stage of respiration – cytoplasm – anaerobic – activation of glucose (by ATP), with production of pyruvate (net gain of 2 ATP)
2. **Krebs** (citric acid) **cycle** – second stage of respiration – mitochondria – aerobic – pyruvate broken down with production of CO_2, 2 ATP, and many electron carriers
3. **Electron** (hydrogen) **transport system** – third stage of respiration – mitochondria – aerobic – hydrogen and electrons stripped from carriers with production of 32 ATP

DIGESTIVE SYSTEM

A. ORGANS AND ENZYMES

1. **Oral cavity** – salivary glands – ptyalin – digestion of starch
2. **Pharynx** – swallowing
3. **Esophagus** – peristalsis
4. **Stomach** – gastric glands – pepsin – digestion of proteins
5. **Small intestine (duodenum, jejunum, ileum)** – final digestion and absorption of disaccharides, peptides, fatty acids, monoglycerides occur in villi.
6. **Large intestine** – reabsorbs water; receives remaining solid material after digestion
7. **Pancreatic enzymes: amylase (starch), lipase (lipids) trypsin (proteins), nucleases (nucleic acids)**
8. **Intestinal enzymes: peptidases (peptides), maltase (maltose), sucrase (sucrose), lactase (lactose)**

RESPIRATION

A. ORGANS

1. **Nose** – mucous membranes warm and humidify air
2. **Pharynx** – paths of respiratory and digestive systems cross here
3. **Trachea** – epiglottis prevents food from entering glottis
4. **Bronchi** – two – each leads to one lung
5. **Lungs** – bronchi branch into bronchioles that enter alveoli in walls of air sacs, where gas exchange occurs via adjacent pulmonary capillaries

CIRCULATORY SYSTEMS

A. HEART – four chambers: two atria, two ventricles

1. **Atria** – upper chambers – thin-walled
2. **Ventricles** – lower chambers – strong pumps – thick-walled.

B. ARTERIES – carry oxygen-rich blood to the body and oxygen-poor blood to the lungs. Thick walls of muscle and connective tissue.

C. VEINS – carry oxygen-poor blood from the body and oxygen-rich blood from the lungs. Walls thin (little muscle); valves prevent backflow.

D. CAPILLARIES – blood from arterioles enters capillaries – walls are single layer of epithelial cells that deliver oxygen and nutrients to tissues and remove metabolic wastes – then to venules, then veins.

E. BLOOD – transports materials to and from tissues; defends against infectious diseases.

1. **Red blood cells** (erythrocytes) – when mature, contain no nucleus, much hemoglobin. Carry oxygen to tissues and carbon dioxide away. Formed in bone marrow.
2. **White blood cells** (leukocytes) – nucleated, no hemoglobin. Protect against disease. Formed in bone marrow, lymph nodes. Include: neutrophils, monocytes, lymphocytes, eosinophils, and basophils.
3. **Platelets** – cell fragments that aid in clotting.

F. LYMPHATIC SYSTEM – lymphatic capillaries (closed-ended) collect intercellular fluid from tissue spaces, deliver it to larger lymphatic vessels (valves prevent backflow), then to veins in lower neck. Lymph is filtered in nodes containing lymphocytes and plasma cells. **Spleen** – lymphoid organ, filters blood and stores red blood cells and macrophages.

EXCRETION

A. SKIN – sweat glands remove water, mineral salts, and urea from blood.

B. LUNGS – CO_2 and H_2O vapor diffuse from blood in capillaries into alveoli (tiny air sacs) – then are excreted by exhaling.

C. LIVER – removes old red blood cells and monosaccharides (except glucose), and deaminates excess amino acids.

D. URINARY SYSTEM – removes excess water, mineral ions, and organic wastes.

1. **Kidneys** – blood enters via renal arteries, leaves via renal veins. **Nephrons** – main structural and functional unit of kidney.
2. **Ureters** – kidney to bladder.
3. **Bladder** – hollow, muscular organ expands with urine.
4. **Urethra** – bladder to outside.

ENDOCRINE SYSTEM

A. HORMONES – chemical substance secreted by specific cells in one area to be used in target organ.

B. ENDOCRINE SYSTEM – ductless glands secrete directly into capillaries.

1. **Thyroid** – thyroxin – rate of metabolism; growth and development. Calcitonin – lowers blood calcium level
2. **Parathyroids** – increase phosphate excretion; parathormone (PTH) – raises blood calcium level
3. **Pituitary**, anterior lobe
   a. **Tropic hormones** – regulate other endocrine glands: thyroid-stimulating hormone (TSH) – stimulates thyroid to produce thyroxin; adrenocorticotropic hormone (ACTH) – stimulates adrenal cortex to secrete hormones; follicle-stimulating hormone (FSH) – acts on gonads – stimulates sperm and egg production; luteinizing hormone (LH) – males – secretion of androgens in testes. Females – ovulation, corpus luteum formation
   b. **Hormones** with non-endocrine targets: growth hormone (GH) – growth of bones; prolactin (PRL) – mammary glands and secretion of milk
4. **Pituitary, posterior lobe**
   a. **Vasopressin** (ADH) – causes muscular walls of arterioles to contract, increasing blood pressure. Regulates water reabsorption in nephrons.
   b. **Oxytocin** – contraction of uterine muscles during childbirth
5. **Pancreas – islets of Langerhans**
   a. **Beta cells** – insulin – storage and oxidation of glucose
   b. **Alpha cells** – glucagon – glucose into bloodstream
6. **Thymus – thymus hormone – stimulates formation of antibody system in infants**
7. **Adrenal cortex**
   a. **Cortisones** – glucose formation from amino and fatty acids
   b. **Cortins** – water and salt balance
   c. **Sex hormones** – sexual development
8. **Adrenal medulla**
   a. **Epinephrine** – releases glucose into bloodstream, increases heartbeat and respiration rates, reduces clotting time, relaxes smooth muscle in bronchioles
   b. **Norepinephrine** – constriction of blood vessels
9. **Gonads – testes – testosterone – development of secondary male characteristics. Ovaries – estrogen-development of secondary female characteristics**

STIMULUS RECEPTORS

A. PHOTORECEPTORS – eye

1. **Sclera** – outer layer. **Cornea** – transparent
2. **Choroid** – middle layer – iris and pupil; light passes through to reach lens.

BIOLOGY

3. **Retina** – contains visual receptors
   a. **rods** – sensitive to light – night vision
   b. **cones** – bright-light color receptors
4. **Optic nerve** – carries stimuli to brain

B. CHEMORECEPTORS

1. **Smell** – receptor cells in olfactory epithelium. Odor molecule combines with active site; signal generated is transmitted to nerve fiber, which the olfactory nerve carries to brain for interpretation.
2. **Taste** – active sites in four types of taste buds on the tongue – sweet, sour, salty, bitter.

C. MECHANORECEPTORS

1. **Touch** – pacinian corpuscles: pressure receptors in skin and some internal organs, connected to sensory neurons.
2. **Hearing** – ear
   a. **Outer ear** – pinna and auditory canal, up to eardrum.
   b. **Middle ear** – tiny bones (anvil, hammer, stirrup) transmit sound waves across middle ear cavity. Eustachian tube from pharynx equalizes pressure.
   c. **Inner ear** – cochlea (with organ of Corti: contains vibration receptors) and three semicircular canals. Receptors initiate nerve impulses that travel through auditory canal to brain.

NERVOUS SYSTEM

A. COMPONENTS

1. **Neuron** – conducts electrochemical impulses. Nerve impulses generated in dendrites conducted along the axon, a long fiber covered by myelin sheath.
2. **Sensory neuron** – conducts impulses from receptors to the central nervous system (CNS).
3. **Interneurons** – in the spinal cord and brain. Link sensory and motor neurons.
4. **Motor neurons** – conduct impulses from CNS to effectors (muscles and glands), resulting in body's responses to stimuli.
5. **Nerve impulse** – the signal: electrical charge that travels the length of the neuron.
6. **Synapse** – the junction between axon of one neuron and dendrite of the next neuron.

B. CENTRAL NERVOUS SYSTEM

1. **Brain** – central control – surrounded by three meninges and bony skull.
   a. **Forebrain** – cerebrum – thought and neural processing.
   b. **Midbrain** – relays impulses between fore- and hindbrain.
   c. **Hindbrain** – medulla oblongata and cerebellum – reflex centers for respiration, heartbeat, coughing, swallowing, sneezing.
2. **Spinal cord** – enclosed by three meninges and spinal column vertebrae. In its center runs a narrow canal filled with cerebrospinal fluid. Pathway for impulses between peripheral nervous system and brain; connecting center for sensory and motor neurons.

C. PERIPHERAL NERVOUS SYSTEM

1. **Somatic** – nerves transmit impulses from receptors to CNS and from CNS to skeletal muscles.
2. **Autonomic** – sensory and motor neurons run between CNS and internal organs.
   a. **Sympathetic system** – motor neurons arise from spinal cord. Accelerates heart rate, constricts arteries, slows peristalsis, relaxes bladder, dilates breathing passages, dilates eye pupil, increases secretion.
   b. **Parasympathetic system** – fibers arise from the brain. Effects opposite to sympathetic system.

SKELETAL SYSTEM

A. CARTILAGE – soft material at ends of bones, especially at joints.

B. LIGAMENTS – strong bands of connective tissue that bind bones.

C. SKELETON – Functions:

1. Allows movements of body parts
2. Supports organs
3. Supplies red blood cells and some white blood cells (bone marrow)
4. Protects internal organs
5. Stores calcium and phosphate salts

MUSCLE SYSTEM

A. TYPES OF MUSCLES

1. **Smooth** – walls of hollow organs
2. **Cardiac** – heart
3. **Skeletal** (striated) – attached to skeleton

B. STRUCTURE

1. **Tendon** – strong connective tissue, attaches muscle to bone
2. **Origin** – end of muscle attached to bone that does not move when muscle contracts
3. **Insertion** – end of muscle attached to bone that moves when muscle contracts
4. **Belly** – thickened part of the muscle that contracts and pulls

C. SKELETAL MUSCLE FIBER STRUCTURE – light bands (I-bands) (actin) bisected by Z-line. Dark bands (A-bands) (myosin) bisected by H-band.

D. SKELETAL MUSCLE ACTIVATION – controlled by nervous system. End brushes of motor neurons contact muscle fibers at motor end plate. Acetylcholine is discharged and muscle contraction occurs with energy (ATP) supplied by mitochondria, and formation of actinomyosin.

REPRODUCTION

A. ASEXUAL – progeny have same kind, quantity of DNA as parent

1. **Binary fission** – parent divides into two daughter cells (protozoa, bacteria, algae)
2. **Budding** – outgrowth of cell grows and separates from parent (yeast, hydra)

B. SEXUAL – two different gametes join: new individual formed

1. **Gonad** – gland that produces the gamete – testis produces sperm; ovary produces egg

C. CELL DIVISION – DEFINITIONS

1. **Chromatin** – genetic material (equal amounts of DNA and histone proteins) of nucleus, seen as chromosomes during mitosis.
2. **Chromatids** – two chromatin strands formed by longitudinal duplication of chromosome; joined by centromere.
3. **Chromosome** – one of the 46 (in humans) bodies in the nucleus that is the bearer of genes.
4. **Centromere** – constriction on chromosome dividing it into two arms during cell division; point of attachment to spindle.
5. **Centriole** – tubular structure in animal cell mitosis; it divides, and daughters migrate to opposite ends of the cell forming spindle fibers between.
6. **Spindle fibers** – tubular structures to which centromeres of chromosomes attach, and along which they move in cell division.

D. MITOSIS – asexual – each daughter nucleus receives same complement of chromosomes as parent. Responsible for cell growth and replacement in multicellular organisms.

1. **Interphase** – active phase of synthesis. Chromosomes duplicated. Chromosomes long and thin.
2. **Prophase** – chromosomes shorten and thicken. Nucleoli, nuclear membrane disappear. Spindle fibers begin to form as centrioles move toward poles of cell.
3. **Metaphase** – centromeres of chromosomes attach to spindle. Chromosomes move to equator.
4. **Anaphase** – sister chromatids of each chromosome separate. Full set (46 in humans) moves toward each pole.
5. **Telophase** – migration to poles completed. Chromosomes lengthen, nuclei reconstruct, cell division occurs.

E. MEIOSIS – process of gamete formation. Two successive cell divisions with one duplication of chromosomes nets haploid number of chromosomes.

1. **Interphase I** – chromosome duplication
2. **Prophase I** – thickening and pairing of homologous chromosomes. Centrioles migrate to opposite poles, nuclear membrane and nucleolus begin to disappear.
3. **Metaphase I** – homologous pairs migrate to equatorial plane. Pair members form attachments to opposite pole spindles.
4. **Anaphase I** – pair members separate and migrate to opposite poles. (Each pole has 23 homologous pairs.)
5. **Telophase I** – formation of two new nuclei, and cell division.
6. **Prophase II** – centriole in each daughter nucleus divides, new spindle forms.
7. **Metaphase II** – chromosomes align on equator of new spindle.
8. **Anaphase II** – centromeres divide, sister chromatids separate, move to opposite poles (23 to each).
9. **Telophase II** – cell division, nuclear membranes reformed.

GENETICS

A. DEFINITIONS

1. **Gene** – part of chromosome; codes for hereditary trait.
2. **Genotype** – genetic makeup of organism.
3. **Phenotype** – visible expression of hereditary makeup.
4. **Homologous chromosomes** – bear genes for same traits.
5. **Allele** – alternate form of gene. Alleles on homologous chromosomes may possess different information.
6. **Homozygote** – possesses identical pair of alleles on homologous chromosomes.
7. **Heterozygote** – possesses pair of different alleles on homologous chromosomes.
8. **Crossing over** – paired chromosomes break and fragments reunite in new combinations.
9. **Linkage** – genes on same chromosome are inherited together. Sex-linked traits are controlled by genes on the X chromosome. Males tend to exhibit sex-linked traits and females to carry them (hemophilia, color-blindness).

B. GENE MUTATION – change in allele that alters genotype.

1. **Chromosomal** – chemical change in chromosomal structure.
   a. **Deletion** – segment of chromosome missing.
   b. **Duplication** – fusion of a portion of one chromosome onto another.
   c. **Translocation** – segments of non-homologous chromosomes are exchanged.
   d. **Inversion** – a removed segment is reinserted backwards.
2. **Point mutation** – substitution of one nucleotide for another (or addition or deletion).

C. DNA – (deoxyribonucleic acid) – double helix of two complementary chains of nucleotides, composed of deoxyribose and phosphate group (backbone) and a nitrogenous base. Nucleotides in adjacent chains are connected by hydrogen bonds.

D. RNA – (ribonucleic acid) – single-stranded chain of ribose and phosphate group (backbone) and one of four nitrogenous bases. Formed from a DNA template by RNA polymerase in the nucleus.

1. **messenger RNA** (mRNA) – translates genetic information from DNA into polypeptide chains.
2. **ribosomal RNA** (rRNA) – integral part of the ribosome where protein synthesis occurs.
3. **transfer RNA** (tRNA) – inserts amino acid specified by mRNA into polypeptide chain.

E. TRANSCRIPTION – assembly of RNA strand on one strand of a DNA double helix.

F. TRANSLATION – interaction of rRNA, tRNA, and mRNA in converting DNA instructions into a polypeptide.

EMBRYONIC DEVELOPMENT

1. **Zygote** – unicellular, diploid result of fertilization of ovum by sperm.
2. **Cleavage** – series of mitotic divisions resulting in daughter cells called blastomeres.
3. **Morula** – solid ball of 16 blastomeres.
4. **Blastula** – hollow ball lined by cells formed after many divisions; fluid-filled cavity at center is blastocoel.
5. **Gastrula** – two, then three embryonic germ layers formed as primitive gut (blastopore) begins to appear. After this period, developing organism is called a fetus.
6. Primary germ layers and their derivatives:
   a. **Endoderm** – pancreas, glands (thyroid, parathyroid, salivary, thymus), bladder, inner linings of alimentary canal, respiratory tract, liver, urethra.
   b. **Mesoderm** – skeletal, muscular, reproductive, excretory, and circulatory systems, dermis, connective tissue.
   c. **Ectoderm** – epidermis, sweat glands, hair, nails, nervous system, parts of eye, ear and skin receptors, pituitary and adrenal glands, tooth enamel.

CHEMISTRY

GENERAL INFORMATION

A. MATTER

1. Chemical changes involve the breaking and/or formation of chemical bonds. Physical changes of substance do not result in the formation of new substances.
2. In a reaction, matter is neither created nor destroyed, but only changed from one form to another.

B. ENERGY

1. Energy is the ability to do work or transfer heat.
2. Energy appears in such forms as light, sound, heat, or mechanical, electrical, or chemical energy.
3. Energy can be converted from one form to another, but can be neither created nor destroyed.
4. Two general classifications of energy are potential energy and kinetic energy.

C. ONE MOLE OF ANY SUBSTANCE – is that which contains Avogadro's number (6.02×10^{23}) of particles. Number of moles = mass/molecular weight.

ATOMIC STRUCTURE AND THE PERIODIC TABLE

A. ATOMIC SPECTRA –
When an electron moves from the ground state to an excited state, it absorbs energy. When it moves from an excited state to the ground state, it emits energy.

B. THE BOHR THEORY OF THE HYDROGEN ATOM

1. Electrons can exist in only certain stable energy levels.
2. When the electronic state of an atom changes, it must absorb or emit exactly that amount of energy equal to the difference between the final and initial states.
3. Light behaves as if it were composed of quanta of energy known as photons: $E_{photon} = h\upsilon$, where h is Planck's constant and υ is the frequency of light.

C. ELECTRIC NATURE OF ATOMS

1. The nucleus of an atom is composed of positively-charged particles called protons and neutral particles called neutrons.
2. The atomic number is the number of protons found in the nucleus.
3. The electrons found in the outermost shell are called valence electrons.

D. THE WAVE MECHANICAL MODEL

1. A wave function corresponds to a certain electronic energy and describes a region about the nucleus (orbital) where an electron having that energy may be found.
2. An atom can be described with four quantum numbers that can be used to define allowed energy states.
3. Pauli exclusion principle: two electrons within the same atom may not have the same four quantum numbers.

E. PERIODIC TABLE

1. The most active metals are in the lower left and the most active nonmetals in the upper right.
2. Metallic properties include high electrical conductivity, high melting points, ductility, and malleability.
3. Nonmetals are poor electrical conductors and form brittle solids.
4. Metalloids have properties intermediate between those of metals and nonmetals.
5. Atomic radius generally decreases across a period from left to right and increases down a group.
6. Electronegativity generally increases from left to right in a period and decreases down a group.
7. Ionization energy decreases going down a group and increases left to right across a period.

BONDING

A. BONDS

1. An ionic bond occurs when one or more electrons are transferred from the valence shell of one atom to another and there is a coulombic attraction between oppositely-charged ions. The atom that loses electrons becomes a positive ion (cation) and the atom that acquires electrons becomes a negatively-charged ion (anion).
2. Atoms tend to gain or lose electrons until their valence shells are filled.
3. In a nonpolar covalent bond, the electrons are shared equally between atoms. In a polar covalent bond there is unequal sharing.

B. INTERMOLECULAR FORCES OF ATTRACTION

1. In polar molecular substances, the positive pole of one molecule attracts the negative pole of another. This force of attraction is called a dipolar force.
2. When a hydrogen atom is bound to a highly electronegative atom, it will become partially positively-charged, and will be attracted to neighboring electron pairs. This is a hydrogen bond.
3. These attractive forces are called van der Waals forces.

C. DOUBLE AND TRIPLE BONDS – are formed by the sharing of two or three electron pairs, respectively.

D. RESONANCE STRUCTURES
One of two or more potential arrangements of a substance which are the the same geometrically but different in electronic configuration.

E. ELECTROSTATIC REPULSION AND HYBRIDIZATION

1. The process of mixing different orbitals of the same atom to form a new set of equivalent orbitals is called hybridization.
2. VSEPR theory permits the geometric arrangement of atoms, or groups of atoms, about a central atom to be determined solely by considering repulsions between electron pairs in the valence shell of the central atom.

F. SIGMA AND PI BONDS

1. A molecular orbital that is symmetrical around the line passing through two nuclei is called a sigma orbital. A bond involving this orbital is called a sigma bond.
2. The bond that is formed by the sideways overlap of two p orbitals is called a pi bond.
3. Pi bonds are present in molecules containing double or triple bonds.

G. PROPERTIES OF IONIC SUBSTANCES –
Ionic crystals are brittle, have large lattice energies, are poor electrical conductors in the solid phase, are good conductors of electric current in the liquid phase, and have relatively high melting and boiling points.

H. PROPERTIES OF MOLECULAR CRYSTALS AND LIQUIDS – Molecular crystals tend to have small lattice energies, are easily deformed, are poor electrical conductors as solids and liquids, and have low melting and boiling points.

RATES OF CHEMICAL REACTIONS

A. TEMPERATURE AND REACTION RATE – are related by $k = Ae^{-E_a/RT}$, where k = rate constant, A = the Arrhenius constant, E_a = activation energy, R = universal gas constant, T = temperature in K.

B. ACTIVATION ENERGY – is the energy necessary to cause a reaction to occur. It is equal to the difference in energy between the transition state (or "activated complex") and the reactants.

C. REACTION RATE LAW

1. For the irreversible reaction A + B → products, rate $\propto k[A]^x[B]^y$. The order of the reaction with respect to A is x, and to B is y. The overall order is x + y. k = rate constant.
2. The rate of reaction depends on the number of collisions per unit time, and the fraction of these collisions which result in a reaction.

GASES

A. BOYLE'S LAW – At a constant T, V = constant × 1/P.

B. CHARLES'S LAW – At constant P, V/T = constant.

C. DALTON'S LAW OF PARTIAL PRESSURES – The total pressure exerted by a mixture of gases equals the sum of the partial pressures of the gases in the mixture.

D. LAW OF GAY-LUSSAC – At constant volume, P∝T.

E. IDEAL GAS LAW – PV = nRT.

F. COMBINED GAS LAW – For a given mass of gas, $(P_1V_1)/T_1 = (P_2V_2)/T_2$.

G. AVOGADRO'S LAW – At constant T and P, equal volumes of different gases contain the same number of molecules.

H. REAL GASES – For a real gas, the "ideal gas law" becomes the van der Waals equation of state $\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$, where n = number of moles of gas, b = the volume taken up by the molecules, and a = proportionality constant that depends on the strength of intermolecular attractions.

I. GRAHAM'S LAWS OF EFFUSION AND DIFFUSION
The rate of effusion is inversely proportional to the square root of the density of the gas. The relative rates at which gases will diffuse will be inversely proportional to the square roots of their respective densities or molecular weights.

J. KINETIC MOLECULAR THEORY

1. The pressure of a gas is the result of collisions between the gas molecules and the walls of the container.
2. The average kinetic energy of all the molecules in a gas is directly proportional to the temperature.

LIQUIDS, SOLIDS, AND PHASE CHANGES

A. LIQUIDS

1. Liquids are incompressible and changes in pressure or temperature have only a small effect on volume.
2. If a molecule gains enough kinetic energy (through increases in T) when it is near the surface of a liquid, it can overcome the attractive forces of the liquid phase and escape into the gaseous phase.

B. THE HEAT OF VAPORIZATION OF A SUBSTANCE

The number of calories required to convert 1 g of liquid to 1 g of vapor without a change in temperature; for one mole it is the molar enthalpy of vaporization. Going from liquid to solid, this is the heat of fusion.

C. VAPOR PRESSURE AND RAOULT'S LAW

1. When the rate of evaporation equals the rate of condensation, the system is in equilibrium.
2. Vapor pressure is exerted by gas molecules when they are in equilibrium with liquid.
3. Vapor pressure increases with temperature.
4. Raoult's law – vapor pressure of a solution at a particular temperature equals the mole fraction of the solvent in the liquid phase multiplied by the vapor pressure of the pure solvent at the same temperature.

D. BOILING POINT AND MELTING POINT

1. The boiling point of a liquid is the temperature at which the pressure of vapor escaping from the liquid equals atmospheric pressure.
2. The melting point of a substance is the temperature at which its solid and liquid phases are in equilibrium.

E. SOLIDS

1. In a solid, particles exhibit only vibrational motion.
2. Sublimation occurs when a solid vaporizes directly without passing through the liquid phase.

PROPERTIES OF SOLUTIONS

A. CONCENTRATION UNITS

1. Mole fraction is the number of moles of a particular component of a solution divided by the total number of moles of all of the substances present.
2. Molarity (M) of a solution is the number of moles of solute per liter of solution.
3. Normality (N) of a solution is the number of equivalents of solute per liter of solution.
4. Molality of a solution is the number of moles of solute per kilogram of solvent.

B. THE SOLUTION PROCESS

1. A saturated solution is one in which solid solute is in equilibrium with dissolved solids.

2. The solubility of a solute is the concentration of dissolved solute in a saturated solution of that solute.

C. HEAT OF SOLUTION – ΔH_{soln} is the quantity of energy absorbed or released when a substance enters solution.

D. EFFECT OF PRESSURE AND TEMPERATURE ON SOLUBILITY

1. The solubility of most solids in liquids usually increases with temperature and decreases for gases in liquids.
2. The relationship between solubility and temperature is given by: $\log\frac{K_2}{K_1}=\frac{-\Delta H^0}{2.30R}\left[\frac{1}{T_2}-\frac{1}{T_1}\right]$, where K_1 and K_2 = solubility constants at T_1 and T_2 respectively, and ΔH^0 = enthalpy change at STP.
3. Pressure has little effect on the solubility of liquids or solids in liquid solvents.

E. COLLIGATIVE PROPERTIES OF SOLUTIONS

1. The vapor pressure of an aqueous solution is always lowered, boiling point raised, and the freezing point lowered by addition of solute in amounts directly proportional to the molal concentration of the solute.

F. OSMOTIC PRESSURE

1. The osmotic pressure (π) of a solution is the minimum pressure that must be applied to the solution to prevent the flow of pure solvent into the solution.
2. $\pi = CRT$ where C is the concentration in molality or molarity, R is the gas constant, and T is the temperature (K).

ACIDS AND BASES

A. DEFINITIONS OF ACIDS AND BASES

1. Bronsted-Lowry Theory: acids are proton donors and bases are proton acceptors.
2. Lewis Theory: acids are electron-pair acceptors and bases are electron-pair donors.
3. An acid, in aqueous form, conducts electricity, has a sour taste, reacts with active metals to form hydrogen, and neutralizes bases.
4. A base, in aqueous form, conducts electricity, has a bitter taste, feels soapy, and neutralizes acids.
5. The base that results when an acid donates its proton is called the conjugate base of the acid and vice versa.

B. FACTORS INFLUENCING THE STRENGTHS OF ACIDS

1. The greater the number of oxygens bound to the element E in a hydroxy compound, H_xEO_y, the stronger the acid.
2. The acidity of an OH bond in M-O-H depends on the ability of M to draw electrons to itself.

ACID-BASE EQUILIBRIA IN AQUEOUS SOLUTION

A. IONIZATION OF WATER, PH

1. Ion product constant for water = $K_w = 1.0\times10^{-14} = [H^+][OH^-]$; $pH = -\log[H^+]$; $pK_w = pH + pOH = 14.0$
2. In an acidic solution pH < 7.0, in a basic solution pH > 7.0, and in a neutral solution pH = 7.0.

B. DISSOCIATION OF WEAK ELECTROLYTES – for the equation $A^- + H_2O \leftrightarrow HA + OH^-$, $K_b = [HA][OH^-]/[A^-]$ where K_b is the base ionization constant. $K_a = [H^+][A^-]/[HA]$ where K_a is the acid ionization constant. $K_b = K_w/K_a$ for any conjugate acid/base pair.

C. POLYPROTIC ACIDS – can donate more than one proton.

D. BUFFERS

1. Buffer solutions are equilibrium systems that resist changes in acidity and maintain constant pH when acids or bases are added.
2. The most effective pH range for any buffer is at or near the pK_a.
3. The pH for a buffer is given by $pH = pK_a + \log[A^-]/[HA] = pK_a + \log[\text{base}]/[\text{acid}]$.

E. HYDROLYSIS – the action of salts of weak acids or bases with water to form acidic or basic solutions by breaking down H_2O molecules.

F. TITRATION – process to determine the amount of a solution of known concentration that is required to react completely with a certain amount of a sample.

1. $V_A \times N_A$ = equivalents of A, where V is the volume in liters and N is the normality.
2. The equivalence point occurs when equal numbers of equivalents of acid and base have reacted.
3. An endpoint is usually marked by a sample's color change.

CHEMICAL EQUILIBRIUM

A. THE LAW OF MASS ACTION

1. At equilibrium, forward and reverse reactions take place at the same rate, and thus the concentrations of reactants and products no longer change with time.
2. For the reaction $aA + bB \leftrightarrow eE + fF$, at constant temperature, the equilibrium constant, $K_c = [E]^e[F]^f/[A]^a[B]^b$. This is the law of mass action; pure solids or liquids are not included.
3. The same type of equation can be applied to a reaction of gases, using their partial pressures, giving the constant K_p.

B. KINETICS AND EQUILIBRIUM

For $aA + bB \leftrightarrow eE + fF$, $\text{rate}_f = k_f[A]^a[B]^b$, $\text{rate}_r = k^r[E]^e[F]^f$ and $k_f/k_r = [E]^e[F]^f/[A]^a[B]^b = K_c$, where k_f and k_r are the rate constants for the forward and reverse reactions, respectively.

C. THERMODYNAMICS AND CHEMICAL EQUILIBRIUM

1. $\Delta G = \Delta G^0 + 2.303RT \log Q$, where Q is the mass action expression for the reaction and ΔG is the free energy.
2. At equilibrium $Q = K_{eq}$, the products and reactants have the same total free energy, such that $\Delta G = 0$. $\Delta G^0 - 2.303RT \log K_{eq} = RT\ln K_{eq}$.

D. THE RELATIONSHIP BETWEEN K_p AND K_c

$K_p = K_c(RT)^{\Delta ng}$ where Δng is the change in the number of moles of gas upon going from reactants to products.

E. LE CHÂTELIER'S PRINCIPLE AND CHEMICAL EQUILIBRIUM

1. Le Châtelier's principle: when a system at equilibrium is disturbed by the application of a stress (change in temperature, pressure, or concentration) it reacts to minimize the stress and attain a new equilibrium.
2. A catalyst lowers the activation energy barrier (activation energy) that must be overcome in order for the reaction to proceed. It speeds the approach to equilibrium, but does not change K_{eq} or ΔG^0.

CHEMICAL THERMODYNAMICS

A. COMMONLY USED THERMODYNAMIC TERMS

1. A **system** is the portion of the universe in which we are interested; everything else is the **surroundings**.
2. A process is **adiabatic** when the system is thermally isolated so that no heat enters or leaves, **isothermal** when the system is maintained at the same temperature, **isopiestic** (isobaric) when the system is maintained at constant pressure.
3. **State functions** depend only on the present state of the substance and not on the path by which the state was attained.
4. **Heat capacity** is the amount of heat energy required to raise the temperature of a given quantity of a substance 1°C. For 1 g this is the specific heat, for one mole this is the molar heat capacity.

B. THE FIRST LAW OF THERMODYNAMICS

1. $\Delta E = q - w$, where E is the internal energy of the system, q is the amount of heat that is added to the system as it passes from the initial to the final state, and w is the work done by the system on the surroundings.
2. q and w are considered by convention to be positive.
3. For an ideal gas at constant T, $\Delta E = 0$ and $q - w = 0$.
4. Considering only work due to expansion of a system against constant external pressure: $w = P_{external} \times \Delta V$.

C. REVERSIBLE AND IRREVERSIBLE PROCESSES

1. In a reversible expansion of a gas, the opposing pressure is virtually equal to the pressure exerted by the gas. Any slight increase in the external pressure will reverse the process and cause compression to occur.
2. The maximum work derived from any change will be obtained only if the process is carried out in a reversible manner.
3. $w_{maximum}$ at constant temperature = $2.30RT \log V_f/V_i$.
4. All real, spontaneous changes are not reversible, and the work that can be derived from an irreversible change is always less than the theoretical maximum.

D. ENTHALPY

1. The heat content of a substance is called enthalpy, H.
2. A heat change in a chemical reaction, carried out at constant pressure, is the change in enthalpy = $\Delta H = q_p$.
3. ΔH is positive for an endothermic reaction and negative for an exothermic reaction.
4. The bond dissociation energy, ΔH^0_{diss}, is the amount of energy per mole required to break a bond and produce two atoms, with reactants and products being ideal gases in their standard states at 25°C.

E. HEAT OF REACTION

1. ΔE = the heat absorbed or evolved by the system under conditions of constant volume. $\Delta E = q_v$.
2. At constant pressure $\Delta H = \Delta E + P\Delta V$.
3. $\Delta H = \Delta E + \Delta nRT$ for a reaction which involves gases. If only solid and liquid phases are present, $\Delta H \approx \Delta E$.

F. HESS'S LAW OF HEAT SUMMATION

1. When a reaction can be expressed as the algebraic sum of two or more reactions, the heat of the reaction, ΔH_r, is the algebraic sum of the heats of constituent reactions.
2. The enthalpy changes associated with the reactions that correspond to the formation of a substance from its free elements in standard states are called heats of formation, ΔH_f.
3. $\Delta H_r^0 = \sum\Delta H_f^0$ (products) – $\sum\Delta H_f^0$ (reactants).

G. SPONTANEITY OF CHEMICAL REACTION

1. In any spontaneous change, the amount of free energy available decreases toward zero as the process proceeds towards equilibrium.
2. A negative ΔG indicates that a reaction can take place spontaneously, but it does not guarantee that the reaction will take place.

H. ENTROPY

1. The greater the randomness of a system (S), the greater the entropy.
2. Second law of thermodynamics – entropy of the universe increases for any spontaneous process.
3. When a process occurs reversibly at constant temperature, the change in entropy, ΔS = the heat absorbed (q) divided by the temperature.
4. The maximum amount of useful work that can be done by any process at constant temperature and pressure is the change in Gibbs free energy, ΔG.
5. The entropy of a substance, compared to its entropy in a perfectly crystalline form at absolute zero is called its absolute entropy, S^0.

OXIDATION AND REDUCTION

A. OXIDATION AND REDUCTION

1. When valence electrons are fully or partially lost, the oxidation state is assigned a positive value for the element. If the valence electrons are gained or partially gained, its oxidation number is taken to be negative.
2. Oxidation – atoms or ions undergo an increase in oxidation state. Reduction – a reaction in which atoms or ions undergo a decrease in oxidation state.

B. NON-STANDARD-STATE CELL POTENTIALS – For a cell at non-standard concentrations and conditions, a potential can be calculated using the Nernst equation: $E_{cell} = E_{cell}^0 - (0.059/n)\log Q$, where E_{cell}^0 is the standard-state cell voltage, n is the number of electrons involved in the reaction, and Q is the mass action quotient.

C. ELECTROLYTIC CELLS

1. Reactions that do not occur spontaneously can be forced to take place by supplying energy with an external current. These are called electrolytic reactions.
2. Electrical energy is converted into chemical energy.
3. The cathode is the negatively-charged electrode and the anode is the positive electrode.

D. FARADAY'S LAW

1. One Faraday (F) = one mole of electrons.
2. One coulomb is the amount of charge that moves past any given point in a circuit when a current of 1 ampere is supplied for one second.
3. Faraday's law: During electrolysis, the passage of 1 F through the circuit brings about the oxidation of one equivalent weight of a substance at the anode and reduction of one equivalent weight at the cathode.

INTRODUCTORY ALGEBRA

SETS AND SET OPERATIONS

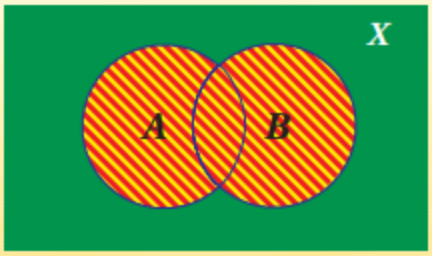
A. DEFINITIONS

1. **Set:** a collection of items, each called a member.
2. **Set notation:** use capital letter or set of braces { }.
3. **Subset:** every member of one set is a member of another set.
4. **Universal set:** a set U from which other sets draw members.
5. **Empty set:** ϕ or { }.

B. SET OPERATIONS

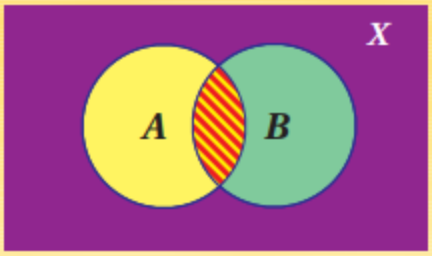
Set operations may be represented graphically by Venn diagrams.

1. **Union: set of all elements in set A or B or both.**



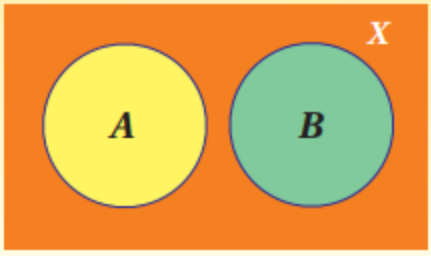
$A \cup B$

2. **Intersection: elements common in both sets A and B.**



$A \cap B$

3. **Disjoint sets: no common elements in sets A and B.**



C. LAWS OF SET OPERATIONS

1. **Identity:** $A \cup \phi = A$, $A \cap \phi = \phi$; $A \cup U = U$, $A \cap U = A$
2. **Idempotent:** $A \cup A = A$, $A \cap A = A$
3. **Complement:** $A \cup A' = U$, $A \cap A' = \phi$, $(A)' = A$, $\phi' = U$, and $U' = \phi$
4. **Commutative:** $A \cup B = B \cup A$, $A \cap B = B \cap A$
5. **Associative:** $(A \cup B) \cup C = A \cup (B \cup C)$; $(A \cap B) \cap C = A \cap (B \cap C)$
6. **Distributive:** $A \cup (B \cap C) = (A \cup B) \cap (A \cup C)$; $A \cap (B \cup C) = (A \cap B) \cup (A \cap C)$
7. **De Morgan's:** $(A \cup B)' = A' \cap B'$; $(A \cap B)' = A' \cup B'$

NUMBER SYSTEMS, ALGEBRAIC LAWS AND OPERATIONS

A. NUMBER SYSTEMS

1. **Integers:** whole numbers, negative whole numbers, and zero. e.g., –1, 0, 1
2. **Rationals:** numbers in the form a/b, where a and b are integers, $b \neq 0$. e.g., $\frac{1}{2}$
3. **Irrationals:** numbers that cannot be expressed in the form a/b, $b \neq 0$. e.g., π
4. **Reals:** integers and rational and irrational numbers.

B. ABSOLUTE VALUE

1. **Absolute value:** $|A| = A$ if $A \geq 0$ or $-A$ if $A < 0$.

C. ALGEBRAIC LAWS

1. **Closure/addition:** $a + b = c$.
2. **Closure/multiplication:** $a \times b = c$.
3. **Commutative/addition:** $a + b = b + a$.
4. **Commutative/multiplication:** $a \times b = b \times a$.
5. **Associative/addition:** $(a + b) + c = a + (b + c)$.
6. **Associative/multiplication:** $(a \times b) \times c = a \times (b \times c)$.
7. **Additive identity:** $a + 0 = a$.
8. **Multiplicative identity:** $a \times 1 = a$.
9. **Additive inverse:** $a + (-a) = 0$.
10. **Multiplicative inverse:** $a \times (1/a) = 1$, $a \neq 0$.
11. **Zero:** $a \times 0 = 0$.
12. **Distributive:** $a(b + c) = ab + ac$ or $a(b - c) = ab - ac$.

D. DECIMALS

1. **Definition:** base-10 notational system for expressing real numbers.
2. **Terminating decimal:** division yields a remainder of 0.
3. **Repeating decimal:** division yields a repeating pattern of integers.

E. IMAGINARY AND COMPLEX NUMBERS

1. **Imaginary:** $\sqrt{-1}$.
2. **Complex:** $a + bi$; a, b = real numbers and $i = \sqrt{-1}$.

EXPONENTS AND RADICALS

A. EXPONENTS

(a, m, and n are positive integers.)

1. **Positive integral:** a^n.
2. **Negative integral:**

$$a^{-n} = \frac{1}{a^n},\ a \neq 0.$$

3. **Positive fractional:**

$$a^{\frac{m}{n}} = \sqrt[n]{a^m}.$$

4. **Zero:** $a^0 = 1$, $a \neq 0$.
5. **General Laws:**

$$a^p a^q = a^{p+q}$$
$$(a^p)^q = a^{pq}$$
$$\frac{a^p}{a^q} = a^{p-q},\ a \neq 0$$
$$(ab)^p = a^p b^p$$
$$\left(\frac{a}{b}\right)^p = \frac{a^p}{b^p},\ b \neq 0$$

B. RADICALS

1. **Laws:**

$$\left(\sqrt[n]{a}\right)^n = a,\quad \sqrt[n]{ab} = \sqrt[n]{a}\sqrt[n]{b}$$
$$\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}},\quad b \neq 0$$
$$\sqrt[n]{a^m} = \left(\sqrt[n]{a}\right)^m$$
$$\sqrt[m]{\sqrt[n]{a}} = \sqrt[mn]{a}$$

C. SCIENTIFIC NOTATION

1. **Definition:** a real number expressed as a product of a real number n and an integral power of 10, where n is $1 \leq n \leq 10$. e.g., $1{,}970 = 1.97 \times 10^3$

POLYNOMIALS AND RATIONAL EXPRESSIONS

A. TERMS AND EXPRESSIONS

1. **Variable:** a placeholder.
2. **Constant:** a symbol that remains unchanged.
3. **Term:** a number, a variable, a product or quotient of numbers and variables, or a combination of products and quotients.
4. **Expression:** a collection of one or more terms.

B. THE POLYNOMIAL

1. **Monomial:** a one-term algebraic expression.
2. **Binomial:** a two-term algebraic expression.