HANDOUTS

ROTECTION, SUPPORT AND MOVEMENT

1.	**Introduction to Protection, Support and Movement** Definition of Animal: A thing having all the properties of life i.e. Nutrition and digestion respiration, excretion, body fluid regulation, reproduction and development etc
2.	**Evolutionary Concept:** Comparative perspective: It is based on the idea that a system cannot be fully understood without comparing it with the systems in different animals.
3.	**Protection: Integumentary system** In Protozoa In Multicellular Invertebrates Animals In Vertebrates Support: Skeletal system Hydrostatic skeleton Exoskeleton Endoskeleton Movement: Non Muscular and Muscular System An Introduction to Animal Muscles Muscular System of Invertebrates Muscular System of Vertebrates
4.	**Integumentary System of Invertebrates (Protozoa)** Integument is the external covering of the animal. It protects the animals from mechanical and chemical injury. It protects the animal from the invasion of microbes. It also regulates the body temperature and excretion of wastes. Also responsible for the conversion of sunlight into Vitamin D Plasma Membrane Pellicle Calcium Carbonate shell
5.	**Integumentary System of Multicellular Invertebrates** Epidermis: single layer of columnar cells. Cuticle: may be thin or elastic as in rotifers or thick and rigid as in crustaceans and insects. Calcium Carbonate Shell: as in Cnidarians (corals) Tegument: a complex syncytium- found in parasitic flukes and tapeworms. Exoskeleton: most complex integument found in Arthropods
6.	**Integumentary system of vertebrates (Jawless fishes, Cartilaginous fishes)** Jawless fishes include Lamprays and Hagfishes. Of several types of epidermal glands, one secretes cuticle. In Hagfishes, slime is secreted by multicellular epidermal glands and covers the body surface. Skin of Cartilaginous fishes (sharks) is multilayered and contains mucous cells and sensory cells. Dermis contains small placoid scales in the form of denticles similar to vertebrate teeth. The denticles are protective in function.
7.	**Integumentary system of bony fishes** Bony fishes (teleosts) contain dermal scales. The dermal tissue is covered over by epidermis. The scales grow at the margins and at the lower surface. Growth lines thus developed are useful to determine the age of the fish. The skin of the bony fishes is permeable to gases. The dermis is richly supplied with blood to facilitate in respiration. The epidermis also contains mucous glands. Mucus prevents the fish from infection. In some species the mucus contains poisonous alkaloids. Deep water fishes have rhodophores that help lures and warnings

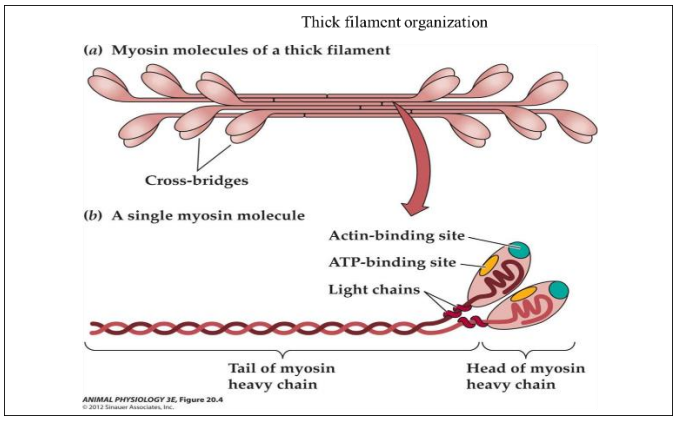
8.	**Skin of Amphibians, Skin of Reptiles** Amphibian skin has layers i) Epidermis ii) Dermis Epidermis is stratified. Dermis is thick containing, pigment layer, mucous & serous glands. During evolution keratin production increased in outer layers of the skin. Skin of Reptiles: i) Epidermis is thick, outer most layer is stratum corneum. Epidermis is modified into keratinized structures e.g. scales, scutes, rattles, claws plaques and spiny crests. These structures are protective in function. Skin of Reptiles: Molting or shedding of skin also occurs in reptiles e.g. snakes. The skin of reptiles reflects their greater commitment to a terrestrial existence.
9.	**Skin of Birds** Skin of birds show many reptilian features with no epidermal glands except uropygial or preening gland. Epidermis is thin having two to three cell layers. Outer keratinized layer is quite soft. Feathers are the most prominent epidermal derivatives. The dermis of birds is similar to those of reptiles containing blood and lymphatic vessels, nerves and sensory bodies. Feathers are important in thermal regulation, flying and behavior.
10.	**Skin of Mammals I** Notable features of mammalian skin are: 1. Epidermis 2. Epidermal glands. 3. Hair 4. Dermis Rapid cell division occurs in the deeper parts of epidermis. As these cells come up the surface, where they die and become keratinized. Later these cells become the outer skin layer, and called the stratum corneum (SC). The SC is the first line of defense against toxins and microbes. Dermis is the thicker portion of mammalian skin. It contains blood vessels, lymphatic vessels, nerve endings, hair follicles, small muscles and glands. The Hypodermis lies underneath the dermis that consists of loose connective tissue, adipose tissue, and skeletal muscles. Main Functions of Mammalian Skin: Main barrier of the body Regulates body temperature by sweating. On exposure to sunlight a chemical present in the skin is converted into Vitamin D. Skin is an important sense organ containing sensory receptors for heat, cold, pressure and pain. **Mammalian Skin Glands:** Sudoriferous glands (sweat glands) Sebaceous glands secrete sebum Sebum is a: i) Lubricant, ii) Skin-softening agent and iii) Also acts as a pheromone. Pigmentation of the skin: *Chromatophores*- Melanin in human skin. • Other skin colors in various mammals help camouflaging, communication, reproductive status etc, • Some colors is due to color of blood. • Hair is composed of keratin-filled cells that develop from epidermis. *Arrector pili* muscles are attached to the connective tissue surrounding the hair follicle. • On contraction of pili muscles the hair gets erect. This condition is called “Goose hump” in human. • In other mammals this condition helps warm the animal in cold environment. • Nail, is one of the characters of Pimates. like hair, nails are the modifications of epidermis.

	• Other mammals have claws and hoofs. • Horns are keratinized derivatives of mammalian skin. (Horns are not to be confused with the bony antlers).
11	**Movement and Support: Skeletal system in invertebrates** Body size increased dramatically as organisms evolved from unicellular to multicellular animals. Systems involved in movement and support evolved simultaneously. With respect to support, organisms have three kind of skeletons: 1. Hydrostatic 2. Exoskeleton 3. Endoskeleton Four cell types contribute to movement: 1. Amoeboid cells 2. Flagellated cells 3. Ciliated cells & 4. Muscle cells
12	**Hydrostatic skeleton** Four cell types contribute to movement: 1. Amoeboid cells 2. Flagellated cells 3. Ciliated cells & 4. Muscle cells Earthworm: Longitudinal and circular muscles contract alternately creating a rhythm that moves the earthworm. Hydro skeleton keeps the body from collapsing when the muscles contract.
13	**Exoskeleton** Exoskeleton is a rigid external frame-work of the body. Functions: • Provides site for muscle attachment. • Supports and protects the body like a shield. • Prevents internal soft tissues from drying out. • Provides protection from enemies. Exoskeleton in Arthropods: • Cuticle waterproofs the body. • It limits the animal growth. • Periodic shedding of exoskeleton. • At the joint regions the cuticle is flexible, where the antagonistic muscles function. • At wing joints, a protein, resilin, stores energy on compression and then releases energy to produce movement. • This is reason for success of arthropods.
14	**Endoskeleton** Introduction: Endoskeleton is the internal framework of the body. Examples: Spicules in Sponges. Calcareous plates (ossicles) in echinoderms Bones in vertebrates.
15	**Mineralized tissues in vertebrates** What are mineralized tissues? Tissues in which inorganic calcium carbonate crystals are embedded in the collagen matrix. About two-third of the living species that contain mineralized tissues are invertebrates. Examples: • Gastropods • Lower chordates
16	**Skeletal System of Vertebrates: Cartilage, Bone.** Introduction:

	Skeletal System of Vertebrates is an endoskeleton enclosed by other tissues. The endoskeleton consists of cartilage and bone. <u>Cartilage is a specialized type of connective tissue that provides:</u> • Support • Helps in movement at joint • Site for muscle attachment. Histologically it consists of: 1. Cells (chondrocytes) 2. Fibers 3. Cellular matrix <u>Bone or Osseous tissue has the following functions.</u> • Provides a point of attachment for muscles. • Support the internal organs of the animal. • Store reserves calcium and phosphate. • Manufactures blood cells. • Bone cells also called osteocytes are located in minute chambers called lacunae, which are arranged in concentric rings around the osteonic canals. • These cells communicate with nearby cells through small channels called canaliculae.
17	**Skeleton of fishes** Bone cells also called osteocytes are located in minute chambers called lacunae, which are arranged in concentric rings around the osteonic canals. These cells communicate with near by cells through small channels called canaliculae.
18	**Skeleton of Tetrapod and Human** <u>Axial Skeleton</u>: • Skull • Vertebral Column • Ribs <u>Appendicular Skeleton</u> • Appendages (Fore and hind limbs) • Girdles Pectoral and Pelvic) <u>Skeleton of Tetrapods</u> Amphibians needed support to replace buoyancy. The adaptations for support on land are: Intervertebral discs Rigid bony skeleton
19	**Movement:** <u>Nonmuscular and Muscular Systems</u> Difference between Movement and Locomotion: Movement is the act of changing location from one place to another e.g. a trolley, a ship Locomotion is the movement of an organism by its natural means. e.g. fish, insect, bird Movement is the characteristic of certain cells, protists and animals: For example: certain WBCs coelomic cells and protists. Movement is also brought about by flagella, cilia and pseudopodia. Movement in invertebrates and vertebrates is due to the muscles and muscular systems.
20	**Non Musclar movements** Protozoans move by means of : Pseudopodia, Flagella and Cilia <u>In amoeboid movement,</u> the fluid endoplasm flows forward into the fountain zone of an advancing pseudopodium. As it reaches the tip of pseudopodium endoplasm changes into the ectoplasm. At the same time the ectoplasm near the opposite end in the recruitment zone changes into endoplasm and begins flowing forward. <u>Flagellar and Ciliary Movement:</u>

	• Structurally, cilia and flagella are similar. • The difference is that cilia are shorter and numerous where as flagella are long and occur singly or in pairs • Cilia and flagella occur in every animal phyla except Arthropoda. • Ciliary movements are well coordinated, for example, in Protozoa. • Cilia occur in rows. • Rows of cilia beat out of phase with one another with the result waves periodically pass over the surface. • Direction of movement is brought about by beating the cilia in reverse direction.
21	**Introduction to Animal Muscles** Muscle is a contractile tissue, having cells the muscle fibers. Physiological properties of muscle tissue are: Contractility or elasticity Extensibility Excitability or irritability Types of muscle tissue: Smooth Skeletal and Cardiac <u>Smooth Muscles:</u> Smooth muscles are involuntary. They are uni-nucleated & spindle shaped. They contract slowly and sustain prolonged contraction and do not fatigue easily. Can maintain good tone without nervous stimulation. Smooth muscles are predominant muscle type in invertebrates. Example is adductor muscles in clams and bivalves. <u>Cardiac Muscles:</u> Cardiac muscles fibers are involuntary. Striated and have single nucleus. They are branched. This branching allows the fibers to interlock for greater strength during contraction. They do not fatigue because relax between contractions <u>Skeletal Muscles:</u> SM are voluntary. Skeletal muscle cells or fibers are multinucleated and striated. These muscles are associated with skeleton. The skeletal muscles work in antagonistic pairs.
22	**Muscular system of invertebrates** <u>Pedal Locomotion:</u> It is the movement by means of waves of activity in muscular system It is a type of locomotion that occurs in flatworms, some cnidarians and certain gastropods. <u>Accordion-Like Locomotion</u>: Example is earthworm. The longitudinal and circular muscles generate accordion-like waves. <u>Looping Movements:</u> Anterior and posterior suckers in leeches provide alternating points of attachments. Caterpillars exhibit same type of locomotion. <u>Looping Movements:</u> Anterior and posterior suckers in leeches provide alternating points of attachments. Caterpillars exhibit same type of locomotion. Movement by Tube Feet Water vascular system in echinoderms is a unique means for locomotion. Along each canal there are reservoir ampullae and tube feet. Water is driven into the tube feet after passing through the ampullae
23	**Terrestrial locomotion in Invertebrates** <u>Walking:</u> The elements required for walking are: Flexible joints Tendons and

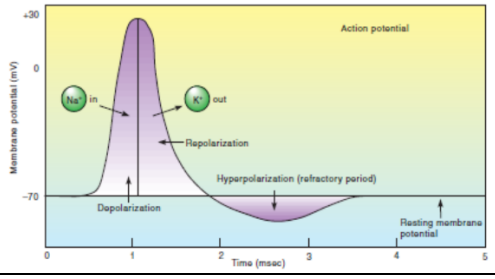
	Muscles that attach to the exoskeleton. Walking limbs of highly evolved arthropods are uniform in structure. <u>Limbs:</u> These are composed of series of jointed elements that become less massive toward the tip. Each joint is articulated to allow movement in only one plane i.e. flexion and extension. <u>Jumping:</u> To jump, the insect exerts a force against the ground to take off with a velocity greater than weight. Jumping insects have relatively long legs having femur, tibia and tarsus. When a flea is resting, the femur of the leg is raised, joints are locked and energy is stored in the protein, resilin. As it to begins to jump joints are unlocked. The force exerted against the ground by the tibia gives the flea a jump. The jump is the result of explosive release of the energy stored in the resilin. The legs with cuticle act as levers in this system. For example: Flea, Grasshopper etc. <u>Flight:</u> Among insects there are two mechanisms of flight: i) Synchronous ii) Asynchronous In synchronous flight the muscles at the base of the wings cause the upward and downward thrust by their contraction and relaxation. This depends upon the nerve impulse. In synchronous flight the muscles at the base of the wings cause the upward and downward thrust by their contraction and relaxation.
24	**Muscular system of vertebrates** In vertebrates, Locomotion occurs by the combined association of: Endoskeleton, Skeletal muscles, Tendons Tendons are tough fibrous bands that attach muscles to the skeleton.
25	**Fish musculature** • In fish the musculature consists of segmental myomeres. • The myomeres are arranged along the vertebral column in 3D 'W' shaped blocks separated by collagenous sheaths called myosepta. • Embedded in the myosepta are distinct tendons. • Within teleosts these tendons often ossify. • These ossified myoseptal tendons are homologous to inter muscular bones. • These intermuscular bones are of various shapes, some are Y shapes, some are brush like etc. • Fish movements are based on myomere contraction. • These myomeres cause the lateral undulations of the trunk and the tail. • These undulations bring about fish locomotion.
26	**Structure of Skeletal muscle I** Skeletal muscle consists of a bundle of long fibers running the length of muscle. Each muscle fiber is a single cell with many nuclei below the cell membrane, the sarcolemma. This reflects its formation by the fusion of many embryonic cells. Each muscle fiber is surrounded by connective tissue called <u>Endomycium.</u> <u>Perimycium</u> is connective tissue that wraps bundles of muscle fibers. <u>Epimycium</u> wraps the whole muscle. Each muscle fiber is itself composed of smaller myofibrils arranged longitudinally. The myofibrils, in turn , are composed of myofilaments, which are i) Thin and ii) Thick Each muscle fiber is itself composed of smaller myofibrils arranged longitudinally. Skeletal muscle is also called striated muscle because of repeating pattern of light and dark bands. Each repeating unit is called a sarcomere. Sarcomere is a basic functional unit of the muscle. The borders of sarcomere is called Z-line.

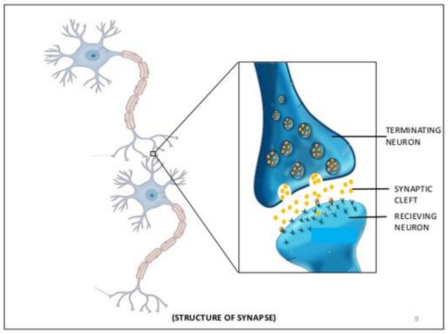
	The Z-lines of adjacent myofibrils contribute to the striations visible with light microscope. Thin filaments are attached to Z lines and project towards the center of the sarcomere They are 7-8 nm in dia. Thick filaments are centered in the sarcomere and are 16nm in diameter. 
27	**Structure of Skeletal Muscle II** Electron Miicroscope reveals the placement of muscle proteins-actin and myosin within the sarcomere. The EM also reveals the detail of A and I bands in the myofibril. A-band is the broad region that corresponds to length of thick filament. I-band corresponds to the thin or actin filaments. H-Zone is in the center of A-band and contains only thick or myosin filaments. Arrangement of thick and thin filaments: Each thick filament is surrounded by six thin filaments. Ultra structure of muscle proteins: The actin molecules are arranged in two chains, which twist around each other. Twisting around the actin chains are two strands of other protein, tropomyosin. Another protein in thin filament is the troponin. The thick filament which is about 16 nm in diameter is composed of myosin molecules. Each myosin molecule has a tail terminating in two globular heads. The myosin tail consists of two polypeptide chains coiled together. The heads are called cross bridges.
28	**Sliding Filament Model of Muscle** T –System: Each muscle fiber is surrounded by membrane called sarcolemma. Sarcoplasmic reticulum is a system like endoplasmic reticulum around each muscle fibril. SR lacks ribosomes. T –System: Each muscle fiber is surrounded by membrane called sarcolemma. Sarcoplasmic reticulum is a system like endoplasmic reticulum around each muscle fibril. SR lacks ribosomes. The T-tubule and the terminal portion of the adjacent envelop of SR form Triad at regular interval along the length of fibril. The nerve impulse is carried through the T-tubule to the adjacent SR. Myosin contains globular projections that attach to actin at specific active binding sites forming cross bridges. One cross bridges are formed, they exert a force on the actin filament and cause it to move.
29	**Control of Muscle Contraction** When a muscle contracts sarcomere is reduced i.e. Z-lines are brought closer to gather. In a contracted sarcomere A-band does not change in length but the I-band shortens and the H-band disappears. The behavior can be explained by the SF Model. According to this model neither the actin nor the myosin filaments change in length, rather they slide past each other. The sliding of the filaments is based on the interaction of the actin and myosin molecules that make up actin and myosin filaments. Cyclic Interaction Between Myosin and Actin in Muscle contraction: To start with, Myosin head is bound to ATP. Myosin head hydrolysis ATP to ADP and Pi (inorganic phosphate)

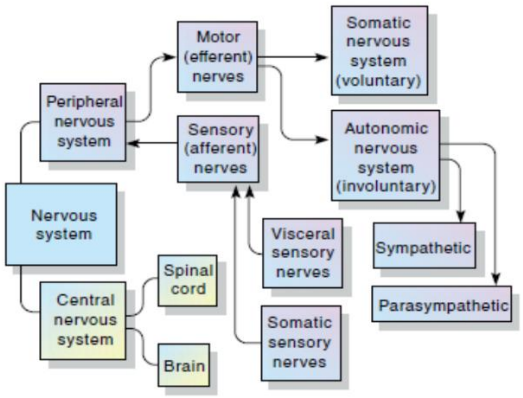
	Myosin head binds to Actin forming a Cross bridge. The releasing ADP and Pi relaxes myosin to low energy state, sliding the actin filament. Binding of a new molecule of ATP releases the myosin head. The myosin head then returns to high energy level and begins a new cycle. *Step A* Myosin head attaches to actin. (High energy ADP + P configuration) *Step B:* Power stroke: Myosin head pivots pulling the actin filament toward the center. Myosin head pivots pulling the actin filament toward the center.
30	**Role of Ca^{++} and Regulatory Proteins in Muscle Contraction** Skeletal muscle contracts only when stimulated by a motor neuron. When muscle is at rest, the binding sites on the actin molecule are blocked by the regulatory protein the tropomyosin. Another set of regulatory proteins, the troponin complex, control the position of tropomyosin on the actin filament. For a muscle to contract Ca ions bind to troponin, that causes the whole tropomyosin-troponin complex to change shape and expose the myosin binding site on actin When Ca++ is present, the sliding of thin and thick filaments occurs and the muscle contracts. When internal Ca++ concentration falls, the binding sites of actin are covered and contraction stops. Ca++ concentration in the cytoplasm of the muscle cell is regulated by the sarcoplasmic reticulum. Transportation of Ca++ from cytoplasm into the SR is by active transport.
31	**<u>Regulation of Skeletal Muscle Contraction</u>** There may be hundreds of neurons controlling a muscle each with its own pool of muscle fibers. When a motor neuron produces an action potential all the muscle fibers in the motor unit contracts as a group Action potential trigged by the motor neuron sweeps across the muscle fiber and into it along T-tubule starting the movement of Ca++that regulates the muscle activity. The events that regulate the skeletal muscle contraction are electrical, chemical and molecular.
32	**Energy Supply for Muscle.** Immediate source of energy for muscle contraction is ATP. Supply of ATP is maintained by the Aerobic breakdown of glucose in muscle cell. During exercise, when more energy is required, it comes from Creatine Phophate. Sometimes during strenuous exercise ATP requirement is met by anaerobic breakdown of glucose into Lactic acid. Accumulation of Lactic acid cause muscle fatigue. This also represents Oxygen debit. At rest i.e. after exercise 1/5 of Lactic acid is broken aerobically and its energy is used to change the remaining 4/5 Lactic acid into glucose and later into muscle glycogen. Thus glycogen is replenished again.

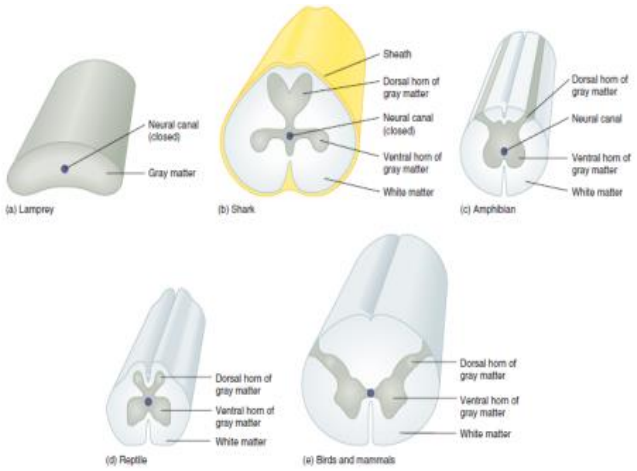
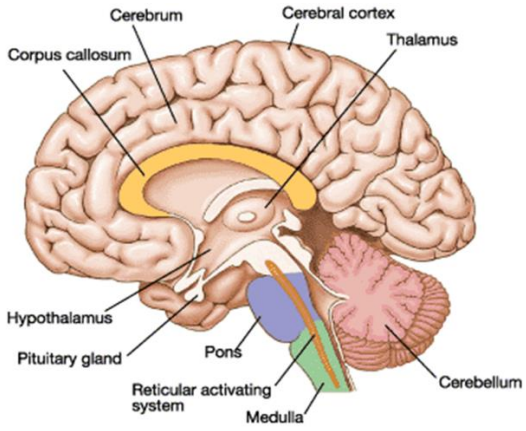
	HAND OUTS (COMMUNICATION I) NERVOUS AND SENSORY SYSTEMS
36	**Introduction of NS** Nervous System helps to communicate, integrate and coordinate the functions of various organs and organ systems in animal body. Information flow through NS has three main steps: i) Collection of information from outside and inside the body. (receptors). ii) Processing of information in the NS. iii) Initiation of appropriate response. (effectors). The two forms of communication that integrate body functions to maintain homeostasis are: i) Neurons ii) Hormones. In this chapter i.e. Communication I focuses on the anatomical organization and function of neurons.
37	**Basic Functional Units of NS** Neurons are the basic functional Unit of NS Neurons are specialized cells to produce signals. The signals are communicated to short and long distances. Neurons have Two properties: i) Excitability and ii) Conductivity Excitability is the ability to respond. Conductivity is the ability to conduct a signal. Types of Neurons: i) Sensory (receptors) ii) Interneurons (CNS) iii) Motor (effectors). Sensory Neurons act as receptors themselves or activated by receptors. Interneurons comprise the integrating centers. Motor Neurons send the processed information to effectors (muscles or glands)
38	**Neural Pathway between Receptors and Effectors** A stimulus initiates impulse within some sensory structure (receptor). The impulses are then transferred visa sensory neurons to interneurons. After response nerve impulses are generated and transferred via motor neuron to an effector (Muscle/gland) <u>Reflex Action:</u> An action which is carried out at once with the interaction of the will of the animal. or Automatic involuntary motor response. The path of reflex action is the reflex arc.

39,40	**Structure of different kinds of neurons I and II** Neurons are composed of: i) Cell Body ii) Dendrites iii) Axon Cell Body: Central body that contains Nucleus. Dendrites: Short thread like branches extending from cell body. Axon is a long cylindrical process that extends from cell body. Schwann Cell: These are the chain of supporting cells that surround the axon forming insulation layer, the Myelin Sheath. Node of Ranvier: A gap in the myelin sheath between adjacent Schwan Cells. Synapse: Is the junction where the one neuron communicates with the other neuron or muscle or gland cell. Also called Neuronal Junction Synapse: To insulate one neuron from another, and To destroy and remove the carcasses of dead neurons (clean up).
41	**<u>Resting and Action Potential</u>** <u>Resting Potential</u>: The plasma membrane of neuron is polarized, Positive outside and negative inside. R/ potential is measured in mV i.e. 1/1000 volt. Normally R/potential is -70mV. The potential is due to unequal distribution of various electrically charged ions Na+ and K+. Na ions are more outside than inside K ions. Cl ions and negative protein are also more concentrated inside. The pump works to establish the resting potential -70 mV across the membrane. <u>Action Potential</u>: When a threshold stimulus is applied to a point along the resting plasma membrane the permeability of Na+ ions increases at that point. This causes the Resting Potential -70mV towards 0.
42	**Ion Channels and Sodium Potassium pump** However, the concentration of Na and K ions remain constant on both sides of the membrane. This is due to the action of Na, K, ATPase pump, which is powered by ATP. The pump actively moves 3 Na ions out for each 2 K in. However, the concentration of Na and K ions remain constant on both sides of the membrane. This is due to the action of Na, K, ATPase pump, which is powered by ATP. The pump actively moves 3 Na ions out for each 2 K in. This movement of K+ outside the cell build up the +ve charge again. This causes the membrane repolarized
43	**Nerve impulse (neuron communication)**

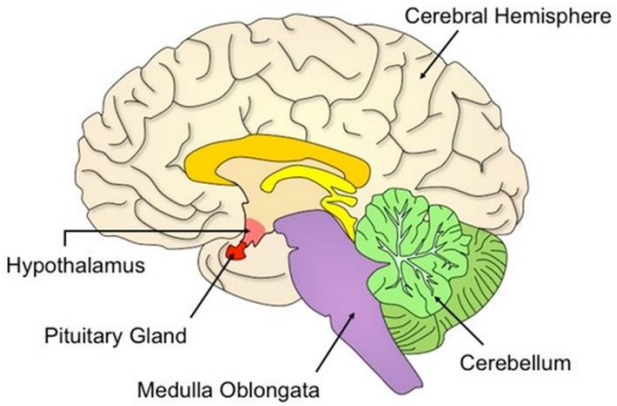
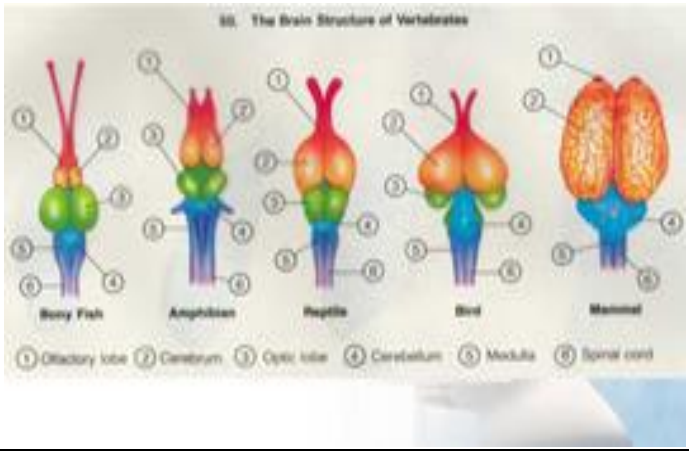
	It is a wave of electro chemical change. Or It is the transmission of an action potential along the neuron plasma membrane. It is a wave of depolarization and repolarization. After each A/Potential, there is an interval of time when it is more difficult for another action potential to occur because the membrane has become hyperpolarized (more – ve than -70 mV). This brief period is called refractory period. All or none principle: The principle states that an axon will 'fire' at full power or not at all. Saltatory conduction: Action Potential jump from one node to the next node. This conduction along the myelinated fibers is called Saltatory conduction 
44	**Synapse and its role in Nervous System** <u>Definition of Synapse:</u> It is the junction between two adjacent neurons. There is no cytoplasmic connection between the two neurons. A microscopic gap or synaptic cleft is present between them. The cytoplasmic knob contains numerous mitochondria and small vesicles (50 nm) The vesicles contain neurotransmitter substance Acetyl -choline There is 20 nm gap called synaptic cleft between pre and post synaptic membranes. Transmission of action potential: On reaching the nerve impulse at the Pre synaptic knob, the vesicle release the neurotransmitter into synaptic cleft. The neurotransmitter molecules bind to the receptor on the post synaptic membrane. This triggers action potential in the post synaptic neuron. Presynaptic membrane is always of a neuron but the postsynaptic membrane can be a neuron, muscle or gland. <u>Functions of Synapse:</u> Allow strong signals to pass Block weak signals Select and amplify weak signals. Channel the signals in many directions

	 (STRUCTURE OF SYNAPSE)
45	**Nervous System of Some Invertebrates I** Nervous system in invertebrate is usually much simpler than the nervous systems found in vertebrates. But there is still a broad range in complexity depending on the type of invertebrate. The simplest type of nervous system is found in hydra and is referred as a "nerve net.“ Nerve nets do not have distinct central or peripheral regions. Lack anything that resembles a brain. Instead, the scattered nerve cells form loose networks in each cell layer of the body wall. Some of these neurons carry information from sensory organs that detect touch, light, or other changes in the environment. Planarians are considered to be among the most primitive animals which acquired the central nervous system (CNS), mesodermal tissues, and bilateral structure during evolution. In Earthworm nervous system can be divided into 2 parts: (i) CNS (ii) PNS CNS is a bilobed brain or cerebral ganglia, sub-pharyngeal ganglia, circum- pharyngeal connectives and a ventral nerve cord.
46	**Nervous System of Invertebrates II** NS in crab differs from that of vertebrates (mammals, birds, fish, etc.) in that it has a dorsal ganglion (brain) and a ventral ganglion. The ventral ganglion provides nerves to each walking leg and all of their sensory organs. Cephalopods have the most highly developed nervous systems among invertebrates. Squids have a complex brain in the form of a nerve ring encircling the esophagus, enclosed in a cartilaginous cranium. Neuron size in squid is one meter long and one mm in diameter. Cephalopods have the most highly developed nervous systems among invertebrates. Squids have a complex brain in the form of a nerve ring encircling the esophagus, enclosed in a cartilaginous cranium. Neuron size in squid is one meter long and one mm in diameter. Cephalopods have the most highly developed nervous systems among invertebrates. Squids have a complex brain in the form of a nerve ring encircling the esophagus, enclosed in a cartilaginous cranium. Neuron size in squid is one meter long and one mm in diameter. Ectoneural system: Pertaining to the oral part of the nervous system. Hyponeural system:

	Part of the nervous system deeper and more weakly developed than the ectoneural system..
47	**CNS in Vertebrates: Basic organization** Characters of Vertebrate Nervous System: Bilateral Symmetry Notochord Tubular Nerve cord Bilateral Symmetry: A body form which is divided into two equal but opposite halves with a central longitudinal plane. Notochord: A rod of mesodermally derive tissue encased in affirm sheath, located ventral to neural tube. First appeared in marine chordates and is present in all vertebrate embryos and is greatly reduced or absent in adults. In vertebrates vertebral column replace the notochord. VC led to the development of Tubular Nerve Cord: It is a tube like structure which underwent expansion, modification and specialization into spinal cord and brain. Overtime the anterior end thickened with nervous tissue and divided into fore, mid and hind brain.  NS has two main divisions: CNS (Brain and Spinal cord) PNS (Peripheral NS):All the nerves of the body out side the brain and SC. Nerves are commonly divided into Sensory (afferent) and Motor(Efferent) nerves. NS has two main divisions: CNS (Brain and Spinal cord) PNS (Peripheral NS):All the nerves of the body out side the brain and SC. Nerves are commonly divided into Sensory (afferent) and Motor(Efferent) nerves.
48	**Spinal cords and spinal nerves of vertebrates** <u>Spinal cord:</u> It extends through hollow opening in each vertebra in the vertebral column. In cross section the spinal cord shows neural canal that contains cerebrospinal fluid. Gray matter ,which consists of cell bodies and dendrites. White matter contains nerve processes and axon.

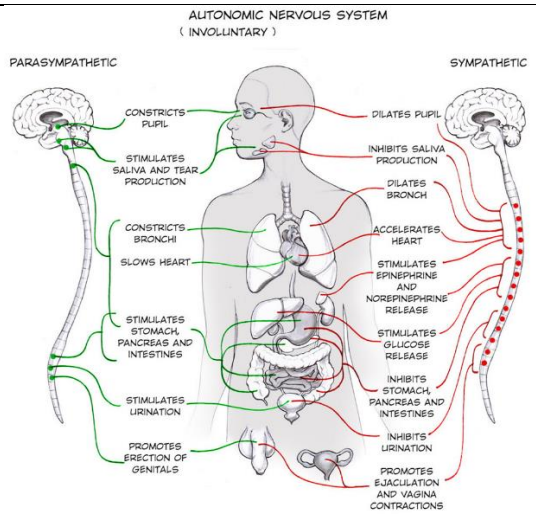
	Extending from the spinal cord are dorsal and ventral roots, which contain sensory and motor fibers respectively. Meninges (sing meninx) surround the spinal cord Dura mater-tough and fiberous Arichnoid- delicate Pia mater-contain blood vessels that nourish the Spinal cord. Dura mater-tough and fiberous Arichnoid- delicate Pia mater-contain blood vessels that nourish the Spinal cord. 
49	**Anatomy of vertebrate brain I** Brain: During development the brain undergoes regional expansion as a hollow tube of nervous tissue. The tube develops into Forebrain, Mid brain and Hind brain.  <u>Forebrain:</u> The vertebrate fore brain has changed a great deal during evolution. The forebrain has two main parts- and telencephalon and diencephalon.

	Telencephalon, the front part of the fore brain expanded rapidly in size and complexity Telencephalon consists of : a. Cerebrum, b. Olfactory bulb, c. Limbic system and d. Corpus Striatum Cerebrum is divided by a deep groove into Rt and Lt Cerebral hemispheres. In mammals, the outer most part of cerebrum is called cortex. Telencephalon consists of : a. Cerebrum, b. Olfactory bulb, c. Limbic system and d. Corpus Striatum Cerebrum is divided by a deep groove into Rt and Lt Cerebral hemispheres. In mammals, the outer most part of cerebrum is called cortex. Telencephalon consists of : a. Cerebrum, b. Olfactory bulb, c. Limbic system and d. Corpus Striatum Cerebrum is divided by a deep groove into Rt and Lt Cerebral hemispheres. In mammals, the outer most part of cerebrum is called cortex. The diencephalon expanded slowly as compared to telencephalon. Diencephalon contains-thalamus. Hypothalamus, Pineal gland and Pituitatory gland, The thalamus relays all the sensory information to higher brain centers. The hypothalamus regulates many functions, sexual drive, Carbohydrate metabolism, hunger and thirst. Pituitary gland is a master endocrine gland and produce about 9 hormones.
50	**Anatomy of vertebrate brain II** Mid Brain: Mid brain contains reticular formation, which is a relay center connecting hind brain with the fore brain. Mid brain did not change in size. The roof of the mid brain is a thickened region of grey mater that integrates visual and auditory signals. Hind Brain: Hind brain is continuous with the spinal cord and includes: a. Pons , b. Cerebellum and c. Medulla oblongata Pons is a bridge of transverse nerve tracts from cerebrum to cerebellum. Cerebellum: It is an outgrowth of medulla oblongata. In tetrapods the cerebellum is laterally expanded. They provide locomotor control of muscles of appendages. Cerebellum is much larger in birds and mammals.

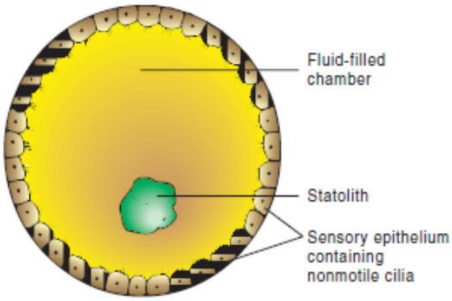
	Medulla oblongata: MO is the enlargement where the spinal cord enters the brain. It contains reflex centers for breathing, swallowing, cardiovascular . It is well developed in jawed vertebrates. 
51	**Vertebrate brains (a comparison)** Evolution of Forebrain: The forebrain expanded rapidly in both size and complexity. Many function shifted from the optic tectum to the expanding cerebrum. The increasing importance of the cerebrum affected many brain regions especially thalamus and cerebellum. In mammals outermost part of cerebrum progressively increased in size and complexity. Evolution of Cerebellum: In cartilaginous fishes the cerebellum has distinct anterior and posterior lobes. In teleosts the cerebellum is large in size in active swimmers and small in relatively inactive fishes. In tetra pods the cerebellum is relatively expanded, that provide locomotor control of appendages muscles. In birds and mammals. the cerebellum is much larger. This is reflection of complex locomotor pattern of limb development. 
52	**Cranial nerves I** <u>I. Olfactory nerve:</u>

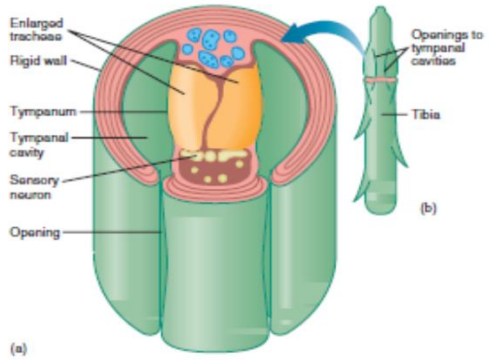
	Olfactory Nerve is the first cranial nerve and conveys special sensory information related to smell. It is the shortest of the cranial nerves and passes from its receptors in the nasal mucosa to the forebrain. II. Optic nerve: It transmits visual information from the retina to the brain. III. Occulomotor: It enters the orbit and innervates muscles that enable most movements of the eye and that raise the eyelid. IV Trochlear: It innervates only single superior oblique muscle of the eye. Controls the downward movement of the eye ball. V Trigeminal: A nerve responsible for sensation in the face and motor functions such as biting and chewing. Its three major branches are: a. Ophthalmic nerve b. Maxillary and c. Mandibular V Trigeminal: A nerve responsible for sensation in the face and motor functions such as biting and chewing. Its three major branches are: a. Ophthalmic nerve b. Maxillary and c. Mandibular Mandibular division Supplies Scalp, skin of jaw, lower teeth, lower gum and lower lip. VI Abducens: It is motor nerve. Supplies jaws, floor of mouth and eye muscles. Olfactory and optic are sensory nerves. Occulomotor and Trochlear are motor. Trigeminal is mixed and Abducens is motor nerve.
53	**Cranial nerves II** VII Facial: It emerges from Pons of the brainstem. Controls the muscles of facial expression, taste receptors of anterior 2/3 of tongue, tear glands and salivary glands. Inflammation or damage of this nerve cause Bell's Palsy VIII Vestibulocochlear: It has two branches -Vestibular and Cochlear. The vestibular nerve innervates the vestibular system of the ear. It is responsible for equilibrium. Cochlear supplies the inner ear and serves the sense of hearing. XI Accessary Nerve: Has two branches-

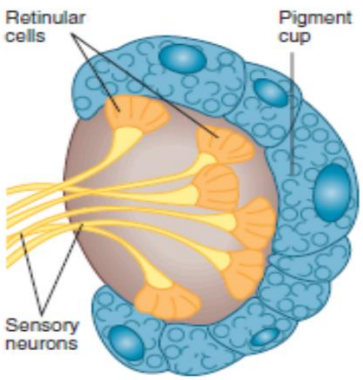
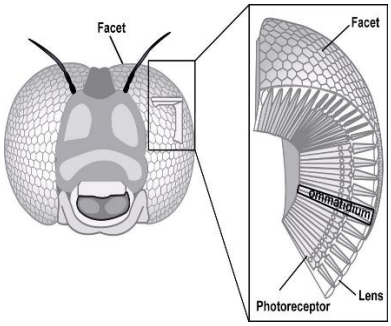
	a) Cranial branch b) Spinal branch Innervates soft palate, pharynx and larynx. It is motor nerve. <u>XII Hypoglossal:</u> It is a motor nerve. Innervates tongue muscles. Facial nerve is a mixed nerve and Vestibulocochlear is a sensory nerve. Glossopharyngeal and Vagus nerves are mixed nerves. Accessory and Hypoglossal are motor nerves.
54	**Introduction of Autonomic NS** Autonomic nervous system (ANS) is the part of peripheral nervous system. PNS also includes Somatic Nervous System (SNS). The SNS consists of motor neurons that stimulate skeletal muscles. In contrast, the ANS consists of motor neurons that control smooth muscles, cardiac muscles and glands. In addition, the ANS monitors visceral organs and blood vessels. In the ANS, the connection between the CNS and its effector consists of two neurons—the preganglionic neuron and the postganglionic neuron. The synapse between these two neurons lies outside the CNS, in an autonomic ganglion. The ANS is further divided into the sympathetic nervous system and the parasympathetic nervous system.
54	**Sympathetic and Parasympathetic NS** Autonomic NS is divided into divisions: Sympathetic and Parasympathetic NS. These two divisions generally make synaptic contacts with the same organ but usually produce opposite effects. <u>Sympathetic NS:</u> It consists of ganglia, nerves and plexues that supply involuntary muscles. This NS arise from middle portion of spinal cord and terminate in ganglia. This system is important during emergency situation. ‘Fight and flight” However neither kind of nerve is exclusively excitatory or inhibitory, For example, the sympathetic fibers increase heart beat but inhibit intestinal peristaltic movements. <u>Parasympathetic NS:</u> This system consists of nerves some of which emerge from brain and others from sacral or pelvic region of the spinal cord. PS division is associated with non stressful activities e.g. resting, eating, digestion & urination. Retards heartbeat.

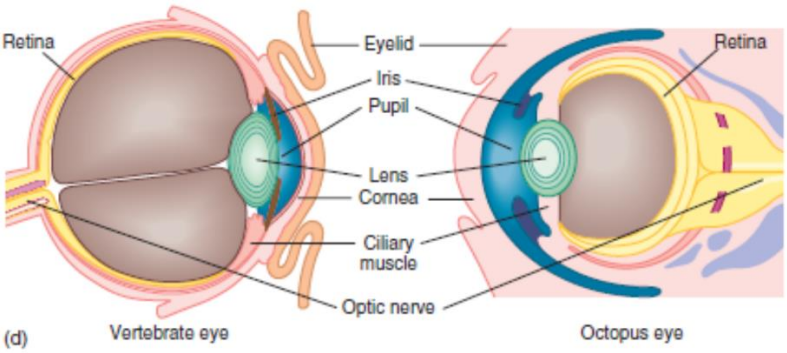
	
55,56	**Introduction of sensory reception** In human five senses- sight, smell, hearing, taste and touch are commonly known. Apart from these there are other senses also found in animals For example: Invertebrates possess the following sensory receptors: i) Tactile receptors that sense touch. ii) Hygroreceptor that detect content of air. iii) Georeceptors That sense pull of gravity. iv) Proprioceptors- that respond to compression, stretching, bending, and tension. v) Phonoreceptors- That are sensitive to sound vi) Baroreceptors- that respond to pressure changes. vii) Chemoreceptors- that are sensitive to air and water borne chemicals. viii) Photoreceptors-that are sensitive to light. ix) Thermoreceptors- that are sensitive to temp changes. vi) Baroreceptors- that respond to pressure changes. vii) Chemoreceptors- that are sensitive to air and water borne chemicals. viii) Photoreceptors-that are sensitive to light. ix) Thermoreceptors- that are sensitive to temp changes. Sensory receptors convert stimuli into nerve impulse. All receptors are tranducers i.e. that convert one form of energy into another. Different types of receptors convert different kinds of stimuli into local electrical potential called generator potential. When the GP reaches the neuron threshold potential, it causes the channels in plasma membrane to open and creates an action potential. The impulse then travels along the axon towards a synaptic junction and becomes information going to the CNS. The nature of the nerve impulse is the same. How then action potential give rise to different sensations? Animals that have, nerve signals from specific receptors always end up in a specific part of brains for interpretation. For example a stimulus that goes to the optic center is interpreted as visual sensation. And so on.
57	**Invertebrate sensory receptors** An animal's behavior is largely a function of its responses to environmental information.

	Invertebrates possess a variety of receptors through which they receive information about their environment. (a) Baroreceptors (b) Chemoreceptors (c) Georeceptors (d) Hygroreceptors (e) Phonoreceptors (f) Photoreceptors (h) Tactile receptors (i) Thermoreceptors
58	**Baroreceptors** Baroreception A barometer is a scientific instrument used to measure air pressure. Pressure tendency can forecast short term changes in the weather. The Zoologists have not identified any specific structures for baroreception in invertebrates. Nevertheless responses to pressure changes have been identified in ocean swelling copepod crustaceans, Ctenophores, jelly fishes medusa and squids. Some crustaceans that live between the tides respond to water pressure changes and coordinate with daily tidal movements.
59	**Chemoreceptors** Chemoreceptors are sensitive to chemicals. Chemoreception is the oldest and most universal sense in animal kingdom. Examples: Protozoans show avoiding response to acid, alkali and salt stimuli. Specific chemical attract predatory ciliates to their prey Location of chemoreceptors: In aquatic invertebrates they are located in pits or depressions, through which water carrying the specific chemicals may be circulated. In arthrpods, the receptors are usually located on the antennae, mouthparts, and legs in the form of hollow hairs called Sensilla containing chemosensory neurons. The types of chemicals to which invertebrates respond are closely associated with their life styles. For example: chemoreceptors are sensitive to humidity; pH, prey tracking, food recognition, and mate location. With respect to mate location the antennae of male silkworm moth detect one bombykol molecule in over a trillion molecules of air. Female silk moth secrete bombykol as a sex attractant. This enables a male to find a female at night from several miles down wind.
60	**Geo receptors: Statocysts, Statoliths** Georeceptors; Respond to the pull of gravity giving animals information about their orientation relative to up and down. Most georeceptors are statocysts. (standing bladder). Statocyst is a fluid filled chamber lined with cilia bearing sensory epithelium. Within the chamber is a solid granule called statolith.

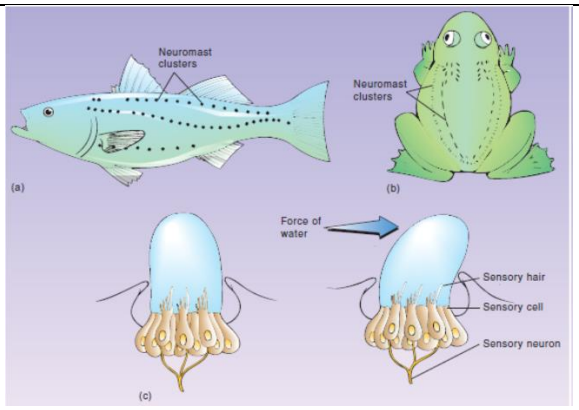
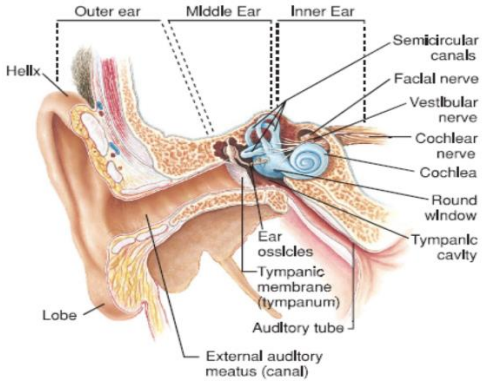
	When animal moves, both the movement of statolith and the flow of fluid over the sensory epithelium provide information about the animal's linear and rotational acceleration relative to the environment.  Occurrence of georeceptors: They are found in various gastropods, cephalopods, crustaceans, nemertines, polychaetes and scyphozoans. Burrowing animals can not rely on photo for orientation instead they rely on georeceptors within he substratum. Planktonic animals orient in their environment using statocysts. They are important at night and deep waters. Most of aquatic insects detect gravity from air bubbles entrapped in tracheal tubes, which stimulate sensory bristles that line the tubes.
61	**Hygroreceptors** Hygroreceptors are sensitive to water content of air. Some insects have hygrorecptors that can detect small changes in the ambient relative humidity. There hygroreceptors are have been identified on the antennae, palps, underside of the body and near the spiracles. Hygroreceptors enables the insects to seek an environment with a specific humidity to modify their physiology or behavior with respect to humidity. Drosophila detect air humidity through hygroreceptors located in a sac like invagination of the antenna. These receptors rapidly respond to a puff of dry air, potentially alerting the animal to the fact that dangerous dry conditions are looming. Swarming, in termite is humidity dependent.
62	**Phonoreceptors (tympanal organ)** Phonoreceptors are the receptors that respond to sound. They have been identified only in insects, archnids and centipedes. Some other invertebrates seem to respond to sound- induced vibrations of the substratum. Crickets, grasshoppers posses phonoreceptors called tympanic or tympanal organs. This organ consists of tough, flexible tympanum that covers internal sac. The sensory neurons are attached to the tympanum.

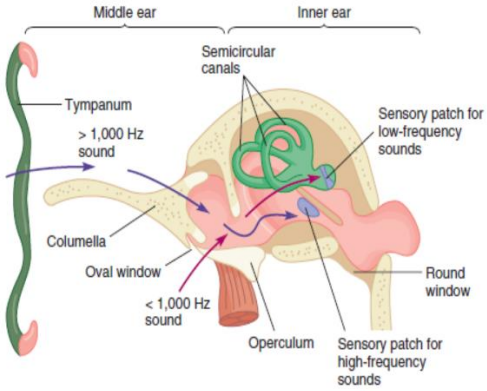
	 When sound waves strike the tympanum it vibrates. When sensory neurons are stimulated by these vibrations generator potential is produced. Most arachnids possess phonoreceptors in their cuticle called slit sense organs that are sensitive to vibrations. Centepedes have organs of Tomosvary, which are sensitive to sound. However, the physiology of these organs i.e. the organs of Tomosvary and slit like organs are poorly known.
63	**Photoreceptors (Ocellus) I** Photoreceptors are sensitive to light. All photoreceptors possess light-sensitive pigments e.g. rhodopsin and carotenoids. These pigments absorb photons of light energy and then produce generator potential. This is basic commonality. Photoreceptors in various organisms: <u>Euglena:</u> Stigma (mass of bright red granule containing carotenoid. Actual photoreceptor is the swelling at the base of the flagellum. Stigma serves as a shield, which is essential if the receptor is to detect light. Thus the photoreceptor plus stigma enable euglena to orient itself so that its receptor is exposed to light. This helps the protozoan maintain itself in the region where sufficient light is available. <u>In earthworm *Lumbricus*,</u> simple unicellular photorecepter cells are scattered over the epidermis or concentrated in particular areas of the body. Other animals possess multicellular photoreceptors that can be classified into: ocilli, compound and complex eyes. <u>Ocellus</u> is simply a small cup lined with light sensitive receptors (retilunar cells) and backed by light absorbing pigment. The retilunar cells contain photosensitive pigments. Stimulation by light causes a chemical change in the pigment.

	 This stimulation leads to generator potential then action potential that sensory neurons carry. This type of visual system gives animal an information about the direction and intensity of light only but no image. Ocelli are common in phyla such as Annelida, Mollusca and Arthropoda.
64	<u>Photoreceptors (compound eye) II</u> This stimulation leads to generator potential then action potential that sensory neurons carry. This type of visual system gives animal an information about the direction and intensity of light only but no image.  Compound eyes consist of many clear units called Ommatidia. Compound eyes occur in some annelids and bivalve molluscs. Best developed and understood in arthropods. Compound eyes may contain thousands of ommatidia each oriented differently. The visual field of a compound eye is very wide. Each ommatidium has its own nerve tract leading to large optic nerve. The visual fields of adjacent ommatidia overlap to some degree. The visual field of a compound eye is very wide. Each ommatidium has its own nerve tract leading to large optic nerve. The visual fields of adjacent ommatidia overlap to some degree. Color vision is particularly important in active, day-flying, nectar drinking insects, such as honeybees. Honeybees learn to recognize particular flowers by color, scent, and shape
65	<u>Photoreceptors (camera eyes) III</u>

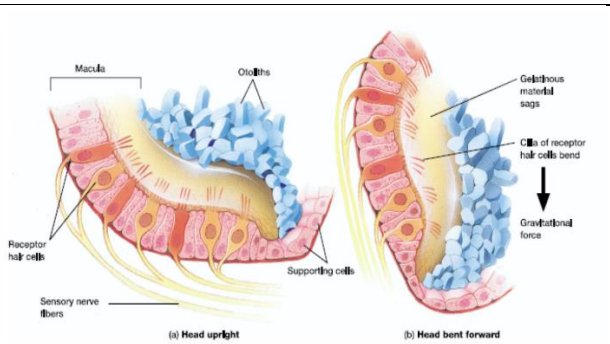
	Complex Camera Eyes occur in squids and octopuses. These eyes are best image forming eyes among invertebrates. Largest eye size is 25 to 30 cm in diameter 45 ft squid. Cephalopod eye is often compared with vertebrate eye in its structure. The eye is composed of thin transparent cornea and a lens that focuses light on retina. Lens is suspended and controlled by ciliary muscles. The eye of squid, however, differs from vertebrate eye in that the receptor site on the retina face the direction of light entering the eye. In the vertebrate eye the retinal layer is inverted and the receptors are the deepest cells in the retina. In cephalopods light is focused by muscles which move the lens toward or away from the retina and by altering theIn the vertebrate eye the retinal layer is inverted and the receptors are the deepest cells in the retina. In cephalopods light is focused by muscles which move the lens toward or away from the retina and by altering the shape of the eye ball. 
66	**Proprioreceptors** Proprioceptors commonly called stretch receptors. Located internally. Sensitive to mechanically induced changes caused by stretching, bending compression or tension. These receptors give an animal information about the movement of its body parts and their position relative to each other. Proprioceptors are associated with appendage joints and body extensor muscles. In these animals the sensory neurons may be attached to the muscles, elastic connective tissue fibers or various membranes that span joints. As shape changes, generator potential starts.
67	**Tactile Receptors** Tactile receptors are generally derived from modifications of epithelial cells associated with sensory neurons. Most tactile receptors of animals involve projections from the body surface. These projections include: bristles, spines, setae and tubercles. When an animal comes in contact with an object in the environment, these receptors are mechanically deformed. These deformations activate the receptors, which in turn activates underlying sensory neuron initiating generator potential.

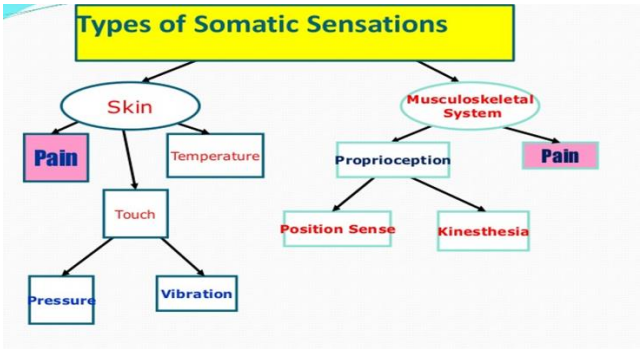
	Most tactile receptors are also sensitive to mechanically induced vibrations propagated through water or a solid substrate. Examples: Tube swelling Annelids bear receptors that allow them to retract quickly from their tubes in response to any movement in surroundings. Web-building spiders have tactile receptors that can sense struggling prey in webs through vibrations of the web threads.
68	**Thermoreceptors** Web-building spiders have tactile receptors that can sense struggling prey in webs through vibrations of the web threads. Leeches and ticks possess heat sensing mechanism that can recognize warm blooded hosts. Certain insects, some crustaceans, and the horseshoe crab (Limulus) can also sense thermal variations. In all of these cases, however, specific receptor structures have not been identified.
69	**Vertebrate Sensory Perception** Vertebrate sensory receptors reflect adaptations to the nature of sensory stimuli in environment. The environment has chemical and physical characteristics that affect the kinds of energy and molecules that carry sensory information. For example, our external environment consists of the media that surrounds us: the earth that we stand on and the air that we breathe. Other animals may have different external environments: a trout may be immersed in the cool, clear water of a mountain stream. A turtle may be submerged in the turbid water of a swamp; and a salmon may be swimming in the salty water of the sea.
70	**Lateral line system** The lateral line system is electrical sensing that occur both in jawless and jawed fishes and some amphibians, along the sides of head and body It consists of sensory pores in the epidermis of the skin that connect to canals leading into electroreceptors called ampullary organs. These organs can sense feeble electrical field produced by organisms living in surrounding water. This ability to detect these fields help a fish to find mate, capture prey or avoid predators. This is especially valuable sense in deep, turbulent or murky water where vision is of little use. In fact, some fishes actually generate fields and then use their electroreceptors to detect how surrounding objects distort the field. This allows these fishes to navigate in murky or turbulent waters.
71	**Lateral line system & Mechanoreception** Mechanoreceptor also called Neuromasts are the part of Lateral Line system. These receptors are fund in cyclostomes, sharks, aquatic amphibians and some advanced fishes. Neuromasts are located in pits along the body but not in head region. Neuromasts are responsive to local water disturbance.

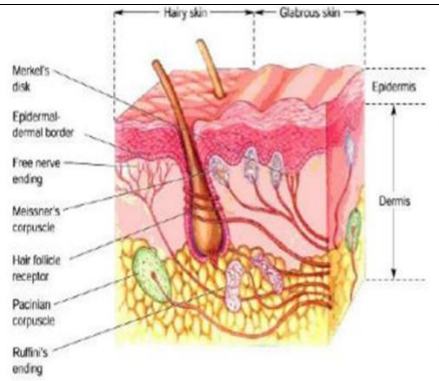
	 When water near the lateral line moves, water in the pits also moves. This movement disturbs hair like cells of the neuromasts causing the generator potential in the associative sensory neurons. This helps the animal to detect the direction and force of water currents and thus the movement of other animals in the vicinity and become alert from the predators. For example this sense enables a trout to orient the head upstream in water.
72	**Hearing and Equilibrium in air** Hearing is important to vertebrates as a mechanism to: a) become alert against nearby or faraway dangerous activity. b) become important for the location of food communicated by other animals e.g. Crows. c) respond the calls for mating e.g. cats, cows. Hearing and Equilibrium are the sensations that occur together in the same vertebrate organ, ear.  For hearing it is the Auditory organ and for equilibrium and posture, the Vestibular apparatus. The main part of auditory apparatus which is involved with hearing is the cochlea. The part of the ear which is involved with equilibrium are the semicircular canals. Sound results when waves transmit energy through some medium such as air or water. Adaptation of hearing in air resulted from the evolution of an acoustic transformer that incorporates a thin membrane that is exposed to air.
73	**Tympanum in Amphibians** Tympanum or the ear drum first evolved in Amphibians. Ears of Anurans consists of : a) Tympanum b) Middle ear and

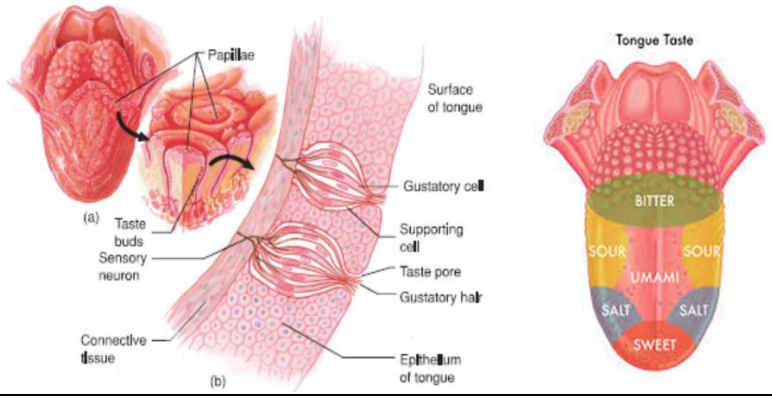
	c) Inner ear Tympanum is modified integument stretched over cartilaginous ring.  Touching the tympanum is an ossicle, called columella or stapes. The opposite end of the stapes touches the membrane of the oval window that stretches between middle and inner ear. There are 3 semicircular canals which attached by their end. The semicircular canals are fluid filled. A second small ossicle, the operculum, also touches the oval window. Muscles attached to the operculum and columella can lock either or both of these ossicles, allowing a frog to screen out either high or low frequency sounds. The semicircular canals are fluid filled. A second small ossicle, the operculum, also touches the oval window. Muscles attached to the operculum and columella can lock either or both of these ossicles, allowing a frog to screen out either high or low frequency sounds. The semicircular canals are fluid filled. A second small ossicle, the operculum, also touches the oval window. Muscles attached to the operculum and columella can lock either or both of these ossicles, allowing a frog to screen out either high or low frequency sounds.
74	**Hearing in Reptiles** Reptilian ears vary in structure. Ears of snakes lack a middle ear cavity and tympanum. They have vestiges of the hearing apparatus inside their heads. A bone of jaw articulates with the stapes and receives vibrations of the ground or substratum. Reptilian ears vary in structure. Ears of snakes lack a middle ear cavity and tympanum. They have vestiges of the hearing apparatus inside their heads. A bone of jaw articulates with the stapes and receives vibrations of the ground or substratum. Airborne sounds are transmitted from the skin receptors to the lungs and then to the inner ear and 8th cranial nerve to the brain. Snakes hear low frequency sounds. In some reptiles tympanum or ear drum may be on the surface or in small depression in the head. The structure of the inner ear is similar to that of amphibians.
75	**Hearing in Birds** The ear openings in birds are just below and behind the eyes and are covered by fine feathers called auricular or ear coverts.

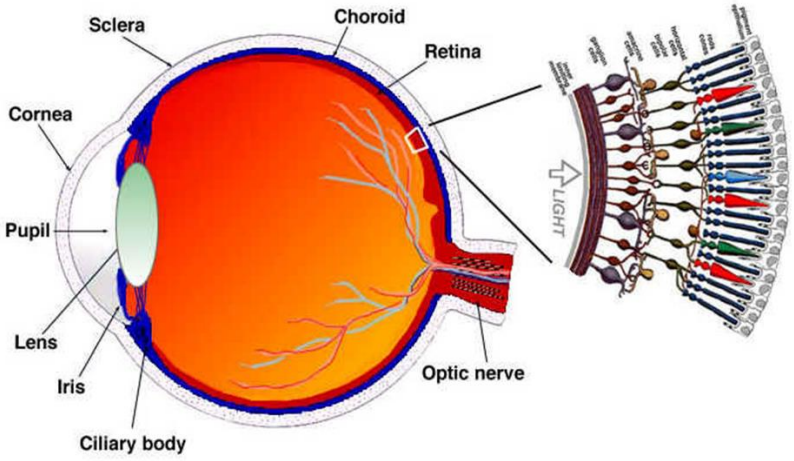
	These ear coverts funnel sounds from to the ear opening down to the eardrum. Movement of the fluid caused by the vibration of the membrane moves these hairs, or cilia. In birds there is just one stapes or columella, which transmits vibrations from the eardrum to the membrane across the oval window in the cochlea of the inner ear. The cochlea is a hair lined, fluid-filled chamber. The movement of these hairs excites nerve endings to transmit signals to the brain where it is translated and interpreted as sound. There is another opening in the cochlea, the round window, which is covered by yet another membrane and this allows the pressure waves moving the cilia to dissipate. Also in the inner ear are the semicircular canals used to determine orientation and to regulate balance.
76	**Anatomy of Human Ear** In birds there is just one stapes or columella, which transmits vibrations from the eardrum to the membrane across the oval window in the cochlea of the inner ear. The cochlea is a hair lined, fluid-filled chamber. Three small ossicles are the parts of middle ear. These ossicles include: i) malleus (hammer) ii) incus (anvil) iii) stapes (stirrup) The malleus adheres the tympanic membrane and connects to the incus. The incus connects to the stapes which adheres to the oval window. Auditory or eustachean tube extends from the middle ear to the nasopharynx. This equalizes air pressure between middle ear and throat. Auditory or eustachean tube extends from the middle ear to the nasopharynx. This equalizes air pressure between middle ear and throat. The entire inner ear is bathed in a cushioning fluid, the endolymph. The sensory cells which have hair-like projections are called Organs of Corti. These organs are located on the basilar membrane that forms the base of cochlea.
77	**Hearing of Human Ear** Sound waves enter the outer ear and reach the tympanic membrane to vibrate. These vibrations move the ossicles one after the other against the oval window. When the middle ear transfers the vibrations to the cochlea the fluid in the cochlea is displaced. This displacement of the fluid make the hair cells move. Signals from the cells are converted into nerve impulse and sent to the brain through the auditory nerve, thereby helping the process of hearing. Receptor cells of the organ of Corti which have hair-like projections bend causing generator potential, which leads to action potential that travels along the vestibule cochlear nerve to the brain for interpretation. When the body is still, the otoliths in the semilunar canals rest on hair cells. When the head horizontally or vertically the granules are displaced. This displacement bends the hair slightly so that hair cells initiate generator potential. Continuous movements cause motion sickness.

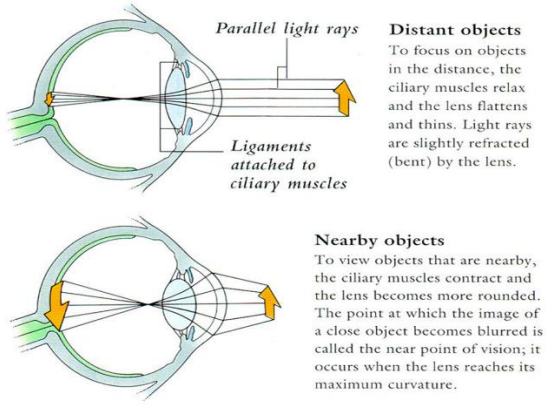
	 The sense of equilibrium can be divided into two equal senses- Static and Dynamic Static refers to sense movement in one plane (vertical or horizontal). Dynamic refers to angular or rotation movements. Humans are not able to hear low-pitched voice below 20 cycles per second. Young children can hear high pitched sound up to 20,000 cycles per second. Dog can easily detect sound of 40,000 cycles per second. An otolith also called statoconium or otoconium or statolith, is a calcium carbonate structure in the saccule or utricle of the inner ear, specifically in the vestibular system of vertebrates. In mammals, otoliths are mall particles, composed of a combination of a gelatinous matrix and calcium carbonate in the viscous fluid of the saccule and utricle. The inertia of these small particles causes them to stimulate hair cells when the head moves.
78	**Hearing and Equilibrium in Water** In bony fishes, the receptors for equilibrium and hearing are in the inner ear. Semicircular canals detect the rotational movements by detecting the direction of gravitational pull. Since the fishes lack the outer and middle ears, the vibrations pass from the water through the bones of the skull to the inner ear. A few fishes have chains of bony ossicles that pass between the swim bladder and back of the skull. Sound waves that enter the pharynx are transmitted to swim bladder causing it expand and contract according to the intensity of incoming waves. The vibrations of contraction pass forward along the chain of ossicles and then to the inner ear. Sharks' hearing, have a sharp sense of hearing and can possibly hear prey many miles away in water. Some species of Carp and Herring, hear through their swim bladders, which function like a hearing aid. Fish can also sense sound through their lateral lines and their otoliths (ears).
79	**Skin Sensors of Damaging Stimuli** Pain receptors are bare or naked nerve endings through out the body of mammals except for the brain & intestine. These nerve endings are called Nociceptors. The may be: External nociceptors- found in tissue such as the skin, the corneas, and the mucosa. Damaging or noxious stimulus is actually or potentially tissue damaging event. Noxious stimuli can either be: Mchanical (pinching or other tissue deformation),

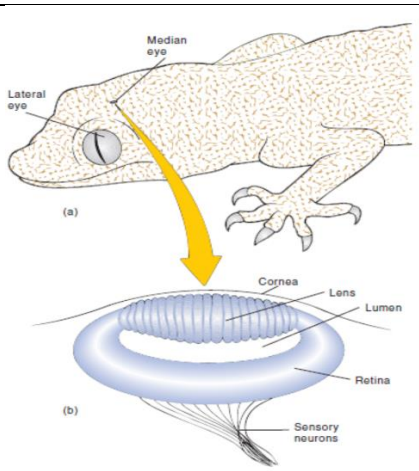
	Chemical (exposure to acid or irritant), or Thermal (high or low temperatures). Internal nociceptors- found in a variety of organs, such as the muscles, the joints, the bladder, the gut, and the digestive tract. Severe heat, cold, irritating chemicals, and strong mechanical stimuli may elicit a response from nociceptors that the brain interprets as pain or itching. 
80	**Skin sensors of heat and cold**: Sensors of temperature or Thermoreceptors are also bare nerve endings. They are located in epidermis or dermis of the mammalian skin. Mammals have different areas sensitive to heat and cold. Cold receptors respond to temperature below skin temperature. Heat receptors respond to temperature above skin temperature. The ability to detect changes in temperature has become well developed in a number of animals. For example Pit organs in rattlesnakes and vipers. Heat receptors respond to temperature above skin temperature. The ability to detect changes in temperature has become well developed in a number of animals. For example Pit organs in rattlesnakes and vipers.
81	**Skin Sensors of Mechanical Stimuli** To obtain information from the environment, the animals rely on tactile stimuli. Following are the mechanical receptors found in the skin. i) Bare sensory nerve endings: These are widely distributed receptors in the vertebrate body and are involved in pain, heat and feeble pressure. ii) Tactile (Meissner's) corpuscles: They are a type of nerve endings in the skin that are responsible for sensitivity to light touch. iii) Bulbs of Krause: the recepters found in dermis in certain parts of the body that respond to physical position changes. iv) Pacinian corpuscles: These are responsible for sensitivity to vibration and pressure. v) Organs of Ruffini: Detect stress deformation within joints and warmth. Many mammals have specially adapted sensory hairs called Vibrissae on their wrists, snout, eye brows and whiskers. Around the base of each vibrissa is a blood sinus. Nerves bordering the sinus carry impulses to the brain for interpretation.

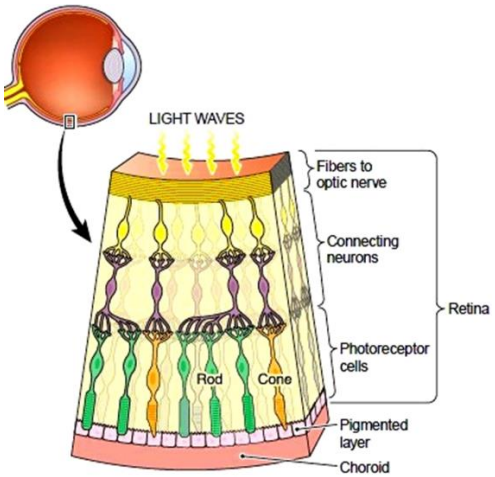
	 ■ **Merkel's disk** ○ Skin Curvature ■ **Meissner Corpuscle** ○ Light Touch ■ **Free Nerve Endings** ○ Pain ○ Chemicals ■ **Ruffini's ending** ○ Heat ○ Stretch ■ **Pacinian Corpuscle** ○ Deep Pressure ○ Vibrations
82	**<u>Sonar or Echolocation</u>** Sonar/biosonar/ Echolocation is a physiological process for locating distant objects by means of sound waves reflected back to the emitter (such as a bat) by the objects. Echolocation is used for orientation, obstacle avoidance, food procurement, and social interactions. Other animals which have this sense of sonar are, shrews, several cave dwelling birds, whales, and dolphins. These animals emit high frequency sounds which return after bouncing off objects in the environment. The returning waves from the object (e.g.flying insect) provide enough information for the bat to locate and catch the prey. This process lasts for 2-3 miliseconds and are repeated several hundred times per second
83	**Smell or olfaction:** The sense of smell or olfaction is due to the olfactory neurons (receptor cells) present in the roof of nasal cavity of the vertebrates. These receptor cells are densely packed. In dog, there are more than 40 million olfactory receptor cells per square centimeter. Each olfactory cell ends in a tuft of cilia containing receptor site for various chemicals. How odor is perceived? Odor molecules physically interact with protein receptors on the plasma membrane. This interaction alters membrane permeability and leads to generator potential.
84	**Olfactory sense in various vertebrates:** <u>In Fishes</u> Most of the fishes such as Lamprey and Salmon return to spawn in the same stream in which they hatched years earlier. Their migration in the steams often involve distances of hundreds of km. This migration is guided by fishes' perception of characteristic odor of their spawning stream <u>In amphibians</u> olfaction is used to detect noxious chemicals, food and mate. <u>In reptiles</u> olfaction is better adapted than in amphibians. Jacobson's (vomeronasal) organ:

	Apart from olfactory epithelium most reptiles possess Jacobson's organs. These organs are best developed in snakes and lizards. Jacobson's organ is a spherical structure having a narrow duct that opens into mouth. The protrusible, forked tongue of snakes is used to take sample of air borne chemicals. Snake flicks the tongue out take the sample and then moves to the Jacobson's organ which perceive odor molecules. Turtles and Tuatara use the Jacobson's organ to taste objects held in oral cavity. In birds olfactory epithelium is poorly developed, so olfaction plays minor role in the lives of birds. Exceptions are vultures. They locate dead and dying prey largely by smell. In birds olfactory epithelium is poorly developed, so olfaction plays minor role in the lives of birds. Exceptions are vultures. They locate dead and dying prey largely by smell.
85	**Taste or gustation:** Taste receptors are the chemoreceptors. Tongue is the primary organ of taste. The tongue is equipped with many taste buds housed in papillae on its dorsal surface. Papillae give the tongue a bumpy appearance. All sugars are sweet because they contain OH groups with a particular orientation that can interact with the taste receptor for sweetness in our tongues. 
86	**Taste in various vertebrates** Vertebrates other than mammals may have taste buds on other parts of the body. Taste buds are inside the fish's mouth, on its tongue and scattered all over the body including barbles and fins. Vertebrates other than mammals may have taste buds on other parts of the body. Taste buds are inside the fish's mouth, on its tongue and scattered all over the body including barbles and fins. Vertebrates other than mammals may have taste buds on other parts of the body. Taste buds are inside the fish's mouth, on its tongue and scattered all over the body including barbles and fins. However, some birds have an acute sense of taste. Extensive research into bird senses has shown that vultures, seabirds, kiwis and parrots have well-developed olfactory glands, giving them some sense of smell and taste.
87	**Photoreception:**

	Photoreception/Vision is defined as any of the biological responses of animals to stimulation by light. Photoreception refers to mechanisms of light detection that lead to vision Vision depends on specialized light-sensitive cells called photoreceptors, which are located in the eye. The quality of vision provided by photoreceptors varies enormously among animals. Some simple eyes such as those of flatworms have few photoreceptors and are capable of determining only the approximate direction of a light source. The quality of vision provided by photoreceptors varies enormously among animals. Some simple eyes such as those of flatworms have few photoreceptors and are capable of determining only the approximate direction of a light source. 
88	**Anatomy of Human eye** The eye is composed of the anterior and the posterior segments. The anterior segment is made up of the cornea, iris and lens. The cornea is transparent and more curved, and is linked to the larger posterior segment. The posterior segment is composed of the vitreous, retina, choroid and the outer white shell called the sclera. The transparent cornea is continuous with the sclera and covers the front of the eye ball. Choroid tissue also extends the front of the eye ball to form iris, ciliary body and suspensory ligaments. The cornea is about 11.5 mm in diameter, and 1/2 mm in thickness. The iris is the circular pigmented structure which is composed of radial and circular muscles surrounding the center of the eye. The pupil is an aperture which appears to be black present in the center of iris The size of the pupil is adjusted by the iris muscles. A clear fluid, the aqueous humor fills the anterior chamber and jelly-like vitreous humor fills the posterior chamber. The retina is the innermost light sensitive layer composed of rods and cones. The size of the eye ball is about 24 mm in diameter. At birth it is 16-17 mm and attains maximum size by 12 years of age. However, the maximum increase is within three years. The moist mucous membrane that covers the eye ball is the conjunctiva. The fovea is a tiny pit in the retina aligned with the central axis of the lens.

	Fovea contains closely spaced cones (no rods) and produces the highest visual resolution anywhere on the retina.
89	**Accommodation of eye:** Accommodation is the adjustment of the optics of the eye to keep an object in focus on the retina as its distance from the eye varies. It is the process of adjusting the focal length of a lens. Accommodation is the ability of the eye lens to see both near and distant objects by adjusting its focal length. The minimum distance at which the eye can see objects clearly is called near point vision. The farthest at which the eye can see objects clearly is called far point vision. 
90	**Adaptation of Amphibians Eye** <u>Fish eyes:</u> Eyes of fishes are similar in most respects to the eyes of other vertebrates in both structure and function. However, fish eyes are without eye lids. Lens is spherical and close to cornea. Focusing requires moving the lens forward and backward. <u>Amphibian Eye:</u> In anurans and salamander eyes are close together on the front of head and have binocular vision. Some salamanders have smaller and lateral eyes and lack binocular vision. Laterally placed eyes permit such animals to see well off to their sides. Binocular vision is a type of vision in which an animal having two eyes is able to perceive a single three-dimensional image of its surroundings.
91	**Vision in Reptiles** Eye in Reptiles are similar in structure to those of amphibians. Most reptiles have a ring of bones around each eye that supports the eyeball except crocodiles and snakes. Some lizards and tuatara contain a third eye called a parietal eye, located on the top of their head.

	 This eye develops from optic tactum (midbrain) This eye contains a cornea, lens, and retina like the lateral eyes. Snakes do not possess eyelids. A scale that is actually part of the skin, a spectacle, protects the eye. Most reptiles possess upper and lower eye lids, nictitating membrane that protect and cleanse the surface of the eye. Usually, non-poisonous snakes have round pupils while poisonous snakes have elliptical pupils. Most reptiles possess upper and lower eye lids, nictitating membrane that protect and cleanse the surface of the eye. Usually, non-poisonous snakes have round pupils while poisonous snakes have elliptical pupils.
92	The structure of bird eye is similar to that of other vertebrates. Birds are highly visual animals with unique features and adaptations that allow them to fly. But they have a number of adaptations which give visual acuity superior to that of other vertebrate groups. Birds have unique double focusing mechanism Padlike structures control the curvature of the lens and ciliary muscles. Also change the curvature of the cornea. Instantaneous focusing of both allows the bird of prey to descend down rapidly to catch fish. judgment of distances. Nocturnal species have but a high density of rod cells which function well in poor light. Birds can see ultraviolet (UV) light because their lenses and other ocular media transmit UV. They possess a class of photoreceptor, which is maximally sensitive to violet or UV light, depending on the species.
93	**Functioning of eye** The retina is a thin layer of tissue that lines the back of the eye on the inside. The retina is a light-sensitive layer which is composed of pigmented epithelium, that covers the choroid layer.

	Nervous tissue that contains photoreceptor cells lies on this basement layer. The photoreceptor cells are called rod and cone cells. Rods are sensitive to dim light whereas cones respond to high intensity light and involved in color perception. With the help of the cornea and crystalline lens, image is formed on the retina which transforms it into nerve impulses and sent to the brain. Chemistry of Vision: Visual perception in humans occurs through the absorption of electromagnetic radiations by photoreceptors in the retina. When rhodopsin, a pigment in rod cells, absorb light energy. 
94	**Light, Eye Vision** Light is electromagnetic radiation that has properties of waves. The electromagnetic spectrum can be divided into several bands based on the wavelength. As we have discussed before, visible light represents a narrow group of wavelengths between about 380 nm and 730 nm. Nature of light is said to dual i.e. it shows characteristics of both waves and particles. These particles are called photons when comes into contact with matter. Photon as the particle of light has no charge and always move at the speed of light. The photon has only energy and no mass. When a pigment (rhodopsin) in a rod cell absorbs light energy, the energy that this reaction releases triggers the generator potential in an axon and then an action potential that leaves the eyeball via the optic nerve to the brain. When the photoreceptor cells are not being stimulated (i.e., in the dark), vitamin A and energy from ATP convert rhodopsin back to its light-sensitive form. <u>Fovea</u> In the middle of the retina is a small dimple called the fovea or fovea centralis. This is the center of the eye sharpest vision and the location of most color perception. Our perception of color is based on perception of the light wavelength. Blue, yellow and red are the primary colors. These colors contain only one wavelength so they are called pure colors.
95	**Common eye defects** *Myopia (nearsightedness),* *Hyperopia (farsightedness) and*

	Astigmatism are common eye defects. They are often called "refractive errors". *Cataract* *Glaucoma* Nearsightedness or Myopia, is a vision condition in which close objects are seen clearly, but objects farther away appear blurred. Farsightedness or hyperopia, is a vision condition in which distant objects are seen clearly, but close objects does not come into proper focus. Hyperopia occurs if the eyeball is too short. Light entering the eye is therefore, not focused correctly. Astigmatism is a vision condition that causes blurred vision due to the irregular shape of the cornea or the curvature of the lens inside the eye. the light entering the eye is not focused correctly Cataract is a condition that occurs when the inner lens of the eye becomes darkened or opaque. Glaucoma is a disease which damage the eyes optic nerve and can result in vision loss and blindness.
96	**Shining eyes:** Eye shine can be seen in many animals. Eye shine occurs in a wide variety of colors including white, blue, green, yellow, pink and red. Eye shine is a type of iridescence. E.g Soap bubbles, sea shells: Eye shine is a visible effect of the tapetum lucidum Tapetum is a layer of tissue in the eye of many vertebrates. It lies immediately behind the retina. When light shines into the eye of an animal having a tapetum, the pupil appears to glow. The tapetum lucidum functions as a retro reflector. It reflects visible light back through the retina, increasing the light available to the photoreceptors.
97	Summary of the Chapter Part I
98	Summary of the Chapter Part II
99	Summary of the Chapter Part III