NERVOUS SYSTEM: The system that integrates, coordinates and communicates the various systems of the organism. • Neurons-Functional unit of Nervous system • They are specialized cells to produce signals, which are communicated from one part to the body to other.	Neurons have two important properties- the excitability and conductivity. • Structurally the neuron is composed of dendrites, cell body and axon. • The language of neuron in the nerve impulse or action potential.	The plasma membrane of a living neuron is polarized i.e. there is trans membrane potential. • Outside is positively charged and inside negatively charged. • The sodium-potassium ATPase pump and diffusion of ions across membrane channels maintain this polarization.	When a stimulus is applied to a resting neuron, the neuron depolarizes causing an action potential. • In myelinated neuron the conduction of impulse is saltatory. • Nerve impulse is transmitted from one neuron to the next through synapsis, which involve neurotransmitters.
The more complex an animal, the more detailed its i) Nervous System ii) Cephalization iii) Bilateral symmetry iv) More interneurons v) The more complicated behavior.	THE VERTEBRATE NERVOUS SYSTEM • 1. The Central Nervous System (CNS) has two main divisions: brain and spinal cord. • 2. Perpheral Nervous System (PNS)- all the nerves out side the brain and spinal cord.	THE VERTEBRATE BRAIN is divided into: fore brain, • mid brain and the • hind brain. • The fore brain is composed of cerebrum, thalamus, hypothalamus, pineal gland and the pituitary.	The mid brain is a thickened region of grey matter that integrates visual and auditory signals. • The hind brain is continuous with spinal cord and includes the cerebellum, pons and medulla oblongata.
THE SPINAL CORD serves two functions: • a) It is the connecting link between brain and the body. • b) It is involved in the reflex actions.	CRANIAL NERVES: • In reptles, birds and mammals the CNs are 12 pairs: I. Olfactory S II. Optic S III. Oculomotor M IV. Trochlear M V. Trigeminal Mix VI Abducens M VII. Facial Mix VIII. Vestibulocochlear S	IX. Glossophryneal Mix X. Vagus Mix XI. Accessory Mix XII Hypoglossal Mix • Fishes and Amphibians have 10 pairs of Cranial Nerves.	AUTONOMIC NERVOUS SYSTEM: • ANS consists of: • a) Sympathetic and b) Para sympathetic NS These are antagonistic to each other.
PARASYMPARHTIC NS: • It contains nerves that arise from the brain and sacral region of the spinal cord. • It relaxes the body and inhibits or slows many energy functions. • Rest and digest	SYMPATHETIC NS: • It contains nerves that arise from the thoracic and lumbar regions of the spinal cord. • It prepares body for intense physical activity. • Fight and Flight	Sensory Reception: • Identification of five senses-sight, hearing, smell , taste and touch. • Features of Sensory Receptors: • 1. Contain sensitive receptor cells or finely branched peripheral endings of sensory neurons that respond to a stimulus by	2. Their structure is designed to receive a specific stimulus. • 3. Their receptor cells synapse with afferent nerve fibers that travel to the CNS along specific neural pathways. • 4. In the CNS the nerve impulse is translated into a recognizable

		creating a generator potential.	sensation, such as sound
INVERTEBRATE SENSORY RECEPTORS: • Baroreceptors • Chemoreceptors • Georeceptors • Hygroreceptors • Photoreceptore • Proprioceptors • Tactile receptors	VERTEBRATE SENSORY RECEPTORS • Lateral-line system and mechanoreceptors • Hearing & Equilibrium in air and water. • Skin sensors of heat and cold. • Skin sensors of mechamical stimuli. • Sonar. • Smell • Taste • Vision	**<u>SENSORY RECEPTION:</u>** • Identification of five senses-sight, hearing, smell , taste and touch. • Features of Sensory Receptors: • 1. Contain sensitive receptor cells or finely branched peripheral endings of sensory neurons that respond to a stimulus by creating a generator potential.	2. Their structure is designed to receive a specific stimulus. • 3. Their receptor cells synapse with afferent nerve fibers that travel to the CNS along specific neural pathways. • 4. In the CNS the nerve impulse is translated into a recognizable sensation, such as sound.
INVERTEBRATE SENSORY RECEPTORS: • Baroreceptors- statocysts • Chemoreceptors- • Georeceptors- statocysts, that respond to gravity • Hygroreceptors-detect water content of air. • Phonoreceptors-such as tympanic organs.	Photoreceptors- such as stigmata, ocelli, compound eyes, complex camera eyes that respond to light. • Proprioceptors- that respond to mechanically induced changes caused by stretching. • Tactile receptors- such as bristles, sensilla, spines, setae and tubercles that sense touch.	VERTEBRATE SENSORY RECEPTORS • Lateral-line system- contain neuromasts. They are present in the head area of most fishes, some amphibians and platypus. They are sensitive to water disturbance.	Lateral Line System in jawless fishes, jawed fishes and certain amphibians contain ampulary organs, which are sensitive to electric currents in water and production of generator potential.
Hearing & Equilibrium in air and water. Hearing (audition) and equilibrium (balance) are considered together because both sensations are received in the same vertebrate organ—the ear.	Skin Sensors of Heat and Cold. • Pit organs in snakes • Skin Sensors of Mechanical Stimuli- They are: • Bare sensory nerve endings, • Meissner's corpuscles, • Bulbs of Krause, • Paccinian Corpuscle • Vibrissae	Vision: • Eyes, Median eye • Photoreceptor cells- rods and cones • Monocular and Binocular vision, • Accommodation, • Rhodopsin	Sonar- • Echolocation in bats, whales, dolfin, cave dwelling birds. • Smell- • Receptor in nasal cavity • Jacobson's organs. • Taste or gustation: • Taste buds on tongue. Barbles in fishes • Pharynx in birds

Chemical messengers are involved in: • 1. Communication • 2. Maintenance of homeostasis in an animal's body, • 3. Body's response to various stimuli. • One type of chemical messenger is a hormone	Only those cells that have specific receptors for a hormone can respond to that hormone. • Hormones work with nerves to communicate, coordinate, and integrate activities within the body of an animal. • Almost every invertebrate produces hormones	However, the physiology of invertebrate hormones is often quite different from that of vertebrate hormones. • The major endocrine glands of vertebrates include: • hypothalamus, pituitary, thyroid, parathyroids, adrenals, pineal, thymus, pancreas, and gonads.	Various other tissues, however, such as the kidneys, heart, digestive system, and placenta also secrete hormones.

101Evolutionarily, new messengers are uncommon. • Instead, "old" messengers are adapted to new purposes. • For example, some ancient protein hormones are in species ranging from bacteria to humanScientists suggest that chemical messengers may initially have evolved in single-celled organisms to coordinate feeding or reproduction. Evolution in Coordination • As multicellularity evolved, more complex organs also evolved to govern the many individual coordination tasks, but control centers relied on the same kinds of messengers that were	**102The development of** most animals commences with fertilization and the subsequent division of the zygote. • Further development then depends on continued cell proliferation, differentiation and growth. **Chemical Messengers Part I** • Integration communication, and coordination of all physiological processes, such as metabolism, respiration, excretion, movement, and reproduction, depend on chemical messengers. Chemical Messengers Part I • The chemical messengers are the	**104**Biochemically the hormones may be the • i) Proteins (polypeptides) e.g. insulin • ii) Derivatives of amino acids (amines), e.g. TSH • iii) Steroids e.g. Sex hormones and adrenocortical hormones. Biochemistry of Hormones • iv) A few are fatty acid derivatives. For example- Postglndins • They are synthesized in the walls of blood vessels. • Regulate the contraction of smooth muscle tissue. • Involved in inflammation. **105 General characteristics of hormones are as**	**108 Hormones modify the biochemical activity of a target cell or tissue. Two basic mechanisms are involved.** • 1. Fixed membrane-receptor mechanism. • 2. Mobile-receptor mechanism. Mechanisms of Hormone Action Part I • Fixed membrane-receptor mechanism • In this mechanism, an endocrine cell secretes a water-soluble hormone. • At the cells of the target organ, the hormone binds to a specific receptor site on the plasma membrane. • This forms a complex called hormone-receptor complex. Mechanisms of Hormone Action Part I

present in the simpler organisms
Evolution in Coordination
• Some of the messengers worked fairly slowly but had long-lasting effects on distant cells; these became the modern hormones .
Evolution in Coordination
• Others worked more quickly but influenced only adjacent cells for short periods; these became the neurotransmitters and local chemical messengers.
Evolution in Coordination
• Clearly, chemical messengers have an ancient origin and must have been conserved for hundreds of millions of years .
• It seems likely that the chemical messengers. regulating growth and reproduction were among the first to appear.
Evolution in Coordination
• These messengers were probably
• Later, specific hormones developed to play important regulatory roles in molting, growth, reproduction and metamorphosis, in various invertebrates.
Evolution in Coordination
• Chemical messengers and their associated secretory structures molecules that are synthesize and secreted by specialized cells.
Chemical messengers can be categorized as follows:
• i) Local chemical messengers.
• Many cells secrete chemicals that alter physiological conditions in the immediate vicinity.
• Most of these chemicals act on adjacent cells and do not accumulate in the blood.
Chemical Messengers Part II
• Vertebrate examples include some of the chemicals called lumones that the gut produces and that help regulate digestion.
• In a wound, mast cells secrete a substance called histamine that participates in the inflammatory response.
Chemical Messengers Part II
• ii) Neurotransmitters. Neurons secrete chemicals called neurotransmitters (e.g., nitric oxide and acetylcholine) that act on immediately adjacent target cells.
• These chemical messengers reach high concentrations in the synaptic cleft, act quickly, and are actively degraded and recycled.
follows:
• i) Hormones are secreted by specialized cells, the endocrine cells.
• ii) Hormones are chemical messengers. The are chemical signals that circulate in the body fluids.
Characteristics of Hormones
• iii) Hormones are directly secreted into the blood stream and are carried by the blood throughout the entire body, yet they affect only certain cells.
• iv) Specific cells that respond to a given hormone have receptor sites for that hormone.
Characteristics of Hormones
• v) Hormones are required in very minute quantities.
• vi) Steroid hormones help control
• Metabolism,
• Inflammation,
• Immune functions,
• Salt and water balance,
• Development of sexual characteristics and
• Ability to withstand illness and injury.
Hormones are not released in a constant, steady stream.
• Rather they are secreted in fluctuations depending on the
• This complex activates the enzyme-adenylate cyclase in the membrane.
• The activated enzyme converts ATP into a nucleotide called cyclic AMP.
• Cyclic AMP diffuses throughout the cytoplasm and activates an enzyme called protein kinase.
Mechanisms of Hormone Action Part I
• Which then phosphorylates specific proteins in the cell, thereby triggering the biochemical reaction, leading ultimately to the cell’s response.
• After inducing the target cell to perform its specific function, the phosphodiesterase inactivates cyclic AMP
Mechanisms of Hormone Action Part I
• In the meantime, the receptor on the plasma membrane loses the first messenger and now becomes available for a new reaction.**109**
Hormones modify the biochemical activity of a target cell or tissue. Two basic mechanisms are involved.
• 1. Fixed membrane-receptor mechanism.
• 2. Mobile-receptor mechanism.
Mechanisms of Hormone Action Part II

became even more complex with the appearance of vertebrates.

110 The survival of any group

of animals depends on growth, maturation, and reproduction.

• Thus, chemicals regulating growth, maturation, and reproduction probably were among the first hormones to appear during the course of animal evolution.

Hormones of Porifera and Cnidarians

• The first hormones were probably neurosecretions.

• Most of the chemicals functioning as hormones in invertebrate animals are neurosecretions called neuropeptides.

• Molluscs, arthropods, echinoderms have hormones other than neurosecretions.

Hormones of Porifera and Cnidarians

• The porifera (sponges) do not have classical endocrine glands.

• Since sponges do not have neurons, they also do not have neurosecretory cells.

Hormones of Porifera and Cnidarians

• The nerve cells of Hydra contain a growth-promoting hormone that stimulates budding,

103Chemical Messengers Part II

• iii) Neuropeptides. Some specialized neurons (called neurosecretory cells) secrete neuropeptides (neurohormones). The blood or other body fluids transport neuropeptides to nonadjacent target cells, where neuropeptides exert their effects

Chemical Messengers Part II

• In mammals, for example, certain nerve cells in the hypothalamus release a neuropeptide that causes the pituitary gland to release the hormone oxytocin, which induces powerful uterine contractions during the delivery of offspring.

Chemical Messengers Part II

• iv) Hormones. Endocrine glands or cells secrete hormones that the bloodstream transports to nonadjacent target cells.

• Many examples are given in the rest of this chapter.

• Thyroxin, Insulin, Glucagon, FSH, LH etc.

Chemical Messengers Part II

• v) Pheromones. Pheromones are

physiological demand for their actions.

• A negative feedback system is used to regulate the secretion of hormones.

Feedback Control of Hormones Secretion II

• Such as that the release of a specific hormone is increased or decreased in response to physiologic changes.

• Some hormones are released in short bursts in periods, showing daily or even monthly cycles (such as a menstrual cycle).

Feedback Control of Hormones Secretion II

• The regulation of blood glucose concentration is an example of how the endocrine system uses negative feedback to maintain homeostasis.

• When blood glucose concentration is high, insulin is released by the pancreas in response to the negative feedback of elevated blood glucose levels

Feedback Control of Hormones Secretion II

• In response to insulin, cells take up glucose, thereby returning blood glucose concentration back to normal.

• Insulin release is then inhibited until blood glucose levels rise again.**112**

NEMATODES:

• No classical endocrine

• Mobile-receptor mechanism.

• A steroid hormone molecule (e.g., testosterone) diffuses from the blood to a target cell across the plasma membrane of the target cell.

• Once in the cytoplasm, the hormone binds to a receptor that carries it into the nucleus.

Mechanisms of Hormone Action Part II

• This steroid-protein complex triggers transcription of specific gene regions of DNA.

• The messenger RNA transcript is then translated into a gene product via protein synthesis in the cytoplasm.

• The new protein then mediates the cell's response.**113**

MOLLUSCS

• The ring of ganglia that constitutes the central nervous system of molluscs is richly endowed with neurosecretory cells.

• The neuropeptides that these cells produce help regulate heart rate, kidney function, and energy metabolism.

Hormones of Molluscs and Arthropods

• In certain gastropods, such as the common land snail Helix, a specific hormone stimulates

regeneration, and growth.
For example, when the hormone is present in the medium in which fragments of Hydra are incubated, "head" regeneration is accelerated.
This so-called "head activator" also stimulates mitosis in Hydra.
Hormones of Porifera and Cnidarians
• For example, when the hormone is present in the medium in which fragments of Hydra are incubated, "head" regeneration is accelerated.
• This so-called "head activator" also stimulates mitosis in Hydra.**114**
Crustacean:
• The endocrine systems of advanced invertebrates (crustaceans and insects) are excellent examples of how hormones regulate growth, maturation, and reproduction.
• The endocrine system of
crayfish, controls functions such as ecdysis, color changes & sex determination Here we discuss only
Ecdysis.
• X-organs are neurosecretory tissues in the crayfish eye stalks.
• Associated with each X-

chemical messengers released to the exterior of one animal that affect the behavior of another individual of the same species.**111**
Platyhelminths:
• Zoologists identified neurosecretory cells in various flatworms These cells are in the cerebral ganglion and along major nerve cords.
• The neuropeptides that the cells produce function in regeneration, asexual reproduction, and gonad maturation.
Hormones of Platyhelminths and Nemerteans
• For example, neurosecretory cells in the scolex of some tapeworms control shedding of the proglottids or the initiation of strobilization.
Hormones of Platyhelminths and Nemerteans
• NEMERTEANS
Nemerteans (ribbon worms) have more cephalization than platyhelminths and a larger brain, composed of a dorsal and ventral pair of ganglia connected by a nerve ring.
• The neuropeptide that these ganglia produce appears to control gonadal development and
to regulate water

glands have been identified in nematodes.
• However, they do have neurosecretory cells associated with the central nervous system.
• The neuropeptide that this nervous tissue produces apparently controls ecdysis of the old cuticle.
Hormones of Nematodes and Annelids
• The neuropeptide is released after a new cuticle is produced .
• It stimulates the excretory gland to secrete an enzyme (leucine aminopeptidase) into the space between the old and new cuticle.
• The accumulation of fluid in this space causes the old cuticle to split and be shed.
Hormones of Nematodes and Annelids
• ANNEDIDS
• Annelids have a well-developed and cephalized nervous system, a well-developed circulatory system, and a large coelom.
• Correspondingly, they have well-developed endocrine control of physiological functions.
Hormones of Nematodes and Annelids
• The various endocrine systems of annelids are generally involved with morphogenesis,

spermatogenesis.
• Another hormone, termed egg-laying hormone, stimulates egg development; and hormones from the ovary and testis stimulate accessory sex organs.
Hormones of Molluscs and Arthropods
• In all snails, a growth hormone controls shell growth.
• In cephalopods, such as the octopus, and squid, the optic gland in the eye stalk produces one or more hormones.
• These hormones stimulate gametetogenesis and the development of secondary sexual characteristics.**116**
Other neurosecretory cells in the brain and nerve cords produce the hormone bursicon
• Bursicon influences certain aspects of epidermal development, such as tanning (i.e., hardening and darkening of the chitinous outer cuticle layer).
• Tanning is completed several hours after each molt.
Some More Hormones in Arthropods
• Another hormone, juvenile hormone (JH), is also involved in the morphological differentiation that occurs during the

organ is a sinus gland that accumulates and releases the secretions of the X-organ.
• Other glands, called Y-organs, are at the base of the maxillae.
Hormones of Arthropod-Crustacean
• X-organs and Y-organs control ecdysis as follows.
• In the absence of an appropriate stimulus, the X-organ produces molt-inhibiting hormone (MIH), and the sinus gland releases it.
• The target of this hormone is the Y-organ.
• When MIH is present in high concentrations, the Y-organ is inactive.
Hormones of Arthropod-Crustacean
• Under appropriate internal and external stimuli, MIH release is prevented, and the Y-organ releases the hormone ecdysone, which leads to molting..
117 The echinoderms are deuterostomes, they are more closely allied with chordates than are the protostome invertebrates.
• However, the endocrine systems of echinoderms provide few insights into the evolution of chordate endocrine systems, because echinoderm hormones and endocrine glands are very different

balance.**115**
INSECTS
• The sequence of events in insects is similar to that of crustaceans, but it does not involve a molt-inhibiting hormone.
• The presence of an appropriate stimulus to the central nervous system activates certain neurosecretory cells (pars intercerebralis) in the optic lobes of the brain. These cells secrete the hormone ecdysiotropin, which axons transport to the corpora cardiaca (a mass of neurons associated with the brain).
Hormones of Arthropod-Insect
• The Corpora Cardiaca produces thoracotropic hormone, which is carried to the prothoracic glands, stimulating them to produce and release ecdysone, which induces molting, the reabsorption of some of the old cuticle and the development of a new cuticle.**118**Vertebrates have the best understood system of hormonal control.
• As the earliest vertebrates evolved, hormone-producing cells and tissues developed.
• Sets of nerve cells in the brain direct some endocrine tissues, such

development, growth, regeneration, and gonadal maturation.
• For example, in polychaetes, juvenile hormone inhibits the gonads and stimulates growth and regeneration.
Hormones of Nematodes and Annelids
• Another hormone, gonadotropin, stimulates the development of eggs.
• In leeches, a neuropeptide stimulates gamete development and triggers color changes.
• Hormones for osmoregulation have been reported in oligochaetes.
Hormones of Nematodes and Annelids
• Hormone that maintains a high concentration of blood glucose has been reported in oligochaete, Lumbricus.
“Hyperglycemic hormones”

119 Vertebrates other than
birds or mammals have somewhat similar endocrine systems, but differences do exist.
• In fishes, the brain and spinal cord are the most important producers of hormones, with other glands being rudimentary.

molting of insects.
• Just behind the insect brain are the paired corpora allata
Some More Hormones in Arthropods
• These structures produce JH. High concentrations of JH in the blood of an insect inhibit differentiation.
• In the absence of an appropriate environmental stimulus, the corpora allata decrease JH production, which causes the insect larva to differentiate into a pupa.
Some More Hormones in Arthropods
• The pupa then forms a cocoon to overwinter. In the spring, a final surge of ecdysone, in the absence of JH, transforms the pupa into an adult moth.**120**
Endocrine System in amphibians and reptiles is vey much like many fishes.
• For example the melatonin from the pineal gland control variations in skin color.
• When this hormone produced by one species is injected into another species, it can induce dramatic color changes.
ES of Amphibians and Reptiles
• This type of experiment indicates that some hormones have a close

from those of chordates. Zoologists do know, however, that the radial nerves of sea stars contain a neuropeptide called gonad-stimulating substance.

• When this neuropeptide is injected into a mature sea star, it induces immediate shedding of the gametes, spawning behavior, and meiosis in the oocytes.

Hormones in Echinoderms

• The neuropeptide also causes the release of a hormone called maturation-inducing substance, which has various effects on the reproductive system.**121** In vertebrates thyroxine(T4) and triiodothyronine (T3) regulate metabolism. growth, and tissue differentiation.

• In amphibians, they play an additional role in metamorphosis.

• Specifically timed changes in the concentrations of three hormones--

Hormonic Control of Metamorphosis in Frog

• prolactin, thyroxine, and triiodothyronine— control metamorphosis in the frog.

• Low thyroxine and triiodothyronine as the medullary areas of the adrenal glands.

An Overview of Vertebrate ES

• The hypothalamus of the brain stimulates the pituitary gland (hypophysis), which inturn control others.

• Still others function independently of either nerves or the pituitary gland. Vertebrates possess two types of glands:

• 1. Exocrine glands,

• 2 Endocrine glands

• Exocrine Glands: These glands secrete chemicals into ducts that, in turn, empty into body cavities or onto body surfaces (e.g., mammary, salivary, and sweat glands).

An Overview of Vertebrate ES

• Endocrine Glands:

• These glands, have no ducts and secrete chemical messengers, the hormones, directly into the tissue space next to each endocrine cell.

• The hormones then diffuse into the blood stream, which carries them throughout the body to their target cells.**122** Reptiles have slightly different ES as compared to Amphibians and Fishes.

• The thyroids vary with the species and may be single, bilobed or paired.

Endocrine System of Fishes

• In jawed fishes, three major regions that secrete neuropeptides:

• 1. Pineal gland

• 2. Preoptic nuclei

• 3. Urophysis

Endocrine System of Fishes

• The pineal gland: It is located in the epithalamus of the brain.

• It produces neuropeptides that affect pigmentation.

• One specific hormone that the pineal gland produces is melatonin.

• Melatonin has broad effects on body metabolism by synchronizing activity patterns with light intensity and day length.

Endocrine System of Fishes

• The Preoptic Nuclei: These are present in the hypothalamus of the brain.

• Produce various other neuropeptides that control different functions in fishes (e.g., growth, sleep, locomotion).

Endocrine System of Fishes

• Urophysis.

• This is a discrete structure in the spinal cord of the tail.

• It produces neuropeptides that help control water and ion chemical similarity despite the distant evolutionary relationships among the animals producing them.

• Another example is the hormone prolactin produced by the pituitary gland).

ES of Amphibians and Reptiles

• Prolactin stimulates reproductive migrations in many animals (e.g., the movement of salamanders to water).

• It also helps control water and salt balances,

ES of Amphibians and Reptiles

• Prolactin causes brooding behavior in some fishes.

• It is also essential for certain saltwater fishes to enter freshwater during spawning.

ES of Amphibians and Reptiles

• Hormonal Control of Frog When frog is immersed in water containing the hormone melatonin light-color is exhibited.

• When melanocyte stimulating hormone is injected in frog dark color is exhibited.**124**The endocrine glands in birds include:

• pituitary,

• thyroid,

• parathyroids,

• adrenals,

• pancreas,

• pineal,

concentrations and high prolactin concentrations in young tadpoles stimulate larval growth and prevent metamorphosis.
Hormonic Control of Metamorphosis in Frog
• As the hypothalamus and
pituitary glands develop in the growing tadpole, the hypothalamus releases thyroid-stimulating hormone and prolactin-inhibiting hormone.
• Their release causes the pituitary gland to release thyroid-stimulating hormone and to cease production of prolactin.
Hormonic Control of Metamorphosis in Frog
• This results the concentrations of thyroxine and triiodothyronine to rise.
• This triggers the onset of
metamorphosis i.e.tail resorption and other changes follow.**125** The endocrine glands in mammals include:
• pituitary,
• thyroid,
• parathyroids,
• adrenals,
• pancreas,
• pineal,
• hypothalamus,
• thymus,
• Testes
• Ovaries
The pituitary gland (also known as the

and the parathyroids are paired.
Endocrine System of Reptiles
• In turtles, snakes, and Sphenodon it is unpaired; in Crocodilia it is markedly bilobed.
• Among lizards there is wide diversity in thyroid morphology and position.
• Hyperparathyroidism are
commonly diagnosed diseases in captive reptiles.
Endocrine System of Reptiles
• The thyroids are involved in control of ecdysis.
• The pancreas is usually attached to the duodenum and may be pale pink in colour.
• It contains alpha and beta cells that produce glucagon and insulin.
Endocrine System of Reptiles
• The cells are not grouped
into islets and diabetes appears to be relatively rare.
• It is both an endocrine and exocrine organ.**126** The true endocrine portion of the pituitary is the adenohypophysis, which synthesizes six different hormones:
• All of these hormones are polypeptides.
• Produce two types of hormones:

balance, blood pressure, and smooth muscle contractions.**123** Chromaffin tissue is a group of neuroendocrine cells in the adrenal medulla that synthesizes steroid hormones.
• These hormones are adrenaline (epinephrine) and noradrenaline (norepinephrine)
• These hormones prepare
some vertebrates for stressful emergency situations (fight and flight) In jawless and cartilaginous fishes chromaffin tissue develops as clusters near the kidneys.
Chromaffin Tissues in Selected Vertebrates
• In teleosts, the chromaffin tissue is generally at the anterior end of the kidney (pronephric region).
• In anurans, the chromaffin tissue is interspersed in a diffuse gland on the ventral surface of each kidney.
Chromaffin Tissues in Selected Vertebrates
• In lizards, the chromaffin
tissue forms a capsule around the steroidogenic-producing tissue.
• In birds, the chromaffin tissue is interspersed within an adrenal capsule.
Chromaffin Tissues in

• hypothalamus,
• thymus,
• testes
• ovaries
Endocrine System of Birds
• ultimobranchial and
• bursa of Fabricius.
• The hormones that most
of these glands produce and their effects on target tissues are nearly the same as in mammals.
Endocrine System of Birds
• Some unique hormones and their functions in birds are:
• In some birds (e.g., pigeons and doves), the pituitary gland secretes the hormone prolactin.
• Prolactin stimulates the production of “pigeon’s milk” by desquamation (sloughing off cells) in the pigeon’s crop.
Endocrine System of Birds
• Prolactin also stimulates
the development of the brood (incubation) patch
Endocrine System of Birds
• The brood patch helps keep the eggs at a temperature between 33 and 37° C.
• In birds thyroxine regulates the normal development of feathers, molt cycle, and plays a role in the onset of migratory behavior.

hypophysis) is directly below the hypothalamus. The pituitary has two distinct lobes:
• a) the anterior lobe (adenohypophysis) and b) the posterior lobe (neurohypophysis).
Endocrine System of Mammals Part I
• Differences Between these lobes:
• i) The adenohypophysis is larger than the neurohypophysis.
• ii) Secretory cells called pituicytes are in the adenohypophysis, but not in the neurohypophysis.
• iii) The neurohypophysis has a greater supply of nerve endings.**129** The pineal gland is also known as the third eye.
• It is an endocrine gland in the Brain.
• The pineal gland is located behind the third cerebral ventricle in the brain between the two cerebral hemispheres.
• Darkness makes Pineal gland to produce Melatonin.
Pineal Gland
Pineal Gland
• Melatonin hormone modulates wake/sleep and seasonal changes.
• Light inhibits the enzymes needed for melatonin synthesis.
• Because of its cyclical production, melatonin can affect many

• A) Tropic and
• B) Non tropic
Hormones of Adenohypophysis Part I
• Tropic Hormones are the hormones whose primary target is another endocrine gland. e.g TSH, ACTH, LH and FSH
• Nontropic hormones are the growth hormone (GH) and prolactin.
• (TSH) thyroid-stimulating hormone stimulates the thyroid gland to secrete thyroxine, which is the main thyroid hormone.
Hormones of Adenohypophysis Part I
• Adrenocorticotropic hormone (ACTH) stimulates the adrenal gland to produce and secrete steroid hormones called glucocorticoids (cortisol).
Hormones of Adenohypophysis Part I
• Secretion of ACTH is regulated by the secretion of corticotropin-releasing factor (CRF) from the hypothalamus.
• CRF in turn, is regulated by a feedback system that involves factors such as stress, insulin, ADH, and other hormones.
Hormones of Adenohypophysis Part I
• Luteinizing hormone (LH), in females, stimulate ovulation i.e.

Selected Vertebrates
• In most mammals, the chromaffin tissue forms adrenal medulla, and the steroidogenic tissue forms the cortex.**127** Adenohypophysis, synthesizes six different hormones:
• Produce two types of hormones:
• a) Tropic and
• b) Non tropic
• Non Trophic Hormones are:
• a. Growth Hormone
• b. Prolactin
Hormones of Adenohypophysis Part II
• Growth Hormone (GH) or Somatotrophic Hormone does not influence a particular target tissue.
• It affects all parts of the body that are concerned with growth.
• It directly induces the cell division necessary for growth.
Hormones of Adenohypophysis Part II
• It also influences protein synthesis in most types of cells by stimulating the uptake of amino acids, RNA synthesis, and ribosome activity.
• Prolactin (PRL) has the widest range of actions of the adenohypophyseal hormones.
• It plays an essential role in many aspects of reproduction.

• These are in addition to the regular functioning of thyroxine.
Endocrine System of Birds
• In male birds, the testes produce the hormone testosterone.
• Testosterone controls the secondary sexual characteristics of the male, such as bright plumage color, comb (when present), and spurs—all of which strongly influence sexual behavior.
Endocrine System of Birds
• The ultimobranchial glands are small, paired structures in the neck just below the parathyroid glands.
• They secrete the hormone, calcitonin, which is involved in regulating blood calcium concentrations.
Endocrine System of Birds
• The bursa of Fabricius is a sac that lies just dorsal to the cloaca.
• During the bird's embryological development it is well developed and it begins to shrink soon after hatching.
Endocrine System of Birds
• Its tissues produce secretions that are responsible for the maturation of white blood cells (B

physiological processes and adjust them to diurnal and seasonal cycles.
Pineal Gland
• In humans, decreased melatonin secretion may help trigger the onset of puberty.
• Melatonin is best known for the role it plays in regulating sleep patterns. Sleep patterns are also called circadian rhythms.
Pineal Gland
• If one has sleep disorder, it is the symptom that pineal gland is not producing the correct amount of melatonin.
• Some health providers believe that sleep can be improved by the use of detox.
• This activates the pineal gland to improve sleep and to open third eye**.130The** thyroid gland is
located in the neck, anterior to the trachea.
• Two of its secretions are
thyroxine and triiodothyronine, both of which influence overall growth, development, and metabolic rates.
• Another thyroid hormone, calcitonin, helps control extracellular levels of calcium ions.
Thyroid Gland
Thyroid Gland
cause the release mature ova from the ovary.
• LH also stimulates corpus
luteum, a temporary endocrine tissue in the ovaries.
• In response the ovaries secretes the female sex hormones, the estrogen and progesterone.
Hormones of Adenohypophysis Part I
• In the male, the LH, stimulates Leydig cells in testes that secrete the male hormone, the testosterone.
• FSH (Follicle Stimulating Hormone regulates the development, growth, pubertal maturation and reproductive processes of the body.
• LH and FSH are called gonadotropins.**131**
Several different disorders can arise when thyroid produces too much hormone (hyperthyroidism) or not enough (hypothyroidism)
• Goitre is associated with
thyroid when it is not functioning properly.
Thyroid Disorders
• Several different disorders can arise when thyroid produces too much hormone (hyperthyroidism) or not enough (hypothyroidism).
• Hyperthyroidism (overactive thyroid)
Hormones of Adenohypophysis Part II
• For example, it stimulates reproductive migrations in many mammals, such as elk and caribou.
• Prolactin also enhances mammary gland development and milk production in female mammals.**133** In mammals, two
adrenal glands rest on top of the kidneys.
• Each gland consists of two separate glandular tissues.
• The inner portion, the medulla, and the outer portion the cortex.
Adrenal Gland
Adrenal Gland
• The adrenal cortex secretes three classes of steroid hormones:
• 1. Glucocorticoids (cortisol),
• 2. Mineralocorticoids (aldosterone), and
• 3. Sex hormones (androgens, estrogens).
Adrenal Gland
• The glucocorticoids, such
as cortisol, help regulate overall metabolism and the concentration of blood sugar.
• They also function in defense responses to infection or tissue injury.
• Aldosterone helps maintain concentrations of solutes (Na +) in the extracellular fluid.
Adrenal Gland
lymphocytes), which play an important role in immunological reactions.**134** The pancreas is an elongated, fleshy organ posterior to the stomach.
• It functions both as an exocrine and endocrine gland.
• The endocrine portion of
the pancreas makes up only about 1% of the gland.
Pancreas
Pancreas
Pancreas
• This portion synthesizes,
stores, and secretes hormones from clusters of cells called pancreatic islets of Langerhans.
• The pancreas contains 200,000 to 2,000,000 pancreatic islets scattered throughout the gland. Each islet contains four special groups of cells, called alpha, beta, delta and F cells.
Pancreas
• The Alpha cells produce the hormone glucagon,
• Beta cells produce insulin.
• The delta cells secrete somatostatin, (the hypothalamic growth-hormone inhibiting factor) that also inhibits glucagon and insulin secretion.
Pancreas
• F-cells secrete a pancreatic polypeptide

• This helps promoting the
deposition of these ions into bone tissue when their concentrations rise.
• Once calcium returns to its homeostatic concentration, thyroid cells decrease their secretion of calcitonin.
Thyroid Gland
• Since the main purpose of thyroid hormone is to "run the body's metabolism," it is understandable that people with low thyroxine will have symptoms associated with a slow metabolism
135
In humans the testes occur as a pair of oval-shaped organs lodged in the out pocketing of the skin, the scrotum.
• Testes, also called testicles, in animals, the organ that produce sperms and male hormones, the androgens.
Testes
Testes
• The gonads (ovaries and
testes) secrete hormones that help regulate reproductive functions.
• In the male, the testes secrete testosterone, which acts with luteinizing and follicle-stimulating hormones.
• LH and FSH are produced
by adenohypophysis to occurs when thyroid gland produces too much of the hormone thyroxine.
Thyroid Disorders
• Hyperthyroidism can accelerate your body's metabolism, causing unintentional weight loss and a rapid or irregular heartbeat. nervousness, anxiety, rapid hand tremor.
• Goitre may occur may occure associated with a thyroid that is not functioning properly.
Thyroid Disorders
Thyroid Disorders
• Hypothyroidism:
• Its symptoms are
• Fatigue. Weakness. Weight gain or difficulty losing weight (despite reduced food intake) Coarse, dry hair and dry skin.**136**
The gonads (ovaries and testes) secrete hormones that help regulate reproductive functions.
• Four major classes of ovarian hormones help to regulate female reproductive functions.
• 1. Estrogens (estrin, estrone, and estradiol).
• 2. Progestins
• 3. Relaxin
• 4. Inhibin
Ovaries
Ovaries
• The estrogens help regulate the menstrual and estrus cycles and the development of the mammary glands and
• It plays a major role in maintaining the homeostasis of extracellular fluid.
• The sex hormones consist of male hormones called androgens(mainly dehydroepiandrosterone
)
• Lesser amounts of female
hormones called estrogens.
Adrenal Gland
• The adrenal medulla is under neural control.
• It contains neurosecretory cells secrete epinephrine (adrenaline) and norepinephrine (noradrenaline).
• Both of which help control heart rate and carbohydrate metabolism.
Adrenal Gland
• Brain centers and the hypothalamus govern the secretions via sympathetic nerves.
• During times of excitement, emergency, or stress, the adrenal medulla contributes to the overall mobilization of the body through the sympathetic nervous system.
Adrenal Gland
• In response to epinephrine and norepinephrine, the heart rate increases, blood flow increases to many vital organs.
that is released into the bloodstream after a meal and inhibits somatostatin secretion, gallbladder contraction, and the secretion of pancreatic digestive enzymes.
Pancreas
• When glucose concentrations in the blood are high, such as after a meal, beta cells secrete insulin.
• Insulin promotes the uptake of glucose by the body’s cells, including liver cells, where excess glucose can be converted to glycogen (a storage polysaccharide).
Pancreas
• Insulin and glucagon are
crucial to the regulation blood glucose concentrations.
• When the blood glucose
concentration is low, alpha cells secrete glucagon.
• Glucagon stimulates the
breakdown of glycogen into glucose, which is released into the blood to raise the blood glucose level.
Pancreas
Pancreas
• The figure shows the negative feedback system that regulates the secretion of glucagon and insulin and the maintenance of appropriate blood

stimulate
spermatogenesis.
Testes
Testes
• Testosterone is also necessary for the growth and maintenance of the male sex organs.
• Promotes the development and maintenance of sexual behavior.
• In humans, it stimulates the growth of facial and pubic hair,
Testes
• It also stimulates the enlargement of the larynx, which deepens the voice.
• The testes also produce inhibin, which inhibits the secretion of FSH.**139**
KIDNEYS
• Produce three hormones:
• 1. Erythropoietin
• 2. Urotensin and
• 3. Calcitrol
• Erythropoietin
• stimulates red blood cell
production, the target is bone marrow.
• Urotensin Stimulates constriction of the arteries.
Other Sources of Hormones
• Calcitrol aids in the absorption of dietary calcium and phosphorus from
small intestine.
• ADIPOSE TISSUE
• It produces the hormone leptin that other female secondary sexual characteristics.
• The progestins (primarily progesterone) also regulate the menstrual and estrus cycles, and the development of mammary glands.
Ovaries
• It also aid in placenta formation during pregnancy.
• Relaxin, which is produced in small quantities, softens the opening of the uterus (cervix) at the time of delivery.
• The ovaries also produce
inhibin, which inhibits the secretion of FSH.**140**
For smooth metabolic activity to proceed in an animal, the chemical environment of each cell must be maintained within fairly narrow limits (homeostasis).
• This is accomplished using negative feedback systems.
Summary of the Chapter Part I
• This involves integration, communication, and coordination.
• Specialized cells secrete messenger molecules.
• These chemical messengers can be categorized as
Summary of the Chapter Part I
• 1. Local chemical

• The airways in the lungs dilate, and more oxygen is delivered to all cells of the body.
Adrenal Gland
• This group of events is sometimes called the “fight-or flight” response and permits the body to react strongly and quickly to emergencies.**137**
The thymus gland is a small organ behind the breastbone (sternum) that plays an important function both in the immune system and endocrine system.
• It is only active until puberty.
• After puberty, the thymus starts to shrink slowly and become replaced by fat.
Thymus
• .
Thymus
• Tymus produces, the hormone thymosin.
• It stimulates the development of white blood cells, called
T- lymphocytes, which protect the body against infections.
• T-cells created by the thymus also help other organs in the immune system grow properly.
Thymus
• There are two types of T-
cells in your body:
• Helper T-cells and
• Killer T-cells.
• Killer T-cells do the

glucose concentrations.**138**
Placenta
• Digestive Tract
• Heart
• Kidneys and
• Adipose tissue are some
more major organs that produce hormones.
Other Sources of Hormones Part I
• PLACENTA:
• Produces estrogens, progesterone, human chorionic gonadotropin (hCG), human chorionic somatomammotropin (hCS.
• Maintain pregnancy.
• Target areas are the Ovaries, mammary glands and uterus.
Other Sources of Hormones Part I
• DIGESTIVE TRACT
• Produce Secretin, Gastrin
and Cholecystokinin (CCK).
• Secretin stimulates the release of pancreatic juice to neutralize stomach acid.
• Gastrin stimulates digestive enzymes and HCl in stomach.
Other Sources of Hormones Part I
• Cholecystokinin (CCK).
• It stimulates the release of pancreatic enzymes and bile from gallbladder.
• HEART
• Produces the hormone, Atriopeptin that lowers

suppresses appetite by targeting brain
141
Most of the chemicals functioning as hormones in invertebrate animals are neurosecretions called neuropeptides.
• Advanced invertebrates (e.g., molluscs, arthropods, echinoderms) have non neurosecretory hormones.
Summary of the Chapter Part II
• In all vertebrates there is a neuroendocrine control center.
• This center coordinates, communicates and integrate activities for the entire body.
• This center consists of the hypothalamus and pituitary gland. .
Summary of the Chapter Part II
• The vertebrate endocrine system consists of several major glands :
• Hypothalamus,
• Pituitary gland,
• Pineal gland,
• Thyroid gland,
• Parathyroid glands,
• Adrenal glands,
• Pancreas,
• Gonads, and
• Thymus.
Summary of the Chapter Part II
• In addition to these major glands, other glands and organs that messengers (lumones),
• 2. neurotransmitters (e.g., acetylcholine),
• 3. Neuropeptides,
• 4. Hormones and
• 5. Pheromones (e.g., sex attractant.
Summary of the Chapter Part I
• A hormone is a specialized chemical messenger that an endocrine gland or tissue produces.
• Hormones are usually steroids, amines, proteins, or fatty acid derivatives.
Summary of the Chapter Part I
• Negative feedback systems often regulate hormone secretion.
• Hormones modify the biochemical activity of a target cell or tissue.
• Mechanisms of hormone action are:
Summary of the Chapter Part I
• 1. the fixed-membrane receptor mechanism (water-soluble hormones).
• 2. the mobile receptor mechanism (steroid hormones)**143**
Protozoa are small, with high surface area-to-volume ratios.
• Plasma membrane and cytoplasm are the media through which materials such as gas, nutrients and wastes work of destroying the infected cells.
• The Helper T-cells coordinate the attack.**142**
Evolutionary Perspective:
• Unicellular animals have a large surface area to volume ratio.
• There is sufficient area available for the transport of substances which move into and out of the bodies.
• This transport in by different ways:
• Diffusion, Osmosis, Active transport .
Introduction of Transport System in Animals
• Thus there is no special transport system in unicellular animals.
• Same is true with simple aquatic multicellular animals. E.g. Hydra.
• On the contrary, multicellular animals possess well developed and well arranged transport system in the form of blood transport system.**144**
In flatworms, such as the planarian the gastrovascular cavity is more complex than that of Hydra.
• In planarian, branches penetrate to all parts of the body.
• The branched gastrovascular cavity runs close to all body cells.
blood pressure and maintains fluid balance.
• Streptokinase
Other Sources of Hormones Part I
• HEART
• Produces the hormone, Atriopeptin that lowers blood pressure and maintains fluid balance.
• This is in response to a rise in blood pressure, the heart releases two peptides:
Other Sources of Hormones Part I
• A-type Natriuretic Peptide (ANP) This hormone of 28 amino acids is released from stretched atria (hence the "A").
• B-type Natriuretic Peptide (BNP) This hormone (29 amino acids) is released from the ventricles.
Other Sources of Hormones Part I
• Streptokinase is a protein (but, despite its name, not an enzyme).
• Streptokinase is used to dissolve blood clots that have formed in the blood vessels.
• Because of its antigenic nature, streptokinase is quickly removed from circulation.**145**
Larger and complex animals in which surface area-to-volume ratio is very little, diffusion in ineffective to transport materials.
• Therefore, these

carry on hormonal activity include: • Placenta, • Digestive tract, • Heart, and • Kidneys • Mind-body link occurs through the hypothalamus. Summary of the Chapter Part II • Mental states strongly affect the function of many endocrine glands. • This mind-body link occurs through the hypothalamus. • Try to describe yourself, how thoughts are transformed into physiological responses? Summary of the Chapter Part II • Compared to enzymes and genes, hormones are remarkably small molecules.	diffuse to various parts of the organism, or between the organism and the environment. Transport System in Protozoa, Porifera & Cnidaria • Sponges circulate water from the external environment through their bodies, instead of circulating an internal fluid. • Cnidarians, such as Hydra, have a fluid-filled internal gastro vascular cavity. Transport System in Protozoa, Porifera & Cnidaria Transport System in Protozoa, Porifera & Cnidaria • This cavity supplies nutrients for all body cells lining the cavity, provides oxygen from the water in the cavity. • It is a reservoir for carbon dioxide and other wastes. • Simple body movement moves the fluid.	TS in Flatworms & Pseudocoel omates TS in Flatworms & Pseudocoel omates • Diffusion is effective for the transport of nutrients, gases, and wastes. • Body movement helps distribute materials to various parts of the body. TS in Flatworms & Pseudocoel omates • Pseudocoelomate invertebrates, such as rotifers, gastrotrichs, and nematodes, use the coelomic fluid of their body cavity for transport. • Coelomic fluids, are in direct contact with the internal organs and, produce adequate transport	animals have evolved systems in the form of circulatory system. Transport System and its Types Components of Transport System: 1. Circulatory Fluid(blood) 2. Pumping device (heart) 3. Vessels (arteries, veins, capillaries) Types of Circulatory System Open CS and Closed CS Transport System and its Types Open Circulatory System: • In this system the circulatory fluid, the hemolymph is pumped out in the body cavity and comes in direct contact with other body cells. E.g arthropods, mollusks etc. Closed Circulatory System: • Blood circulates in vessels. E.g. Annelis and vertebrtaes.
146 The annelids, such as the earthworm, have a closed circulatory system in which blood travels through vessels delivering nutrients to cells and removing wastes. • Most molluscs and arthropods have open circulatory systems TS in Annelids, Molluscs and Arthropods	**147** Some invertebrates e.g. annelids, echinoderms, use coelomic fluid as a sole circulatory or supplementary system. • Coelomic fluid may be identical in composition to interstitial fluids or may differ, particularly with respect to specific proteins and cells. Coelomic Fluid & Haemolymph in	**148** The coelomic fluid, hemolymph, or blood of most animals contains circulating cells called blood cells or hemocytes. • Some cells contain a respiratory pigment, such as hemoglobin, and are called erythrocytes or red blood cells. Blood Cells in Invertebrates	**149** All vertebrates have a closed circulatory system in which the blood never leaves the blood vessels. • Blood moves from the heart, through arteries, arterioles, capillaries, venules, veins, and back to the heart. • Exchange between the blood and extracellular fluid only occurs at the capillary level.

CS of earthworm
TS in Annelids, Molluscs and Arthropods
CS of a Mollusc
TS in Annelids, Molluscs and Arthropods
• In Insects heart pumps hemolymph through vessels that open into a body cavity (hemocoel).
• Hemolymph directly bathes the cells and tissues rather than being carried only in vessels.
150
Portal system is a system of blood vessels that carry blood from one bed of capillaries to the other bed of capillaries.
• Three portal systems are
common:
• 1. Hepatic portal system
• 2. Renal portal system
• 3. Hypophysial Portal System
Blood Portal Systems in Vertebrates
Blood Portal Systems in Vertebrates
Blood Portal Systems in Vertebrates
Blood Portal Systems in Vertebrates
• Hepatic Portal System
• Nutrients from the small
intestine and the right half of the colon are absorbed into blood through the bed of capillaries.
• This blood then moves to the liver through the

Invertebrates
• Coelomic fluid transports
gases, nutrients, and waste products.
• It also may function as a
hydrostatic skeleton in certain invertebrates such as in annelids.
• Hemolymph is the circulating fluid of animals with an open circulatory system.
Coelomic Fluid & Haemolymph in Invertebrates
• Most arthropods, ascidians, and many molluscs have hemolymph.
• In these animals, a heart
pumps hemolymph at low pressures through vessels to tissue spaces (hemocoel) and sinuses.
• Generally, the hemolymph volume is high and the circulation slow.
Coelomic Fluid & Haemolymph in Invertebrates
• Essential gases, nutrients, and wastes are transported by hemolymph.
• Many times, hemolymph
has non circulatory functions.
• For example, in insects, hemolymph pressure assists in molting of the old cuticle and in the movements of the wings.

• These cells are usually present in high numbers to facilitate oxygen transport.
• Cells that do not contain
respiratory pigments have other functions, such as blood clotting.
• The number and types of
blood cells vary dramatically in different invertebrates.
Blood Cells in Invertebrates
• For example, annelid blood contains hemocytes that are phagocytic.
• The coelomic fluid contains a variety of coelomocytes:
• 1. amoebocytes,
• 2. eleocytes,
• 3. lampocytes and
• 4. linocytes
Blood Cells in Invertebrates
• They all function in phagocytosis, glycogen storage, encapsulation, defense responses, and excretion.
• The hemolymph of molluscs has two general types of hemocytes:
• 1. Amoebocytes and
• 2. Granulocytes)
Blood Cells in Invertebrates
• Apart from the functions
already mentioned, they have another function called nacrezation (pearl formation) in some

Transport System in Vertebrates
Transport System in Vertebrates
Transport System in Vertebrates
• The heart is the center to
the circulatory system.
• It is fist-sized pump that circulates the blood throughout the body.
• As animals became more
multicellular & complex the circulatory system evolved because simple diffusion was insufficient to supply all of the cells with nutrients.
Transport System in Vertebrates
• The coordination of the circulatory system and the respiratory system to ensure proper gas exchange is very important in animals that have lungs and gills.**151** Renal Portal System
• The veins which carry blood to capillary system in kidneys constitute the renal portal system.
• The renal portal vein collects blood from all parts of the hind limbs and enters the kidney by number of branches from outer margin.
Blood Portal Systems in Vertebrates
• Inside the kidney these veins divide and redivide to form capillaries. These capillaries form 5 to 6

Hepatic Portal Vein to store and metabolize in liver. Blood Portal Systems in Vertebrates • From the liver the blood enters main blood stream via hepatic vein into the inferior vena cava to the heart.	Coelomic Fluid & Haemolymph in Invertebrates • In certain jumping spiders, hydrostatic pressure of the hemolymph provides a hydraulic mechanism for limb extension.	bivalves. • Natural Pearls form when an irritant - usually a parasite is coated by a fluid as a defense. Layer upon layer of this coating, called 'nacre', is deposited until a lustrous pearl is formed. Blood Cells in Invertebrates • Insect hemolymph contains large numbers of various hemocyte types that function in phagocytosis, encapsulation, and clotting.	renal veins on emerging from the kidneys and open into post caval vein. All these veins forms renal portal system. Blood Portal Systems in Vertebrates Blood Portal Systems in Vertebrates • Hypophysial System: • A portal system between the hypothalamus and the anterior pituitary gland.
152 Blood (circulatory fluid) • Blood is the medium in which the dissolved nutrients, gases, hormones and wastes are transported through the body. • Blood defends against harmful microorganisms, cells and viruses. Vertebrate Blood Vertebrate Blood • It also prevents blood loss through coagulation (clotting); and helps regulate body temperature and pH. Vertebrate Blood • It is a specialized type of connective liquid tissue which is composed of two main components: • 1. fluid matrix called plasma and • 2. formed elements- RBCs, WBCs and	**153** The Vertebrate Blood Cells or formed-element fraction consists of: • 1. Erythrocytes (red blood cells or RBCs), • 2. Leukocytes (white blood cells or WBCs • 3. Thrombocytes [Plate lets) Vertebrate Blood Cells Part I Human RBCs a. Salamander b. Snake c. Ostrich d. Red Kangroo e. Camel Vertebrate Blood Cells Part I Erythrocytes or RBCs • RBCs vary dramatically in size, shape, and number in the different vertebrates. • For example, the RBCs	**154** • White Blood Cells are scavengers that destroy microorganisms at infection sites, remove debris that results from dead or injured cells. • All WBCs are derived from immature cells (called stem cells) in bone marrow by a process called hematopoiesis. Vertebrate Blood Cells Part II Cellular Components of Vertebrate Blood. Vertebrate Blood Cells Part II b. Eosinophil; c. Basophil; d. Neutrophil (granulocytes) e. Monocytes; f. Lymphocyte (agranulocytes) Vertebrate Blood Cells Part II • RBCs can be grouped	**155** The bony fish heart has two chambers—the atrium and ventricle. • Blood leaves the heart via the ventral aorta, which goes to the gills. • In the gills, blood becomes oxygenated, loses carbon dioxide, and enters the dorsal aorta. Hearts & Circulatory Systems of Bony Fishes…. • The dorsal aorta distributes blood to all of the body organs, and then blood returns to the heart via the venous system. • Because blood only passes through the heart once, this system is called a single circulation circuit. Hearts & Circulatory Systems of Bony Fishes…. Hearts & Circulatory

Platelets.
Vertebrate Blood
• Plasma is straw-colored liquid.
• In mammals, plasma is composed of:
• 1. Water (about 90%)
• 2. A group of proteins (albumin, fibrinogen and globulins)-7%.
• 3. The remaining 3% of plasma is composed of:
Vertebrate Blood
• Electrolytes, amino acids,
glucose and other nutrients, various enzymes, hormones, metabolic wastes, and traces of many inorganic and organic molecules.
• Albumin represents about 60% of the total plasma proteins, it plays important roles with respect to water movement.
Vertebrate Blood
• Fibrinogen is necessary for blood coagulation (clotting), and the
• Globulins include the immunoglobulins, which functions in the immune response because it consists mostly of antibodies.
• Serum is plasma from which fibrinogens have been removed.**156**
In Birds and Mammals blood circulates in two main circuits:
• 1. Pulmonary and
• 2. Systemic circuits.
• The pulmonary circuit supplies blood only to of
most vertebrates are nucleated, but mammalian RBCs are enucleate.
• Among all vertebrates, the salamander, Amphiuma has the largest RBC.
Vertebrate Blood Cells Part I
• Among birds, the ostrich
has the largest RBC.
• Most mammalian RBCs are biconcave disks however, the camel and llama have elliptical RBCs.
Vertebrate Blood Cells Part I
• 95% of mass of a RBC is hemoglobin, an iron-containing oxygen carrying protein.
• The remaining 5% consists of enzymes, salts and other proteins.
• The major function of hemoglobin is to transport oxygen in the form of oxyhemoglobin, from the environment to body tissues.
Vertebrate Blood Cells Part I
• Hemoglobin also carries waste carbon dioxide (in the form of carbaminohemoglobin) from the tissues to the lungs (or gills) for removal from the body.**158**
The lymphatic system is part of the vascular system.

into two main types:
• 1. Granulocytes
• 2. Agranulocytes
• Granulocytes have granules in their cytoplasm and they include:
• Neutrophils
• Eosinophils
• Basophils
Vertebrate Blood Cells Part II
• Eosinophils are phagocytic, and ingest foreign proteins and immune complexes rather than bacteria.
• In mammals, eosinophils
also release chemicals that counteract the effects of certain inflammatory chemicals released during allergic reactions.
Vertebrate Blood Cells Part II
• Basophils are the least numerous WBC. When they react with a foreign substance, their granules release histamine and heparin.
• Histamine causes blood vessels to dilate and leak fluid at a site of inflammation, and heparin prevents blood clotting.
Vertebrate Blood Cells Part II
• Neutrophils are the most
numerous of the white blood cells.
• They are chemically attracted to sites of

Systems of Bony Fishes….
• In amphibians, a single ventricle pumps blood both to the lungs and to the rest of the body.
• However, because most amphibians absorb more oxygen through their skin than through their lungs or gills, blood returning from the skin also contributes oxygenated blood to the ventricle.
Hearts & Circulatory Systems of Bony Fishes….
• The blood pumped out to the rest of the body is thus highly oxygenated.
Hearts & Circulatory Systems of Bony Fishes….
Hearts & Circulatory Systems of Bony Fishes….
• In the heart of most reptiles, the ventricle is partially divided into a right and left side.
• Oxygenated blood from the lungs returns to the left side of the heart via the pulmonary vein and does not mix much with deoxygenated blood in the right side of the heart.
Hearts & Circulatory Systems of Bony Fishes….
• When the ventricles contract, blood is pumped out two aortae for distribution throughout the body, as well as to the lungs.
• The incomplete separation of the ventricles is an important adaptation for reptiles,

the lungs. • It carries deoxygenated blood from the heart to the lungs, where carbon dioxide is removed, and oxygen is added. Hearts & Circulatory Systems of Birds & Mammals • It then returns the oxygenated blood to the heart for distribution to the rest of the body. • The systemic circuit supplies all the cells, tissues, and organs of the body with oxygen-rich blood and returns oxygen-poor blood to the heart.**157** In bony fishes, the heart's two chambers (atrium, ventricle) pump in series. Respiratory and systemic circulations are not separate. Evolutionary Perspective of Vertebrate Hearts • The amphibian heart has two atria and one ventricle. Blood from the lungs enters the left atrium, and blood from the body enters the right atrium. • The blood from both atria empties into one ventricle, which then pumps it into the respiratory and systemic circulations. Evolutionary Perspective of Vertebrate Hearts • Most reptiles exhibit a greater degree of	• The system begins with network of lymphatic vessels that carry a clear fluid called lymph. • The small lymphatic capillaries merge to form larger lymphatic vessels called lymphatics. Lymphatics are thin- walled vessels with valves that ensure the one-way flow of lymph. • Lymph is the extracellular fluid that seeps from the bloodstream and accumulates in the lymph vessels. • Vertebrate Lymphatic System • The lymphatic vessels pass through the lymph nodes on their way back to the heart. • Lymph nodes concentrate in several areas of the body and act as disposal centers for foreign particles and cellular debris. • They play an important role in the body's defense against disease. Vertebrate Lymphatic System • The system also help transport lipids that have been absorbed from the small intestine. • In addition to the lymph nodes, the mammalian lymphatic system consists of lymphoid organs—the spleen the thymus gland, tonsils,	inflammation and are active phagocytes. Vertebrate Blood Cells Part II • Agranulocytes have clear cytoplasm. These include: • 1. Monocytes and • 2. Lymphocytes. • Monocytes give rise to macrophages which destroy larger particles by phagocytosis. • Lymphocytes are of types of two types: B cells and T cells, both of which are central to the immune response. Vertebrate Blood Cells Part II • B cells originate in the bone marrow and colonize the lymphoid tissue, where they mature. • T cells are associated with and influenced by the thymus gland before they colonize lymphoid tissue and play their role in the immune response. Vertebrate Blood Cells Part II • Platelets (Thrombocytes) are disk-shaped cell fragments that initiate blood clotting. • When a blood vessel is injured, platelets immediately move to the site and clump, attaching themselves to the damaged area, and thereby beginning the process of blood	such as turtles Hearts & Circulatory Systems of Bony Fishes…. • Because it allows blood to be diverted away from the pulmonary circulation during diving and when the turtle is withdrawn into its shell. • This conserves energy and diverts blood to vital organs during the time when the lungs cannot be ventilated**159** Lymph is colorless fluid where as • Blood is colored fluid. • Lymph is the part of lymphatic system whereas Blood is the part of Blood circulatory system. • Lymph helps in the body's defence as it is the part of immune system. Where as,blood is associated with circulation of O 2, CO 2 Difference Between Blood and Lymph • Blood has RBCs, WBCs, platelets and fluid called plasma. • Where as lymph has WBCs and watery fluid, both have immune and circulatory functions in them. Difference Between Blood and Lymph • substances like hormones waste products, products of digestion etc. • Lymph contains plasma and a lesser number WBCs and platelets,

anatomical division of the ventricle into two halves. Evolutionary Perspective of Vertebrate Hearts • In crocodilians, birds, and mammals, the ventricle is completely divided, forming a four-chambered heart. • Blood flow through the lungs completely separated from the flow to other tissues.	and adenoids. • In birds the bursa of Fabricius is an additional lymphoid tissue. Vertebrate Lymphatic System • The system also help transport lipids that have been absorbed from the small intestine. • In addition to the previously mentioned parts, the lymphatic system of birds and mammals consists of lymphoid organs—the spleen and or the thymus gland, tonsils, and adenoids in mammals	coagulation.	whereas blood containsplasma, RBCs, WBCs and Platelets. • Lymph contains low amount of O2, blood carries large ampount of O2. Difference Between Blood and Lymph • Lymph lacks protein, whereas blood plasma has Ca +2 & PO 4 -3. • Flow of lymph is slow where flow of blood is fast. • Lymph clots slowly as less fibrinogen is present, where as blood clots quickly as high high amount of fibrinogen is present.
<u>160</u> The human heart is a hard-working pump located in the chest cavity. • Heart is enclosed in double membrane sac called pericardium. • Space between these membranes is filled up with pericardial fluid. • The wall of the heart is composed of three layers: Structure of Human Heart Structure of Human Heart • Epicardium(Connective .tissue) • Myocardium (cardiac muscles)and • Endocardium (single layer of cells). • The heart has four chambers: 2 atria and 2	**<u>161</u>** Adult human heart beats or pumps 72 times a minute. • In the beating of the heart the atria contract simultaneously and ventricles immediately after words. • The deoxygenated blood from the lower and upper part of the body is brought into the right atrium. Pumping Action of Human Heart Pumping Action of Human Heart • From the right atrium it is driven by atrial contraction into the right ventricle. • At the same time the oxygenated blood brought by the	**<u>162</u>** The alternate contraction and relaxation of the heart chambers is called Cardiac Cycle. • The contraction phase of the cycle is called Systole and the relaxation phase is called Diastole. • Average heart beat of human when at rest is 72 beats a minute. The Cardiac Cycle The Cardiac Cycle • One cardiac cycle take about 0.8 sec. • Heart beat can be differentiated into three phases. • 1. Relaxation Phase: This phase is also called atrial and ventricular diastole. • During this phase the	**<u>163</u>** Cardiac cycle is the sequence of muscle contractions and relaxations. • A “pacemaker,’’ is a small mass of tissue called the sin atrial node (SA node) at the entrance to the right atrium, initiates each heartbeat. Electrical Conduction System of Human Heart • The SA node initiates the cardiac cycle by producing an action potential that spreads over both atria, causing them to contract simultaneously. • The action potential then passes to the atrioventricular node (AV node), near the inter atrial septum.

ventricles) • The 2 atria are separated by Inter atrial septum. Structure of Human Heart • The two ventricle are separated by Inter ventricular septum. • The two atria communicate with the ventricles through atrioventricular apertures. • On the right side the apertures is provided with Tricuspid valve. • On the left side it is bicuspid valve. Structure of Human Heart • The flaps of the valves are connected to the papillary muscles by means of chordae tendenae. • The right atrium receives the inferior and superior vena cavae opening separately. • The left atrium receives pulmonary veins, 2 from each lung. Structure of Human Heart • From the right ventricle arises the pulmonary artery and from the left ventricle, the Aorta. • At the point of origins of aorta and pulmonary artery there are valves called semilunar valves. **164** ECG is the record of electrical activity or action potential over	pulmonary veins from the lungs into the left atrium and then driven into left ventricle. Pumping Action of Human Heart • On the contraction of the ventricles the blood from the right ventricle is taken to the lungs by the pulmonary artery. • The valves open and close due to blood pressure changes when the heart contracts during each heartbeat. Pumping Action of Human Heart • Like the valves in veins, heart valves keep blood moving in one direction, preventing backflow.**166** Leukemia • It is the result of uncontrolled production of WBCs. • It is caused by a mutation in the cells of bone marrow called myelogenous cells. • These cell without completing the cell cycle, spread to other parts of the body by blood stream. Some Cardiovascular Disorders • This process is called metastasis. • The undifferentiated cells are defective and produced at a faster that normal rate. • It is a serious disorder. The patient needs regular change of blood.	walls of the atria and ventricle relax, The Cardiac Cycle • The deoxygenated blood enters the right atrium through the vena cava and at the same time the oxygenated blood enters the Left atrium through the pulmonary vein. • As the atria are filled up with blood, they have more pressure than the ventricles. The Cardiac Cycle • 2. Atrial Systole and Ventricular Diastole: This phase lasts 0.1 sec. During this phase atria contract simultaneously forcing all the blood out of atria into the relaxed ventricles. • 3. Atrial diastole and ventricular systole : This phase lasts 0.3 sec. During this phase of the cycle both the ventricles contract simultaneously The Cardiac Cycle • pumping the blood to pulmonary arteries and aorta. • This follow the first phase, the relaxation phase, again which lasts 0.4 sec. • This completes the cardiac cycle extending over 0.8 sec. • The heart of an average adult beats more than 100,000 times without Fatiguing.**167** Food is the rich source of chemical energy.	Electrical Conduction System of Human Heart Electrical Conduction System of Human Heart • From here, the action potential continues through the atrio ventricular bundle (bundle of His), at the tip of the inter ventricular septum. • The atrioventricular bundle divides into right and left branches, which are continuous with the Purkinje fibers in the ventricular walls. Electrical Conduction System of Human Heart • Stimulation of these fibers causes the ventricles to contract almost simultaneously and eject blood into the pulmonary and systemic circulations.**168** Properties of Respiratory surfaces in animals: • 1. Large surface area • 2. Moist • 3. Thin epithelium • 4. Ventilation • 5. Capillary network Invertebrate Respiratory Systems Part I • In protozoa, gaseous exchange take place by diffusion across the plasma membrane • Some multicellular invertebrates e.g. Hydra gases diffuse into and out of the animal cells through the entire inner and outer surfaces, which are in contact

the surface of the heart as waves called P,Q,R,S and T. currents
• The electrical activity is produced when impulses travel through cardiac muscles during the heart cycle.
Electrocardiogram EKG or ECG
• The electrical activity thus produced in the form of electrical current through body fluids to the body surface.
• These currents can be detected by electrodes placed on the skin and recorded as waves-P,Q,R,S and T.
Electrocardiogram EKG or ECG
• ECG gives important information concerning the spread of excitation to different parts of the heart.
• ECG is of great value in the diagnosis of cases of abnormal cardiac rhythm and myocardial damage.
• EGC is recoded by a device called elctrocariograph.**169**
Crustaceans and molluscs have gills that are compact and protected with hard covering devices.
• Such gills divide into highly branched structures to maximize the area for gas exchange.
Invertebrate Respiratory
• It can be cured by bone marrow transplant.
Some Cardiovascular Disorders
• Thalassemia It is hereditary anemia produced by defective production of of alpha or beta Hb polypeptide chain.
• Thalassemia is characterized by fatigue, severe anemia, enlargement of heart and jaundice.
• It can be treated by bone
marrow transplant.
Some Cardiovascular Disorders
• Myocardial Infarction commonly called heart attack.
• Occurs when blood flow
decreases or stops to a part of the heart, causing damage to the heart muscle.
• The most common symptom is chest pain or discomfort which may travel into the shoulder, arm, back, neck or jaw.**170**
There are two models of breathing in vertebrates:
• 1. Bimodal breathing
2.Trimodal breathing
• Bimodal breathing is the
ability of an organism to exchange respiratory gases simultaneously with both air and water. e.g., some salamanders,
• How do animals utilize this chemical energy into useable form?
• First, they must digest the organic matter so that it can enter the cells.
• Second, they must provide cells with an adequate supply of oxygen.
Gas exchange: Respiratory Surfaces
• This is required for aerobic respiration and a way of eliminating the carbon dioxide that aerobic respiration produces.
• This process of gas exchange with the environment, also called external respiration or breathing is the subject of the rest of this chapter.
Gas exchange: Respiratory Surfaces
• Respiratory Surfaces: Protists and animals have five main types of respiratory systems (surfaces):
• 1. Simple diffusion across plasma membranes,
• 2. Tracheae
• 3. Skin or cutaneous (integument or body surface) exchange,
Gas exchange: Respiratory Surfaces
• 4. Gills and
• 5. lungs.
• Each of these surfaces will be discussed in the next modules.**171**
with water.
Invertebrate Respiratory Systems Part I
Amoeba
Sea anemone
Planarian
Invertebrate Respiratory Systems Part I
• In flat worms e.g. Planarian, body is thin-walled. Again, gases diffuse into and out of the
animal.
• In earthworms that live in moist environments use integumentary exchange.
• Earthworms have capillary networks just under their integument, and they exchange gases with the air.
Invertebrate Respiratory Systems Part I
• Some annelid worms e.g. Nereis have prominent lateral projections called parapodia that are richly supplied with blood vessels and function as gills.**172**
Gills are respiratory organs that have thin, moist epidermis over highly vascularized dermis for gaseous exchange.
• Larval forms of a few fishes and amphibians have external gills projecting from their bodies.
• Adult fishes have internal
gills covered with

Systems Part II • Some terrestrial invertebrates (e.g., insects, centipedes and some mites, ticks, and spiders) have tracheal systems consisting of highly branched chitin-lined tubes called tracheae. Invertebrate Respiratory Systems Part II • Tracheae open to the outside of the body through spiracles, which usually have some kind of closure device to prevent excessive water loss. • Spiracles lead to branching tracheal trunks that eventually give rise to smaller branches called tracheoles, whose blind ends lie close to all cells of the body. Invertebrate Respiratory Systems Part II Invertebrate Respiratory Systems Part II • Most insects have ventilating mechanisms that move air into and out of the trachea. • For example, contracting flight muscles of insects alternately compress and expand the large tracheal trunks and thereby ventilate the tracheae. Invertebrate Respiratory Systems Part II • Arachnids possess tracheae, book lungs, or both.	crabs, barnacles, bivalve molluscs, and lung fishes. Vertebrate Respiratory Systems • These animals use gills for water breathing and lungs for air breathing. • Trimodal Breathing is the ability of an organism to exchange respiratory gases through three surfaces i.e. skin, gills, and lungs. Vertebrate Respiratory Systems • Bimodal breathing was an important respiratory adaptation with evolutionary transition between aquatic and terrestrial habitats. • Fundamental changes in the structure and function of the respiratory organs accompanied the transition from water to air breathing. Vertebrate Respiratory Systems • In terrestrial vertebrates i.e. reptiles, birds, and mammals, gills were replaced with lungs. • Cutaneous, gills and lungs are the three vertebrate respiratory surfaces which will be discussed in upcoming modules.**175** Human respiratory system includes: 1. Air conducting portion	• Cutaneous Respiration: It is the exchange of gases through skin. • Cutaneous exchange is most highly developed in frogs, toads, lungless salamanders and newts • Some more vertebrates such as some aquatic turtles, salamanders with lungs, snakes, fishes, and mammals (Bat). Cutaneous Respiration Salamander Newt Cutaneous Respiration • These animals have lungs or gills, use cutaneous respiration to supplement gas exchange. • Amphibian skin has the simplest structure of all the major vertebrate respiratory organs. • In frogs, a uniform capillary network lies in a plane directly beneath the epidermis. Cutaneous Respiration • This vascular arrangement facilitates gas exchange between the capillary bed and the environment by both diffusion and convection. • A slimy mucous layer that keeps amphibian skin moist and protects against injury and helps in gas exchange. Cutaneous Respiration • Some amphibians obtain about 25% or more of their oxygen by	operculum. Gill Respiration • Below the operculum there are four gill arches, and each arch consists of many filaments. • A filament houses capillaries within lamellae where the direction of water flow opposes that of blood flow. Gill Respiration • This counter current flow allows the fish to extract the maximal amount of oxygen from the water.**173** Amphibian Respiration • As the tadpole grows, the gills disappear and lungs grow. • Amphibian lungs are simple saclike structures. • Internally lungs lack the complex spongy appearance unlike the lungs of birds and mammals. Lung Respiration in Amphibians and Reptiles Amphibian lungs Lung Respiration in Amphibians and Reptiles • Adult amphibians lack or have a reduced diaphragm, so breathing through the lungs is forced. • The lungs of most amphibians receive a large proportion of the total blood flow from the heart. Lung Respiration in

• Book lungs are paired invaginations of the ventral body wall that are folded into a series of leaf-like lamellae.
• The Pulmonate Lung. The mantle cavity of the pulmonate snail, Lymnaea, is highly vascularized and functions as a lung.**174**
Respiration in birds is complex and efficient.
• It consists of lungs , 5-6 pairs of air sacs and air passages.
• Trachea divides into right and left bronchi
• Bird lungs have tunnel-like passages called parabronchi, which lead to air capillaries in which gas exchange occurs.
Respiration in Birds
• The end of each bronchus divides into small branches leading into air sacs.
• These sacs are collapsible, and open and close as a result of muscle contractions around them.
• The arrangement of air sacs make one-way flow possible.
Respiration in Birds
Respiration in Birds
• Mechanism of Breathing
• Inhaled air bypasses the lungs and enters the abdominal (posterior) air sacs.
• It then passes through the lungs into the

2. Gas exchange portion.
• Air Conducting portion are the air passage ways that consist of nostrils, nasal cavities, pharynx, larynx, trachea, bronchi, bronchioles and alveolar ducts which ultimately leads into the alveolar sacs.
Human Respiratory System Part I
Human Respiratory System Part I
• As air enters through nostrils up to alveoli, air is filtered, moistened and conditioned.
• In the pharynx the traffic of air and food is kept properly channeled by flap called epiglottis.
• Alveoli are single layered endothelial walls.
Human Respiratory System Part I
Human Respiratory System Part I
Human Respiratory System Part I
• Overlying the alveoli there is rich network of blood capillaries providing site for gaseous exchange.
• The air passage ways are kept from collapsing by cartilage C-shaped rings in trachea and complete rings in bronchi.
Human Respiratory System Part I
• The rings are progressively replaced

this exchange, and the lungless salamanders carry out all of their gas exchange through the skin and buccal-pharyngeal region.**176**
Gas Exchange Portion of the Respiratory system: The Lungs
• Lungs are spongy closed sacs present in the chest cavity.
• They are composed of millions of alveoli, a great amount of connective tissue and some muscles.
Human Respiratory System Part II
• Lungs are covered by a thin layer of tough epithelium called visceral pleura.
• A similar layer, parietal pleura lines the inner surface of the wall of the chest.
• The cavity between these layers is called pleural cavity. • The chest cavity is bounded by spine, ribs and sternum.
• The sides and floor are the intercostal muscles and muscular diaphragm. • Alveoli are the functional units of the lungs (gas exchange portion). Passive diffusion, driven by a partial pressure gradient, moves oxygen from the alveoli into the blood and moves carbon dioxide from the

Amphibians and Reptiles
Lung Respiration in Amphibians and Reptiles
• Even though the amphibian ventricle is undivided, there is surprisingly little mixture of blood from the left and right atrial chambers within the single ventricle.
• As a result, the lungs are perfused primarily with deoxygenated blood from the systemic tissues.
Lung Respiration in Amphibians and Reptiles
Amphibian Reptilian Birds
Lungs of
Lung Respiration in Amphibians and Reptiles
• All reptiles breathe using lungs.
• Aquatic turtles have developed more permeable skin, and some species have modified their cloaca to increase the area for gas exchange.
• Because of this constraint, most Lizards and snakes are forced to hold their breath during intense runs.
Lung Respiration in Amphibians and Reptiles
• In these reptiles the lungs are ventilated almost exclusively by the muscles of the chest wall.
• Crocodiles and

thoracic (anterior) air sacs.
• Finally, air is exhaled from the thoracic air sacs. This whole process requires two complete breathing cycles.
Respiration in Birds
• Mechanism of Breathing
• Inspiration and expiration result from alternate expansion and compression of the air sacs.
• Inhaled air bypasses the lungs and enters the abdominal (posterior) air sacs.
Respiration in Birds
• It then moves to the thoracic (anterior) air sacs after passing through the lungs.
• Finally, air is exhaled from the thoracic air sacs.
• This whole process requires two complete breathing cycles.
• Two cycles are required for the air to pass all the way through the system and out of the bird.**178**
A breathing control center in the medulla sets the basic rhythm, of inhalations and exhalations.
• Nerves from the medulla's control center send impulses to the breathing muscles- diaphragm and rib muscles.
The Control of Breathing
• A person when at rest, these nerve impulses

by irregular cartilage plates.
• The bronchioles totally lack cartilage but made of mainly circular smooth muscles.
179
As we know that oxygen must be transported from the environment to each and every cell of an animal’s body.
• Various systems (e.g., tracheae, cutaneous exchange, gills, lungs) help accomplish this transport.
Transport of Respiratory Gas Oxygen
• As animals became larger and acquired higher metabolic rates, simple diffusion became increasingly inadequate as a means of delivering oxygen to the tissues
• In general, more active animals have an increased demand for oxygen.
Transport of Respiratory Gas Oxygen
• Water-based body fluid does not guarantee internal transport of sufficient oxygen to meet this increased demand.
• The reason is the low solubility of oxygen in water-based body fluids.
• Thus, fluid-borne respiratory pigments reversibly binding large quantities of oxygen evolved in most phyla.
Transport of Respiratory

blood into the alveoli.**177**
Ventilation or Breathing has two phases:
• 1. inhalation, the intake of air; and
• 2. exhalation, the outflow of air.
• These air movements result from the rhythmic increases and decreases in thoracic cavity volume.
Ventilation of Human Lungs
• Changes in thoracic volume lead to reversals in the pressure gradients between the lungs and the atmosphere; gases in the respiratory system follow these gradients.
• The mechanism of inhalation operates in the following way:
Ventilation of Human Lungs
• Several sets of muscles, the main ones being the diaphragm and intercostal muscles, contract.
• 1.The intercostal muscles stretch from rib to rib, and when they contract, they pull the ribs closer together, enlarging the thoracic cavity.
Ventilation of Human Lungs
• 2. The thoracic cavity further enlarges when the diaphragm contracts and flattens.
• 3. The increased size of the thoracic cavity causes

alligators
have a large sheet of muscle below the lungs, called a diaphragm, that controls their breathing.**180**
Hemoglobin: is a reddish pigment that contains iron as the oxygen-binding metal.
• It is the most common respiratory pigment in animals, being found in a variety of invertebrates (e.g., platyhelminths, nemerteans, nematodes, annelids, crustaceans, some insects, and molluscs
Respiratory Pigments Part I
• All vertebrates with the exception of a few fishes.
• Icefish (Channichthyidae) are the only known vertebrates that lack hemoglobin in their blood.
• This wide distribution suggests that hemoglobin evolved very early in the history of animal life.
Respiratory Pigments Part I
• Hemoglobin may be carried within red blood cells (erythrocytes or simply dissolved in the blood or coelomic fluid.
• Hb + O 2 = HbO 2 under (Under high O 2 concentration) in lungs
• HbO 2 = Hb + O 2

result in about 10 to 14 inhalations per minute.
• Between two inhalations
the muscles relax and the person exhales.
• Sensors in the medulla detect changes in the pH of the blood and cerebrospinal fluid bathing the surface of the brain.
The Control of Breathing
• sensors in major blood vessels detect changes in blood pH and send nerve impulses to the medulla.
• In response, the medulla's control center alters the rate and depth of breathing, increasing both if CO_2 levels rise or decreasing both if CO_2 levels fall.
The Control of Breathing
• Other sensors in the aorta and carotid arteries signal the medulla to increase the breathing rate when O~ levels in the blood become very low.**182**
Carbon dioxide produced within the respiring cells diffuse into blood, then transported to lungs from where exhaled.
• CO_2 is transported in the
following three states:
• 1. as carboxyhemoglobin (about 20% of CO_2) combines with amino group of Hb.
• 2. CO_2 as such (5%)

Gas Oxygen
• Four most common respiratory pigments are:
1. Hemoglobin,
2. Hemocyanin,
3. Hemerythrin, and
4. Chlorocruorin.**181**
Hemocyanin is the most commonly occurring respiratory pigment in molluscs and certain crustaceans.
• Hemocyanin contains metallic copper, has a bluish color when oxygenated, and always occurs dissolved in hemolymph.
Respiratory Pigments Part I
• Unlike most hemoglobin, hemocyanin tends to release oxygen easily and to provide a ready source of oxygen to the tissues.
Respiratory Pigments Part I
• Hemerythrin contains iron and is pink when oxygenated.
• It is in nucleated cells, rather than free in body fluids or hemolymph.
• A few brachiopods and some polychaetes have hemerythrin.
Respiratory Pigments Part I
• Chlorocruorin also contains iron but is green when associated with low oxygen concentrations and bright red when associated with high oxygen concentrations.
• Chlorocruorin occurs in

pressure in the cavity to drop below the atmospheric pressure.
• Air rushes into the lungs,
and the lungs inflate.
Ventilation of Human Lungs
• During expiration or exhalation, air is expelled from the lungs in the following way:
• 1. The intercostal muscles and the diaphragm relax, allowing the thoracic cavity to return to its original, smaller size and increasing the pressure in the thoracic cavity.
Ventilation of Human Lungs
• 2. Abdominal muscles contract, pushing the abdominal organs against the diaphragm, further increasing the pressure within the thoracic cavity.
• 3. The action in step 2 causes the elastic lungs to contract and compress the air in the alveoli
Ventilation of Human Lungs
• With this compression, alveolar pressure becomes greater than atmospheric pressure, causing air to be expelled (exhaled) from the lungs.**184** Animals that respire aerobically need a constant supply of

• (Under high O_2 concentration)
• in tissues
Respiratory Pigments Part I
• Factor that affect oxygen
combining capacity of Hb:
1. Carbon Dioxide
2. Temperature
3. pH of blood
• 1% CO in blood cause death.
• Hb conc. increases at high altitudes.
• Human fetuses have high
conc. of Hb.**185** Animals are constantly
under attack by infectious
agents that cause disease.
• For a pathogen, an animal
body is a nearly ideal habitat.
• The host offers a ready source of nutrients, a protected setting for growth and reproduction.
• Hosts also provide means
of transport to new hosts and environments.
Introduction of Immune System
• Having this opportunity, pathogens, mostly viruses, bacteria, protists, and fungi, infect a wide range of animals, including humans.
• If not eliminated they may deal with abnormal

• 3. As bicarbonates (75%)
Transport of Respiratory Gas CO_2
• Bicarbonates are formed
from CO_2 and H_2O in the
tissues by the following reaction and Process.
• Reaction in Tissues: CO_2
and H_2O combine to form
Carbonic acid.
• This reaction is catalyzed
by carbonic anhydrase present in RBCs.
• Carbonic acid then ionizes
into HCO_3^- and H^+
Transport of Respiratory Gas CO_2
• Most of CO_2 is transported as HCO_3 ions from the tissues to the lungs.
• Reactions in Lung Capillaries:
• $HCO_3 + H^+ = H_2CO_3$
• H_2CO_3------------H_2O+CO_2
• CO_2 thus formed passes
out of the capillaries into the alveoli from where it is exhaled.**189**The lymphatic system
clears away infection and keeps body fluids in balance.
• Adenoids are a patch of tissue that is high up in the throat.
• They, along with the tonsils, are part of the several families of polychaete worms.**183** Any system that supplies the body tissues with oxygen, nutrients, hormones, and removes waste products is called transport system or circulatory system.
• The two basic types of circulatory systems are open and closed. Open systems generally circulate hemolymph, and closed systems circulate blood.
Summary of the Chapter Part I
• Blood is a type of connective tissue made up of blood cells (red blood cells and white blood cells), plasma, and platelets.
• he heart pumps blood through a series of vessels in the following order: arteries, arterioles, capillaries, venules, veins, and back to the heart .
Summary of the Chapter Part I
• The action of the heart consists of cyclic contraction (systole) and relaxation (diastole). Systolic contraction generates blood pressure that forces blood through the closed system of vessels.
• The lymphatic system consists of one-way vessels that help return fluids and proteins to the circulatory system**190**
The thymus is a oxygen.
• The process of acquiring
oxygen and eliminating carbon dioxide is called external respiration
• The exchange of oxygen and carbon dioxide occurs across respiratory surfaces.
Summary of the Chapter Part II
• Such surfaces include gills, cutaneous surfaces, and lungs.
• The air-conducting portion of the respiratory system of air-breathing vertebrates moves air into
(inhalation) and out of (exhalation) this system. This process of air movement is called ventilation.
Summary of the Chapter Part II
• Oxygen and carbon dioxide diffuse from areas
of higher concentration to areas of lower concentration.
• Once in the blood, oxygen diffuses into red blood cells and binds to hemoglobin for transport to the tissues.
Summary of the Chapter Part II
• Carbon dioxide is transported bound to hemoglobin, as well as in the form of the bicarbonate ion and carbonic acid.
• Respiratory pigments cells and develop into cancer.
• To counter these threats
animals have evolved defense systems.
Introduction of Immune System
• Additional responses to infection take many forms, including proteins that punch holes in bacterial membranes or block viruses from entering body cells.
• These and other defenses
make up an immune system, which enables an animal to avoid or limit many
infections.**186**Phagocytic White Cells:
• Nonspecific internal defense mechanism depends mainly on Phagocytosis.
• It is the ingestion of invading particles by certain types of WBCs
• These phagocytic WBCs are the neutrophils (65%) and monocytes (5%).
• Monocytes soon enlarge
and become macrophages.
Nonspecific Defense Mechanism Part II
• Neutrophils are attracted
by chemotaxis in he infected tissue.
• Both these WBCs phagocytose the microbes like amoeba.
• Eosinophils have

lymphatic system.
• The adenoids and tonsils
work by trapping germs coming in through the mouth and nose .
Organs of Immune System
Organs of Immune System
• Lymph nodes, are small,
bean-shaped, soft nodules of tissue.
• There are several groups
of lymph nodes in the body.
• Swollen lymph nodes may signal an infectionThe thymus is a specialized primary lymphoid organ of the immune system.
• Within the thymus, T-lymphocytes or T cells, mature.
• T cells are extremely important type of white blood cell.
• It plays an important function both in the immune system and endocrine system.
Organs of Immune System
• The spleen plays multiple roles in the body.
• It acts as a filter for blood
as part of the immune system.
• Old RBCs are recycled in the spleen and platelets and WBCs are stored there.

specialized primary lymphoid organ of the immune system.
• Within the thymus, T-lymphocytes or T cells, mature.
• T cells are extremely important type of white blood cell.
• It plays an important function both in the immune system and endocrine system.
Organs of Immune System Part II
• The spleen plays multiple roles in the body.
• It acts as a filter for blood
as part of the immune system.
• Old RBCs are recycled in the spleen and platelets and WBCs are stored there.
• The spleen also helps fight certain kinds of bacteria that cause pneumonia and meningitis.
Organs of Immune System Part II
• Peyer's patches are small
masses of lymphatic tissue found throughout the ileum region of the small intestine.
• They form an important part of the immune system and prevent the growth of pathogenic bacteria in the intestines.
Organs of Immune System Part II
• Appendix

are
organic compounds that have either metallic copper or iron that binds oxygen.
Summary of the Chapter Part II
• Examples include hemoglobin, hemocyanin, hemerythrin, and chlorocruorin.**191**
Lymphocyte is a type of white blood cell (leukocyte) that is of fundamental importance in the immune system.
• Lymphocytes are the cells that determine the specificity of the immune response to pathgens and other foreign substances.
Specific Defense Mechanism (Immune System)
• There are three main types of lymphocytes:
• 1. T cells,
• 2. B cells, and
• 3. Natural killer cells.
• A T cell is a type of lymphocyte which mature in the thymus .
• T cells are different from
other lymphocytes by the presence of a T-cell receptor on the cell surface.
Specific Defense Mechanism (Immune System)
• B cells are responsible for generating antibodies to specific antigens, which they

limited
phagocytic activity but contain destructive enzymes to kill the invaders.
Nonspecific Defense Mechanism Part II
• Antimicrobial Proteins: either attack microorganisms directly or retard their reproduction.
• Complement proteins and interferon are important antimicrobial proteins present in tissues and blood.
• Interferons are most effective in controlling short term infections such
as cold and flu.
Nonspecific Defense Mechanism Part II
• Interferons being very active antiviral agents are now mass produced by recombinant DNA technology.
Inflammatory Response
• Localized response is triggered by release of histamine when tissue is injured by a physical cut or microorganisms.
• Histamine induce the permeability of the capillaries causing redness
Nonspecific Defense Mechanism Part II
• Interferons being very active antiviral agents are now mass produced by recombinant DNA technology.
Inflammatory Response

• The spleen also helps fight certain kinds of bacteria that cause pneumonia and meningitis.
Organs of Immune System
• Peyer's patches are small
masses of lymphatic tissue found throughout the ileum region of the small intestine.
• They form an important part of the immune system and prevent the growth of pathogenic bacteria in the intestines.
Organs of Immune System
• Appendix
• The appendix is a small, pouch-like sac of tissue that is located in the first part of the colon (cecum)
• Lymphatic tissue in the appendix aids in immune function.
• The appendix harbors bacteria.
Organs of Immune System
• Bone Marrow is a semi-solid tissue which is found within the spongy or portions of bones.
• In birds and mammals, bone marrow is the primary site of new blood cell production or hematopoiesis.
• It is composed of hematopoietic cells and adipose tissue.
Organs of Immune System
• In adult humans, bone

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Organs of Immune System Part II
• Bone Marrow is a semi-solid tissue which is found within the spongy or portions of bones.
• In birds and mammals, bone marrow is the primary site of new blood cell production or hematopoiesis.
• It is composed of hematopoietic cells and adipose tissue.
Organs of Immune System Part II
• In adult humans, bone marrow is primarily located in the ribs, vertebrae, sternum, and bones of the pelvis.
• Human marrow produces approximately 500 billion blood cells per day.
• The red bone marrow is a
key element of the lymphatic system.
Organs of Immune System Part II
• generate lymphocytes from immature hematopoietic progenitor cells.
• The bone marrow and thymus constitute the primary lymphoid tissues

bind via B cell receptors (BCR). Natural killer cells is a
component of innate immune system.
• NK cells play a major role
in the host-rejection of both tumors and virally infected cells.
Specific Defense Mechanism (Immune System)
• Antigens: The foreign substance that elicits the immune response is called an antigen.
• The immune system responds to an antigen by producing specific proteins called antibodies.
• The antigens include molecules belonging to viruses, bacteria, fungi and parasitic worms.
Specific Defense Mechanism (Immune System)
• Each antigen has a unique molecular shape and stimulates the production of antibodies.
• Antigens are bound to antibodies through weak and non covalent interactions such as electrostatic interactions, hydrogen bonds, Van der Waals forces, and hydrophobic interactions.

• Localized response is triggered by release of histamine when tissue is injured by a physical cut or microorganisms.
• Histamine causes redness
and swelling by the permeability of vessels.
Nonspecific Defense Mechanism Part II
• Certain chemicals also release that attract phagocytic cells.
• After their arrival at the site of injury, these phagocytes consume some pathogens and cell debris and the tissue heals.**192**Acquired immunity:
Acquired or adaptive immunity is the body's third line of defense.
• This is protection against
specific types of pathogens.
• Acquired immunity may be either natural or artificial in nature.
• Both natural and artificial
immunity have active and passive components .
Acquired Immunity
Acquired Immunity
• Active immunity . the immunity which results from the production of antibodies by the immune system in response to the presence of an antigen.
• Active immunity comes from exposure to a pathogen.

marrow is primarily located in the ribs, vertebrae, sternum, and bones of the pelvis **193** Vaccine is a substance used to stimulate the production of antibodies and provide immunity against one or several diseases. • Vaccines are prepared from the causative agent of a disease or its products. • It may be a synthetic substitute, treated to act as an antigen without inducing the disease. Vaccines • "there is no vaccine against the virus“. • Vaccine, suspension of weakened or killed microorganisms or toxins or of antibodies or lymphocytes that is administered to prevent disease. • Vaccines contain a dead or weakened version of a microbe. Vaccines • There are 4 main types of vaccines: • Live-attenuated vaccines. • Inactivated vaccines. • Subunit, recombinant, polysaccharide, and conjugate vaccines. • Toxoid vaccines. Vaccines • The first inactivated polio vaccine (IPV) was produced by Salk using	involved in the production and early selection of lymphocytes**194** Passive immunity is conferred from outside the body, so it doesn't require exposure to an infectious agent or its antigen. • There is no delay in the action of passive immunity. Its response to an infectious agent is immediate. Passive immunity is not as long-lasting as active immunity . Passive Immunity Passive Immunity • An example of natural passive immunity is a baby's protection against certain infections by getting antibodies through colostrum or breast milk. • An example of artificial passive immunity is getting an injection of antisera, which is a suspension of antibody particles. Passive Immunity • Artificially-acquired passive immunity is an immediate, but short-term immunization provided by the injection of antibodies, such as gamma globulin, that are not produced by the recipient's cells. • These antibodies are developed in another individual or animal and		Acquired Immunity • E. Jenner, English physician and scientist was the pioneer of smallpox vaccine, the world's first vaccine. • Vaccine contains a small amount of the disease germ (virus or bacteria) or parts of the germ. Examples are the measles virus, whooping cough bacteria and tetanus toxoid. Acquired Immunity • Surface markers on the pathogen surface act as antigens, which are binding sites for antibodies. • Antibodies are Y-shaped protein molecules, which can exist on their own or attach to the membrane of special cells. • The body doesn't keep a store of antibodies on hand to take down an infection immediately. Acquired Immunity • Naturally acquired active immunity occurs when the person is exposed to a live pathogen, develops the disease, and becomes immune as a result of the primary immune response. • Once a microbe penetrates the body's skin, mucous membranes, or other primary defenses, it

virus grown on monkey kidney cells and inactivated with formalin. • Attenuated or Weakened • Inactivated (Killing by formaline) • measles, mumps, and rubella (MMR)	then injected into another individual.		interacts with the immune system. Acquired Immunity • results from an infection or an immunization, while passive immunity comes from naturally or artificially gaining antibodies. Acquired Immunity • An example of natural passive immunity is a baby's protection against certain infections by getting antibodies through colostrum or breast milk. • An example of artificial passive immunity is getting an injection of antisera, which is a suspension of antibody particles. Acquired Immunity • Artificially acquired active immunity can be induced by a vaccine, a substance that contains the antigen.