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HANDOUT

ZOO516T

Animal Form & Function-I (Theory)

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ZOO516T

Animal Form & Function-I (Theory)

Lecture Handouts

Prepared for the students of Virtual University of Pakistan

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1. The Unity and Diversity of Animal Form

LEARNING OBJECTIVES

- Explain the form-function relationship
- Describe levels of organization
- Classify animal body plans

Form fits function at every scale: a bird's hollow bones, an insect's tracheae, a fish's streamlined body - each structure is explicable by what it must do. Zoology studies this through **levels of organization**: protoplasmic (single cells, e.g. Amoeba), cellular (aggregates, e.g. sponges), tissue (cnidarians), organ (flatworms) and organ-system (all higher animals). Complexity increased stepwise in evolution, but 'lower' grades persist because they work.

Body plans: **symmetry** - asymmetry (sponges), radial (cnidarians, echinoderm adults), bilateral (most animals - enabling cephalization: heads with brains); **body cavities** - acoelomate (flatworms), pseudocoelomate (roundworms), coelomate (annelids onward - the true coelom houses organs and enables independent gut movement); **segmentation** (annelids, arthropods, chordates - repeated modules); and **cephalization**. These architectural decisions constrain everything an animal can become.

Homology vs analogy

Homologous structures share evolutionary origin (bat wing, whale flipper); analogous structures share function only (insect wing, bird wing) - convergent solutions to flight.

SECTION SUMMARY

Form serves function across five organizational grades. Symmetry, coelom, segmentation and cephalization are the body-plan decisions underlying all animal diversity.

2. Tissues: The Fabric of the Body

LEARNING OBJECTIVES

- Classify the four tissue types
- Relate epithelial structure to function
- Explain connective tissue diversity

Four primary tissues build every organ: **epithelial** (covering/lining - protection, absorption, secretion), **connective** (support/binding - the most diverse), **muscular** (movement), **nervous** (control). **Epithelia** classify by layers (simple/stratified) and cell shape (squamous, cuboidal, columnar): simple squamous lines lungs and vessels (diffusion); stratified squamous arms skin; columnar with microvilli absorbs in the gut; ciliated moves mucus in airways. Basement membrane anchors; tight junctions seal.

Connective tissues: loose areolar (packing), dense fibrous (tendons/ligaments), adipose (energy/insulation), **cartilage** (flexible support - chondrocytes in lacunae), **bone** (rigid - osteocytes, Haversian systems), and **blood** (fluid connective tissue - cells in plasma matrix). **Muscle:** skeletal (striated, voluntary), cardiac (striated, branched, involuntary, intercalated discs), smooth (spindle, involuntary - gut, vessels). **Nervous:** neurons + glia - the control network detailed in later sections.

SECTION SUMMARY

Epithelia cover (shape/layers fit the job); connective tissues support in forms from blood to bone; three muscle types and nervous tissue complete the fabric.

3. Integument: Skin and Its Derivatives

LEARNING OBJECTIVES

- Describe vertebrate skin structure
- Explain skin functions
- Survey integumentary derivatives

Vertebrate skin has **epidermis** (stratified squamous epithelium - keratinized in land vertebrates, waterproofing against desiccation) over **dermis** (connective tissue with vessels, nerves, glands). Functions: **protection** (pathogens, UV, abrasion), **thermoregulation** (sweat glands, vasodilation, fur/feathers), **sensation**, **excretion** (minor), **vitamin D synthesis**, and **waterproofing**. Amphibian skin stays thin and moist for cutaneous respiration; reptilian scales, bird feathers and mammalian hair are all **keratin** derivatives.

Derivatives: **fish scales** (dermal bone), **reptile scales/scutes**, **feathers** (flight, insulation, display - evolved from dinosaur scales), **hair** (insulation, sensation - defining mammals), **claws/nails/hooves/horns/antlers** (keratin or bone), **glands** (sweat, sebaceous, scent, mammary - milk defining mammals). **Coloration:** camouflage (cryptic), warning (aposematic - poison dart frogs), mimicry (Batesian/Mullerian), sexual display - produced by chromatophores and structural color.

SECTION SUMMARY

Epidermis + dermis protect, thermoregulate and sense. Keratin derivatives - scales, feathers, hair, claws - and coloration strategies adapt skin to each vertebrate lifestyle.

4. Skeletal System: Support and Movement

LEARNING OBJECTIVES

- Compare hydrostatic, exoskeleton and endoskeleton
- Describe bone structure and growth
- Explain joints and muscle leverage

Three support strategies: **hydrostatic skeletons** (fluid under pressure - earthworms, cnidarians; muscles squeeze against incompressible fluid), **exoskeletons** (arthropod chitin - strong but must be **molted/ecdysis** for growth, a vulnerable moment), **endoskeletons** (vertebrate bone/cartilage - grows with the animal, protects organs, anchors muscles). Bone is living: **compact bone** (osteons/Haversian systems) resists bending; **spongy bone** (trabeculae) resists compression; **marrow** makes blood cells.

Bone growth: **endochondral ossification** (cartilage model replaced - long bones) and intramembranous (flat bones); **epiphyseal plates** lengthen bones until puberty. **Joints**: fibrous (immovable skull sutures), cartilaginous (slightly movable vertebrae), synovial (freely movable - hinge, ball-and-socket, lubricated by synovial fluid). Muscles work as **lever systems** with bones: flexors/extensors in antagonistic pairs (biceps/triceps); insertion near the joint favors speed, far favors force.

SECTION SUMMARY

Hydrostatic, exo- and endoskeletons solve support three ways. Living bone grows, remodels and makes blood; joints and antagonistic muscle pairs convert contraction into movement.

5. Nutrition and the Digestive System

LEARNING OBJECTIVES

- Compare feeding strategies
- Trace the vertebrate gut regionally
- Explain digestion and absorption chemistry

Feeding modes: **filter feeders** (bivalves, baleen whales), **deposit feeders** (earthworms), **fluid feeders** (aphids, mosquitoes, vampire bats), **bulk feeders** (most vertebrates - herbivores, carnivores, omnivores). Gut plans match diet: herbivores have long intestines and fermentation chambers (ruminant four-chambered stomach; cecum in horses/rabbits); carnivores short guts; birds add **crop** (storage) and **gizzard** (grinding, replacing teeth).

Human/vertebrate gut: mouth (mechanical + salivary amylase) -> esophagus (peristalsis) -> **stomach** (HCl + pepsin, chyme) -> **small intestine** (duodenum: bile emulsifies fats, pancreatic enzymes; jejunum/ileum: villi + microvilli absorb - enormous surface area) -> **large intestine** (water absorption, gut flora) -> rectum. Regulation: **gastrin/secretin/CCK** hormones; the liver (bile, metabolism) and pancreas are the great accessory glands. Symbionts digest cellulose - no

vertebrate makes cellulase.

■ VERY IMPORTANT

The ruminant stomach chambers (rumen, reticulum, omasum, abomasum) and villi/microvilli surface-area logic are perennial exam diagrams.

SECTION SUMMARY

Feeding mode shapes gut design; regional specialization (acid stomach, enzymatic duodenum, absorptive villi, fermenting hindgut) plus liver/pancreas chemistry extract nutrients efficiently.

6. Gas Exchange and the Respiratory System

LEARNING OBJECTIVES

- Explain diffusion constraints on gas exchange
- Compare respiratory organs
- Describe breathing mechanics

All gas exchange is **diffusion** across moist, thin, large-area surfaces - Fick's law: rate scales with area and gradient, inversely with thickness. Solutions: **body surface** (earthworms - hence must stay moist), **gills** (fish - filaments/lamellae with **countercurrent exchange**: blood flows opposite water, extracting ~80% of oxygen vs ~50% in concurrent flow), **tracheae** (insects - air tubes opening at spiracles, delivering O₂ directly to tissues), **book lungs** (spiders), and **lungs** (vertebrates - amphibian simple sacs to mammalian alveoli: ~300 million, huge area).

Mammalian breathing: **diaphragm + intercostals** create negative pressure (inhalation active, exhalation passive); **tidal volume**, vital capacity, residual volume define lung volumes. Control: medullary centers respond to **CO₂/pH** (not O₂) via chemoreceptors. **Birds** use rigid lungs with **air sacs** and cross-current flow - the most efficient vertebrate system, powering flight. **Diving mammals** (seals, whales) exploit myoglobin stores and the dive reflex.

SECTION SUMMARY

Diffusion demands thin, moist, large surfaces: gills (countercurrent), tracheae, lungs (alveoli). Mammals breathe by negative pressure controlled by CO₂; birds' air-sac system is the efficiency champion.

7. Circulation: Hearts and Vessels

replaces failed kidneys artificially.

■ VERY IMPORTANT

The loop of Henle's countercurrent multiplier is the conceptual heart of this section: descending limb leaks water, ascending pumps salt, multiplying one gradient into concentrating power.

SECTION SUMMARY

Waste strategy follows water availability (ammonia/urea/uric acid). The nephron filters, reabsorbs and concentrates via the loop of Henle's countercurrent multiplication under ADH control.

9. Nervous System: Organization

LEARNING OBJECTIVES

- Describe neuron structure and signaling
- Compare nerve nets to centralized systems
- Outline the vertebrate brain

The **neuron**: dendrites (receive), axon (transmit), synapse (chemical handoff). **Action potential**: resting -70 mV; stimulus opens Na⁺ channels (depolarization spike), K⁺ restores (repolarization) - **all-or-none**, self-propagating, **myelinated** axons conduct saltatorily (fast - vertebrate innovation; unmyelinated invertebrate giant axons are the alternative). **Synapses**: neurotransmitters (acetylcholine, glutamate, GABA) cross clefts; summation decides firing; drugs/venoms target these steps.

Evolution: **nerve nets** (cnidarians - diffuse), **cephalization** (flatworms: ladder-like cords + ganglia), **ventral nerve cord** (annelids/arthropods), **dorsal hollow nerve cord** (chordates - the defining trait). Vertebrate brain: hindbrain (medulla - breathing/heart; cerebellum - coordination), midbrain (visual/auditory relay), forebrain (thalamus relay; **cerebrum** - sensation, cognition; hypothalamus - homeostasis). **Autonomic** (sympathetic/parasympathetic) runs the viscera involuntarily.

SECTION SUMMARY

Neurons signal electrochemically (all-or-none spikes, transmitter synapses). Nervous systems centralize from nets to dorsal cords; the vertebrate brain regionalizes control from medulla to cerebrum.

10. Sense Organs

LEARNING OBJECTIVES

- Explain how receptors transduce stimuli
- Compare eye designs
- Describe hearing, smell and lateral lines

Receptors **transduce** energy into neural signals: mechanoreceptors (touch, hearing, balance), chemoreceptors (smell, taste), photoreceptors (vision), thermoreceptors, electroreceptors (sharks, electric fish). **Eyes** evolved repeatedly: **compound eyes** (arthropods - many ommatidia, superb motion detection, mosaic vision), **camera eyes** (cephalopods and vertebrates - lens focusing on retina; vertebrate retina is 'wired backwards' with a blind spot, cephalopod retina is not - a famous evolution debate exhibit). Color vision: cones (birds see UV; mammals vary - primates trichromatic).

Hearing: mammalian ear - pinna funnels, eardrum + **ossicles** (malleus, incus, stapes - repurposed jaw bones!) amplify to the cochlea's hair cells; **semicircular canals** sense balance. **Echolocation** (bats, dolphins) and **lateral line** systems (fish - water movement/pressure) extend sensing beyond human ranges. **Smell:** olfactory epithelium - dogs' 300 million receptors vs humans' 6 million; **pheromones** coordinate insect societies; taste is smell's gatekeeper.

SECTION SUMMARY

Receptors transduce specific energies; camera and compound eyes solve vision convergently; mammalian hearing chains repurposed jaw bones to cochlear hair cells; lateral lines and echolocation transcend human senses.

11. Endocrine System and Chemical Coordination

LEARNING OBJECTIVES

- Compare nervous vs endocrine control
- Map the major glands and hormones
- Explain feedback regulation

Nervous = fast, local, brief; **endocrine** = slow, broadcast, sustained - hormones travel in blood to distant targets. **Pituitary** (master gland: GH, TSH, ACTH, gonadotropins - driven by hypothalamic releasing factors); **thyroid** (thyroxine - metabolic rate; iodine deficiency -> goiter, cretinism); **parathyroid** (calcium); **adrenal** (cortex: cortisol stress response; medulla: adrenaline fight-or-flight); **pancreas** (insulin/glucagon - blood glucose; diabetes when failed); **gonads** (testosterone/estrogen - reproduction, secondary sexual traits); **pineal** (melatonin - rhythms).

Negative feedback dominates: high thyroxine suppresses TSH; high glucose triggers insulin which lowers it - homeostasis by loop. **Positive feedback** is rare (oxytocin in childbirth, LH surge). Invertebrate hormones: **ecdysone** (molting) and juvenile hormone (insect

development/metamorphosis - complete vs incomplete); crustacean molt cycles; **pheromones** as external hormones coordinating colonies. Endocrine disruptors (pollutants mimicking hormones) are a modern ecotoxicology concern.

SECTION SUMMARY

Hormones broadcast slow, sustained commands; the pituitary-hypothalamus axis commands; negative feedback holds set points. Insect ecdysone/juvenile hormone orchestrate metamorphosis.

12. Reproduction and Development

LEARNING OBJECTIVES

- Compare asexual and sexual reproduction
- Explain gametogenesis and fertilization
- Outline embryonic development stages

Strategies: **asexual** (fission, budding - hydra; parthenogenesis - aphids, some lizards: fast, no mate needed, no genetic variation) vs **sexual** (meiosis + fertilization: variation's engine, at the cost of males and mating). **Gametogenesis**: spermatogenesis (millions daily, continuous) vs oogenesis (limited oocytes, meiotic arrest, massive yolk investment) - the anisogamy defining male/female. **Fertilization**: external (fish, frogs - many gametes, water-dependent) vs internal (land animals - fewer gametes, copulation, shelled eggs/amniotes freed reproduction from water).

Development: **cleavage** (rapid divisions; patterns reflect yolk - holoblastic vs meroblastic), **blastula**, **gastrulation** (the most important event: germ layers form - ectoderm, mesoderm, endoderm), **neurulation** (nerve cord), **organogenesis**. **Protostomes** (mouth first - arthropods, molluscs) vs **deuterostomes** (anus first - echinoderms, chordates): the deep embryological divide. **Metamorphosis** (indirect development - caterpillar to butterfly, tadpole to frog) vs direct development.

SECTION SUMMARY

Sexual reproduction trades efficiency for variation; anisogamy defines sexes; internal fertilization + amniotic eggs conquered land. Gastrulation builds the three germ layers - development's pivotal moment.

13. Thermoregulation and Homeostasis

LEARNING OBJECTIVES

- Define homeostasis
- Compare ectothermy and endothermy
- Explain thermoregulatory adaptations

Homeostasis (Cannon): maintaining stable internal conditions - temperature, pH, glucose, water - via **negative feedback** loops (receptor → control center → effector). **Ectotherms** (most animals: 'cold-blooded' - better: outside-heated) use behavior (basking, burrowing); **endotherms** (birds, mammals) generate metabolic heat - expensive (high food intake) but enabling night activity, cold climates and sustained exertion. **Heterotherms** (bats, hummingbirds) mix strategies; **torpor/hibernation** saves winter energy.

Adaptations: **insulation** (fur, feathers, blubber - Arctic mammals), **countercurrent heat exchange** (rete mirabile in legs/flippers - dolphins, wolves, birds' feet), **evaporative cooling** (sweating, panting), **vasomotor** control (shunting blood), **behavioral** (microhabitats), **brown fat** (non-shivering thermogenesis in mammalian infants). **Bergmann's and Allen's rules**: colder climates favor larger bodies and smaller extremities - testable biogeography from thermoregulation logic.

SECTION SUMMARY

Homeostasis = feedback-held stability. Ectothermy is cheap, endothermy is powerful; insulation, countercurrent exchange and behavior bridge the gap - Bergmann's and Allen's rules map it geographically.

14. Exam Pointers

High-yield topics

- Body plans: symmetry types, coelom types, segmentation, cephalization; homology vs analogy.
- Tissues: epithelial classification by layers/shape; bone vs cartilage; three muscle types.
- Gut: ruminant chambers, villi/microvilli, accessory glands; nitrogenous waste trio (ammonia/urea/uric acid).
- Gas exchange: countercurrent in gills; insect tracheae; diaphragm mechanics; bird air sacs.
- Heart: chamber counts by group; double circulation; SA/AV nodes; blood cells' functions.
- Nephron: filtration → reabsorption → loop of Henle multiplier → ADH; flame cells vs Malpighian tubules.
- Neuron: action potential steps; synapse; brain regions' functions; autonomic divisions.
- Senses: compound vs camera eye; ossicle chain; lateral line; photoreceptor types.
- Endocrine: gland-hormone-function table; negative feedback examples; ecdysone.

- Reproduction: gametogenesis contrast; external vs internal fertilization; gastrulation; protostome/deuterostome.
- Thermoregulation: ecto vs endothermy; countercurrent heat exchange; Bergmann's/Allen's rules.

SECTION SUMMARY

Draw every system: gut, gills, heart, nephron, neuron, eye, feedback loops. Structure answers as structure -> mechanism -> adaptive significance -> one example.