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HIGHLIGHTED HANDOUT

ZOO519T

Physiology (Theory)

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Physiology (Theory)

STUDY HANDOUT

A complete topic-wise study handout for ZOO519T Physiology (Theory), prepared from animal physiology lecture series. Covers the cellular basis, nervous and muscular systems, circulation, respiration, digestion, excretion, endocrine control, reproduction and thermoregulation - with mechanisms, comparisons across animal groups, and exam pointers. 

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Lecture 1: Introduction to Animal Physiology

Key terms: physiology, homeostasis, feedback, adaptation

Physiology studies how animals work - the mechanisms behind life processes. Its central principle is homeostasis: the maintenance of stable internal conditions (temperature, pH, glucose, water) despite external change, achieved through feedback loops. Negative feedback reverses deviations (insulin lowers blood sugar); positive feedback amplifies them (oxytocin in labour). Comparative physiology reveals how different animals solve the same problems.

- Homeostasis: stability through change - the core concept.
- Negative feedback: most regulation; positive feedback: rare, explosive events.
- Structure-function: anatomy makes sense only through physiology.

EXAM POINTER: Define homeostasis and explain negative vs positive feedback with examples. 

Lecture 2: Cells, Membranes and Transport

Key terms: cell membrane, diffusion, osmosis, active transport

The plasma membrane's phospholipid bilayer is selectively permeable. Passive transport (diffusion, facilitated diffusion, osmosis) moves substances down gradients for free; active transport (Na⁺/K⁺ ATPase) pumps against gradients using ATP. Bulk transport: endocytosis and exocytosis move large cargo. Every physiological system - nerves, kidneys, gut - is membrane transport writ large.

- Na⁺/K⁺ pump: 3 Na⁺ out, 2 K⁺ in - sets up the gradients nerves use.
- Osmosis: water follows solute - the basis of kidney function.
- Membrane potential arises from unequal ion distribution.

Lecture 3: Nervous System I: Neurons and Signals

Key terms: neuron, action potential, synapse, neurotransmitter

Neurons carry information electrically and chemically. The resting membrane potential (~-70 mV) reflects K⁺ gradients. A stimulus opens Na⁺ channels: depolarisation to threshold fires the all-or-none action potential, travelling down the axon; myelin sheaths speed conduction via saltatory jumps. At synapses, neurotransmitters (acetylcholine, glutamate, GABA) cross to the next cell.

- All-or-none: action potentials are identical; intensity is coded by frequency.
- Myelin: 50x faster conduction - vertebrate innovation.
- Synaptic integration: thousands of inputs summed at the axon hillock.

Lecture 4: Nervous System II: Organisation

Key terms: CNS, PNS, brain, spinal cord, autonomic

The central nervous system (brain + spinal cord) integrates; the peripheral nervous system connects. The autonomic division runs involuntary functions: sympathetic ('fight or flight') vs parasympathetic ('rest and digest'). Vertebrate brains regionalise: hindbrain (vital rhythms), midbrain, forebrain (cerebrum - complex behaviour). Invertebrates manage with ganglia and nerve cords - less centralised, still effective.

- Reflex arc: the simplest circuit - sensory to motor via spinal cord.
- Sympathetic vs parasympathetic: antagonistic control of organs.
- Cephalisation: concentration of nervous tissue at the head with complexity.

Lecture 5: Muscle Physiology

Key terms: muscle, sliding filament, contraction, muscle types

Muscles convert chemical energy to movement via the sliding filament mechanism: myosin heads bind actin, power-stroke, detach - powered by ATP, triggered by Ca^{++} released after neural excitation (excitation-contraction coupling). Skeletal muscle (voluntary, striated), cardiac muscle (involuntary, rhythmic, gap junctions synchronise), smooth muscle (visceral, slow, sustained). Rigor mortis reveals the mechanism: without ATP, cross-bridges lock.

- Sliding filament: filaments slide, they don't shorten.
- Ca^{++} is the trigger; ATP the fuel - both essential.
- Cardiac muscle never fatigues: mitochondria-packed and aerobic.

EXAM POINTER: Describe the sliding filament mechanism step by step.

Lecture 6: Circulation I: Hearts and Vessels

Key terms: circulation, heart, open, closed, double

Circulatory systems transport nutrients, gases, wastes and hormones. Open systems (arthropods, most molluscs) bathe tissues in hemolymph; closed systems (annelids, vertebrates) confine blood to vessels - faster, more controllable. Fish: single circulation; amphibians/reptiles: incomplete double; birds/mammals: complete double - separating oxygenated and deoxygenated blood for endothermy's high metabolism.

- Double circulation's payoff: high pressure, high metabolism.
- Arteries carry blood away from the heart (not always oxygenated).
- Capillaries: where exchange actually happens - thin walls, slow flow.

Lecture 7: Circulation II: The Mammalian Heart

Key terms: cardiac cycle, systole, diastole, ECG, blood pressure

The cardiac cycle: atrial systole fills ventricles, ventricular systole ejects blood, diastole refills - valves enforce one-way flow, their closure makes heart sounds. Pacemaker cells (SA node) set rhythm; the ECG records the electrical wave (P, QRS, T). Blood pressure (120/80 mmHg) drives filtration; it is regulated by cardiac output, vessel resistance, and hormones (adrenaline, ADH).

- SA node: the natural pacemaker; AV node delays for filling.
- Systolic/diastolic: contraction vs relaxation pressures.
- Baroreceptors adjust heart rate and vessel tone reflexively.

Lecture 8: Blood: Composition and Functions

Key terms: blood, erythrocytes, leukocytes, platelets, haemoglobin

Blood is connective tissue: plasma (water, proteins, solutes) plus cells. Erythrocytes carry O₂ on haemoglobin (4 O₂ per molecule; no nucleus in mammals - more room for haemoglobin). Leukocytes defend (phagocytes, lymphocytes). Platelets seed clotting via the coagulation cascade. Haemopoiesis in bone marrow replaces millions of cells per second.

- Haemoglobin's S-shaped dissociation curve: loads in lungs, unloads in tissues.
- Bohr effect: CO₂/acidity unloads more O₂ where needed most.
- Clotting: cascade amplifies a small trigger into a fibrin mesh.

Lecture 9: Respiration I: Gas Exchange

Key terms: respiration, gas exchange, gills, lungs, tracheae

Gas exchange needs moist, thin, large surfaces: gills (fish - countercurrent exchange with water), tracheae (insects - air direct to tissues), lungs (tetrapods - tidal ventilation). Countercurrent flow in gills extracts ~80% of dissolved O₂ - supremely efficient. Amphibians add cutaneous respiration; some turtles even respire through cloacal bursae.

- Fick's law: rate depends on area, thinness, and concentration gradient.
- Countercurrent: blood and water flow oppositely, preserving the gradient.
- Water holds little O₂ - aquatic animals work harder to breathe.

Lecture 10: Respiration II: Mammalian Breathing

Key terms: ventilation, diaphragm, alveoli, gas transport

Mammals ventilate tidally: diaphragm and rib muscles expand the thorax, air flows in; elastic recoil exhales. Alveoli (300 million, huge surface) exchange gases with capillaries. O₂ rides haemoglobin; CO₂ travels as bicarbonate (carbonic anhydrase), carbamino compounds, and dissolved gas. Breathing rhythm comes from medullary centres sensing blood CO₂/pH - not O₂.

- Inspiration is active (muscles); quiet expiration is passive.
- Surfactant prevents alveolar collapse - vital at birth. ☰
- CO₂/pH, not oxygen, is the main drive to breathe.

EXAM POINTER: Explain how CO₂ is transported in blood and what controls breathing rate.

Lecture 11: Digestion I: Feeding Strategies

Key terms: digestion, intracellular, extracellular, feeding modes

Animals harvest energy diversely: filter feeders, deposit feeders, fluid feeders, mass feeders. Digestion is intracellular (sponges - food vacuoles) or extracellular (most animals - gut lumen). Complete guts (mouth to anus, e.g. annelids onward) allow sequential processing - ingestion, digestion, absorption, egestion - far more efficient than blind sacs (cnidarians, flatworms).

- Complete gut: one-way traffic, specialised regions.
- Teeth and beaks: mechanical breakdown matches diet.
- Gut length reflects diet: herbivores long, carnivores short.

Lecture 12: Digestion II: The Mammalian Gut

Key terms: stomach, intestine, enzymes, absorption

The mammalian gut is a production line: mouth (mechanical + salivary amylase), stomach (acid + pepsin begin protein digestion), small intestine (pancreatic enzymes, bile emulsifies fats; villi and microvilli absorb), large intestine (water absorption, gut flora). Hormones (gastrin, secretin, CCK) coordinate secretion and motility. Ruminants outsource cellulose digestion to foregut microbes - regurgitation and re-chewing.

- Villi + microvilli: enormous absorptive surface.
- Bile: no enzymes - emulsifies fat for lipase attack.
- Ruminant symbiosis: microbes digest cellulose, host digests microbes.

Lecture 13: Excretion I: Nitrogenous Wastes

Key terms: excretion, ammonia, urea, uric acid

Protein catabolism yields toxic ammonia; animals handle it three ways. Ammonotelic (ammonia - fish): cheap but needs abundant water. Ureotelic (urea - mammals, amphibians): less toxic, costs energy, needs moderate water. Uricotelic (uric acid - birds, reptiles, insects): paste-like, minimal water - the adaptation for dry eggs and desert life. Waste strategy follows water availability.

- Ammonia: toxic, cheap, aquatic; urea: safer, costlier; uric acid: safest, costliest.
- Birds' uric acid: why droppings are white paste.
- Metabolic cost rises as water need falls.

Lecture 14: Excretion II: The Mammalian Kidney

Key terms: kidney, nephron, filtration, ADH

The nephron filters then refines: glomerular filtration (blood pressure forces fluid out), proximal tubule reabsorbs glucose/salts, loop of Henle builds the medullary gradient, distal tubule and collecting duct fine-tune under ADH and aldosterone. Result: concentrated urine, stable blood. ADH (dehydration -> more water reabsorbed) and the RAAS system regulate volume and pressure.

- Filtration is non-selective; reabsorption is the selective work.
- Loop of Henle: the countercurrent multiplier concentrating urine.
- Desert mammals have long loops - extreme concentrating ability.

EXAM POINTER: Trace filtrate through the nephron, naming what happens in each part. 

Lecture 15: Osmoregulation Across Habitats

Key terms: osmoregulation, freshwater, marine, terrestrial

Water balance challenges differ: freshwater animals (hyperosmotic to medium) gain water, lose salts - they excrete dilute urine and actively uptake salts via gills. Marine bony fish (hypoosmotic) lose water, gain salts - they drink seawater and excrete salts via gills. Terrestrial animals conserve water: waxy cuticles, concentrated urine, nocturnal habits. Each habitat demands opposite engineering.

- Freshwater: dilute urine + salt uptake; marine: drink + salt excretion.
- Sharks retain urea to match seawater osmolarity.
- Kidney concentrating power tracks habitat aridity.

Lecture 16: Endocrine System I: Hormones

Key terms: endocrine, hormone, feedback, glands

Hormones are chemical messengers: secreted by glands into blood, acting on distant targets. Classes: peptides (insulin), steroids (testosterone - from cholesterol), amines (adrenaline). Endocrine (ductless, blood-borne) vs exocrine (ducted). Control is usually negative feedback (thyroid axis: hypothalamus -> pituitary -> thyroid -> feedback). Slow but sustained - the complement to rapid neural control.

- Peptide vs steroid: water-soluble vs lipid-soluble - different receptor logic.
- Tropic hormones: pituitary hormones controlling other glands.
- Neuroendocrine link: hypothalamus bridges nervous and endocrine.

Lecture 17: Endocrine System II: Major Glands

Key terms: pituitary, thyroid, adrenal, pancreas, hormones

Pituitary (master gland): growth hormone, TSH, ACTH, gonadotropins. Thyroid: thyroxine sets metabolic rate (iodine-dependent). Adrenal: cortex (cortisol - stress metabolism; aldosterone - salt balance), medulla (adrenaline - fight or flight). Pancreas: insulin lowers, glucagon raises blood glucose - diabetes is this axis failing. Gonads: sex steroids drive reproduction and secondary characters.

- Insulin/glucagon: the glucose seesaw - know both directions.
- Thyroxine: too little = sluggish; too much = hyperactive metabolism.
- Adrenaline: instant sympathetic amplification.

Lecture 18: Reproduction I: Strategies

Key terms: reproduction, sexual, asexual, ovipary, vivipary

Asexual reproduction (fission, budding, parthenogenesis) is fast and cheap but genetically static; sexual reproduction is costly (mates, meiosis) but generates variation - the raw material of adaptation. Reproductive modes: ovipary (egg-laying), ovovivipary (eggs hatch inside), vivipary (live birth with placental nourishment). Parental investment theory predicts behaviour: the higher-investing sex is choosier.

- Parthenogenesis: all-female species (some lizards) - variation via mutation only.
- Vivipary evolved repeatedly - over 100 times in reptiles alone.
- Trade-off: many cheap offspring vs few well-provisioned ones.

Lecture 19: Reproduction II: Mammalian Reproduction

Key terms: oestrous, menstrual, gestation, lactation

Mammalian reproduction: gametogenesis (spermatogenesis continuous; oogenesis cyclic), hormonal cycles (oestrous in most mammals, menstrual in primates - estrogen/progesterone

orchestrate), fertilisation (usually internal), gestation (placental exchange), and lactation (mammary glands - the defining mammalian trait). Hormonal contraception works by feedback-suppressing ovulation - applied endocrinology.

- Oestrous vs menstrual: reabsorb vs shed the uterine lining.
- Placenta: the interface - nutrition, gas exchange, hormone production.
- Lactation: nutrition plus passive immunity for the newborn.

EXAM POINTER: Compare oestrous and menstrual cycles and explain hormonal contraception.

Lecture 20: Thermoregulation

Key terms: thermoregulation, endotherm, ectotherm, torpor

Endotherms (birds, mammals) generate internal heat - high, stable body temperature enabling sustained activity at the cost of huge food intake. Ectotherms (most others) rely on behaviour (basking, shade) - cheap but temperature-dependent performance. Adaptations: countercurrent heat exchangers (dolphin flippers, bird legs), insulation (fur, feathers, blubber), torpor and hibernation (controlled shutdown to survive scarcity).

- Endothermy: ~10x the metabolic cost of ectothermy.
- Countercurrent exchange retains core heat in extremities.
- Hibernation: body temperature near ambient, metabolism minimal.

Lecture 21: Revision: Midterm Practice Set

1. Define homeostasis; explain negative and positive feedback with examples. (10 marks)
2. Describe the action potential and synaptic transmission. (10 marks)
3. Explain the sliding filament theory of muscle contraction. (10 marks)
4. Compare single, incomplete double and complete double circulation. (10 marks)
5. Trace an oxygen molecule from air to tissues in a mammal. (5 marks)

Lecture 22: Revision: Final-Term Practice Set

1. Compare ammonotelic, ureotelic and uricotelic excretion. (10 marks)
2. Trace filtrate through the nephron with functions of each part. (10 marks)
3. Explain insulin/glucagon control of blood glucose. (10 marks)
4. Compare endothermy and ectothermy with adaptations. (10 marks)
5. Describe the mammalian reproductive cycle and its hormones. (10 marks)

End of Handout - Good luck with your exams!