Excretory Products and Their Elimination — Assignment 2

Class 11 Biology · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Answer with the correct NCERT values and units (mL/min, mOsmolL^{-1}, etc.).
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Modes of Excretion — Ammonotelism, Ureotelism and Uricotelism

2 Mark Questions

1. Distinguish between ammonotelism, ureotelism and uricotelism with one example of each.

3 Mark Questions

1. Terrestrial animals are generally either ureotelic or uricotelic, not ammonotelic. Justify, using the toxicity and solubility of the nitrogenous wastes.

Human Excretory System — Organs

2 Mark Questions

1. Explain the roles of the ureters, urinary bladder and urethra in urine transport and storage.

3 Mark Questions

1. Trace the path of urine from the kidney to the external urethral opening, naming each part involved.

Structure of the Kidney — Cortex, Medulla and Pyramids

2 Mark Questions

1. Describe the internal structure of the kidney — capsule, cortex, medulla, pyramids, pelvis and calyces.

3 Mark Questions

1. Give a labelled account of the longitudinal section of the human kidney and describe the medullary organisation.

Nephron — Structure and Types

2 Mark Questions

1. Distinguish between cortical and juxta medullary nephrons.

3 Mark Questions

1. Describe the structure of a nephron along with its blood supply — glomerulus, Bowman's capsule, PCT, loop of Henle, DCT, collecting duct, peritubular capillaries and vasa recta.

Urine Formation — Glomerular Filtration, GFR and JGA

2 Mark Questions

1. Explain the role of the JGA in regulating GFR.

3 Mark Questions

1. Explain the autoregulatory mechanism of GFR with the help of the juxta glomerular apparatus.

Function of the Tubules — PCT, Loop of Henle, DCT, Collecting Duct

2 Mark Questions

1. List the functions of the PCT.

3 Mark Questions

1. Describe the functions of the PCT, loop of Henle, DCT and collecting duct with reference to reabsorption and secretion.

Countercurrent Mechanism — Concentration of the Filtrate

2 Mark Questions

1. Explain the role of the vasa recta as a counter current exchanger.

3 Mark Questions

1. Give a brief account of the counter current mechanism and the role of the loop of Henle and vasa recta in concentrating urine.

Regulation of Kidney Function — ADH, Renin-Angiotensin and ANF

2 Mark Questions

1. Explain the role of osmoreceptors and ADH in regulating the water balance of the body.

3 Mark Questions

1. Describe the hormonal feedback regulation of kidney function involving the hypothalamus, the JGA and the heart.

Micturition and Accessory Excretory Organs

2 Mark Questions

1. Explain the neural mechanism of micturition.

3 Mark Questions

1. Explain micturition — how urine is stored and released through the micturition reflex.

Disorders of the Excretory System — Uremia, Hemodialysis, Renal Calculi

2 Mark Questions

1. Describe how hemodialysis removes nitrogenous wastes using the artificial kidney.

3 Mark Questions

1. Describe the main disorders of the excretory system — uremia, renal calculi, glomerulonephritis, and the corrective methods of hemodialysis and kidney transplantation.

Part B — Integrated problems (multi-topic)

1. A healthy adult's kidneys filter about 180 L of fluid every day, yet only about 1.5 L is released as urine. Account for this difference quantitatively, naming the processes and the nephron segments involved. What would happen if the GFR dropped sharply without autoregulation?

2. A patient with diabetes insipidus passes several litres of very dilute urine daily. Trace the feedback loop — plasma osmolarity, osmoreceptors, ADH, collecting duct — that is disrupted, and explain how the normal mechanism prevents diuresis.

3. During hemodialysis of a uremic patient, heparin is added to the blood as it is drawn from the vein. Explain why heparin is essential, and state the composition and function of the dialysing fluid. Give one reason why the dialysing fluid is not simple distilled water.

4. State the osmolarity values from the kidney cortex (about 300 $mOsmol L^{-1}$) to the inner medulla (about 1200 $mOsmol L^{-1}$). Explain how the two limbs of the loop of Henle build this gradient, and how the vasa recta preserves it while exchanging solutes and water.

5. Compare and contrast the three hormonal regulators of kidney function — ADH, aldosterone and ANF — with reference to the feedback they provide on body-fluid volume and blood pressure.

6. A patient reports severe colicky pain radiating from the loin to the groin; urinalysis shows blood and crystals of calcium oxalate. Identify the disorder, explain how it forms, and describe its corrective management.

Answer Key

Modes of Excretion

2M(1): Ammonotelism — ammonia is the chief nitrogenous waste, e.g. bony fish (ammonia needs large water volumes). Ureotelism — urea, formed in the liver, e.g. mammals (moderately toxic, needs less water). Uricotelism — uric acid, almost insoluble, e.g. birds, reptiles, insects (paste/solid, least water). 3M(0): Ammonia is highly toxic and needs large volumes of water to be washed out, so it suits aquatic animals. On land, water is scarce; terrestrial animals conserve it by converting ammonia either to the less toxic urea (ureotelic) or to the almost insoluble uric acid (uricotelic) which is eliminated as a paste with minimal water loss.

Human Excretory System

2M(0): Ureters — musculo-membranous tubes that carry urine from the renal pelvis to the urinary bladder by peristalsis. Urinary bladder — stores urine temporarily until micturition. Urethra — carries urine from the bladder to the exterior; its sphincters control release. 3M(1): Urine is formed in the kidneys → passes through the calyces and renal pelvis → down the ureters by peristalsis → stored in the urinary bladder → released through the urethra to the external urethral opening (controlled by sphincters, aided by the micturition reflex).

Structure of the Kidney

2M(0): A tough capsule covers the kidney; inside are two zones — outer cortex (with the malpighian bodies) and inner medulla (medullary pyramids projecting into calyces). The cortex extends between pyramids as the Columns of Bertini. Inner to the hilum lie the funnel-shaped renal pelvis, whose calyces collect urine. 3M(0): Longitudinal section: outer cortex and inner medulla; medullary pyramids project into calyces; renal columns (Columns of Bertini) between pyramids; hilum → renal pelvis (funnel shaped) broken into projections (calyces) that collect the urine draining from the collecting ducts. The pyramids' striations are the collecting ducts and loops of Henle converging on the papilla.

Nephron

2M(0): Cortical nephrons lie mostly in the cortex, have a shorter loop of Henle extending only slightly into the medulla, and a vasa recta is either highly reduced or absent. Juxtamedullary nephrons lie near the cortex–medulla junction, have a long loop of Henle running deep into the medulla, and possess a well-developed vasa recta responsible for the counter current mechanism. 3M(0): Each nephron has the glomerulus (a tuft of capillaries formed by the afferent arteriole) enclosed in Bowman's capsule (= malpighian/renal corpuscle) and a renal tubule: PCT (highly coiled), loop of Henle (descending and ascending limbs) and DCT, which opens into the collecting duct. Blood supply: renal artery → afferent arteriole → glomerular capillaries → efferent arteriole → peritubular capillaries / vasa recta → venous drainage.

Urine Formation

2M(1): The JGA is formed at the region where the DCT contacts the afferent arteriole. Its juxtaglomerular cells release renin; JG cells act as chemoreceptors and macula densa cells as osmoreceptors. On a fall in GFR, renin is released, which stimulates glomerular blood flow and restores GFR to normal — this is the autoregulatory mechanism. 3M(1): A fall in GFR activates the JG cells of the JGA to release renin. Renin stimulates the conversion of angiotensinogen to angiotensin, which (a) acts as a powerful vasoconstrictor and (b) stimulates aldosterone release. Glomerular blood flow (and capillary pressure) is thereby raised and GFR restored to normal — the JGA autoregulates GFR.

Function of the Tubules

2M(1): PCT functions — reabsorbs nearly all of glucose, amino acids, vitamins, and the 70–80% of electrolytes and water; maintains pH by selective secretion of H+, ammonia and reabsorption of bicarbonate; the brush border greatly increases the absorbing surface. 3M(0): PCT — maximum reabsorption (nutrients, 70–80% electrolytes and water, passive water; pH via H+/NH3 secretion). Descending limb — water permeable, concentrates filtrate; ascending limb — impermeable to water but actively transports NaCl into the interstitium (building the gradient); DCT — selective secretion of H+, K+ and reabsorption of Na+, water (under ADH/aldosterone) to maintain pH and ionic balance; collecting duct — large amounts of water reabsorbed (under ADH), small amounts of urea pass into the medullary interstitium to keep up osmolarity, and H+/K+ are secreted to maintain pH and ionic balance.

Countercurrent Mechanism

2M(0): The vasa recta runs parallel to the loop of Henle and acts as a counter current exchanger. Blood in the descending limb loses water and gains NaCl while descending into the gradient, and the ascending limb regains water and loses NaCl on the way out — the blood is kept isotonic with the interstitium, so it neither washes out nor adds to the gradient, and (via its slow flow) helps maintain the medullary osmotic gradient. 3M(0): The two limbs of the loop of Henle plus the vasa recta run in opposite (counter) directions. NaCl transported out by the ascending limb and urea returned by the collecting duct build an osmolarity gradient from about 300 $mOsmolL^{-1}$ (cortex) to about 1200 $mOsmolL^{-1}$ (inner medulla). The vasa recta, a counter current exchanger with slow blood flow, removes the reabsorbed water and solutes without disturbing the gradient, so that the collecting duct can concentrate urine up to about four times the filtrate.

Regulation of Kidney Function

2M(0): A fall in body-fluid osmolarity/volume is detected by osmoreceptors (likely in the hypothalamus). They trigger the release of ADH from the posterior pituitary, which increases the permeability of the DCT and collecting duct to water — more water is reabsorbed and the urine becomes concentrated (diuresis is prevented). This restores water balance by feedback. 3M(0): Hypothalamus — osmoreceptors detect fluid loss → posterior pituitary releases ADH → DCT and collecting duct reabsorb more water (concentrated urine); JGA — fall in GFR triggers renin → angiotensin → aldosterone → Na+ and water reabsorption, raising blood pressure and volume; Heart — atrial wall stretch releases ANF → vasodilation, inhibits renin release → lowering blood pressure and checking the renin–angiotensin mechanism. Together they provide positive checks and balances on fluid and ionic homeostasis.

Micturition and Accessory Excretory Organs

2M(0): Distension of the urinary bladder stimulates stretch receptors in its wall. Impulses pass to the CNS (micturition centre), which sends motor messages back that contract the smooth muscle of the bladder and relax the urethral sphincters — urine is released. The neural mechanism is the micturition reflex; it is under voluntary control in adults.

3M(1): Urine is stored in the urinary bladder. When it distends beyond a threshold, stretch receptors in the wall are stimulated and the micturition reflex is initiated — motor messages contract the bladder's smooth muscle and relax the urethral sphincter, so urine flows out through the urethra. The reflex is coordinated by the CNS, giving voluntary control in healthy adults.

Disorders of the Excretory System

2M(0): In hemodialysis, the patient's blood is drawn from the vein, heparin is added (to prevent clotting), and the blood is passed through the coiled tube of a dialysing unit surrounded by dialysing fluid (composition like plasma minus nitrogenous wastes). Nitrogenous wastes (urea, uric acid) diffuse out of the blood and the cleared blood is returned to the vein — the artificial kidney removes the wastes the patient's kidney can no longer eliminate. 3M(1): Uremia — urea accumulates in blood when kidneys fail to eliminate nitrogenous wastes; corrected by hemodialysis (artificial kidney) or kidney transplantation. Renal calculi — stone-like deposits (e.g. calcium oxalate) in the kidney; corrected by medicines, lithotripsy or surgery. Glomerulonephritis — inflammation of the glomeruli of the kidney. Kidney transplantation — a functioning kidney from a donor (preferably close relative to avoid immune rejection) is placed in the recipient with immunosuppressants.

Integrated problems

1: 180 L filtered − 1.5 L urine ⇒ 99% reabsorbed. Filtration at the glomerulus, reabsorption (mostly in PCT, then loop/DCT/collecting duct) and tubular secretion bring the volume down; a sharp GFR drop without JGA autoregulation would allow toxic wastes (urea) to accumulate in the blood (uremia). 2: In diabetes insipidus the ADH mechanism fails — plasma osmolarity rises (fluid lost), osmoreceptors (hypothalamus) sense it but ADH release/action is defective, so the DCT and collecting duct stay largely water-impermeable and large volumes of dilute urine are passed. Normally ADH from the posterior pituitary increases water reabsorption from the DCT and collecting duct, producing concentrated urine and restoring body fluid volume. 3: Heparin prevents the blood from clotting inside the dialysing unit of the artificial kidney. The dialysing fluid is similar in composition to plasma minus nitrogenous wastes, so urea and uric acid diffuse out of the blood across the semipermeable membrane (along their concentration gradients) while useful solutes like glucose are retained — distilled water would not selectively remove wastes and would disturb the electrolyte balance by osmotic pulling of salts. 4: Cortical filtrate ≈ 300 $mOsmolL^{-1}$ rising to ≈ 1200 $mOsmolL^{-1}$ at the inner medulla. The ascending limb actively transports NaCl into the interstitium (and is impermeable to water), while the descending limb lets water leave, concentrating the filtrate. The vasa recta runs as a counter current exchanger with sluggish blood flow — descending it gains solutes/loses water, ascending it regains water/loses solutes — so it removes reabsorbed substances without washing out the gradient, enabling urine as concentrated as ~1200 $mOsmolL^{-1}$. 5: ADH (released by the posterior pituitary on rise in osmolarity) increases water permeability of DCT/collecting duct → water conservation, concentrated urine. Aldosterone (via renin–angiotensin on a fall in GFR/blood volume) increases Na^+ reabsorption → water follows → raises blood volume and pressure. ANF (released by the heart wall on distension) acts oppositely: vasodilates and inhibits renin release → lowers blood pressure and checks the renin–angiotensin mechanism. Together: ADH manages water balance, aldosterone manages Na^+/volume, and ANF prevents runaway fluid/BP elevation. 6: Renal calculi (kidney stones) — stone-like deposits, here of calcium oxalate, forming in the kidney; colicky pain radiates from the loin to the groin along the ureters, blood in the urine (haematuria). Corrective management: increased fluid intake, medicines to dissolve/expel the stone, lithotripsy (shock waves to break the stone), or surgical removal in severe cases.