Control water, conserve useful solutes

Osmoregulation maintains the water potential of body fluids. It limits excessive water movement into or out of cells by osmosis, helping preserve cell volume and function.

1. THE KIDNEY HAS DISTINCT REGIONS

A fibrous capsule encloses the kidney. The outer cortex contains glomeruli, Bowman's capsules and convoluted tubules. Loops of Henle extend into the medulla; collecting ducts pass through it. Urine drains into the renal pelvis, then the ureter and bladder.

2. FOLLOW BLOOD AND FILTRATE SEPARATELY

BLOOD

Renal artery → afferent arteriole → glomerulus → efferent arteriole → capillaries around tubules → renal vein

FILTRATE

Glomerulus → Bowman's capsule → proximal convoluted tubule (PCT) → loop of Henle → distal convoluted tubule (DCT) → collecting duct → renal pelvis → ureter

Ultrafiltration transfers water and small solutes from blood into the capsule. Reabsorption returns substances from the tubule, through surrounding tissue fluid, to the blood.

3. FILTRATE IS NOT FINAL URINE

Fresh filtrate contains glucose, amino acids, ions, water and urea. Its composition changes along the tubule. Useful solutes and much of the water are reclaimed; the final urine contains urea and variable amounts of water and ions.

Urea is made in the liver following deamination of excess amino acids. Kidneys excrete urea; they do not make it by filtering the blood.

Kidney regions and fluid routes: OpenStax, Biology 2e 41.2.
Nephron structures: OpenStax, Anatomy and Physiology 2e 25.4.

Scope: Cambridge Biology 9700, section 14.1, outcomes 3-8, p. 37.

Filter first, then selectively reclaim

Ultrafiltration is pressure-driven movement into the nephron. Selective reabsorption returns particular substances from the filtrate to the blood.

1. ULTRAFILTRATION IN THE RENAL CORPUSCLE

High hydrostatic pressure in glomerular capillaries drives water and small solutes through a filtration barrier. Fenestrated capillary endothelium, the basement membrane and filtration slits between podocyte processes allow filtration while normally retaining blood cells and most plasma proteins. Filtrate enters Bowman's capsule; the whole blood does not.

2. THE PCT IS ADAPTED FOR REABSORPTION

Microvilli	Large surface area facing the filtrate.
Many mitochondria	ATP supply for active transport.
Membrane transporters	Selective movement of ions and organic solutes.
Nearby capillaries	Carry reabsorbed substances away.

3. RECLAIM GLUCOSE, IONS AND WATER

Sodium-potassium pumps move Na^+ out of PCT cells into surrounding tissue fluid, using ATP. The resulting sodium gradient drives sodium-glucose cotransport from filtrate into the cells. Glucose then leaves towards the blood by facilitated diffusion. Water follows solute reabsorption by osmosis. Normally, essentially all filtered glucose and amino acids are reabsorbed.

4. ESTABLISH A GRADIENT FOR WATER RECOVERY

The loop of Henle helps create a low water potential in the medulla. Its ascending limb reabsorbs salts but is relatively impermeable to water. This gradient allows water to leave collecting ducts when their walls are sufficiently permeable.

Filtration barrier and PCT adaptations: OpenStax, Anatomy and Physiology 25.4.
Transport mechanisms and nephron function: NCBI Bookshelf, Physiology, Renal.

Scope: Cambridge Biology 9700, section 14.1, outcomes 3-8, p. 37.

ADH adjusts how much water is saved

ADH (antidiuretic hormone) is synthesised in hypothalamic neurones, transported along their axons, and released into the blood from the posterior pituitary.

1. COMPARE THE TWO FEEDBACK RESPONSES

LOW BLOOD WATER POTENTIAL	HIGH BLOOD WATER POTENTIAL
↓	↓
More ADH is released	Less ADH is released
↓	↓
More aquaporins in duct membranes	Fewer aquaporins in duct membranes
↓	↓
More water reabsorbed	Less water reabsorbed
↓	↓
Small volume of concentrated urine	Large volume of dilute urine
↓	↓
Blood water potential rises	Blood water potential falls

Osmoreceptors in the hypothalamus detect the change. As water potential returns towards its normal range, ADH release is adjusted by negative feedback.

2. AQUAPORINS CHANGE PERMEABILITY

ADH binds to receptors on collecting-duct cells, triggering insertion of aquaporin water channels into the membrane facing the filtrate. Water moves by osmosis into the lower-water-potential medullary tissue fluid and then the blood. With less ADH, channels are removed from that membrane, reducing water permeability.

3. DO NOT REVERSE THE LOGIC

Water loss usually makes blood water potential lower (more negative). A larger urine volume means more water is lost, not more water is reabsorbed. ADH changes permeability; it does not actively pump water or create the medullary gradient.

ADH, aquaporins and water conservation: OpenStax, Biology 2e 41.5.
Osmoreceptors and feedback: Cambridge Biology 9700, 14.1 outcome 8.

Scope: Cambridge Biology 9700, section 14.1, outcomes 3-8, p. 37.