FIRST MBBS · INTEGRATED TEACHING · RENAL SYSTEM & DIABETES

A E T C M

The Kidney

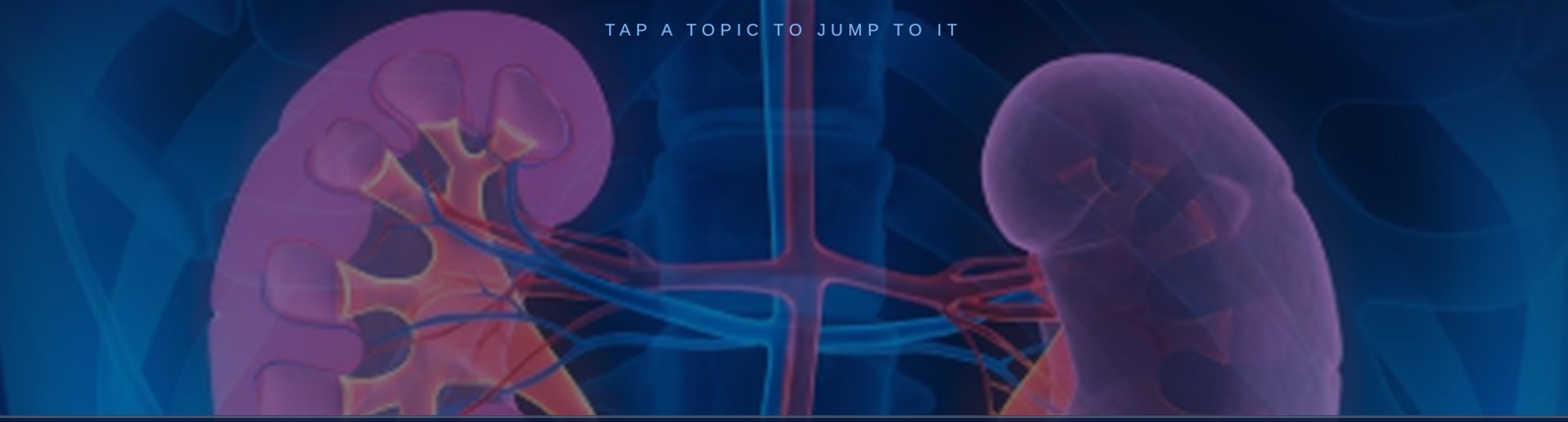
An Integrated Story of Diabetic Kidney Disease

Anatomy · Physiology · Disease · Biochemistry · Treatment, told simply

Anu, a first-year MBBS student, notices that her uncle's legs are swollen and takes him to her professor. Through their conversations she learns how the kidney is built and how it works, how years of uncontrolled sugar damage its filters, which tests pick up the damage, what targets protect it, and which tablets and insulin (with doses) keep it working.

The swollen legs › | Where the kidneys live › | Inside the kidney › | Ureter, bladder, urethra ›
The nephron › | Water, salts & waste › | Hormones of the kidney › | How sugar damages ›
Why legs swell › | Stages › | Biochemistry & tests › | Targets › | Lifestyle › | Kidney-protecting drugs ›
Diabetes tablets & insulin › | BP & other drugs › | Follow-up › | Summary › | Viva ›

TAP A TOPIC TO JUMP TO IT



ANATOMY
position · relations · nephron

PHYSIOLOGY
filtration · water · salts · hormones

DISEASE
diabetic kidney disease · stages

BIOCHEMISTRY
urea · creatinine · albumin · HbA1c

TREATMENT
targets · lifestyle · drugs & doses

SEE IT ONLINE · TAP TO OPEN

Kidney anatomy ↗ | The nephron ↗ | Countercurrent ↗ | Diabetic nephropathy ↗ | KDIGO guideline ↗ | eGFR calculator ↗

All links (visual atlas) ›



Conceptualised by

Dr. Gireesh Kumar K.P.

For first-year MBBS students, interns and teachers of integrated renal physiology

AETCM · ACADEMY FOR EMERGENCY, TRAUMA & CRITICAL CARE MEDICINE

The Kidney — An Integrated Story of Diabetic Kidney Disease

Anatomy · Physiology · Disease · Biochemistry · Treatment for First MBBS

Conceptualised by **Dr. Gireesh Kumar K.P.**

Academy for Emergency, Trauma & Critical care Medicine (AETCM) · First edition · November 2026

How to use this book

In the first year of MBBS you meet the kidney in the dissection hall (Anatomy), in the physiology classroom (filtration, water and salts) and in biochemistry (urea, creatinine, acid–base). Years later you meet it again, this time in a diabetic patient with swollen legs. In this book we have tried to put all of these together as **one story**, the story of Anu and her uncle.

The book follows the first-year way of thinking in five parts: **Anatomy** (Ch 2–4) tells you where things are, **Physiology** (Ch 5–7) how they work, **Disease** (Ch 8–10) what diabetes does to them, **Biochemistry** (Ch 11) which molecules we measure in blood and urine, and **Prevention & Treatment** (Ch 12–17) what we do about it.

Each chapter starts with a short **story box** where the professor talks to Anu. After that the science follows in plain words, with tables for revision and flowcharts you can draw in the exam. **Green boxes** are "remember" summaries; **amber boxes** are exam tips; **red boxes** are safety warnings. In the **Integration corner** you will see how the different subjects explain the same point.

Tap to see it

Small buttons such as ▶ Image ▶ Animation ▶ Guideline open free online pictures, animations and guidelines. A one-page visual atlas with QR codes is given at the end for the printed copy.

Unlike the Heart book, the treatment chapters here **do give usual adult doses**, because Anu wanted to understand her uncle's prescription. They are given for learning; always check the current formulary and individualise for the patient. Tags used: A Anatomy P Physiology B Biochemistry C Clinical bridge.

Contents

—	Foreword: from Dr. Gireesh Kumar K.P.	INTRODUCTION	3
1	The swollen legs: the story begins	THE STORY	4
2	Where the kidneys live: position, relations, coverings	ANATOMY	5
3	Inside the kidney: cross-section, ultrasound and blood supply	ANATOMY	7
4	The drainage pipes: ureter, bladder, urethra, micturition	ANATOMY	10
5	The nephron: one million tiny filters	PHYSIOLOGY	11
6	The cleaning plant: water, electrolytes, acid and waste	PHYSIOLOGY	13
7	More than a filter: hormones, anaemia and EPO	PHYSIOLOGY	15
8	When sugar damages the filter: diabetic kidney disease	DISEASE	17
9	Why Ammavan's (uncle's) legs swelled: oedema and proteinuria	DISEASE	19
10	How far has it gone?: stages of DKD and CKD	DISEASE	20
11	Biochemistry: finding the damage: tests, lab methods and results	BIOCHEMISTRY	22
12	Numbers to protect the kidney: targets and prevention	PREVENTION	24
13	The kitchen and the walk: lifestyle	PREVENTION	25
14	The four pillars: kidney-protecting drugs with doses	TREATMENT	26
15	Controlling the sugar: tablets and insulin in kidney disease	TREATMENT	28
16	BP, fluid, cholesterol and the rest	TREATMENT	30
17	Ammavan's (uncle's) prescription and follow-up plan	TREATMENT	31
18	The professor's summary: Anu explains, complications and thanks	REVISION	32
19	Viva questions with short answers	REVISION	35
—	Visual atlas: tap or scan	REVISION	37
—	Also by the author		38

FOREWORD

Foreword

From Dr. Gireesh Kumar K.P.



Dear first-year students,

India is often called the diabetes capital of the world. Walk into any medicine outpatient department in Kerala and you will meet a man or woman who has had “a little sugar” for ten or fifteen years, who took tablets when they felt like it, and who now comes with swollen feet, frothy urine and a creatinine report that worries everyone. Today diabetes is the commonest reason why Indians end up on dialysis.

What saddens me is that most of this damage is **silent and preventable**. A urine test done once a year picks up kidney damage years before the legs swell, and a few correctly chosen tablets, taken regularly, slow it down a great deal. Very often the medicine is available; the understanding is not. The patient does not know why the tablets matter, and the young doctor does not link the kidney she dissected in first year with the patient sitting in front of her.

In the emergency department I see the end of this story almost every week: the patient gasping with fluid in the lungs, the potassium of 7.5, the first emergency dialysis at midnight. I wanted first-year students to see the **beginning** of the story, when something can still be done.

That is why I have written it as a story. Anu, a first-year student, sees her uncle’s swollen legs and asks a simple question: “What is happening inside his kidneys?” Her professor answers the way I wish all of us would teach. He starts with the kidney in the abdomen, goes on to the nephron and its many jobs, and then explains how sugar slowly harms the filter, how we find the damage, what targets we aim for, and which tablets and insulin protect the kidney, with their usual doses.

Please read it slowly and draw the nephron yourself. When you see a diabetic patient in the wards, look at the urine report a little more carefully. And once you are a doctor, make it a habit to ask every person with diabetes, **“When was your urine albumin last checked?”** I have seen that one question save many kidneys.

I thank my colleagues in Anatomy, Physiology, Biochemistry, Medicine and Nephrology, whose integrated teaching shaped this book, and the AETCM team for bringing it to you. Suggestions from students and teachers are always welcome.

With best wishes for a wonderful journey into medicine,

Dr. Gireesh Kumar K.P.
Academy for Emergency, Trauma & Critical care Medicine (AETCM)
November 2026

The three questions for every page

- **Where is it?** The anatomy of the kidney and urinary tract.
- **How does it work?** Filtration, reabsorption and hormones.
- **What goes wrong, and how do we protect it?** Diabetic kidney disease, tests, targets and treatment.

CHAPTER 1 · THE STORY BEGINS

The Swollen Legs

A vacation visit, a worried niece and a patient professor

📖 **Onam vacation, Kottayam**

*Anu had just finished her first three months of MBBS. During the Onam vacation she visited her uncle, **Suresh Ammavan** ("Ammavan" means uncle in Malayalam), 58 years, a retired KSRTC conductor. As he sat on the veranda with his mundu (dhoti) folded up, she noticed that both his legs were swollen. When she pressed his shin with her thumb, a dent stayed behind for several seconds. "It's nothing, mole (dear)," he laughed. "The sugar has been there for fourteen years. I take the tablets when I remember." He also told her that his urine had become frothy, he got up twice at night to pass urine, and that he took a "pain tablet" from the medical shop for his knees almost every day.*



Figure 1.1. Anu presses her uncle's swollen shin at home. The dent that stays behind (pitting oedema) is where our story begins.

*After the vacation Anu brought him to her college hospital to see her **Professor of Medicine**. He examined Ammavan (uncle), looked into his eyes with an ophthalmoscope and said, "This is most probably **diabetic nephropathy**, that is, diabetic kidney disease." Anu did not follow a word of it. "Sir, can you explain it from the beginning?" she asked. The professor smiled and pulled up a chair for her. "All right, sit down. We will start with two small organs at the back of your abdomen."*

To understand what happened to Ammavan (uncle), Anu will need all four of her subjects: **Anatomy** (where the kidneys are and what they look like inside), **Physiology** (how the nephron filters blood and keeps water and salts in balance), **Biochemistry** (how sugar damages proteins and blood vessels, and what urea and creatinine are), and the **Clinical bridge** (how we test, set targets and treat).

Lens	Question it answers	In Ammavan's (uncle's) kidneys
A **Anatomy**	Where? Which structure?	The damage is in the **glomeruli**; the tiny filters inside both kidneys; the kidneys still look normal in size on ultrasound
P **Physiology**	What stopped working?	The filter has become leaky (protein in urine) and is slowly losing its filtering power (falling GFR); salt and water are being retained → swelling

B Biochemistry	What happens in the molecules?	Years of high glucose → sugar sticks to proteins (glycation, AGEs), damages the filter membrane and podocytes; albumin leaks; creatinine and urea rise
C Clinical bridge	What does the doctor do?	Measure urine albumin and eGFR; control sugar, BP and cholesterol; give kidney-protecting drugs (ARB, SGLT2 inhibitor); stop the painkillers

The kidney in one paragraph

The kidneys are two bean-shaped organs, each about the size of your fist (**11 × 6 × 3 cm, about 150 g**), lying on the back wall of the abdomen on either side of the spine. Together they receive **one-fifth to one-quarter of all the blood the heart pumps**, which is about 1.2 litres every minute. Every day they filter about **180 litres** of plasma, take back almost everything useful, and send out only about **1.5 litres** of urine carrying waste, extra salt, extra water and acid. They also make hormones that control blood pressure, red cell production and bone health. All this work is done by about **one million nephrons** in each kidney, and these are the nephrons that diabetes slowly destroys.

Ammavan (uncle) at a glance	
Age / job	58 years, retired bus conductor
Diabetes	Type 2, 14 years; tablets irregular
Complaints	Swollen legs 2 months, frothy urine, nocturia, tiredness
Habits	Daily painkiller (diclofenac) for knee pain; smokes 5 beedis/day; extra salt, pickle and pappadam
Examination	BP 168/100 mmHg; weight 78 kg; pitting oedema up to mid-shin; **pale, anaemic (Hb 10.8 g/dL)**; fundus shows diabetic retinopathy

Remember the four big ideas

- **Structure decides function.** The glomerulus is a filter with three layers, and damage to any layer lets protein leak.
- **Albumin in the urine is the earliest warning.** It appears years before creatinine rises or the legs swell.
- **Diabetic kidney disease rarely comes alone.** The eyes (retinopathy), nerves and heart are usually affected too.
- **It can be slowed.** Control of sugar, BP and lipids, along with four kidney-protecting drug groups, can delay dialysis by many years.

CHAPTER 2 · ANATOMY

Where the Kidneys Live

Position, relations, coverings and surface marking

📖 "Point to your kidneys, Anu"

*Anu put her hands on her waist, in front. The professor laughed. "Everyone points there, and everyone is wrong. Put your hands on your **back**, just below the last ribs. Your kidneys are there, behind the intestines, against the back muscles and partly covered by the lower ribs. We call them **retroperitoneal**, meaning they lie behind the lining of the abdomen."*

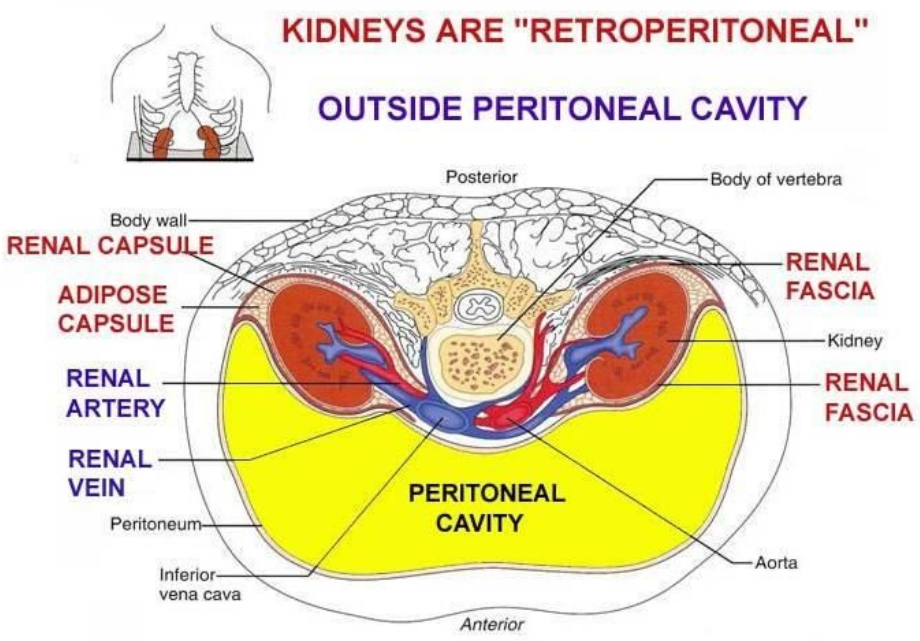


Figure 2.1. Cross-section of the abdomen at the level of the kidneys: the kidneys lie **behind the peritoneal cavity** (retroperitoneal), on either side of the vertebra, wrapped in the renal capsule, adipose (perirenal fat) capsule and renal fascia; the renal vein drains to the IVC and the renal artery arises from the aorta

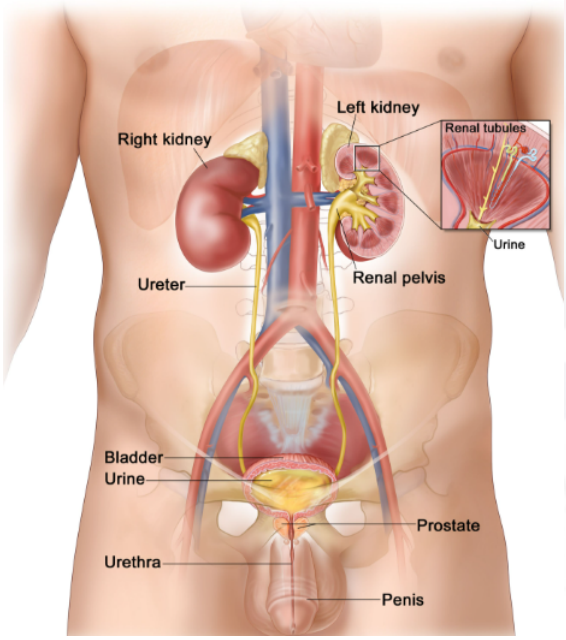


Figure 2.2. The urinary system: kidneys, ureters, bladder, prostate and urethra (male). Note the renal tubules (inset) where urine is made.

▶ Image

A The kidneys lie on the **posterior abdominal wall**, one on each side of the vertebral column, from about **T12 to L3**. The **right kidney is about 1–2 cm lower** than the left because the large liver sits above it. Each kidney has an upper and lower pole, a convex lateral border and a concave medial border with a slit called the **hilum**.

At the hilum, structures enter and leave in a fixed order from front to back: **Vein – Artery – Pelvis (V-A-P)**. The renal pelvis continues down as the ureter.

The **hilum** lies about 5 cm from the midline at the level of **L1 (transpyloric plane)**. The upper pole of each kidney carries the **adrenal (suprarenal) gland** like a cap.

> **Exam tip: the renal angle**
>
> The angle between the 12th rib and the lateral border of the erector spinae is the **renal angle**. Tenderness here (punch tenderness) suggests kidney infection (pyelonephritis) or stone.

Relations of the kidneys: the neighbours

Surface	Right kidney	Left kidney
Anterior	Suprarenal gland, liver, 2nd part of duodenum, hepatic flexure of colon, small intestine	Suprarenal gland, stomach, spleen, pancreas (tail) with splenic vessels, splenic flexure and descending colon, jejunum
Posterior (both)	Diaphragm (upper part, with 12th rib, and the pleura behind it!), psoas major, quadratus lumborum, transversus abdominis; subcostal, iliohypogastric and ilioinguinal nerves	

Coverings: from inside out

Layer	What it is	Clinical bridge
Fibrous (true) capsule	Thin tough membrane stuck to the kidney surface	Stretching it causes the dull loin ache of kidney swelling
Perirenal fat	Fat cushion around kidney and hilum	Loss of fat in starvation → kidney may drop (nephroptosis)
Renal (Gerota's) fascia	Fascial envelope enclosing kidney and adrenal	Limits spread of blood or pus around the kidney
Pararenal fat	Fat outside the fascia, more behind	—

ANATOMY

Upper pole lies against the diaphragm, behind the 11th–12th ribs.

PHYSIOLOGY

Kidneys move 2–3 cm up and down with breathing.

CLINICAL

For a kidney biopsy the patient lies **prone**; the needle goes into the lower pole while the patient holds the breath, well away from the pleura.



Figure 2.3. The two kidneys on either side of the spine, with the renal vessels joining the aorta and IVC and the ureters running down

CHAPTER 3 · ANATOMY

Inside the Kidney

The cut surface, the collecting system and the blood supply

📖 **Cutting the bean in half**

*"Cut a kidney lengthwise, the way you split a bean," said the professor, "and you will see three zones. Outside is the pale **cortex**. Inside it is the darker **medulla**, made of triangles called pyramids. In the centre is a funnel, the **pelvis**, which collects the urine much like the funnel in a coconut-oil mill."*

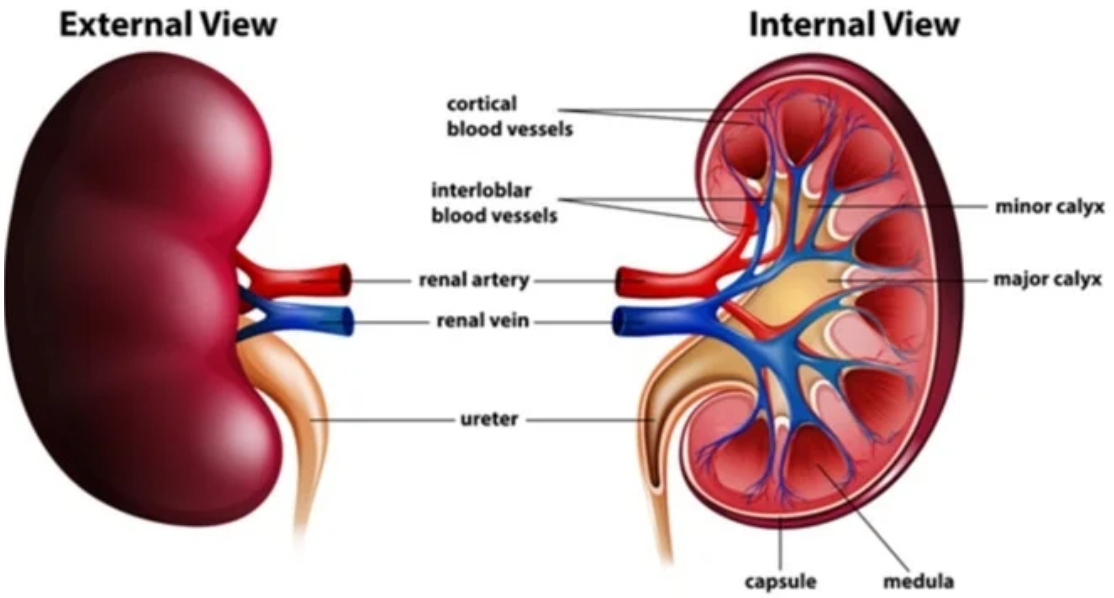


Figure 3.1. External view (left) and internal (coronal) view (right): cortex, medulla, minor and major calyces, renal pelvis, and the branching arteries and veins

Part	What it is	What happens there
Cortex	Outer 1 cm; extends between pyramids as **renal columns**	All glomeruli, proximal and distal tubules; **filtration** happens here
Medulla	8–18 cone-shaped **pyramids**, base towards cortex	Loops of Henle and collecting ducts; **concentration** of urine
Papilla	Tip of each pyramid	Urine drips out through tiny openings
Minor calyx → major calyx	Cups around papillae (7–13) join to form 2–3 major calyces	Collect urine; papillary necrosis (in diabetics on painkillers!) can block them
Renal pelvis	Funnel formed by major calyces	Continues as the ureter at the pelvi-ureteric junction

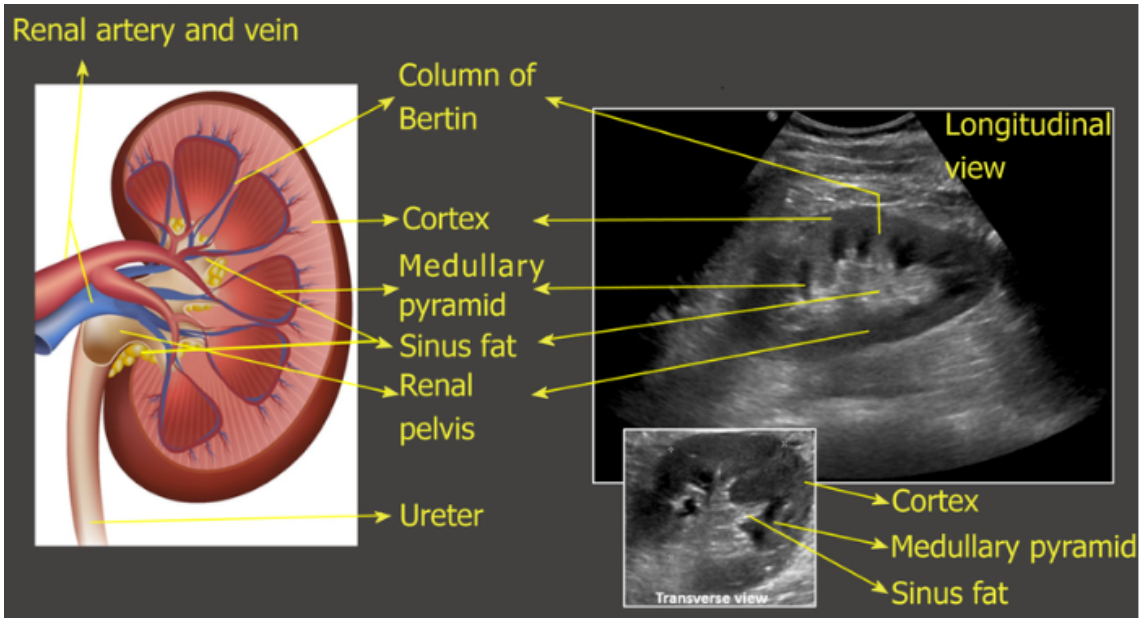


Figure 3.2. The same structures on ultrasound (longitudinal and transverse views): bright sinus fat in the centre, dark medullary pyramids, the cortex around them and the columns of Bertin between pyramids. In DKD the kidneys are usually normal or large, with a brighter (more echogenic) cortex.

The blood supply: a tree with special branches

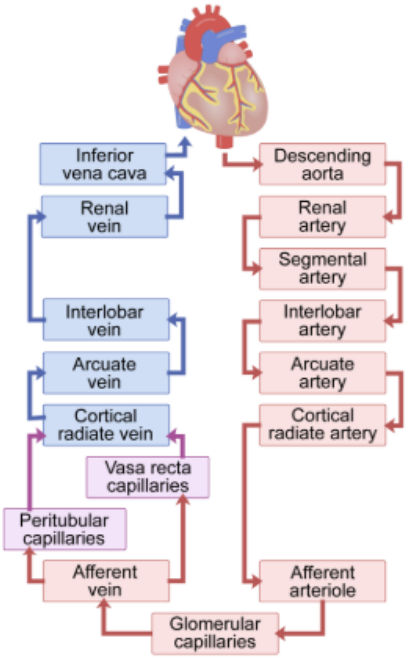


Figure 3.3. Renal circulation: aorta → renal artery → segmental → interlobar → arcuate → cortical radiate → afferent arteriole → glomerular capillaries → efferent arteriole → peritubular capillaries / vasa recta → veins → IVC

Vessel	Key point
Renal artery	From aorta at L1–L2; right one passes behind the IVC
Segmental (5)	**End arteries**; block one and a wedge infarcts
Interlobar → arcuate → cortical radiate	Run between pyramids, arch at the cortico-medullary junction, then climb into the cortex
Afferent arteriole	Brings blood to the glomerulus; renin made here (JG cells)
Glomerular capillaries	1st capillary bed; **filtration**
Efferent arteriole	The “tap” that sets glomerular pressure
Peritubular capillaries / vasa recta	2nd capillary bed; **reabsorption**; keep the medulla salty

Why two capillary beds?

The **glomerular capillaries** work at high pressure (~55 mmHg) to filter; the **peritubular capillaries** work at low pressure with high oncotic pressure to take fluid back. The **vasa recta** run alongside the loops of Henle and keep the medulla salty.

ANATOMY

Segmental arteries are **end arteries**. If one is blocked, a wedge of kidney dies (infarct).

PHYSIOLOGY

Kidneys get ~**20–25% of cardiac output** (1.2 L/min) though they are only 0.5% of body weight. The blood is there for filtering, not for the kidney’s own oxygen needs.

CLINICAL

The **efferent arteriole** is the “tap” that sets glomerular pressure. Angiotensin II tightens it and ACE inhibitors/ARBs loosen it. Keep this in mind for Chapter 14.

Remember

The left renal vein is longer and crosses **in front of the aorta** (below the superior mesenteric artery); it receives the left gonadal and left suprarenal veins. The right renal artery is longer and passes **behind the IVC**. Accessory renal arteries are common (~25%).

The Drainage Pipes

Ureter, urinary bladder and urethra, and why diabetics get urinary problems

📖 **"Why does Ammavan (uncle) get up at night?"**

"The kidney makes the urine," the professor went on, "but the urine still has to travel. It goes down two thin pipes into a storage tank, and then out through one last tube. Ammavan's (uncle's) nerves have also been touched by sugar, so even his bladder does not empty as well as it should."

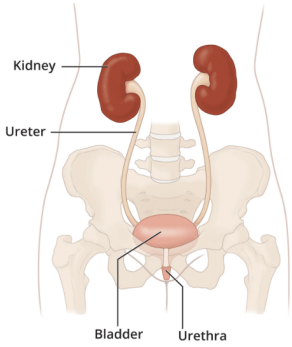


Figure 4.1. The urinary tract

Organ	Key anatomy	Function and clinical bridge
Ureter	25–30 cm muscular tube, half abdominal and half pelvic; runs on psoas, crosses the **bifurcation of the common iliac artery**, enters bladder obliquely. **Three narrow points**: pelvi-ureteric junction, pelvic brim, uretero-vesical junction	Peristalsis (1–5 waves/min) pushes urine down. Stones stick at the narrow points → **colicky "loin to groin" pain**. Oblique entry acts as a valve that prevents reflux
Bladder	Hollow muscular sac behind the pubic symphysis; muscle = **detrusor**; smooth triangle at the base = **trigone** (two ureteric openings + internal urethral opening)	Stores 400–500 mL; urge felt at ~150–300 mL. Lies in the pelvis when empty, rises into the abdomen when full (palpable in retention)
Urethra (male)	~20 cm: prostatic, membranous (narrowest, passes through external sphincter), spongy (penile) parts	Enlarged prostate in older men compresses the prostatic urethra → poor stream, nocturia, retention
Urethra (female)	~4 cm, opens in front of the vagina	Short → urinary tract infections (UTIs) more common in women

Micturition reflex: how we pass urine

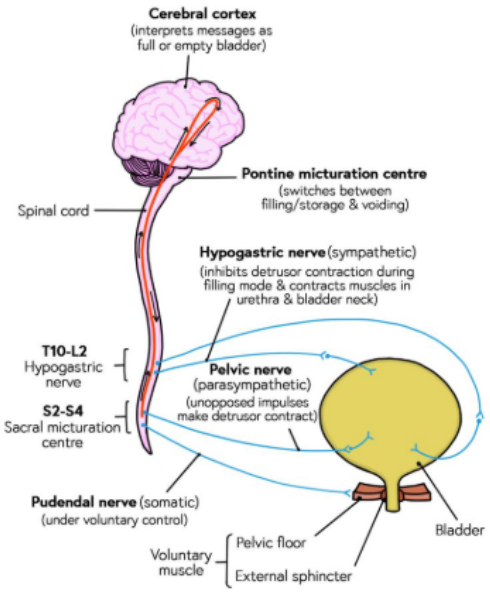


Figure 4.2. Neural control of the bladder: cortex, pontine micturition centre, sacral centre (S2–S4), hypogastric (sympathetic), pelvic (parasympathetic) and pudendal (somatic) nerves

Bladder fills → stretch receptors fire

↓

Pelvic nerves → sacral centre (S2–S4)

↓

Pontine micturition centre + cortex decide "now"

↓

Parasympathetic → detrusor contracts

↓

Internal sphincter opens; pudendal nerve relaxes external sphincter

During filling, the **hypogastric (sympathetic, T10–L2)** nerve relaxes the detrusor and tightens the bladder neck; the pudendal nerve keeps the external sphincter closed.

ANATOMY

Nerve supply: parasympathetic S2–S4 (empties), sympathetic T11–L2 (stores), pudendal S2–S4 (voluntary control).

PHYSIOLOGY

Bladder is a **low-pressure** store: its pressure stays low till ~400 mL because smooth muscle stretches (plasticity).

CLINICAL: DIABETIC CYSTOPATHY

Autonomic neuropathy reduces bladder sensation → large residual urine → **UTIs** and back-pressure. Check post-void residue in long-standing diabetics.

Why urinary infection matters more in diabetes

- Glucose in urine feeds bacteria and fungi; immunity is weaker.
- Infections may go up to the kidney (pyelonephritis), form abscesses or cause **emphysematous pyelonephritis**, which is seen almost only in diabetics.
- Painkiller (NSAID) use + diabetes → **papillary necrosis**: a dead papilla can fall off and block the ureter.
- SGLT2 inhibitors (Chapter 14) increase genital fungal infections, so teach genital hygiene.

Remember

Kidney → minor calyx → major calyx → pelvis → ureter → bladder → urethra. Anything that blocks this path (stone, prostate, neurogenic bladder) raises back-pressure and can itself damage the kidney (**obstructive uropathy**). Always ask about urinary stream in an old diabetic man.

CHAPTER 5 · ANATOMY & PHYSIOLOGY

The Nephron: One Million Tiny Filters

Structure, the filtration barrier, GFR and the juxtaglomerular apparatus

📖 The water purification plant

*"Imagine the water purification plant of a town," said the professor. "Each kidney is like that, with a million small units working side by side. Each unit is a **nephron**. At the top it has a sieve, the **glomerulus**. After that comes a long, twisted pipe, the **tubule**, where the workers take back everything useful from the filtered water. Whatever is left at the end is urine."*

AETCM
Academy for Emergency, Trauma & Critical care Medicine

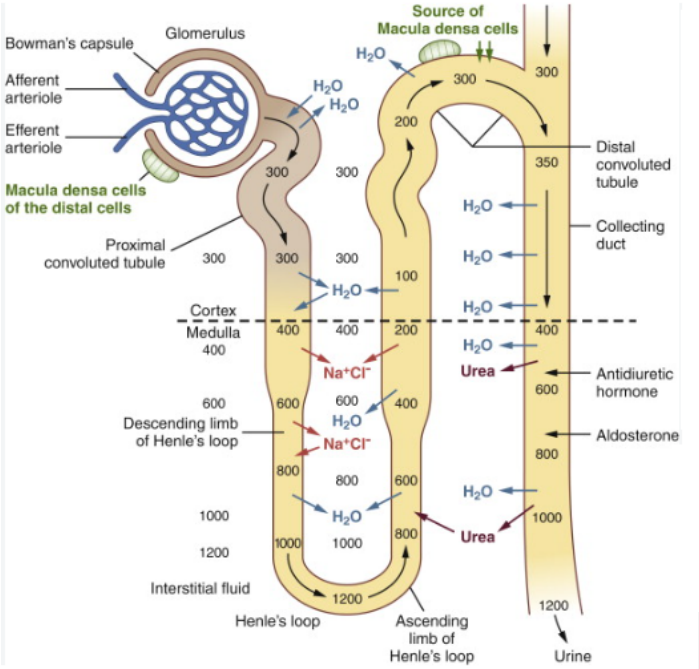


Figure 5.1. The nephron: glomerulus in Bowman's capsule, proximal tubule, loop of Henle, distal tubule and collecting duct. Numbers show osmolality (mOsm/kg) rising deep into the medulla. ▶ Animation

Part	Main job
Glomerulus + Bowman's capsule (renal corpuscle)	Filters plasma: water and small molecules pass; cells and big proteins stay
Proximal convoluted tubule (PCT)	Takes back ~65% of Na^+ and water, **all glucose** and amino acids, most bicarbonate
Loop of Henle	Makes the medulla salty (countercurrent) so urine can be concentrated
Distal convoluted tubule (DCT)	Fine-tunes Na^+, Ca^{2+} (PTH); macula densa senses salt
Collecting duct	Final control of water (ADH), Na^+/K^+ (aldosterone) and acid

Two types: cortical nephrons (85%, short loops) and **juxtamedullary nephrons** (15%, long loops dipping deep into the medulla; these concentrate the urine).

The filtration barrier: three layers, two kinds of sieve

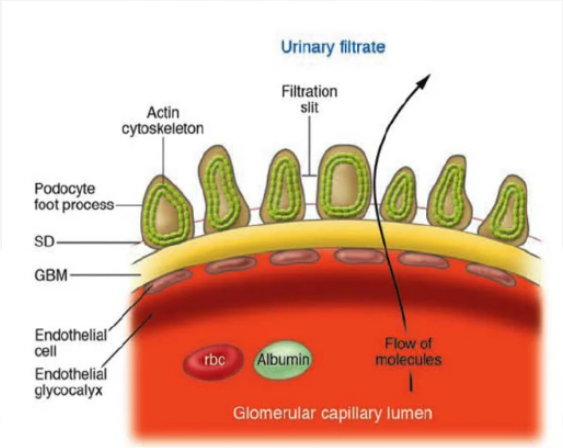


Figure 5.2. The glomerular filtration barrier: endothelial cell with its glycocalyx, glomerular basement membrane (GBM), and podocyte foot processes joined by slit diaphragms (SD). Water and small molecules pass into the urinary filtrate; red cells and albumin stay in the capillary. ▶ Image

Layer	Structure	What it stops, and what goes wrong in diabetes
1. Capillary endothelium	Fenestrated (holes 70–100 nm)	Stops blood cells. Damaged by high glucose and inflammation
2. Glomerular basement membrane (GBM)	Type IV collagen, laminin and **negatively charged heparan sulphate** B	Stops proteins by **size and charge**; albumin is negative and is repelled. In diabetes the GBM **thickens** but loses negative charge → albumin leaks
3. Podocytes (visceral epithelium)	Foot processes with **slit diaphragms** (protein nephrin)	The final, finest sieve. Diabetes makes podocytes flatten and fall off; loss of podocytes means heavy proteinuria

GFR: how much is filtered?

P The **glomerular filtration rate (GFR)** is the volume of plasma filtered by both kidneys per minute: normally about **125 mL/min (180 L/day)** in a young adult. It falls by roughly 1 mL/min every year after 40. Filtration is driven by Starling forces across the glomerular capillary:

Glomerular capillary hydrostatic pressure ≈ 55 mmHg pushes OUT
−
Bowman's space pressure ≈ 15 mmHg pushes back
−
Plasma oncotic pressure ≈ 30 mmHg pulls back
=
Net filtration ≈ 10 mmHg

After filtration: how much remains along the tubule

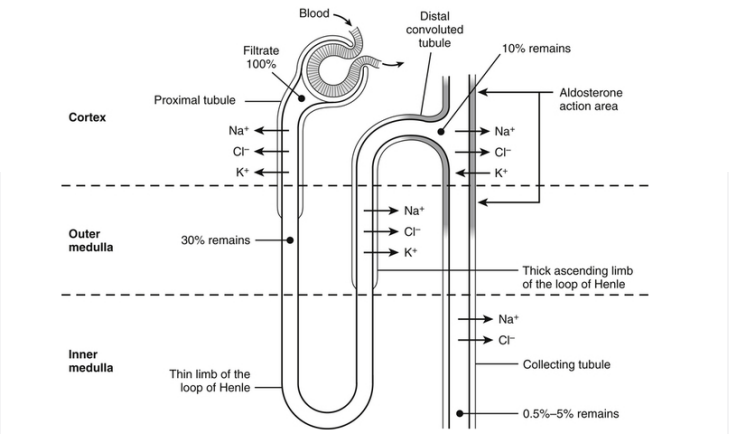


Figure 5.3. Salt handling along the nephron: 100% of filtrate enters the proximal tubule, only ~30% remains after it, ~10% reaches the distal tubule, and just 0.5–5% is left in the collecting tubule. Aldosterone fine-tunes Na^+ and K^+ in the late distal and collecting tubules (details in Chapter 6).

JUXTAGLOMERULAR APPARATUS
Where the DCT touches its own afferent arteriole: **macula densa** (salt sensor), **JG cells** (make renin) and lacis cells.
▶ Image

TUBULOGLOMERULAR FEEDBACK
Much salt reaching the macula densa → afferent arteriole constricts → GFR falls back to normal. This protects the glomerulus from high pressure.

CLINICAL
In diabetes this feedback is switched off (Chapter 8), and **SGLT2 inhibitors switch it back on**. This is how they protect the kidney.

Exam tip: autoregulation

GFR and renal blood flow stay nearly constant between mean arterial pressures of about **80 and 180 mmHg**, by two mechanisms: the **myogenic response** (afferent arteriole constricts when stretched) and **tubuloglomerular feedback**. Hypertension and diabetes blunt both, so high systemic BP reaches the glomerulus directly.

CHAPTER 6 · PHYSIOLOGY & BIOCHEMISTRY

The Cleaning Plant

Water, electrolytes, acid–base balance and removal of waste

📖 180 litres a day

*"Anu, how much water do you drink in a day?" "About two litres, sir." "Your kidneys filter **180 litres** of plasma every day. That is your whole plasma, about 60 times over. But you pass only one and a half litres of urine. So where does the rest go?" Anu thought for a moment. "It is taken back?" "Correct. The kidney filters, yes, but most of its work is **recycling**."*

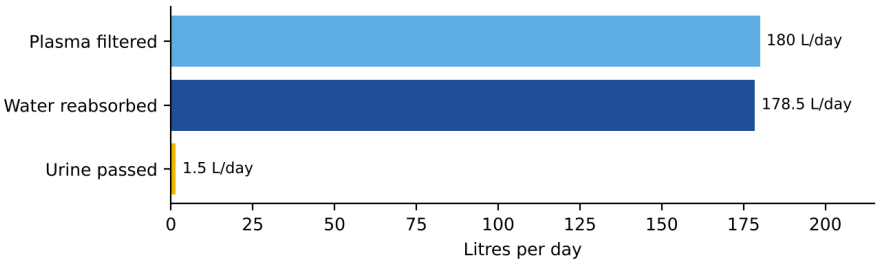


Figure 6.1. The kidney's daily numbers: 180 L filtered, over 99% of water reabsorbed, ~1.5 L passed as urine

1. Sodium and water: where each is taken back

Segment	% Na^+ taken back	Main transporter	Hormone control	Drug that acts here
PCT	~65%	Na^+/H^+ exchanger; **SGLT2** (Na^+ + glucose)	Angiotensin II	**SGLT2 inhibitors** (dapagliflozin); acetazolamide
Thick ascending limb	~25%	**Na^+–K^+–2Cl^-** co-transporter (NKCC2); water cannot follow	—	**Loop diuretics** (furosemide, torsemide)
DCT	~5%	**Na^+–Cl^-** co-transporter (NCC)	PTH (Ca^{2+})	**Thiazides** (chlorthalidone, indapamide)
Collecting duct	2–3%	Epithelial Na^+ channel (ENaC); **aquaporin-2** for water	**Aldosterone** (Na^+ in, K^+ out); **ADH** (water)	Spironolactone, **finerenone**, amiloride

P **Concentrating urine:** the thick ascending limb pumps salt out but is impermeable to water, so the deep medulla becomes very salty (up to 1200 mOsm/kg; Figure 5.1). When **ADH** puts aquaporin-2 channels into the collecting duct, water is pulled out into this salty medulla and urine becomes concentrated. This is the **countercurrent mechanism**; urea recycling adds to it. ▶ Animation

2. Potassium, calcium, phosphate and magnesium

Ion	How the kidney handles it	When the kidney fails
Potassium (K^+)	Almost all filtered K^+ is reabsorbed early; what appears in urine is **secreted** in the collecting duct under aldosterone	**Hyperkalaemia**; worsened by ACEi/ARB, MRA, NSAIDs; can stop the heart
Calcium (Ca^{2+})	Reabsorbed in PCT, loop, and DCT (under PTH)	Low Ca^{2+} (less active vitamin D)
Phosphate	Reabsorbed in PCT; PTH and FGF-23 increase excretion	High phosphate → secondary hyperparathyroidism, bone disease
Magnesium	Mostly in the thick ascending limb	Usually retained in late CKD

3. Acid–base: the kidney as the body's acid outlet

B Every day metabolism of protein produces about **50–100 mmol of fixed acid** (sulphuric, phosphoric) that the lungs cannot breathe out. The kidney handles it in three ways: it **reabsorbs almost all filtered bicarbonate** (mainly in the PCT, using carbonic anhydrase), it **secretes H^+** which is buffered by phosphate (titratable acid), and it makes **ammonia from glutamine**, and NH_4^+ carries the acid away in urine. Each H^+ excreted creates a new HCO_3^- for the blood. In chronic kidney disease less ammonia is made, bicarbonate falls, and the result is **metabolic acidosis**.

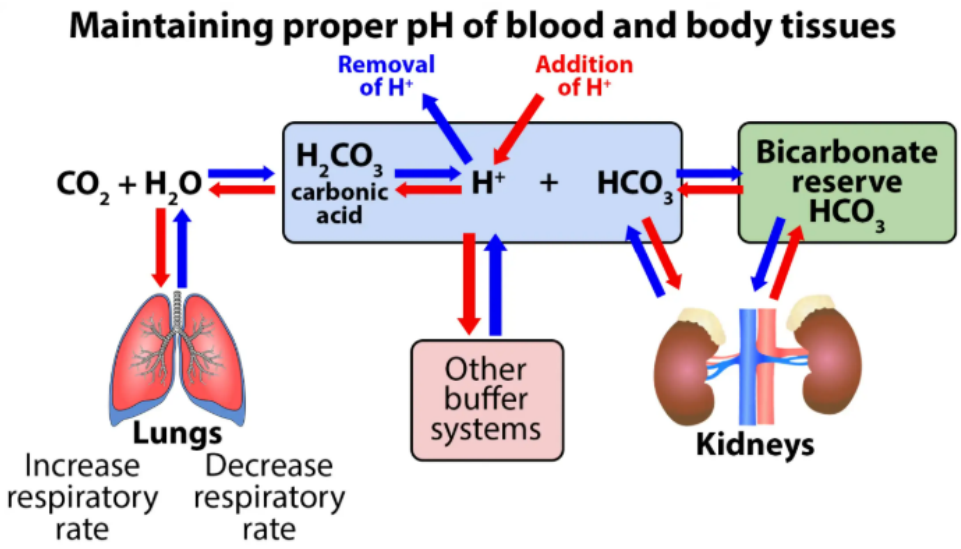


Figure 6.2. Three lines of defence for blood pH: buffers act in seconds, the lungs adjust CO_2 in minutes, and the kidneys remove H^+ and rebuild the bicarbonate reserve over hours to days

4. Waste products: the chemistry of urea and creatinine

Waste	Where it comes from B	Normal blood level	Teaching point
Urea	Made in the **liver** by the urea cycle from ammonia of protein breakdown	15–40 mg/dL (BUN 7–20)	Rises with high protein, GI bleed, dehydration; not only kidney failure
Creatinine	Made at a steady rate from **creatine phosphate** in muscle	0.6–1.2 mg/dL	Filtered, hardly reabsorbed → best simple marker of GFR. Depends on muscle mass
Uric acid	End product of **purine** breakdown	3.5–7 mg/dL	Rises in CKD; gout. SGLT2 inhibitors lower it
Drugs & toxins	Water-soluble drugs and metabolites	—	Many drugs need dose reduction in CKD (Chapter 15)

PHYSIOLOGY: GLUCOSE THRESHOLD

SGLT2 (PCT, 90%) and SGLT1 take back all filtered glucose up to a **renal threshold of ~180 mg/dL** (transport maximum ~375 mg/min).

BIOCHEMISTRY

Above that, glucose spills into urine (**glycosuria**) and pulls water with it. This is the cause of polyuria and thirst in uncontrolled diabetes.

CLINICAL

In diabetes, SGLT2 transporters **increase**, so the kidney takes back even more sugar and salt. Blocking them lowers glucose and protects the kidney.

CHAPTER 7 · PHYSIOLOGY & BIOCHEMISTRY

More Than a Filter

The kidney as an endocrine organ, and why failing kidneys cause anaemia, high BP and weak bones

📖 **"Why is Ammavan (uncle) pale?"**

*Anu had noticed that Ammavan's (uncle's) eyelids looked pale. "His haemoglobin is 10.8," said the professor. "Diabetes itself does not cause anaemia. The kidney, though, makes a hormone that tells the bone marrow to produce red cells, and a damaged kidney makes less of it. So you see, the kidney is also a **hormone factory**."*



Figure 7.1. Pallor. When the lower eyelids are pulled down, the conjunctiva looks pale instead of the normal pink-red. This is the bedside sign of anaemia that Anu noticed in Ammavan (uncle).

Job	How it works	When kidneys fail
Renin → BP and salt control	JG cells release renin when BP falls, salt delivery falls or sympathetic tone rises (RAAS below)	Hypertension, salt and water retention
Erythropoietin (EPO)	Made by peritubular interstitial cells when they sense low oxygen → stimulates red cell production in the marrow	**Anaemia of CKD** (normocytic, normochromic); earlier and worse in diabetics
Activating vitamin D B	PCT enzyme **1α-hydroxylase** converts 25-OH vitamin D to **1,25-$(OH)_2$ vitamin D (calcitriol)**	Low calcium, high phosphate, high PTH → **CKD–mineral bone disease**
Gluconeogenesis B	Kidney cortex makes glucose from lactate, glutamine, glycerol; up to 20–25% of glucose during fasting	Less glucose production → **hypoglycaemia risk**
Breaking down insulin	Kidney removes and degrades ~30–40% of circulating insulin	Insulin and sulfonylureas last longer → **more hypos; insulin doses must fall**
Prostaglandins	PGE_2 and PGI_2 dilate the afferent arteriole and keep GFR up when blood flow is threatened	**NSAIDs** block them → sudden fall in GFR (Ammavan's (uncle's) diclofenac!)

Treating Ammavan's (uncle's) anaemia, and a note on erythropoietin (EPO) therapy

- **Check iron first.** Many CKD patients are also iron deficient. Give iron until ferritin is > 100 ng/mL and transferrin saturation > 20%. Use oral iron, or IV iron (iron sucrose, ferric carboxymaltose) if oral iron fails or is not tolerated.
- **Start EPO** (recombinant human erythropoietin) when Hb stays **< 10 g/dL** despite enough iron, after excluding bleeding, B12/folate deficiency and infection.
- **Dose:** epoetin alfa/beta **50–100 IU/kg/week SC**, in 1–3 divided doses (e.g. 4,000 IU once or twice weekly); long-acting **darbepoetin 0.45 µg/kg once weekly** (or every 2 weeks). Check Hb every 2–4 weeks and adjust by ~25%.
- **Target Hb 10–11.5 g/dL, never above 13.** Pushing Hb to normal increases stroke, thrombosis and BP.
- **Side-effects:** rise in BP, clotting of AV fistula, headache; rarely pure red cell aplasia (antibodies to EPO). Poor response → think iron deficiency, infection, bleeding, hyperparathyroidism.
- **Ammavan (uncle)** (Hb 10.8, ferritin 62): iron first; EPO only if Hb falls below 10 despite iron. Newer oral **HIF-prolyl hydroxylase inhibitors** (e.g. desidustat, approved in India) make the kidney produce its own EPO; they are an option under specialist care.

The renin–angiotensin–aldosterone system (RAAS)

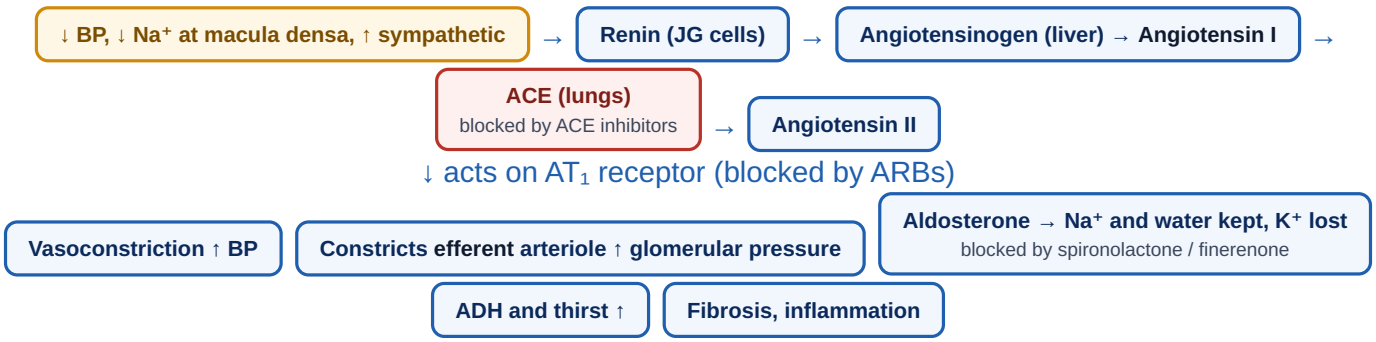


Figure 7.2. RAAS and the points where kidney-protecting drugs act. ▶ Image

Other hormones that act on the kidney

Hormone	From	Action on kidney
ADH (vasopressin)	Posterior pituitary	Aquaporin-2 in collecting duct → water retained, concentrated urine
Aldosterone	Adrenal cortex (zona glomerulosa)	Na^+ reabsorption and K^+/H^+ secretion in collecting duct
ANP / BNP	Atria / ventricles when stretched	Increase GFR and Na^+ excretion; inhibit renin; the body's own diuretic
PTH	Parathyroid glands	↑ Ca^{2+} reabsorption, ↑ phosphate excretion, ↑ 1α-hydroxylase

Remember: "A WET BED" for the kidney's jobs

Acid–base balance · **W**ater balance · **E**lectrolyte balance · **T**oxin and waste removal · **B**lood pressure control (renin) · **E**rythropoietin · vitamin **D** activation. Every feature of chronic kidney disease is simply one of these jobs failing.

CHAPTER 8 · THE DISEASE

When Sugar Damages the Filter

Diabetic kidney disease: definition, risk factors, how it happens and what the pathologist sees

📖 Sugar is sticky

"If you boil sugar syrup in a steel vessel every day and never wash it, what happens?" asked the professor. "It gets coated and sticky. Fourteen years of high sugar have done much the same to the tiny vessels in Ammavan's (uncle's) kidneys and eyes. His filter is now thick, stiff and leaky, and the pressure inside it is too high."

C **Diabetic kidney disease (DKD)**, also called diabetic nephropathy, is chronic kidney disease in a person with diabetes, shown by **persistently raised urine albumin (UACR ≥ 30 mg/g)** and/or **reduced eGFR (< 60 mL/min/1.73 m²)** for more than 3 months, without another cause. It develops in roughly **30–40% of people with diabetes** and is the leading cause of kidney failure and dialysis in India and worldwide. ▶ Read more

Risk factors you cannot change	Risk factors you CAN change (Ammavan (uncle) had most of them)
Long duration of diabetes · family history of DKD or hypertension · genetic factors · South Asian ethnicity · older age	Poor sugar control (HbA1c) · **high BP** · smoking · obesity · high LDL and triglycerides · high-salt and high-protein diet · **NSAID painkillers** · repeated urinary infections

How it happens: three roads to one damaged kidney

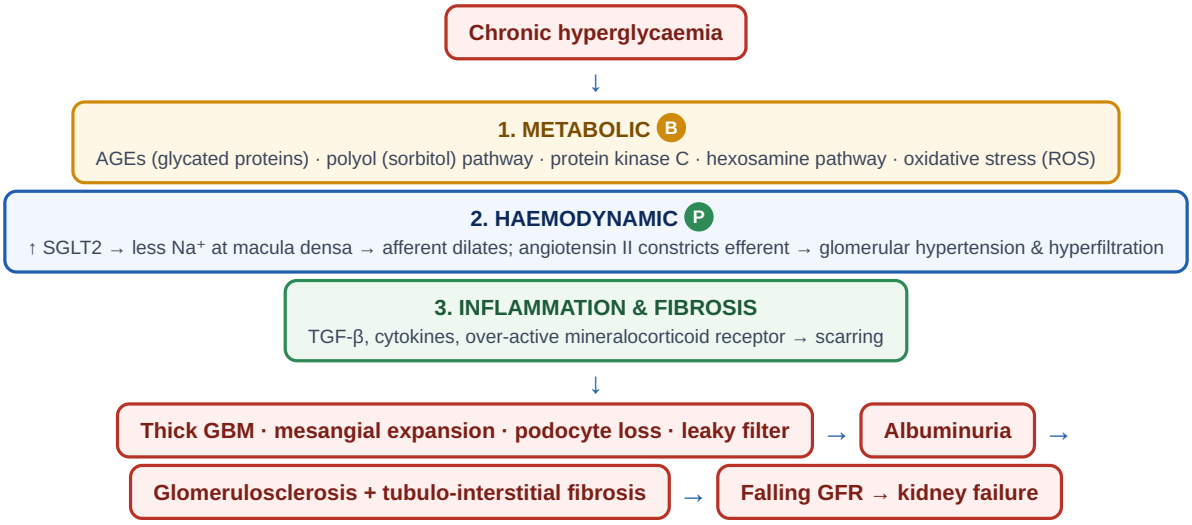
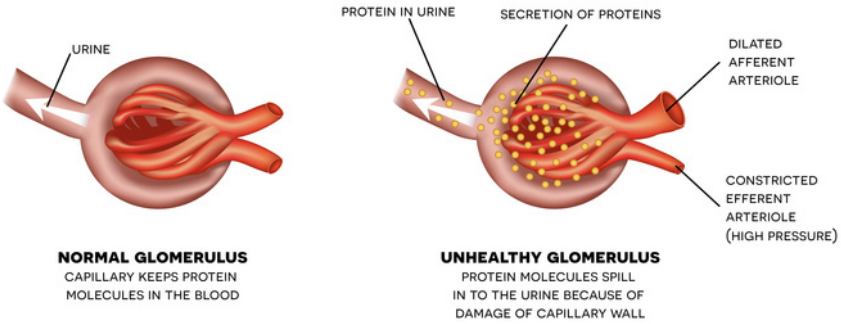


Figure 8.1. Pathogenesis of diabetic kidney disease. Each road has a drug that blocks it (Chapter 14).



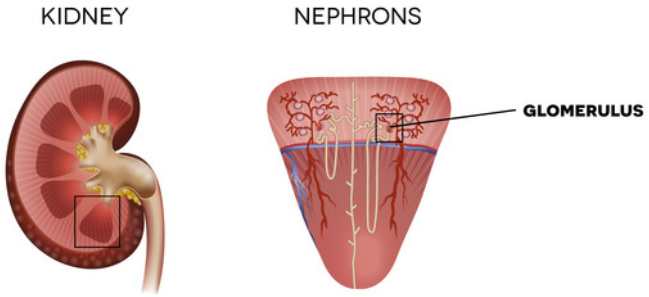


Figure 8.2. Normal glomerulus keeps protein in the blood; the damaged glomerulus (dilated afferent, constricted efferent → high pressure) lets protein spill into urine

What the pathologist sees	Meaning
GBM thickening (earliest)	Extra matrix laid down by glycation and TGF-β
Diffuse mesangial expansion	Mesangium swells and squeezes the capillaries
Kimmelstiel–Wilson nodules	Round pink nodules (nodular glomerulosclerosis), **pathognomonic** of diabetic nephropathy
Hyaline arteriolosclerosis	Of **both afferent and efferent** arterioles (efferent involvement is typical of diabetes)
Tubular atrophy, interstitial fibrosis	Best predictor of falling GFR

Eyes and kidneys go together: the microvascular triad

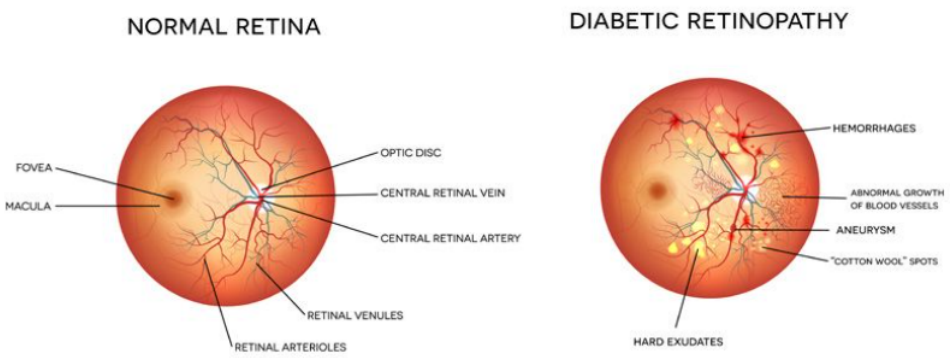


Figure 8.3. Normal retina and diabetic retinopathy (haemorrhages, microaneurysms, hard exudates, cotton-wool spots, new vessels). ▶ Image

SAME VESSELS
Retina and glomerulus are both beds of tiny capillaries damaged by the same processes.

SAME TIMING
A diabetic with albuminuria almost always has retinopathy (especially in type 1).

CLINICAL CLUE
Proteinuria **without retinopathy** → think of another kidney disease and consider biopsy (Chapter 11).

CHAPTER 9 · PHYSIOLOGY MEETS CLINIC

Why Ammavan's (uncle's) Legs Swelled

Proteinuria, low albumin, salt retention, and other causes of oedema in a diabetic

📖 **The dent that stays**

*"When you pressed his shin, the dent stayed," said the professor. "That is **pitting oedema**. Extra fluid has come out of the vessels and is sitting in the tissues. You remember the Starling forces from the heart chapter? In Ammavan (uncle), two of them have gone wrong together."*



Figure 9.1. Bilateral pitting pedal oedema

Grade	Pit depth / recovery
1+	2 mm, disappears quickly
2+	4 mm, 10–15 s
3+	6 mm, up to 1 min
4+	8 mm, 2–5 min

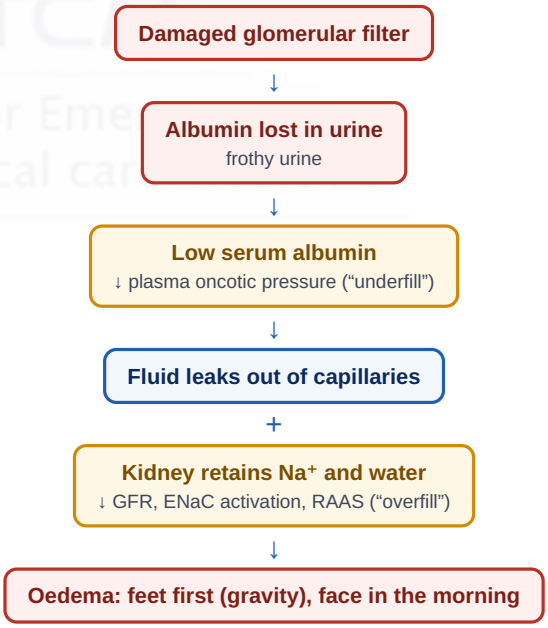


Figure 9.2. Two mechanisms of renal oedema

Not every swollen leg in a diabetic is due to the kidney. Check for these

Cause	Clue	Test
Diabetic kidney disease / nephrotic syndrome	Frothy urine, facial puffiness, retinopathy	UACR, serum albumin, creatinine
Heart failure	Breathlessness on lying flat, raised JVP, basal crackles	ECG, echo, NT-proBNP
Drugs	**Amlodipine** (ankle oedema), **pioglitazone** (fluid retention), NSAIDs (salt retention), new insulin	Drug history (insulin oedema: early weeks, settles)
Liver disease	Jaundice, ascites, alcohol	LFT, albumin, USG
Hypothyroidism	Non-pitting, weight gain, cold intolerance	TSH
Venous disease / DVT	One-sided, varicose veins, calf pain	Doppler

Exam tip: nephrotic syndrome

Proteinuria **> 3.5 g/day** (UPCR > 3000–3500 mg/g) + serum albumin **< 3 g/dL** + oedema + hyperlipidaemia. Advanced DKD is a common cause in adults. Ammavan (uncle) had 2.6 g/day with albumin 2.9, which is **heavy ("nephrotic-range"-approaching) proteinuria**, plus salt retention from diclofenac and BP.

Remember: Starling forces again

Capillary hydrostatic pressure pushes fluid out; plasma oncotic pressure (mainly albumin) pulls it in. Oedema = more pushing out (salt and water retention, venous pressure) and/or less pulling in (low albumin). Diuretics treat the first; reducing proteinuria treats the second.

CHAPTER 10 · CLINICAL BRIDGE

How Far Has It Gone?

The natural history of DKD and the KDIGO staging of chronic kidney disease

📖 The silent years

*The professor drew two lines on a sheet of paper. "This is the unfortunate part. For the first ten years Ammavan (uncle) felt nothing at all. His GFR was normal, in fact a little higher than normal. Only one test would have warned us, and that is **urine albumin**. By the time the legs swell, more than half the filters may already be scarred."*

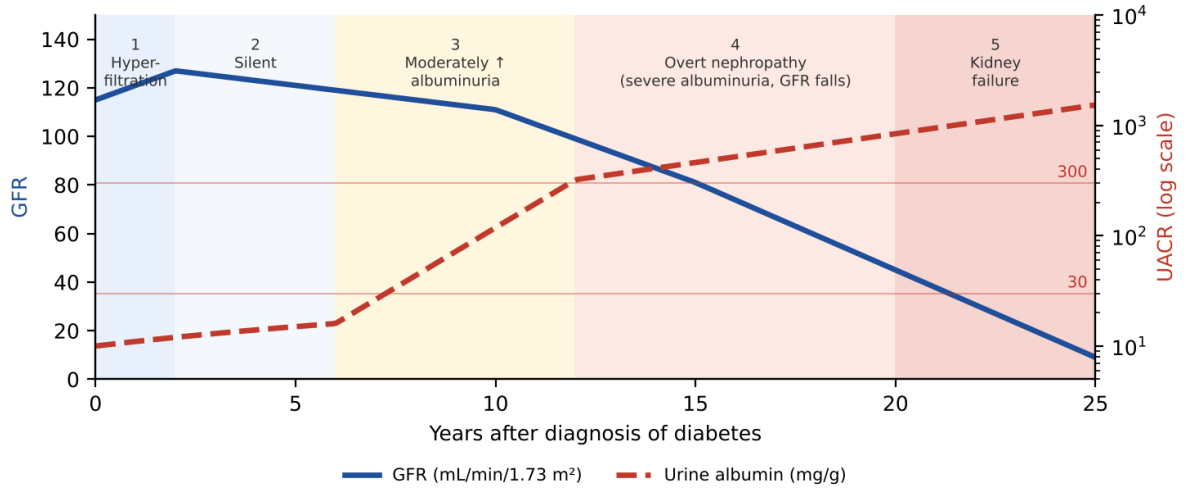


Figure 10.1. Classic course of diabetic nephropathy (Mogensen stages): early hyperfiltration, the silent years, rising albuminuria and then falling GFR. Good treatment flattens both curves. Some patients lose GFR without much albuminuria.

KDIGO staging: two numbers, one colour

CKD is staged by **G (GFR category)** and **A (albuminuria category)**. Together they predict the risk of kidney failure, heart attack and death. Colours: green = low risk, yellow = moderate, orange = high, red = very high.

GFR category (mL/min/1.73 m²)		Albuminuria: UACR, urine albumin-to-creatinine ratio (mg/g)		
		A1 < 30 normal–mild	**A2 30–300 moderately increased**	**A3 > 300 severely increased**
G1	**≥ 90 · normal/high**	Low*	Moderate	High
G2	**60–89 · mildly ↓**	Low*	Moderate	High
G3a	**45–59 · mild–moderate ↓**	Moderate	High	Very high
G3b	**30–44 · moderate–severe ↓**	High	Very high	**Very high ★ Ammavan (uncle)**
G4	**15–29 · severely ↓**	Very high	Very high	Very high
G5	**< 15 · kidney failure**	Very high	Very high	Very high

*No CKD if there is no other marker of kidney damage. Adapted from the KDIGO CKD classification. ▶ Guideline

Stage (Mogensen)	What is happening	What the patient / doctor sees
1. Hyperfiltration	GFR ↑ 20–40%, kidneys enlarge	Nothing; tests are normal
2. Silent stage	GBM thickening, mesangial expansion begin	Normal UACR; albumin may rise after exercise
3. Incipient nephropathy	UACR 30–300 mg/g (“microalbuminuria”)	Only a urine test finds it; BP starts rising. **Fully reversible stage**
4. Overt nephropathy	UACR > 300, dipstick protein +; GFR falls	Hypertension, oedema, frothy urine (Ammavan (uncle))
5. Kidney failure	GFR < 15	Uraemia, anaemia, acidosis, high K^+; dialysis or transplant

AETCM
Academy for Emergency, Trauma & Critical care Medicine

PART 4

BIOCHEMISTRY: THE LABORATORY STORY

After Anatomy (where), Physiology (how) and Disease (what went wrong) comes Biochemistry: the molecules we measure in blood and urine

CHAPTER 11 · BIOCHEMISTRY

Biochemistry: Finding the Damage

Investigations in blood and urine: what each test measures, how the laboratory measures it, and Ammavan's (uncle's) results

📖 Two tests that every diabetic needs

*Ammavan (uncle) gave blood and a morning urine sample. "The two most important tests," said the professor, "are the cheapest: a spot **urine albumin-to-creatinine ratio** and a **serum creatinine** to calculate eGFR. Every person with type 2 diabetes should have them at diagnosis and then **every year**. In type 1, start 5 years after diagnosis." Then he turned to Anu. "Now your **biochemistry** classes come in. Each number on this report is a molecule you studied in first year: urea from the urea cycle, creatinine from creatine phosphate, HbA1c from glycation of haemoglobin."*

ANATOMY TOLD US

Where: the glomerulus is in the cortex of both kidneys.

PHYSIOLOGY TOLD US

How: filtration falls (GFR) and the filter leaks (albuminuria).

BIOCHEMISTRY TELLS US

How much: measured as molecules, i.e. creatinine, urea, albumin, glucose, HbA1c, electrolytes, lipids.

A. The report: what each test tells us

Test	Why we do it	Normal	Ammavan (uncle)
Urine albumin-to-creatinine ratio (UACR)	Earliest marker; stages albuminuria (A1–A3); tracks response to treatment	< 30 mg/g (< 3 mg/mmol)	**1,850 mg/g (A3)**
24-h urine protein	Quantifies heavy proteinuria	< 150 mg/day	2.6 g/day
Urine routine	Protein, glucose, pus cells; **RBCs or RBC casts suggest another disease**	Nil protein, no casts	Protein 3+, sugar 2+, no RBCs
Serum creatinine → eGFR (CKD-EPI 2021)	Filtering power; stages G1–G5; adjusts drug doses	Cr 0.7–1.2 mg/dL; eGFR ≥ 90	Cr 1.8 mg/dL → **eGFR 43 (G3b)**
Blood urea	Waste retention	15–40 mg/dL	58 mg/dL
Na^+, K^+, HCO_3^-	Baseline before ACEi/ARB, MRA, diuretics; acidosis	K^+ 3.5–5.0; HCO_3^- 22–28	Na 136, K 4.6, HCO_3 21
FBS / PPBS, HbA1c	Glucose control over 3 months	HbA1c < 5.7%	FBS 196, PPBS 312, HbA1c 9.6%
Serum albumin	Nephrotic picture, nutrition	3.5–5 g/dL	2.9 g/dL
Lipid profile	CV risk; statin target	LDL < 100 mg/dL	LDL 148, TG 220
Haemoglobin, iron studies	Anaemia of CKD; iron deficiency	Hb 13–17 g/dL (M)	Hb 10.8; ferritin 62
Ca, phosphate, PTH, vit D	CKD–mineral bone disease (from G3)	—	Ca 8.8, PO_4 4.6
USG kidneys	Size, echo, obstruction; rules out other causes	10–12 cm	10.8 & 11.1 cm, ↑ echogenicity
Fundoscopy	Retinopathy supports diabetic cause	Normal	Moderate NPDR

ECG ± echo	LVH, silent ischaemia, heart failure	—	LVH on ECG

B. How the laboratory measures it: your first-year biochemistry practicals

Analyte	Biochemistry behind it	Laboratory method (principle)	Pitfall to remember
Creatinine	Creatine (made from arginine, glycine, methionine) → creatine phosphate in muscle → non-enzymatic cyclisation to **creatinine** at ~2%/day	**Jaffe reaction**; creatinine + alkaline picrate → orange-red complex; or **enzymatic** (creatininase) method	Jaffe falsely high with ketones (DKA), cephalosporins; values vary with muscle mass
Urea	Urea cycle in liver mitochondria/cytosol; NH_3 + CO_2 + aspartate → urea (5 enzymes; CPS-I is rate-limiting)	**Urease–GLDH** (urea → NH_3, NADH consumed at 340 nm) or diacetyl monoxime (colour)	High with GI bleed, high protein diet, dehydration, steroids
Urine albumin (UACR)	Albumin (66 kDa, negatively charged) is made by the liver and held back by the glomerular basement membrane	**Immunoturbidimetry** (antibody–albumin complex makes turbidity), divided by urine creatinine	Dipstick detects only > 300 mg/L; misses early (A2) albuminuria
Urine protein (dipstick)	Proteins bind dye and change its colour	**"Protein error of indicators"**; tetrabromophenol blue turns green–blue with protein	Mainly detects albumin; very alkaline urine → false positive
Glucose (blood, urine)	Hyperglycaemia; renal threshold ~180 mg/dL	**Glucose oxidase–peroxidase (GOD-POD)** or hexokinase; urine; Benedict's (reducing sugar) or dipstick	Sample must reach lab quickly or use fluoride tube (glycolysis lowers glucose)
HbA1c	**Non-enzymatic glycation**; glucose attaches to N-terminal valine of β-chain (Amadori product); reflects ~3 months	**HPLC** (ion-exchange), immunoassay	Falsely low in anaemia/EPO therapy, blood loss; falsely high in iron deficiency
Na^+, K^+	Na^+/K^+-ATPase keeps K^+ inside cells	**Ion-selective electrodes (ISE)**	Haemolysed sample → **falsely high K^+**
Bicarbonate / ABG	Henderson–Hasselbalch: pH = 6.1 + log $[HCO_3^-]/(0.03 \times pCO_2)$	Enzymatic (PEP carboxylase) or blood gas analyser	Low HCO_3^- with high anion gap → uraemic acidosis
Lipid profile	Cholesterol and triglycerides (TG) are carried in lipoproteins; LDL carries cholesterol to tissues	Cholesterol oxidase (CHOD-PAP); LDL by **Friedewald**: LDL = TC − HDL − TG/5	Friedewald invalid if TG > 400 mg/dL
Serum albumin	Main plasma protein; keeps oncotic pressure	**Bromocresol green** dye binding	Low in nephrotic syndrome, liver disease, malnutrition
Cystatin C	Small protein made at a constant rate by all nucleated cells; freely filtered	Immunoturbidimetry	Independent of muscle mass; confirms eGFR
Ca, PO_4, PTH, vitamin D	1α-hydroxylase in PCT activates vitamin D (Ch 7)	Arsenazo/o-cresolphthalein (Ca), phosphomolybdate (PO_4), immunoassay (PTH, 25-OH D)	Correct Ca for low albumin

Exam tip: calculations you must know

UACR = urine albumin (mg/L) ÷ urine creatinine (g/L) → mg/g · **Corrected calcium** = measured Ca + 0.8 × (4 − albumin g/dL) · **Anion gap** = $Na^+ - (Cl^- + HCO_3^-)$, normal 8–12 · **Creatinine clearance** = (U × V) ÷ P · **eGFR** by CKD-EPI 2021 (creatinine, age, sex; no race).

Formula: the CKD-EPI 2021 equation for eGFR

CKD-EPI = Chronic Kidney Disease Epidemiology Collaboration; 2021 equation, no race (KDIGO).

eGFR = $142 \times \min(Scr/\kappa, 1)^{\alpha} \times \max(Scr/\kappa, 1)^{-1.200} \times 0.9938^{Age} \times 1.012$ [if female] mL/min/1.73 m²

Scr = serum creatinine (mg/dL) · κ = 0.7 (female), 0.9 (male) · α = −0.241 (female), −0.302 (male) · Age in years.

Ammavan (uncle): man, 58 years, Cr 1.8 → $142 \times (1.8/0.9)^{-1.200} \times 0.9938^{58} = 142 \times 0.435 \times 0.697 \approx$ **43 (G3b)**.

In practice use a calculator (e.g. kidney.org); learn what goes into it: creatinine, age and sex.

C. Interpreting the report

How to diagnose albuminuria correctly

- Use a **first-morning spot urine** sample for UACR.
- Confirm: **2 of 3 samples abnormal over 3–6 months**.
- False rise: exercise in last 24 h, fever, UTI, heart failure, very high sugar or BP, menstruation.
- Kidneys in DKD are usually **normal or large** on USG; small shrunken kidneys suggest other or very late disease.

Suspect NON-diabetic kidney disease (refer; may need biopsy) if

- No retinopathy, or diabetes < 5 years (type 1)
- Blood or RBC casts in urine (active sediment)
- Rapid fall in eGFR or sudden heavy proteinuria
- Rapid rise in creatinine (> 30%) after starting ACEi/ARB → renal artery stenosis
- Signs of another systemic disease (lupus, myeloma)

Exam tip: why eGFR, not creatinine alone?

Creatinine depends on muscle mass. A thin elderly woman with creatinine 1.2 may have an eGFR of only 45. eGFR equations (CKD-EPI 2021) use creatinine, age and sex. Cystatin C can confirm eGFR when muscle mass is unusual. ▶ eGFR calculator

CHAPTER 12 · PREVENTION

Numbers to Protect the Kidney

Targets for sugar, BP, proteinuria and lipids, and the three levels of prevention

📖 The scorecard

The professor wrote a small table on a card and gave it to Ammavan (uncle). "From today this is your scorecard. If we reach these numbers, your kidneys will last much longer. Bring this card every time you come." Anu took a photo of it on her phone for her notes.

What we measure	Target	Notes
HbA1c	**< 7%** for most; individualise **6.5–8%**	Lower (6.5%) if young and no hypos; up to 8% if elderly, advanced CKD, frequent hypoglycaemia (KDIGO)
Fasting / pre-meal glucose	80–130 mg/dL	Higher limits (100–150) acceptable in G4–G5 or elderly
2-h post-meal glucose	< 180 mg/dL	Home glucometer log
Blood pressure	**< 130/80 mmHg**	KDIGO suggests systolic **< 120** if tolerated, using standardised measurement; avoid dizziness and falls
Urine albumin (UACR)	Reduce by **≥ 30%**; ideally **< 30 mg/g**	Falling albuminuria = kidney protection is working
LDL cholesterol	**< 70 mg/dL** (< 55 if very high risk)	Diabetes + CKD = very high cardiovascular risk
Serum potassium	3.5–5.0 mmol/L	Check 2–4 weeks after starting/raising ACEi, ARB, finerenone
Haemoglobin (if anaemic)	10–11.5 g/dL on treatment	Do not push higher with EPO (stroke risk)
Weight / waist (Asian)	BMI 18.5–22.9; waist < 90 cm (M), < 80 cm (F)	5–10% weight loss reduces albuminuria
Salt	< 5 g salt/day (< 2 g sodium)	Makes ACEi/ARB work much better
Dietary protein	0.8 g/kg/day	Avoid high-protein diets (> 1.3 g/kg) in CKD
Smoking	Zero	Smoking doubles the speed of decline

Three levels of prevention

PRIMARY: STOP DKD STARTING

Good glucose and BP control from the day of diagnosis; no smoking; healthy weight; **yearly UACR + eGFR** screening.

SECONDARY: CATCH IT EARLY

Moderately increased albuminuria (A2) found on screening → ACEi/ARB + SGLT2 inhibitor; often **reverses**.

TERTIARY: SLOW ESTABLISHED DKD

All four pillars, treat anaemia, acidosis and bone disease, avoid nephrotoxins, plan for dialysis/transplant in time.

Remember: the ABCDE of diabetic kidney care

A: A1c and Albuminuria · **B**: Blood pressure · **C**: Cholesterol and Cigarettes · **D**: Drugs that protect (and drugs to avoid) · **E**: Exercise, Eyes and Education.

CHAPTER 13 · LIFESTYLE

The Kitchen and the Walk

Diet, salt, exercise, smoking, painkillers and sick-day rules

📖 Ammayi (aunt) joins the class

Anu's Ammayi (aunt), Ammavan's wife, had come along this time. "Doctor, what should I cook for him?" she asked. The professor laughed. "Ammayi (aunt), what you cook matters as much as what I prescribe. The tablets will not work well unless the kitchen helps. Less salt, less rice, more vegetables, a walk every day, and no more painkillers from the medical shop."

Area	Advice	Kerala kitchen example
Salt	**< 5 g/day** (one level teaspoon in total, including cooking)	Avoid **pickles, pappadam, dried salted fish (unakkameen), chips**, instant noodles, bakery snacks; no extra salt on rice or kanji (rice gruel)
Carbohydrate	Smaller portions, more fibre; half plate vegetables	One small cup rice (not a mound), or 2 chapatis; prefer matta (red parboiled) rice, ragi, oats; avoid sweets, payasam, sweetened tea
Protein	**0.8 g/kg/day** (about 60 g for Ammavan, our uncle); not more	Fish curry (not fried), egg white, dal, curd; avoid protein powders and very large meat portions
Fats	Less saturated and fried food	Limit coconut oil quantity; avoid deep-fried items (banana fritters or pazhampori, porotta-beef)
Potassium	Restrict **only if K^+ is high** (> 5.0) or G4–G5	Then limit tender coconut water, banana, orange, dry fruits, potato; soak and boil vegetables
Fluids	Drink to thirst; restrict only if oedema is severe or G5	No "flushing the kidney" with large volumes
Exercise	**150 min/week** moderate activity + muscle strengthening twice a week	30 minutes brisk walking, 5 days a week; check feet daily
Weight	Lose 5–10% if overweight	Ammavan (uncle): 78 → 72 kg in 6 months
Smoking & alcohol	Stop smoking completely; avoid alcohol	Beedis included; ask for nicotine replacement help
Sleep & stress	7 hours sleep; screen for sleep apnoea if snoring	—

Avoid these nephrotoxins

- **NSAIDs**: diclofenac, ibuprofen, aceclofenac, nimesulide, “gas/pain tablets”. Use **paracetamol** for pain.
- Unknown herbal or “kidney cleansing” powders (heavy metals, aristolochic acid).
- Iodinated contrast without precautions (hydrate; hold metformin).
- Aminoglycosides, high-dose PPIs long term, lithium.
- “Triple whammy”: ACEi/ARB + diuretic + NSAID → acute kidney injury.

Sick-day rules: “SADMANS”

If vomiting, diarrhoea or fever with poor intake, **temporarily stop** and restart 24–48 h after eating and drinking normally:
Sulfonylureas · **A**CE inhibitors · **D**iuretics · **M**etformin · **A**RBs · **N**SAIDs · **S**GLT2 inhibitors.
Keep taking insulin (dose may be reduced); check sugar every 4 h; drink fluids; see a doctor if unwell > 24 h.

Vaccines and foot care

Yearly **influenza**, **pneumococcal** vaccine, and **hepatitis B** vaccine (check antibody) before dialysis is ever needed. Look at the feet every day, because neuropathy and poor healing are common in DKD.

CHAPTER 14 · TREATMENT

The Four Pillars

Kidney-protecting drugs (RAS blockers, SGLT2 inhibitors, finerenone and GLP-1 receptor agonists) with doses

📖 Four pillars of a house

“Can a house stand on one pillar?” the professor asked. “For about twenty years that is all we had for these patients: ACE inhibitors and ARBs. Now we have four groups of drugs. Each one blocks a different pathway of damage that you read about in Chapter 8, and used together they can cut the risk of dialysis by more than half.”

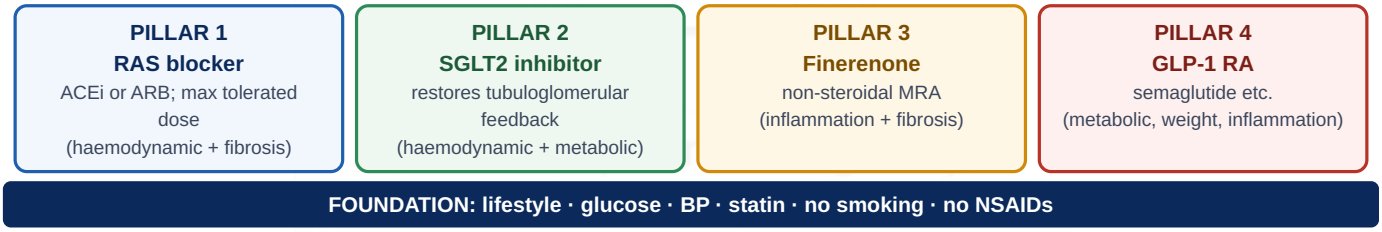


Figure 14.1. Pillars of kidney protection in type 2 diabetes with CKD (KDIGO 2022 / ADA Standards of Care 2026). ▶ ADA Standards

Pillar 1: ACE inhibitors / ARBs

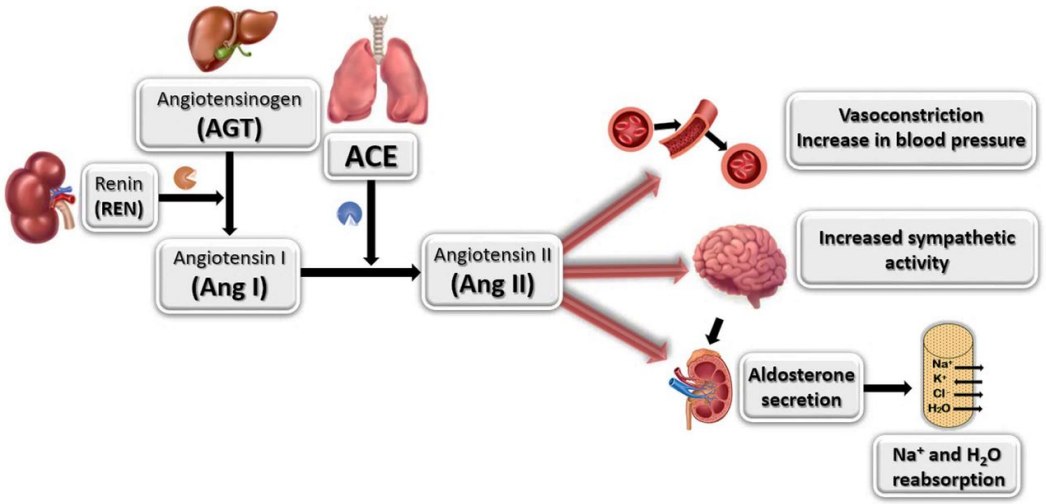


Figure 14.2. The renin–angiotensin system: renin (kidney) converts angiotensinogen (liver) to angiotensin I; ACE (lungs) makes angiotensin II, which constricts vessels, raises sympathetic activity and releases aldosterone (Na^+ and water retention). ACE inhibitors block ACE; ARBs block the angiotensin II (AT_1) receptor.

P They block angiotensin II → **efferent arteriole relaxes** → glomerular pressure falls → less albumin leaks, less scarring. They also lower systemic BP. **Indication:** diabetes with hypertension and albuminuria (A2–A3). Titrate to the maximum tolerated dose. Use **one**: never combine ACEi + ARB.

Drug	Starting dose	Usual maximum	Notes
Ramipril	**2.5 mg OD**	10 mg OD	ACEi; dry cough (bradykinin) in ~10%
Enalapril	**2.5–5 mg OD**	20 mg BD	ACEi; angioedema rare but serious
Lisinopril	**5 mg OD**	40 mg OD	ACEi; renally excreted
Telmisartan	**40 mg OD**	80 mg OD	ARB; long-acting, popular in India
Losartan	**50 mg OD**	100 mg OD	ARB (RENAAL trial); mild uric-acid lowering
Irbesartan / Olmesartan	**150 mg / 20 mg OD**	300 mg / 40 mg OD	ARB (IDNT trial used irbesartan)

Monitoring rule after starting or increasing

Check **creatinine and K^+ in 2–4 weeks**. A rise in creatinine of **up to 30%** is expected (the pressure in the glomerulus has fallen), so **continue** the drug. If > 30%: look for dehydration, NSAIDs, diuretics, renal artery stenosis. If K^+ > 5.5: diet, review drugs, add diuretic or potassium binder before stopping. Avoid in pregnancy.

Pillar 2: SGLT2 inhibitors

P Block glucose–sodium reabsorption in the PCT → more Na^+ reaches the macula densa → **tubuloglomerular feedback restored** → afferent arteriole constricts → glomerular hypertension falls. They lose glucose (≈ 60–80 g/day), weight and BP, reduce heart failure and protect the kidney **independent of glucose lowering**. ▶ KDIGO

Drug	Dose	eGFR rule	Notes
Dapagliflozin	**10 mg OD**	Start if eGFR **≥ 20**; continue until dialysis or transplant	DAPA-CKD trial
Empagliflozin	**10 mg OD (25 mg for glucose)**		EMPA-KIDNEY trial
Canagliflozin	**100 mg OD**		CREDENCE trial

Expect an initial eGFR dip of 3–5 mL/min. This is the protective effect and not harm, so do not stop the drug. Glucose-lowering is weak below eGFR 45 but kidney and heart protection continue. **Side-effects:** genital fungal infection (hygiene), volume depletion (reduce diuretic), **euglycaemic ketoacidosis**. Hold the drug 3 days before surgery and during acute illness (sick-day rules).

Pillar 3: Finerenone (non-steroidal mineralocorticoid receptor antagonist)

P In diabetes the mineralocorticoid receptor is over-active in kidney and heart, driving **inflammation and fibrosis**. Finerenone blocks it with less hyperkalaemia and no gynaecomastia compared with spironolactone. **Indication:** type 2 diabetes, UACR ≥ 30 mg/g, eGFR ≥ 25, normal K^+, **already on maximum tolerated ACEi/ARB** (FIDELIO-DKD, FIGARO-DKD).

eGFR at start	Starting dose	Target dose	Potassium rules
25 – < 60	**10 mg OD**	20 mg OD (increase after 4 weeks if K^+ ≤ 4.8)	Start only if K^+ ≤ 5.0. Check K^+ at 4 weeks. K^+ 4.9–5.5: keep dose; **> 5.5: withhold**, restart 10 mg when ≤ 5.0
≥ 60	**20 mg OD**		

Pillar 4: GLP-1 receptor agonists

B Mimic the gut hormone GLP-1 → glucose-dependent insulin release, less glucagon, slower stomach emptying, less appetite → lower glucose and weight; reduce heart attacks and stroke. **Semaglutide** reduced kidney failure and death in people with diabetes and CKD (FLOW trial). **No dose change for eGFR**; low hypoglycaemia risk.

Drug	Start → titrate	Maintenance	Notes
Semaglutide SC	**0.25 mg weekly × 4 wk → 0.5 mg weekly**	1 mg weekly	Kidney outcome evidence (FLOW)
Semaglutide oral	**3 mg OD × 30 days → 7 mg OD**	7–14 mg OD	Empty stomach, ≤ 120 mL water, wait 30 min
Dulaglutide	**0.75 mg weekly**	1.5 mg weekly	CV benefit (REWIND)
Liraglutide	**0.6 mg SC OD × 1 wk → 1.2 mg**	1.2–1.8 mg OD	CV benefit (LEADER)

Side-effects: nausea, vomiting (start low and go slow, because dehydration can harm the kidney); avoid with past pancreatitis or medullary thyroid cancer; do not combine with DPP-4 inhibitors.

CHAPTER 15 · TREATMENT

Controlling the Sugar

Oral anti-diabetic drugs and insulin in kidney disease, with doses and eGFR adjustments

📖 **"Why did my tablets change?"**

Ammavan (uncle) had been taking glibenclamide and metformin 1 g twice daily "when he remembered". The professor changed both. "Many diabetes drugs are cleared by the kidney. When the kidney is weak, some of them stay in the body too long and drop the sugar dangerously, and some are simply not safe. So we have to match every tablet to the eGFR."

Drug (class)	Usual adult dose	Adjustment for kidney function (eGFR, mL/min/1.73 m²)	Teaching point
Metformin (biguanide)	**500 mg OD with food → up to 1 g BD**	≥ 45: full dose · **30–44: max 1 g/day**, do not start new · **< 30: stop**	First-line with SGLT2i. Hold for contrast/sick days. Check vitamin B12 yearly
Gliclazide (SU)	**40–160 mg BD; MR 30–120 mg OD**	Usable with caution in G3–G4; start low	Preferred SU in CKD; hypoglycaemia risk
Glimepiride (SU)	**1–4 mg OD**	Start 1 mg if eGFR < 60; avoid if < 30	—
Glibenclamide (SU)	**—**	**Avoid in CKD**	Active metabolites → prolonged hypos
Linagliptin (DPP-4i)	**5 mg OD**	**No adjustment**	Liver/bile excretion; convenient in CKD

Teneligliptin (DPP-4i)	**20 mg OD (max 40)**	No adjustment	Widely used in India
Sitagliptin (DPP-4i)	**100 mg OD**	45+: 100 · 30–44: 50 mg · < 30: 25 mg	Weight neutral, low hypo risk
Vildagliptin (DPP-4i)	**50 mg BD**	< 50: 50 mg OD	Check LFT
Pioglitazone (TZD)	**15–30 mg OD**	No adjustment	**Fluid retention, heart failure; avoid with oedema** (Ammavan (uncle))
Acarbose / voglibose	**25–100 mg TDS / 0.2–0.3 mg TDS**	Avoid acarbose if eGFR < 30	With first bite of meal; gas
SGLT2i, GLP-1 RA	**See Chapter 14**		Preferred add-ons for kidney protection

Insulin: the safest glucose-lowering drug at any eGFR

Type (examples)	Onset	Duration	Use
Rapid-acting (aspart, lispro, glulisine)	10–15 min	3–5 h	Just before meals
Short-acting (regular/ soluble)	30 min	6–8 h	30 min before meals; IV in hospital
Intermediate (NPH/ isophane)	1–2 h	12–16 h	Basal, usually BD
Long-acting (glargine U100, degludec)	1–2 h	24 h / > 40 h	Basal, once daily, fewer night hypos
Premixed (30/70 human; biphasic aspart 30/70)	30 min / 15 min	12–16 h	Twice daily before breakfast and dinner; common in India

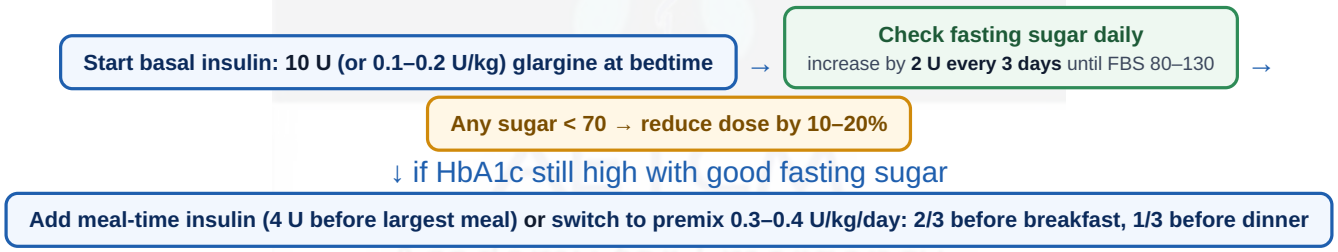


Figure 15.1. Simple insulin start and titration. Basal–bolus regimen: 0.4–0.5 U/kg/day, half basal, half split across three meals.

Insulin and the failing kidney

- The kidney degrades insulin (Chapter 7). As eGFR falls, the same dose acts longer: reduce total insulin by about **25% when eGFR is 15–50** and about **50% below 15**, then titrate.
- **Hypoglycaemia (< 70 mg/dL):** "Rule of 15": take 15 g glucose (3 teaspoons sugar in water), recheck in 15 min, repeat; then a snack. Teach the family glucagon use.
- HbA1c may be falsely low in advanced CKD with anaemia or EPO treatment, so use glucometer or CGM readings too.

CHAPTER 16 · TREATMENT

BP, Fluid, Cholesterol and the Rest

Antihypertensive steps, diuretics for oedema, statins and drugs for complications of CKD

📖 The BP ladder

"Ammavan's (uncle's) BP is 168/100," said the professor. "With one tablet we rarely reach the target in a diabetic kidney patient. We go up step by step, like a ladder, and the first step is always a drug that also protects the kidney."

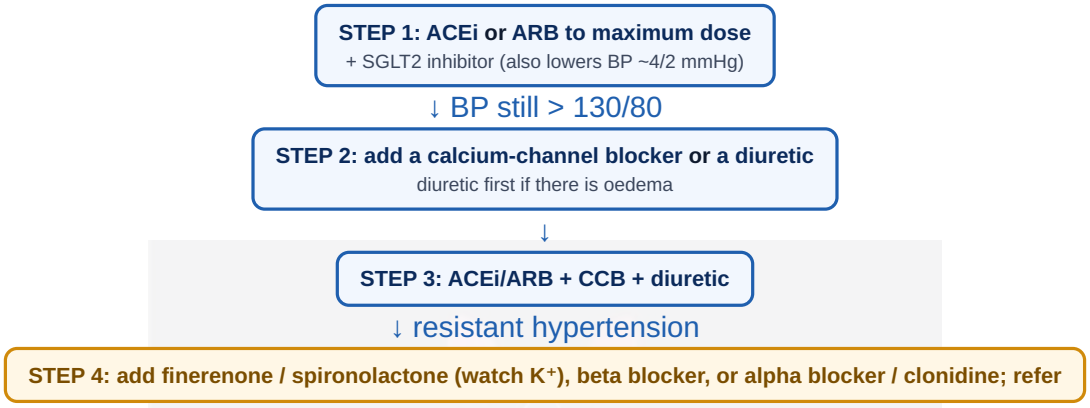


Figure 16.1. Antihypertensive ladder in diabetic kidney disease

Class / drug	Dose	Points for the kidney patient
Amlodipine (CCB)	**2.5–10 mg OD**	Strong BP lowering; **ankle oedema** (not fluid overload) at higher doses
Cilnidipine (CCB)	**5–20 mg OD**	L/N-type; less pedal oedema; used widely in India
Chlorthalidone (thiazide-like)	**12.5–25 mg OD**	Works even at eGFR 15–30 (CLICK trial); watch Na^+, K^+, uric acid, sugar
Indapamide SR	**1.5 mg OD**	Thiazide-like; metabolically neutral
Furosemide (loop)	**20–40 mg OD–BD; higher (80+) at low eGFR**	**Drug of choice for oedema**; target weight loss 0.5–1 kg/day
Torsemide (loop)	**10–20 mg OD (up to 40–100)**	Longer acting, better absorbed than furosemide
Metoprolol succinate / Nebivolol	**25–200 mg OD / 2.5–10 mg OD**	If heart disease or tachycardia; may mask hypoglycaemia
Carvedilol	**3.125–25 mg BD**	Heart failure; metabolically friendlier
Spironolactone	**12.5–25 mg OD**	Resistant HTN; high K^+ risk with ACEi/ARB; check K^+
Prazosin XL / Clonidine	**2.5–10 mg / 0.1–0.3 mg BD**	Add-ons; postural drop; do not stop clonidine suddenly

Cholesterol, heart and the complications of CKD

Problem	Drug and dose	Notes
High LDL / CV risk	**Atorvastatin 20–80 mg OD or rosuvastatin 10–20 mg OD (max 10 mg if eGFR < 30) ± ezetimibe 10 mg**	All diabetics with CKD (not on dialysis) aged ≥ 40 should get a statin; atorvastatin needs no renal adjustment
Established heart disease / stroke	**Aspirin 75 mg OD**	Secondary prevention only; not routinely for primary prevention
Anaemia of CKD	**Oral iron (≈ 100 mg elemental/day) or IV iron if ferritin < 500 and TSAT < 30%; then erythropoietin 50–100 IU/kg/week SC**	Treat iron deficiency first; target Hb 10–11.5 g/dL

Metabolic acidosis	**Sodium bicarbonate 500 mg–1 g BD–TDS**	If HCO_3^- < 18–22 mmol/L; slows CKD and protects bone
High phosphate / low vit D	**Calcium acetate 667 mg with meals; cholecalciferol if 25-OH D low; calcitriol 0.25 µg if PTH high**	From G3b–G4 under supervision
Hyperkalaemia (chronic)	**Low-K diet; loop/thiazide diuretic; sodium zirconium cyclosilicate 5–10 g OD**	Allows ACEi/ARB to continue; K^+ > 6.0 or ECG changes = emergency

CHAPTER 17 · PUTTING IT TOGETHER

Ammavan's (uncle's) Prescription and Follow-up

How the professor turned the physiology into a treatment plan and a follow-up calendar

📖 **The new prescription**

The professor wrote the prescription slowly, explaining each line to Anu. "Look, every tablet here goes back to something in your physiology book." Then he gave Ammavan (uncle) a follow-up card. Three months later, Ammavan's (uncle's) legs were thin again, his BP was 132/82, his HbA1c was 7.6% and his UACR had fallen from 1,850 to 820 mg/g. "The kidneys will not become new again," the professor said, "but we have slowed the damage down."

#	Medicine (eGFR 43, K^+ 4.6)	Why: the physiology link	Change from before
1	**Telmisartan 40 mg OD** → 80 mg after 2 weeks	Relaxes efferent arteriole; ↓ BP and albuminuria (Ch 7, 14)	New. Creatinine + K^+ at 2 weeks
2	**Dapagliflozin 10 mg OD**	Restores tubuloglomerular feedback (Ch 5, 14)	New. Genital hygiene; sick-day rule
3	**Metformin 500 mg BD** after food	eGFR 30–44 → max 1 g/day (Ch 15)	Reduced from 1 g BD
4	**Insulin glargine 10 U at bedtime**, +2 U every 3 days to FBS 80–130	HbA1c 9.6% needs insulin; safe in CKD (Ch 15)	New. Glibenclamide **stopped**
5	**Furosemide 40 mg OD** (morning) for 2–3 weeks, then review	Removes retained Na^+ and water (Ch 6, 9)	New. Daily weight
6	**Atorvastatin 40 mg OD** at night	LDL 148 → target < 70 (Ch 12)	New
7	**Paracetamol 500 mg** SOS for knee pain	NSAIDs block prostaglandins → ↓ GFR (Ch 7)	**Diclofenac stopped**; amlodipine stopped (oedema)
8	Ferrous sulphate (≈ 100 mg elemental iron) OD	Hb 10.8, ferritin 62 → iron first; EPO if Hb < 10 despite iron (Ch 7)	New
—	**Planned next:** finerenone 10 mg OD at 3 months if UACR still ≥ 30 and K^+ ≤ 5.0 on full-dose telmisartan; semaglutide if HbA1c above target or weight not falling. Stop smoking; salt < 5 g; walk 30 min daily.		

Follow-up calendar (KDIGO very-high-risk patient: G3b A3)

When	What to check
Daily at home	Fasting sugar (titrating insulin), weight, feet; BP 3–4 days a week
2–4 weeks after any change	Creatinine/eGFR, K^+, Na^+, BP; after starting or increasing ACEi/ARB, finerenone or diuretic
Every 3 months	HbA1c, eGFR, K^+, **UACR**, BP, weight, drug review (doses vs eGFR)
Every 6 months	Hb, iron studies, Ca, phosphate, bicarbonate, albumin; lipid profile (3 months after starting statin, then yearly)

Every year	Dilated fundus exam, foot exam (monofilament), ECG ± echo, vitamin B12 (on metformin), PTH/vitamin D, vaccines (influenza)

Red flags: come to hospital at once

- Breathlessness, especially lying flat; weight gain > 2 kg in 3 days
- Very little urine; vomiting or diarrhoea that does not settle
- Sugar < 70 not improving, or > 300 with vomiting / abdominal pain
- Muscle weakness, palpitations (high K^+); confusion, chest pain

Refer to a nephrologist when

- eGFR < 30, or UACR persistently > 300 mg/g despite treatment
- eGFR falling fast (> 25% drop or > 5 mL/min/year)
- K^+ persistently high, resistant hypertension, or doubt about the cause
- Planning for dialysis (AV fistula) or transplant; start at G4

CHAPTER 18 · PUTTING IT ALL TOGETHER

The Professor's Summary: Anu Explains

A revision conversation, the complications of poor treatment, and a word of thanks

📖 **The last visit before college reopens**

*Three months later Anu brought Ammavan (uncle) for his review. The swelling in his legs had gone and he looked cheerful. The professor leaned back in his chair. "Anu, you have heard the whole thing now. Today **you** explain it to me, and say it simply enough for your uncle to follow. I will ask the questions."*

PROFESSOR
Where are the kidneys, and what do they look like inside?

ANU
They lie at the back of the abdomen, behind the intestines, from T12 to L3. The right one is a little lower because of the liver. Inside there is an outer cortex, inner medullary pyramids and a central pelvis that collects urine. Urine then goes down the ureters to the bladder and out through the urethra.

PROFESSOR
What is the working unit?

ANU
The nephron, sir. There are about a million in each kidney. The glomerulus is a three-layer filter: endothelium, basement membrane and podocytes. The tubule then takes back almost everything useful. We filter 180 litres a day but pass only about one and a half litres of urine.

PROFESSOR
And what jobs does the kidney do?

ANU
We remember them as "A WET BED": acid–base balance, water balance, electrolytes, removing toxins and waste like urea and creatinine, blood pressure control through renin, erythropoietin for red cells, and activating vitamin D. It also helps make glucose and breaks down insulin.

PROFESSOR
So what did diabetes do to your uncle's kidneys?

ANU

Years of high sugar made proteins sticky, thickened the filter and damaged the podocytes. At the same time the pressure inside the glomerulus went up, because the afferent arteriole opened and angiotensin II tightened the efferent one. The filter became leaky, which is why his urine was frothy with albumin, and slowly it started to scar. That is how his eGFR came down to 43.

PROFESSOR

Why did his legs swell, and why was he pale?

ANU

He lost albumin in the urine, so the oncotic pressure in his blood fell; and his kidneys held back salt and water, which the diclofenac made worse. The fluid went into his tissues: pitting oedema. He was pale because his damaged kidneys made less erythropoietin, so his haemoglobin fell to 10.8.

PROFESSOR

Which tests found the damage?

ANU

The urine albumin-to-creatinine ratio, which was 1,850 mg/g (category A3), and serum creatinine to calculate the eGFR, which was 43 (category G3b). That puts him in the “very high risk” box. The fundus showed retinopathy, which supports a diabetic cause. Every diabetic needs UACR and eGFR every year.

PROFESSOR

What numbers must he reach?

ANU

HbA1c about 7%, BP below 130/80, UACR falling by at least 30%, LDL below 70, potassium 3.5–5, salt below 5 g a day, protein 0.8 g/kg, no smoking and a 30-minute walk every day.

PROFESSOR

And the medicines?

ANU

The four pillars. Telmisartan relaxes the efferent arteriole; dapagliflozin restores the macula densa feedback; finerenone may be added to stop inflammation and scarring; semaglutide if sugar or weight need more help. Metformin was reduced to 500 mg twice daily because his eGFR is below 45, glibenclamide was stopped, and glargine insulin started. Furosemide removed the fluid, atorvastatin protects the heart, iron is for the anaemia, with EPO if the Hb falls below 10. And no more painkillers from the medical shop, only paracetamol.

PROFESSOR

Good. Now the most important question of all. If your uncle stops his tablets again, what will happen to him?

Anu explains the complications if DKD is not treated properly

Complication	Why it happens	What uncle would feel or face
Kidney failure (G5)	Continuing glomerular hypertension and scarring; eGFR keeps falling	Tiredness, vomiting, itching, breathlessness; **dialysis 3 times a week** or a kidney transplant
Fluid overload, pulmonary oedema	Kidney cannot remove salt and water	Severe breathlessness at night, cannot lie flat; emergency admission
Hyperkalaemia	Failing K^+ excretion (worse with some drugs, banana, tender coconut)	Muscle weakness, palpitations, **sudden cardiac arrest**
Heart attack, stroke, heart failure	Diabetes + CKD + high BP + high LDL damage arteries; DKD patients more often die of heart disease than reach dialysis	Chest pain, paralysis, breathlessness
Metabolic acidosis	Less ammonia and bicarbonate production	Fast breathing, bone and muscle loss

Worsening anaemia	Less erythropoietin, iron loss	Breathlessness, poor exercise tolerance, may need EPO injections and transfusions
CKD–mineral bone disease	Less active vitamin D, high phosphate, high PTH	Bone pain, fractures, calcified blood vessels
Uraemia	Waste products accumulate	Loss of appetite, metallic taste, confusion, pericarditis, bleeding tendency
Dangerous hypoglycaemia	Insulin and sulfonylureas stay longer when kidneys fail	Sweating, confusion, fits or coma; especially at night
Blindness	Retinopathy progresses alongside nephropathy	Bleeding in the eye, retinal detachment, loss of vision
Foot ulcer, amputation	Neuropathy + poor circulation + slow healing	Painless ulcers, infection, gangrene
Serious infections	High sugar and poor immunity; neurogenic bladder	Pyelonephritis, sepsis, emphysematous pyelonephritis
Acute kidney injury on CKD	NSAIDs, dehydration, contrast, “triple whammy”	Sudden fall in urine, rapid rise in creatinine

PROFESSOR
Very good. Suresh, did you follow what your niece said?

AMMAVAN (UNCLE)
Yes, doctor. For fourteen years I thought sugar was just a number on a lab report. I did not know it was slowly damaging my kidneys, my eyes and my heart. I will take my tablets and insulin every day, check my sugar and BP, keep the salt low, walk every evening, stop the beedis, and never again buy painkillers from the shop.

ANU
And I realise that one urine test a year could have caught this ten years earlier. When I become a doctor, I will ask every diabetic patient: “When was your urine albumin last checked?”

PROFESSOR
That is what I wanted to hear. The kidneys will not become new, but if you stick to this plan they can keep working for many more years. Come back in three months with your scorecard.

ANU & AMMAVAN (UNCLE)
Thank you, sir. You explained it so patiently, from the nephron right up to the tablets, that both of us understood all of it.

The whole book in five lines

- The kidney is a filter (glomerulus) plus a recycler (tubule) plus a hormone factory.
- Diabetes damages it by sticky sugar, high glomerular pressure and scarring.
- Albuminuria is the first warning sign; eGFR shows how much function is left. Check both every year.
- Targets: HbA1c ~7%, BP < 130/80, UACR ↓ ≥ 30%, LDL < 70, salt < 5 g, no smoking, no NSAIDs.
- The four pillars (ACEi/ARB, SGLT2i, finerenone, GLP-1 RA), together with correctly dosed diabetes drugs, slow the progression to dialysis.

CHAPTER 19 · VIVA VOCE

Viva Questions with Short Answers

40 questions across Anatomy, Physiology, Biochemistry and the clinical bridge

A **Q1. At what vertebral levels do the kidneys lie? Which is lower and why?**
T12–L3; the right kidney is 1–2 cm lower because of the liver.

A **Q2. Order of structures at the hilum from front to back?**
Renal vein, renal artery, renal pelvis (V-A-P).

A **Q3. Name the coverings of the kidney from inside out.**
Fibrous capsule, perirenal fat, renal (Gerota's) fascia, pararenal fat.

A **Q4. Name three anterior relations of the left kidney.**
Stomach, spleen, pancreas (tail), splenic flexure, jejunum, suprarenal gland.

A **Q5. Why is a renal infarct wedge-shaped?**
Segmental arteries are end arteries; blockage kills the wedge of tissue they supply.

A **Q6. Where are the three narrow points of the ureter?**
Pelvi-ureteric junction, pelvic brim (crossing iliac vessels), uretero-vesical junction.

A **Q7. What is the trigone?**
Smooth triangular area at the bladder base between the two ureteric openings and the internal urethral opening.

A **Q8. Nerve supply of the detrusor?**
Parasympathetic S2–S4 (pelvic splanchnic) contracts it; sympathetic T11–L2 relaxes it.

A **Q9. Name the parts of a nephron.**
Renal corpuscle (glomerulus + Bowman's capsule), PCT, loop of Henle, DCT; drains into collecting duct.

A **Q10. Components of the juxtaglomerular apparatus?**
Macula densa, juxtaglomerular (renin) cells of afferent arteriole, extraglomerular mesangial (lacis) cells.

P **Q11. Normal GFR and renal blood flow?**
GFR ~125 mL/min (180 L/day); renal blood flow ~1.2 L/min (20–25% of cardiac output).

P **Q12. What forces decide glomerular filtration?**
Glomerular capillary hydrostatic pressure (out) minus Bowman's space pressure and plasma oncotic pressure (in) ≈ 10 mmHg net.

P **Q13. Name the layers of the filtration barrier.**
Fenestrated endothelium, glomerular basement membrane, podocyte slit diaphragms.

P **Q14. What is tubuloglomerular feedback?**
More NaCl at the macula densa → afferent arteriole constricts → GFR returns toward normal.

P **Q15. Where is most sodium reabsorbed?**
Proximal convoluted tubule (~65%).

P **Q16. What is the renal threshold for glucose?**
About 180 mg/dL; above it glucose appears in urine.

P **Q17. How does ADH concentrate urine?**
Inserts aquaporin-2 into collecting duct cells; water moves into the hypertonic medulla.

P **Q18. Which part of the nephron is impermeable to water but pumps out salt?**
Thick ascending limb of the loop of Henle (NKCC2). It is the basis of the countercurrent multiplier.

P **Q19. Actions of angiotensin II on the kidney?**
Constricts efferent arteriole, ↑ PCT Na^+ reabsorption, releases aldosterone, promotes fibrosis.

P **Q20. Name four hormones made or activated by the kidney.**
Renin, erythropoietin, calcitriol (1,25-$(OH)_2$ vitamin D), prostaglandins.

B **Q21. Where do urea and creatinine come from?**
Urea comes from the urea cycle in the liver (from protein ammonia); creatinine comes from creatine phosphate in muscle.

B **Q22. How does the kidney excrete acid?**
Reabsorbs bicarbonate, secretes H^+ as titratable acid (phosphate) and ammonium (NH_4^+ from glutamine).

B **Q23. Which enzyme activates vitamin D in the kidney?**
1α-hydroxylase in the proximal tubule.

B Q24. Name four metabolic pathways by which glucose damages tissues.
Advanced glycation end products, polyol (sorbitol) pathway, protein kinase C activation, hexosamine pathway; all of them increase oxidative stress.

B Q25. Why does albumin normally not pass the GBM?
Its size (~66 kDa) and negative charge; it is repelled by negatively charged heparan sulphate.

B Q26. Why are hypoglycaemic episodes more common in CKD?
Less renal insulin breakdown, less renal gluconeogenesis, and longer action of sulfonylureas.

C Q27. Define diabetic kidney disease.
CKD in a person with diabetes: UACR ≥ 30 mg/g and/or eGFR < 60 for > 3 months without another cause.

C Q28. Pathognomonic lesion of diabetic nephropathy?
Kimmelstiel–Wilson nodules (nodular glomerulosclerosis).

C Q29. Earliest clinical marker of DKD? Best screening test?
Moderately increased albuminuria; spot urine albumin-to-creatinine ratio (UACR).

C Q30. When should diabetics be screened for kidney disease?
Type 2 at diagnosis and then yearly; type 1 from 5 years after diagnosis, then yearly.

C Q31. Name the albuminuria categories.
A1 < 30, A2 30–300, A3 > 300 mg/g.

C Q32. When would you suspect non-diabetic kidney disease?
No retinopathy, active urine sediment, rapid GFR fall, sudden nephrotic syndrome, short diabetes duration.

C Q33. Target BP and HbA1c in DKD?
BP < 130/80 (SBP < 120 if tolerated); HbA1c individualised 6.5–8%, < 7% for most.

C Q34. Name the four pillars of kidney protection in type 2 diabetes.
ACEi/ARB, SGLT2 inhibitor, finerenone, GLP-1 receptor agonist.

C Q35. How much creatinine rise is acceptable after starting an ARB?
Up to 30%. Continue the drug and recheck.

C Q36. How do SGLT2 inhibitors protect the kidney?
More Na^+ reaches macula densa → afferent constriction → ↓ intraglomerular pressure; also ↓ BP, weight, uric acid.

C Q37. Metformin rules by eGFR?
≥ 45 full dose; 30–44 maximum 1 g/day, do not start; < 30 stop.

C Q38. Which sulfonylurea should be avoided in CKD and why?
Glibenclamide, because its active metabolites accumulate and cause prolonged hypoglycaemia.

C Q39. What is the "triple whammy"?
ACEi/ARB + diuretic + NSAID together → acute kidney injury.

C Q40. What does SADMANS stand for?
Sick-day drugs to pause: Sulfonylureas, ACEi, Diuretics, Metformin, ARBs, NSAIDs, SGLT2 inhibitors.

High-yield study tips for First MBBS

- Draw three diagrams from memory: the coronal section of the kidney, the nephron with its transporters, and the RAAS flowchart.
- Link every transporter to a drug: SGLT2 → gliflozins, NKCC2 → furosemide, NCC → thiazides, ENaC/MR → amiloride/finerenone.
- Remember the two screening tests for every diabetic (UACR and eGFR) and the four pillars of treatment.

VISUAL ATLAS

See It Online: Tap or Scan

Free images, animations, calculators and guidelines for the printed copy

Kidney anatomy
Position, relations, hilum
wikipedia.org ↗

Urinary bladder
Trigone, detrusor, nerves
wikipedia.org ↗

The nephron
Parts and functions
wikipedia.org ↗

Glomerular filtration rate
Measurement and equations
wikipedia.org ↗

Countercurrent multiplier
How urine is concentrated
wikipedia.org ↗

Juxtaglomerular apparatus
Macula densa and renin
wikipedia.org ↗

Renin–angiotensin system
Flowchart and drugs
wikipedia.org ↗

Diabetic nephropathy
Pathology and course
wikipedia.org ↗

Diabetic retinopathy
Fundus pictures
wikipedia.org ↗

eGFR calculator
CKD-EPI 2021 (NKF)
kidney.org ↗

KDIGO guideline
Diabetes management in CKD
kdigo.org ↗

ADA Standards of Care
Section 11, CKD & risk management
diabetes.org ↗

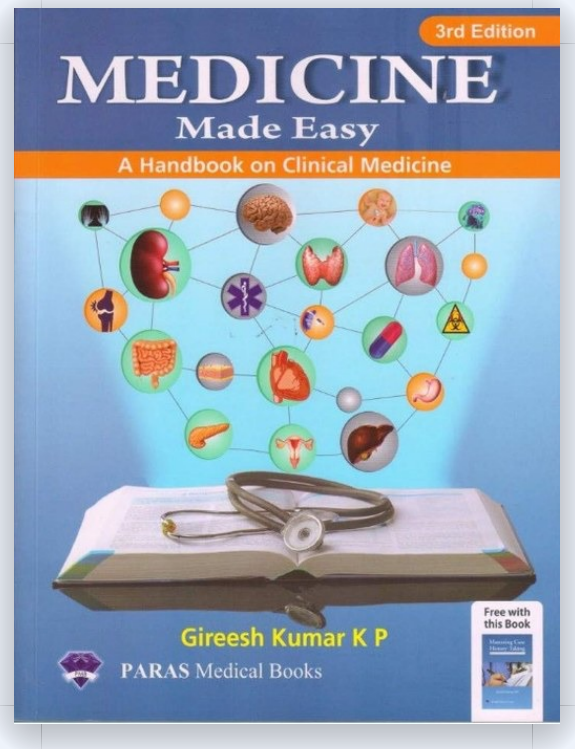
Sources for the clinical chapters

KDIGO 2022 Clinical Practice Guideline for Diabetes Management in CKD; KDIGO CKD classification; American Diabetes Association Standards of Care in Diabetes 2026 (Section 11); landmark trials named in the text (RENAAL, IDNT, DAPA-CKD, EMPA-KIDNEY, CREDENCE, FIDELIO-DKD, FIGARO-DKD, FLOW, CLICK). Doses are usual adult doses for teaching; always confirm with the current product information and individualise.

ALSO BY THE AUTHOR

Dr. Gireesh Kumar K.P.

Tap the book or scan its code to buy



Medicine Made Easy

A Handbook on Clinical Medicine

3rd Edition

A short, easy-to-read handbook of clinical medicine. Once you reach the wards and meet patients like Ammavan (uncle), this is the book to pick up next.

BUY NOW on Amazon.in

Scan to buy

or tap BUY NOW

PARAS Medical Books

AETCM
Academy for Emergency, Trauma & Critical care Medicine