How you remove wastes from your body

EXCRETORY SYSTEM
Excretion: waste removal from body

Kidneys: Unique Problem

Keep Good Things

Get Rid of Bad Things in blood
How the kidneys do this:

1. **Filtering** - everything except blood cells & protein (big)

2. Bad things → out with urine

3. **Recycling** (reclaiming):
   Good things → back to blood
Bad things (waste): your kidneys remove
Example: urea from breakdown of protein

Good things: reclaimed
Example: H₂O, glucose, amino acids
50 gallons of blood: pumped through kidneys/day
½ gallon: waste + H₂O leaves body as urine
Damage to kidneys (failure): poor filter

Dialysis machine: filter/remove wastes
Kidney Dialysis

- Kidney disease > 60% caused by hypertension & diabetes
- Toxic wastes build up
- Dialysis (separation): 3X/week each 4-6 hr
- Patient blood → artery → tubes

selectively permeable membrane
Kidney Dialysis

- Good things added: bicarbonate ions (blood pH)
- Wastes: discarded
Kidney Transplantation
2009: 78,000 people- waiting list

1. Best donor (kidneys last longer): living, matching (family) donor

2. Unrelated living donor

3. Deceased donor

Newer technique: “preconditioning” transplant recipient’s blood before operation: cleanse of antibodies (cause of rejection)
Newer surgery on **donor**: Laparoscopic Nephrectomy (small cut in **abdomen**)

Remove kidney → **recipient**

“New” kidney starts working immediately
• Many donated kidneys still working > 25 years
• **Donor**: normal life span
• Remaining kidney “compensates” for loss of donated kidney
"KIDNEY SWAP"

New England people - Kidney Disease:
3-5 year wait for **cadaver kidney**

- Second problem: incompatible donor
- **Alternative:** NE Kidney Exchange Program (Newton)
- Computerized data pool
- ↑ Likelihood match, ↓ Donation time
Other things your kidneys do:

1. Control your **blood volume**: 
   
   $\pm$ H$_2$O

2. Control **ion balance** in your body *(sodium, potassium)*

3. Help keep blood **pH** normal
Urinary system: 2 kidneys: filter blood, produce urine

- kidney: produces urine
- ureter: transports urine toward urinary bladder
- urinary bladder: temporarily stores urine
- urethra: transports urine out of body
Right Kidney → Ureters → Urinary Bladder (Muscles contract) → Urine → Urethra → Outside Body

Left Kidney → Ureters → Urinary Bladder (Muscles contract) → Urine → Urethra → Outside Body
Male Urinary System

- Kidneys
- Ureter
- Urinary bladder
- Vas deferens
- Seminal vesicle
- Prostate gland
- Epididymis
- Urethra
- Testis
How the kidney filters: big picture

1. Blood **into** kidneys: renal artery from aorta
2. Blood filtered
3. Blood **out** of kidneys: **renal vein**

4. Cleaned blood returned to **heart**
How kidneys filter blood: the little picture

Little filtering units: nephrons
1.25 million = each kidney
FIGURE 18.2 Anatomy of a kidney. (a) A cross section of a kidney, showing the outer cortex and inner medulla. The medulla consists of segments called renal pyramids. (b) A magnified view of a renal pyramid, showing the orientation of nephrons. (c) A close-up view of one nephron and a collecting duct.
Nephron Parts:
1. Bowman’s capsule
   Collects Filtered Blood Plasma: Good + Bad Things
2. Complex, twisted tubes
3. Collecting duct: final urine collected
4. Many collecting ducts
  Send urine to renal pelvis (cavity)
5. Renal pelvis $\rightarrow$ urine $\rightarrow$ ureter
6. Blood into nephron from renal artery (arteriole)
7. Blood forms ball of capillaries: **Glomerulus** (porous)
Close up view: **glomerulus**

**Blood under pressure**

- Ascending limb of loop of Henle
- Macula densa cells sense distal tubule flow and release paracrine factors that affect afferent arteriole diameter.
- Bowman's capsule
- Glomerulus
- Proximal tubule
- Efferent arteriole
- Granular cells
- Endothelium
- Afferent arteriole
Glomerulus blood under pressure:
1. Small molecules leak out: H2O, glucose, sodium, potassium, vitamins
2. Also leaking out: metabolic wastes:
   A) Urea- from protein breakdown
   B) Creatinine: waste product from muscle contraction

**FIGURE 18.7** The three exchange processes in the renal tubule occur in the renal corpuscle, is the bulk flow of protein-free plasma into Bowman’s capsule. Reabsorption, which occurs along the tubule, also occurs along the tubules, but it is the movement of solute from capillaries into the lumen of the tubules. A fourth process, excretion, urine out of the body.
4. Glomerulus (capillaries) form arteriole: exits Bowman’s capsule
5. 2nd capillary network formed around nephron
6. Finally, capillaries form small vein: blood returned to heart
This was **filtration** by nephron: filtering blood: 1<sup>st</sup> thing kidney does.
2d thing kidney does: **Reabsorption**: save good things

**FIGURE 18.7** The three exchange processes in the renal tubule: filtration occurs in the renal corpuscle, is the bulk flow of protein-free plasma into Bowman’s capsule. Reabsorption, which occurs along the tubule, water or solute from the lumen of the tubules into the peritubular also occurs along the tubules, but it is the movement of solute from capillaries into the lumen of the tubules. A fourth process, excretion, urine out of the body.
1. Cells in tubes actively pump sodium to outside of tube.
2. Sodium moves into capillaries.
3. H2O follows the sodium (osmosis): into capillaries.
H₂O lost during filtration + glucose + nutrients: reclaimed back into blood

This is **REABSORPTION**

Wastes: most **urea** in tube not reabsorbed: pass out → urine
3rd thing kidney does: **Secretion** (to release)  
H+ (balances blood pH), Potassium, Drugs, Poisons:  
Move: capillaries → tubes → urine
4th thing kidney does: **concentration**

More **sodium**

Pumped out-end tube moves into capillaries-

H₂O follows: moves into **blood**
Concentration: you save 99% of $\text{H}_2\text{O}$ filtered

You produce concentrated urine: wastes + some water

Very important for land animals: $\text{H}_2\text{O}$ conservation - prevents us from drying out
Summary 4 things your kidneys do:

#1 **Filter** everything except protein & blood cells

#2 **Reabsorb**: H₂O, sodium, glucose, vitamins

#3 **Secrete**: H+ & potassium from blood $\rightarrow$ tubule

#4 **Concentrate**: save H₂O, concentrate wastes $\rightarrow$ urine

(Excretion)
Summary
Kidneys & sodium/potassium balance

- Our kidneys evolved: conserve sodium & excrete potassium (homeostasis)
- Prehistoric diet
Today’s diet: **overloads** kidney’s with salt
Our kidney’s have not adapted “modern” diet: result- **hypertension**
Natural way to control blood pressure

- Return to **caveman** diet
- Dietary Approaches to Stop Hypertension (DASH) Eating Plan
- National Heart, Lung & Blood Institute
DASH

- Fruits & veggies
- Low fat milk (calcium) products
- Eat more: poultry, fish, nuts
- Eat less: red meat, sugar in processed foods/drink

If all Americans ate DASH: dramatic drop in heart attacks/stroke
What controls how much $\text{H}_2\text{O}$ you lose in your urine?

- Walking - desert
- Drinking many glasses $\text{H}_2\text{O}$

Your body adjusts
- Concentrated yellow urine
- Dilute yellow urine
In Nevada Desert:
1. Lose H₂O - breath, sweat
2. ↓ Blood volume (concentrated)
3. Brain (hypothalamus) detects change blood volume
4. Signals → pituitary gland

Antidiuretic Hormone (ADH)
Infundibulum is the stalk that connects the pituitary to the brain.

Posterior pituitary is an extension of the neural tissue.

Anterior pituitary is a true endocrine gland of epithelial origin.
Diuretic = \uparrow \text{urine secretion}

Antidiuretic Hormone

- Makes tubules/collecting ducts more permeable to water
- Water moves into blood
- Result: more H₂O in blood, urine-concentrated
- Important: saves body water - desert
You arrive at **Las Vegas Hotel-thirsty**

- Drink several bottles H$_2$O
- ↑ Blood volume
- H$_2$O comes in from intestine
- Pituitary ↓ ADH
- Nephron tubules/collection duct less permeable
- More H$_2$O leaves → urine
Drink 12 ounces Beer or Water

• Beer - more urination
• Alcohol: ↓ ADH production
• Alcohol = diuretic
• ↑ Urine secretion
• Dehydrating effect part of hangover
To the outside......

Urine $\rightarrow$ ureters $\rightarrow$ urinary bladder

holds 27 ounces
**Urethra**: from bladder to outside
Men: 7-8 inches - through penis
Women: ~ 1 inch
Prostate gland: produces fluid for semen
Prostate: below bladder, surrounds urethra-
Enlarged Prostate
↓ Urine Stream
Urination
• Urethra: has **sphincter** muscle around it: **voluntary control**
• When bladder has 7 ounces urine:
  • **Stretch receptors**- wall of bladder
    “urge to urinate” ↔ brain
• Sphincter muscle **relaxes**, bladder muscle **contracts**: urine passes out of body (1/2 gallon/day)
Kidney Stones: detected 7000 year old mummies

The blue-tinted zone on the torso is where the pain of kidney stones most often occurs. Stones originate in the kidneys and can travel down into the ureters and bladder.
Kidney stones: more common men

- **Concentrated urine**: crystal formation: calcium, uric acid stones
- Small ➔ pebble
- Very painful
- Occur in tubules, collecting ducts, ureters
- Can block urine flow if big
Treatment:

1. Drink fluids - pass stone
2. Surgery
3. Medicine: to relax smooth muscles: pass stone
4. **Shock waves**: you sit in tub of water: machine - high energy shock waves: pulverize stones
I felt like I had been shot,” remembers 59-year-old Bethesda, Maryland, writer Ron Collins. “One moment I was standing, then all of a sudden I was lying on the floor in agony. I had no idea what was going on. I was absolutely helpless.”

In excruciating pain in his lower abdomen, Collins was rushed by his wife to the hospital emergency room, where he was diagnosed with a kidney stone and admitted for treatment.

“The experience humbled me very quickly,” he says. “I’ll never forget it.”
Kidney Stones (calcium oxalate)

Risk Factors

• Men 2X risk
• Overweight
• Diabetes
• “Stone belt”: people in Southeastern US: ↑ 20% risk: related-sweating, more concentrated urine?
• ↑ Grapefruit juice, ↑ stones
• ↑ Megadoses of Vitamin C
After the stone has passed into urine

- Drink enough fluids
- ↓ Salt in diet
- Children ↑ animal protein & salt stones
- Coffee drinkers: ↓ risk
Good Bacteria

Many kidney stones: calcium oxalate

Oxalate: spinach, beets, nuts

*Oxalobacter formigenes* in intestine

Digests oxalate

People up *Oxalobacter* down Kidney stones
Urinary Tract Infections

More common women

- **90%** due to E. Coli (colon bacteria)

- Anus close to urethra: bacteria multiply

- Result: bladder infection (cystitis) & urethra infection (urethritis)
Urinary Tract Infections

Other causes - bacteria infections

1. Sexual intercourse
2. Pregnancy
3. Urinary obstruction

Cranberries/cranberry juice

10 ounces/day: protection
Prevent growth E. Coli and attachment to urinary bladder
DIABETES
What is diabetes?

- Diabetes mellitus
- Diabainein (Greek) = “to pass through”
- Mellitus (Latin) = “sweetened with honey”
- Glucose spills into urine
- Sweet urine - ants
Diabetes

• Consistently ↑ blood glucose

• Result of:

  1) ↓ insulin from pancreas
      and/or
  2) ↓ insulin sensitivity
      (responsiveness) by body cells

  “insulin resistance”
“Starvation in the midst of plenty”
Symptoms (warning signs): diabetes

1. Frequent urination
2. Excessive thirst
3. Extreme hunger
4. Unusual weight loss
5. Increased fatigue
6. Irritability
7. Blurry vision
Normal Blood Glucose: **80-100 mg**

Renal Threshold Glucose: **160-180 mg**
At **renal threshold**:

Glucose **filtered** > Glucose **reabsorbed**

Spillover $\rightarrow$ **urine** (wasted energy)
Diabetes

- Without glucose, body breaks down (partially) fat-energy ketones (acids)
- Brain, other tissues adapt to use ketones for energy
- Excessive ketones → urine (test kit)
Diabetes

- Ketones: ↑ acidity of blood (ketoacidosis)
- Rapid/deep breathing, very thirsty, urination, loss appetite
- Fruity breath odor
- Weakness, fatigue, confusion
- Severe dehydration, coma, death
- Requires immediate treatment