The Mammalian Excretory System consists of:

- Posterior vena cava
- Renal artery and vein
- Aorta
- Ureter
- Urinary bladder
- Urethra

The Kidney

1. Vertebrate kidneys perform
   A. Ion balance
   B. Osmotic balance
   C. Blood pressure
   D. pH balance
   E. Excretion
   F. Hormone production

The Nephron: the basic unit of the kidney.
Nephron
1. Bowman’s Capsule
2. Proximal Convoluted Tubule
3. Loop of Henle
4. Distal Convoluted Tubule
5. Collecting ducts

Vasculature
1. Renal artery
2. Afferent arteriole
3. Glomerulus
4. Efferent arteriole
5. Vasa recta
6. Renal vein

Kidney Structure Figure 29.6

Cortex = outer portion of the kidney
Medulla = inner portion of the kidney
Renal pelvis

1. Fig 29.7  Comparative kidney structure in terrestrial mammals native to different habitats
2. Fig 29.9  The relation between relative medullary thickness and body size depends on whether mammals are native to arid, mesic, or aquatic habitats
Vertebrate Kidney: Structure and basic function

1. About 20-25% of the total cardiac output goes to the kidneys
2. Cardiac output: 3000 ml/min
3. Renal blood flow: 600 ml/min
4. Filtered 125 ml/min (~20%) or 180 l/day
5. Excreted 1.5 l/day (<1%)

Urine Production

1. (Ultra)Filtration
2. Reabsorption of selected salts, nutrients and water
3. Secretion
4. Excretion
First Step in Urine Production

1. Ultrafiltration is non-selective
   A. Bowman’s capsule and glomerulus
   B. Solutes of high molecular weight and blood cells are left behind.
   C. Advantage ___________
   D. Disadvantage ___________

2. Formation of primary urine

Nephron Structure

1. Tubule leads from the Bowman’s capsule.
2. Divided into:
   A. Proximal tubule
   B. Loop of Henle
   C. Distal tubule
   D. Collecting tubule

Proximal Convoluted Tubule

1. Reabsorption of water, bicarbonate, glucose, amino acids, sodium, etc.
2. Secretion of H+ and NH₃
Loop of Henle
1. present in birds and mammals.
2. In the Descending limb, there is
   1) $\text{H}_2\text{O}$ reabsorption
   2) No active or passive salt transport

Ascending Limb
1. Thin ascending limb
   A. No active salt transport
   B. High NaCl permeability
   C. Low H$_2$O permeability
2. Thick ascending limb
   A. Low H$_2$O permeability
   B. Active NaCl transport

Function of the Vasa Recta
Distal Convoluted Tubule

1. Reabsorbs more water and sodium, etc.
2. Secretion of H⁺ and potassium.
3. Aldosterone affects permeability.

Collecting duct

1) the last chance to reabsorb sodium and water
2) Variable permeability to H₂O
3) Passive diffusion of urea
4) ADH regulates permeability

Endocrine hormones affect kidney function

1. Diuretics – stimulate excretion of water
2. Antidiuretics – reduce excretion of water
3. Steroid hormones – slow response (act over hours)
4. Peptide hormones – rapid response
Vertebrate Kidney: Structure and basic function

1. We filter our entire blood volume about twice an hour
2. Re-absorption is quite fine-tuned
3. Tubular maximum
4. Some poisons are specifically secreted to speed excretion from body

How Renal Function is Studied BOX 28.2

1. Net Process:
   Amount of substance “A” in Urine = Amount Filtered - Amount Reabsorbed + Amount Secreted

How Renal Function is Studied

1. Glomerular Filtration Rate (GFR).
   A. rate kidneys filter blood plasma
2. Substances used to measure GFR
   A. Inulin
   B. Creatinine
How Renal Function is Studied

1. $V \times U = GFR \times P$
2. where
   A. $V =$ rate of urine production in, in mL/min
   B. $U =$ urine concentration of “A”, in mg/mL
   C. $(VU =$ amount of inulin in the urine per minute)
   D. $GFR = $ glomerular filtration rate of plasma, in mL/min
   E. $P =$ plasma concentration of “A”, in mg/mL
   F. $GFR = \frac{VU}{P}$

Solving for GFR ($V_{filtrate}$)

1. If
   1) Urine flow: $V_{urine} = 1.2$ ml/min
   2) Inulin in urine = 2%
   3) Inulin in plasma = 0.02%
2. Then
   4) $V_{filtrate} = $ Glomular filtration rate = 120 ml/min

How Renal Function is Studied

1. 99% filtrate is reabsorbed
2. In 24 hours, human kidneys reclaim
   A. ~1,300 g of NaCl
   B. ~400 g NaHCO$_3$
   C. ~180 g glucose
   D. almost all of the 180 liters of water that entered the tubules.
Clearance measurements

1. tell you how the kidney handles the substance:
2. Filtered only
   1) C = GFR (about 120 mL/min)
3. Filtered and then reabsorbed:
   2) C for that substance will be less than about
      120 mL/min
4. Filtered and then secreted
   3) C for that substance will be higher than
      about 120 mL/min

example

1. C = GFR = \( V_{\text{urine}} \times (U / P) \)
   1) Urine flow: \( V_{\text{urine}} = 1.2 \text{ ml/min} \)
   2) ammonia in urine: = 0.0025 mg/ml
   3) NH\(_3\) in plasma = 0.00002 mg/ml
   4) Computed GFR = ____ * ____ = ____ ml/min
   5) BUT: GFR from inulin = 120 ml/min
      1) if no secretion U/P = ____ ml/min / ____ ml/min
      1) 100:1 = \([\text{NH}_{\text{urine}}]\) / 0.00002 = 0.002 mg/ml
      2) 0.0005 mg of \(\text{NH}_3\) has been secreted into
         each ml of urine
      3) 0.002 + 0.0005 = 0.0025 mg/ml

Example for Glucose

1. Normal
   A. plasma glucose = 1 mg/ml
   B. Urine flow (V) = 1.2 ml/min
   C. glucose in urine: = 0 mg/ml
2. If glucose in plasma = 2.7 mg/ml
3. and no glucose in urine
4. C = GFR = V * (U / P) = 0 = 100% resorption
5. If GFR = 120 ml/min
   A. ____ mg/min of glucose is resorbed
6. Tubular maximum
   A. Maximum rate at which a substance
      can be actively absorbed
Alcohol and Caffeine

1. Alcohol inhibits ADH release from the brain.
2. Caffeine blocks ADH attachment to the collecting duct epithelium, increases glomerular filtration rate, and decreases the tubular reabsorption of Na.

Diabetes insipidus

1. A deficiency of ADH or inheritance of mutant genes for its receptor
2. Severely-affected patients can produce 30 liters of urine / day.
3. The disease is accompanied by terrible thirst, and patients must continually drink water to avoid dangerous dehydration.

Figure 29.22 The posterior gut and Malpighian tubules of an insect
Nitrogen Excretion: General

1. Most nitrogen in an animal's system is from digestion of proteins.
2. Excess nitrogen released during deamination of amino acids is usually in the form of NH₃.
3. Metabolism of nucleic acids and other nitrogen compounds also yields ammonia.
Nitrogen Excretion: Ammonia

1. Requires little energy to produce
2. Highly soluble and highly toxic
3. Requires large volumes of water to store and excrete
4. Ammonia is
   A. Excreted by teleosts, cyclostomes, and most invertebrates
   B. lost mainly through skin and gills
   C. no special organ needed

Nitrogen Excretion: Urea

1. Soluble and not too toxic
2. In sharks and marine frogs it is re-absorbed for osmotic balance
3. Tadpoles excrete ammonia, while frogs excrete urea
4. Lungfish excrete ammonia

Nitrogen Excretion: Uric Acid

1. An adaptation to reducing water loss in desert animals
2. Birds and reptile embryos in eggs need to excrete without losing much water
3. Water in cloaca and hindgut absorbed through osmosis
   A. active transport may also be involved