Chapter 44: Internal Environment Regulation

Water Balance & Waste Disposal

Osmoregulation: Management of the body's water content and solute composition via movement of solutes between the internal fluids and external environment

Transport Epithelium:
Specialized epithelial layers that regulate solute movement (controlled amounts in specific directions)
- Tight junctions present
- May require ATP

Transport epithelia in excretory organs have dual role:
1) Maintain water balance
2) Dispose of metabolic waste

Nitrogenous Wastes Correlated with Animal Phylogeny / Habitat:

- Proteins (amino acids)
- Nucleic acids (nitrogenous bases)

Ammonia
- Toxicity: must be diluted
- Lost across body / via gills

Amino acids
- Lower toxicity: stored in lipid
- Synthesized in liver / corals

Urea
- Relatively non-toxic (paste)
- Xeric environ. / shelled eggs
Cells Require Balance Between Water Gain / Loss:

**Osmolarity**: Moles of a solute / liter of solution (e.g., blood = 300 mosm/L)

Solutions to Balancing Water Gain / Loss:

1) **Osmoconformer**: Organism does not actively adjust internal osmolarity
   - Animals internal osmolarity the same as the external environment
   - Requires stable external osmolarity (marine environment)
2) **Osmoregulator**: Organism actively controls internal osmolarity
   - Allows for existence in diverse environments (e.g., freshwater / terrestrial)
   - Energetically expensive (5 – 30% resting metabolic rate)

- **Stenohaline** = ↓ tolerance for change / Euryhaline = ↑ tolerance for change

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### Maintaining Water Balance in the Sea (marine vertebrates = osmoregulators):
- Marine environment strong dehydrator
  - Lose water (osmosis): gain salts (diffusion)
  - Very little urine produced
  
  **Note**:
  - Sharks maintain ↑ [urea] in body; Actually pull water in via osmosis (do not drink)

### Maintaining Water Balance in Freshwater:
- Gain water (osmosis): lose salts (diffusion)
  - Active uptake of salts (gills)
  - High volumes of urine produced

**Note**:
- Salmon, which migrate between fresh / salt water, switch between osmoregulatory strategies

### Maintaining Water Balance on Land:
- 12 – 25% water loss → death for terrestrial animals
- Water loss adaptations necessary:
  1) Anatomical adaptations (e.g., keratinized cells)
  2) Behavioral adaptations (e.g., time of activity)
- Water recovered via drinking, eating and metabolic water
Two-Step Process for Urine Filtration (Universal):

1) Body fluid collected
   • Filtration: Passage of fluid through selectively-permeable membrane
     • Retain cells / large proteins
     • Filtrate = Filtered fluid

2) Composition of fluid adjusted via selective reabsorption / secretion
   • Reabsorption of essential small molecules (filtration non-selective)
     • Active transport
   • Secretion of waste too large to filter (active transport)

Excretory Systems Based on Tubular Theme:

1) Protonephridium (Flame-bulb System – e.g., flatworms):
   • Network of dead-end tubes lacking internal openings
   • Flame bulb: Filtering unit (ciliated)
   • Nephridiopore: Exit opening in body wall

   • Function for:
     1) Osmoregulation in freshwater flatworms
     2) Waste disposal in parasitic flatworms

2) Metanephridia (e.g., earthworms):
   • Network of tubes with internal openings that collect fluids

   Both osmoregulatory and excretory function

3) Malpighian Tubules (e.g., insects):
   • Network of dead-end tubules that empty into digestive tract
     • Reabsorption occurs in digestive system
Excretory Systems Based on Tubular Theme:

4) Kidneys (e.g., mammals):

Cortical Nephrons (80%):
- Entirely contained in cortex

Juxtamedullary Nephrons (20%):
- Descends into medulla

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Formation of Urine:
- Glomerulus (= filtration):
  - Driven by blood pressure
  - Non-selective

PCT (= secretion / reabsorption):
- Secrete H+ and ammonia
- Reabsorb essential molecules

Loop of Henle (= reabsorption):
- Descending = water
- Ascending = NaCl (active)

DCT (= reabsorption / secretion):
- Absorb water / NaCl (hormones)
- Secretes H+ / K+ / drugs

Collecting Duct (= reabsorption):
- Absorb NaCl / water / Urea
- Secretes H+ / K+ / drugs

Conservation of Water:
- Osmotic gradient exists within kidney (costly process)
  - Allows for [urine] of 300 – 1200 mosm / L
  - Water removed from filtrate in descending loop of Henle (concentrates filtrate)
  - Salt removed from filtrate in ascending loop of Henle (creates osmotic gradient)
  - Urea leaks out in collecting duct assisting in gradient
Hormonal Control of Kidney Function:

1) **Antidiuretic Hormone**
   - Secreted by posterior pituitary:
     - Increases permeability of DCT and collecting ducts to water
     - \( \downarrow \) urine volume / \( \uparrow \) [urine]

2) **Aldosterone** (Renin-angiotensin Mechanism)
   - Secreted by adrenal cortex:
     - Increases permeability of DCT and collecting ducts to salt
     - \( \downarrow \) urine volume