1. Osmoregulation
2. Kidney Function

Text:
Chapters 25-28

- Thank Eldon Braun
- Manuscript Reviews
- Exam Scoring
- Return Papers
Osmoregulation by Birds

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(08 November 2005)

What are the three fluid compartments in vertebrates?

1. Intracellular
2. Extracellular
   A. Interstitial
   B. Blood Plasma

What are Colligative Properties?

Depends on Solute concentration:
Osmolality, Freezing Point, Boiling Point, Water Vapor Pressure

What is a micron?

\[ \text{um} = 1/1,000,000 \text{ of a meter} = 10^{-6} \text{m} = \mu \text{m} \]

Hill et al. 2004, Fig 25.7
### Organs that Contribute to Osmoregulation in Vertebrates

<table>
<thead>
<tr>
<th>Group</th>
<th>Osmoregulatory Organs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish</td>
<td>Kidneys, Gills, Bladder, Intestine</td>
</tr>
<tr>
<td>Amphibians</td>
<td>Kidneys, Gills, Bladder, Skin, Intestine</td>
</tr>
<tr>
<td>Reptiles</td>
<td>Kidneys, Salt Glands, Intestine</td>
</tr>
<tr>
<td>Birds</td>
<td>Kidneys, Salt Glands, Intestines</td>
</tr>
<tr>
<td>Mammals</td>
<td>Kidneys</td>
</tr>
</tbody>
</table>

**How are birds and reptiles related?**
Serum Albumin

SDS PAGE of avian Urine and plasma

Albumin is the protein of the highest concentration in plasma.

Albumin transports many small molecules in the blood (for example, bilirubin, calcium, progesterone, and drugs).

It is also of prime importance in maintaining the oncotic pressure of the blood. This is because, unlike small molecules such as sodium and chloride, the concentration of albumin in the blood is much greater than it is in the extracellular fluid.

Because albumin is synthesized by the liver, decreased serum albumin may result from liver disease. It can also result from kidney disease, which allows albumin to escape into the urine. Decreased albumin may also be explained by malnutrition or a low protein diet.

Normal Values (3.4 to 5.4 g/dL)  

Allometry:
Mouse-to-Elephant Curve

4 g shrew eats 2 g/day

Elephant is 1 million x larger

$\text{MR} = aM^b$

$log\text{MR} = loga + b(logM)$

$\text{slope} = 0.75$
\log M_{\text{skeleton}} = \log a + b(\log M)

Isometry is rare

\textbf{b} = 1.13
(slope)

Figure 47. Weight of the skeleton of mammals increases more than proportionally to an increase in body weight. The slope of the regression line is 1.13. (Data from Kayser and Heusner, 1964.)
Locomotor Mode

Hill et al. 2004, Fig 26.15
Free

Preformed

Metabolic

\[ C_6H_{12}O_6 + 6O_2 \leftrightarrow 6CO_2 + 6H_2O \]

**TABLE 25.3** Average gross amount of metabolic water formed in the oxidation of pure foodstuffs

<table>
<thead>
<tr>
<th>Foodstuff</th>
<th>Grams of H_2O formed per gram of foodstuff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate(a)</td>
<td>0.56</td>
</tr>
<tr>
<td>Lipid</td>
<td>1.07</td>
</tr>
<tr>
<td>Protein with urea production(b)</td>
<td>0.40</td>
</tr>
<tr>
<td>Protein with uric acid production(b)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Source: After Schmidt-Nielsen 1964.

* Starch is assumed for the specific value listed.

* Water yield in protein catabolism depends on the nitrogenous end product.

**TABLE 25.4** Approximate catabolic gains and losses of water in caged kangaroo rats (Dipodomys) and laboratory rats (Rattus) when eating air-dried barley and denied drinking water at 25°C and 33% relative humidity

<table>
<thead>
<tr>
<th>Category of water gain or loss</th>
<th>Kangaroo rats</th>
<th>Laboratory rats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross metabolic water produced</td>
<td>0.54 g/g</td>
<td>0.54 g/g</td>
</tr>
<tr>
<td>Obligatory water losses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>Urinary</td>
<td>0.14</td>
<td>0.24</td>
</tr>
<tr>
<td>Fecal</td>
<td>0.00</td>
<td>0.03</td>
</tr>
<tr>
<td>Total obligatory water losses</td>
<td>0.47</td>
<td>0.60</td>
</tr>
<tr>
<td>Net gain of metabolic water</td>
<td>+ 0.07</td>
<td>- 0.06</td>
</tr>
</tbody>
</table>
Water

Lose water:
- evaporation
- urine
- feces
- salt glands

Alter behavior and physiology to minimize water loss.
Water balance limits activity in time and space.

Amphibs lose most water via evaporation.
- cutaneous resistance
  1 dried mucus
  2 cocoon
  3 wax

**Phylomedusa**

![Image of Phylomedusa](image)

Figure 5-4  Wiping behavior of the tree frog Phylomedusa sauvagii. (Courtesy of Rodolfo Rubel)  Pough et al., 2001
Less evap.

More evap.

Figure 5-8  Cutaneous resistance to evaporation for amnals and reptiles. The scale is logarithmic. (Source: Skelton 1990.) Pough et al., 2001

Water

Chuckwalla (lizards have more lipids in skin)

Monkey Tree Frog
Anolis lizard

Alligator

Softshell Turtle
Bufo, Spadefoots, Rana
(free water surface)

Camel

K-rat

Oryx

Hopping Mouse
Volume Regulation

Osmotic Regulation

Ionic Regulation

How do these differ?

Kidney Function

Group C
Freshwater and terrestrial invertebrates

extracellular
~300 mOsm

Organic solutes
Inorganic ions
Na\(^+\)Cl\(^-\)

Group D
Freshwater and terrestrial vertebrates; marine vertebrates not in A or B

intracellular
~300 mOsm

Organic solutes
Inorganic ions
Na\(^+\)Cl\(^-\)

Organic solutes
Inorganic ions
K\(^+\)
Na\(^+\)Cl\(^-\)

Osmotic concentration

Animal Physiology Figure 23.11 (Part 2) © 2008 Elsevier Inc.
Nephron Anatomy

1 - Proximal tubule
2 - Loop of Henle
   - descending
   - ascending
3 - Distal tubule

- numerous nephrons empty into collecting duct
- collecting ducts empty into renal pelvis
Nephron Anatomy

Figure 5.8: Diagram of a mammalian kidney. The kidney contains a large number of nephrons, each with a loop of Henle and a distal convoluted tubule. The outer portion of the kidney, the cortex, contains the Malpighian bodies and the proximal and distal convoluted tubules. The capillary network within the Malpighian body is known as the glomerulus. The inner portion, the medulla, contains Henle's loops and collecting ducts.

The urine is initially formed in the renal pelvis, then passes down the ureter and into the urinary bladder. [Knut Schmidt-Nielsen 1997]

Figure 9.11 Diagram of the renal medulla and cortical nephrons. The renal medulla and cortex are divided into inner cortical, outer cortical, and outer medullary regions. The renal vessels are illustrated as being linked to the renal capsule by the renal artery and renal vein. [Knut Schmidt-Nielsen 1997]

Vasa recta

Countercurrent exchange

DOG KIDNEY Close-up view of glomerulus from a dog kidney after arterial injection of silicone rubber. The glomerulus in the center of the photo shows the slightly thicker vessel leading into the glomerulus and the somewhat thinner vessel leaving it. The diameter of these vessels is about 15 to 20 μm; the diameter of the glomerulus is about 150 μm. [Source: A. Clifford Barger, Harvard University] [Knut Schmidt-Nielsen 1997]
Kidney Processes- overview

1. FILTRATION
   blood --> filtrate

2. REABSORPTION
   filtrate --> blood

3. SECRETION
   blood --> filtrate

All 3 involved in final Urine Composition

Filtration plus secretion

**Table 9.2** The maximum concentration of various mammals is correlated with the animal, desert animals having the highest concentrations and fresh-water animals.
Filtration:

**Bowman’s capsule**
- 3 layers
  1. **Glomerular endothelial cells**
     - 100x leakier than other capillary walls
  2. **Basement membrane**
     - negatively charged glycoproteins
     - repel plasma proteins by charge
  3. **Epithelial cells**
     - podocytes create slits

**Filtrate** = protein-free and cell-free plasma

**Glomerular Filtration Rate (GFR)**
- **Humans:** 125 ml/min or 180 L/day (60x plasma vol.)
About 20% of the plasma and solutes that enter glomerulus end up in BC.
1. Starvation Implications?

2. Kidney Stone Implications?

Filtration Regulation:

1. **Myogenic** props. of afferent arteriole resist stretch

2. Secretions from cells of **juxtaglomerular apparatus** (where distal tubule passes near bowman’s capsule)

   - **Macula densa** cells (distal tubule)
     - monitor osmolarity and flow in distal tubule
     - paracrine hormonal activity on afferent arteriole

   - **Granular or juxtaglomerular** cells (afferent arteriole)
     - release **renin** which alters blood pressure...
Filtration Regulation:

**Renin** (from granular cells) released in response to
- low renal BP,
- low solute [ ] in distal tubule,
- or sympathetic activation

Renin leads to activation of **Angiotensin II** which causes systemic **vasoconstriction** to inc. BP
stimulates **aldosterone** from adrenal cortex
**vasopressin (ADH)** from post. pit.
(these promote salt, water **reabsorption**)

3. **Sympathetic innervation** (reduce GFR)
   - afferent vasoconstriction
   - decreased space between podocytes