Lecture 04, 01 Sept 2005
Chapters 2, 3, and 10

Vertebrate Physiology
ECOL 437 (aka MCB 437, VetSci 437)
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instr: Kevin Bonine
t.a.: Kristen Potter

Chapter 2
1. Membranes and Biological Compounds
2. Enzymes

Chapter 3
3. Water and Movement of Solutes

Chapter 10
4. Nervous System Introduction

Physiology

Vertebrate Physiology 437

Chapter 2
Lactate dehydrogenase
2 alleles

Hill et al 2004

Membrane Signaling

Hill et al 2004

(a) Ligand-gated channel
(b) G protein-coupled receptor and associated G protein system

Membrane Signaling

Hill et al 2004
Membrane Signaling

2nd Messengers

1 cyclicAMP
2 CyclicGMP
3 NO
4 DAG
5 IP3
6 Calcium

Movement Across Membranes

How does glucose cross membranes?

Most tissues:
- Passive transport down [ ] gradient via carrier proteins

In gut:
- 2° active to move Glu against [ ] gradient into blood from “food”

Amplification

Transport (pore or carrier) may be highly selective
Movement Across Membranes

1. Passive Diffusion (= simple diffusion)
   - nonpolar/nonelectrolyte
   - lipid soluble (steroid hormones)
   - few H bonds
   - ~smaller size
   - rate depends on [ ] gradient
   - No saturation

   Fick Equation:
   \[ J = D \frac{C_1 - C_2}{X} \]
   - net rate of diffusion
   \( D \) = diffusion coefficient (depends on permeability and Temp)
   \( C_1, C_2 \) = [gradient]
   \( X \) = distance separating C1 from C2

TABLE 3.1 The time required for diffusion through water to have a concentration difference. Values are calculated for small solutes such as O₂ or Na⁺. For each distance between solutions, the time listed is the time that will be required for diffusion to transport half the solute molecules that must move to reach concentration equilibrium. It is assumed that no electrical effects exist, and thus only diffusion based on concentration effects is occurring.

<table>
<thead>
<tr>
<th>Time required to have a concentration difference by diffusion</th>
<th>Distance Between solutions</th>
<th>A biological dimension that exemplifies the distance specified</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 nanoseconds</td>
<td>10 nanometers</td>
<td>Thickness of a cell membrane</td>
</tr>
<tr>
<td>100 microseconds</td>
<td>10 micrometers</td>
<td>Radius of a small mammalian cell</td>
</tr>
<tr>
<td>17 minutes</td>
<td>1 millimeter</td>
<td>Half-thickness of a bony anterior muscle</td>
</tr>
<tr>
<td>1.1 hours</td>
<td>1 centimeter</td>
<td>Half-thickness of a human ear</td>
</tr>
<tr>
<td>4.6 days</td>
<td>1 millimeter</td>
<td>Length of a long human nerve</td>
</tr>
<tr>
<td>32 years</td>
<td>1 meter</td>
<td>Thickness of the human heart muscle</td>
</tr>
</tbody>
</table>

Source: After Weiss, 1996.

What is a boundary layer?

Movement Across Membranes

2. Passive Transport (= facilitated diffusion)
   - pores show some saturation, but not as much as carriers

   Down Electrochemical gradient
   A. pore
   B. carrier mediated

Movement Across Membranes

3. Active Transport (1°, 2°)
   - Na⁺/K+ ATPase Pump
   - Pores show some saturation, but not as much as carriers
Galapagos Marine Iguana (Iguanidae)

El Nino → lack of food

Starvation b/c high cost of salt excretion

Animals may lose 15% body length
- bone absorption

Only adult vertebrate known to regularly shrink
(astronauts)

Largest animals die
- sexual selection
- natural selection

(Most efficient salt glands known in reptiles)

(See Pelis et al 2001)
Movement Across Membranes

- Passive diffusion through membrane
- Passive transport through channels
- Carrier-mediated transport (passive or active)

**How would you describe this movement across membrane?**

**Na+/K+ ATPase Pump**

1. Na+ is released from cytosol.
2. ATP hydrolysis favors original conformation.
3. K+ is released to cytosol. Cyclic can repeat.

**Na+/K+ ATPase Pump**

- Exocytosis fluid
- Unporter
- Symporter
- Antiporter

**Facilitated transport**

**Coupled transport**

**Key Transports**

- **Na+/K+ ATPase**
- Transport against the electrochemical gradient
- **Cotransporter**
- Transport in the direction of the electrochemical gradient

**Movement Across Membranes**

**Na+-glucose cotransporter in apical membrane**

- **KEY TRANSPORTERS**
  - ATPase
  - Cotransporter

**Solute Movement**

- Transport against the electrochemical gradient
- Transport in the direction of the electrochemical gradient
Ion Channels

- Ion selectivity
- Leaky channels (e.g., K+)
- Voltage-gated channels (e.g., Na+, K+, Ca+)
- Ligand-gated channels etc.

Electrochemical equilibrium

Osmotic Properties of Cells and Relative Ion Concentrations

Permeabilities

K+ >> Na+ ; Cl-

Movement Across Membranes

How does water move across membranes?

Movement of water

In specific tissues and cells:

- Iso
- Hypo
- Hyper

Aquaporins
Osmotic Properties of Cells and Relative Ion Concentrations

Na+  K+  Ca++  Cl-

Colligative Properties
- Osmotic Pressure
- Freezing Point
- Water Vapor Pressure (boiling point; evaporation)

Hypertonic Cell Contents

Osmolarity
1 osmolar solution (Osm)
has 1 Avogadro’s number of dissolved particles/liter solvent

1 milliosmolar solution (mOsm)
has 0.001 Avogadro’s number of dissolved particles/liter solvent

What osmolarity do you get if you add $6 \times 10^{23}$ molecules of glucose to a liter of water?

What osmolarity do you get if you add $6 \times 10^{23}$ molecules of table salt to a liter of water?

NaCl (strong electrolyte)
Rate of Osmosis = \( \frac{K}{X} \) 

- **Proportionality Coefficient** (~ permeability and temp)
- **Distance between solutions**
- **Difference in osmotic potential**

Osmotic Pressure Vs. Hydrostatic Pressure

Movement Across Membranes

- **Electrochemical Gradient**
  - **Electrical gradient**
  - **Concentration gradient**
  - **Electrochemical equilibrium**

- **Equilibrium potential** \( (E_x \text{ in mV}) \)
  - when [X] gradient = electrical gradient

Equilibrium potential \( (E_x \text{ in mV}) \)

"Every ion’s goal in life is to make the membrane potential equal its own equilibrium potential \( (E_x \text{ in mV}) \)"

Nervous System

Comprises
- **Neurons / Nerve Cells**
- **Glial Cells** (support)
- **Signalling via combination of Electrical and Chemical**
  - Integrate information **AFFERENT**
  - Coordinate Response **EFFERENT**