Lecture 02, 25 Aug 2005  
Chapters 1 and 2

Vertebrate Physiology  
ECOL 437 (aka MCB 437, VetSci 437)  
University of Arizona  
Fall 2005

instr: Kevin Bonine  
t.a.: Kristen Potter

3x5 card
1. Discussion section: 9am or 2pm on Wed.

2. Name (and what you prefer to be called)  
   - distinguishing characteristics

3. Email address

4. Year in school

5. Major

6. Relevant courses taken, or research projects, etc.

7. Why are you taking this course? / What do you hope to get out of it?
Vertebrate Physiology 437

1. 3x5 cards
2. Syllabus
3. Photos
4. Vertebrate Physiology
   Homeostasis
   Feedback
   Adaptation
   Literature
5. Membranes and Biological Compounds

Graph:
Regulator vs. Conformer

Explain:
energy required vs. freedom of organism
Homeostasis  

(a) Conformer  
(b) Regulator

Value of variable in internal environment

Value of variable in external environment

energy vs. freedom

Line of conformity

Zone of stability where homeostasis is maintained

Feedback Loops

negative

set point (can be reset)

homeostasis

(blood glucose)

positive

less common
-voiding
-pregnancy
-congestive heart failure
-nerve transduction
(action potentials)

e.g.: Temp. salinity [glucose] pH [ion] pO$_2$

Randall et al. 2002
Vertebrate Physiology

Animal
1 - “An animal is not a discrete material object” (Hill et al 2004 p. 10)
2 - Energy required for organization (to fight entropy)
3 - Body size:

![Body size graph](image)

Physiology

1. Mechanism
2. Origin
   Adaptive Significance

TINKERING
Vertebrate Physiology

Evolutionary Processes

**Evolution:** Change of gene frequencies over time

1. Adaptation: a subset of evolution, driven by natural selection

2. Genetic Drift
3. Founder Effect
4. Pleiotropy (one gene, several traits)
5. No longer adaptive

Role of Genetic Variation

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**Adaptation**

**TIME**

**TABLE 1.2 The five time frames in which physiology changes** Hill et al. 2004

<table>
<thead>
<tr>
<th>Type of change</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changes in physiology that are responses to changes in the external environment</td>
<td></td>
</tr>
<tr>
<td>1. Acute changes</td>
<td>Short-term changes in the physiology of individual animals; changes that individuals exhibit right after their environments have changed; acute changes are reversible</td>
</tr>
<tr>
<td>2. Chronic changes (acclimation and acclimatization)</td>
<td>Long-term changes in the physiology of individual animals; changes that individuals display after they have been in new environments for days, weeks, or months; chronic changes are reversible</td>
</tr>
<tr>
<td>3. Evolutionary changes</td>
<td>Changes that occur by alteration of gene frequencies over the course of many generations in populations exposed to new environments</td>
</tr>
<tr>
<td>Changes in physiology that are internally programmed to occur whether or not the external environment changes</td>
<td></td>
</tr>
<tr>
<td>4. Developmental changes</td>
<td>Changes in the physiology of individual animals that occur in a programmed way as the animals mature from conception to adulthood and then to senescence</td>
</tr>
<tr>
<td>5. Changes controlled by periodic biological clocks</td>
<td>Changes in the physiology of individual animals that occur in repeating patterns (e.g., each day) under control of the animals’ internal biological clocks</td>
</tr>
</tbody>
</table>

Genotype vs. Phenotype
Adaptation

Evolution by natural selection

Acclimatization

Modification in response to environment within a lifetime (reversibility?)

Acclimation (laboratory)

Similar to acclimatization but more artificial

Adaptation

Plasticity

Ontogenetic, environmental
Environments

Chemical, physical, and biological components of an organism’s surroundings

1. Temperature
2. Oxygen (air, water)
3. Water (osmoregulation)

- Microhabitats
- Behavior

Vertebrate Physiology

Environments

Vertebrate Physiology

- Microhabitats
- Behavior

Figures 1.13, 1.15
Hill et al. 2004
**Krogh principle**

For many physiological questions, there is an animal model ideally suited to answer it.

- *Xenopus eggs*  
- Giant squid axons
- Sea raven (fish) heart  
- Kangaroo rat kidney
- Horned lizard diet

**Genetic engineering** (diabetic mice, knockouts, obesity, etc.)

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**Discussion Question**

In small groups of about 3 students:

How would you design an experiment to test the hypothesis that saltwater crocodiles are osmoconformers?

OR

How would you ascertain whether or not the extra-long loops of Henle in Kangaroo Rat kidneys were an adaptation to their desert habitat and lifestyle?
### Organism-level Approaches

- **Physiological State**
  - Sleeping
  - Resting
  - Alert
  - Exercising
  - Stress-level
  - Fasting or Fed

- **Age**
- **Sex**
- **Season**
- **Reproductive Condition**

- **BMR**
- **RMR**

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**Scientific Literature 1/4**

<table>
<thead>
<tr>
<th>Table 1-2</th>
<th>A sampling of scientific journals that publish physiological research papers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Abbreviation*</td>
</tr>
<tr>
<td>General journals</td>
<td></td>
</tr>
<tr>
<td>American Journal of Physiology</td>
<td>Am. J. Physiol.</td>
</tr>
<tr>
<td>Pflügers Archiv für Physiologie (now European Journal of Physiology)</td>
<td>Acta Physiol.</td>
</tr>
<tr>
<td>journal of Physiology</td>
<td>J. Physiol.</td>
</tr>
<tr>
<td>journal of General Physiology</td>
<td>J. Gen. Physiol.</td>
</tr>
</tbody>
</table>

| Comparative Physiology and Biochemistry |
| journal of Comparative Physiology | Comp. Physiol. | - Many different areas, with emphasis on lower vertebrates and invertebrates |
| journal of Experimental Biology | J. Exp. Biol. | -                                                                 |
| Physiological and Biochemical Zoology | Physiol. Biochem. Zool. | -                                                                 |

*Single-word journal names are not abbreviated.
Randall et al. 2002
### Scientific Literature 2/4

#### Table 1-2  A sampling of scientific journals that publish physiological research papers

<table>
<thead>
<tr>
<th>Specialty journals</th>
<th>Abbreviation*</th>
<th>Topics covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain, Behavior, and Evolution</td>
<td>Brain Behav. Evol.</td>
<td></td>
</tr>
<tr>
<td>Cell</td>
<td>Circ. Res.</td>
<td></td>
</tr>
<tr>
<td>Circulation Research</td>
<td>Evol. Dev.</td>
<td></td>
</tr>
<tr>
<td>Evolution and Development</td>
<td></td>
<td>Research related to specific areas or processes indicated by journal's name</td>
</tr>
<tr>
<td>Gastroenterology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Endocrinology</td>
<td>Mol. Endocrinol.</td>
<td></td>
</tr>
<tr>
<td>Nephron</td>
<td>Nephrol. Physiol.</td>
<td></td>
</tr>
</tbody>
</table>

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Randall et al. 2002

### Scientific Literature 3/4

#### Table 1-2  A sampling of scientific journals that publish physiological research papers

<table>
<thead>
<tr>
<th>Annual reviews</th>
<th>Abbreviation*</th>
<th>Topics covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological Reviews</td>
<td>Physiol. Rev.</td>
<td>Summaries and evaluations of original papers on particular topics published in other journals</td>
</tr>
</tbody>
</table>

*Single word journal names are not abbreviated.

Randall et al. 2002
### Table 1-2  A sampling of scientific journals that publish physiological research papers

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<tr>
<th></th>
<th>Abbreviation(s)</th>
<th>Topics covered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Taxonomy-oriented journals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Auk</td>
<td></td>
<td>Physiology and other topics related to birds</td>
</tr>
<tr>
<td>Condor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eau</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crustaceana</td>
<td></td>
<td>Physiology and other topics related to crustaceans</td>
</tr>
<tr>
<td>Copia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herpetologica</td>
<td></td>
<td>Amphibian and reptilian physiology</td>
</tr>
<tr>
<td>Journal of Herpetology</td>
<td>J. Herpetol.</td>
<td>Physiology and other topics dealing with mammals</td>
</tr>
<tr>
<td>Journal of Mammalogy</td>
<td>J. Mammal.</td>
<td></td>
</tr>
<tr>
<td><strong>Weekly journals</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nature</td>
<td></td>
<td>Preliminary reports about topics of general interest to the scientific community</td>
</tr>
<tr>
<td>Science</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Single-word journal names are not abbreviated.*

Randall et al. 2002

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Hill et al. Chapter 2

**Molecules and Cells in Animal Physiology...**
- **MEMBRANES**

- Origins of Life
- Universal Solvent
- Polar Covalent Bonds
- Dipole

- H bonds between molecules
  - transient and weak, but many
  - high specific heat
  - surface tension, cohesiveness

- Density changes
In Water:

- hydrophilic
- hydrophobic

-amphipathic molecules
e.g., micelles
Phospholipid bilayers

Membrane Structure and Composition

1 Phospholipids
   bilayer, fluidity

2 Cholesterol
   stabilizer

3 Proteins
   - integral
   - peripheral
Biological Molecules

- **Lipids**

  - saturated -> cholesterol
  - No double bonds in side chains (saturated with hydrogens)
  - ~solid at room temperature
  - high energy/gram
  - phospholipids

`Figure 2.2  The structure of membrane phospholipid molecules
(a) A phospholipid molecule

Table 3-3  The energy content of the three major categories of foodstuffs

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Energy content (kcal·g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>4.0</td>
</tr>
<tr>
<td>Proteins</td>
<td>Migrating bird?</td>
</tr>
<tr>
<td>Fats</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Randall et al. 2002

Hill et al. 2004

Randall et al. 2002`
Figure 2.3
Degree of unsaturation of brain phospholipids in fish varies with habitat temperature

Membrane Structure and Composition

Protein Structure

Fluid Mosaic Model
- Type of lipids
- Length of tails
- Amount of cholesterol
- Amount and type of protein
- “Sided”
Discussion Question

How do scientists come up with the protein conformations such as pictured here:

Biological Molecules

- Proteins
- linear chains of amino acids
- 20 common alpha-amino acids
- amphoteric
- peptide bonds
- polypeptide chains

(a) General structure of alpha-amino acids

(b) Structure of a tetrapeptide
Biological Molecules
- **Proteins**

- $1^\circ, 2^\circ, 3^\circ, 4^\circ$

**Box 2.1, Figure A** The structural hierarchy of **proteins**

- linear chains of amino acids
Box 2.1, Figure A  The structural hierarchy of proteins

- Denaturation
- Chaperone Proteins (e.g., HSPs)

TABLE 2.1  The five functional types of membrane proteins and the functions they perform

<table>
<thead>
<tr>
<th>Functional type</th>
<th>Function performed (defining property)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>Permits simple or quasi-simple diffusion of solutes in aqueous solution (page 71)—or osmosis of water (page 84)—through a membrane; a simplified view of a channel is that it creates a direct water path from one side to the other of a membrane (i.e., an aqueous pore) through which solutes in aqueous solution may diffuse or water may undergo osmosis.</td>
</tr>
<tr>
<td>Transporter (carrier)</td>
<td>Binds noncovalently and reversibly with specific molecules or ions to move them intact across a membrane; the transport through the membrane is active transport (page 74) if it employs metabolic energy; it is facilitated diffusion (page 74) if metabolic energy is not employed.</td>
</tr>
<tr>
<td>Enzyme</td>
<td>Catalyzes a chemical reaction in which covalent bonds are made or broken (page 41).</td>
</tr>
<tr>
<td>Receptor</td>
<td>Binds noncovalently with specific molecules and as a consequence of this binding, initiates a change in membrane permeability or cell metabolism; receptor proteins mediate the responses of a cell to chemical messages (signals) arriving at the outside face of the cell membrane (page 56).</td>
</tr>
<tr>
<td>Structural protein</td>
<td>Attaches to other molecules (e.g., other proteins) to anchor intracellular elements (e.g., cytoskeleton filaments) to the cell membrane; creates junctions between adjacent cells (Figure 2.7); or establishes other structural relations.</td>
</tr>
</tbody>
</table>

Hill et al. 2004
Biological Molecules

- **Carbohydrates**
  - \((\text{CH}_2\text{O})_n\)
  - monosaccharides, (disaccharides)
  - glucose is common metabolic currency from plants to animals
  - glycogen (storage)

- **Nucleic Acids**
  - pyrimidine (T,C) or
  - purine (A,G)
  - Phosphodiester linkages between adjacent
  - transcription (nucleus)
    DNA -> mRNA
  - translation (ribosome)
    mRNA -> tRNA -> protein (genetic code)
Junctions between cells

1. **Gap**
   ~ linked

2. **Tight**
   ~ impermeable barriers

Junctions between cells and solute movement

1. **Transcellular path**

2. **Paracellular path**

4-32 Randall et al. 2002

4-35 Randall et al. 2002
Solute movement and variability of membrane properties

Solute movement and subsequent water movement

**Osmosis**
Enzymes and Energetics

Energetics (sun is origin)
- metabolism
- energy/ATP
- building blocks
- small, controlled oxidation steps

- 1st law - energy neither created or destroyed
- 2nd law - entropy will reign

- free energy $\Delta G$
  (energy available to do useful work)

- $\Delta G + \Delta G$
- exergonic (~liberate heat)
- endergonic (uphill)
Energetics

- **exergonic** (liberate heat) - $\Delta G$
- **endergonic** (uphill) + $\Delta G$

**Phosphorylation**
- Protein Kinases
- Protein Phosphatases
Energetics

- Activation Energy
- Enzymes
- Temperature
- \( \uparrow \) Reaction Rates

Figure 2.13  Enzymes speed reactions by lowering the needed activation energy
Enzymes

- **pH, temperature**
- **Cofactors**
  (often vitamins)

Randall et al. 2002

<table>
<thead>
<tr>
<th>Metal ion</th>
<th>Some enzymes requiring this cofactor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca^{2+}</td>
<td>Phosphodiesterase</td>
</tr>
<tr>
<td></td>
<td>Protein kinase C</td>
</tr>
<tr>
<td>Cu^{2+}</td>
<td>Cytochrome oxidase</td>
</tr>
<tr>
<td></td>
<td>Tyrosinase</td>
</tr>
<tr>
<td>Fe^{3+} or Fe^{2+}</td>
<td>Catalase</td>
</tr>
<tr>
<td></td>
<td>Cytochrome</td>
</tr>
<tr>
<td></td>
<td>Ferrodoxin</td>
</tr>
<tr>
<td></td>
<td>Ferritin</td>
</tr>
<tr>
<td>K^{+}</td>
<td>Pyruate phosphokinase (also requires Mg^{2+})</td>
</tr>
<tr>
<td>Mg^{2+}</td>
<td>Phosphohydrolases</td>
</tr>
<tr>
<td>Mn^{2+}</td>
<td>Phosphotransferase</td>
</tr>
<tr>
<td>Na^{+}</td>
<td>Phosho kinase, ATPase (also requires K^{+} and Mg^{2+})</td>
</tr>
<tr>
<td>Zn^{2+}</td>
<td>Alcohol dehydrogenase</td>
</tr>
<tr>
<td></td>
<td>Carbonic anhydrase</td>
</tr>
<tr>
<td></td>
<td>Carboxypeptidase</td>
</tr>
</tbody>
</table>

Source: Adapted from Nelson and Cox, 2000.

Enzymes

- **Regulation**
  1 - Competitive
  2 - Allosteric

Randall et al. 2002

- **(a)** Competitive inhibition
- **(b)** Allosteric inhibition
Enzymes

- Rates of Rxn (V)
- MM constant (Km)

Michaelis-Menten equation

\[ V_0 = \frac{V_{\text{max}}[S]}{K_m + [S]} \]

Figure 2.14 The approach to saturation depends on enzyme-substrate affinity

(b) Determination of $K_m$ for two of the enzymes from (a)
Enzymes
- Lineweaver-Burk Plot

\[ \frac{1}{V_0} = \frac{K_m}{V_{max}[S]} + \frac{1}{V_{max}} \]

Figure 2.12 Reaction velocity as a function of substrate concentration

Enzyme Kinetics
- hyperbolic
- sigmoidal

Hill et al. 2004