BIOD33H: Comparative Animal Physiology

Fall 2014

Course Instructor

Dr. Stephen Reid; Office S526; sgreid@utsc.utoronto.ca

Office Hours

Monday and Wednesday, 11:15 to 12:30 and Thursday 1:15 to 2:30 or by appointment (e-mail for an appointment)

Recommended Textbook

Animal Physiology by Hill, Wyse and Anderson. Sinauer. ISBN: 0-87893-315-8. The bookstore carries the latest version. Earlier editions are also perfectly suitable.

Evaluation

Midterm Exam #1 (held during a scheduled term-test time), 25%
This exam will cover the material from lectures 1-4.

Midterm Exam #2 (held during a scheduled term-test time), 25%
This exam will cover the material from lectures 1-8 with two-thirds of the questions coming from lectures 5-8.

Note, UTSC Scheduling typically does not release the term test schedule until late in the third week of the semester. I will announce the dates, times and locations of the midterm exams once they are released. I have requested midterm exam dates that are a minimum of one-week after the last lecture that will be covered on the exams.

Final Exam, 50%
The final exam will cover the entire course with more emphasis on lectures 9-12 and 5-8. A breakdown of the exam questions will be provided prior to the exam.

All exams will be a combination of multiple choice questions and short answer/essay questions.

Topics

A. Introduction to Comparative Physiology

1. August Krogh Principle
2. Structure – Function Relationships
3. Time Domains of Physiological Change
4. Extreme Environments
5. Hydrothermal Vents

B. Respiratory Physiology

1. Breathing in Invertebrates
- **a.** Aquatic Invertebrates
- **b.** Insect Tracheal System

2. Breathing in Fish
- **a.** Water – Breathing Fish
  - *i) Gill Morphology*
  - *ii) Countercurrent Gas Exchange*
  - *iii) Mechanics of Breathing*
  - *iv) Aquatic Surface Respiration*
- **b.** Air – Breathing
- **c.** Respiratory Control Systems
  - *i) Gill Chemoreceptors*
  - *ii) Hypoxic Ventilatory Response*
  - *iii) Hypercapnic Ventilatory Response*
  - *iv) Breathing Pattern Formation*
  - *v) The Root Effect*
  - *vi) Plasma Catecholamines during Hypoxia*
  - *vii) Plasma Catecholamines and Air Breathing*

3. Breathing in Amphibians
- **a.** Gas Exchange
- **b.** Mechanics of Breathing
- **c.** Respiratory Control Systems

4. Breathing in Reptiles
- **a.** Lung Structure
- **b.** Intrapulmonary Chemoreceptors

5. Breathing in Birds
- **a.** Lung Structure
- **b.** Avian Respiratory Cycle
- **c.** Concurrent Gas Exchange

C. Cardiac and Cardiovascular Physiology

1. Mammalian Fetal Circulation

- **a.** Circulatory Structure
- **b.** Changes at Birth

2. Hearts and Circulation in Fish

- **a.** Teleost and Elasmobranch Hearts
- **b.** Circulatory Patterns
- **c.** Circulation in Lungfish
- **d.** Hypoxic Bradycardia

3. Hearts and Circulation in Amphibians and Reptiles

- **a.** Amphibian Heart Structure
- **b.** Amphibian Blood Flow Patterns
- **c.** Non-Crocodilian Reptile Hearts
- **d.** Crocodilian Reptile Hearts
    - *i) Heart Structure*
    - *ii) Blood Flow during Normal Breathing*
    - *iii) Blood Flow during Breath Holds or Diving*
- **e.** Cardiac Shunting
    - *i) Left to Right and Right to Left Shunts*
    - *ii) Cardiorespiratory Synchrony*

4. Hearts and Circulation in Invertebrates

- **a.** Cephalopod Hearts
- **b.** Neurogenic Hearts
- **c.** Insect Circulation

D. Animal Energetics

1. Measuring Metabolic Rate (short-term): Calorimetry and Respirometry

2. Aerobic Capacity and Swimming Performance of Tuna

3. Measuring Metabolic Rate (long-term): Doubly-Labeled Water Technique

4. Feeding and Specific Dynamic Action
- **a.** Metabolic Changes during Feeding in a Python
- **b.** Regulation of Heart Rate during Rest, Feeding and Exercise in a Python

5. Basal Metabolic Rate and Standard Metabolic Rate

6. Metabolic Rate and Body Size
- **a.** Weight Specific Metabolic Rate: Metabolic Scaling /Allometric Relationships
- **b.** Physiological and Ecological Consequences of Metabolic Scaling
- **c.** Metabolic Scaling: The Same Relationship across all Forms of Life
- **d.** Rubner's Surface Law, Fractal Theory and Multiple Causes Theory

7. Muscle Fatigue and Oxygen Deficits

E. Thermal Regulation

1. Types of Heat Exchange

2. Heat Exchange between an Animal and its Environment

3. Categories and Types of Thermal Regulation

4. Poikilothermy / Ectothermy
- **a.** Advantages of Ectothermy
- **b.** Behavioural Thermoregulation
- **c.** Acute Responses to Temperature Change
- **d.** Chronic Responses to Temperature Change
- **e.** Enzyme-Substrate Affinity
- **f.** Homeoviscous Adaptation
- **g.** Adaptive Responses of Poikilotherms to Freezing Conditions (9)
  - *i) Extracellular versus Intracellular Freezing*
  - *ii) Freeze Tolerance*
  - *iii) Freeze Avoidance*
    - *Antifreeze Compounds*
    - *Supercooling*

5. Endothermy / Homeothermy

a. Advantages of Endothermy (and Heterothermy)

b. The Vertebrate Thermostat

i) Peripheral Thermoreceptors
ii) Thermal Set-Point
iii) The Hypothalamus (the thermostat)
iv) Warm, Cold and Temperature-Insensitive Neurons

c. Heat Transfer between an Animal and its Environment

i) The Thermoneutral Zone
ii) Linear Heat Transfer Equation
iii) Below the Thermoneutral Zone

d. Mechanisms of Heat Production / Retention

i) Behavioural Mechanisms
ii) Changes in Blood Flow
iii) Shivering Thermogenesis
iv) Non-Shivering Thermogenesis and Brown Adipose Tissue
v) Regional Heterothermy and Countercurrent Heat Exchange

e. Temperature Acclimation (metabolic rate and insulation)

f. Controlled Hypothermy (Daily Torpor and Hibernation)

i) Energy Savings
ii) Hibernation Bouts
Euthermia
Entrance into Hibernation and Initiation of Hypometabolism
Reduction in ATP Demand / Synthesis
Maintenance of Hibernation
Arousal from Hibernation
Deep Hibernation and Linear Heat Transfer
Lipid Availability and the Dynamics of Hibernation
Heart Rate Control during a Hibernation Bout
iii) Bear Hibernation

g. Linear Heat Transfer above the Thermoneutral Zone

h. Defenses against the Heat

i) Behavioural Mechanisms
ii) Insulatory Mechanisms
iii) Cycling of Body Heat
iv) Controlled Hyperthermia
v) Brain Cooling
vi) Active Evaporation

F. Osmoregulation

1. Body Fluid Compartments

2. Osmoregulation and Osmoconformity

3. Aquatic Environments

4. Life in Freshwater

- **a.** Water Gain and Ion Loss
- **b.** Ion-Regulatory Mechanisms in the Gills
  - *i) Sodium, Potassium, Calcium, H^+ and HCO_3^- Regulation*
  - *ii) Effects of Hypercapnia*
  - *iii) Effects of Softwater*
  - *iv) Effects of Cortisol / Growth Hormone*
- **c.** Ion-Regulation, Breathing and Acid-Base Balance Compromises
- **d.** Toxic Metals and the Gills
- **e.** Nitrogen Handling (
  - *i) Ammonia, Urea and Uric Acid*

5. Life in the Sea

- **a.** Marine Invertebrates
- **b.** Marine Teleosts
  - *i) Water Loss and Ion Gain*
  - *ii) Drinking Sea Water to Counter Water Loss*
  - *iii) Gill Ion Exchange to Counter Ion Gain*
- **c.** Marine Elasmobranchs
  - *i) Hyperosmotic and Hypoionic to Sea Water*
  - *ii) Urea and TMAO Retention*
  - *iii) Rectal Gland for Ion Regulation*
- **d.** Brackish Waters
- **e.** Marine Birds and Reptiles

6. Life on Land

- **a.** Deserts
- **b.** Humidic Animals
- **c.** Xeric Animals
  - *i) Countercurrent Water Exchange in the Respiratory System*
  - *ii) Water Loss (Evaporative and Excretory)*
  - *iii) Water Conservation and Metabolic Water*
- **d.** Urine Formation in Insects
  - *i) Malpighian Tubules*
  - *ii) The Cryptonephridial Complex*

G. Recent Advances in Comparative Physiology