BIOD33: Comparative Animal Physiology
Summer 2018

Course Instructor
Dr. Stephen Reid; Office SW526; sgreid@utsc.utoronto.ca

Stephen Reid's Office Hours
I will hold formal office hours on Tuesday from noon to 2 PM starting during the second week of classes. However, you may stop by my office any time my door is open throughout the summer. You may also (via e-mail) book a specific appointment. I will also answer questions via e-mail.

Teaching Assistant
Raafay Syed, Office SW521; raafay.ali@mail.utoronto.ca

Recommended Textbook
Animal Physiology by Hill, Wyse and Anderson. Sinauer. The bookstore carries the latest version. Earlier editions are also perfectly suitable.

Evaluation

Assignment #1, 10%.

Meeting with instructor or TA to discuss the assignment: May 28 to June 1 (i.e., week 4 of lectures).

You may also book the meeting earlier at a mutually convenient time. There are 50 students in the course and the plan is for 25 to meet with myself and 25 with Raafay for each assignment. A sign-up system will be developed during the first week of classes.

Due on or before Thursday June 14 (week 6 of lectures).

Assignment #2, 20%

Meeting with instructor or TA to discuss the assignment: June 25 to July 6 (i.e., weeks 7 and 8 of lectures; reading week doesn't count in the numbering).

You may also book the meeting earlier at a mutually convenient time. There are 50 students in the course and the plan is for 25 to meet with myself and 25 with Raafay for each assignment. A sign-up system will be developed during the first week of classes.

Due on or before Thursday July 26 (week 11 of lectures; reading week doesn't count in the numbering).

Midterm Exam, 30%

This exam will cover the material from lectures 1-6. It will consist of a combination of multiple choice questions, short-answer questions and long-answer (essay) questions.

Final Exam, 40%

The final exam will cover the entire course with with three-quarters of the questions coming from lectures 7-12. A breakdown of the exam questions will be provided prior to the exam. The format will the the same as the midterm.

NEW UTSC POLICY REGARDING ILLNESS AND TERM WORK

PLEASE SEE THE FOLLOWING LETTER FROM THE VICE-DEAN UNDERGRADUTE REGARDING A NEW POLICY FOR SELF-DECLARATION OF ILLNESS THAT DELAYS THE SUBMISSION OF TERM WORK.

Dear Students:

This summer we are trying a pilot program regarding the requirement of submitting the Verification of Student Illness form for missed term assignments. Specifically, if you are ill during the term, and this illness influences your ability to meet a deadline for submission of a term assignment, rather than submitting a Verification of Student Illness form in your request for accommodation you can submit a Self-Declaration of Student Illness form, indicating the days in which you were ill. This form is meant to take the place of the more typical medical form, and will be available on the department's website.

Please note the following aspects related to this Self-Declaration of Student Illness form:

1. Similar to the submission of a medical form, YOU ARE RESPONSIBLE for contacting the administrative staff in your department to make arrangements for an accommodation for this work.

2. You may use the Self-Declaration of Student Illness form ONLY for term assignments. For any term exams in this course you will need to submit a Verification of Student Illness form. For the final exam you will need to follow the typical procedures for petitioning to write a deferred exam.

3. You may use the Self-Declaration of Student Illness form up to five times in this course. If you require an additional accommodation for a term assignment you must then use the standard Verification of Student Illness form.

4. Submitting a false Self-Declaration of Student Illness form constitutes academic misconduct, and could be subject to sanctions under the Code of Behaviour on Academic Matters.

Please submit any Self-Declaration of Student Illness forms in the same fashion as you would have a previous Verification of Student Illness form. Accordingly, you will need to submit this form to the appropriate departmental administrator, within three days of the missed term work.

Please let me know if you have any questions or concerns regarding this pilot project.

Sincerely,

Mark A. Schmuckler
Professor and Vice-Dean Undergraduate Office of the Dean & Vice-Principal Academic

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Topics

The following list of topics will give you a general idea of what is going to be covered in this course. However, within these broad topics the sub-topics may change.

A. Introduction to Comparative Physiology

1. August Krogh Principle
2. Time Domains of Physiological Change
3. Extreme Environments
4. 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