BIOL 3103

PRINCIPLES OF PHYSIOLOGY:
LESSONS FROM LIFE AT THE EXTREMES

A PRESIDENTIAL DREAM COURSE FOR FALL 2015

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Prerequisites: ZOO/BIOL 1124 or ZOO/BIOL 1114+1121 and BIO 1134, or instructor permission

Class Meetings: T/R 10:30-11:45 AM; Dale Hall 103

COURSE BOOK

In lieu of a textbook I am putting together a course book for principles of physiology. It will be under construction during the semester but I intend to have each chapter ready prior to each reading assignment in the schedule. The url is:

www.ouopentextbooks.org/biol3103

This course book makes extensive use of information on the internet in the public domain, and I

encourage students to use other sources as they work to understand the course material. Some excellent free resources include Wikipedia.org, Physiology Web (www.physiologyweb.com), Khan Academy, and You Tube.

The course will make extensive use the **Desire to Learn website** (Henceforth D2L). Lecture slides and study materials will be posted on D2L in advance of each class period. Some movies posted to (e.g. online lectures) should be viewed with the **VLC Video Player**, which is a **free download from videolan.org**.

ABOUT THE COURSE

In 1929, Nobel Laureate August Krogh, wrote in *The American Journal of Physiology*, "For such a large number of problems there will be some animal of choice or a few such animals on which it can be most conveniently studied." This idea has come to be known as the Krogh Principle and it is a guiding light for the study of physiology. If we want to understand or illustrate a physiological principle, we do well to study organisms for which the principle lies at the forefront of the species' existence. More often than not, these exemplary organisms live in extreme environments that present significant challenges to survival. In fact, many of the fundamental principles of physiology were discovered or extended by investigating such organisms. From kangaroo rats in Death Valley to Weddell seals in Antarctica, animals that cope with extreme conditions teach us about the physiological constraints and capacities that apply to all complex organisms, including humans.

This special offering of Principles of Physiology will take you to the far corners of the Earth to seek out and understand the biochemical and physiological mechanisms that permit life in the harshest places on the planet. We will then expand the scope of the course beyond the planet Earth, and apply the course concepts to issues such as human survival during space travel and potential forms of extraterrestrial life. You will be guided not only by your instructors of record but also by a team of guest instructors and lecturers from the US, the UK and from OU. As a dream course guest lecturers from other institutions will interact with the class and present a public lecture about their research. Hence this course will intersect with the broader OU community.

The course will be a lot of fun, but it will still be grounded in fundamental physiological principles. Physiology is a blend of chemistry, biology, and mathematics. So doing well in this course will require not just memorization, but integration of information. The subject matter of the course will focus on the function of vertebrate (and some invertebrate) bodies and how their various components are adapted to help keep an organism alive and fit to reproduce. But more generally, the course will require an ability to absorb and synthesize information. You will be expected not only to know the material but also to apply general knowledge to particular cases. After completing this course, you should be able to:

1) Identify the important structures in the various animal organ systems (e.g., nervous, endocrine, respiratory, digestive) and describe their functions.
2) Explain how the components of each organ system work together to maintain homeostasis or mediate reproduction.
3) Predict how each organ system will alter its function in response to a specific perturbation of the internal or external environment.
4) Explain how specific interactions between systems can a) increase the probability of survival and/or reproduction or b) cause health problems.

5) Understand that physiological principles underlie animal responses to a wide variety of environmental challenges, both natural and human-made.

The course will follow a molecules-to-organisms progression. The first few weeks will concentrate on the molecular machinery that allows organisms to use energy, replicate their DNA, generate new biological molecules, conduct nerve impulses, and orchestrate processes via chemical messengers. We will then progress through the major organ systems that sustain a complex organism (e.g., sensory systems, muscular movement, cardiovascular, immune systems, digestion, excretion). Our guest lecturers will bring to the course expertise on animals that reside in environments that place extraordinary demands on particular physiological systems. Examples include: 1) Bar-Headed Geese that must supply oxygen to working muscles while migrating at an altitude of 9,000 meters (30,000 feet); 2) Crocodiles that live in some of the most bacteria-laden environments on Earth but manage to avoid infections even when wounded; 3) and communities of invertebrates associated with deep sea vents where no light penetrates and where water temperatures exceed 300°C (but the pressure is too high for the water to boil).

During the semester's final weeks, we will take the concept of extreme conditions to the next level and apply what we have learned to environments beyond the planet Earth. We will first consider the difficulties in sustaining human life during prolonged space flight. Then we will stretch our imaginations even further by making predictions about how complex life might appear and function on other planets. These learning activities will be guided by guest experts, one with expertise in space medicine and one who is an astrobiologist.

As a final project, we will work in teams of 4 or 5 students to describe a form of complex alien life. This project will blend art and imagination with what we have learned throughout the semester. As a grand finale we will have an Alien Life Expo, where each group will present their projects to the rest of the class as well as a panel of judges consisting of OU faculty and graduate students.

COURSE ORGANIZATION

The course material will be offered as a combination of lectures (both on-line and in-class), classroom activities, and homework assignments. Class periods will typically be divided into several sessions that may entail lectures on specific topics, demonstrations, or other classroom activities. Most class periods will require preparation on the part of each student, which will include readings, on-line lectures, or short assignments. I assume that all students have done these assignments, and in-class lectures and activities will typically build upon the preparatory materials. The class schedule lists the preparatory materials assigned for each class period, and these materials will be organized by class period on D2L.

The BIOL3103 website on D2L (learn.ou.edu) will be central to the course. I will use it to post course materials (readings, online lectures, lecture slides, study materials, and interesting stuff I come across that intersects with the course material), manage grades, and make important announcements. All students should make it a habit to check email and D2L regularly.

Both in-class and online lectures will be based in PowerPoint and will generally cover a lot of material. To help students keep up I will post lecture slides on D2L. The lectures will not be scripted, so downloading the slides and reading them is no substitute for attending class. Slides will appear in pdf format. You will need software such as Adobe Reader (http://get.adobe.com/reader/) to view the slides.

GUEST LECTURERS

One of the most exciting aspects of this course is the opportunity to hear about some of the fascinating physiological research being carried out by our guest instructors. Among these guests are five scholars who are visiting OU for the express purpose of participating in this dream course. These visitors will interact with the class and make a public presentation of their work. Attendance of public lectures is not required but I really hope you will make an effort to see them. Bonus questions on mini exams will likely be based on material from the public lectures. Here is a list of our visiting instructors and a brief description of their areas of expertise.

Dr. Jennifer Glass
Assistant Professor of Biogeochemistry, Georgia Institute of Technology

Deep in the world's oceans one can find entire ecosystems that are fueled by the dusty chemical deposits and hydrothermal fluids emitted by undersea geysers. Our first guest instructor, Dr. Jennifer Glass, studies the biochemistry of organisms that live near deep sea vents. Her work demonstrates that the concept of diversity applies not just to species but also to the multitude of biochemical processes that make life possible. Moreover, in showcasing these unusual forms of life, Dr. Glass will foreshadow the theme of astrobiology. Although her experimental work lies in the depths of the ocean, Dr. Glass applies what she learns to theories about life beyond our planet as part of NASA's Astrobology Program. Many of the same minerals that feed the organisms she studies are abundant on a number of planets in our own solar system. Hence, the biological communities associated with deep-sea vents could be analogous to extraterrestrial ecosystems. Among Dr. Glass's active research projects are: anaerobic oxidation of methane coupled to metal reduction (NASA), nano-scale imaging of trace elements in environmental microorganisms (DOE), and trace metal micronutrients and microbial greenhouse cycling in marine oxygen minimum zones.

Dr. Mark Merchant
Professor of Biochemistry, McNeese State University

Crocodilian fossils date back to the Jurassic period and suggest that this group of animals has changed relatively little over 200 million years of evolutionary history. According Dr. Mark Merchant of McNeese State University the secret to their success may be their immune systems. Alligators and crocodiles occupy some of the most challenging environments in the world from the perspective of a microbiologist. The warm, wet environments where crocodilians thrive are often a veritable soup of bacterial diversity. Yet these reptiles rarely suffer an infection from this onslaught of would-be invaders. Dr. Merchant and his colleagues have discovered that crocodiles and alligators have a remarkably robust innate immune system that can repel microbes ranging from *E. coli* to the human immunodeficiency virus (HIV). Even faced with sizeable lacerations from fighting with each other, crocodilians avoid many infections that would quickly overwhelm other organisms. This extreme resistance to infection appears to result from an evolutionary arms race between would-be parasites and a sophisticated immune system. Dr. Merchant's research is an excellent example of how evolutionary studies can

lead to practical applications as his lab is currently testing antibiotics distilled from alligator blood.

Dr. Lucy Hawkes
Lecturer in Physiological Ecology, University of Exeter, United Kingdom

Every year, thousands of migratory geese fly from the steppes of the Tibetan Plateau to the warm lowlands of India. Although trans-continental migration is an amazing physiological feat in its own right, for some of these geese it is a particularly demanding exposure to an extreme environment. The migrations of many Bar-Headed Geese take them over the Himalayas, wherein the birds cruise at altitudes comparable to jet liners (about 9,000 meters or 30,000 feet). At these heights, air pressure is about ¼ of what we measure at sea level, and few humans could take in enough oxygen to survive much less sustain any sort of muscular activity. Dr. Lucy Hawkes of the University of Exeter has led an international team of scientists to study the behavior and physiology that makes the high flights of Bar-Headed Geese possible. Using implanted data loggers and state-of-the art tracking technology, Dr. Hawkes has monitored the vital signs of Bar-Headed Geese as they cross the world's tallest mountain range. Her research touches on the fundamentals of gas exchange and oxidative respiration while maintaining the popular appeal of an adventure story.

Dr. Jonathan Clark
Associate Professor of Neurology, Baylor College of Medicine

The complexities of space travel are enormous, but few would dispute that the human race will someday seek its destiny among the stars. Outer space offers an environment far more extreme than anything found on Earth. How can we maintain life during prolonged expeditions to neighboring planets? How can we sustain generation upon generation of humans should we attempt to move beyond our solar system? Are these endeavors feasible in consideration of factors such as energy balance and waste production? Our class will discuss these issues in the company of Dr. Jonathan Clark. Dr. Clark is an Associate Professor of Neurology at the Baylor College of Medicine. He served as a space shuttle crew surgeon six times and teaches Space Medicine at Baylor's Center for Space Medicine. Dr. Clark will help our students apply the course material to real world problems concerning the health of astronauts both before and after launch. But perhaps more importantly, his record of service and accomplishments will inspire students who seek careers in medical fields.

Dr. Christopher Lowe
Associate Professor Department of Biology and Hopkins Marine Station, Stanford University

As we speculate about what multicellular life might be like on other planets, we inevitably look to our own planet for examples of how complexity emerged. Dr. Christopher Lowe studies the early evolution of hemichordates and echinoderms, which are the precursors to our own phylum, the chordates. Dr. Lowe and his students use

descriptive and functional techniques to address fundamental hypotheses about the macroevolution of animal body plans. His research addresses the question of how the radial body plans we see in starfish and sea cucumbers evolved from the bilateral body plans of their ancestors. He is currently funded by NASA's Astrobiology Program to use his approach to developmental and evolutionary biology to delimit our thinking about complex life in extraterrestrial systems. By understanding the constraints and possibilities revealed by his Earth-based study systems, Dr. Lowe hopes to reveal new generalities about the evolution of body plans that can be applied to questions about complex life on other planets

GRADING

Grades will be based on several mini exams (each requiring about 15-20 minutes and worth 50 points), a final exam (worth 100 points), a final group project (worth 200 points), as well as a variety of quizzes, in-class activities, and homework assignments throughout the semester (with varying point values). There will also be occasional opportunities for students to earn extra credit by helping with class demonstrations or through outstanding work on in-class assignments.

For final grade calculations I will omit the lowest grade from among all the exams and assignments. However, the group project grade will not be omitted.

Grading errors: If you believe there was an error in grading an exam, I must be made aware of the apparent mistake within ONE WEEK of receiving the graded work. For the final exam, you must contact me within 5 days after I have posted the final exam grades. I will not consider grade protests after these deadlines.

COURSE POLICIES

Cell Phones and Electronic Devices: As a courtesy to the rest of the class please silence all cell phones and other noisy electronic devices and refrain from using them except for true emergencies. Use of laptops during the class period should only be for taking notes (i.e., not web surfing, emailing, movie watching, etc.). Your screen can be a distraction to those behind you, so I ask students to help me in keeping everyone on task. I do encourage students to bring laptops with them as some class activities will involve accessing tools or information on the Internet.

Academic Dishonesty: Regulations and responsibilities stated in the Student Code and Faculty Handbook will be followed in the event of academic dishonesty. For a summary of what academic honesty means, see the provost's and OU Student Association's summaries at http://www.ou.edu/provost/integrity and www.ou.edu/honorcouncil.

Withdrawal Policy: If a grade of W (withdraw) or I (incomplete) is requested, university policy will be followed.

Students with Disabilities: If you have a disability that may prevent you from fully demonstrating your abilities, please contact me as soon as possible to discuss accommodations necessary to ensure your full participation and help you exploit your educational opportunities to the fullest.

COURSE SCHEDULE:

Class period 1: Tuesday Aug 25: INTRODUCTION

Preparation: None

Session 1: Course organization and introduction: Syllabus and evaluation; educational goals of the course.
Session 2: Physiology past and present: Who are the famous physiologists? Who are the physiologists in your neighborhood, Who are the scientists visiting as part of the Dream course?
Session 3: Approaches to physiology: What are you doing right now? levels of biological organization; Proximate and Ultimate levels of understanding; Examples of clinical and field based physiology.

Class period 2: Thursday Aug 27: BIOLOGICAL COMPLEXITY AND BIOMOLECULES

Preparation: Chapters 1, 2, and 3 of Principles of Physiology online course book; online lecture on the four basic types of biomolecules; movies on translation and transcription, cell anatomy figure.

Session 1: Scaling and complexity
Session 2: DNA transcription and translation; regulation of gene products.

Class period 3: Tuesday Sept 1: DERIVING ENERGY

Preparation: Course Book Chapter 4. D2L videos of glycolysis, the citric acid cycle, and oxidative phosphorylation.

Session 1: The Glucose Journey
Session 2: Variation in oxidative phosphorylation
Session 3: Other sources of chemical energy (fats, proteins, nucleic acids)

Assignment: KEGG biochemical pathways worksheet (due Sept 8; 20 points)

Class period 4: Thursday Sept 3: LIFE AT DEEP SEA VENTS– Guest instructor: JENNIFER GLASS

Preparation: None

Public Lecture: "**"Insane in the Methane: How Extreme Microbes Eat and Excrete"**
Thursday, Sept 3, Sam Noble Museum, Kerr Auditorium, 7:00pm

Class period 5: Tuesday Sept 8: MEMBRANES AND MEMBRANE TRANSPORT

Preparation: Course Book Chapter 5. D2L videos - "What you don't know about membranes," and explanation of Gibbs-Donnan equilibrium.

KEGG biological pathways worksheet due

Session 1: Quick quiz over biomolecules and energy deriving pathways.
Session 2: Don't be a stiff: Membranes in extreme cold.
Session 3: Barriers and conduits: Fick's law of diffusion; chemical and electrical gradients; Osmosis and tonicity; Membrane transport modes, Membrane transport molecules.

Membrane worksheet distributed (Due Sept 15)

Class period 6: Thursday Sept 10: INTRODUCTION TO CELLULAR SIGNALLING

Preparation: Online readings on G-proteins, tyrosine kinease receptors, and PIP2 second messenger systems linked on D2L.

Session 1: Fundamental cell-signaling pathways: Types of signaling; Hydrophobic and hydophillic messengers; Ligands and receptors; Saturation and regulation; Signal amplification; three types of second messenger systems.
Session 2: Neurons and the need for speed.

Class period 7: Tuesday Sept 15: MEMBRANES AS CAPACITORS

Preparation: Do what you can with the worksheet. Bring it to class

Session 1: Membrane equilibrium, Nernst equation, GCK equation
Session 2: Work on membrane worksheet – hand in at end of class.

Class period 8: Thursday Sept 17: NEURONS AND ACTION POTENTIALS

Preparation: Course Book Chapter 6. Videos on action potentials.

Session 1: Action Potential and Graded Potential demonstration
Session 2: Neuron structure and function: types of neurons, roles of neurons, action potentials, refractory period, graded potential
Session 3: In-class exercise – Apply the GHK equation to an action potential.

Class period 9: Tuesday Sept 22: SYNAPSES AND NEUROTRANSMITTERS

Preparation: Course book chapter 7; Online lecture on synapses.

Session 1: Mini exam on membranes, action potentials and graded potentials
Session 2: Propagation of action potentials from neuron to neuron;

Session 3: Types of receptors and neurotransmitters.Adrenergic and Cholinergic neurotransmitter systems, Signaling pathways, Agonists and antagonists, neural synapse video challenge (not graded)
Session 3: Overview of the nervous system

Class period 10: Thursday Sept 24: AUTONOMIC NERVOUS SYSTEM

Preparation: Course book chapter 8; Online lecture on the divisions of the nervous system.

Session 1: Sympathetic and parasympathetic nervous systems
Session 2: Responses to extreme situations.

Autonomic nervous system figure assignment

Class period 11: Tuesday Sept 29: PERIPHERAL NERVOUS SYSTEM

Preparation: Continue course book chapter 8.

Session 1: Responses to extreme situations continued.
Session 2: Peripheral nervous system
Session 3: This is your brain on drugs: examples of the effects of drugs.

Assignment: write an exam question and submit it via D2L (due by end of day).

Class period 12: Thursday October 1: CENTRAL NERVOUS SYSTEM

Preparation: Reading on glial cells; human brain diagram on D2L.

Session 1: CNS: Brain evolution; Brain anatomy and function; Neurogenesis; Neural plasticity in birds. Gray/white matter, Nerve pathways, Reflexes; Somatic maps, Memory and learning.
Session 2: Class activity: changing your mind. (Darts activity)

Autonomic nervous system figures due

Class period 13: Tuesday October 6: SENSORY SYSTEMS – MECHANORECEPTION AND CHEMORECEPTION

Preparation: Online lectures on sensory systems

Session 1: Mini exam on the nervous system.
Session 2: Sensory demonstrations
Session 3: Sense of taste: Guest lecturer: Chris Lemon.

Class period 14: Thursday October 8: SENSORY SYSTEMS – VISION AND ELECTRORECEPTION

Preparation: Online lecture on the evolution of visual systems and photoreceptors

Session 1: Center surround and on and off center fields: limits to visual acuity; Detection of edges
Session 2: The physiology of illusions (Hermann's grid…Blind spots)
Session 3: ELECTRORECEPTION: SEEING IN THE DARK - Michael Markham.

~~Take home exam~~ D2L quiz on sensory systems distributed.

Class period 15: Tuesday October 13: CIRCULATORY SYSTEM: BLOOD CONSTITUENTS AND CLOTTING

Preparation: Course book chapter on blood.

Session 2: What's in your blood: plasma constituents, blood cell types.
Session 3: Clotting: clotting cascade, role of thrombin, dissolving old clots.
Session 4: Gas exchange; hemoglobin structure, function, and binding affinity

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Class period 16: Thursday October 15: CIRCULATORY SYSTEM: HEARTS, BLOOD, AND IMMUNE SYSTEM

Preparation: ~~Course book chapter on circulatory system.~~ NOT FINISHED (or even started). Instead use the following sections in the Openstax Anatomy and Physiology text: 4.2.1, 4.2.2, 4.2.3, 4.2.4, 4.2.5, 4.3.1, 4.3.2, 4.3.3, 4.3.4, and 4.3.5.

The website is here: http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22

~~Hand in Take-home exam on sensory systems~~
D2l quiz on sensory systems due.

Session 1: Diversity of cardiac pumps, two, three, & four chambered hearts
Session 2: Blood vessels
Session 3: Cardiac output, autonomic control of blood pressure regulation.
Session 4: Class demonstration: Blood pressure measurement
Session 5: Intro to the immune system.

Class period 17: Tuesday, October 20: IMMUNE SYSTEM

Preparation: course book chapter on immune system

Session 1: Innate immune system – primary layers of protection
Session 2: Acquired immune response

Session 3: Zombies

Class period 18: Thursday October 22: LIFE IN THE BACTERIAL SOUP: INNATE IMMUNE SYSTEMS OF CROCODILLIANS – Guest instructor: MARK MERCHANT

Preparation: watch "The Antibiotic Hunters" episode of the *Nature of Things*.

Public Lecture: **"Immunology of the American Alligator: From Marsh to Medicine"**
Thursday, October 22, Physical Sciences Room 201, 6:00pm

Class period 19: Tuesday October 27: ENDOCRINE SYSTEM

Preparation: Course book chapter on endocrine system.

Session 1: Stress physiology and the HPA Axis
Session 2: metabolism and the HPT Axis
Session 3: HPGH axis, regulation of growth

Class period 20: Thursday October 29: ENDOCRINE SYSTEM CONTINUED

Preparation: online lecture on fuel metabolism, OpenStax Anatomy and Physiology, Sections 5-3-6 (Metabolic States of the Body) and 3-6-10 (The Endocrine Pancreas). Text accessible here: http://cnx.org/contents/14fb4ad7-39a1-4eee-ab6e-3ef2482e3e22

Session 1: Mini-exam on immune system and circulatory system
Session 2: Class demonstration: Measuring blood sugar
Session 3: Insulin vs. Glucagon: regulation of food intake, blood sugar balance, diabetes.
Session 4: Calcium balance – storage and mobilization
Session 5: Does calcium limit egg laying? – Michael Patten

Class period 21: Tuesday November 3: MUSCLES – SLIDING FILAMENT HYPOTHESIS

Preparation: Online readings and videos on D2L

Session 1: Question and answer session about muscle contraction.
Session 2: Class activity: pipe cleaner art contest.

Class period 22: Thursday November 5: MUSCLE CONTROL

Preparation: None

Session 1: Lecture: Proprioceptors and muscle control

Main topics: Spindle fibers, Golgi organs, reflexes.
Session 2: Class demonstration: Tricking the proprioceptors.
Session 3: Lecture: Muscle cell types and fiber types.
Motor units, oxidative and glycolytic fibers, smooth muscle, cardiac muscle.

Class period 23: Tuesday November 10: RESPIRATORY SYSTEM

Preparation: Course book chapter on respiratory systems

Session 1: Mini exam on endocrine system and muscles
Session 2: Gas exchange in water breathers
Session 3: Gas exchange in air breathers

Wednesday November 11 – Public lecture by Lucy Hawks.

"On a Wild Goose Chase for the World's Highest Flying Bird"
Wednesday November 11, 2015. Sam Noble Museum, Kerr Auditorium, 7pm

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Class period 24: Thursday November 12: HIGH FLIERS – guest lecturer: Lucy Hawkes

Preparation: Read Science Article on roller-coaster flight posted on D2L

Class period 25: Tuesday November 17: Excretory system.

Preparation: course book chapter on excretory system; Online lecture: introduction to kidney anatomy and function

Session 1: Control of water balance
Session 2: Group activity: Urinalysis case studies

Class period 26: Thursday November 19: DIGESTIVE SYSTEMS

Preparation: Course book chapter on digestive systems. Reading on enteric nervous system.

Session 1: Mini exam on respiratory and excretory systems
Session 2: Digestion, nutrient uptake, regulation of gut length
Session 3: Appetite control

Class period 27: Tuesday November 24: REPRODUCTION IN EXTREME ENVIRONMENTS – Rosemary Knapp.

Preparation: To Be Announced

November 25-29: Thanksgiving Holiday

Class period 28: Tuesday, December 1: SPACE MEDICINE – guest lecturer: Dr. Jonathan Clarke

Preparation: To Be Announced

Public Lecture: "**Surviving an Upper Atmospheric Supersonic Bailout from Near Space"**
Wednesday Dec 2, Physical Sciences, Room 201, 4:30 pm.

Class period 29: Thursday, December 3: WHY IS EVERYTHING STILL SO DAMNED COMPLICATED?

Sum up and review

Class period 30: Tuesday, December 8:

Session 1: Final exam (~30 minutes)
Session2: Group project assignment – form groups, brainstorm ideas

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Public Lecture by Christopher Lowe: Title to be announced
Wednesday Dec 9, Physical Sciences, Room 201, 4:30 pm

Class period 31: Thursday, December 10: THE EVOLUTION OF BODY PLANS – guest lecturer: Dr. Christopher Lowe

Preparation: To Be Announced

Final exam period: Thursday December 17: Group projects presented at the **Alien Life Expo**.
8:00 am – 9:00 am: Set up.
9:00am – 10: am: Presentations.