IB 150 Syllabus and Course Policies

Lectures: Tuesdays and Thursdays 3:30-4:50 PM, Lincoln Hall Theater

Discussion: 2090 & 3098 Natural History Building (check your class schedule for your discussion room & time)

Lecture Instructor: Dr. Benjamin Clegg
Office: 2006A Natural History Building

Course email: ib150@life.illinois.edu

Course Webpage

You will find links to all pre-lecture lessons and other assignments each week on the Moodle course webpage:

https://learn.illinois.edu/course/view.php?id=35050

Login with your University NetID and password. We recommend that you bookmark this page after you accessed the course page for the first time.

Textbooks and Other Required Materials

(Required) Textbook: Freeman. Biological Science. eText of 6th edition. Pearson. (Purchasing a paper copy of the text is also possible. However, make sure that you purchase a version that includes access to Pearson Mastering Biology). See the course webpage for more information on how to register your online components to your textbook.

(Required) IB 150 AL1 Spring 2019 course manual

(Required) iClicker

(Required) A non-programmable calculator other than your smart phone for simple calculations on exams.
## Tentative Class Schedule

Below is a tentative class schedule, highlighting the relationship between Lectures, Discussions and Readings. We reserve the right to make changes to the class schedule. Please consult the course homepage at learn.illinois.edu for assignment due dates and to check for any updates to this schedule.

<table>
<thead>
<tr>
<th>Lectures</th>
<th>Discussions</th>
<th>Readings</th>
</tr>
</thead>
</table>
| **Unit 1**  
Life and Energy | | |
| **Week 1**  
Jan. 14-20 | 1.1 Introduction to Organismal Biology  
1.2 Why do all organisms need energy? | Science of Life  
Chapters : 1; 2.3; 8.1-8.4; 40.1 |
| **Week 2**  
Jan. 21-27 | 1.3 Cellular Respiration  
1.4 Other metabolic pathways | Thermodynamics & Life  
Chapters : 9 |
| **Week 3**  
Jan 26 – Feb. 3 | 1.5 Energetic Constraints on Anatomy  
1.6 Physiological Trade-offs of Respiratory Systems | Cellular Respiration & other metabolic pathways  
Chapters : 6.3; 39.2-39.4; 42.1-42.3 |
| **Week 4**  
Feb. 4-10 | 1.7 Form and Function of Respiratory Systems  
1.8 Blood and Hemoglobin | Surface Area to Volume Ratio  
Chapters : 42.3-42.4 |
| **Unit 2**  
Life and Heredity | | |
| **Week 5**  
Feb. 11-17 | 2.1 Molecular Basis for Heredity  
2.2 Origin of Genetic Diversity | Applying Fick’s Law to the Physiology of Respiratory Systems  
Chapters : 16 |
| **Week 6**  
Feb. 18-24 | 2.3 Passing on genetic information  
**EXAM 1 (covers Lectures 1.1-1.8)** | Central Dogma & Mutations  
Chapters : 47.1; 12.1-12.2; |
| **Week 7**  
Feb. 25 – Mar. 3 | 2.4 Generating genetically variable offspring  
2.5 Genetic Crosses | Understanding Meiosis  
Chapters : 13, 14 |
| **Week 8**  
Mar. 4-10 | 2.6 Dihybrid Crosses & Epistasis  
2.7 Testing for Linkage Disequilibrium & Linkage Mapping | Genetic Crosses  
Chapters : 14 |
| **Unit 3**  
Evolving Life | | |
| **Week 9**  
Mar. 11-17 | 3.1 Population Genetics  
3.2 Hardy-Weinberg Equilibrium | Testing for Linkage  
Chapters : 23.1 |
| **Week 10**  
Mar. 18-24 | | |
| | | **Spring Break** |
| **Week 11**  
Mar. 25-31 | 3.3 Evolutionary Mechanisms I  
**EXAM 2 (covers Lectures 2.1-2.7)** | Population Genetics  
Chapters : 23.4,23.6 |
| **Week 12**  
April 1-7 | 3.4 Evolutionary Mechanisms II  
3.5 Evolutionary Mechanisms III | Making Evolutionary Inferences  
Chapters : 22, 23.2, 23.3, 23.5 |
| **Week 13**  
April 8-14 | 3.6 Natural Selection Case Study  
3.7 Macroevolution - Speciation | Natural Selection  
Chapters : 24, 25.1-25.2 |
| **Unit 4**  
Integrative Approach to Biology | | |
| **Week 14**  
April 15-21 | 3.8 Cladistics  
4.1 Form & Function of Circulatory Systems | Great Clade Race  
Chapters : 39.1; 39.5; 42.5 |
| **Week 15**  
April 22-28 | 4.2 Evolution of Novel Anatomical Structures  
**EXAM 3 (covers Lectures 3.1-3.7)** | Generating Proximate & Ultimate Hypotheses in Anatomy & Physiology of Organisms  
Chapters : 21.1 |
| **Week 16**  
April 29 – May 1 | 4.3 Comparative Anatomy | No Discussion  
Chapters : 42.5 |
| **Finals**  
May 3-10 | Comprehensive Final Exam (covers Lectures 1.1-4.4) | Tentative date & location: TBA |
## Course Grade Scale.

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<tr>
<th>Letter Grade</th>
<th>Percentage Range</th>
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<td>A+</td>
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<tr>
<td>A</td>
<td>93–99</td>
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<tr>
<td>A–</td>
<td>90–92</td>
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<td>B+</td>
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<td>B</td>
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<td>B–</td>
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## Course Grade Structure.

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<td>Final Exam</td>
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<td></td>
<td></td>
<td>Includes Pre-Lecture Lessons (2 pt) &amp; clicker participation (4 pt)</td>
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<td>Weekly homework sets</td>
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<td>Weekly Packback Posts</td>
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<td>Participation in Cromley Research Study</td>
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<td>COURSE TOTAL</td>
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<td>(+50 pts extra credit)</td>
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Course Policies

Exam Information

There are three hour exams, each covering the preceding Unit, and one cumulative final exam that covers all four Units in this course. Material from Unit 4 is only covered on the final exam, while material from Units 1-3 are covered both on respective individual hour exams and the comprehensive final exam.

Exams are proctored, closed book, closed notes, and are based on the learning objectives of the lecture and discussion activities of each respective unit.

Hour exams consist of a combination of 25 multiple choice (MC), 3 short answer questions, and 1 essay question. Practice Exams for the Hour Exams will be available on the course webpage.

To be excused for an exam and granted a make-up exam, you need to notify the instructor (Benjamin Clegg) PRIOR to the beginning of the exam by e-mail (ib150@life.illinois.edu), AND provide documentation for illness, family emergency, or athletic events (only applicable to U of I athletes) no later than 1 week (5 business days) after the hour exam. Make-Up Exams will only be given to students whose absences are eligible under University Policies.

Please consult the Student Code Article 1, Part 5 to check whether a particular reason for absence is eligible to be excused from the regularly scheduled exam time: http://studentcode.illinois.edu/article1_part5_1-501.html.

Exam Dates

This course’s hour exams are scheduled during an extended lecture period giving you two hours from 3:30-5:30 pm on the following dates:

- Exam 1: Thursday, February 21st
- Exam 2: Thursday, March 28th
- Exam 3: Thursday, April 25th

If you have another exam, course, University athletic event scheduled at the same time, please contact ib150@life.illinois.edu at least 1 week prior to the hour exam to sign up to take a conflict exam.

Questions and corrections to exam grades

All exams are secure exams, so you will not be allowed to view them again after you turn them in. A key to the exam will not be posted. Students who believe that the scantron machine has graded their exam incorrectly should contact ib150@life.illinois.edu within 1 week of exam scores being posted and your exam will be manually reviewed for scoring errors.
Final Exam
The Final Exam will be administered tentatively on TBA and location TBA. Once the University assigns the final exam dates, the updated information will be announced on the moodle course page as soon as it becomes available.

Final exam scope: The Final Exam will be cumulative and cover lecture, assigned readings, homework, and discussion material from throughout the entire semester.

In case of illness or personal emergency the day of the final exam, contact a Dean in your college. Only a Dean can excuse a student from a final exam.

Final exam conflict requests: Requests for a Conflict Final Exam should be made by filling out the Final Exam Conflict Request Form (available on moodle in the Final Exam module) and turning it in to Benjamin Clegg (ib150@life.illinois.edu). The ONLY reasons for such a request are:

1. The student has three final exams within a 24 hour period as defined in Section § 3-201.5 of the UIUC Code of Policies and Regulations Applying to All Students (http://admin.illinois.edu/policy/code/). None of the 3 exams can be a conflict exam. If a conflict exam causes you to have 3 exams in a row, you need to request a different conflict exam time for that course.

2. The student has another final exam scheduled at the same time as the IB 150 Final Exam. The conflicting course's enrollment must be LOWER than the IB 150 enrollment for you to take the IB 150 Conflict Final Exam and must be a Non-Combined course final exam. The conflicting exam must not be a conflict exam for another course.

3. The student has a verified personal problem, and has received written permission to take the IB 150 Conflict Final Exam from a Dean in their College.

Travel plans or wanting to leave campus early before the last day of scheduled finals are NOT reasons to request a Final Exam Conflict.

Please be aware that as per university policy, an unexcused absence from a final exam will result in a course grade of ABS, which is counted like an F towards your GPA. Only a dean in your college can excuse you from a final exam.

Resurrection Policy:
If your score on the final exam is higher than your average exam scores (final exam and scratch ticket scores inclusive), the final exam % will replace your hour exam category %. Homework, lecture, & discussion scores are NOT replaced by this policy.
Course Components

Pre-Lecture Lessons

You are required to complete the online pre-lecture lessons found on the moodle course webpage under each lecture before the beginning of each lecture. You are allowed multiple attempts at the complete lessons. Your final score will be the average score of your attempts at a full pre-lecture lesson. You can rework the questions in the study versions that open after the due date for practice or exam review without credit.

Lecture Activities

We will have group activities during many of the lecture periods and attendance is mandatory. Answers to lecture activities are submitted via iClickers. iClicker scores are scored for participation. You must attend lecture and answer at least 75% of all clicker questions to earn the points associated with each lecture. If your iClicker did not register your clicks, you can turn in a paper sheet at the end of the lecture with your clicker answers, name, netID, and the date to be given lecture attendance credit. Please see the section on excused absences for information on how to make up work in cases of excused absences.

Lecture and Discussion Etiquette

We are a very large class and we need your help to make the learning environment in the large lecture hall the best as it can be. So please:

1. Arrive on time. Try to arrive early if possible. If you cannot avoid arriving late, please enter quietly and find a seat on the aisle or back of the hall so you will disturb as few of your fellow students as possible.

2. Silence pagers and cell phones, and please do not text-message during lecture. Also refrain from using laptops during lecture for anything other than IB150 lecture material (i.e., no playing online games, shopping online, watching movies, TV shows, etc.). Extra sounds and lights are distracting to those around you and negatively impacts the learning environment.

3. Be considerate of the people around you. Please no talking unless you are doing so as part of a lecture activity. If you have questions please feel free to raise your hand and the instructor or TA will assist you. Sound carries very far in the lecture hall. Even conversations held at a whisper are very distracting to others in this hall.

4. Remember that the lecture is not over until you have been dismissed. Packing up during lecture is disruptive and irritating to other classmates and instructors. If you must leave early, please sit at the back of the lecture hall so you disturb as few people as possible.
Weekly Online Homework Sets

Each week has an online homework set that is due on the Friday of the same week at 11:59 pm. Links to these assignments are found on the moodle course page in each week’s module. Each of these homework sets is worth 5 points. You have 2 attempts at each question for multiple choice questions, the second scored for half credit. Written responses have only a single attempt and are manually graded by your TA. All efforts are made to have a fast turn-around time on grading the free responses, however we only guarantee that your attempt is graded within 1 week of the due date of each assignment. Note that you can check for automatic feedback immediately after the due date by visiting the homework set after its due date, however.

Weekly PackBack posts

Due Sunday of each week, these posts consist of an open-ended question (a question that cannot simply be answered with a definition or yes and no), and TWO replies to questions from other students. You are encouraged to ask questions that apply weekly content to additional, real-life examples, or explore new aspects of the concepts we discussed in class. The purpose of these posts is to allow you to brainstorm how the covered concepts work, and how they can be used to gain new insights into biological phenomena. The access code to your PackBack login is found in the front of your course manual for SP19. Each complete post of question and answers is worth 5 points per week, and is graded on the quality of your post.

TA Grading Disputes

If you think an assignment has been graded unfairly bring it to the attention of your TA within one week after assignment is returned. Disputes will not be considered after one week. If the situation is not resolved, contact Benjamin Clegg to set up an appointment (ib150@life.illinois.edu) immediately after meeting with your TA. We will not address disputes more than two weeks after the assignment was returned.
Late Assignments, Missed Attendance, Section Change

Late Submissions of Assignments

Online assignments are typically due at 11:55 pm CDT/CST on their listed due dates, unless otherwise noted. Discussion Prep sheets are due by the beginning of your discussion session, unless otherwise noted. All assignments must be completed on time. Late submissions will NOT be graded, unless incurred due to extenuating circumstances. Proper documentation for illness, family emergency, athletic event or other legitimate reason is required in order to receive an extension for submitting assignments.

Please consult the Student Code Article 1, Part 5 to check whether a particular reason for absence is eligible for late submission of work: http://studentcode.illinois.edu/article1_part5_1-501.html.

Missed Lecture and Discussion Attendance

You must attend lecture and discussion to earn the points associated with each lecture activity. If your iClicker did not register your clicks, you can turn in a paper sheet at the end of the lecture with your clicker answers, name and netID to be given lecture attendance credit. However, if your TA sees you walking in more than 10 minutes late, no paper attendance records will be accepted for the day. The head TA will accept a maximum of 5 paper sheet submissions for lecture participation credit during the semester.

If you cannot make lectures due to an excused absence you may turn in a COMPLETED copy of the missed lecture worksheet in the course manual together with a written doctor’s note or letter from emergency dean documenting your absence as excused. You have until the lecture period immediately following the end of your excused absence period to turn your worksheet in to receive lecture participation points.

To be excused from discussion, please provide your TA a copy of the doctor’s note or letter from emergency dean at the beginning of the discussion immediately following the excused period of absence. See additional details on Discussion syllabus at the beginning of the discussion materials of this manual.

Please consult the Student Code Article 1, Part 5 to check whether a particular reason for absence is eligible for late submission of work: http://studentcode.illinois.edu/article1_part5_1-501.html.
Section Changes, Add and Drop Information

Use the UI Enterprise System. Instructors or TAs cannot perform any registration functions for you. Students must attend the discussion sections in which they are enrolled unless they have received authorization from their TA to attend a make-up section. Make-up requests may be denied if a section is full. Apply at your College Office before the deadline if you wish to elect the Credit/No Credit option. To drop the course after the drop deadline, students must petition a Dean in their College Office. Petitions obtained at the College Office should then be brought to the office of Dr. Clegg (2006A Natural History Building).

Late Registration

Adding the course after the first day of classes does not excuse you from assignments that you have missed. If you add the course late, you need to contact your TA within 24 hours of adding the course to set up an appointment to go over what you have missed to date. Students that add late will have due dates extended one week following their add date to allow the opportunity to complete any missed assignments.

Academic Integrity

All students are responsible for reading the University of Illinois Student Code. Pay particular attention to http://admin.illinois.edu/policy/code/article1_part4_1-402.html concerning plagiarism and cheating.

- Penalties for plagiarism on course assignments result in a reduced grade for the assignment and a note in your student file. Plagiarism is the copying or leaning on sources without properly citing your source. To avoid a charge of plagiarism, all submissions need to be your own synthesis of information, demonstrating your own understanding, and any sources you used to obtain information must be properly attributed at the end of your submissions.

- If you are caught with two clickers, both you and the student whose clicker you brought into class will forfeit ALL iclicker points for the semester. Additionally, you will be charged with cheating and impersonation, and will receive a note of this academic violation in your student record.

- Copying or leaning on unauthorized student files or keys obtained from other students (downloaded from the web or sharing of physical copies) will be charged as cheating and the use of unauthorized materials rather than a charge of plagiarism, and results in a score of zero on the assignment, and will receive a note of this academic violation in your student record.
• Uploading or sharing of physical answer sets or keys to assignments with other students will be charged as facilitation of cheating with a note in the student file, and a reduction in course grade by one letter grade. An additional lawsuit for copyright infringement may be filed in court if applicable.

• Any form of cheating on hour exams will result in an automatic score of zero on the hour exam and a note in the student file, regardless of the extent to which a student cheated on the exam.

• Cheating on the final exam will result in an automatic score of zero for the course and a note in your student file.

If you have been found guilty of any academic violation, you forfeit the resurrection policy.

Additional penalties may be imposed by the university, including dismissal from the university, depending on the presence of aggravating factors or if this was not your first infraction.

Getting Help

• Only contact your instructor directly if you have a personal question.
• For all other questions about course content, activities, deadlines, technical problems, etc., please check the General Q & A forum at the top of the Moodle Course Webpage to see if someone else has already asked your same question and received a response.
• If your question isn’t there yet, post your question to the General Q & A forum.
• Feel free to answer peers in the General Q&A Forum if you know the answer!
• If you still have a question, email ib150@life.illinois.edu.

Disability Accommodations

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES you may visit 1207 S. Oak St., Champaign, call 333-4603 (V/TTY), or e-mail a message to disability@illinois.edu.
Tips for Success

To be successful in IB 150 you will need to do more than come to class and cram for exams. We have compiled the following tips to help you be successful in IB 150 and the other science classes you will be taking.

Course structure and philosophy:

This course is designed not as a survey course about biology, but as a course that trains you how to think and ultimately become a biologist.

What this means is that this course will not value memorized factoids, as fascinating as they may be, but instead aims to provide you with some of the core tools that an organismal biologist can use to apply in novel contexts, test new hypotheses, and arrive at reasonable and testable predictions on the quest to learn new aspects of how living systems work.

This does not mean that factual knowledge is unimportant – you will need to learn the nuts and bolts of the concepts covered. But it is not enough. You will need to gain a deeper understanding of the causal and mechanistic nature of processes that allow you to extrapolate or deduce implications in novel contexts.

Most students have taken HS and other intro courses that focused at the cognitive level of “memorizing” and “understanding”, collectively called “Lower Order Cognitive Skills”. Professional schools like med schools, grad schools, and employers alike mostly value “Higher Order Cognitive Skills”. Proficiency in these requires multiple years of dedicated training. In this course we will repeatedly push ourselves to the application, and occasionally to the analyzing level to start on this journey.

In summary: Learning should push you into the unknown and give you the power to evaluate the rigor of a logical argument or interpretation of results in the context of our previous understanding of a concept. In this course, and hopefully throughout your college career, always push yourself to whether you understand “why” and “how” something works, to where you are confident you could apply it to solve problems in a new setting using the covered concepts.
What to do before class:

1. Pre-lecture videos have been created for each IB 150 lecture. As you watch these videos, take notes and record the key terms. Incorporate this information into your class notes.
2. Read or at least skim the assigned reading before coming to class. You will have an easier time keeping up with lecture and learning the information if you have read over the information before attending class. This will also help you prepare for in-class quizzes.

What to do in class:

1. Come prepared to learn. It is very easy to get distracted in a large lecture hall. Minimize electronic distractions. Research has shown that people don’t learn as well when they are trying to multitask.
2. Take notes
   a. While many students prefer to take notes on their computers, it is easy to get in the habit of trying to record everything the instructor is saying without actually understanding the material. Recent research suggests that taking notes by hand is a better option for many students and leads to higher learning gains.
   b. For taking notes by hand - one useful technique is the use of right page/left page notes. In class, use the right page to record your class notes. After class, use the left page to organize your notes (make tables, concept maps) and add additional supporting material (from pre-lecture videos, textbook, or discussion).
3. Ask for clarification if you don’t understand something.
4. Actively engage in learning activities with your group. One of the best ways to learn material is by explaining it to someone else.

What to do after class:

1. Review your notes - do this as soon as you can after class. Rewriting your notes in your own words can be a very helpful way to learn. Take this opportunity to create graphical organizers such as Venn diagrams, tables, and concept maps. These organizers will help you see how the content goes together in each class.
2. If after reviewing your notes you have questions - get help (go see a TA or Dr. Clegg). The content in science classes builds on previous classes. Make sure you take the time to master the content as you are learning it - don’t wait until the exam.
Study tips:

You will not learn the material covered in IB 150 by cramming the night before an exam. Here are some tips that will help you be successful on exams:

1. Review the material (class and discussion) frequently.
2. Build concept maps using key terms - make sure you understand the relationships between these terms. Simply making flashcards and memorizing definitions will not lead to success.
3. Create exam questions from class and discussion material and then try to answer them. Try to make questions that require application of knowledge not just memorization of facts.
4. Make drawings from your notes. Making a diagram or flowchart from your notes can help you understand how concepts are related.
5. Study in blocks - don't study for hours on end. Study some biology and then take a break or study something else.
6. Make sure that you get some sleep after studying - you need to sleep for your brain to process any new information.
7. If you have exam anxiety, research has shown that journaling can improve student exam success. Before the exam, take 10 minutes to write down what is making you anxious about the exam (or other things that may be going on). This will free up your brain, and break the cycle of thinking about your anxieties more than about what you have achieved. These studies have shown that exam performance increases by half a grade to a grade simply by writing down what is on your mind to free the mind to tackle the exam questions.
How to use the provided learning goals and targets:

Each unit in this course is accompanied by a set of learning goals and targets that should be your learning guide as you study.

Be careful not to confuse the role of targets and goals!

The **goals** are the bold, numbered, broad questions. It is this goal that you want to focus on fully understanding and gain the ability to apply its implications in novel scenarios.

The **targets** are a set of components that you need to be able to apply synthetically in your full explanation of the goal.

In other words, fully understanding, explaining and applying the goals to gain new insights is what you want to reach. The targets are steps or components that help you get there.

**One effective way to use the goals and targets** is to take a goal you are studying and see if you can write an essay in 1 or 2 paragraphs to fully explain how it works. Then you can use the targets to “grade” yourself whether you were able to draw on all the relevant aspects in your essay to explain this goal.

➔ **Memorizing terms, steps, or answers to individual targets will not be enough to succeed on exams in this course!**
IB 150 Learning Goals

Unit 1 Learning Goals & Outcomes

1. Understand how to use a manipulative experiment to answer questions with the scientific method.
   A. Define and be able to write a hypothesis as a statement that reflects a potential explanation for the research question.
   B. Use deductive logic to derive unique, testable predictions to a hypothesis.
   C. Differentiate between independent and dependent variables, and use them appropriately to set up predictions of concrete results you would expect, if the hypothesis is correct.
   D. Graph qualitatively the predicted data, identifying which treatments are expected to differ significantly (more than expected due to chance alone).
   E. Set-up an appropriate experiment that controls for the independent variable and minimizes the effect of other environmental variables, and includes a control treatment and replication in its design.
   F. Identify the role and utility of control treatments, replication of treatments, and sample size in any experiment.

2. What does it mean to be alive?
   A. List five characteristics all organisms on Earth share.
   B. Explain why all but evolution require input of energy.
   C. Understand how the ability to perform work is related to being alive.
   D. Predict the direction of net flow of water across a cell membrane due to osmosis given information about solute concentrations on either side of the membrane. Explain what happens to rates of movement of water molecules in both directions across the membrane at equilibrium.
   E. Understand that net flow of molecules due to osmosis is a result of the rates of movement of particles in both directions, NOT as a result of an inherent preference or force moving these molecules in one direction or the other.

3. Be able to apply the First and Second Law of Thermodynamics and explain their relevance to living processes
   A. Define the First and Second Law of Thermodynamics.
   B. Use the First Law of Thermodynamics to explain how chemical reactions transfer energy from one molecule to another.
   C. Understand how molecules store chemical potential energy.
   D. Determine whether a change of a system increases or decreases in enthalpy ($\Delta H$) and entropy ($\Delta S$) over the course of the reaction.
   E. Use the Second Law of Thermodynamics to predict whether a process is exergonic or endergonic and thus will proceed spontaneously or not by qualitatively applying the equation $\Delta G = \Delta H - T\Delta S$.
   F. Define exergonic and endergonic chemical reactions.

4. How do organisms control reaction rates?
   A. Be able to draw a graph that illustrates activation energy in a graph of the time course of a chemical reaction
   B. Explain why raising temperature helps overcome the activation energy of a chemical reaction.
   C. Explain how adding catalysts helps overcome the activation energy of a chemical reactions
   D. Be able to use these terms in context: catalyst, enzyme, active site
   E. Understand why the majority of chemical reactions an organism relies on are catalyzed by enzymes.
5. Explain how organisms manage to run endergonic reactions without violating the Second Law of Thermodynamics.
   A. Explain why four of life’s characteristics are endergonic processes.
   B. Understand that energy to sustain life is derived from chemical potential energy.
   C. Be able to identify the most common sources of chemical potential energy.
   D. Explain how organisms can drive endergonic reactions via energetically coupled reactions.
   E. Know the overall ΔG of energetically-coupled reactions. Understand what happens to the energy represented by ΔG of the overall, coupled reactions.
   F. Use the concepts of energetically-coupled reactions to explain how ATP does work in the cell via substrate-level phosphorylation, and classify the sub-reactions during phosphorylation as either endergonic or exergonic.

6. How is ATP produced during Cellular Respiration?
   A. Differentiate and relate the roles of glucose and ATP in cellular respiration
   B. Write the overall equation for Cellular Respiration
   C. List the four major reactions of Cellular Respiration and (separately) the inputs and outputs of each.
   D. Identify the locations within a eukaryotic cell where each of the major reaction pathways of cellular respiration takes place.
   E. Trace the flow of energy from chemical potential energy in C-H bonds of glucose to ATP produced.
   F. Identify which steps of Cellular Respiration produce ATP, and which step is responsible for the vast bulk of ATP production during Cellular Respiration.
   G. Understand the role of oxygen in Cellular Respiration.
   H. Describe the role of cellular respiration in the transfer of energy from glucose to work done in the cell.

7. Understand the importance of Cellular Respiration to (almost) all life on Earth
   A. Predict what the consequences are for an organism following disruption of any of the major reaction pathways of Cellular Respiration.
   B. Differentiate between aerobic cellular respiration, anaerobic cellular respiration, and fermentation.
   C. Justify why some organisms would use aerobic cellular respiration and others would use anaerobic metabolic processes (either anaerobic cellular respiration or fermentation).
   D. Distinguish between facultative and obligate anaerobic organisms.
   E. Justify why most life on Earth uses aerobic cellular respiration, instead of anaerobic metabolic processes.

8. Energetic constraints on the cell/body size and shape
   A. Define diffusion versus osmosis
   B. Predict (in a general sense) changes in the rate of diffusion given changes in the various parameters of Fick’s Law of Diffusion
   C. Justify why the net movement of a group of molecules along a concentration gradient due to diffusion can be caused by the random movement of individual molecules.
D. When provided with equations for the surface area and volume of a shape, use them to explain why the SA:V of a small shape is greater than that of the same shape at a larger size.

9. How do physical and physiological limitations determine the anatomy of respiratory systems?
   A. Illustrate the path of a molecule of $O_2$ from the atmosphere to a cell within the body of a mammal and (separately) a fish, and an organism that does not possess a circulatory system (such as a plant).
   B. Identify and contrast the features of the respiratory and circulatory systems of insects and mammals that allow mammals, but not insects, to attain large body sizes.
   C. Identify variables of Fick's Law in anatomical structures.
   D. Use surface area:volume ratio to explain the relationship between respiratory surface area and the body size and respiratory anatomy of animals.
   E. Explain how counter-current flow increases the ability to absorb oxygen from the environment.
   F. Justify alternative hypotheses for why not all organisms possess seemingly “optimal” solutions.

10. What is the role of respiratory pigments?
    A. Relate the role of respiratory pigments in blood to variables in Fick’s Law.
    B. Use oxygen concentration of blood to predict location on blood with respect to systemic or pulmonary capillary beds.
    C. Use shape of oxygen dissociation curves (hyperbolic versus sigmoidal) to predict whether a respiratory pigment is a monomer or tetramer and whether it can engage in facilitation.
    D. Describe how changes in the shape (R versus T state) of hemoglobin affect its oxygen affinity.
    E. Relate the shape of the sigmoidal oxygen dissociation curve to the process of facilitation as caused by changes in shape and $O_2$-affinity in high versus low-oxygen environments.
    F. Explain how the affinity of hemoglobin changes due to allosteric binding of $H^+$ in the presence of high $CO_2$ concentrations in its environment (Bohr effect).
    G. Compare and contrast the function of hemoglobin and myoglobin and explain how the two pigments facilitate efficient movement of oxygen from the blood into muscle tissue.
Unit 2 Learning Goals & Outcomes

11. What is the structure and function of DNA?
   A. Know the structure and function of DNA
   B. Know the base-pairing rules and be able to apply them to create complementary DNA strands during DNA replication.
   C. Understand how base-pairing rules lead to a semi-conservative model of DNA replication.
   D. Be able to use the following terms in context: base-pairing rules, sugar-phosphate backbone, nucleotide, nitrogenous base, hydrogen-bonding of nitrogenous bases.

12. How does DNA encode genetic information?
   A. Describe the Central Dogma of Biology, and know the basic steps involved: transcription, translation.
   B. Differentiate RNA from DNA.
   C. Be able to transcribe and translate a gene sequence to the protein product, if given an mRNA codon chart, including predicting the amino acid sequence that results from a particular mutation in the DNA sequence.
   D. Distinguish between genotype and phenotype
   E. Define a mutation, and relate it to alleles and genetic diversity in a population.
   F. Illustrate how mutations occur at the DNA level.
   G. Distinguish the effects on the protein product of a missense mutation, a silent mutation, a nonsense mutation, and a single-nucleotide frameshift mutation, and predict the severity of the mutation for the resulting protein’s function.
   H. Identify and define the property of the triplet genetic code that permits a genetic mutation to have no effect on the resulting protein product.
   I. Identify two natural mechanisms that help prevent mutations from occurring during DNA replication.
   J. Be able to use the following terms in context: mRNA, tRNA, rRNA, gene product, polypeptide, protein, amino acid, ribosome, codon, start and stop codon, substitution, indel, silent, missense, frameshift, nonsense mutations, redundancy and unambiguity of genetic code.

13. Mitosis: How do organisms pass on genetic information during asexual reproduction?
   A. Identify how genetic information is organized in a karyotype of an organism
   B. Differentiate autosomal chromosomes (autosomes) from sex chromosomes.
   C. Draw the same chromosome in the replicated and unreplicated state, explain why both structures represent a single chromosome, and then label the sister chromatids in the replicated chromosome.
   D. Draw and identify a cell of any ploidy (haploid, diploid, tetraploid, etc) and chromosome number.
   E. Describe the cell cycle during mitosis, and be able to draw diagrams that show how chromosomes move and are divided between daughter cells.
   F. Explain when mutations can occur during the cell cycle.
   G. Explain the significance of the events that occur during Mitosis, and why these events result in the production of two genetically identical daughter cells.
   H. Be able to use the following terms in context: Karyotype, chromosomes, autosomes, sex chromosomes, chromatids, ploidy, diploid, haploid, homologous chromosomes, G1 phase, S phase, G2 phase, M phase, centosome, centromere, spindle fibers, cytokinesis
14. Different forms of sharing genetic information and life cycles
   A. Compare and contrast “bacterial sex” to “true” sex
   B. Depict the life cycle of animals, fungi and plants
   C. Describe the process of gametogenesis: Differentiate the process for males and females, and explain how oogenesis can result in very large egg cells.
   D. Provide at least one hypothesis for why many sexually reproducing species have evolved two sexes that produce very different types of gametes.
   E. Be able to use the following terms in context: plasmid, gamete, gametophyte, sporophyte, diploid versus haploid-dominated life cycle and alternation of generations

15. How does Meiosis result in the production of genetically distinct, haploid gametes?
   A. Diagram the major events in meiosis for a diploid organism, relating each part of meiosis with the ploidy of the cell (see Figure 13.4).
   B. Use a diagram of chromosome dynamics during meiosis to trace on a diagram maternal and paternal alleles into gametes.
   C. Describe the fundamental similarities and differences between mitosis and meiosis (Fig 13.8 and Table 13.2).
   D. Diagram how the process of Independent Assortment results in genetic diversity of gametes by shuffling alleles of two or more genes located on different chromosome types.
   E. Predict how many genetically unique gametes can be produced via Independent Assortment alone, given information on chromosome number.
   F. Diagram how the process of crossing-over results in genetic diversity of gametes by shuffling alleles of two or more genes located on the same chromosome type.
   G. Relate recombination of alleles of linked genes to crossing-over during meiosis.
   H. Use the concepts of Independent Assortment and crossing-over to explain how it is possible for the offspring of a single, self-fertilizing parent to have different combinations of alleles that are not present in that parent.
   J. Compare/Contrast asexual and sexual reproduction, and the opportunities for genetic diversity afforded by each
   K. Be able to use the following terms in context: DNA, gene, allele, chromosome, chromatid, locus, ploidy, chromosome, chromatid (sister and non-sister), homologs, and gametes

16. Understand how sexual reproduction (i.e. the combination of meiosis and fertilization) results in a large genotypic and phenotypic diversity
   A. Define and relate ploidy, alleles and dominance
   B. Differentiate expected proportions of gametes/offspring from observed proportions of gametes/offspring
   C. Relate genotype to phenotype, given information on which alleles are dominant and recessive
   D. Define the term “carrier” with respect to a genetically determined trait
   E. Predict genotypes of all possible gametes produced by an individual, following any given number of genes.
   F. Understand how the Punnett Square is used as a probability table of combining every combination of possible events.
   G. Determine the potential offspring of two parents of known genotype for mono- and dihybrid crosses, showing the potential gametes of each parent, and all potential combinations thereof, organized in the form of a Punnett square.
   H. Apply the "and" and the "or" rule to calculate the probability of a future event (or events).
   I. Calculate the probabilities of the genotypes and phenotypes of offspring from well-defined crosses.
J. Justify (explain in your own words) why any particular cross between parents of known genotypes results in a particular ratio of potential offspring genotypes and phenotypes.

K. Use genotypic (or phenotypic) ratios of offspring to predict the genotypes of parents.

L. Use a test-cross to determine parental genotypes, and explain why a test cross is uniquely suited for this task (compared to other possible crosses)

M. Identify on a pedigree: males, females, mating couples, parents and offspring, genotypes and phenotypes (where indicated)

N. For a given trait, use information on gender and phenotypes of relatives to predict their genotypes (for example using a pedigree)

O. For a given trait, use information on gender and phenotype to predict the mode of inheritance of that trait (e.g., autosomal recessive) (e.g. using a pedigree)

17. More complex patterns of inheritance
   A. Solve and explain genetic patterns resulting from genes that lie on the sex chromosomes and be able to recognize sex-linked traits (both X- and Y-linked traits) in pedigrees.
   B. Predict all possible gamete genotypes produced by an individual when following more than one gene.
   C. Explain how independent assortment relates to production of gamete and genotypic frequencies in crosses involving more than one gene (specifically, what assorts, and when during meiosis do they happen?)
   D. Predict phenotypes resulting from polygenic traits that result in quantitative phenotypic trait distributions
   E. Predict phenotypes of crosses involving two or more epistatically interacting genes
   F. Articulate the utility of model organisms for understanding basic biological principles, including understanding aspects of human biology
   G. Be able to use the following terms in context: homologous genes, Sex-linkage, X-linkage, hemizygous, polygenic traits, epistasis, model organism

18. How does recombination through crossing-over result in genetic diversity of offspring for linked genes?
   A. For gametes produced by heterozygous and homozygous parents, trace on a diagram maternal and paternal alleles into gametes.
   B. Explain why linkage between two genes on a single chromosome does not allow the two genes to assort independently.
   C. Differentiate sex-linkage from linkage.
   D. Predict parental and recombinant type frequencies, assuming two genes are independently assorting
   E. Explain why parental and recombinant frequencies differ from predicted frequencies of independently assorting genes for linked genes.
   F. Use the concept of probability to explain why X-linked traits are more common in males than females (in those organisms with a XY sex determination system).

19. Creating linkage maps of an organism's genome
   A. Understand how genetic crosses can be used as experiments to test hypotheses related to inheritance of traits
   B. Understand why we need statistical tests to differentiate differences between observed and expected results that occur because of an underlying mechanism responsible for these differences versus differences between observed and expected results due to chance alone.
   C. Understand what the p-value in a statistical test indicates.
D. Apply the Chi-Square statistic to test whether observed parental and recombinant frequencies deviate from expected frequencies of independently assorting genes more than would be expected due to chance alone (with p<0.05).

E. Interpret results from the Chi-Square test that indicate deviations of observed from predicted recombinant and parental type frequencies in test-crosses with dihybrid individuals.

F. Predict the relative chances of a crossing over event when given the location on a single chromosome of two genes with respect to a third.

G. Construct linkage maps of linked genes using recombinant frequencies in centiMorgan (cM).
Unit 3 Learning Goals & Outcomes

20. What is biological evolution?
   A. Differentiate between different sources of diversity among individuals in a population, including heritable variation and environmentally-induced variation due to phenotypic plasticity.
   B. Identify variation that is of evolutionary significance
   C. Define biological evolution with respect to allele frequencies

21. Understand the intimate relationship between populations and genetic diversity
   A. Calculate allele frequencies given genotype frequencies or number of individuals with each genotype
   B. Explain (in your own words) the predictions of the Hardy-Weinberg (HW) Principle.
   C. List and restate (in your own words) the five assumptions/conditions of the Hardy-Weinberg principle, and know under which conditions it is OK to make these assumptions, or why you are testing for violations of these assumptions.
   D. Predict allele and genotype frequencies of rare genetic disorders in a population from phenotypic data alone, ASSUMING that the population is in Hardy-Weinberg Equilibrium, and understand the limitations of your estimates.
   E. Calculate the expected frequencies of offspring of particular genotypes or phenotypes expected in the next generation if the population is in Hardy–Weinberg equilibrium given allele or genotype frequencies in the current generation
   F. Be able to apply the Hardy–Weinberg equation to estimate the frequencies of carriers in a population, assuming alleles of the gene in question is in Hardy–Weinberg Equilibrium
   G. Understand in what sense the Hardy-Weinberg equation represents the prediction of the null hypothesis of biological evolution.
   H. Determine whether or not a population is in Hardy-Weinberg equilibrium using the Chi-Square statistic to compare expected and observed genotype frequencies of a population, and explain the biological implications of either rejecting or failing to reject the null hypothesis based on your results.

22. What causes genotype frequencies not to be in HW equilibrium in a population?
   A. List the four processes that change allele frequencies and the five that change genotype frequencies in populations through time.
   B. Restate (in your own words) what it means for an allele to be fixed in a population or lost from a population.
   C. Relate allele fixation to genetic diversity (e.g., what is the effect of fixation on genetic diversity?).
   D. Identify processes that can cause alleles to be fixed or lost and re-introduced.
   E. Describe the concept of “random sampling of alleles” in genetic drift making specific reference to the parental gene pool and offspring genotypes.
   F. Understand how genetic drift can cause alleles to become more or less common or fixed in populations
   G. Predict the relative effects of genetic drift in large vs. small populations and predict the relative time to allele fixation for large vs. small populations undergoing drift.
   H. Compare and contrast the causes and consequences of the “founder effect” and population bottlenecks.
   I. Define gene flow and relate it to migration between populations
   J. Explain how gene flow influences effective population size, allele frequencies, and genetic divergence between populations living in different regions.
K. Understand how non-random mating can influence genotype frequencies, and be able to illustrate graphically why non-random mating alone will not change allele frequencies.

L. Predict how inbreeding will change genotype frequencies, and be able to graphically illustrate why non-random mating will not by itself change allele frequencies.

M. Justify why inbreeding does not cause evolution directly, yet can speed the rate of evolutionary change.

N. Justify why ALL natural populations will evolve, making reference to assumptions made under the Hardy-Weinberg Principle.

23. How do biotic and abiotic interactions lead to adaptations?
   A. List the four postulates of natural selection.
   B. Discuss the consequences of differential survival and reproduction for variation in a population.
      (Why is “Survival of the fittest” not capturing the whole story?)
   C. Compare and relate the roles of reproduction and survival in natural selection.
   D. Identify sexual selection as a sub-category of natural selection that increases reproductive success through mate acquisition.
   E. Define fitness in the context of natural selection.
   F. Identify that evolution by natural selection results directly from intraspecific competition between individuals of different genotypes.
   G. Explain why natural selection does not result in evolution of a trait because a population “needed it”, but can only operate on pre-existing variation in the population.
   H. Defend the statement that selection is reactive, and not a directed process with foresight.
   I. Justify why traits/behaviors for the “good of the species” (but at the cost of an individual’s fitness) would not be favored by natural selection.

24. How does natural selection cause non-random changes in allele frequencies in a population?
   A. Predict how biotic and abiotic selection pressures result in changes of allele frequencies in a genetically diverse population.
   B. Discuss the causes of heritable variation and the consequences of differential survival and reproduction for variation in a population.
   C. Justify why mutation is a random process to introduce alleles, but evolution by natural selection is a nonrandom process that can alter allele frequencies in a population.
   D. Compare and contrast expected changes in allele frequency in a population depending on if that allele is under selection vs. experiencing drift.
   E. Compare and contrast different modes of natural selection and relate them to differences in fitness of phenotypes and resulting changes in allele frequencies: (Directional, Stabilizing, Disruptive Selection)
   F. Explain multiple ways in which a deleterious allele can persist in a population.

25. How do new species arise?
   A. Define a biological species.
   B. Define reproductive isolation and relate it to gene flow among populations.
   C. Explain why gene flow makes speciation by reproductive isolation less likely.
   D. Compare and contrast forms of pre-zygotic and post-zygotic reproductive isolation and be able to give examples of each.
   E. Contrast allopatric and sympatric speciation.
   F. Define the concept of “divergence” with respect to two recently isolated populations.
   G. Be able to identify how genetic drift and different modes of natural selection can enhance divergence between recently isolated populations.
H. Identify why disruptive selection is a conducive mechanism to result in sympatric speciation.
I. Explain how secondary traits (such as sexually selected traits) that lead to increased reproductive isolation can increase fitness of individuals among sympatrically diverging populations.

26. How can we infer evolutionary relatedness using cladistics?
   A. Define nodes and branches
   B. Explain how we can use traits/characters to group related organisms
   C. Define a clade and know that clades are nested groupings of organisms, clade within clade, that group organisms by ever more distant common ancestors.
   D. Compare and contrast shared derived traits and shared ancestral traits, and know which is used to define a clade
   E. Understand that any character that is a shared derived character for one clade, can be a shared ancestral character for another clade.
   F. Contrast Monophyletic, Paraphyletic, Polyphyletic groupings
   G. Be able to use a set of characters for different species to create a cladogram, using the principle of maximum parsimony.
   H. Contrast homologous versus analogous characters, be able to give examples.
   I. Be able to identify a character as homologous versus analogous when presented with a cladogram of a lineage that displays these characters.
   J. Explain how convergent evolution can result in analogous traits
   K. Understand how DNA sequences can be used as characters in cladistic analysis.
   L. Explain the basic assumptions made in cladistic analyses, what errors can occur, what causes these errors in inferring evolutionary relationships to occur, and how to guard against errors in constructing phylogenies/cladograms.
Unit 4 Learning Goals & Outcomes

27. How does the mammalian circulatory system function?
   A. Conceptually illustrate the relationship between the respiratory and circulatory system in vertebrates.
   B. Know the general flow of blood through the mammalian circulatory system.
   C. Know the major layout and function of the mammalian heart.
   D. Explain two reasons for changes in blood pressure in arteries vs. capillary beds vs. veins and know anatomical differences between arteries and veins to account for these differences in blood pressure and ability to move blood under these differing conditions.
   E. Be able to use the following terms in context: pulmonary and systemic circuit, arteries, arterioles, veins, capillaries, vena cava, pulmonary artery, aorta, left and right atrium, left and right ventricle, septum.

28. Why do we need information from the fossil record to understand our own anatomy?
   A. Contrast proximate versus ultimate explanations.
   B. Highlight the main evolutionary changes associated with the origin of tetrapods, and tetrapod limbs in particular.
   C. Define "pre-adaptations".
   D. Contrast the selective pressures that tetrapod limbs originally evolved under, with what they were later co-opted for in terrestrial tetrapod lineages.
   E. Explain why we essentially never see the appearance of a brand-new structure "from scratch", but rather tinkering with pre-existing structures that can be co-opted for new functions.
   F. Reconstruct basic developmental organization of a common ancestor, given information about shared regulatory genes among members of descendant species.

29. How do genes control development of a multi-cellular organism?
   A. Explain how cell differentiation gets started during oogenesis: Cytoplasmic Determinants, maternal effect genes.
   B. Understand how cytoplasmic determinants (maternal effect genes) can initiate differential expression of secondary developmental genes, including Segmentation Genes and Hox Genes.
   C. Explain how some of these genes can act as morphogens, and can elicit different cellular responses depending on their concentration.
   D. Understand how changes in timing and location of expression of regulatory genes can result in dramatic morphological changes.
   E. Explain why many of the fundamental regulatory genes are so strongly conserved between distantly related organisms.
   F. Explain how novel structures in organisms can derive from tinkering with expression patterns using pre-existing developmental genes.
   G. Explain what can explain the patterns that underlies Haeckel's Law of Recapitulation, but why the law itself is not an actual, firm law of nature.

30. Ultimate anatomical explanations: How did the mammalian heart evolve?
   A. Compare and contrast the general outline of the mammalian/avian circulatory system with that in fish, lungfish and amphibians, reptiles and crocodiles.
   B. Be able to generate hypotheses regarding the evolutionary origin of anatomical structures given information on the phylogenetic relationships between lineages.
   C. Be able to use the following terms in context: derived structures, analogous structures, shared ancestral structures, phylogenetic constraint.