**Genetics and Molecular Biology (BIOL 202)**

**SUMMER SESSION I 2015**

Dr. Blaire Steinwand

MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY AT 9:45AM

**Instructor:** Dr. Blaire Steinwand  
blairejs@email.unc.edu

**Office hours:** Wednesday 11:15am-1:00pm and Friday 11:15am-12:00pm in Coker 212  
I am also available by appointment. Feel free to contact me so that we can set up a time!

**Graduate Teaching Assistant:** Antonio Serrato-Capuchina (gaserrat@email.unc.edu)

**Office Hours:** TBA

**Undergraduate Supplemental Instructor:** Sam Eure (euresa@live.unc.edu).

**SAKAI SITE**
(you must have an onyen to log on - go to  
https://itsapps.unc.edu/improv/#UserCreateOnyenPlace:createOnyen if you do not have an onyen.) The Sakai site will have postings from lectures such as outlines, power point slides, and supplemental material we mention in lecture. I will also post announcements regarding student concerns on this site. *It is your responsibility to check it regularly.*

**REQUIRED TEXT AND REQUIRED ONLINE MASTERING GENETICS ACCESS:**
*Genetic Analysis.* 1st Edition by Sanders and Bowman  
Feel free to choose a physical book or the ebook. The ebook is the cheaper option if you do not plan to keep your book.  
**Required access to Mastering Genetics the online activity and homework tool. This comes included with a NEW physical textbook or ebook, but can be purchased separately if you buy a used book. If you have a used physical book, you can buy the Mastering Genetics access card at the bookstore but be aware that the cost of the access and a used book may be greater than purchasing a new book.**

Required reading: Particular chapters are required (see course outline for "Guided Reading" details) and you will be expected to have read them **before** class so that you can complete the Mastering Genetics homework assignments and be able to participate fully in the in-class activities.
ADDITIONAL REQUIREMENTS: Basic knowledge of biology and chemistry as demonstrated by a C or above in BIOL 101 and CHEM 101 or 102 or equivalent.

HOMEWORK VIA MASTERING GENETICS: (10% of your grade) Homework will be due the morning before almost every class period at 9:00AM. Some assignments will take you as little as 15 minutes and others will take over an hour with the animations and short tutorials interspersed in the homework. **It is your responsibility to start it in a timely fashion, so that you finish it before the deadline.** To be safe, assume your clock is 5 minutes slower than the official Mastering Genetics time. Late homework will receive zero credit, even though you can still do them for practice. **DO NOT ASK ME TO MAKE AN EXCEPTION TO THIS RULE.** It is YOUR responsibility to finish the homework early so that any late-evening crises do not prevent your finishing on time. Do not count on the Mastering program to give an accurate account of how long an assignment will take. These estimates can be wildly off! There will be numerous graded at-home assignments. See my Goal #1 below and realize that we are trying to help you to succeed by giving you these regular assessments. **See Sakai for how to register for Mastering Genetics.** Be sure to sign up to see the assignments for our class: MGENSTEINWAND27601.

LEARNING CATALYTICS/PARTICIPATION (5% of your final grade): As an incentive to come to class and be engaged, 5% of your grade will come from participation. We will use a program called Learning Catalytics that you use through your laptop or mobile phone. Note - missing just a couple of classes can quickly affect your participation grade! You can access LC through Mastering Genetics or directly by visiting learningcatalytics.com. Your instructor will provide the “session ID” for each class.

SUPPLEMENTAL INSTRUCTION (SI): Sam was a VERY successful student of mine and is equipped with the knowledge and skills that you need to be successful in this course. He will offer 1-2 sessions of supplemental instruction a week and will post problem sets for you on Sakai. In order for him to help you approach and analyze problems, you should bring questions you have to SI only after you have reviewed and attempted to solve problems on your own. Each session will be scheduled for 1 hour - the times and location of these sessions will be posted on Sakai during the first week of class. You are not required to attend SI, but it is highly recommended, since this is your opportunity to get more “one-on-one” attention for this course. It is worth noting that Sam has seen many of my exams! I suggest you fit SI into your schedule early in the semester and attend it weekly as if it is a required class. Sam’s contact information is listed above.

PIAZZA: There are many of you and your questions are important to us. However, it is often difficult for a single instructor with so many students to address all of the e-mails that are received throughout the course of the semester. Unfortunately, as a result, sometimes your e-mails even fall to the bottom of our inboxes and go unanswered. Therefore, in order to address your questions and concerns more efficiently, we will be using an online platform called “Piazza.” You may post any questions that you have about the course to this site at any time and they will
be answered by a fellow student, a TA, SI instructor, or your instructor. Your questions may be more general and may relate to the course itself or they may be more specific and instead relate directly to content and/or material from class. In any case, Piazza will help you get them answered ASAP. You will receive a welcome e-mail from your instructor granting you access to the course within the first week of the semester and can start using Piazza right away.

WHAT YOU SHOULD BRING TO CLASS EVERY DAY:
1. Outlines from Sakai (either printed or on laptop).
2. Extra blank paper for drawings, notes, activities etc. (or tablet computer for drawing)
3. 3 x 5 index cards (with or without lines, preferably white).
4. Learning Catalytics device: either your cell phone for texting or laptop/ipad/smartphone for web access
5. Your thinking cap!

COURSE GOALS: Many students like to complain that this is a “weed out” course. Of course this is not true, but why does it have this reputation? Fact: the average grade in this class is in the B/C range; C’s are not bad - they are average. If you are wondering if there is a pre-determined number of students that receive a C, D, or F - the answer is no! In theory, if the whole class performs at an A level, then the whole class is given A’s.

And, this brings us to the goals of our course...

1. To provide you with the core principles of genetics and molecular biology. The lecture and the book will provide the basic content. We will take a historical approach at times to see how famous experiments were performed. We will examine the basic “rules” of genetics that may then be altered to account for more complex situations. After this class, you will be prepared to do research in a lab on campus and to build upon this content with Biol 205 and upper level genetics courses.

2. To gain higher level thinking skills.
   To the right you can see the “Amended Bloom’s Taxonomy” pyramid. It was developed as a method of classifying educational goals for student performance evaluation. You should be well-equipped at remembering facts and content with good study habits. We are looking for you to apply and analyze. You are UNC students, we KNOW you can memorize! Move beyond this level of thinking. How can we achieve this? We will have in-class questions to practice this immediately and you will have homework problems to practice on your own. We will also explore classic experiments as a way of thinking through the logic of experiments and to see where the foundations of this content come from. While these may be
new ways of thinking for you, practice is the most important way to gain these skills. FYI: UNC's medical school sees this is an excellent pre-req course for medical school because it teaches students to think.

3. This course should excite you about basic science and its applications.
   A foundation in genetic crosses with model organisms (basic science tool) allows you to understand human genetic diseases. A foundation in making recombinant DNA constructs (basic science tool) allows you to understand how plants are modified to be herbicide resistant or how recombinant proteins can be turned into medicines. Genetics and molecular biology provide the "tools" that other disciplines call upon in biological research. Plant biologists, evolutionary biologists, clinical researchers etc. all use these tools.

TESTS: There will be three tests and a cumulative final exam given during the session. The format will be multiple choice and short answer so you will need to bring two #2 pencils and a scantron form purchased at the bookstore to the test. With the exception of the final, these are not cumulative tests and will only cover the material specified on the course schedule. Although you are expected to take each exam, I will drop your lowest exam score. If a test MUST be missed - it will count as your dropped exam. To see your scores from the multiple choice section of the exam follow the link on Sakai for "results of machine scored exams." There will be a final exam given, and it will be cumulative. For all exams, you will need your PID number as identification on your exam sheet. Additionally, you may be asked to verify your identity, so it is required that you bring your one-card to each exam. Failure to produce a one-card or other picture ID if asked may result in a zero on that exam. Test material to study: chapter reading outlines/homework, lecture activities, power point slides, learning objectives, recitation material, and problem sets. To succeed in this class, it behooves you to take each reading/homework seriously and actively engage in all class discussions.

DIGITAL ETIQUETTE:
This course will require you to use your laptop and/or cell phone during class time. While I recognize that you are an excellent multi-tasker, research suggest that your peers are not. Please be respectful of your classmates and restrict your use of digital devices to course content. If we see that you or your peers are distracted, we will ask you to put your devices away and you may forfeit your ability to earn participation points that day. There will be times when you have completed your work or answered a poll question, but your peers have not. We ask that you assist your peers when appropriate or use the time to review your notes while you wait. I understand that your devices connect you to your friends and family (a wonderful thing!) but the classroom should be a place apart, however briefly (even if it seems like an eternity to you), from the outside world and distractions. You will learn more if you concentrate on the course while you are here and your classmates will thank you for not impeding their ability to learn.
HOW IS YOUR GRADE DETERMINED? (Note: there will be no changes to HOW your final average is calculated at the end of the semester...so please don't ask! You will get the grade you EARN!) Your final average is calculated:

Total for the semester =
(0.25 x test) + (0.25 x test) + (0.25 x final exam) + (0.10 x homework average) +
(0.10 x recitation average) + (0.05 x participation score)

In general, the scale for each letter grade comes very close to a 10 point scale. However I reserve the right to change that scale since it is impossible to predict the difficulty level of any particular test. I will keep you updated about the estimated scale as the course moves along.

COPYRIGHT POLICY
All course materials including your class notes and in-class assignments are covered by University Copyright Policy, @http://www.unc.edu/campus/policies/copyright%20policy%2000008319.pdf. This means it is illegal and an honor code offense to share your notes or any other course materials, including Mastering Genetics items with anyone not directly affiliated with this particular class. No uploading to non-class sharing sites.
### Class Schedule:

<table>
<thead>
<tr>
<th>Date</th>
<th>Lecture #</th>
<th>Assignments to be completed BEFORE this class</th>
<th>Topics covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wed 5/13</td>
<td>1</td>
<td>Read the syllabus! Complete online activities on Learn Genetics.com - “What is a Chromosome” and “Are telomeres the key to aging and cancer.” Read article “Lifestyle changes may lengthen telomeres, a measure of cell aging.”</td>
<td>Structure and function of genes and genomes</td>
</tr>
<tr>
<td>Thurs 5/14</td>
<td>2</td>
<td>Read article - “How do genes pick eye color?” (Link on Sakai)</td>
<td>Genetic variation - From genotype to phenotype</td>
</tr>
<tr>
<td>Fri 5/15</td>
<td>3</td>
<td>Guided Reading on Chapter 7 and online activities on PCR and gel electrophoresis at Learn Genetics.com</td>
<td>DNA Replication</td>
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<tr>
<td>Mon 5/18</td>
<td>4</td>
<td>Guided Reading on Chapter 8</td>
<td>The flow of genetic information - Transcription</td>
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</tbody>
</table>

**Recitation 5/18: PCR Activity** - Print activity and complete questions 19 on the PAPER PCR worksheet. Bring this to recitation. You will finish the activity as a class with your TA.

<table>
<thead>
<tr>
<th>Date</th>
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<th>Assignments to be completed BEFORE this class</th>
<th>Topics covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tues 5/19</td>
<td>5</td>
<td>Guided Reading Chapter 9</td>
<td>The flow of genetic information continued - Translation</td>
</tr>
</tbody>
</table>

**Recitation 5/19: Storyboarding the flow of genetic information** - Review the processes of transcription and translation.

<table>
<thead>
<tr>
<th>Date</th>
<th>Lecture #</th>
<th>Assignments to be completed BEFORE this class</th>
<th>Topics covered</th>
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</thead>
<tbody>
<tr>
<td>Wed 5/20</td>
<td>6</td>
<td>Guided Reading on Chapter 4 and 12</td>
<td>Genetic variation arises by mutation</td>
</tr>
<tr>
<td>Thurs 5/21</td>
<td>7</td>
<td>Guided Reading on Chapter 3.2 and 13.1</td>
<td>Genetic variation arises by chromosomal rearrangements</td>
</tr>
</tbody>
</table>

**Recitation: Review for exam** - BRING SPECIFIC QUESTIONS!
<table>
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<tr>
<th>Day</th>
<th>Date</th>
<th>Activity</th>
<th>Topic</th>
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</thead>
<tbody>
<tr>
<td>Fri 5/22</td>
<td>8</td>
<td>Read article “Shutting Down the Extra Chromosome in Down’s Syndrome Cells.” (See Sakai)</td>
<td>Gene dosage</td>
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<tr>
<td>Mon 5/25</td>
<td></td>
<td>NO CLASS/NO RECITATION - HOLIDAY</td>
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<tr>
<td>Tues 5/26</td>
<td></td>
<td>EXAM 1</td>
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<tr>
<td>NO Recitation 5/26</td>
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<tr>
<td>Wed 5/27</td>
<td>10</td>
<td>Guided Reading on Chapter 14</td>
<td>Prokaryotic gene regulation</td>
</tr>
<tr>
<td>Thurs 5/28</td>
<td>11</td>
<td>Online module on HOX genes at LearnGenetics.com</td>
<td>Eukaryotic gene regulation</td>
</tr>
<tr>
<td>Recitation 5/28: RNAi Activity</td>
<td></td>
<td>Read the articles “A Lethal Dose of RNA” and “Genetic weapon against insects raises hope and fear in farming” and watch the video on RNA Interference.</td>
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<tr>
<td>Friday 5/29</td>
<td>12</td>
<td>Online Activity - “Lick your Rats“ at LearnGenetics.com</td>
<td>Eukaryotic gene regulation continued - Epigenetics</td>
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<tr>
<td>Mon 6/1</td>
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<td>EXAM 2</td>
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<tr>
<td>NO Recitation 6/1</td>
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<tr>
<td>Tues 6/2</td>
<td>13</td>
<td>Guided Reading on Chapter 16</td>
<td>Recombinant DNA Technology</td>
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<td>Recitation 6/2: GMOs</td>
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<td>Find out which GMO your TA assigned to you and complete the guided reading assignment on that particular GMO. Bring your completed guided reading assignment to recitation.</td>
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<tr>
<td>Wed 6/3</td>
<td>14</td>
<td>Guided Reading on GMOs</td>
<td>Genetically Modified Organisms</td>
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<tr>
<td>Thurs 6/4</td>
<td>15</td>
<td>Guided Reading on SNPs, haplotypes, and personalized medicine</td>
<td>Personal genomics</td>
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<tr>
<td>Recitation: Review! BRING SPECIFIC QUESTION.</td>
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<tr>
<td>Fri 6/5</td>
<td>16</td>
<td>Review</td>
<td>Catch up</td>
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<tr>
<td>Mon 6/8</td>
<td></td>
<td>EXAM 3</td>
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<tr>
<td>NO Recitation 6/8</td>
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<tr>
<td>Date</td>
<td>Week</td>
<td>Activity</td>
<td>Notes</td>
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<tr>
<td>Tues 6/9</td>
<td>17</td>
<td>Guided Reading on Chapter 2</td>
<td>How genes affect phenotypes</td>
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<tr>
<td>Wed 6/10</td>
<td>18</td>
<td>Guided Reading on Chapter 4.1</td>
<td>Dominance relationships</td>
</tr>
<tr>
<td>Thurs 6/11</td>
<td>19</td>
<td>Guided Reading Chapter 2.6 (pages 50-52), Chapter 3 (pages 90-94), and the pdf – “Calculating risks in pedigree analysis.”</td>
<td>Pedigrees</td>
</tr>
<tr>
<td>Fri 6/12</td>
<td>20</td>
<td>Guided Reading on Chapter 4.3</td>
<td>Genes and pathways</td>
</tr>
<tr>
<td>Mon 6/15</td>
<td>21</td>
<td>Guided Reading on Chapter 5.1 and 5.2</td>
<td>Genetic linkage</td>
</tr>
</tbody>
</table>

**Recitation 6/9:** A Right to her genes: *A case study* - Write a one-page report on your character (TA will assign you a character) and bring this to class along with the “Group discussion questions.” You will turn in your report at the beginning of recitation so it must be completed prior to your meeting.

**Recitation 6/11:** Pedigree practice problems - *Print problem set on sakai and bring to class. You will solve these in class.*

**Recitation:** FINAL REVIEW!

**FINAL CUMULATIVE EXAM WEDNESDAY JUNE 17th 8AM**
<table>
<thead>
<tr>
<th>Date</th>
<th>Lecture #</th>
<th>Learning Objectives</th>
<th>Topics covered</th>
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</thead>
</table>
| Wed 5/13 | 1         | • Diagram a typical eukaryotic gene and indicate the locations of (i) regions that are genic but not coding, (ii) regions that are transcribed but not translated, and (iii) regions that are both transcribed and translated.  
• Describe the general organization, possible function, and frequency of genes and non-gene DNA sequences in a typical eukaryotic genome.  
• Explain the functional significance of packaging DNA into chromosomes and the lack of correlation between chromosome number and genetic information content.  
• Explain how all cells can have the same genetic content and yet have different functions in the body. | Structure and function of genes and genomes          |
| Thurs 5/14 | 2       | • Explain the meaning of ploidy (haploid, diploid, etc.) and how it relates to the number of homologues of each chromosome.  
• Describe how the positions of individual genes on a given chromosome are related to their positions on the homolog of that chromosome  
• Differentiate between a gene and an allele.  
• Describe the molecular basis of the allele that determine eye color | Genetic variation -  From genotype to phenotype       |
| Fri 5/15  | 3         | • Draw a cartoon of the two experiments that identified DNA as the genetic material.  
• Explain the experiment that demonstrated that DNA replication is semi-conservative and interpret the results obtained by Messelson and Stahl when they conducted this experiment  
• Describe how the two, anti-parallel strands of the DNA molecules are replicated simultaneously  
• Design a PCR reaction to amplify a gene and interpret the results of gel electrophoresis  
• Explain why some DNA replication errors do not result in mutation. | DNA Replication                                       |
| Mon 5/18  | 4         | • List and describe the function of the different kinds of RNA in cells.  
• Outline the anatomy of a gene and compare and contrast this with the anatomy of a transcript (mRNA)  
• Construct a story board that illustrates the three main steps of transcription | The flow of genetic information - Transcription       |
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<tr>
<th>Day</th>
<th>Date</th>
<th>Exercises</th>
<th>Topics</th>
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| Tues    | 5/19 | - Decide which of the two strands of DNA serve as a template strand for a particular gene when given the direction of synthesis  
- Explain how RNA polymerase recognizes a gene and knows when to initiate transcription  
- Design an experiment that allows you to identify different cis-acting regulatory sequences  
- Explain how a single mRNA can encode multiple proteins | The flow of genetic information - Transcription cont.                  |
| Wed     | 5/20 | - Construct a story board that illustrates the three main steps of translation  
- Determine the minimal number of tRNAs needed to recognize a given amino acid sequence  
- Locate an open reading frame  
- Translate an mRNA sequence into a protein | The flow of genetic information continued - Translation                 |
| Thurs   | 5/21 | - Explain, using diagrams, how nucleotide changes result in the alteration of protein activity.  
- Explain why germline mutations can be passed onto the next generation, whereas somatic mutations cannot.  
- Explain why some mutations do not affect protein structure or function.  
- Describe how mutations arise and how environmental factors can increase mutation rate  
- Distinguish between loss of function and gain of function mutations and their potential phenotypic consequences.  
- Interpret results obtained from the Ames test | Genetic variation arises by mutation                                   |
| Fri     | 5/22 | - Describe, using diagrams, the sequence of events involving DNA in meiosis from chromosome duplication through chromosome segregation.  
- Distinguish between sister chromatids and homologous chromosomes.  
- Discuss how errors in chromosome number can arise during meiosis, and why such alterations can be detrimental. | Genetic variation arises during meiosis                                |
|         |      | - Explain the gene dosage dilemma in aneuploidy  
- Describe the basic molecular mechanism for dosage compensation in mammals involving Xist  
- Explain how female mammals can be mosaics | Gene dosage                                                            |
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<tr>
<th>Day</th>
<th>Date</th>
<th>Class</th>
<th>Tasks</th>
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<tbody>
<tr>
<td>Mon</td>
<td>5/25</td>
<td>NO CLASS - HOLIDAY</td>
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<tr>
<td>Tues</td>
<td>5/26</td>
<td>EXAM 1</td>
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| Wed     | 5/27  | 10    | • Describe how the control of gene expression relates to the conservation of energy  
       |       |       | • Compare and contrast positive and negative regulation of gene expression  
       |       |       | • Classify mutations in the lac operon as gain-of-function or loss-of-function  
       |       |       | • Classify mutations in the lac operon as cis-acting or trans-acting mutations  
       |       |       | • Use illustrations to explain how mutations could effect the lac operon |
| Thurs   | 5/28  | 11    | • Describe how gene expression can be differentially regulated in different cell types  
       |       |       | • Predict the results of a promoter swap  
       |       |       | • Explain how a single HOX gene can regulate the development of an entire body part  
       |       |       | • Define the term “promoter” explain its role in regulating gene expression |
| Friday  | 5/29  | 12    | • Define the epigenome and describe how it is influenced by the environment that we live in.  
       |       |       | • List a few examples from your everyday life that could potentially alter your epigenome. |
| Mon     | 6/1   | EXAM 2 |                                                                   |
| Tues    | 6/2   | 13    | • Compare and contrast the expression and function of a dominant and recessive allele in a heterozygote.  
       |       |       | • Use a flow chart to outline the process by which a safe supply of growth hormone is produced.  
       |       |       | • Name the three main components of a recombinant vector/plasmid  
       |       |       | • Write a protocol that outlines the steps involved introducing a gene to a plasmid  
       |       |       | • Interpret the results from selection  
       |       |       | • Explain why cDNA was used to make recombinant bacteria  
<pre><code>   |       |       | • Name a technique that allows scientists to verify that a gene was integrated into a plasmid |
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<tr>
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<th>Day</th>
<th>Activity</th>
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<tbody>
<tr>
<td>Wed 6/3</td>
<td>14</td>
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<td>Make a scientific argument for/against GMO technology</td>
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<td>Outline how recombinant DNA technology could be used to create a GMO</td>
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<td>Genetically Modified Organisms</td>
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<td>Thurs 6/4</td>
<td>15</td>
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<td>Explain the method of SNP mapping and interpret SNP mapping data to pinpoint the chromosomal location of a human disease gene.</td>
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<td>Personal genomics</td>
<td>Discuss how primary care medicine is being affected by personal genetic testing.</td>
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<td>Define “direct to consumer” (DTC) genetic testing.</td>
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<td>Explain what is meant by a (SNP) and how SNPs can be used as genetic markers even if they do not cause phenotypic changes.</td>
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<td>Explain how haplotypes are inherited and identify individual haplotypes when given parent and offspring alleles.</td>
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<tr>
<td>Fri 6/5</td>
<td>16</td>
<td>Review</td>
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<td>Mon 6/8</td>
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<td>EXAM 3</td>
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<tr>
<td>Tues 6/9</td>
<td>17</td>
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<td>Design genetic crosses to provide information about genes, alleles, and gene function.</td>
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<td>Explain why it is advantageous to use true-breeding organisms in crosses.</td>
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<td>Predict progeny genotypic frequencies given the genotypes of the parental gametes.</td>
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<td>Identify an allele’s mode of inheritance from progeny phenotypes.</td>
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<td>Wed 6/10</td>
<td>18</td>
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<td>Distinguish between incompletely dominant alleles co-dominant alleles, recessive lethal alleles, alleles in a series, temperature sensitive and alleles</td>
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<td>Give an example of an incompletely dominant alleles and co-dominant alleles</td>
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<td>Explain the arbitrary nature of terms like dominance, co-dominance, and incomplete dominance.</td>
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<td>Define “recessive lethal”</td>
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<td>Dominance relationships</td>
<td>Decide whether an allele is dominant, co-dominant, incompletely dominant, or recessive lethal based on phenotypic ratios</td>
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<td>Differentiate between pleiotropy and polygeny</td>
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<td>Date</td>
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<td>Topic</td>
<td>Subtopics</td>
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<td>Thurs 6/11</td>
<td>19</td>
<td>Pedigrees</td>
<td>• Draw a pedigree based on information in a story problem.</td>
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<td>• Distinguish between dominant, recessive, autosomal, and X-linked modes of inheritance.</td>
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<td>• Calculate the probability that an individual in a pedigree has a particular genotype.</td>
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<td>• Define the terms incomplete penetrance, variable expressivity, and sex-limited phenotype, and explain how these phenomena can complicate pedigree analysis.</td>
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<td>• Differentiate between incomplete penetrance and variable expressivity.</td>
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<td>Fri 6/12</td>
<td>20</td>
<td>Genes and pathways</td>
<td>• Interpret the results of epistasis tests, comparing the phenotypes that result from single mutations in two different genes with the phenotype of the double mutant.</td>
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<td>• Determine if two mutations affect the same gene using complementation tests, and explain the requirements and the basis for interpreting results from these tests.</td>
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<tr>
<td>Mon 6/15</td>
<td>21</td>
<td>Genetic linkage</td>
<td>• Determine gene linkage and genetic map distances from the frequencies of progeny with recombinant phenotypes from genetic crosses.</td>
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<td>• Explain how a specific combination of linked alleles (haplotype) can persist through many generations.</td>
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</table>

**FINAL CUMULATIVE EXAM WEDNESDAY JUNE 17th 8AM**