BIOL 220 Molecular Genetics Dr. Gidi Shemer

Fall 23- TR 2:00-3:15 pm

Molecular Genetics is an intermediate-level biology course, geared towards advanced first years, sophomores, and juniors majoring in biology or in related fields. This is a comprehensive course,which covers transmission and molecular genetics; DNA replication, repair and mutation; the central dogma, gene regulation mechanism, and manipulation of genes at the molecular level. We will also learn the impact of molecular genetics on development and disease. The course will be based on the foundations that were learned in BIOL 101 and in the following class- How Cells Function (BIOL 103), which are prerequisites for this course.

This syllabus will introduce you to the main resources and tools that we will be using in BIOL 220, followed by a schedule with detailed objectives that will help you view what we will cover during the semester. Finally, you will find two lists of learning objectives- one focused on concepts and one on skills.

The course is composed of two class meetings each week. **This is NOT a class for passive learners. You are expected to be actively engaged in this course through class discussions, class activities, and pre- as well as post-lecture assignments and readings.** You are expected to **visit peer-mentors** routinely. Check in regularly, maybe with a buddy or small group. Form your own study groups too. Attend **SI sessions**.

I value the perspectives of individuals from all backgrounds reflecting the diversity of our students. I broadly define diversity to include race, gender identity, national origin, ethnicity, religion, social class, age, sexual orientation, political background, and physical and learning ability. I strive to make this classroom an inclusive space for all students. Please let me know if there is anything I can do to improve, I appreciate suggestions.

Prerequisites

BIOL 101 – Principles of Biology
BIOL 103 – How Cells Function

Your Instructor

Dr. Gidi Shemer

Office hours: Check the course Canvas site
Web page: http://www.bio.unc.edu/Faculty/Shemer/
Email: bishemer@email.unc.edu

Textbook

Essentials of Genetics/Klug, 10th ed. The textbook comes with a web-based software package called Mastering-Genetics, a platform through which you will be quizzed and receive short pre-lecture assignments. The package also includes an interactive eBook.
In order to register to Mastering-Genetics, check the Canvas Syllabus folder and the file "MasteringGenetics registration instructions". The MG course ID for our section is- shemer77627

Peer-mentors

Several of my best students who excelled in my Genetics class in the past will serve as peer mentors. They will be present in class and assist during class activities and each will offer a weekly 1.5 hours of one-on-one mentoring session (check the Discussion board and our Canvas site for updated mentoring session hrs.).

Supplemental Instruction (SI)

Twice a week, we will offer supplemental instruction (SI) sessions (days- TBA). The sessions will be led by two undergraduate students. The SI sessions will allow you to process and actively practice material that was taught in the previous week. Students referred to the SI sessions in the past as one of the most significant tools that improved their learning

Class Attendance

Students are expected to participate in our class meetings. Students are responsible for all the materials covered in these sessions **Most of the material discussed in lecture will not be found in the textbook**. You are responsible **for all material and announcements made in lectures**. You are also responsible for material **covered by your assigned reading and online videos.**

Assignments

Each week you will have **pre-class, in-class, and sometimes post-class assignments**:

- The pre-class assignments will be based on **assigned readings from the textbook** and in some cases- **online lectures**. The assignments will be given via the **Mastering** system and via **Canvas Assignments.**
- In-class assignments will include **Learning Catalytics** (see below), notecards, and other activities.
- Other assignments will include mostly **Mastering, Canvas** assignments and **PeerWise** activities (see below).
- **We will analyze a scientific paper in the Molecular Genetics field. This paper will be accompanied by short, asynchronous lectures as well as Guided reading questions that you will complete and submit.**

The due dates for submitting your assignments can be found on the **class detailed schedule** posted on Canvas (check the Syllabus folder).
You are responsible to follow the schedule and submit the assignments on time. Make sure you check the schedule and plan your time carefully. The time for all **due dates is 10:00 am.**

Oops token

Late assignments receive a 0% if not excused, but all students will receive 3 "oops" tokens they can use for an extension for a regular Canvas assignment, PW or LC assignments (not for Mastering, or for the Journal club assignments). Deadline to submit the oops tokens is the Friday of the week before LWOC). Here is the link to the form: https://forms.gle/mrxLxs9UYS4UBSFNA.

Interactive educational tools

Learning Catalytics

During class time we will use Learning Catalytics (LC), an interactive program that will allow you to participate in assignments through your device. LC comes as part of a package when you purchase the MasteringGenetics and the textbook. For accessing LC, check the Canvas Syllabus folder and the file "Learning Catalytics access instructions".

PeerWise

One of your assignments during the semester will be to create multiple choice questions that address the material we learn. Asking questions and evaluate your peers' questions has been shown to be an invaluable tool in developing deep learning. Posting and reviewing questions will be done through an interactive system called PeerWise. Instructions on how to register and how to use PeerWise will be given during the semester.

Discussion board

We will be using the Discussion tool on Canvas. You may post any questions that you have about the course to this site at any time and they will be answered by either a fellow student, a mentor, or me. 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 or material from class. You should not post anything unrelated to the class. No personal attacks or usage of offensive language will be allowed. No posts that directly give the answers to assignments are allowed. That being said, you are allowed to ask questions concerning the assignments, and your classmates are allowed to respond, as long as the conceptual framework is being discussed.

Grading

Your grade for this course will be determined as follows:

3 midterm exams + 1 (cumulative) final exam (1st = 16, and each of the others = 20)	= 76%
Mastering assignments	= 5%
Assignments and participance (Canvas= 8, LC= 5, PeerWise = 1)	= 14%
Scientific paper activities	= 5%

Letter grades will not be assigned for individual exams, only scores. Final letter grades will be assigned based on the total number of points for the entire semester:
A (93-100) A- (90-92.99) B+ (87-89.99) B (83-86.99) B- (80-82.99) C+ (77-79.99) C (73-76.99) C- (70-72.99) D+ (66-69.99) D (60-65.99) F (<60)

Your grade will be based on your performance and not on comparing your performance to your peers'. Exam questions will be taken **mainly from lectures**, and to some extent- from assigned readings and pre-class videos. **Grades will not round up**. B= 83, NOT 82.96. Exams must be taken on the dates indicated during the regular class period; no makeup exams except in special circumstances, i.e. medical or family emergency documented in writing. **I do not drop exam grades.**

Accessibility Resources & Service: UNC-Chapel Hill facilitates the implementation of reasonable accommodations for students with learning disabilities, physical disabilities, mental health struggles, chronic medical conditions, temporary disability, or pregnancy complications, all of which can impair student success. See the ARS website for contact and registration information: https://ars.unc.edu/about-ars/contact-us

Struggling with mental wellness? **CAPS is strongly committed** to addressing the mental health needs of a diverse student body through timely access to consultation and connection to clinically appropriate services, whether for short or long-term needs. Go to their website: https:// caps.unc.edu/ or visit their facilities on the third floor of the Campus Health Services building for a walk-in evaluation to learn more.

Title IX reporting: Any student who is impacted by discrimination, harassment, interpersonal (relationship) violence, sexual violence, sexual exploitation, or stalking is encouraged to seek resources on campus or in the community. Reports can be made online to the EOC at https:// eoc.unc.edu/report-an-incident/. Please contact the University's Title IX Coordinator (Elizabeth Hall, interim – titleixcoordinator@unc.edu), Report and Response Coordinators in the Equal Opportunity and Compliance Office (report and response@unc.edu), Counseling and Psychological Services (confidential), or the Gender Violence Services Coordinators (gvsc@unc.edu; confidential) to discuss your specific needs. Additional resources are available at safe.unc.edu.

All course materials including your notes and assignments are covered by University Copyright Policy

This means it is illegal and an honor code offense to share your notes or any other course materials with anyone not directly affiliated with this class.

The professor reserves the right to make changes to the syllabus, including project due dates and test dates. these changes will be announced as early as possible.

Topic	Objectives	Pre-class assigned readings	Pre-class assignments (Due 1:45 pm)	Other assignments (Due 11:59 pm)
T Aug 22 1. Introduction to the course	- Introduce ourselves. - List the basic structure and components of the course.			
R Aug 24 2. Chromosome structure and diversity	- Compare genomes from different organisms and the relationship between genome size and organism complexity or number of genes. - Diagram a eukaryote chromosome structure.	GRQ 2	**MG (How genetic information is organized)**	
T Aug 29 3. How genetic information is stored in the genome	- Describe the general organization, possible function, and frequency of genes and non-gene DNA sequences. - Describe how DNA is packed with other proteins into chromosomes. - Discuss the functional significance of packaging DNA into chromosomes. - Explain the structure and function of chromosomal territories.	GRQ 3	**MG (How genetic information is stored in your genome)** **Submit answers to GRQ 3 (via sakai)**	**Pre-semester assessment test**
R Aug 31 4. How genetic information is copied- DNA replication and the cell cycle	- Identify the key molecular players involved in DNA replication and explain their roles. - Explain how the cell cycle regulates the pre-replication and initiation complexes. - Predict the fate of different components of these complexes during replication. - Draw a replication bubble. -Explain why the ends of eukaryotic chromosomes shorten with each round of replication and how telomerase can prevent this.	GRQ 4	**MG (DNA replication)** **Submit answers to GRQ 4**	
T Sep 5	Well-being day			

R Sep 7 5. DNA Recombination and repair	- Describe examples of DNA damage from both endogenous and environmental sources. - Explain the mechanisms of DNA proofreading and of MMR. - Analyze research evidence and deduce the mechanism of NER.			
T Sep 12 6. DNA repair	- Demonstrate the contribution of recombination to genetic diversity. - Explain the molecular mechanisms of DNA recombination in meiosis and repair.	GRQ 6	**Submit answers to GRQ 6**	**Submit answers to GRQ 4b (a post-lecture assignment – telomeres)**
R Sep 14 7. DNA repair	- Predict the consequences of mutations in DNA repair genes. - Explain and describe the major components of the DNA damage response. - Demonstrate how p53 regulates cell cycle and program cell fate in response to DNA damage.			**PeerWise- DNA structure and replication**
T Sep 19 8. Gene expression- Transcription	- Describe the central dogma. - Identify trans- and cis- acting components in transcription.	GRQ 8	**MG (RNA); MG (Promoter)** **Submit answers to GRQ 8**	
R Sep 21 Exam 1	Covering lectures 1-7			
T Sep 26 9. Gene expression- The making of a transcript	- Describe the events taking place during transcription. -Predict which strand would be transcribed by RNA polymerase. - Predict the functions of cis and trans elements in regulating alternative splicing. - Synthesize and summarize the mechanisms and outcomes of RNA processing.	GRQ 9	**MG (The making of a transcript)** **Submit answers to GRQ 9**	
R Sep 28 10. Gene expression- Translation	- Introduction to PeerWise. - Describe the events that take place during translation. - Explain how tRNA molecules function as interpreters of the language of RNA to protein.	GRQ 10	**MG (Translation)** **Submit answers to GRQ 10**	
T Oct 3 11. The nature of the genetic code	- Characterize the nature of the genetic code. - Identify ORFs in mRNA sequences and DNA sequences and translate the ORFs. - Explain how the code was deciphered.	GRQ 11	**Submit answers to GRQ 11**	
R Oct 5 12. Regulation of gene expression- the Lac operon	- Describe bacterial conjugation and predict outcomes of conjugation between different strains. - List the various ways that gene expression can be regulated. - Describe how lactose induces the expression of the lac operon.	GRQ 12	**MG (Regulation of gene expression I)** **Submit answers to GRQ 12**	

T Oct 10 13. Regulation of gene expression- analyzing mutants	- Predict genotypes and phenotypes of mutants using the PaJaMo conjugation experiments. - Identify cis/trans elements and dominant/recessive allele based on the real PaJaMo results.			**ORF assignment** **Deciphering the code assignment** **PeerWise- gene expression**
R Oct 12 14. Regulation of gene expression I- Transcriptional level ***(Asynchronous lecture)***	- Compare and contrast transcriptional regulation in prokaryotes and eukaryotes. - Name different levels of control of gene expression in eukaryotes. - Explain how tissues can express different genes from the same genome. - Predict what will happen when enhancers and genes are recombined in different ways.	GRQ 14	**Submit answers to GRQ 14** **MG (Regulation of gene expression in Eukaryotes)**	**MG (Review- Gene expression I)** **MG (Review- Gene expression II)** Optional- MG practice- Regulation in Prokaryotes Optional- MG gene expression quiz (timed with one chance to answer) *** all can be submitted by 10/17**
T Oct 17 Exam 2	Covering lectures 8-13			
R Oct 19	Fall Break			
T Oct 24 15. Regulation of gene expression II- Epigenetics	- Define epigenetics and explain how epigenetic mechanisms regulate transcription. - Explain genomic imprinting and predict outcomes of mutations in imprinted genes. - Discuss the effects of the environment on the epigenome.	GRQ 15	**Submit answers to GRQ 15**	
R Oct 26 16. Regulation of gene expression III- Alternative splicing and miRNAs	- Explain the role of alternative splicing in gene regulation, and how it is regulated. - Predict the factors that confer tissue-specific alternative splicing. - Explain the functions of miRNA in regulation. - Distinguish between properties that affect translation and those that affect mRNA stability. - Compare and contrast miRNAs and dsRNAs.	GRQ 16	**Submit answers to GRQ 16** **MG (Small RNAs mediate regulation)**	
T Oct 31 17. Developmental Genetics	- Distinguish between forward and reverse genetics. - Design molecular constructs to identify gene expression at the tissue and the cellular levels.			**Journal club 1-** Queen vs. Worker honeybees- role of nutrition and epigenetics

R Nov 2 18. Recombinant DNA Technology I-Cloning a gene	-Explain how to isolate a gene that you want to clone. - Describe the steps of inserting a gene into a plasmid and determining if you were successful. - Summarize the steps of cloning. - Design a vector that will allow you to express a human gene in bacteria.	GRQ 18	**Submit answers to GRQ 18** **MG (Recombinant DNA technology)**	**MG (Review-Regulation of gene expression)** **PeerWise-Epigenetics**
T Nov 7 19. Recombinant DNA Technology II- CRISPR	- Outline the CRISPR-Cas9 system and explain the essential role played by each contributing part. - Explain how homologous recombination (HR) and nonhomologous end joining (NHEJ) have a role in CRIPSR.			**Journal club 2-** Queen vs.Worker honeybees- role of nutrition and epigenetics
R Nov 9 20. Catch up				
T Nov 14 Exam 3	Covering lectures 14-20			
R Nov 16 21. Transmission Genetics I	- Set up two and three gene crosses and determine the phenotypes and genotypes of the offspring. - Predict the genotypes of the parents based on the phenotypes of the offspring of dihybrid crosses. - Compare transmission of genes that independently assort vs. genes that are linked. - Calculate map distances between two genes from dihybrid x tester crosses.	GRQ 21	**Submit answers to GRQ 21** **MG (Transmission genetics)**	
T Nov 21 22. Transmission Genetics II	- Predict outcomes of crosses involving modifications of Mendelian ratios. - Analyze gene interactions. - Contrast variable expressivity and incomplete penetrance. - Explain how X-chromosome inactivation leads to mosaicism.	GRQ 22	**Submit answers to GRQ 22** **MG (Gene interactions)**	**Journal club 3** Queen vs.Worker honeybees- role of nutrition and epigenetics
R Nov 23	Thanksgiving Break			
T Nov 28 23. Transmission Genetics- Alleles and mutations 24a. Genomics	- Explain the molecular basis for dominant and recessive alleles. - Compare and contrast different loss-of-function and gain of function mutations. - Predict the effects of mutations on RNA structure function and/or protein structure and function. - Predict the location and decipher the sequence of an unknown gene. - Distinguish between genetic and physical maps.	GRQ 23	**Submit answers to GRQ 23**	
R Nov 30 24b. Genomics	- Describe the main outcomes of the Human Genome project. - Explain the whole genome sequencing approach. - Describe features of the genome, including genome architecture. - Describe metagenomics - what it can tell us about microbes in the environment and our own microbiome.			

T Dec 5 25. Genomics	- Explain how genome-wide association studies (GWAS) can be used to associate specific genetic variations with particular diseases. - Explain how genomic analysis can promote personalized medicine (case study in cancer).	GRQ 25	**Submit answers to GRQ 25**	**PeerWise- Transmission genetics**
Final Exam	Cumulative final exam			

Molecular Genetics Learning Outcomes- **Concepts**

- 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.
- Describe in detail the process of DNA replication and how it is regulated by the cell cycle.
- Demonstrate how recombination is a major contributor to genetic diversity and technology.
- Describe DNA repair mechanisms and explain how the DNA damage response regulates the cell cycle and cellular fate.
- Explain the flow of genetic information, based on the central dogma- from DNA to proteins.
- Predict how a mutation might affect RNA structure, RNA translation, protein structure, protein function in different biological settings.
- Explain how mutations increase genetic diversity.
- Describe how ribonucleoproteins function during replication, transcription, translation and DNA repair.
- Explain how a gene can be regulated transcriptionally and post-transcriptionally and how this leads to differential expression under different conditions (such as in different environments, during the course of development, or disease conditions) in both prokaryotes and eukaryotes.
- Describe how the epigenome is impacted by the environment and predict how epigenetic marks affect gene expression and phenotypic traits. Discuss how the epigenome is inherited from a cell to its daughter cells and and the current research on transgenerational epigenetic inheritance
- Predict the outcome of experimental manipulations of genes (e.g. GFP-tagging to investigate gene expression in different tissues).
-Explain how the concepts of polygenic inheritance, pleiotropy, and epistasis can complicate patterns of expected phenotypes.
- Explain the utility of research in genetic model organisms to understand fundamental biological phenomena (e.g. developmental processes, PCD); distinguish between forward and reverse genetic approaches to pursue such research.
- Explain the difference between genetic and physical maps and how such maps serve as the scaffold for genome sequence assembly.
- Relate population genetics to medical genetics.
- Analyze genomic datasets using modern Genomic tools.
- Explain how genomic analysis can promote personalized medicine.
- Discuss complex ethical issues with regards to personalized medicine and analyzing an individual's genome.
- Design a genetic screen to identify mutants and isolate genes (e.g. involved in programmed cell death).
- Decipher a signaling pathway through epistasis analysis of mutants found in your screen.
- Describe the basic steps in gene cloning (restriction, ligation, etc.).
- Design a transgenic animal or bacterial strain, where a protein of interest is specifically produced.
- Demonstrate how genetic information can be exchanged or "shuffled" via recombination.
- Demonstrate how to inactivate a gene by insertional mutagenesis (e.g. a transposon) or via indel creation using CRISPR.
- Predict how large-scale chromosome rearrangements (e.g. translocations) can alter gene expression.

- Identify bioethical concerns and key stakeholders for gene editing, articulating the main arguments both for and against use in humans.

Molecular Genetics Learning Outcomes- **Competencies**

Molecular Genetics Vision and Core Competencies and Sub-competencies

1. Ability to apply the process of science:
   - Evaluate data presented in primary literature
   - Generate narrative summaries if given a primary data figure and associated legend
   - Articulate the main research question(s) and hypotheses being tested being tested in a paper / or figure
   - Design an experiment to clone and express a gene of interest

2. Ability to use quantitative reasoning:
   - Compare different metrics for calculating evolutionary time based on mutation rate
   - Calculate probabilities associated with genetic crosses (using specific scenarios or population-level data)
   - Complete a statistical analysis of an experimental data set to evaluate an hypothesis

3. Ability to communicate and collaborate with other disciplines:
   - Articulate the use and value of genomic techniques to diverse disciplines including forensics, philosophy, ethics, cancer, evolution, anthropology, and medicine
   - Relate course topics to diverse disciplines including forensics, philosophy, ethics, cancer, evolution, anthropology, and medicine
   - Identify diverse careers related to the fields of genetics and molecular biology

4. Ability to explore the relationship between science and society:
   - Identify key stakeholders and their chief concerns in issues of reproductive medicine, genetic engineering, forensic genetics, etc.
   - Develop ability to hold competing ethical views at the same time, and articulate their respective values

5. Ability explain how genomic technologies inform our knowledge of genetics and molecular biology:
   - Ability to visualize large data sets and interpret genomic data
   - Explain how genomic techniques facilitate unique insights (e.g. single cell approaches reveal many more cell types than can be discerned with traditional approaches; metagenomics reveals species we did not know existed, comparative genomics reveals mechanisms of evolution (e.g. horizontal gene transfer)).

As part of the General Education curriculum, Biology 220 will enable you to learn how to make and interpret scientific descriptions and explanations of the natural world, practice the skills of scientific inquiry, and evaluate scientific evidence within the contexts of both scientific communities and society.

Questions to consider as a student

1. What rules govern the natural world and how are they discovered, tested, and validated?
2. What is distinctive about the approach to understanding employed in the natural sciences?
3. What challenges are encountered in making measurements of the natural world?

4. What are the limits of investigation in the natural sciences?

General Education Natural Scientific Investigation Learning Outcomes

1. Demonstrate the ability to use scientific knowledge, logic, and imagination to construct and justify scientific claims about phenomena, including validation through rigorous empirical testing.
2. Analyze and apply processes of natural scientific inquiry as dictated by the phenomena and questions at hand. These include generating and testing hypotheses or theories; using logic and creativity to design investigations to test these hypotheses; collecting and interpreting data; making inferences that respect measurement error; building and justifying arguments and explanations; communicating and defending conclusions; revising arguments and conclusions based on new evidence and/or feedback from peers; and synthesizing new knowledge into broader scientific understanding.
3. Evaluate science-related claims and information from popular and/or peer-reviewed sources by examining the relationship between the evidence, arguments, and conclusions presented and by assessing consistency with existing knowledge from valid and reliable scientific sources.
4. Identify, assess, and make informed decisions about ethical issues at the intersections of the sciences and society.

Students will encounter capacities in gen ed class to reinforce specific ideas and skills:

Pose problems and questions that require systematic thinking about evidence, argument and uncertainty. In Biology 252, you will have multiple opportunities to examine evidence from data from real experiments and published papers. You will find uncertainty in data interpretation, as well as scientific debates in various fields of physiology (e.g. nutrition recommendations with regards to the digestive system). We will address competing hypotheses at times, and we will evaluate the strength of evidence that support those hypotheses.

Consider its content in the context of human difference between and within societies; the full range of legitimate debate in its field; and/or change over time. In Biology 252 we will investigate differences and similarities between individuals and between communities, as our physiology is affected by both genetic and environmental factors that vary among those groups. For example, we will discuss how genetic as well as socio-economic backgrounds affects the risks and the pathophysiology of diabetes type 2. As mentioned above, we will address debates in different physiology-related fields (e.g. effects of different nutritional approaches on the digestive and the cardiovascular systems) and evaluate the scientific evidence that supports those approaches.

Writing totaling at least 10 pages in length, or the intellectual equivalent. We will not have one long assignment, but a variety of short writing assignments in class and beyond, as well as daily writing assignments based on reading comprehension (guided reading questions). Many of these will be graded for completion and some will be graded for quality.

Presenting material to the class, small groups, or the public through oral presentations, webpages, or other means that enable corroboration of fact and argument. We will not have one large presentation, but a variety of daily assignments to present your ideas to classmates in small group discussions and to the larger class in lecture.

Collaborating in pairs or groups to learn, design, solve, create, build, research or similar. Throughout the semester you will work with your peers in groups or pairs to address challenging questions that will be presented to you during the class meetings. In addition, throughout the semester you will use an online tool called PeerWise to create and solve practice problems, as well as to evaluate and provide feedback to your peers.