BICD 156 – Population Genetics

Fall Quarter 2021
Syllabus

Basic Course Information

Course website: https://canvas.ucsd.edu/courses/29297 – check in several times a week
Instructor: Sergey Kryazhimskiy <skryazhi@ucsd.edu>

Instructional Assistant (IA): Huanyu Kuo <hukuo@ucsd.edu>

Instructor's Office: Muir Biology Building, #2205

Office Hours: By appointment (in person or by Zoom)

Lectures and Discussion sections:

Lecture	Day	Time	Location
A00	Monday Wednesday Friday	4:00 PM to 4:50 PM	MANDE B-150

Discussion sections are an important and required part of the course. You will be graded on your participation in the discussion sections. Sections will be devoted to solving homework problems, answering your questions, and otherwise discussing the material.

Section	Day	Time	Location
A01	Monday	8:00 AM to 8:50 AM	CENTR 217A
A02	Friday	2:00 PM to 2:50 PM	CENTR 217B

COVID Provisions

- Do NOT come to class if you tested positive for COVID in the last two weeks.
- Podcasts, lecture slides and other materials will be available online, so that you can continue learning during isolation/quarantine.
- Masks are required at all times in lectures and sections.
- If you are isolating or in quarantine, notify the instructor.
- If you are isolating or in quarantine and about to miss a quiz, midterm or final, reach out to the instructor by email and make an alternate Zoom arrangement BEFORE the said quiz, midterm or final.

- If the instructor must isolate or quarantine, all lectures will be moved online for the duration of the isolation/quarantine.

Course Description

How do natural selection, mutation, migration and genetic drift drive evolution? You will learn how these forces operate and how to describe them quantitatively with simple mathematical models. We will discuss how to apply this knowledge to understand the spread of drug resistance in pathogens, the evolution of beneficial as well as disease traits in our own species, the evolution of engineered organisms and more.

Learning Outcomes

In this course, you will learn how and why genetic composition of populations changes over time, and what practical implications these changes can have. By the end of the course, you will be able to:

- Give examples of currently on-going evolutionary changes in various biological systems.
- Explain what genetic variation is, why it is important, how it can be measured, where it comes from and how it changes over time.
- Explain how models are different from reality and why we need models to understand nature.
- Describe models that we use to understand the evolutionary processes in populations, and explain why certain models are used in certain situations.
- List the forces that determine the dynamics of allele frequencies in a population and explain how these forces affect the dynamics.
- Write down a simple mathematical model of an exponentially growing population and analyze it.
- Write down a simple mathematical model of a competition between two genotypes in a population and analyze it.
- List and explain the sources of randomness in evolution. Write down an expression for the probability of fixation an allele in a population, and analyze it.
- Make basic population genetic calculations and estimates. For example, calculate the expected number of mutations that will arise in a population, or estimate the number of generations to the most recent common ancestor of a group of individuals.
- Give examples of the types of information one can extract from genetic data. Design a simple sampling and analysis procedure to obtain some of this information.
- Make basic inferences about population's evolutionary past from simple genealogical trees.

Course Prerequisites

1. BICD 100 (Genetics)
2. MATH 10A or MATH 20A

Population genetics is a quantitative discipline. To understand the material in this course, in addition to basic knowledge of genetics, you also need to have a working knowledge of calculus. We will review the key topics that will be necessary for this course, but please review this material before the start of the course.

Required Learning Materials

Short writing activities will be done in class and in discussion sections, so please bring paper, pens and/or pencils. Calculators are sometimes necessary.

Optional Learning Materials

Richard Halliburton. "*Introduction to population genetics*", 1st edition. Pearson Education Inc (ISBN 0-13-016380-5).

Daniel L. Hartl and Andrew G. Clark. "Principles of population genetics", Sinauer Associates, Inc (ISBN 0-13: 978-0-87893-308-2).

All the required material will be covered in class. However, reading textbooks will likely be very helpful. Halliburton is a basic introductory text, Hartl & Clark is more comprehensive. Textbooks will give you a sometimes different and/or wider perspective on some issues. It also has useful exercises similar to those that will be given on the exams.

Assessment

Item	Percent
Midterm 1	10%
Midterm 2	15%
Final exam	15–25% [a]
Homeworks	20 to 35% [a]
Group project and presentation	10%
Participation in class and discussion sections	5 to 15% [a]
Quizzes in class	5%
Extra credit	Up to 5%

[a] Assessments whose percentages are given as ranges can be to some degree substituted for each other, always to the student's advantage. For example, if you are doing very well on participation and homeworks, your final will have less weight. If you did not do very well on participation and homeworks, you will have a chance to recuperate some the lost points at the final. The point is that by the end of the course you should be able to demonstrate certain skills and knowledge in some form of assessment.

Midterms and final

Midterms will be written exams in class, during the regular lecture time. The final will be a hybrid take-home + oral exam.

COVID accommodation: Students who are isolating or under quarantine will be able to take a midterm or the final over Zoom on the same weeks as the in-class exam. Students need to make this arrangement with the instructor before the in-class exam takes place.

Homeworks

Homeworks are an essential element of the course. Homeworks will primarily consist of problem sets, but there may also be other assignments. Problems in the exams will be similar to those in the homeworks, but easier. So, if you do well on your homeworks, you will do really well on the exams. You will do well on the homeworks if you attend discussion sections and ask questions. If you have difficulties with homework problems, please talk to the instructor or IA.

Homeworks will be due in class as specified in the Lecture Plan (see below), unless instructed otherwise.

COVID accommodation: Those who are isolating or under quarantine will be allowed to turn in their homework assignments electronically.

Group Presentation

Two of the most valuable soft skills that you need to master to succeed in any future career are (i) working effectively in a team and (ii) presenting your work in a clear compelling way.

To sharpen these skills, everyone will participate in a team project resulting in a presentation. The goal of the project is to read and understand a primary research paper about evolution and present it to the class. Each team will consist of 2-3 people. The total score for the presentation for each person will consist of two parts, the Quality Score (QS) and the Contribution Score (CS). The total score is calculated as $0.8 \times QS + 0.2 \times CS$. All team members will receive the same QS based on the assessment of the quality of the presentation by the instructor. CS will be determined by each individual's contribution to the team.

Participation

You will have many opportunities to interact with the instructor. Please use them. The instructor will ask questions during class and you can ask your own questions. Please do not hesitate to ask questions to clarify whatever is unclear to you. If something is unclear to you, chances are it is unclear to other students too. Thus, your questions will help you and your fellow students. Your questions will also help the instructor to teach more effectively. Testing your individual knowledge is NOT the purpose of these interactions. Thus, it is always better to say something wrong than to say nothing.

In the Discussion sections, you will work with the instructor and the IA on problem sets. The instructor or IA will ask each of you to come to the board and solve problems. Again, the purpose of these activities is not to test your knowledge, but to help you learn.

Here is how the participation point (PP) system works:

1. Each PP is worth 1% of your final grade.
2. You can earn up to 3 PPs per week.
3. To get 100% on your final grade you, will need to earn at least 5 PPs. Since there are 20 opportunities to earn PPs, the expectation is that each student earns at least 5 PPs.
4. You can earn a maximum of 10 PPs during the entire course.
5. What earns you a PP is inherently somewhat informal, but here is a rough guide:
   a. Work on the blackboard during class or discussion section will automatically earn you a PP. Whether you succeed in solving the problem at hand is irrelevant.
   b. Participating in team exercises during lectures or discussion sections automatically earns you a PP.
   c. Answer instructor's questions during lectures or discussion sections will usually earn you a PP. However, not all questions and not all answers will have the same value. For example, if you make a serious attempt to answer a difficult question, you will get one PP. But you might need to answer multiple smaller questions to earn one PP. Your answer does not have to be correct, but it needs to make sense. Nonsensical answers will not earn PPs.
   d. Asking a substantive and/or insightful question on the topic of the lecture can earn you a PP. This is something that may occasionally happen, but it is NOT a default mechanism of earning PPs.
6. Activities that will NOT earn you PPs (but you should still do them):
   a. Being present at lectures
   b. Being present at discussion sections
   c. Asking clarifying or tangential questions during lecture
   d. Asking questions about problem sets
   e. Working through problem on the board and/or paper when meeting one-on-one with the instructor and/or IA
   f. Any interaction with the instructor at times other than lectures or discussion sections

COVID accommodation: Depending on the number of students who are isolating or under quarantine at any given time, one of the discussion sections may be moved to Zoom.

Quizzes

We will have a 5-minute quiz in class on Mondays. Please, bring a pen/pencil and a calculator. Quizzes are designed for the instructor to gauge how you absorb the material, NOT to test your knowledge. Quizzes should be easy. If you feel that you do

not know how to solve the problem on the quiz, talk to the instructor or the IA. Midterm and the final will most certainly have problems that are analogous to those in quizzes.

Each quiz will be between 5 and 7 points worth, of which 1 point will be given for merely writing your name on the paper.

COVID accommodation: The instructor will arrange quizzes over zoom (typically, on Monday right after the lecture) for those who are isolating or under quarantine.

Extra credit

A number of extra credit (bonus) assignments will be given throughout the course. Bonus problems/assignments will be more difficult than usual. However, each bonus point will be equal to 1% of your final grade. You can earn at most 5 bonus points.

Other Course Policies

- COVID accommodations are discussed above in relevant sections.
- Late turn-ins will generally not be accepted.
- Make-ups. There will generally be no make-ups. Extraordinary circumstances will be considered on a case by case basis. If you have such an emergency, inform the instructor as soon as possible. No midterm make-ups will be possible after the graded exams and answer keys have been returned.
- Teamwork Policy. You are encouraged to work together with other students on homeworks and take-home exams, or you can consult with the IAs or the instructor, if you have questions. However, you must write the final answers by yourself based on your own understanding, without consulting with other students. Thus, no two handed-in homeworks/exams should ever be exactly identical.
- Academic Conduct Policy. Compliance with the general academic conduct policy is expected at all times. Visit the Office of Academic Integrity (OAI) for more information.

Lecture plan

Check Canvas for the current lecture plan.

Instructor Goals

At a minimum, I hope to pursue the following goals and solicit your open and timely feedback on how well we are meeting these goals:

- Communicate effectively and frequently;
- Be an enthusiastic, active and involved;
- Demonstrate a mastery of the discipline;
- Relate material to current practices;
- Clearly explain complex concepts and ideas;
- Provide a framework for lifelong learning;
- Strive to involve participant in class activities;
- Be available to assist participants in or out of class; and

- Have respect and concern for all participants.

To provide your feedback, you can either talk to the instructor in person during office hours, or relay your feedback through your IA (anonymously, if you wish).

W	DATE	WD	L #	MODULE	TOPICS	QUIZ	WHAT'S DUE?	NOTES
0	24-Sep-21	F	1	Module 1. Introduction	What is population genetics? Why is it useful?			
1	27-Sep-21	M	2	Module 1. Introduction	Allele and genotype frequencies			
1	29-Sep-21	W	3	Module 1. Introduction	The five forces of evolution		HW 0	
1	1-Oct-21	F	4	Module 1. Introduction	Reality versus models			
2	4-Oct-21	M	5	Module 2. Exponential growth	Model with discrete generations	Quiz 1: Basic concepts of population genetics		
2	6-Oct-21	W	6	Module 2. Exponential growth	Model with overlapping generations		HW 1	
2	8-Oct-21	F	7	Module 2. Exponential growth	Inference and prediction			
3	11-Oct-21	M	8	Module 3. Natural selection in asexual populations	Competition between two types. Selection coefficient	Quiz 2: Exponential growth		
3	13-Oct-21	W	9	Module 3. Natural selection in asexual populations	Logistic equation. Phase plane analysis		HW 2	
3	15-Oct-21	F	10	Module 3. Natural selection in asexual populations	Phase plane analysis (continued). Fixation			
4	18-Oct-21	M	11	Module 3. Natural selection in asexual populations	Competition between many types. Clonal interference			
4	20-Oct-21	W	–	MIDTERM 1 (IN CLASS)			HW 3	
4	22-Oct-21	F	12	Module 4. Single-locus population genetics in sexual populations	Hardy-Weinberg equilibrium			
5	25-Oct-21	M	13	Module 4. Single-locus population genetics in sexual populations	Natural selection	Quiz 3: Hardy-Weinberg equilibrium		
5	27-Oct-21	W	14	Module 4. Single-locus population genetics in sexual populations	Hardy-Weinberg quasi-equilibrium		HW 4	
5	29-Oct-21	F	15	Module 4. Single-locus population genetics in sexual populations	Co-dominance, overdominance and underdominance		Self-organize into teams	
6	1-Nov-21	M	16	Module 5. New mutations	Introduction to new mutations	Quiz 4: Single-locus pop. gen. in sexual populations		
6	3-Nov-21	W	17	Module 5. New mutations	Modeling new mutations		HW 5	
6	5-Nov-21	F	18	Module 5. New mutations	Modeling new mutations (continued)		Select paper for presentation	
7	8-Nov-21	M	19	Module 5. New mutations	Measuring mutation rates	Quiz 5: New mutations		
7	10-Nov-21	W	20	Module 5. New mutations	Drug resistance in HIV. Mutation-selection balance		HW 6	
7	12-Nov-21	F	–	MIDTERM 2 (IN CLASS)				
8	15-Nov-21	M	21	Module 6. Genetic drift	Key concepts			
8	17-Nov-21	W	22	Module 6. Genetic drift	Wright-Fisher model			
8	19-Nov-21	F	23	Module 6. Genetic drift	Decay of heterozygosity. Time-scale of genetic drift			
9	22-Nov-21	M	24	Module 6. Genetic drift	Genetic drift and natural selection. Fixation probability	Quiz 6: Genetic drift	HW 7	
9	24-Nov-21	W	25	Module 7. Molecular evolution	Molecular clock. Muller's ratchet. Dating past events using molecular clock.			
9	26-Nov-21	F	–	NO CLASS: THANKSGIVING			Submit video (by midnight)	
10	29-Nov-21	M	26	Module 7. Molecular evolution	Inferring ancestry from genomic data			
10	1-Dec-21	W	27	Module 7. Molecular evolution	Hitchkinking. Signatures of natural selection in genomic data: linkage disequilibrium, dN/dS.			
10	3-Dec-21	F	28	Module 8. Applications of population genetics	Applications of population genetics	Quiz 7: Molecular evolution		
	7-Dec-21	Tu		FINAL EXAM				
					Clonal interference and the Fisher-Muller hypothesis for the advantage of sexual reproduction			