BSC 4445C: Special Topics
Genomics Lab: Methods in Data Collection and Analysis
Fall 2017 (Forsman)
4 credits

Course Description

The field of genomics focuses on understanding the collective function of all components encoded in an organism's genomic blueprint. Over the past decade, there has been an explosion of new and cost-effective methodologies to sequence the genetic material of life. Originally, high-throughput sequencing was slow, costly, and was used only to sequence the genomes of model organisms. Today genome-scale datasets are essential to most molecular biology applications in any taxonomic group, including phylogenetics and population genetics, metagenomic and targeted amplicon sequencing of entire biological communities, functional genomics of the expressed portion of the genome, and whole-genome assembly and characterization of an organism's complete biological code. An integral, related, and emerging field of study is bioinformatics, which focuses on developing computational tools to analyze these massively large sequence data sets. In this class, we take a hands-on approach to understanding (1) how genomic datasets are generated in the lab, and (2) how they are analyzed computationally using bioinformatics pipelines. We begin, in both lecture and lab, with the fundamental biochemistry of DNA and the tools biologists have developed to isolate and manipulate genomic elements. We then scale up to address the "Next Generation" Sequencing (NGS) revolution, including how and why new methodologies have made genome-scale analyses achievable for nearly any organism, and the detailed methodologies and skills necessary to prepare samples for whole-genome, whole-transcriptome, and whole-community metabarcode sequencing. We spend the second half of the course learning about and utilizing bioinformatics pipelines to manipulate and analyze the sequencing datasets we have generated. Imparting a working knowledge of practical methods for generating and analyzing genomic datasets is the fundamental goal of this course. By generating, analyzing, and presenting (in both written and oral formats) novel genomic data, students will hone their writing, critical thinking, and problem solving skills. The importance of genomics for all facets of the life sciences will be emphasized, particularly the impacts of genomic datasets on recent advances in phylogenetics, evolutionary ecology, epigenetics, functional genomics, health and medicine.

Course Objectives

- To understand the molecular biology behind existing methods for isolating, manipulating, and sequencing DNA and RNA
- To understand the NGS revolution and the computational demands of modern molecular analyses
- To understand the types of research and analyses that fall under the umbrella of genomics, including data generation, manipulation, and bioinformatics
- To become a skilled molecular biologist capable of maintaining a laboratory notebook and successfully performing core molecular protocols, including:
    - purifying nucleic acids
    - quantifying nucleic acids
    - DNA amplification
    - quantitative DNA amplification

  - gel electrophoresis
  - cDNA library construction
  - library preparation for NGS of whole bacterial genomes, whole transcriptomes (RNAseq), and 16S gene transcripts for gene targeted characterization of microbial communities (i.e., metabarcoding)
- To learn how to manipulate genome-scale datasets using established bioinformatics pipelines for whole genome assembly, whole transcriptome assembly, and metabarcode community characterization
- To gain analytical, writing, and scientific communication skills by writing and presenting results from semester-long group projects

Prerequisites

A grade of B or better in undergraduate genetics or consent of the instructor. Completion of EHS Lab Safety Training online course and practical by end of add/drop period, Friday, August 25, 2017 (mandatory).

Class Meetings: M/W 12:00 – 2:50

Lecture: 60 minutes at the start of class on Mondays and occasionally on Wednesdays

Lab: remainder of session on Mondays and Wednesdays

The lab will also be open throughout the week for students to complete protocols or re-do failed samples, during which time the instructor and/or TA's will be present to answer questions and provide guidance. Please arrange for this in advance.

Lecture Instructor: Dr. Anna M. Forsman

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Office Hours: Wednesdays 10:00am – noon and by appointment.

Teaching Assistants

Michael Haney
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Teaching assistants will maintain lab and reagents for students in the course and will help with lab procedures during class. They will also be available for questions, troubleshooting, and help with protocols outside of class hours by appointment.

If you would like to schedule a meeting or labtime outside of class hours, please do so in advance by email to ensure that someone is available to help you during that particular time. This will avoid you having to wait for assistance if Dr. Forsman or the TA's are in meetings or working with other students.

Webcourses Site

There is a course web site available through Webcourses (https://webcourses.ucf.edu), which will be used to post materials for the course, including the syllabus, assignment due dates, lecture presentations, and grades.

Required Text

No text is required. We will provide all of the reading materials you will need to prepare for assessments. Students will be responsible for identifying articles from the primary literature to support the final research report and oral presentation.

Class Policies

1. Attendance is not strictly required but will contribute to each student's participation grade. A large portion of the grading for this hands-on methodology course will be based on lab participation, and success in this class requires completion of lab procedures. It is the student's responsibility to arrange to make up any missed work outside of class hours.
2. Quiz and lab make ups will not be given without valid documentation that is presented prior to the absence or within 24 hours of the missed lab or quiz.
3. Assigned readings should be completed before attending class and will be provided via webcourses or handed out in class.
4. You are encouraged to discuss any and all portions of the class with me. Please feel free to come to my office hours or make an appointment to discuss the class, especially if you are having trouble.
5. Respect should be given to fellow students, the TA's, and the instructor. Please do not arrive late to class or lab or leave early.
6. Hateful or offensive speech or writing will not be tolerated.
7. Cell phones, iPods, and other electronic devices should be silenced and put away before class starts.
8. Academic dishonesty (cheating and plagiarism) is strictly prohibited and will be taken very seriously and will result at least in an "F" for that assignment (and may, depending on the severity of the case, lead to an "F" for the entire course) and may be subject to appropriate referral to the Office of Student Conduct for further action. See the UCF Golden Rule for further information.

Course Accessibility

My goal for this class is to provide an accessible and welcoming experience for all students, including those with disabilities that may impact learning in this class. If anyone believes the design of this course poses barriers to effectively participating and/or demonstrating learning in this course, please meet with me to discuss reasonable options or adjustments. You may also contact SAS (Ferrell Commons 185; 407-823-2371; sas@ucf.edu) to talk about academic accommodations.

Grading

Grades will be assigned according to the following scale:
A: 90-100; B: 80-89; C: 70-79; D: 60-69; F: <60

The final grade for this course will be based on six components:

Assignment	**% of final grade**
Week 1 attendance assignment	1%
Quizzes (4)	20%
Participation	30%
Lab notebook	15%
Project outline	2%
Rough draft – final report	4%
Final report	15%
Practice oral presentation	3%
Final Oral Presentation	10%

(1) Week one attendance assignment on Webcourses to determine work groups (**1%**)

(2) Four semester **quizzes** will be given in class on the dates indicated on the schedule (5% each; **20% total**). They will consist of multiple choice, short answer, and essay questions based on lecture material. The purpose of these quizzes is to challenge students to synthesize and apply their knowledge at a level that may be expected of independent student researchers and graduate students.

(3) Students will be graded on **lab participation** (**30% total**), including asking questions, performing protocols, and generating the necessary data for each week to move forward to the next lab session. Keep in mind that additional lab time outside of the scheduled class hours will be necessary to complete protocols for the majority of labs.

(4) The **lab notebook,** to be maintained by each group of three students working on a unique project, will be evaluated four times during the semester (**15% total**). During the first portion of the semester we will use a physical notebook that will be kept in the lab and during the second portion we will instead be using a virtual lab notebook, which will be submitted through webcourses. Students will be given feedback on how to improve their note taking and record keeping of all lab activities and results. The final lab notebook grade will be based on previous grades and improvement over the course of the semester. The lab notebook record keeper will rotate weekly among the three group members during the nine weeks of molecular lab, and each student will be graded individually on their own three entries.

(5) Each group will submit a semester project **outline** (2%) and **rough draft** (4%) of the final written report to ensure sufficient time for instructor feedback and peer-review.

(6) Each group will submit a **final written report** of their project in the format of a scientific journal article, including the following sections: Abstract, Introduction, Methods, Results (with figures/tables) and Discussion (**15%**; **each group receives one grade**).

(7) During the final exam period, each group will give a 15-minute **oral presentation** on their project, including projected slides showing methods and results. Each student will speak for 5 minutes and be graded individually (**10%**). We have found that students that practice their presentations with us and revise their PowerPoint after constructive feedback perform significantly better at their final presentation. Therefore, we recquire a practice presentation of all groups prior to the final exam period (**3%**).

Schedule:

The following schedule is approximate and dates may be changed at any time.

Week 1:
Lecture 1: Intro and overview of course, overview of 3 focal projects (metabarcoding, whole-genome sequencing, and RNAseq) and methods to be used
Molecular Lab 1: Keeping a lab notebook, lab safety and etiquette, pipetting training followed by serial dilution qPCR test to assess pipetting skill level.

Week 2:
Lecture 2: Basics of molecular biology; isolating and characterizing nucleic acids
Molecular Lab 2: DNA extractions (WGS and metabarcoding groups) or RNA extractions (RNAseq groups). Quantitative and qualitative analysis of DNA and using Take3 and Tapestation. First and second-strand cDNA synthesis for RNAseq groups.

Week 3 (Labor Day – no class Monday):
Lecture 3: Polymerase Chain Reaction (PCR) and Quantitative (q)PCR.
Molecular Lab 3: Continue DNA extractions (metabarcoding) and DNA shearing (RNAseq and WGS).

HURRICANE IRMA – WEEK 4 (NO CLASS)

Week5:
Lecture 4: Genomic and cDNA libraries. ***Quiz 1 (Wed).***
Molecular Lab 4: 16S library prep PCR reactions (metabarcoding) and shotgun library prep, including: dC-tailing, stubby adapter ligation, and bead-based cleanups (RNAseq and WGS).

Week 6:
Lecture 5: Overview of Sanger and next-generation sequencing
Molecular Lab 5: 16S library quantification using Picogreen assay, sample pooling (metabarcoding) and ligation of Nextera sequencing adapters using high-fidelity low-cycle PCR with Phusion taq and Kapa qPCR on serial dilutions of libraries to precisely quantify the amount of available material for sequencing (RNAseq and WGS).

Week 7:
Lecture 6: Overview of Next Generation Sequencing technologies
Molecular Lab 6: qPCR lab for disease prevalence (metabarcoding). Finish up library preps, sample pooling (RNAseq and WGS). ***Project outline due.***

Week 8:
Lecture 7: Overview of Illumina library prep. ***Quiz 2 (Wed)***
Molecular Lab 7: Complete any remaining labwork and submit sample pool to NGS core lab for sequencing.

Week 9:
Lecture 8: Genomic analysis 1: Quality control, NCBI, GenBank, and BLAST
Computer Lab 1: Intro to Geneious and gene identification using GenBank

Week 10:
Lecture 9: Genomic analyses 2: Bioinformatics overview
Computer Lab 2: basics of command line and perl; bioinformatics pipeline tutorials (QIIME, Trinity/Tuxedo, or Geneious whole-genome assembly, depending on project) using sample data.

Week 11:
Lecture 10: Whole genome assembly, genomes and genome browsers
Computer Lab 3: Manipulating Illumina data and Quality Control (QC) using Prinseq; start running pipeline on lab-generated data (students work in groups).

Week 12:
Lecture 12: Genome-scale analyses: RadSeq, SNPs and GWAS. ***Quiz 3 (Wed)***
Computer Lab 4: Continue running pipelines on lab-generated data; analyze results/generate summary statistics (students work in groups).

Week 13:
Lecture 13: Microarrays, transcriptomics, and RNAseq.
Computer Lab 5: Finish/troubleshoot lab-generated data analysis; finish analyzing results and work on tables, figures and reports (students work in groups).

Week 14:
Lecture 14: *Metagenomics and metabarcoding*
Computer Lab 6: Work on final report and presentation.
Rough draft of Final Report due (Wed)

Week 15:
Lecture 15: Presenting genomic data. ***Quiz 4 (Wed)***
Computer Lab 7: Work on figures, final report and final presentation.
Practice presentations due by the end of this week.

FINAL REPORT DUE on Friday, Dec.1.

Monday, Dec.4: **Final Exam: 1:00pm-3:50pm.** Group presentations of data analysis and results.

Schedule:

The following schedule is approximate and dates may be changed at any time.

Week	Date	Topic
1	21 Aug M	Course overview **Lecture** ~ lab project intro ~ Lab Notebooks ~ Pipetting **Lab 1a**
	23 Aug W	Group project assignments ~ Pipetting **Lab 1b** ~ qPCR pipetting assessment
2	28 Aug M	Molecular biology **Lecture** ~ DNA and RNA extractions **Lab 2**
	30 Aug W	DNA quantification/visualization w/ Take3/Tapestation ~ cDNA synthesis **Lab 3**
3	4 Sep M	**Labor Day – No Class**
	6 Sep W	PCR/qPCR **Lecture** ~ Continue extractions & DNA shearing **Lab 4**
4	11,13 Sep	**HURRICANE IRMA – UCF CLASSES CANCELED**
5	18 Sep M	Genomic and cDNA libraries **Lecture** ~ Begin shotgun & 16S library prep **Lab 5**
	20 Sep W	Shotgun & 16S library prep ***Quiz 1***
6	25 Sep M	Sequencing technologies I **Lecture** ~ Continue Illumina library prep as needed
	27 Sep W	Complete library prep, quantify libraries, equimolar pooling **Lab 6**
7	2 Oct M	Sequencing technologies II **Lecture** ~ Finalize libraries, qPCR (16S)
	4 Oct W	Finalize and submit libraries for sequencing. ***Project outline due.***
8	9 Oct M	Illumina library preparation overview **Lecture** ~ Finalize libraries
	11 Oct W	Finalize libraries. ***Quiz 2.***
9	16 Oct M	Analyzing sequence data and genetic databases **Lecture** ~ Geneious **Lab 7**
	18 Oct W	Complete Geneious Lab 7
10	23 Oct M	Bioinformatics overview **Lecture** ~ Basics of command line **Lab 8**
	25 Oct W	Bioinformatics pipeline tutorials **Lab 9**
11	30 Oct M	Genomes, genome browsers, SNPs & GWAS **Lecture** ~ Sequence QC **Lab 10**
	1 Nov W	Start group-specific bioinformatics pipelines with student data **Lab 11**
12	6 Nov M	Genome-scale analyses: Radseq & sequence capture **Lecture**
	8 Nov W	Group-specific analyses and bioinformatics ~ ***Quiz 3***
13	13 Nov M	Microarrays, transcriptomics and RNAseq **Lecture** ~ Data analyses
	15 Nov W	Group-specific analyses and bioinformatics
14	20 Nov M	Metagenomics and metabarcoding **Lecture** ~ Data analyses
	22 Nov W	Work on final report and PowerPoint presentation ~ ***Rough Draft Report Due!***
15	27 Nov M	Presenting genomic data **Lecture** ~ Complete analysis of project data
	29 Nov W	Work on final report and PowerPoint presentation ~ ***Quiz 4***
16		****FINAL REPORT DUE on Friday, Dec. 1****
	4 Dec M	**1:00pm-3:50pm **FINAL PRESENTATIONS****