Syllabus: HRT 841: Foundation in Computational Plant Sciences

Fall 2020, MW 3:00-4:20 pm, online, 3 credit hours

Instructors: Dr. Robert VanBuren and Dr. Dan Chitwood

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Office hours: Students are highly encouraged to schedule individual one-on-one and small group meetings with the instructors. Please email instructors to set-up an appointment. Additionally, the instructors will always be available for an hour after the normally scheduled class period, if needed.

Course description:

This course will bring together plant biologists and computational/data scientists to address grand challenges in plant biology. This project-based course will teach fundamental concepts in plant science through a computational lens. The first half of the course will consist of a mix of lectures and thought experiments and hands-on activities in Python implemented in Jupyter notebooks. Students will learn basic programming concepts implemented using cutting edge datasets and computational approaches. In the second half of the course, students will download previously published data and conduct a bioinformatics class project implementing the computational and data science skills they have learned. Results from the project will be written up as a manuscript, the goal of which is to submit to a research journal with students as authors. Foundation in Computational Plant Sciences is open to graduate students in any program and no prerequisite experience in coding or computational biology is required. Foundation in Computational Plant Sciences is the first course in the NSF-IMPACTS series training program. This course will be taught using a flipped classroom approach.

Course goals:

The course will synthesize concepts from computational and data science with plant biology principles. The goals for this course are for students to:

(1) acquire foundational knowledge and skill sets in plant biology and data science

(2) formulate hypothesis-driven questions stemming from grand challenges at the interface of plant biology and data sciences

(3) synthesize the acquired skills to solve questions in collaborative teams

(4) communicate persuasively across disciplines with peers and the public

By the end of the course, students will be able to identify and create strategies to address current problems in plant biology using cutting edge computational tools and approaches. Through interactive lectures and 'thought experiments' students will learn to communicate across disciplines to explore emergent biological processes.

Course Format:

We will be using Discord for lectures and small group meetings. Discord allows a record of chats and links to resources for each lecture to be recorded and accessible at later dates. Breakout rooms can be created and students and instructors can freely move between them and small groups can spontaneously video chat if they want to. An invitation link will be sent to you by the instructors to join the Discord server for the class. Using Discord does not preclude the use of Zoom or other messaging and video chat platforms, especially if small groups or individuals prefer to meet using other platforms outside of class. The platform used is flexible, and if the class prefers a different one, it can be used as well. Please give the instructors feedback on your preferences about online platforms and class structure: we are here for you!

Assessment and grading:

Graded assignments include a midterm and end of the semester project as well as weekly attendance, participation, and completion of the Jupyter notebooks. The breakdown is as follows:

50% Attendance, participation, and completion of the in-class Jupyter notebooks and weekly summaries

- 12.5% Attendance
- 12.5% Participation
- 25% Assignments: in-class Jupyter notebooks and weekly summaries

25% Midterm project

25% Final project

Attendance/Participation: Because this course will be offered online, it is vital that you attend the online lectures. Attendance will be taken promptly when the class starts at 3pm ET on Monday and Wednesday and is part of your grade. The class format is flipped, meaning that through Jupyter notebooks and online videos, lectures are viewed at home. In class, the instructors will begin with a small lecture and review, but most of the class will be in small groups performing activities. Groups will report back at the end of class and present results. Participation is graded by contributing to group activities and group reports at the end of class.

Assignments: For the first half of the class, Python coding and bioinformatics will be taught using Jupyter notebooks. There is a notebook for each lecture. You are expected to read through each notebook before each class. If there are video tutorials in the notebook, you are expècted to watch them before coming to class. There are in-class activities within each notebook. At the end of class, after reporting

group results, each individual is expected to turn in a notebook. You will be graded by turning in the notebook and completing it, yourself. Even though working in a group, students found copying and pasting code, rather than working on their own notebook together with their group, will be given zeros for the notebook. Grading is solely based on an honest attempt by a student to complete the notebook with their group. Students are expected to heavily comment on their code and the instructors will go over each notebook and provide feedback. In the second half of the course, students will be working in groups on the class project. Students are expected to 1) give weekly one slide summaries of progress to the class for feedback and discussion and 2) turn in weekly Jupyter notebooks with their coding progress. Grading for assignments in the second half of the course is based on participating in the above activities.

Midterm/Final project: You will be working on a class project this semester where you put to use the coding and computational skills you learn during the first part of the course. Hopefully, the project will result in a research manuscript authored by students (see the manuscript from the previous year's course: https://doi.org/10.1101/2020.06.22.163899). The project will have two parts: 1) a plan, composed by students with specific aims, objectives, and deadlines for completing analyses and work and 2) the final product, a draft manuscript with results written up and the conclusions presented, as well as documented code and data for others to reproduce the work. The manuscript will be submitted to a research journal the semester after the course. The midterm will be a presentation and submission of the project plan for the rest of the semester and the final the presentation and submission of the project results.

This year, the class project will be a meta-analysis of previously published RNAseq data across plant evolution and development. Some major elements of the class project below, but we will discuss in more detail later in the class:

- Download RNAseq samples that have identifiable 1) species and 2) tissue information, and 3) possibly environmental stress
- Decide as a class the scope of what is analyzed. Which taxa? Which tissues? Which stresses? How many samples?
- Map reads back to the original genome sequence and calculate expression levels
- Group transcripts into orthogroups for comparison across plant evolution
- Perform clustering, dimension reduction, manifold learning techniques on data
- Build networks based on 1) phylogenetic relationships, 2) developmental tissues, and 3) possibly environmental stress and devise a measurement of network statistics to see how the network changes in each condition
- Build prediction models based on the above three conditions to see if evolutionary, developmental, and environmental attributes of an RNaseq sample can be predicted from gene expression levels

Communication: This class is taking place under unprecedented circumstances of a pandemic and online education. The above grading policies on attendance, participation, and assignments will be strictly enforced. However, because of the exceptional circumstances, without question students only need to communicate to the instructors that they will miss an online class period or need an extension on turning in an assignment and the request will be granted. The class is flexible and accommodating to

students, but it ***requires communication with the instructors BEFORE the student will miss a class or turn in an assignment late*.**

Grade Point Assignment (Grading Scale)

The table below describes the relationships between letter grades, percent, and performance. The first column describes the letter grade. The second column describes the percentage associated with that letter grade. The third column describes the performance represented by that letter grade and percentage.

Grade Point	***Percentage***	***Performance***
4.0	90 to 100%	Excellent Work
3.5	80 to 89%	Above average
3.0	70 to 79%	Good Work
2.5	60 to 69%	Mostly Good Work
2.0	50 to 59%	Average work
1.5	40 to 49%	Below average work
1.0	30 to 39%	Poor work
0	0 to 29%	Failing work

Course Policies

Diversity Equity and Inclusiveness

Diversity, Equity and Inclusion are important, interdependent components of everyday life in the College of Agriculture and Natural Resources (CANR) and are critical to our pursuit of academic excellence. Our aim is to foster a culture where every member of CANR feels valued, supported and inspired to achieve individual and common goals with an uncommon will. This includes providing opportunity and access for all people across differences of race, age, color, ethnicity, gender, sexual orientation, gender identity, gender expression, religion, national origin, migratory status, disability / abilities, political affiliation, veteran status and socioeconomic background. (See the full CANR statement: https://www.canr.msu.edu/news/canr-statement-on-diversity-equity-and-inclusion)

Commit to Integrity: Academic Honesty

Article 2.3.3 of the Academic Freedom Report states that "The student shares with the faculty the responsibility for maintaining the integrity of scholarship, grades, and professional standards." In addition, the (insert name of unit offering course) adheres to the policies on academic honesty as specified in General Student Regulations 1.0, Protection of Scholarship and Grades; the all-University Policy on Integrity of Scholarship and Grades; and Ordinance 17.00, Examinations. (See Spartan Life: Student Handbook and Resource Guide and/or the MSU Web site: www.msu.edu.)

Therefore, unless authorized by your instructor, you are expected to complete all course assignments, including homework, lab work, quizzes, tests and exams, without assistance from any source. You are expected to develop original work for this course; therefore, you may not submit course work you completed for another course to satisfy the requirements for this course. Also, you are not authorized to use the www.allmsu.com Web site to complete any course work in this course. Students who violate MSU academic integrity rules may receive a penalty grade, including a failing grade on the assignment or in the course. Contact your instructor if you are unsure about the appropriateness of your course work. (See also the Academic Integrity webpage.)

Inform Your Instructor of Any Accommodations Needed

From the Resource Center for Persons with Disabilities (RCPD): Michigan State University is committed to providing equal opportunity for participation in all programs, services and activities. Requests for accommodations by persons with disabilities may be made by contacting the Resource Center for Persons with Disabilities at 517-884-RCPD or on the web at rcpd.msu.edu. Once your eligibility for an accommodation has been determined, you will be issued a Verified Individual Services Accommodation ("VISA") form. Please present this form to me at the start of the term and/or two weeks prior to the accommodation date (test, project, etc.). Requests received after this date may not be honored.

Participation and Engagement

During all classes, the instructor expects students to be fully engaged and prepared to discuss reading assignments. Students are encouraged to ask questions of the instructor, guest speakers, and their peers.

Active participation includes, but is not limited to, the following behaviors:

1. Asking and answering questions of the instructors, peers, or guest speakers
2. Bringing forth new ideas, information, or perspectives to academic conversations
3. Discussing your readings and reflections with instructors and peers

4. Meeting with the instructors to discuss your interests, assignments, or project
5. Questioning information presented and discussed
6. Participating in small group discussions and activities
7. Assuming responsibility for personal behavior and learning

While working on group projects, students should be mindful of other students in their group; therefore, it is important for all participants to exercise:

- Respect for themselves, each other
- Openness and a positive attitude toward new ideas and other's ideas
- Flexibility and tolerance of ambiguity
- Good communications amongst themselves.

General college and university policies

All other general college and university policies applicable to this course are available at https://www.canr.msu.edu/academics/courses/policies . Please review these policies.
Topics covered in these general policies include:

- Students with disabilities, Resource Center for Persons with Disabilities (RCPD) and accommodations
- Student rights under the family educational rights and privacy act (FERPA)
  - Student release authorization form
- Religious holiday policies
- Grief absence policies
- Students in distress policies
- MSU student athlete policies
- Course add-drop policies
- Honors options
- Course Management system policies
- Final exam policy and attendance
- Grade dispute policies
- Academic honesty and integrity, plagiarism, and disciplinary procedures
- Disruptive behavior
- Harassment and discrimination policies
- RVSM University reporting protocols
- Limits to confidentiality
- Social media policy
- Web accessibility policies
- MSU Code of Teaching Responsibility
- SIRS
- Commercialization of lecture notes
- University Learning Goals

Detailed course schedule:

Day	Date	Notebook	Title	Activity	Learning objectives
		0	Getting Started with Jupyter	Download, start using, and become familiar with Jupyter notebooks. Write your very first Python code!	Successfully load and use a Jupyter notebook on each student's computer. Become familiar with Jupyter notebooks and run very simple first code in Python. Explain the structure and goals of the
Wed	26-Aug-20		Pre-class	Optional but recommended: Discord hang-out with the instructors at 3pm ET	Experiment with Discord and make sure you can use it. Ask the instructors questions or speak about what is on your mind about the course
Mon	31-Aug-20		Pre-class	Optional but recommended: Discord hang-out with the instructors at 3pm ET	Experiment with Discord and make sure you can use it. Ask the instructors questions or speak about what is on your mind about the course
Wed	2-Sep-20			Introductions and go over the syllabus, make sure everybody can use Jupyter and Discord. Introduction to class format and the first lesson	Be able to use Discord and run Jupyter. Get to know your classmates and take a pre-class survey about your coding skills
Mon	~~7-Sep-20~~		LABOR DAY		
Wed	9-Sep-20	1	Intro to Plants and Python: Lists & Leaves	Learn about the macroevolutionary history of plants using lists and different datatypes. Explore matplotlib plotting grapevine leaf shapes.	How to create variables, learn what different data types are, how to create a list, how to index lists and strings, how to modify lists, how to use print(), .append(), len(), str(), float(), int(), how to use matplotlib
Mon	14-Sep-20	2	Calculating the Golden Angle with Loops	Use loops to calculate the Fibonacci sequence and the golden angle.	How to write a for loop, how to use range(), how to write a while loop, using a counter, how to use a loop to modify a list

Wed	16-Sep-20	3	How to Build a Sunflower	Model a sunflower disc and its growth.	Use loops and math to model phyllotaxy, create double loops, create animations and model plant development dynamically, create and use models to understand natural phenomena
Mon	21-Sep-20	4	Dictionaries and functions	Students from the previous year will teach this class	How to use dictionaries and functions, central dogma of molecular biology
Wed	23-Sep-20	5	Biopython	Read, store, write, and manipulate sequences in Biopython. Learn basic unix command line and submit jobs.	Learn basic utilities of Biopython, develop a basic understanding of what DNA sequences are and what they represent
Mon	28-Sep-20	6	Comparative genomics and sequence analysis	Denote, format, and visualize genome features. Construct and visualize phylogenetic trees,	How to compare genomes between species. Understand what biological information is found within the genome.
Wed	30-Sep-20	7	Short read analysis 1 (RNAseq)	Download and process Illumina data from SRA. Short read alignment, quantification, and QC.	How to process and analyze gene expression data. Understand what RNAseq data is, how it is derived, and what it means.
Mon	5-Oct-20	8	Short read analysis 2 (variant discovery)	Run principle component analysis and hierarchical clustering to quantify genetic diversity in plants	How to generate, process, manipulate, and interpret genetic variant data. Understand concepts of genetic diversity between individuals.
Wed	7-Oct-20	9	Short read analysis 3 (co-expression)	Normalize expression values, generate and vidualize gene co-expression networks	How to generate gene coexpression networks. Understand principles of gene co-expression and network interactions.
Mon	12-Oct-20			Project planning	
Wed	14-Oct-20			Project planning	
Mon	19-Oct-20			Project planning	
Wed	21-Oct-20		MIDTERM	Project planning	
Mon	26-Oct-20			Group project work	

Wed	28-Oct-20			Group project work	
Mon	2-Nov-20			Group project work	
Wed	4-Nov-20			Group project work	
Mon	9-Nov-20			Group project work	
Wed	11-Nov-20			Group project work	
Mon	16-Nov-20			Group project work	
Wed	18-Nov-20			Group project work	
Mon	23-Nov-20			Group project work	
Wed	25-Nov-20		DAY BEFORE THANKSGIVING	Group project work	
Mon	30-Nov-20			Group project work	
Wed	2-Dec-20			Group project work	
Mon	7-Dec-20			Group project work	
Wed	9-Dec-20		FINAL	Final presentations	