School of Molecular & Cellular Biology

MCB 545, Spring 2023

Functional Genomics in Principle and Practice

3 credit hours

Instructor

Kevin Van Bortle
B521 CLSL
kvbortle@illinois.edu
217-333-3797

Class Meeting Schedule

M,W 10-11:20AM
Location: IGB computer room
Office Hour: By appointment

Course Overview and Description

This course is focused on experimental and analytical foundations of functional genomics, tailored to experimental biologists who are interested in using high-throughput sequencing technologies to analyze function in animal genomes. Lectures will cover the experimental methods and the tools available for data analysis; students will gain experience in experimental design and the use of bioinformatics tools through assignments and group projects.

Course Prerequisites, Requirements met

Advanced knowledge in eukaryotic molecular genetics is needed but bioinformatics skills are not required.

Student Learning Outcomes

At the end of the course, through assignments, discussions, activities and assessments, students will be able to:

- Understand basic principles of modern functional genomics methods and current sequencing approaches
- Navigate and utilize a high-performance computing (HPC) cluster environment
- Apply data processing and quality control pipelines to evaluate high-throughput sequencing data
- Perform computational analysis of sequencing-based genomic assays (RNA-seq, ChIP-seq, ATAC-seq, etc.).
- Interpret common data visualization techniques and apply these approaches using R

- Integrate multi-omic data to generate hypotheses related to the regulation and function of a given gene(s) of interest.

Course Text/Materials Information

Computational Genomics with R. Altuna Akalin. Chapman and Hall CRC Press. 2020
https://compgenomr.github.io/book/
Hands-on programming with R. Garrett Grolemund. O'Reilly Media. 2014
https://rstudio-education.github.io/hopr/basics.html
Student assignments will also include reading primary literature and reviews related to topics over the course of the semester.

Course Tools

MCB545 will utilize a Slack workspace as a resource for course communication between students, instructor, and between team members for group projects (https://slack.com).

Grading Information and Breakdown

20% Class participation: includes attendance and group participation (20 points total)
20% Graded homework assignments (20 points total)
40% Graded project assignments/presentations (2 total, 20 points each)
20% Final project assignment (20 points total)

100 Total points
Grade format = ABCDF, plus/minus
90% = A, 80% = B, 70% = C, etc.

MCB545 Course Calendar (updated)

January 18	Lecture Topic: Course overview, Intro to genomics
January 23	Lecture Topic: The Human Genome. Intro to Linux & Biocluster Reading: Rood & Regev 2021; Stothard, linux for bioinformatics. 2016
January 25	Lecture Topic: Linux & Biocluster (continued)
January 30	Lecture Topic: High-throughput sequencing (**Dr. Alvaro Hernandez**) Reading: Reuter, Spacek, Snyder, 2015. PMID: 26000844
February 1	Lecture Topic: Genome annotation. Data retrieval. Reading: Mudge and Harrow, 2016 PMID:27773922
February 6	Lecture Topic: DRBPs. Introduction to R (metadata). Reading: Hudson and Ortlund, 2014 PMID: 25269475. Akalin Chapter 2, https://rstudio-education.github.io/hopr/
February 8	Lecture Topic: Sequencing data, QC, processing, job submission.

Project [1] which genes are sensitive to disruption of your DRBP protein?

February 13	Lecture Topic: RNA-sequencing methods & workflows. Read alignment. Reading: Stark, Grzelak, Hadfield 2019 PMID: 31341269
February 15	Lecture Topic: Introduction to R continued (packages)
February 20	Lecture Topic: Gene silencing approaches. DEG analysis. Reading: Boettcher & McManus, 2015 PMID: 26000843. McDermaid et al., 2019 PMID: 30099484
February 22	Lecture Topic: DEG analysis (continued). Data visualization in R. Reading: Akalin Chapter 8.1-8.3.7
February 27	Lecture Topic: Functional enrichment analyses (GO, pathway, GSEA) Reading: Akalin Chapter 8.3.8; Reimand et al., 2019 PMID: 30664679
March 1	Lecture Topic: Functional enrichment analyses (continued).
March 6	Lecture Topic: Normalization schemes and clustering.
March 8	Project [1] Presentations

March 11-19 Spring Break

Project [2] which genes are targeted by your DRBP at the DNA- and RNA- level?

March 20	Lecture Topic: Chromatin immunoprecipitation methods (ChIP-seq pt. I) Reading: Akalin Chapter 9.1-9.4
March 22	Lecture Topic: ChIP-seq standard analysis – Peak calling (ChIP-seq pt. II) Reading: Akalin Chapter 9.4-9.6
March 27	Lecture Topic: Operating on Genomic Intervals (Bedtools) https://bedtools.readthedocs.io/en/latest/content/overview.html
March 29	Lecture Topic: Data integration and analysis: *Are genes sensitive to DRBP disruption targeted at the gene level?*
April 3	**No Class: MCB retreat, 8am-5pm at I-Hotel & Conference Center**
April 5	Lecture Topic: RNA immunoprecipitation methods (eCLIP pt. I) Reading: Hafner et al., 2021 (CLIP and complementary methods)
April 10	Lecture Topic: eCLIP standard analysis Reading: Van Nostrand et al., 2016 PMID: 27018577
April 12	Lecture Topic: eCLIP data integration and analysis: *Are genes sensitive to DRBP disruption targeted at the RNA level?*

April 17	Lecture Topic: Multi-omic data integration and analysis
April 19	Project [2] Presentations

Final project: Exploring gene regulatory mechanisms and expression of your DRBP

April 24	Lecture Topic: Chromatin accessibility, enhancers, & DNA methylation.
April 26	Lecture Topic: The 3D Genome: DNA- (and RNA-) interaction mapping
May 1	Lecture Topic: Genome-wide eQTL mapping, cancer mutations, repeats
May 3	Lecture Topic: The big picture: tapping into "the vast data"

Classes end May 3, Final project due May 12

Assignments, due dates, and course expectations

MCB545 is geared towards the practical application of functional genomic data analysis and will function as a hybrid lecture and hands-on lab course series. Attendance and in-class participation (maximum 20 points, 20% of total) is critical for actively learning this broad subject area. Students must contact me immediately or in advance if it becomes necessary to be absent from class to identify a reasonable action plan. Lecture topics will be linked to learning programming in-class and through multiple homework assignments that will be submitted electronically (maximum 20 points, 20% of total). This course encourages team-learning, including regular communication and group work on the MCB545 Slack workspace. However, homework assignments must be written up and submitted independently. Group assignments, on the other hand, will feature opportunities to analyze, discover, and finally present novel genomic findings through short team-based presentations (maximum 40 points, 40% of total). Towards the completion of the semester, a final project assignment will require each student to independently apply data processing tools and data analysis methods taught during the semester, as well as integrate and synthesize all data analyzed throughout the course to establish a hypothesis about the regulation and function of a specific gene. Final project assignments, unlike group assignments, must be completed independently.

Academic integrity

Students are expected to be familiar with the code of policies and regulations applied in all instances of academic misconduct. Please refer to http://studentcode.illinois.edu, and, in particular, Article 1 part 4: http://studentcode.illinois.edu/article1/part4/1-401/

Accommodations

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603 (V/TDD), or e-mail a message to disability@uiuc.edu. http://www.disability.illinois.edu/.

Inclusive classroom statement

The effectiveness of this course is dependent upon the creation of an encouraging and safe classroom environment. Exclusionary, offensive or harmful speech, such as racism, sexism, homophobia, and transphobia, will not be tolerated and in some cases will be subject to University harassment procedures. We are all responsible for creating a positive and safe environment that allows all students equal respect and comfort. We expect each of you to help establish and maintain an environment where you and your peers can contribute without fear of ridicule or intolerant or offensive language.

Sexual misconduct policy and reporting

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX and Disability Office. In turn, an individual with the Title IX and Disability Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options. A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential. Other information about resources and reporting is available here: wecare.illinois.edu.