**BIOL BC2500:** MATLAB for scientists, Fall 2022

**Instructor:** Dr.Allison J. Lopatkin (she/her)

**Location/Time:** QLAB Sulzberger Hall,T 1:00-4:00pm

**Office:** Altschul 1014

**Office hours:** Monday 12-1:00pm

**Email:** [alopatkin@barnard.edu](mailto:alopatkin@barnard.edu)

**TA:** Lo/renza Bartu (they/them)

**Office hours:** Thursday 12:30-1:30p

**Location:** Altschul 1207

**Course overview:**

The advent and widespread accessibility of ‘omics technologies, combined with increasingly cheap and highly-available computational power, has revolutionized science research over the past few decades – as a result, datasets continue to grow in both size and complexity. One of the greatest challenges facing biologists in the coming years is to make sense of all this data. Appropriate choice of numerical methods and rigorous implementation of these methods are crucial to transform meaningless lists of numbers into significant scientific discoveries. In this course, we will use MATLAB as a programming language to learn and implement these numerical and computational methods. To remove the abstractness of programming and demonstrate its utility, MATLAB capabilities will be introduced in parallel with applications to relevant biological questions. Course material includes introduction to MATLAB programming (matrix algebra, functions, algorithmic data processing and data visualization); curve fitting and data interpolation; linear systems; modeling biological systems of ordinary differential equations; image analysis.

**Prerequisites:**

Introductory biology sequence (BIOL BC1500 and BC1502); Calculus I (MATH UN1101). No prior programming experience is required.

**Why MATLAB?**

*“MATLAB is designed for Engineers and Scientists” – MathWorks*

* The basic data element is the MATrix: many mathematical operations that work on arrays or matrices are built-in to the MATLAB environment.
* Vectorized operations: adding two arrays together needs only one command, instead of a for or while loop.
* The graphical output is optimized for interaction: you can plot your data very easily, and then change colors, sizes, scales, etc., by using the graphical interactive tools.
* MATLAB’s functionality can be greatly expanded by the addition of toolboxes: toolboxes are sets of specific functions that provide more specialized functionality.
* MATLAB is a language and a programming environment: You can perform operations from the command line, as a sophisticated calculator.

**Learning objectives:**

This course will provide a comprehensive foundation in programming methodology for quantitative biology applications that can be readily applied to any programming language. It is recommended for students interested in establishing or expanding their computational biology skillset. After completing this course, students should be able to:

1. Explain the role of numerical methods in Biology
2. Execute numerical computations using MATLAB
3. Design algorithms in MATLAB to analyze diverse biological data and implement them using scripts and functions
4. Apply numerical techniques to model linear and non-linear biological systems
5. Implement programmatic solutions to analyze images associated with biomedical topics
6. Recognize common programming motifs that can be readily applied to other widely used languages

**Course materials and affordable access to course texts**

All students deserve equal access to course texts. For this reason, there is no required textbook for this class. All relevant readings and lectures are available on the course github: <https://github.com/ajlopatkin/matlab_for_scientists>.

All material will also be posted on Canvas prior to class. The following are suggested to supplement material covered in class, available on reserve at the library, online, or on the course website:

* Numerical and Statistical Methods for Bioengineering: Applications in MATLAB (M. R. King)
* Applied Numerical Methods with MATLAB for Engineers and Scientists (S. C. Chapra)
* MATLAB documentation: www.mathworks.com/help/matlab/
* MATLAB good coding practices: [datatool.com/downloads/matlab\_style\_guidelines.pdf](http://www.datatool.com/downloads/matlab_style_guidelines.pdf)
* **Canvas: MATLAB\_handbook.pdf**

All students must have access to MATLAB 2016b or higher. This is made available on each computer in the computer lab, and/or can be downloaded for free using a Columbia license. Also, office hours are a great time to get specific questions answered. This is time I specifically set aside for **you**, so use it!

**Class structure and Grading:**

Class will be a mix of three formats:

1. Lectures to go over higher level concepts
2. Live-coding examples to go through technical aspects of new topics together
3. Problem sets to work through examples first hand, and learn from your peers + prof (leftover class time can be used to begin problem sets)

Homework: 7 graded problem sets (112 pts; 16 pts each)

Exam 1: 50 pts (12.5%)

Exam 2: 66 pts (16.5%)

Final independent project: 116 pts total (29%)

Final report (professional code + paper): 100 pts

Final presentation: 16 pts

Class participation: 56 pts (2 pts per day; 14%)

**Homework policy:**

Problem sets are assigned weekly**.** Homework should be submitted through canvas by the following Monday at 11:59pm. Every homework file must be completely executable by me without error. Formatting for HW 1 and 2 can be found in week 1 lecture notes. Anything handed in by HW3 and later (including the final project) must be formatted according to the specifications in assignment\_coding\_guidlines.pdf on canvas.

**Final independent project:**

The skills learned throughout the semester will be demonstrated in an independent final project where you will use MATLAB to develop an image analysis pipeline. Grading milestones for this project consist of a written report (containing executable code), and an oral presentation. During the presentation, students will be expected to explain programmatic steps and answer questions regarding programming logic; evaluation for the oral presentation is based on a pre-defined rubric that will be posted to the course website, and will be 10 minutes long. Specific details for the final project will be discussed later in the semester.

**Late policy:**

Due to the large portion of class time devoted to homework exercises, unexcused late work cannot be accepted. Any late assignments will result in a 10% per day grade deduction, and up to a maximum 30% grade deduction. No assignments will be accepted if they are over 3 days late. Please note that there will be **no late assignments** accepted for your independent project report **or** presentation.

**Center for Accessibility & Disability Services (CARDS) Statement:**

If you believe you may encounter barriers to the academic environment due to a documented disability or emerging health challenges, please feel free to contact me and/or the Center for Accessibility Resources & Disability Services (CARDS). Any student with approved academic accommodations is encouraged to contact me during office hours or via email. If you have questions regarding registering a disability or receiving accommodations for the semester, please contact CARDS at (212) 854-4634, cards@barnard.edu, or learn more at barnard.edu/disabilityservices. CARDS is located in 101 Altschul Hall.

**Honor Code:**

Programming is an exercise in creativity if you let it. I encourage you to work with peers during in-class break-out sessions. However, trial and error is the best tutor for becoming a competent MATLAB programmer. Feel free to discuss logic amongst each other, but I expect you to use the homework sets as a time to develop your own personal programming style – that means when it comes time to write the code, it should be done on your own. There are infinitely many solutions, and two codes will never look identical. As it pertains to this course, if I suspect that a student has violated the Honor Code, I will forward my concerns to the Dean of Studies. All work for this course must be conducted in accordance with the Barnard Honor Code: <http://barnard.edu/dos/honorcode>,established in 1912, updated 2016.

**Wellness:**

It is important for everyone to recognize and identify the different pressures, burdens, and stressors you may be facing, whether personal, emotional, physical, financial, mental, or academic. We as a community urge you to make yourself--your own health, sanity, and wellness--your priority throughout this term and your career here. Sleep, exercise, and eating well can all be a part of a healthy regimen to cope with stress. Resources exist to support you in several sectors of your life, and we encourage you to make use of them. Should you have any questions about navigating these resources, please visit these sites:

* <http://barnard.edu/primarycare>
* [http://barnard.edu/counseling](http://barnard.edu/counsel)
* <http://barnard.edu/wellwoman/about>
* [Stressbusters Support Network](http://health.columbia.edu/files/healthservices/pdf/alice_Stressbusters_Support_Network.pdf)

**Religious holidays:**

All conflicts of this class with religious observances must be made known to me *in advance*. Please let me know of such a conflict as soon as you discover it so that we may make appropriate alternative arrangements.

**Email policy:**

I will not respond to emails regarding exam or assignment materials after 5:00pm on the night before an exam, or the day an assignment is due. Otherwise, I will do my best to answer all emails within 24 hours (exceptions include weekends and other non-work holidays, emergencies, or other extenuating circumstances).

**Participation policy:**

To learn MATLAB effectively, it is so important to be actively engaged in programming exercises during class – this is why participation is such a high component of your grade. All students are expected to come to class fully prepared and contribute to both instructor-lead and break-out exercises. During in-class practice problems, we will move through the exercises in groups of two, and periodically stop to share and compare answers together. It does not matter if your answer is correct – it only matters if you have attempted it. Participation points are earned by engaging in class activities; examples include actively working on the questions as groups, using technology respectfully (phone use, computer for MATLAB, etc.), helping others around you, and staying through the entire class duration. If you need to miss class, notify me *at least 1 week* in advance.

**Previous programming experience is not required to be successful in this course and master MATLAB – everybody in this class has a different level of programming experience. Therefore, concepts learned near the beginning of the semester may be familiar to some and not to others. Every single student should feel comfortable asking any and all questions pertaining to class material that is unclear. Students who do not contribute to an open and respectful class environment will receive zero participation points that day. Participation grades will be shared regularly with students.**

**Tentative schedule:**

Class time will be broken into lectures to go over background theory, live-coding demonstrations of this theory, and groupwork to apply this theory in practice. Everyone is expected to participate.

|  |  |  |
| --- | --- | --- |
| **Week** | **Topic** | **Assignment due** |
| 1 (Sep 6) | L1: Introduction to MATLAB /MATLAB as a calculator/script writing |  |
| 2 (Sep 13) | L2: ASYNCHRONOUS Vectors, matrices, built-in functions, simple data IO | HW1 |
| 3 (Sep 20) | L3: Matrix and cell indexing using standard and logical methods | HW2 |
| 4 (Sep 27) | NO CLASS |  |
| 5 (Oct 4) | L4: Control logic, user-defined functions, and debugging | HW3 |
| 6 (Oct 11) | **EXAM 1** |  |
| 7 (Oct 18) | L5: Advanced data IO, cell arrays, plotting | HW4 |
| 8 (Oct 25) | L6: Descriptive statistics, hypothesis testing, & error visualization |  |
| 9 (Nov 1) | L7: Numerical methods (regression, curve fitting, differentiation) | HW5 |
| 10 (Nov 8) | L8: Image analysis I: Image display and basic image processing | **EXAM 2/HW6** |
| 11 (Nov 15) | L9: Image analysis II: ROI and advanced processing | HW7 |
| 12 (Nov 22) | L10: Final project overview (HW8 is part 1 of final project) |  |
| 13 (Nov 29) | NO CLASS | HW8 |
| 14 (Dec 6) | **Final project presentations** | Final presentation |
| X (Dec 12) |  | Final report |