CS 5970 : Bioinformatics

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Fall 2025

Course Description:

This course offers a comprehensive introduction to the theory and application of algorithms and computational techniques in bioinformatics. Topics include sequence analysis algorithms, functional genomics, single cell omics, and machine learning methods in computational biology.

Course Prerequisites:

C S 2413 or C S 2414; and C S 2813 or MATH 2513; and permission of instructor.

1 Introduction

Recent technological advances are providing unprecedented opportunities to analyse the complexities of biological systems at this minute level. High-throughput analyses of the genomes, transcriptomes and proteomes are providing novel and important insights into diverse processes such as development, gene-expression dynamics, tissue heterogeneity and disease pathogenesis. Computer Science and especially bioinformatics are at the heart of this new frontier. This course covers the algorithmic and machine learning foundations of bioinformatics and computational biology combining theory with practice. We will cover foundational topics, current research frontiers, and work directly with current large-scale biological datasets.

Examples of the topics that may be covered:

- Definition and scope of bioinformatics. (Historical perspective and evolution of the field, importance and applications in biological research, examples of Biological Databases).
- Sequence and Genome Analysis.
  - DNA, RNA, and protein sequence analysis.
  - Sequence mapping and alignment.
  - Markov chains and hidden Markov models.

- Phylogenetics (Tree construction algorithms)
- Structural Bioinformatics (Protein structure prediction and modeling)
- Next-Generation Sequencing (NGS)
- Single Cell Omics Technologies: (What they are, when to use them, input libraries and interpreting outputs)
  - Single Cell Gene Expression (RNA-Seq)
  - Other Single Cell Modalities (Single Cell DNA-Seq, Single Cell Epigenomics (ATAC-Seq and Multiomics cytometry), Immune Receptor Mapping (single cell TCR/BCR-Seq), High Definition spatially resolved transcriptomics, Single Cell Proteomics, Metagenomics, CRISPR Screening.
- Functional Genomics:
  - Primary vs. Secondary pipelines
  - Computational methods for single cell data
  - Computational challenges in single-cell transcriptomics
- Visualization techniques for biological data.
- Machine Learning and Algorithms for omics data
  - Type vs. State identification
  - Differential and Enrichment Analysis
  - Trajectory inference
  - Interaction Maps
  - Multimodal integration
- Practical applications of bioinformatics in research projects: (Areas: Precision/personalized medicine, Immunology, Oncology, Neuroscience, Developmental Biology, Drug Resistance, Genetic Disease)
- Ethical considerations in bioinformatics research. (Data sharing, privacy, and security.)
- Hands-on Scientific Programming Workshops may include one of the following:
  - Primer to R programming language
  - Introduction to python notebooks
- Recent Advances and Emerging Trends
- Research Projects and Case Studies

2 Course Information and Material

Instructor's Office Hours: W 15:00 - 17:00, in DEH 253 *and/or* Zoom link here by appointment.
Course Texts and Material (Textbooks are optional): An Introduction to Bioinformatics Algorithms. A **Classic** Book by Neil Jones and Pavel Pevzner.[1]
Bioinformatics Algorithms: An Active Learning Approach. 3rd edition(2018), book by Phillip Compeau.[2]
Assigned readings ahead of class (Typically up to 2 papers will be shared on Canvas for each unit/topic: One classic paper or review and one recent (state-of-the-art) methods.
Time: August 25 - December 12, 2025. TR 4:30 - 5:45 pm
Location: Carson Engr Ctr 0121
Scheduled final exam: December 15, 2025. M 4:30 - 5:45 pm. Carson Engr Ctr 0121.
Learning Activities, Assignments, and Assessment: Choose 3 out of 4 Assignments/Small Projects, due 2 weeks from release date, each of the top three worth 10% of final grade (30% total). These could also be multiple small programming challenges assigned through Rosalind. Extra Credit opportunities up to 5% of total course grade (e.g. for using Latex or participating in poster sessions).
Projects, Midterms and Final: One Journal-club-style presentation and one paper review report (i.e. presenting a reviewed paper or paper collection on a topic) each 15% (30% total); Final Project is worth 30%. Project milestones include project idea overview, project proposal, and final report and code deliverable.
Class Participation: 10% total ($\approx$ 5 small in-class surveys or quizzes each worth 2%).
Grading Scale: Letter grades will be assigned based on the scale below. The scale already includes the rounding up allowed. $90\% \leq A \leq 100\%$; $80\% \leq B < 90\%$; $70\% \leq C < 80\%$; $60\% \leq D < 70\%$; $C < 60\%$.
Tentative Schedule: Table 1 and potential updates on Canvas.
Prerequisites: C S 2413 or C S 2414; and C S 2813 or MATH 2513; and permission of instructor.

Notes: Canvas - Please check the course on Canvas for announcements, updates to schedule, zoom links to office hours, etc.

Mastering course prerequisites - If you have not mastered any of the course prerequisites, consider reaching out to me or a teaching assistant for additional resources.

Assignments and Exams - I am interested in your learning and your approach to problem solving, therefore, partial credit will be given when you have solved parts of the problem correctly. If you feel you are falling behind or stressed about the material, please come see me or a teaching assistant, we will help.

Attendance - I do not take attendance in class, however there can be graded surveys and quizzes counted towards class participation. I recommend that all students attend every lecture and review, regardless of previous performance. All students will learn something new in class, receive tips and best practices to solving problems, learn about potential pitfalls and frequently made mistakes and attending class is one of the best ways to learn the concepts and improve your skills with minimal stress.

Additional Support - Consider additional services and support offered by OU, e.g. free

walk-in tutoring sessions through Action Tutoring or support from the Accessibility and Disability Resource Center.

Week	Topics	Assignments / Reports	Notes
1	Syllabus + Introduction		
2	Next-Generation Sequencing (NGS) and High-Throughput Data		
3	Sequence and Genome Analysis I	Assignment 1	
4	Sequence and Genome Analysis II		
5	Markov chains and hidden Markov models	Assignment 2	
6	Phylogenetic / Minimum Spanning Tree algorithms		
7	Single Cell Technologies	Assignment 3	
8	Visualization techniques for biological data		journal-club-style presentations
9	Computational methods for single cell data		journal-club-style presentations cont'd[1]
10	Machine Learning and Algorithms for omics data	Assignment 4	journal-club-style presentations cont'd
11	Biostatistical methods for Differential and Enrichment Analysis		journal-club-style presentations cont'd
12	Applications of bioinformatics algorithms in medical research		journal-club-style presentations cont'd
13	Advanced Algorithms: e.g. Trajectory Inference and Shared Space Embeddings (Multi-modal integration)	Paper Review	
14	Ethical considerations in bioinformatics research		Thanksgiving
15	Final Projects Presentations		
16	Pre-Finals Week		
17	Finals Week - Final Projects Presentations Continued		

Table 1: ***Tentative*** *schedule for Bioinformatics Fall 2025. See Canvas for most recent updates.*

[1] 15 min presentations scheduled as needed based on class size.

3 Course Policies

3.1 Submissions

Typeset, electronic versions (preferably in PDF format) of assignments and tests should be submitted to Canvas by the due dates. Late submissions of homework assignments might be accepted with a per day 10% penalty. No late submissions/uploads of tests will be accepted.

3.2 Typesetting

You are required to typeset your assignments using a word processor or other tools with an equation editor or -preferably but **optional**- using LaTeX [3] which is a software system for document preparation that is especially well-suited for documents with complex mathematical equations, scientific notation, and technical content. LaTeX excels in typesetting mathematical equations and symbols. It provides extensive support for various mathematical notations, making it the preferred choice for writing papers in fields like mathematics, physics, computer science, and engineering. LaTeX also simplifies the process of cross-referencing sections, equations, figures, and tables within your document. It also seamlessly integrates with BibTeX or BibLaTeX for managing and formatting citations and bibliographies. LaTeX and related material and resources will be discussed in some detail during the first week of class. Examples and templates as well as cheat sheets will also be provided. We highly encourage using Overleaf, MiKTeX or other free LaTeX tools.

3.3 Generative AI Policy: Based on the Assignment

Throughout this course, you will develop the skills needed to effectively use Generative AI as an aid in your learning and in preparation for our changing field. There will be times in which you will not be permitted to use Generative AI or may only use it in particular ways. These decisions are intentionally made to support you in developing the skills and content knowledge needed in order to effectively use Generative AI. Follow assignment instructions carefully, as they will guide you in what you are permitted to use Generative AI for in each assignment. Where Generative AI is used, you must follow assignment instructions for appropriate citation and reflection about your usage. Use of Generative AI outside of the scope of what is explicitly defined in our assignments, and without acknowledgment, will be considered a violation of the academic integrity policy for this course. If you have any questions about how Generative AI may or may not be used on an assignment, please talk with me. Consequences for Violating the Generative AI Usage Policy: Deviating from guidelines provided in each assignment may be considered a violation of the academic integrity policy of this course. Per our usage policy, you will be responsible for accuracy, including appropriately citing and summarizing any articles you find through AI research tools, and thus must read the material you are citing. Submitting data or research that is not real (a risk when overly relying on Generative AI) may result in an academic integrity violation for falsifying information. Additionally, there may be times, such as in-class quizzes, midterms, or finals, where Generative AI usage is prohibited. Any use of AI in those cases will be considered a violation of the academic integrity policy.

My Use of Generative AI: I will model appropriate Generative AI usage by clearly disclosing when I use it and why. Expected use cases may include: creating Generative AI course tutors, revising quiz or exam questions and responses (with my oversight), drafting case studies or educational games to help connect our course topics to the real-world, using my notes and previous PowerPoints to improve the structure of my lectures so that they are clearer to you all as students, graphic design, revising assignment instructions and rubrics to improve clarity for students, receiving feedback on how I communicate with students, and using AI research tools to find current articles to update our course readings. I will never use Generative AI to grade your work.

3.4 References and Literature Citations

Any statement or answer in any submitted work (assignments, tests, exams, projects, etc.) that relies on external sources of information (i.e. not the student's own new ideas or findings or solutions or general knowledge) should use a citation.

Citations are allowed in any format including but not limited to : APA, MLA, Chicago, and Harvard. You are free to choose which style to use as long as you use it consistently within an assignment or submitted work. You are encouraged to explore styles and use a citation generator.

You are generally allowed to use any external sources of information when solving your assignments and tests or examinations that are marked as 'open-book' as long as you properly and accurately cite your references. Misrepresenting an answer as original work will constitute a violation of the academic integrity policy, for more information see section 3.6 of this syllabus.

3.5 Citing (generative) artificial intelligence (AI):

How to cite ChatGPT and similar generative AI[4] websites and tools: You can generally follow the APA (American Psychological Association) citation style for citing online software or tools. Here's an example of how you might format a citation for an online software tool (e.g. ChatGPT):

OpenAI. (Year). ChatGPT [Computer software]. Retrieved Month Day, Year, from https://www.openai.com/chatgpt/

Here's an example of how to cite *a specific conversation* with ChatGPT:

ChatGPT. (Year, Month Day). Conversation Title. [Response to prompt: "User prompt or question"]. Retrieved from [URL of the platform where the conversation took place].

Please replace "Year, Month Day" and the URL with the actual year, retrieval date, and URL as needed, e.g.:

ChatGPT. (2023, January 18). How do you cite an answer in ChatGPT. [Response to user question "How do you cite an answer in ChatGPT"]. Retrieved from https://chat.openai.com/.

3.6 Expectations for Academic Integrity and Plagiarism

The overall goal of this course is your learning. In order to demonstrate that you have reached this goal, the work you turn in needs to be your own. This includes putting written

work into your own words and citing your sources to avoid plagiarism. If you work in a group, seek assistance from a tutor, use a resource on campus, and/or use online resources (including AI software), the work you turn in must be your own, demonstrating your own understanding of the material that you have gained through the learning process. If you have questions about academic integrity or plagiarism, please ask: my aim is to foster an environment where you can learn and grow, while also maintaining academic honesty and a clear representation of your learning and ideas. Penalties for serious offenses include a zero on the assignment and egregious offenses can even result in expulsion from the university, so it is important to understand expectations.

Plagiarism as defined by the OU Integrity Office includes: • Copying words and presenting them as your own writing. • Copying words, even if you give the source, unless you also indicate that the copied words are a direct quotation • Copying words and then changing them a little, even if you give the source. • Even if you express it in your own words, it is plagiarism to use someone else's idea as your own. Visit the OU Integrity Office for more information on what constitutes plagiarism.

4 Land Acknowledgement Statement

Long before the University of Oklahoma was established, the land on which the University now resides was the traditional home of the "Hasinais" Caddo Nation and "Kirikir?i:s" Wichita & Affiliated Tribes. We acknowledge this territory once also served as a hunting ground, trade exchange point, and migration route for the Apache, Comanche, Kiowa and Osage nations. Today, 39 tribal nations dwell in the state of Oklahoma as a result of settler and colonial policies that were designed to assimilate Native people. The University of Oklahoma recognizes the historical connection our university has with its indigenous community. We acknowledge, honor and respect the diverse Indigenous peoples connected to this land. We fully recognize, support and advocate for the sovereign rights of all of Oklahoma's 39 tribal nations. This acknowledgement is aligned with our university's core value of creating a diverse and inclusive community. It is an institutional responsibility to recognize and acknowledge the people, culture and history that make up our entire OU Community.

5 University Policies

Mental Health Support Services

Support is available for any student experiencing mental health issues that are impacting their academic success. Students can either be seen at the University Counseling Center (UCC) located on the second floor of Goddard Health Center or receive 24/7/365 crisis support from a licensed mental health provider through TELUS Health. To schedule an appointment or receive more information about mental health resources at OU, please call the UCC at 405-325-2911 or visit University Counseling Center. The UCC is located at 620 Elm Ave., Room 201, Norman, OK 73019.

Title IX Resources and Reporting Requirement

The University of Oklahoma faculty are committed to creating a safe learning environment for all members of our community, free from gender and sex-based discrimination, including sexual harassment, domestic and dating violence, sexual assault, and stalking, in accordance with Title IX. There are resources available to those impacted, including: speaking with someone confidentially about your options, medical attention, counseling, reporting, academic support, and safety plans. If you have (or someone you know has) experienced any form of sex or gender-based discrimination or violence and wish to speak with someone confidentially, please contact OU Advocates (available 24/7 at 405-615-0013) or University Counseling Center (M-F 8 a.m. to 5 p.m. at 405-325-2911).

Because the University of Oklahoma is committed to the safety of you and other students, and because of our Title IX obligations, I, as well as other faculty, Graduate Assistants, and Teaching Assistants, are mandatory reporters. This means that we are obligated to report gender-based violence that has been disclosed to us to the Institutional Equity Office. This includes disclosures that occur in: class discussion, writing assignments, discussion boards, emails, and during Student/Office Hours. You may also choose to report directly to the Institutional Equity Office. After a report is filed, the Title IX Coordinator will reach out to provide resources, support, and information, and the reported information will remain private. For more information regarding the University's Title IX Grievance procedures, reporting, or support measures, please visit Institutional Equity Office at 405-325-3546.

Reasonable Accommodation Policy

The University of Oklahoma (OU) is committed to the goal of achieving equal educational opportunity and full educational participation for students with disabilities. If you have already established reasonable accommodations with the Accessibility and Disability Resource Center (ADRC), please submit your semester accommodation request through the ADRC as soon as possible and contact me privately, so that we have adequate time to arrange your approved academic accommodations.

If you have not yet established services through ADRC, but have a documented disability and require accommodations, please complete ADRC's pre-registration form to begin the registration process. ADRC facilitates the interactive process that establishes reasonable accommodations for students at OU. For more information on ADRC registration procedures, please review their Register with the ADRC web page. You may also contact them at (405) 325-3852 or adrc@ou.edu, or visit www.ou.edu/adrc for more information.

Note: disabilities may include, but are not limited to, mental health, chronic health, physical, vision, hearing, learning and attention disabilities, pregnancy-related. ADRC can also support students experiencing temporary medical conditions.

Religious Observance

It is the policy of the University to excuse the absences of students that result from religious observances and to reschedule examinations and additional required classwork that may fall

on religious holidays, without penalty. [See Faculty Handbook 3.15.2]

Adjustments for Pregnancy and Related Issues

Should you need modifications or adjustments to your course requirements because of pregnancy or a pregnancy-related condition, please request modifications via the Institutional Equity Office website or call the Institutional Equity Office at 405/325-3546 as soon as possible. Also, see the Institutional Equity Office FAQ on Pregnant and Parenting Students' Rights for answers to commonly asked questions.

Final Exam Preparation Period

Pre-finals week will be defined as the seven calendar days before the first day of finals. Faculty may cover new course material throughout this week. For specific provisions of the policy, please refer to OU's Final Exam Preparation Period policy.

Emergency Protocol

During an emergency, there are official university procedures that will maximize your safety.

Severe Weather: If you receive an OU Alert to seek refuge or hear a tornado siren that signals severe weather.

1. Look for severe weather refuge location maps located inside most OU buildings near the entrances.
2. Seek refuge inside a building. Do not leave one building to seek shelter in another building that you deem safer. If outside, get into the nearest building.
3. Go to the building's severe weather refuge location. If you do not know where that is, go to the lowest level possible and seek refuge in an innermost room. Avoid outside doors and windows.
4. Get in, Get Down, Cover Up
5. Wait for official notice to resume normal activities.

Additional Weather Safety Information is available through the Department of Campus Safety.

The University of Oklahoma Active Threat Guidance

The University of Oklahoma embraces a Run, Hide, Fight strategy for active threats on campus. This strategy is well known, widely accepted, and proven to save lives. To receive emergency campus alerts, be sure to update your contact information and preferences in the account settings section at one.ou.edu.

RUN: Running away from the threat is usually the best option. If it is safe to run, run as far away from the threat as possible. Call 911 when you are in a safe location and let them know from which OU campus you're calling from and location of active threat.

HIDE: If running is not practical, the next best option is to hide. Lock and barricade all doors; turn off all lights; turn down your phone's volume; search for improvised weapons; hide behind solid objects and walls; and hide yourself completely and stay quiet. Remain in place until law enforcement arrives. Be patient and remain hidden.

FIGHT: If you are unable to run or hide, the last best option is to fight. Have one or more improvised weapons with you and be prepared to attack. Attack them when they are least expecting it and hit them where it hurts most: the face (specifically eyes, nose, and ears), the throat, the diaphragm (solar plexus), and the groin.

Please save OUPD's contact information in your phone.

NORMAN campus: *For non-emergencies call (405) 325-1717. For emergencies call (405) 325-1911 or dial 911.*

TULSA campus: *For non-emergencies call (918) 660-3900. For emergencies call (918) 660-3333 or dial 911.*

Fire Alarm/General Emergency

If you receive an OU Alert that there is danger inside or near the building, or the fire alarm inside the building activates:

1. *LEAVE* the building. Do not use the elevators.
2. *KNOW* at least two building exits.
3. *ASSIST* those that may need help.
4. *PROCEED* to the emergency assembly area.
5. *ONCE safely outside, NOTIFY first responders of anyone that may still be inside building due to mobility issues.*
6. *WAIT* for official notice before attempting to re-enter the building.

[OU Fire Safety on Campus]

References

[1] Neil C Jones and Pavel A Pevzner. *An introduction to bioinformatics algorithms*. MIT press, 2004.

[2] Phillip Compeau. *Bioinformatics algorithms: an active learning approach*. Active Learning Publishers, 3rd edition edition.

[3] LaTeX-Project. Latex, 2023.

[4] OpenAI. ChatGPT, 2021.