



University of Wisconsin-Madison
ONCOLOGY 778: BIOINFORMATICS FOR BIOLOGISTS

CREDITS: 3

COURSE DESIGNATIONS: Graduate attribute

MEETING TIME: T/TH 1:00-2:15 PM, SPRING SEMESTER

LOCATION: 7571 Wisconsin Institutes for Medical Research

INSTRUCTIONAL MODE: Face-to-face lecture and computer practical sessions.

COURSE CREDIT INFORMATION: This class meets on Tuesday/Thursday for two, 75-minute class periods each week for the spring semester and carries the expectation that students will work on course learning activities (reading, writing, problem sets, studying, etc.) for about 3 hours out of the classroom for every class period.

INSTRUCTORS: Eric Johannsen, M.D., WIMR 6531, ejohannsen@medicine.wisc.edu, Phone: 608-262-9952
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OFFICE HOURS: By appointment.

DESCRIPTION: Familiarizes students with bioinformatics theory and principles. Provides students with real-world experience that they can apply to their own work. Provides a foundation of knowledge that students can use to critically evaluate existing bioinformatics tools that can be used in their work, and in the absence of an appropriate tool, identify the analyses that demand the development of novel tools.

REQUISITES: (1) Consent of instructor.

LEARNING OUTCOMES: (1) Identify the appropriate analysis tools for common bioinformatics problems, format data, execute the analysis, and adjust necessary parameters. (2) Interpret results of common bioinformatic analyses including their own results as well as the published works of others. (3) Demonstrate competence in bioinformatic analysis by conducting an original analysis of primary data from their own lab or public databases. (4) Understand the assumptions and principles of bioinformatic pipelines and their implications for validity and statistical significance.

GRADING: Students will be assessed on the following: Class Participation (20 points), Problem Sets (140 points), and their final project (40 points). The final grade will be determined by the percentage earned of total points available for the course:

- A: 186-200 points
- AB: 176-185 points
- B: 166-175 points
- BC: 156-165 points
- C: 146-155 points
- D: 130-145 points
- F: 0-129 points

GUIDELINE FOR EVALUATING PARTICIPATION (10% of final grade):

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|-----------------|---|
| Outstanding | Contributions in class reflect exceptional preparation. Ideas offered are always substantive; provide one or more major insights as well as direction for the class. Challenges are well substantiated and persuasively presented. If this person were not a member of the class, the quality of discussion would be diminished markedly. (Outstanding contributors will receive full credit = 20 points .) |
| Good | Contributions in class reflect thorough preparation. Ideas offered are usually substantive; provide good insights and sometimes direction for the class. Challenges are well substantiated and often persuasive. If this person were not a member of the class, the quality of discussion would be diminished. (Good contributors will receive 15 out of 20 points .) |
| Adequate | Contributions in class reflect satisfactory preparation. Ideas offered are sometimes substantive, provide generally useful insights but seldom offer a new direction for the discussion. Challenges are sometimes presented, fairly well substantiated, and are sometimes persuasive. If this person were not a member of the class, the quality of discussion would be diminished somewhat. (Adequate contributors will receive 10-14.5 out of 20 points .) |
| Non-Participant | This person says little or nothing in class. Hence, there is not an adequate basis for evaluation. If this person were not a member of the class, the quality of discussion would not be changed. (Non-participants will receive 5.5- 9.5 out of 20 points .) |
| Unsatisfactory | Contributions in class reflect inadequate preparation. Ideas offered are seldom substantive; provide few if any insights and never a constructive direction for the class. Integrative comments and effective challenges are absent. If this person were not a member of the class, valuable airtime would be saved. (Unsatisfactory contributors will receive 0-5.0 out of 20 points .) |

PROBLEM SETS (70% of final grade): Problem Sets will be distributed to students throughout the semester. These are intended to provide hands-on experience in the evaluation and application of bioinformatics algorithms and tools. Some problems will require the use of bioinformatics software (both locally installed on students' computers and cloud-based tools) to solve real-world problems.

| Assignment | Distributed Date | Due Date |
|---------------|------------------|---------------|
| Problem Set 1 | Thursday Wk2 | Thursday Wk3 |
| Problem Set 2 | Thursday Wk4 | Thursday Wk5 |
| Problem Set 3 | Thursday Wk6 | Thursday Wk7 |
| Problem Set 4 | Thursday Wk8 | Thursday Wk9 |
| Problem Set 5 | Thursday Wk10 | Thursday Wk11 |

FINAL PROJECT (20% of final grade): During the final four class sessions, each student will give a 20 minute presentation on an original bioinformatic project building on one or more concepts covered in the course, ideally relating to their thesis work. An example might include analysis of RNA-seq data from their lab or a publically available database. Students are expected to focus primarily on the bioinformatics principles and pitfalls encountered in this analysis rather than the conclusions of the research per se.

COURSE OUTLINE (Lectures and Computer Practicals):

| Date | Title | Details |
|------|--|--|
| Wk1 | Lecture 1 - Introduction | Objectives, Overview |
| | Practical 1 - Preliminaries | Computer setup, introduction to data structures and flow control |
| Wk2 | Lecture 2 - Global Alignment | Scoring schemes, mismatch penalties, dynamic programming Needleman-Wunch algorithm |
| | Practical 2 - Global Alignment Exercises | Solving global alignment problems by hand and with computational tools |
| Wk3 | Lecture 3 - Local Alignment | Smith-Waterman Algorithm, Basic Local Alignment Search Tool (BLAST), MegaBLAST |
| | Practical 3 - Contig Assembly | Phred/Phrap/Consed; Sanger Sequencing |
| Wk4 | Lecture 4 - Introduction to Next Generation Sequencing (NGS) | Next-Gen sequencing platforms, Quality scores, data formats (e.g., FASTQ) |
| | Practical 4 - NGS Basics | NGS Workflows; File Formats; SRA; Galaxy; FASTQC |
| Wk5 | Lecture 5 - Short Read Alignment DNA | Suffix Trees & other Indices, Aligners (e.g., STAR), Mismatch Handling, SAM format |
| | Practical 5A - DNA Short Read Alignment (I) | Indices, Unaligned Reads, Alignment, UCSC Genome Browser |
| Wk6 | Practical 5B - DNA Short Read Alignment (II) | SNPs/Variants; Alignment-Free Methods |
| | Lecture 6 - Short Read Alignment RNA (transcriptomes) | Strandedness and Libraries, Transcriptomes (GTF format), Two pass methods, CIGAR strings |
| Wk7 | Practical 6 - RNA Short Read Alignment | Indices, handling unmapped reads, CIGAR strings |
| | Lecture 7 - Differential Expression Analysis | DESeq2 and GSEA |
| Wk8 | Practical 7A – Assigning Reads to Genes | Processing STAR output, featureCounts, DESeq2 (Galaxy) |
| | Practical 7B - Differential Expression Analysis | DESeq2 (Local), GSEA |
| Wk9 | Lecture 8 - ChIP-Seq Analysis | Peak Calling, Poisson distribution, Expectancy Maximization (EM), Motif searches |
| | Practical 8 - ChIP-Seq Analysis Exercises | MACS; Visualization of ChIP-Seq tracks on UCSC Genome Browser |
| Wk10 | Lecture 9 - Protein Alignment | Matrices (BLOSUM, PAM), BLASTP (+TBLASTN, BLASTX, & TBLASTX), synonymous/non-synonymous mutations |
| | Practical 9 - Protein Alignment Exercises | BLOSUM, BLASTP |

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| Wk11 | Lecture 10 - Multiple Sequence Alignment | Distance Trees, Progressive Alignments (CLUSTAL), MSA applications: PsiBLAST |
| | Practical 10 - Multiple Alignment Exercises | Multiple alignment of fluorescent proteins, Plasmid annotation |
| Wk12 | Lecture 11 - Protein Structure | Primary vs. Secondary vs. Tertiary, Secondary Prediction (HMM), Tertiary Prediction (Threading) |
| | Practical 11 - Web-based tools for protein structure analysis | TM prediction, domain identification, and threading |
| Wk13-14 | Student Final Project Presentations | |

TEXTBOOK (suggested & available online): An Introduction to Bioinformatics Algorithms (N. C. Jones and P.A. Pevzner), ANE Books, Cambridge, MA (2004). Available online: <http://go.wisc.edu/8gy576>

EXAMS, QUIZZES, PAPERS & OTHER MAJOR GRADED WORK: As discussed above, each student will present a final project, evaluation of which constitutes 20% of the final grade. There are no quizzes or exams.

HOMEWORK & OTHER ASSIGNMENTS: Each student is expected to complete their own homework assignment within the allotted time. Discussion of the homework assignments with each other and the instructors is encouraged; however, plagiarism or other forms of misconduct (see below) will result in zero credit for the assignment and may result in disciplinary action. Homework may be submitted during class as a hardcopy, by email, or via Canvas. Late homework will be accepted and graded, but is not eligible for full credit.

RULES, RIGHTS & RESPONSIBILITIES: Every member of the University of Wisconsin–Madison community has the right to expect to conduct his or her academic and social life in an environment free from threats, danger, or harassment. Students also have the responsibility to conduct themselves in a manner compatible with membership in the university and local communities. UWS Chapters 17 and 18 of the Wisconsin Administrative Code list the university policies students are expected to uphold and describes the procedures used when students are accused of misconduct. Chapter 17 also lists the possible responses the university may apply when a student is found to violate policy. The process used to determine any violations and disciplinary actions is an important part of UWS 17. For the complete text of UWS Chapter 17, see Office of Student Conduct and Community Standards website, or contact them via phone at 608-263-5700 or room 70 Bascom Hall.

No student may be denied admission to, participation in or the benefits of, or discriminated against in any service, program, course or facility of the [UW] system or its institutions or centers because of the student's race, color, creed, religion, sex, national origin, disability, ancestry, age, sexual orientation, pregnancy, marital status or parental status.

ACADEMIC CALENDAR & RELIGIOUS OBSERVANCES: The instructors will make every reasonable effort to avoid scheduling mandatory academic requirements on days when religious observances may cause substantial numbers of students to be absent. Any student with a religious observance conflict will be given an alternative for meeting that academic requirement. The course schedule is distributed and expectations discussed during the first class session. Students are requested to confidentially notify the instructor (e.g., by email) of any potential conflicts within the first week of class so that alternative arrangements can be made by the instructors in a timely fashion.

ACADEMIC INTEGRITY: By virtue of enrollment, each student agrees to uphold the high academic standards of the University of Wisconsin-Madison; academic misconduct is behavior that negatively impacts the integrity of the institution. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these previously listed acts are examples of misconduct which may result in disciplinary action. Examples of disciplinary action include, but is not limited to, failure on the assignment/course, written reprimand, disciplinary probation, suspension, or expulsion. <https://conduct.students.wisc.edu/syllabus-statement/>

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES: The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities are a shared faculty and student responsibility. Students are expected to inform faculty [me] of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA. <https://mcburney.wisc.edu/instructor/>

DIVERSITY AND INCLUSION: Diversity is a source of strength, creativity, and innovation for UW- Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.

The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world. <https://diversity.wisc.edu/>