Metagenomic Analysis
GEOB 589/BIOL 589

Tuesdays, 2:00-5:00 PM, Jones Annex 104
(Some classes and optional work sessions will be held in MSEC 345)

Instructor contact info

Daniel Jones, Ph.D.
<u>Contact:</u> daniel.s.jones@nmt.edu
<u>Office:</u> 314 MSEC
<u>Office hours:</u> TBA, or by appointment.

Course overview: Metagenomics is the study of genomic DNA from entire microbial communities. The ability to reconstruct microbial genomes directly from environmental or clinical samples, without the need for culturing, has revolutionized the fields of geomicrobiology, microbial ecology and evolution, healthcare and human microbiome research, and many others. Even though the first metagenomic studies were published less than 20 years ago, this technique has become a routine part of research on microorganisms in the environment and in human health. This course is designed to be a practical, hands-on introduction to metagenomic analysis. We will dive right in and analyze high-throughput metagenomic datasets, and by the end of the course, you will be equipped with some of the tools you need to use metagenomics to your own research, and will be able to learn and apply other new and useful bioinformatics techniques in your future work.

Place in Curriculum: This course is an elective for graduate degrees offered in the Earth and Environmental Science and Biology Departments.

Course learning outcomes: Upon successful completion of this course, students will be able to:
- Explain how metagenomics can be used for the analysis of environmental microbial communities or human microbiomes.
- Use basic BASH commands to navigate and manage files in a command-line Linux interface.
- Perform standard metagenomic analyses on large next-generation sequence datasets, including quality filtering and trimming, assembly, and sequence comparisons (e.g., BLAST, HMMer) using common software packages.
- Align and create phylogenetic trees from DNA or peptide sequences, and explain the differences among common tree-building algorithms.
- Synthesize and interpret results from their own analysis of microbial community datasets, and communicate that research to a scientific audience.
- Be able to learn and apply new and useful techniques that they may encounter in their future metagenomic research.

Program learning outcomes: Learning outcomes for undergraduate and graduate degrees in Earth and Environmental Science are listed at https://nmt.edu/academics/ees/Outcomes.php, and

program learning outcomes for undergraduate and graduate degrees in Biology can be found on the biology department website at https://nmt.edu/academics/biology/undergrad.php and https://nmt.edu/academics/biology/graduate.php.

Prerequisites: Graduate standing or consent of instructor.

Mode of instruction: Face-to-face. Please make arrangements with me if you are unable to attend in person for COVID-19-related issues, such as during quarantine periods.

Course website: Canvas course website, http://learn.nmt.edu

Readings: Readings will be taken from the scientific literature, and electronic versions of all articles will be made available through the course webpage.

Grading: For this course, I am using a philosophy of assessment called "specifications grading," which has been shown to reduce the impact of grades on the learning process. Students are provided a guide to the work required to achieve a particular grade. Grades are directly tied to learning objectives through satisfactory achievement of assignments, often with opportunities to revise the assignments to achieve a satisfactory score. If you're curious to learn more about this grading philosophy, see *Specifications Grading* by Linda Nilson (2015), or short pieces such as those by Johanesen et al. 2022 (https://doi.org/10.1130/abs/2022AM-382375) or Bayraktar 2020 (https://higheredpraxis.substack.com/p/tip-specs-grading).

Grades will be assigned based on the following criteria:

		Earn C	**Earn B**	**Earn A**
Activities (8 total)	Achieve satisfactory for at least	4	6	7
Papers	Achieve satisfactory for at least	2	2	2 (HQ on 1)
Final project and paper	Achieve satisfactory for at least	*	Sat	HQ
Project proposal, outline, and draft		✓	✓	✓
Presentation		✓	✓	✓
Participation (no more than 2 absences, group discussions, and class participation)		✓	✓	✓

*Students may earn a grade of C by completing a reduced final project, or, with a meaningful but unsuccessful attempt at earning a satisfactory score on a full project and paper.

Achieving satisfactory or high-quality (HQ): Unless otherwise noted, a satisfactory assignment is usually ≥75% of possible points, and high quality (HQ) is usually ≥90% of points. However, this may vary by assignment.

+/- letter grade criteria
- A grade of B+ would mean achieving B criteria, but meeting A criteria in at least 2 categories or with a majority of high quality scores on labs or quizzes; likewise for C+ versus C.
- A grade of B- would mean achieving B criteria in all except one category; likewise for A- versus A and C- versus C.

D/F grades: These grades indicate that most leaning objectives were not met, and therefore a fundamental breakdown of expectations. A grade of D represents a meaningful but unsuccessful attempt at earning a C or above. An "F" represents a lack of evidence of meaningful progress.

Late work: You have the option to turn in three assignments up to one week late. You might think of this as having three "tokens" that allow you a free pass to submit late work. Otherwise, no credit will be given for late assignments, or any assignment that is submitted more than one week late.

Resubmitting substandard or incomplete work: Activities and papers that do not meet the standard of satisfactory may be resubmitted within a week of receiving your score. This does not apply to presentations or your final project paper.

No extra credit is available outside of designated assignments. We will look over any exam or homework questions you think are not graded correctly and adjust your score as appropriate, but we will not negotiate your final grade. If you are having trouble in class for academic or any other reasons and are concerned about your grade, please see me early on so we can discuss how you can improve your understanding and performance.

Participation and Attendance: You are expected to attend class and participate in all activities and group discussions. You are not allowed more than two *unexcused* absences throughout the semester. We will make reasonable accommodations for medical absences and for students that contact us in advance about unavoidable absences (including travel for fieldwork, conference presentations, or other research purposes). This includes COVID-19 and other illnesses; please consult NMT's COVID-19 information page (https://www.nmt.edu/covid19/) for up-to-date guidelines.

Activities: There will be several activities assigned during the term that you will generally have one week to complete. These activities will include specific computational exercises, problem sets, or critical analysis of primary literature. Activities that do not meet the standard of satisfactory may usually be resubmitted within a week of receiving your score.

Papers: You will be asked to write portions of three papers over the course of the semester. Details will be provided in class.

Presentations: As a class, we will present our findings at some combination of NMT's student research symposium (SRS, https://www.nmt.edu/srs/), the New Mexico Geological Society Spring Conference (https://nmgs.nmt.edu/meeting/), or the Rocky Mountain Geobiology Symposium. You will work with in a small group to prepare a poster for one of these events, based on the discoveries you make from your metagenomic dataset, and present at one of more of these conferences.

Writing and presentation resources: Effective communication to both a broad audience and to your scientific peers is paramount for a successful career. **You are STRONGLY encouraged to take advantage of the resources available at the Writing and Communication Lab**, which

offers qualified tutors for graduate and undergraduate students to improve writing skills (https://www.nmt.edu/academics/class/center.php).

Academic Honesty: New Mexico Tech's Academic Honesty Policy for undergraduate and graduate students is found in the catalog, which can be found at: https://www.nmt.edu/registrar/catalogs.php/. Further information about academic honesty can be found on the Associate Vice President for Academic Affairs website: https://www.nmt.edu/academicaffairs/avpaa/academic_honesty.php
You are responsible for knowing, understanding, and following this policy.

Reasonable Accommodations: New Mexico Tech is committed to protecting the rights of individuals with disabilities and providing access and full participation in the educational experience. Students with disabilities who require reasonable accommodations are invited to make their needs known to the Office for Student Access Services (SAS) as soon as possible. Accommodations are not retroactive and may take some time to implement. The process for requesting accommodations can be found at their website https://www.nmt.edu/ds/academicaccommodations.php.

You can contact SAS in person at the Fidel Center Room 245, call 575-835-6209, email access@nmt.edu or book through the link on our website.

Counseling Services: New Mexico Tech offers individual and couples counseling, safety assessments, crisis intervention, outreach and consultations through the Counseling Center. These confidential services are provided free of charge by licensed professionals. Please note that changes in the delivery of counseling services may still be on going. For more information on how to access services, please call 835-6619, email counseling@nmt.edu or check out our website at https://www.nmt.edu/cds/.

Respect Statement: New Mexico Tech supports freedom of expression within the parameters of a respectful learning environment. As stated in the *New Mexico Tech Guide to Conduct and Citizenship* (Student Handbook): "New Mexico Tech's primary purpose is education, which includes teaching, research, discussion, learning, and service. An atmosphere of free and open inquiry is essential to the pursuit of education. Tech seeks to protect academic freedom and build on individual responsibility to create and maintain an academic atmosphere that is a purposeful, just, open, disciplined, and caring community."

COVID-19 and other Health-Related Safety Issues for Face-to-Face Instruction: Please note: provisions on masks, vaccines or other possible COVID-related requirements are subject to change as the situation evolves, based on guidance from the Centers for Disease Control, the State of New Mexico, and university officials (i.e., the President and the Board of Regents). For the most up-to-date guidelines, please consult NMT's COVID-19 information page: https://www.nmt.edu/covid19/.

Students should not come to class if they are feeling ill and should follow any quarantine guidelines that they are given in the event of exposure to COVID-19. If you are sick, you should contact your instructor immediately with a request for making up any missed work and

assignments, contact the Student Health Center, and consider getting tested for COVID-19 (as applicable). Please note the Student Health Center does not provide sick notes to students who are not seen by them.

Title IX Reporting: Sexual misconduct, sexual violence and other forms of sexual misconduct and gender-based discrimination are contrary to the University's mission and core values, violate university policies, and may also violate state and federal law (Title IX). Faculty members are considered "Responsible Employees" and are required to report incidents of these prohibited behaviors. Any such reports should be directed to Tech's Title IX Coordinator (Dr. Peter Phaiah, 122 West Hall, 575-835-5953 (O), 575-322-0001 (C), titleixcoordinator@nmt.edu) or reports can be filed online to Tech's Title IX & Sexual Misconduct Report. Please visit Tech's Title IX Website (www.nmt.edu/titleix) for additional information and resources.

Student Success: New Mexico Tech offers numerous peer tutoring services for students who are struggling in their courses, or who just wish to receive friendly advice, including the Office of Student Learning (Skeen Library, https://www.nmt.edu/osl/), the Writing and Communication Lab (Skeen Library, https://www.nmt.edu/academics/class/center.php), and numerous department-run centers. These services are free of charge to students! Students may also consult the Associate Dean of Student Success, Elaine Debrine Howell (elaine.debrinehowell@nmt.edu) or may receive emails from her if they are struggling in class.

To read about the services a student will need to be successful visit MyNMT: https://www.nmt.edu/mynmt.php

Land Acknowledgement: We acknowledge that the New Mexico Institute of Mining and Technology campus stands on the unceded ancestral lands of the Pueblo and Apache peoples. These lands were taken by Congress in the Indian land Cession 689 on October 1, 1886, and the people forcibly moved to reservations. These injustices were accomplished under false white-supremacist ideologies such as manifest destiny and the doctrine of discovery. As visitors to these lands we appreciate their millennia of stewardship to the land, water, animals and plants, and the opportunity to live and learn here. Please visit https://indianpueblo.org/new-mexicos-19-pueblos/ to learn more about these Native nations, their cultures, and sovereignty.

Language on New Mexico Tech policies from https://www.nmt.edu/academicaffairs/policies.php
Language on learning reflections, tracking participation, and some grading topics courtesy of Dr. Katherine Mattaini, Roger Williams University, and Dr. David Clark, Grand Valley State University.
Land acknowledgement text courtesy of Anne Gray, Chris ChoGlueck, Michael Schaefer, and the EES Diversity, Equity, and Inclusion (DEI) committee.

GEOB/BIOL 589: Metagenomic Analysis
Spring 2023

Module 1: Introduction		
17 Jan	Introduction	Activity: Paper discussion
24 Jan	Command line, dataset overview	Activity: Command line/BASH exercises

Module 2: QC, Assembly, Sequence Comparison		
31 Jan	Quality filtering and screening; start assembly	Activity: Quality filtering and trimming
7 Feb	Metagenome assembly	
14 Feb	Metagenome assembly; sequence comparison	Activity: Assembly
21 Feb	Sequence comparison and database searching	Activity: BLAST and HMMer
		Paper 1 due Monday, Feb 27

Module 3: Binning, MAGs		
28 Feb	Binning	
7 Mar	MAG screening and QC	Activity: Binning
14 Mar	---- No class, Spring Break ----	
21 Mar	MAG screening and QC	

Module 4: Phylogenetics		
28 Mar	Phylogenetic analysis	Activity: Phylogenetic analysis 1
4 Apr	Phylogenetic analysis	Activity: Phylogenetic analysis 2
		Paper 2 due Monday, April 3

Module 5: Special Topics, Projects, and Presentations		
11 Apr	Prepare SRS presentations	
18 Apr	Prepare SRS presentations	Poster presentations (SRS or other)
25 Apr	Final projects/special topics	
2 May	Final projects/special topics	
		Project paper due May 7