BMED 8901 – Graduate Research: Single-Cell and Spatial Omics Analysis

Course Focus. This mentored graduate research course provides hands-on training in the design, analysis, integration, interpretation, and communication of single-cell and spatial omics studies. Students will work on an authentic biomedical research project and develop reproducible computational workflows that connect cellular states, molecular programs, tissue organization, and clinically or biologically relevant phenotypes.

Graduate Research Context. Graduate research is a scholarly project conducted under the guidance of a faculty mentor that contributes new knowledge and/or discoveries to the broader professional community. High-quality mentored research experiences build confidence, foster deeper understanding, and support scientific and professional development.

Course Information

Course prefix and number: BMED 8901

Course name: Graduate Research

Instructor: Manoj Bhasin

Section: BHA

CRN: 95332

Semester / Academic Year: Fall 2026

Course Description

Graduate research conducted under the guidance of a faculty mentor, with an emphasis on computational and integrative analysis of single-cell and spatial omics data. Depending on the project, students may analyze scRNA-seq, CITE-seq, single-cell immune-repertoire data, spatial transcriptomics, spatial proteomics, or multimodal datasets. The course emphasizes biological question formulation, rigorous quality control, reproducibility, quantitative interpretation, and generation of publication-quality results.

Research Scope and Core Topics

- Experimental design for single-cell and spatial studies, including sample structure, biological replication, covariates, batch effects, and appropriate comparisons.
- Preprocessing and quality control of single-cell data, including filtering, normalization, feature selection, dimensionality reduction, clustering, and annotation.
- Identification and interpretation of cell types, cell states, transcriptional programs, differential abundance, differential expression, pathway activity, and trajectory or state-transition patterns where appropriate.
- Spatial analysis, including tissue segmentation or cell assignment, spatial quality control, cell-type mapping, neighborhood analysis, cellular co-localization or exclusion, spatially variable features, and tissue-domain discovery.
- Cell-cell communication and ligand-receptor analysis, interpreted in the context of cell abundance, spatial proximity, and biological plausibility.
- Integration of single-cell and spatial measurements to connect cell state with tissue organization and phenotype.
- Statistical modeling, visualization, biological validation, and preparation of figures and methods suitable for manuscripts, abstracts, presentations, or grant applications.

Course Learning Outcomes

By the end of the semester, the student should be able to:

- Formulate a testable biological or translational research question that can be addressed using single-cell and/or spatial omics data.
- Select and justify an analysis strategy appropriate for the assay, study design, sample size, and biological question.

- Perform and document rigorous quality control and identify technical artifacts, batch effects, confounding, and other threats to interpretation.
- Analyze single-cell data to define cellular composition, cell states, transcriptional programs, and biologically meaningful comparisons.
- Analyze spatial data to quantify cellular neighborhoods, tissue domains, cell-cell proximity, immune exclusion, spatially localized programs, and other relevant spatial features.
- Integrate single-cell and spatial datasets when appropriate and evaluate concordance across technologies or cohorts.
- Apply appropriate statistical approaches and distinguish exploratory findings from validated or confirmatory conclusions.
- Create clear, publication-quality visualizations and communicate methods and findings orally and in writing.
- Maintain reproducible code, analysis documentation, and organized data provenance consistent with FAIR and responsible research principles.
- Demonstrate scientific independence, troubleshoot analytical challenges, incorporate mentor feedback, and recognize limitations and alternative explanations.
- Apply Responsible Conduct of Research principles, including appropriate handling of human genomic and clinical data.

Expected Computational Competencies

Students are not expected to enter the course with mastery of all platforms. Competencies will be developed according to the assigned project. Relevant tools may include:

- R and/or Python for data analysis, statistical testing, visualization, and reproducible scripting.
- Single-cell analysis frameworks such as Seurat, Scanpy, Bioconductor, or equivalent project-appropriate tools.
- Primary-processing pipelines such as Cell Ranger, Space Ranger, Xenium processing software, or technology-specific equivalents, when raw data processing is part of the project.
- Spatial analysis frameworks for neighborhood analysis, spatial domains, spatial statistics, cell-type mapping, and multimodal integration.
- Version control and reproducibility tools such as Git/GitHub, structured project directories, notebooks, environment files, and workflow documentation.
- High-performance or cloud computing resources when datasets exceed local computing capacity.

Research Workflow and Semester Milestones

- Weeks 1–2: Define the biological question, dataset(s), study design, primary endpoints, analysis plan, and expected deliverables.
- Weeks 2–4: Complete data inventory, metadata review, preprocessing, quality-control strategy, and initial exploratory analysis.
- Weeks 4–8: Perform core single-cell and/or spatial analyses; review intermediate findings with the mentor and revise analyses as needed.
- Weeks 8–12: Conduct integrative, statistical, pathway, neighborhood, communication, validation, or sensitivity analyses appropriate to the project.
- Weeks 12–15: Finalize figures, methods, results interpretation, reproducible code, and a final research presentation or written report.

Milestones may be adjusted to match the maturity of the assigned project, data availability, and the student's registered credit hours.

Mentoring, Meetings, and Research Participation

- The student will participate in research activities every week at a level commensurate with registered credit hours.
- The student and mentor will meet regularly, typically weekly or biweekly, to review progress, troubleshoot analyses, interpret results, and establish next steps.
- The student is expected to maintain an analysis log or electronic research notebook that records datasets, software versions, parameters, decisions, problems encountered, and major conclusions.
- The student should arrive at meetings prepared with updated results, specific questions, and a concise summary of completed and planned work.
- Students may also participate in laboratory meetings, data-analysis meetings, journal clubs, single-cell/spatial working groups, or relevant seminars as directed by the mentor.

Data Management, Reproducibility, and Research Rigor

- Raw data should remain unchanged. Processed datasets and analysis outputs should be stored using a clear and documented directory structure.
- Analyses should be performed using scripts, notebooks, workflows, or other reproducible computational records rather than undocumented manual steps whenever feasible.
- Software, package versions, reference genomes/transcriptomes, annotations, thresholds, and major parameters should be recorded.
- Sample identifiers and metadata must be handled consistently. Any protected health information or controlled-access data must be stored and analyzed only in approved environments.
- Analyses should include appropriate checks for batch effects, confounding, outliers, sample-level dependence, multiple testing, and robustness of key conclusions.
- Important biological findings should be validated using orthogonal data, independent cohorts, alternative analysis approaches, or literature-supported evidence when feasible.

Use of Generative AI and Computational Assistance

Generative AI tools may be used to assist with coding, debugging, documentation, or writing only when consistent with mentor expectations and institutional policies. Students remain responsible for verifying all code, statistical analyses, citations, and scientific claims. Protected, unpublished, confidential, or patient-level information must not be entered into unapproved external AI systems. Any substantial AI-assisted contribution should be disclosed to the mentor and documented when appropriate.

Required Course Materials and Resources

- No required textbook. Readings will consist of project-specific primary literature, methods papers, software documentation, and relevant best-practice guidelines.
- Access to project-approved datasets and computing resources will be provided or coordinated by the research group.
- Students are expected to use current documentation for the analysis tools selected for their project and to cite software and methods appropriately.

Assessment and Grading Policy

Grades will reflect research engagement, rigor, progress, independence, reproducibility, and communication rather than whether a particular biological hypothesis is confirmed. The default grading framework is:

- Research engagement, preparation, and professionalism – 20%
- Quality of data processing, quality control, and reproducible workflow – 20%
- Analytical rigor, troubleshooting, and interpretation – 30%
- Progress toward agreed project milestones and deliverables – 15%
- Final presentation, report, figures, or another agreed research product – 15%

The mentor may adapt deliverables to the student's project and registered credit hours, but expectations will be communicated at the beginning of the semester. Satisfactory performance requires consistent participation, documented progress, responsible conduct, and completion of agreed research products.

Attendance Policy

Graduate research students will participate in research activities on a weekly basis commensurate with registered credit hours and as discussed with the faculty research mentor. Because this is a research course rather than a lecture course, attendance includes active participation in scheduled mentor meetings, analysis sessions, research-group activities, and completion of independent research work. Planned absences should be communicated to the mentor in advance whenever possible.

Statement About Acceptable Student Conduct

Faculty research mentors and students should discuss and agree on expectations before beginning the graduate research course. Expectations should include the student's weekly time commitment; methods and frequency of communication; how research will be recorded, stored, analyzed, and shared; standards for authorship and attribution; and when and how students will reflect on successes, limitations, and challenges. Mutual respect, responsibility, scientific rigor, and constructive communication are expected throughout the course. The Georgia Tech Student-Faculty Expectations agreement is available at https://catalog.gatech.edu/rules/22/.

Responsible Conduct of Research, Data Privacy, and Authorship

- Students must follow Responsible Conduct of Research principles and all applicable IRB, data-use, biosafety, institutional, and sponsor requirements.
- Human genomic, transcriptomic, imaging, and clinical data must be treated as sensitive research information and accessed only through authorized systems.
- Results from unpublished projects should not be shared outside the approved research team without mentor permission.
- Authorship and contribution expectations should follow accepted scientific standards and should be discussed early when a project is expected to contribute to a manuscript or conference submission.

Academic Honesty / Integrity Statement

Students are expected to maintain the highest standards of academic integrity. All submitted work must be original or appropriately attributed, and all analyses must accurately represent the data and methods used. Fabrication, falsification, plagiarism, inappropriate manipulation of results, or other forms of academic dishonesty are prohibited and will be addressed under the Georgia Tech Academic Honor Code: https://policylibrary.gatech.edu/student-life/academic-honor-code.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services (404-894-2563) as soon as possible to make an appointment to discuss your needs and obtain an accommodations letter. Please also contact the instructor so that appropriate arrangements can be made.

Campus Resources

The Office of Graduate and Postdoctoral Education provides resources and support for graduate research students and their mentors. Visit https://grad.gatech.edu/ for additional information and resources.

End-of-Semester Deliverables

- Organized and reproducible analysis code or notebooks sufficient for another trained analyst to understand and rerun the principal analyses.
- A concise README or analysis summary documenting datasets, software, major parameters, output locations, and unresolved issues.
- Publication-quality figures and/or tables summarizing the major findings developed during the semester.

- A final oral presentation, written research summary, abstract, manuscript section, or other mentor-approved scholarly product.