

BE 500 – Fall 2024 - Introduction to Systems Immunology

Course Introduction: Welcome to BE 500, “Introduction to Systems Immunology,” where we will cover immunology and data science topics. In this age of global health challenges, understanding the complexity of the human immune system and its responses to pathogens is crucial. Our journey will span the latest vaccine development, leveraging systems vaccinology and employing cutting-edge “OMICS” technologies and artificial intelligence (AI) to dissect and understand immunological data.

Instructor Information: Dr. Adriana Tomic, PhD, Assistant Professor, Biomedical Engineering and Virology, Immunology & Microbiology, **Email:** atomic@bu.edu **Website:** <https://atomic-lab.org/>

Course Description: The BE500 Systems Immunology course offers an engaging, practical approach to bridging theory with real-world applications. Through active participation and critical questions like “Why are some individuals better protected than others?” you will deepen your understanding of systems immunology and its role in tackling infectious diseases. Whether you're focused on advancing vaccine innovation or expanding your immunological expertise, this course equips you with the knowledge and skills to make a meaningful impact on global health challenges.

Course Goals: This course is an introduction to the principles of Systems Immunology, with a particular emphasis on understanding how this knowledge applies to evaluating vaccines against infectious diseases. It will explore the integration of computational tools and immunological data to illuminate the complexities of the immune system and its role in health and disease. Rather than focusing intensively on data analysis, the course aims to familiarize students with the concepts and terminology central to systems immunology and systems vaccinology. The course will leverage current scientific literature to discuss novel approaches to studying and harnessing the immune system for better health outcomes.

Learning Outcomes: Upon completing this course, you will be able to:

1. Critically evaluate current research and methodologies in systems immunology.
2. Utilize AI software to perform exploratory immunological data analysis.

Prerequisites:

- An introductory course in immunology.
- An in-depth understanding of OMICS technologies and data analysis.
- An understanding of AI and other computational analysis concepts.

Major Assessments:

- **Journal Club Presentations:** Dive into recent scientific literature and present your analysis, focusing on how the findings contribute to Systems Immunology.
- **Participation:** Your contributions during discussions are vital. Sharing insights, asking questions, and engaging with presentations will enrich our learning community.

- **Practical Application Sessions:** Hands-on sessions with AI and computational tools will allow you to apply your knowledge to real immunological data sets directly.

Course Schedule:

- **Module 1: Immunology Fundamentals (Week 1)**
Overview of immune system components, defense mechanisms, and vaccination basics.
- **Module 2: Systems Immunology – Theory & Methods (Weeks 2-3)**
Introduction to systems-level approaches, AI, and computational tools in immunology.
- **Module 3: Applications in Infections & Vaccinology (Weeks 4-6)**
Real-world applications of systems immunology in infections and vaccine development.
- **Module 4: AI in Immunological Analysis (Weeks 7-14)**
Hands-on use of AI and machine learning to analyze immunological data and predict immune responses.

Resources:

- Course materials and additional readings will be available on GitHub:
https://github.com/atomiclaboratory/systems_immunology_course_2024/tree/main
- Students must have access to a computer for software installation and practical sessions.

Target Audience:

- This course is designed for Master and PhD students in biomedical engineering, immunology, bioinformatics, or related fields.
- Participants should have a keen interest in the intersection of computational technology and immunological research.

Planned Lecture Schedule for Systems Immunology Course

Date	Day	Module Content
Week 1: Immunology 101: Fundamentals		
9/3/2024	Tuesday	Exploring the Immune System: Defense Mechanisms, Disease, and Vaccination – self-paced module
9/5/2024	Thursday	Reflection and Knowledge Check
Weeks 2-3: Human Systems Immunology & Vaccinology: Theory, Methodology & Prospects		
9/10/2024	Tuesday	Human Immunology 2.0: Era of Systems Immunology – lecture by Dr. Tomic
9/12/2024	Thursday	Bridging Science and Practice in Human Systems Immunology – lecture by Dr. Tomic
9/17/2024	Tuesday	Collaborative Research Synthesis: Application of Systems Immunology Approaches in Real-world Examples: self-paced module
9/19/2024	Thursday	
Weeks 4-6: Systems Immunology in Action: Insights into Infections and Vaccinology		
9/24/2024	Tuesday	Team 1: Predicting Vaccine Success: Systems Biology and the Yellow Fever Vaccine
9/26/2024	Thursday	Team 2: Decoding Influenza Vaccination: Systems Biology Insights
10/1/2024	Tuesday	Team 3: Understanding Personalized Medicine: How Sex Differences Shape Disease and Treatment Responses
10/3/2024	Thursday	Team 4: HIV-1 and Neutralizing Antibodies: A Battle for Control
10/8/2024	Tuesday	Team 5: Understanding Tuberculosis: Immune Factors Influencing Infection Outcomes
10/10/2024	Thursday	Team 6: COMBATING COVID-19 using Systems Immunology Approach
Weeks 7-14: From Theory to Practice: AI in Immunological Cases		
10/17/2024	Thursday	Preparation for AI-Driven Immunology: self-paced module
10/22/2024	Tuesday	SIMON says: Advancing Human Immunology using AI – lecture by Dr. Tomic
10/24/2024	Thursday	PANDORA: Predicting immunological memory to newly emerging viruses: Practical introduction – lecture by Dr. Tomic
10/29/2024	Tuesday	Machine learning algorithms: theory – self-paced module
10/31/2024	Thursday	Team 6 - Bayesian and Discriminant Analysis Approaches to Identify Patterns in Biological Data – presentation
11/5/2024	Tuesday	Team 5 - Decision Trees and Ensemble Methods in Predicting Immunological Responses – presentation
11/7/2024	Thursday	Team 4 - Neural Networks and Regularization: Predicting Complex Outcomes in Immunology – presentation
11/12/2024	Tuesday	Team 3 - Clustering Methods to Reveal Hidden Structures in Immune Response Data – presentation
11/14/2024	Thursday	Team 2 - Simplifying Complexity: Extracting Key Patterns in Immunological Data with PCA – presentation
11/19/2024	Tuesday	Team 1 – Visualizing High-Dimensional Data: tSNE and UMAP for Immune System Insights – presentation
11/21/2024	Thursday	Introduction to the final task

Date	Day	Module Content
11/26/2024	Tuesday	<i>Hands-On Practical Sessions: Team tasks SIMON – self-paced module</i>
12/3/2024	Tuesday	Improving modeling using SIMON – part 1
12/5/2024	Thursday	Improving modeling using SIMON – part 2
		NextGen Immunology: Discussion & Wrap-up

Notes:

- Students are expected to complete the software installation before the hands-on sessions.
- This schedule is subject to change based on student needs and progress throughout the course.