

Immunology Learning Framework

Key Concepts

1. Systems <i>The immune system is interconnected and interacting</i>		
Fundamental Statements	Illustrative Concepts	Sample Learning Objectives
1.1. The immune system is an interconnected and coordinated network of macromolecules, cells, tissues, and/or organs within an organism	1.1.1. Layers of inducible and continuously present defense mechanisms resist, reduce, eliminate or tolerate antigens	<ul style="list-style-type: none"> Describe physical and chemical barriers that protect an organism from potential pathogens Describe the localized and systemic defenses used to minimize the spread of infection Describe the role of resident macrophages in immune responses Explain the role of complement in initiation and amplification of an immune response Describe how dendritic cells bridge communication between innate and adaptive immunity Compare and contrast an immune response to a pathogen that has entered via mucosa versus blood Explain the cell-surface interactions involved in leukocyte movement from blood to tissues Describe the role of CCR7 in the movement of cells within the lymph node Compare and contrast the role of M1 and M2 macrophage in an immune response
	1.1.2. Immune response involves localized and (if necessary) recruited components	
	1.1.3. Immune responses are coordinated among non/partially specific and specific, rapidly-responding and slower-responding defenses	
	1.1.4. Within an organism, the presence of tissue and fluid compartments influence the immune components deployed in a response	
	1.1.5. Immune system plays a role in defense and repair processes	
1.2. Cellular and molecular processes maintain homeostasis of the immune system, and loss of homeostasis may	1.2.1. The mechanisms of central and peripheral tolerance prevent immune responses against the host	<ul style="list-style-type: none"> Describe how a mutation in AIRE gene can result in an autoimmune disease Describe the mechanisms by which a B lymphocyte becomes anergic

result in a variety of immune-mediated disorders	1.2.2. Antigen concentration can be impacted by continually present cellular processes required for homeostasis	<ul style="list-style-type: none"> Describe how IL-10 secreting cells regulate overactive immune responses Explain how autophagy, proteosomal degradation or nuclease activity can prevent initiation of pro-inflammatory processes Explain the role of tissue-resident macrophages in maintaining homeostasis Compare and contrast the mechanism of action of different allergy medications, e.g., corticosteroids vs. anti-histamines Explain why germ-free animals have a weakened immune response Describe changes to the thymic output with age, and its consequences for immune function Describe the mechanisms that aging plants use to maintain immune function Explain why certain vaccines can be effective when administered to newborn humans but other vaccines must be given at later timepoints
	1.2.3. Homeostasis of the immune system can be altered or restored due to genetic or environmental influence	
	1.2.4. Immune system components change over the lifespan of an organism	
1.3. Immunological memory plays a critical role in protective immunity	1.3.1. Immunological memory allows for increased levels of immune cells, effector molecules and/or faster response upon re-exposure to the same antigen	<ul style="list-style-type: none"> Describe how epigenetic changes may influence the innate immune response upon re-exposure to a pathogen Compare the timeline of a primary immune response and a secondary immune response to a pathogen Compare the antigen specificity of memory B lymphocytes and naïve cells Explain how a vaccine can induce herd immunity within a population
	1.3.2. Immunological memory in an individual influences the spread of infection within a population	

2. Structure and Function

The basic structure of organs/tissues, cells, and macromolecules defines their immune function

2.1. Immune responses are influenced by the presence, location and organization of lymphoid organs/tissues_within an organism	2.1.1. Primary and secondary lymphoid tissues have distinct roles in coordinating an immune response	<ul style="list-style-type: none"> Describe the impact of spleen, appendix, tonsils or thymus removal on an individual's immune response Draw the migration routes of a naïve and an effector T lymphocyte, with regards to the peripheral lymph node and site of infection Label the T cell and B cell zones in the lymph node
	2.1.2. Organization within lymphoid organs/tissues influences the deployment of immune cells	
2.2. Immune cell_function is characterized by the presence of macromolecular features	2.2.1. Cell surface, intracellular and/or secreted macromolecules can elucidate immune cell function	<ul style="list-style-type: none"> Describe the phenotypic changes that occur in a dendritic cell after antigen capture Describe the cytokine profiles that distinguish sub-populations of T-helper cells (e.g., Th-1, Th-2, Th-17 etc.) Describe the role of CD4 or CD8 co-receptor in the activation of T lymphocytes Distinguish between granulocytes based on staining patterns and granule contents Identify cellular sub-populations on a flow cytometry scatter plot Discuss how the granule content in neutrophils, eosinophils, basophils, and mast cells relate to their immune function
	2.2.2. Immune cell size, shape, and/or granularity can aid in its laboratory identification	
2.3. Macromolecular interactions influence the outcome of an immune response	2.3.1. A range of antigenic macromolecules can activate a targeted immune response	<ul style="list-style-type: none"> Classify Pathogen Associated Molecular Patterns (PAMPs) and Damage Associated Molecular Patterns (DAMPs) based on their chemical nature (e.g., protein vs. carbohydrate vs. nucleic acids) Describe how peptide-binding cleft structure influences the presentation of peptide antigens by Major Histocompatibility Complex (MHC)-Class I and II Explain how molecular mimicry could result in the development of an autoimmune disorder after exposure to a pathogen Illustrate the role of phosphorylation in altering the structure and function of T-Cell Receptor signaling complex
	2.3.2. Structural differences in binding domains determine the ability of immune cell receptors to recognize antigens	
	2.3.3. Kinetics and strength of receptor-ligand interactions determine the activation of signaling pathways within an immune cell	

3. Information Flow, Exchange and Storage

Immune responses are mediated through the expression of genetic information in context

3.1. Antigen recognition and associated cellular signaling result in differential gene expression, which shapes the organism's targeted immune response	3.1.1. Differential gene expression is driven by recognition of antigenic structure	<ul style="list-style-type: none"> • Compare the Pattern Recognition Receptor (PRR) mediated cell-signaling cascades in response to a viral infection versus a bacterial infection • Describe the phenotypic changes between naïve and activated CD8+ T lymphocytes • Describe how macrophages and T-helper lymphocytes cross-talk to maintain an immune response • Describe the cytokine profiles that are critical for determining M1 versus M2 macrophage • Describe how immunological synapses concentrate intracellular signals required for immune cell activation
	3.1.2. Differential gene expression can change the expression of cell-surface molecules and the secretion of soluble factors	
	3.1.3. Tissue microenvironment can influence gene expression and associated host cell response	
3.2. During development, immune cells differentiate to acquire characteristic phenotypes	3.2.1. Hematopoietic stem cells differentiate into myeloid, erythroid and lymphoid cells	<ul style="list-style-type: none"> • Describe the cell types that can develop from hematopoietic stem cells and the signals necessary for differentiation into each cell type • Describe the mechanisms that limit the generation of self-reactive lymphocytes in the thymus • Predict the role of infant's gut flora on immune system development • Predict the consequences of a common gamma chain receptor deficiency
	3.2.2. A multi-step selection process is involved in lymphocyte development	
	3.2.3. Genetic disorders can alter immune cell development	
3.3. Gene expression and regulation influence the recognition of diverse antigens by the immune system	3.3.1. Genome organization determines antigen receptor diversity	<ul style="list-style-type: none"> • Describe how polygenic, polymorphic and co-dominant MHC expression allows recognition of a diverse array of antigens • Predict the consequence of a decrease in HLA/MHC diversity in a population in regards to pathogen outbreak

	3.3.2. Permanent genetic changes drive the specificity of antigenic receptors	<ul style="list-style-type: none">• Describe how somatic hypermutation and selection increases antibody affinity over the course of an immune response• Describe the process of V(D)J recombination in T-Cell Receptor and B-Cell Receptor generation
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4. Pathways and Transformation of Energy and Matter

Immune system processes change based on chemical transformation pathways and are governed by the laws of thermodynamics

4.1. Immune system activation is an energy-intensive process that can influence and can be influenced by other metabolic demands (e.g., stress, malnutrition, reproduction, circadian rhythm disruption, exercise etc.)	4.1.1. Cells of the immune system utilize biochemical pathways for transport, synthesis and breakdown of nutrients and macromolecules	<ul style="list-style-type: none">• List the bioenergetic demands of an immune cell• Compare and contrast the bioenergetic and biosynthetic needs of a naïve (quiescent) B lymphocyte and a plasma cell
	4.1.2. Alteration of a biochemical pathway in an immune cell can affect the duration and intensity of an immune response	

5. Evolution

The diversity in immune systems evolves over time by the process of genetic change and selection

5.1. Immune defenses vary based on organismal complexity	5.1.1. Immune defenses adapt under selective pressure at micro and macro levels	<ul style="list-style-type: none">• Compare and contrast the molecular mechanisms against viral infection, in bacteria versus the humans• Describe the mechanisms of seasonal antigenic shift and drift in the influenza virus and how that influences immunological memory• Describe how B lymphocyte specificity evolves over the course of a primary immune response• Explain how sub-populations of cells within a tumour microenvironment evolve to bypass immune surveillance• Create a phylogenetic tree depicting the evolution of immunoglobulin domain• Explain how sickle cell anemia-associated allele is advantageous in certain human populations
	5.1.2. Immune defenses can be conserved between ancestral and derived organisms	
	5.1.3. Microbes and hosts dynamically co-evolve	

Key Competencies

Key Competency	Illustrative Skills	Sample Learning Objectives
1. Process of science	1.1. Locate and vet peer-reviewed articles pertaining to immunology	<ul style="list-style-type: none"> Compare the information in an immunology- related news article with the original scientific source Compare the relative level of scientific evidence provided by: a primary research article, a systematic review, and a meta-analysis on an immunological topic
	1.2. Critically analyze key findings and experimental design within primary immunology literature	<ul style="list-style-type: none"> Identify the most critical data that supports the main findings in an immunology research article Identify the sources of implicit bias within experimental designs in immunological literature
	1.3. Design an experiment to address an immunology-based research problem	<ul style="list-style-type: none"> Write a mock research grant proposal to address an immunological question
2. Relationship between science and society	2.1. Identify inaccuracies in popular media about immunological topics that are consumed and shared by the lay public	<ul style="list-style-type: none"> Determine the scientific accuracy of a social media post (e.g., a meme, a blog article, a video) about the immune response against a pandemic virus
	2.2. Discuss the impact of immunological research on society	<ul style="list-style-type: none"> Describe how cancer immunotherapies have impacted public perceptions of the disease Design an advocacy poster to address the societal and ethical implications of vaccination programs Discuss the sources of implicit bias that may impact immunological research

3. Communicate and collaborate with others	3.1. Present an immunological topic to a varied audience	<ul style="list-style-type: none"> • Create and present a poster about recent immunological findings to peers and disciplinary experts • Write a blog article about recent immunological findings for the general public
	3.2. Contribute within a team to move a task forward	<ul style="list-style-type: none"> • Collaboratively write a white paper that addresses an immunology related real-world problem
	3.3. Contribute within a team to promote a positive environment	<ul style="list-style-type: none"> • Describe your approach to gather and give feedback, and achieve consensus within your team • Reflect on and articulate your own and your teammates' contribution to an immunology-related project
	3.4. Demonstrate an ability to manage conflict	<ul style="list-style-type: none"> • Use active-listening techniques within a role-play situation to mediate a health-related conflict
4. Quantitative reasoning	4.1 Apply statistics to analyze immunological data	<ul style="list-style-type: none"> • Choose an appropriate statistical test to analyze an immunological data set and justify your choice
	4.2 Interpret different types of graphical representation of immunological data	<ul style="list-style-type: none"> • Interpret a flow cytometry histogram
	4.3 Draw meaningful conclusions from an immunology-related data set	<ul style="list-style-type: none"> • Compare your interpretation of the data in a figure from an immunological research paper with conclusions drawn by the authors

5. Perform basic lab procedures	5.1 Use standardized safety practices in an immunological laboratory	<ul style="list-style-type: none"> • Demonstrate competence in federal and institutional regulatory protocols (e.g., Biosafety levels, IACUC, OSHA, IRB)
	5.2 Use standardized technical practices in an immunological laboratory	<ul style="list-style-type: none"> • Demonstrate competence in using basic lab equipment (e.g., pipettes, autoclave and centrifuges) and methodologies (e.g., aseptic technique, use of appropriate Personal Protective Equipment, dilution, lab math, animal handling, general chemistry skills, basic microscopy)
	5.3 Use standardized record-keeping practices in an immunological laboratory	<ul style="list-style-type: none"> • Document and report on experimental protocols, results and conclusions in a lab notebook

6. Explain and/or perform laboratory methodology to address an immunology-based research question	6.1 Identify and/or isolate immune cells	<ul style="list-style-type: none"> • Identify specific leukocyte populations on a fixed blood smear slide • Explain how to isolate naive T lymphocytes from a mouse spleen
	6.2 Measure effector functions of immune components	<ul style="list-style-type: none"> • Measure phagocytic uptake by immune cells using a fluorescence-based assay • Explain how antigen-specific lymphocytes can be tracked in an organism using flow cytometry or intravital microscopy
	6.3 Detect the presence of an antigen or an antibody	<ul style="list-style-type: none"> • Use an immunoassay to detect the presence of a cytokine in a cell culture supernatant • Use a hemagglutination assay to determine blood types
	6.4 Measure the immune response upon manipulation of an experimental system	<ul style="list-style-type: none"> • Compare the immune response of a wild type and a genetically modified organism against a pathogen • Predict/assess the effect of a drug on the immune response of <i>Arabidopsis</i> to a pathogen
	6.5 Use modeling/simulation for an immunology-based investigation	<ul style="list-style-type: none"> • Use a computer-based model for HIV infection to determine the lifespan of infected cells • Compare and contrast immune system organization in a model organism (e.g., <i>Caenorhabditis elegans</i>, zebrafish, <i>Drosophila</i>, <i>Arabidopsis</i>) to humans