

Lecture 1 Immunology 3^{ed} stage of Biology Department

1. Introduction: What Is Immunology?

Immunology is the branch of biomedical science concerned with the structure and function of the immune system — the body's defense network against infection, disease, and internal threats such as cancer. Because it sits at the intersection of microbiology, cell biology, genetics, and clinical medicine, immunology has grown from a narrow study of infectious disease resistance into a field that underpins vaccine design, cancer therapy, organ transplantation, and the treatment of allergic and autoimmune conditions.

2. A Historical Overview of Immunology

The history of immunology can be told as a series of puzzles: scientists repeatedly observed that the body could somehow "remember" past encounters with disease, long before anyone could explain how. The table below traces the discipline from its earliest recorded observation to some of the discoveries shaping immunology today.

Year	Key Figure(s)	Contribution to Immunology
c. 430 BCE	Thucydides (Athens)	First written observation that survivors of plague did not contract the same illness twice — the earliest recorded concept of acquired immunity.
10th century CE onward	Variolation practitioners (China, India, Ottoman Empire)	Deliberate exposure to material from smallpox lesions to induce mild disease and future protection — a precursor to vaccination.
1796	Edward Jenner	Demonstrated that inoculation with cowpox protected against smallpox, coining the term "vaccination" (from vacca, cow) and founding the scientific practice of immunization.
1880s	Louis Pasteur	Developed attenuated vaccines for chicken cholera, anthrax, and rabies, establishing that immunity could be induced artificially with weakened pathogens.
1882	Élie Metchnikoff	Discovered phagocytosis, proposing that specialized cells (phagocytes) engulf and destroy invading microbes — the foundation of cellular immunity.
1890	Emil von Behring & Kitasato Shibasaburō	Showed that serum from immunized animals could transfer protection against diphtheria and tetanus, introducing the concept of antitoxins (antibodies) and humoral immunity.
1897	Paul Ehrlich	Proposed the "side-chain theory" of antibody formation, introducing the concept of receptor specificity between antibody and antigen.
1900	Karl Landsteiner	Discovered the ABO blood group system, demonstrating individual antigenic variation and laying groundwork for transfusion immunology.

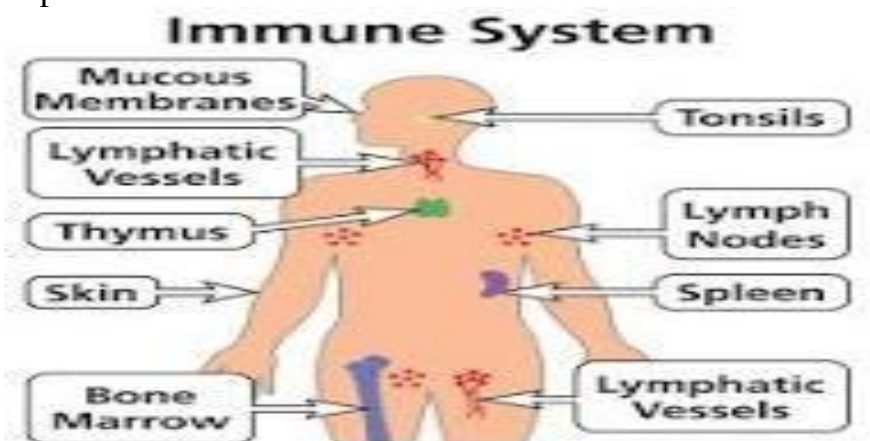
The immune system is not a single organ but a distributed network of cells, tissues, organs, and molecules that constantly patrol the body, communicate with one another, and coordinate a response whenever a threat is detected. For this network to function, it must accomplish several demanding tasks simultaneously: distinguish the body's own healthy cells ("self") from foreign or abnormal material ("non-self"), recognize an almost unlimited diversity of possible pathogens, respond quickly enough to limit damage, and — in its more sophisticated branch — remember past encounters so that future responses are faster and stronger. Today's lecture lays out the overall architecture of this system before we examine each component in depth over the coming weeks.

The Three Lines of Defense

A useful way to organize the entire immune system is as three sequential lines of defense, each engaged only if the previous line is breached.

Line of Defense	Components	Key Feature
1st line — Physical/chemical barriers	Skin, mucous membranes, secretions (mucus, tears, saliva, gastric acid), normal microbiota	Non-specific; prevents entry of pathogens; always active
2nd line — Innate immune response	Phagocytes (neutrophils, macrophages), NK cells, complement system, inflammation, fever	Non-specific but rapid (minutes-hours); no memory
3rd line — Adaptive immune response	B lymphocytes (antibodies), T lymphocytes (helper and cytotoxic)	Highly specific; slower to develop (days) but generates immunological memory

Notice that the first two lines are grouped together as innate immunity — present from birth and ready to act immediately — while the third line, adaptive immunity, must be built specifically for each new threat and therefore takes longer to mobilize on first exposure.



Two Major Divisions: Innate vs. Adaptive Immunity

Although innate and adaptive immunity work together, they differ fundamentally in how they recognize threats and how they improve (or don't) with repeated exposure.

Feature	Innate Immunity	Adaptive Immunity
Speed of response	Immediate to a few hours	Days (first exposure); hours (memory response)
Specificity	Broad; recognizes shared microbial patterns	Highly specific to a single antigen/epitope
Diversity of receptors	Limited, germline-encoded (fixed)	Enormous, generated by gene rearrangement
Memory	None (classically)	Yes — hallmark feature (faster, stronger 2nd response)
Key cells	Phagocytes, NK cells, dendritic cells, mast cells	T lymphocytes, B lymphocytes, plasma cells
Key molecules	Complement, cytokines, pattern-recognition receptors	Antibodies, T-cell receptors

Organs and Tissues of the Immune System

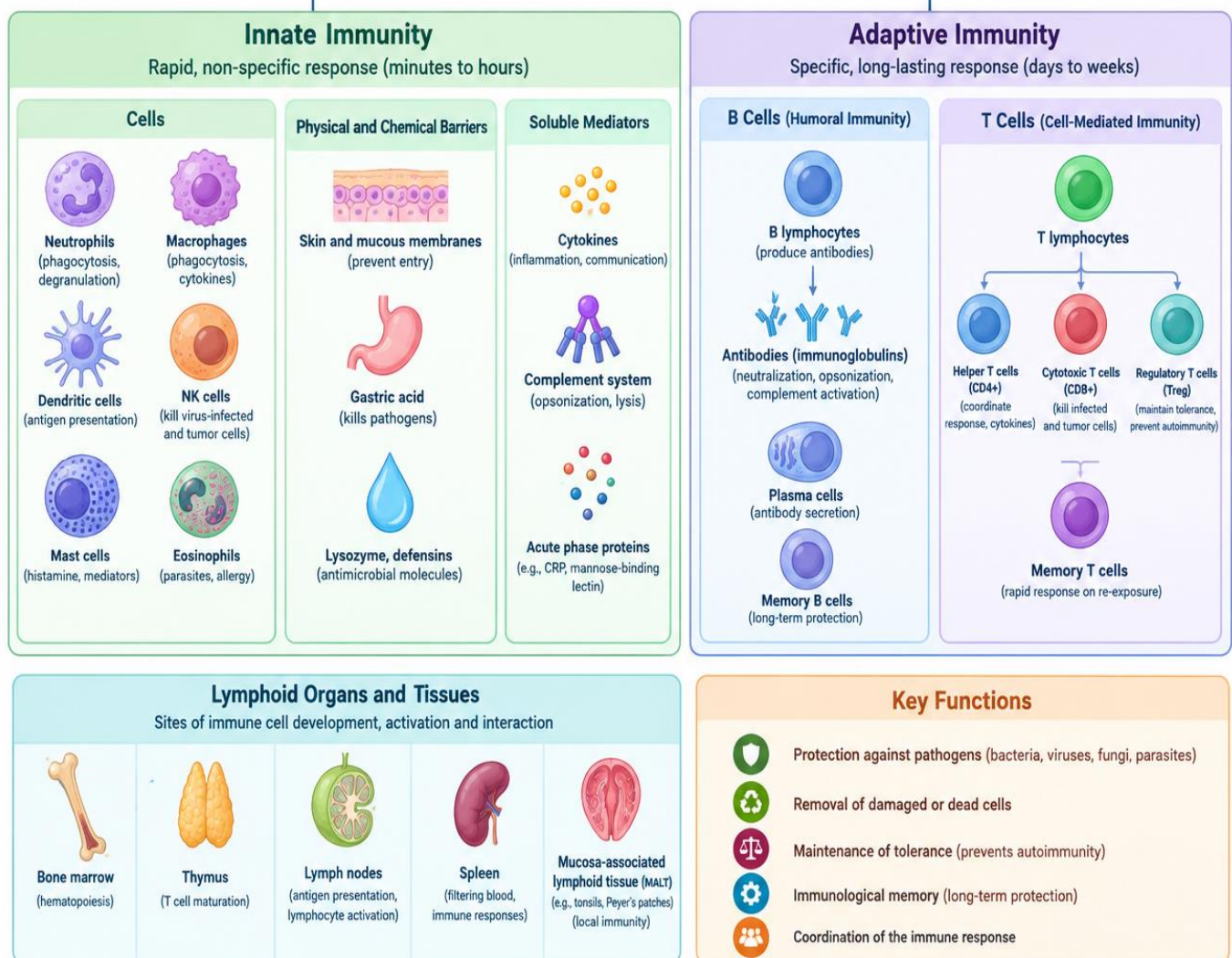
The organs of the immune system are traditionally divided into primary (central) lymphoid organs, where immune cells are generated and mature, and secondary (peripheral) lymphoid organs, where mature cells encounter antigen and mount a response.

Organ / Tissue	Classification	Primary Function
Bone marrow	Primary (central)	Site of haematopoiesis (origin of all immune cells); site of B-lymphocyte maturation
Thymus	Primary (central)	Site of T-lymphocyte maturation and selection
Lymph nodes	Secondary (peripheral)	Filter lymph draining from tissues; site where adaptive immune responses are initiated
Spleen	Secondary (peripheral)	Filters blood; mounts immune responses to blood-borne antigens; removes aged red blood cells
MALT / GALT	Secondary	Mucosa-associated lymphoid

Organ / Tissue	Classification	Primary Function
(tonsils, Peyer's patches, appendix)	(peripheral)	tissue protecting the respiratory, digestive, and urogenital tracts

Components of the Immune System An Overview

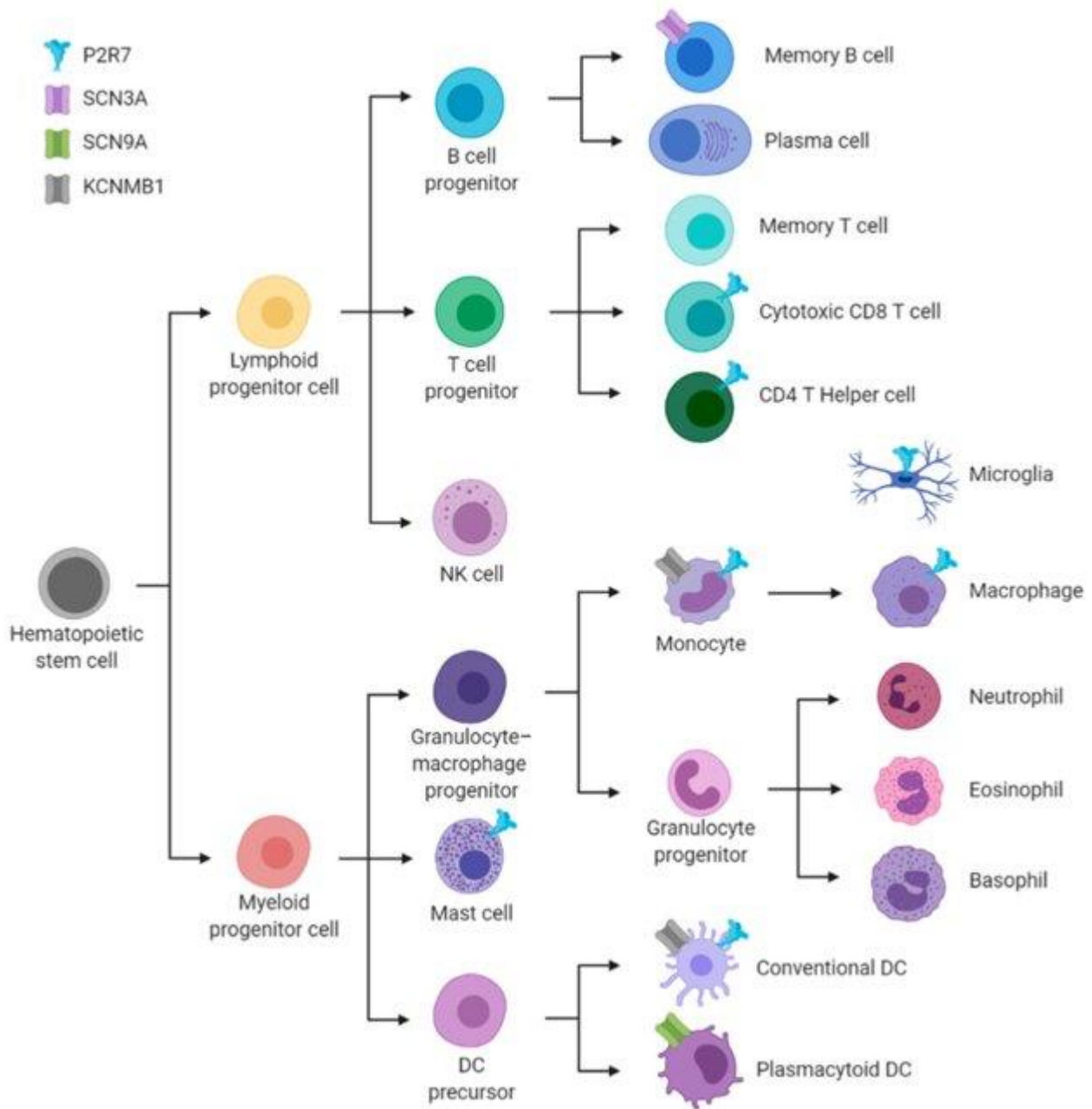
The immune system is a complex network of cells, molecules and organs that work together to protect the body from pathogens, remove damaged cells and maintain homeostasis.



Innate and adaptive immunity work together to provide effective and lasting protection.

Cells of the Immune System

All immune cells arise from a single type of progenitor in the bone marrow: the haematopoietic stem cell (HSC). This stem cell gives rise to two major lineages — the myeloid lineage, which includes most cells of innate immunity, and the lymphoid lineage, which includes the lymphocytes central to adaptive immunity (as well as NK cells, an innate lymphocyte). The table below summarizes the principal cell types you will encounter throughout this course.



Cell Type	Lineage	Main Function
Neutrophil	Myeloid (granulocyte)	First-responder phagocyte; abundant in acute bacterial infection
Macrophage	Myeloid	Phagocytosis; antigen presentation; tissue repair; cytokine release
Dendritic cell	Myeloid	Captures antigen at peripheral tissues and presents it to T cells — the key bridge to adaptive immunity
Mast cell	Myeloid	Releases histamine and mediators of inflammation and allergic responses

Cell Type	Lineage	Main Function
Eosinophil	Myeloid (granulocyte)	Defense against parasitic (helminth) infections; involved in allergic reactions
Basophil	Myeloid (granulocyte)	Releases mediators of inflammation; involved in allergic and anti-parasitic responses
Natural killer (NK) cell	Lymphoid	Kills virus-infected and tumor cells without prior sensitization (innate)
T lymphocyte	Lymphoid	Cell-mediated immunity; helper (CD4+) and cytotoxic (CD8+) subtypes
B lymphocyte / Plasma cell	Lymphoid	Differentiates into antibody-secreting plasma cells (humoral immunity)

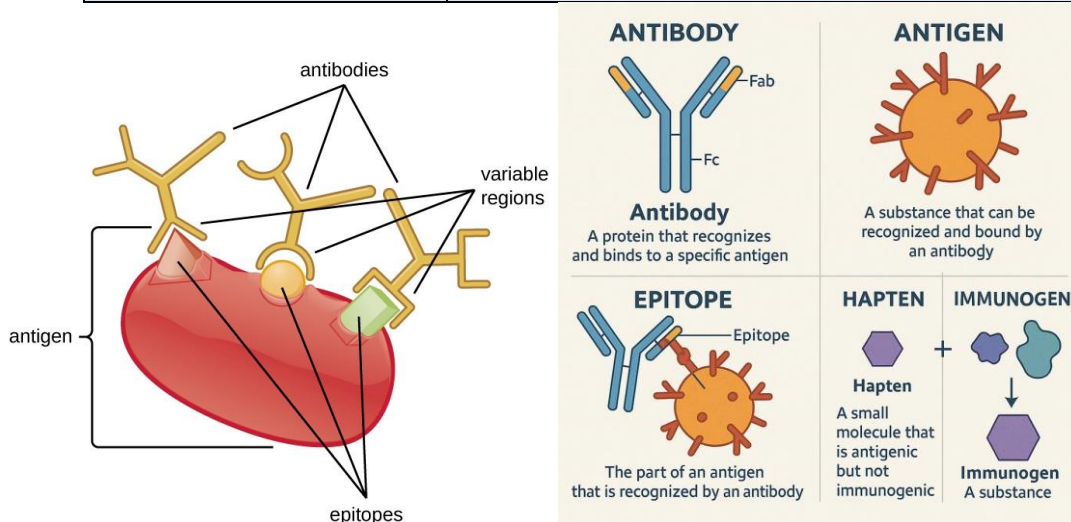
How Innate and Adaptive Immunity Work Together

Although presented as two separate systems for teaching purposes, innate and adaptive immunity are tightly interconnected, and neither functions well in isolation. Dendritic cells provide the clearest example of this connection: they patrol peripheral tissues as innate sentinels, capture antigen from an invading pathogen, and then migrate to the nearest lymph node, where they present that antigen to naive T lymphocytes — effectively switching on the adaptive response. Similarly, the complement system (an innate defense) can tag pathogens in ways that make them easier for antibodies to target, while cytokines released by innate cells during the initial response help determine what type of adaptive response (e.g., antibody-focused vs. cell-mediated) ultimately develops. Over the next several weeks, we will examine each of these components — innate mechanisms first, then the adaptive response — before returning to look more closely at how they integrate.

Foundational Terms

Term	Definition
Immunity	The capacity of an organism to resist and eliminate a potentially harmful foreign substance or organism, and to recognize and tolerate its own tissues.
Immune system	The integrated network of cells, tissues, organs, and molecules that together carry out immune responses.
Pathogen	Any microorganism or agent (bacterium, virus, fungus, parasite, prion) capable of causing disease.
Antigen	Any substance that can be specifically recognized by an antibody or a T-cell receptor; the term derives from "antibody generator."

Term	Definition
Immunogen	An antigen that is capable, on its own, of provoking an adaptive immune response (not all antigens are immunogenic).
Epitope (antigenic determinant)	The specific, small region of an antigen that is actually recognized and bound by an antibody or a lymphocyte receptor.
Antibody (immunoglobulin)	A Y-shaped protein produced by plasma cells that binds specifically to an antigen, helping to neutralize or mark it for destruction.



Mapping antigen classifications by origin and chemistry.

Basis of Classification	Type	Definition	Example
Origin relative to the host	Autoantigens (self-antigens)	The host's own molecules; normally ignored by the immune system, but targeted in autoimmune disease if tolerance breaks down	Thyroglobulin, myelin basic protein
	Alloantigens (isoantigens)	Antigens that differ between genetically distinct individuals of the same species	ABO blood group antigens, HLA/MHC molecules
	Heteroantigens (xenoantigens)	Antigens originating from a different species	Antigens on a pig heart valve used in xenotransplantation
	Exogenous antigens	Antigens that originate outside the host cell (e.g., from an extracellular	Bacterial toxins,

		pathogen); taken up and presented via MHC class II	extracellular bacteria
	Endogenous antigens	Antigens synthesized inside the host's own cells (e.g., by an intracellular pathogen or tumor); presented via MHC class I	Viral proteins made inside an infected cell
Chemical nature	Protein antigens	Highly immunogenic; complex 3D structure provides many distinct epitopes	Diphtheria toxin, viral surface glycoproteins
	Polysaccharide antigens	Repetitive sugar structures; typically weaker, T-independent immunogens	Bacterial capsular polysaccharides (e.g., <i>Streptococcus pneumoniae</i>)
	Lipid antigens	Usually poorly immunogenic on their own; often recognized via CD1 molecules rather than classical MHC	Mycobacterial cell-wall lipids
	Nucleic acid antigens	Weakly immunogenic alone; become clinically relevant as autoantigens	Anti-dsDNA antibodies in systemic lupus erythematosus
Dependence on T-cell help	Thymus-dependent (TD) antigens	Require T-helper cell cooperation to stimulate B cells; generate strong memory and class-switched antibodies	Most protein antigens
	Thymus-independent (TI) antigens	Can activate B cells directly without T-cell help; weaker memory response. Subtypes: TI-1 (polyclonal/mitogenic activators) and TI-2 (repetitive epitope arrays)	TI-1: bacterial LPS; TI-2: pneumococcal capsular polysaccharides
Immunogenic completeness	Complete antigens (immunogens)	Large enough and structurally complex enough to independently trigger an immune response	Most proteins and polysaccharides
	Haptens	Small molecules that are antigenic (can be bound by antibody) but not immunogenic alone — need to be coupled to a larger carrier protein to elicit a response	Penicillin, urushiol (poison ivy allergen)