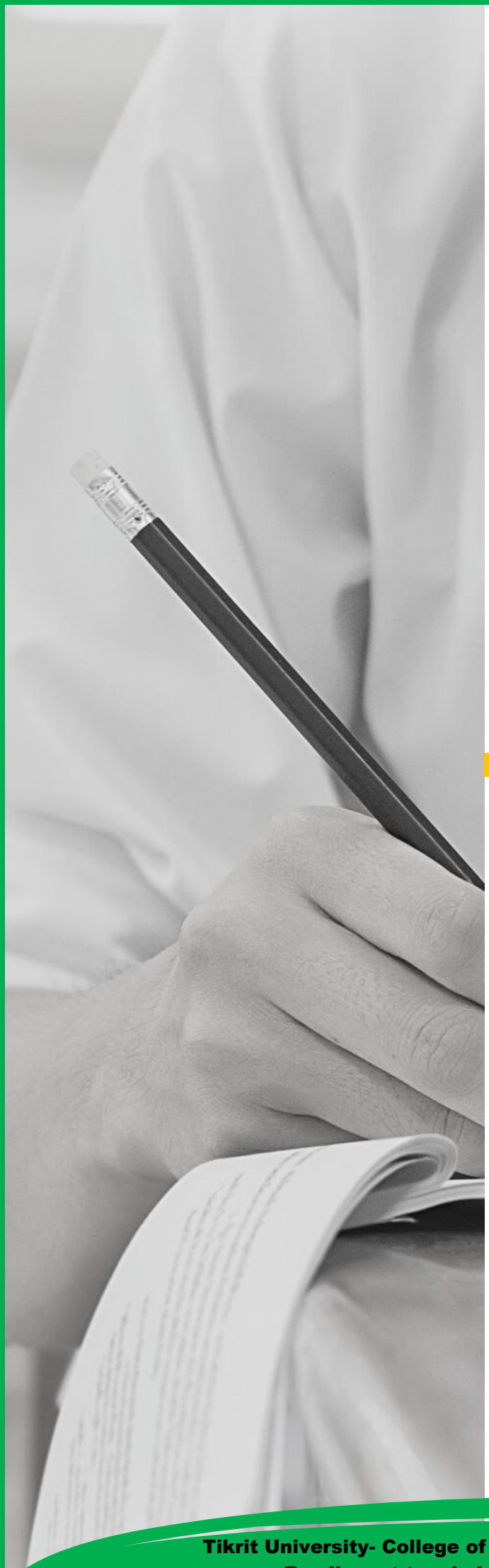

Tikrit University
College of Veterinary Medicine

Lecture Antigens and their Properties

Subject name: Immunology (Theoretical)
Subject year: Third Stage / 3rd Year

Lecturer name:
Prof.Dr.Bashar Sadeq Noomi
Assist.Prof.Dr. Agharid Ali Hussein
Academic Email:
vetbashae@tu.edu.iq
agharidalrasheed@tu.edu.iq

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2026-2025

Antigens and their Properties

I. Definition of Antigens

The adaptive immune system relies on highly specific receptors capable of recognizing almost all foreign macromolecules found in invading microorganisms. These foreign molecules are collectively referred to as **antigens**.

Antigens are substances—typically large biological molecules such as proteins or polysaccharides—present on the surface of pathogens (e.g., bacteria, viruses) or abnormal host cells. When introduced into the body, these molecules have the ability to **trigger an immune response** by activating B cells and T cells.

Importance of Antigens

Understanding antigen structure and behavior is essential for fields such as immunology, infectious disease, and vaccine development. Antigens serve as the primary "signature" through which the immune system distinguishes self from non-self, enabling recognition and targeted immune responses.

II. Types of Antigens

1. Based on Origin

A. Exogenous Antigens

These arise from outside the body and include components of bacteria, fungi, viruses, and parasites.

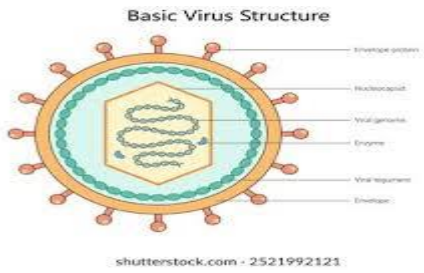
Viral Antigens

Most viruses possess a relatively simple structure consisting of:

- A **nucleic acid core**
- A surrounding **protein coat (capsid)** composed of repeating subunits called **capsomeres**
- Some viruses also possess an **envelope** made of lipoproteins and glycoproteins.

Capsid proteins and envelope glycoproteins are strong antigens, capable of stimulating robust antibody responses.

For example, the **The HN (Hemagglutinin-Neuraminidase) glycoprotein of Newcastle disease virus (NDV)** virus is highly immunogenic.



Bacterial Antigens

Major bacterial antigenic structures include:

- **Cell wall components**
- **Capsule**
- **Pili**
- **Flagella**

Gram-positive bacteria

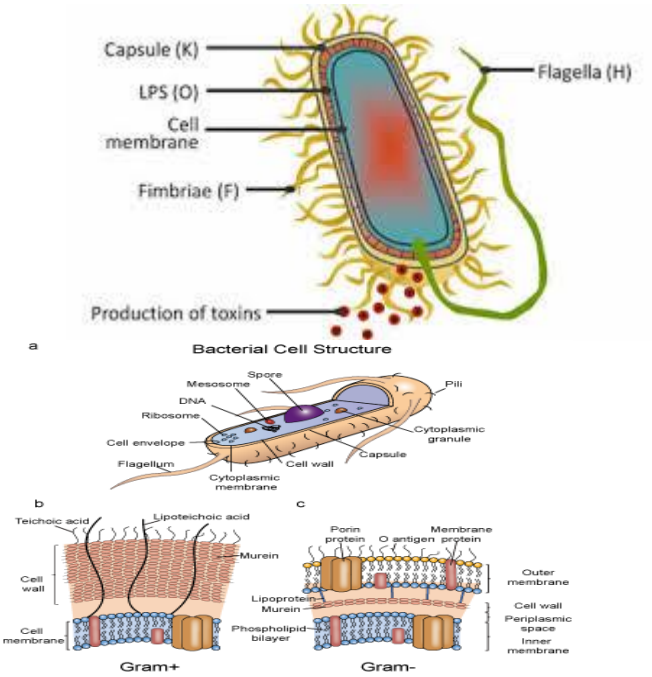
Their cell wall contains **peptidoglycan** and **lipoteichoic acids**, the latter having strong antigenic properties.

Gram-negative bacteria

Their outer membrane contains **lipopolysaccharide (LPS)**, composed of:

- **Lipid A**
- **Core oligosaccharide**
- **O-antigen** (repeating polysaccharide units)

The structure of O-antigens determines the antigenic specificity of the bacterium.



These molecules act as **pathogen-associated molecular patterns (PAMPs)** recognized by **pattern-recognition receptors (PRRs)** such as **Toll-like receptors (TLRs)**.

TLR activation—especially on antigen-presenting cells (APCs)—enhances maturation and promotes **Th1-type immune responses**.

Soluble Bacterial Antigens

Some bacteria release soluble products into their environment.

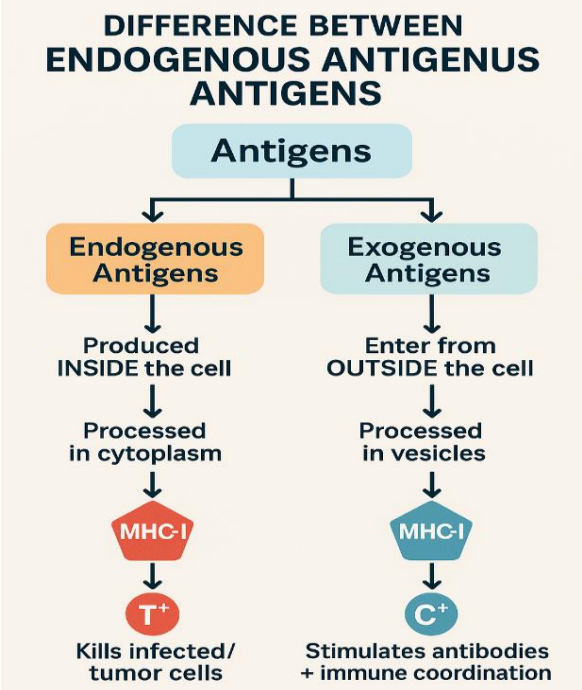
Example: **Clostridium tetani exotoxin**, a potent antigen

B. Endogenous Antigens

These originate within the body, usually due to:

- Viral infection of host cells
- Cellular metabolism
- Mutations leading to **tumor antigens**

Example: Cancer cells often express abnormal surface proteins that can be recognized as antigens.



Aspect	Endogenous Antigens	Exogenous Antigens
Source	Originate *inside* the cell	Come from *outside* the cell
Examples	Viral proteins produced inside infected cells, intracellular bacteria, tumor proteins	Bacteria, fungi, parasites, toxins, allergens
Processing Pathway	Processed in the cytoplasm and presented via MHC-I	Taken up by phagocytosis/endocytosis, processed in vesicles, and presented via MHC-II
MHC Class	**MHC Class I**	**MHC Class II**
Responding T Cells	Cytotoxic T cells **($CD8^+$)**	Helper T cells **($CD4^+$)**
Immune Outcome	Destruction of infected or abnormal cells	Activation of helper immunity: antibody production and cellular activation
Main Purpose	Eliminate infected or cancerous cells	Deal with microbes and materials coming from the external environment
Additional Feature	Can also be presented by "cross-presentation"	Usually processed only inside vesicles

2. Based on Immunogenicity

Immunogens

Not all antigens stimulate an immune response.

An **immunogen** is an antigen capable of inducing an immune response **on its own**.

Key points:

- All immunogens are antigens, but not all antigens are immunogens.
- Immunogens induce antibody production and cellular immunity.
- They are usually large, complex molecules with many epitopes.

Example: Whole pathogens such as the measles virus.

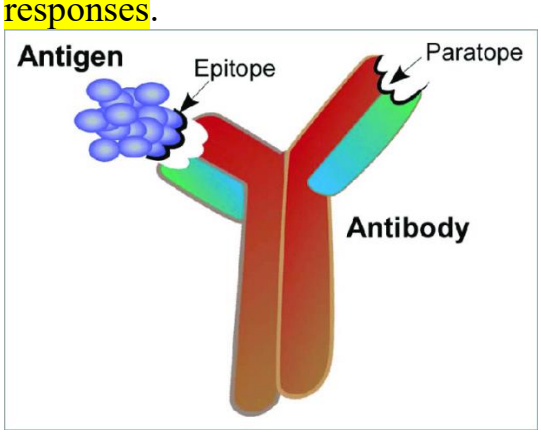
III. Structure of Antigens

Epitope (Antigenic Determinant)

An epitope is the specific region of an antigen recognized by:

- Antibodies
- B-cell receptors
- T-cell receptors (after processing and MHC presentation

One antigen may contain numerous epitopes, enabling multiple immune responses.



Multivalency

Most antigens possess multiple distinct epitopes (multivalent), enhancing their immunogenicity.

Immunodominance

Despite numerous potential epitopes, the immune system often focuses on only a few—referred to as **immunodominant epitopes**.

Immunodominance is the phenomenon where the immune system focuses on a limited number of antigens, or epitopes, from the many potential ones produced by a pathogen or other foreign substance.

These dominate the immune response and influence immunity and vaccine efficacy.

IV. Mechanism of Immune Response to Antigens

Steps of the Immune Response to Antigens

1. Antigen Entry

The antigen enters the body either from outside (exogenous) or forms inside infected cells (endogenous).

2. Antigen Capture

Specialized cells called antigen-presenting cells (APCs)—mainly dendritic cells, macrophages, and sometimes B cells—detect the antigen and engulf it.

3. Antigen Processing

APCs break the antigen into small peptide fragments.

• Endogenous antigens → processed in the cytoplasm

• Exogenous antigens → processed in vesicles

4. Antigen Presentation on MHC

The fragments are loaded onto major histocompatibility complex molecules:

• MHC-I presents endogenous antigens

• MHC-II presents exogenous antigens

The APC then displays this complex on its surface.

5. T-Cell Activation

T cells scan the presented antigen.

• $CD8^+$ cytotoxic T cells bind to MHC-I and become activated to kill infected cells

• $CD4^+$ helper T cells bind to MHC-II and become activated to coordinate the immune response

6. B-Cell Activation and Antibody Production

Activated helper T cells stimulate B cells.

B cells differentiate into plasma cells that produce specific antibodies targeting the antigen.

7. Effector Phase

The immune system eliminates the threat:

• Cytotoxic T cells destroy infected or abnormal cells

• Antibodies neutralize microbes, opsonize them, or activate complement

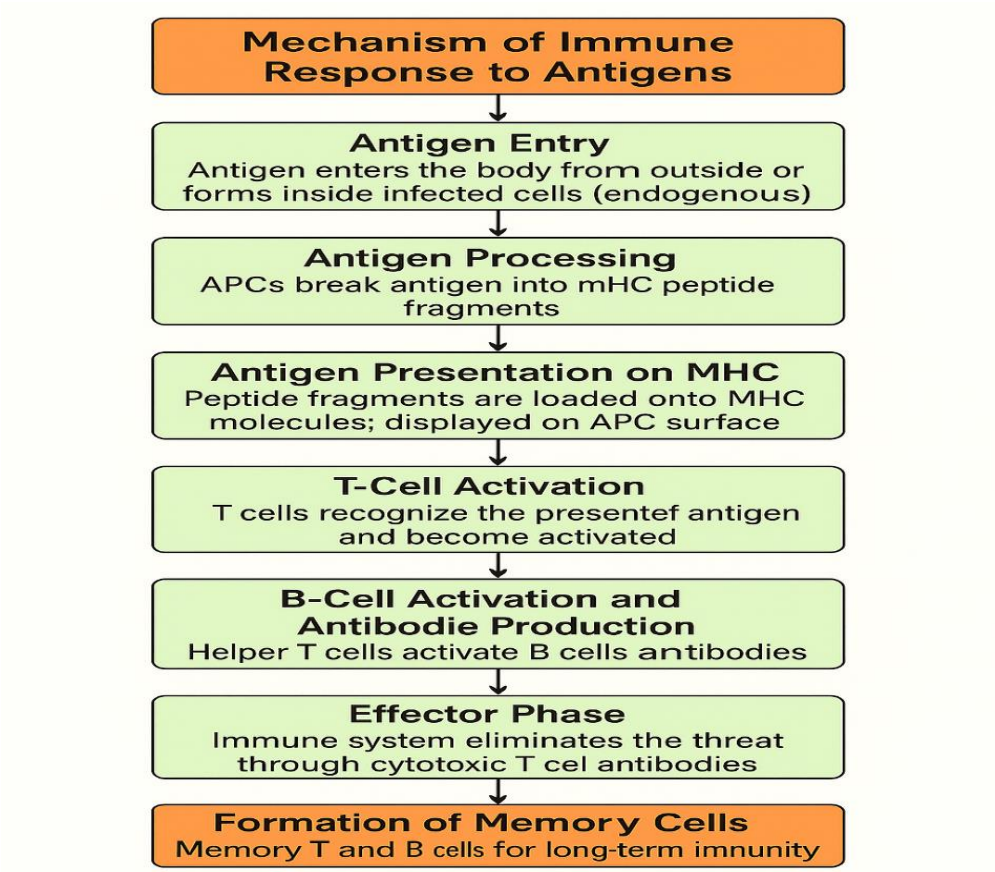
8. Formation of Memory Cells

Both T cells and B cells form long-lasting memory cells.

These provide faster and stronger responses during future exposure to the same antigen.

9. Resolution

Once the threat is controlled, regulatory mechanisms reduce the immune response to avoid unnecessary tissue damage.



V.

Clinical Relevance of Antigens

Autoantigens

Self-antigens mistakenly targeted in autoimmune diseases.

Example: Joint proteins in **rheumatoid arthritis**.

Tumor Antigens

Abnormal antigens on cancer cells serve as diagnostic markers or therapeutic targets.

Example: **CAR T-cell therapy**, where T cells are engineered to target specific tumor antigens.

VI. Haptens and Their Conjugates

Hapten:

A very small molecule that cannot trigger an immune response by itself.

Hapten–Carrier Conjugate:

When a hapten attaches to a large carrier protein, the combination becomes a complete antigen that *can* trigger a strong immune response.

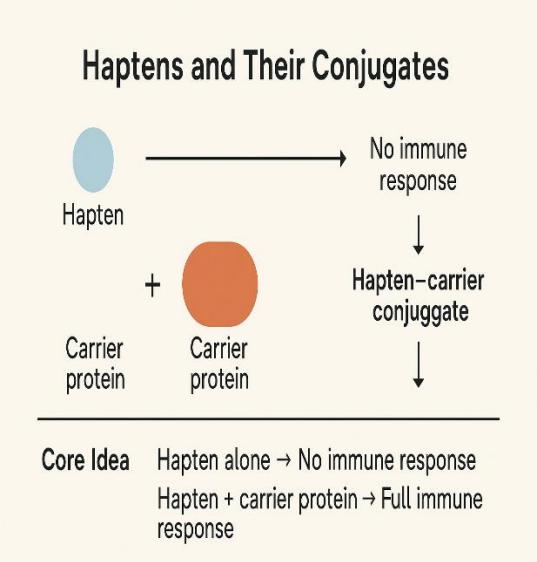
- **Hapten alone → No immune response**
- **Hapten + carrier protein → Full immune response**

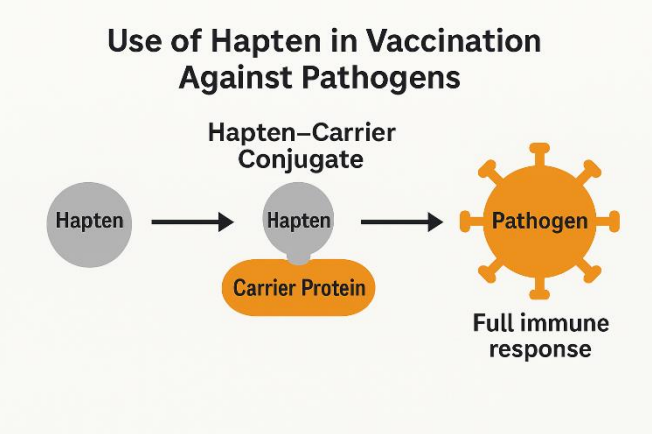
Why this happens

- **The carrier provides the signals needed to activate T cells.**
- **The hapten provides the small unique shape recognized by antibodies.**

Examples

- **Penicillin causes allergy only after binding to body proteins.**





VII. Characteristics of a Good Antigen

A molecule is considered a *good* antigen when it can strongly stimulate the immune system. These are the key features that make it effective:

1. High Molecular Weight

Large molecules (usually >10,000 Daltons) are easier for the immune system to recognize.

Bigger = more complex = more immunogenic.

2. Chemical Complexity

Molecules with complex structures—proteins, polysaccharides—stimulate stronger responses than simple ones.

More branches, folds, and shapes give the immune system more "handles" to grab.

3. Foreignness (Non-self)

The immune system reacts best to substances clearly different from the body's own molecules.

The more foreign, the stronger the response.

4. Structural Stability

A stable antigen keeps its shape long enough for immune cells to recognize and process it.

Unstable molecules fall apart too fast to induce immunity.

5. Degradability (Processability)

The antigen must be breakable into fragments so that antigen-presenting cells can process it and present peptides on MHC molecules.

If it can't be processed → no T-cell activation.

6. Protein Nature

Proteins are the best antigens because they are large, complex, degradable, and contain many epitopes.

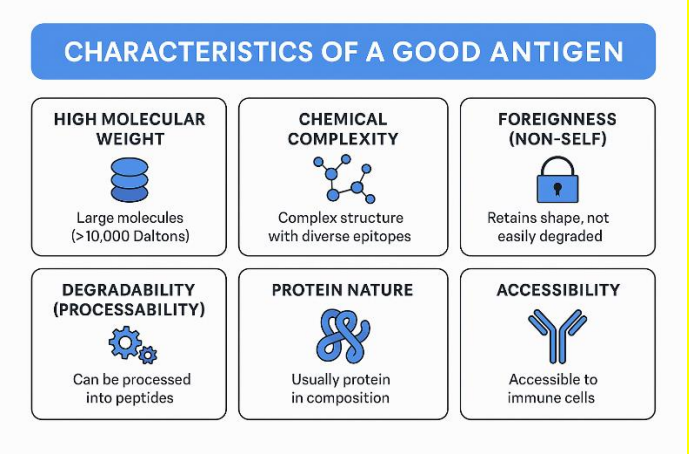
Carbohydrates are moderate; lipids and nucleic acids are usually weak unless combined with carriers.

7. Accessibility

The antigen must be exposed and reachable by immune cells or antibodies. Buried or hidden molecules are less effective.

A strong antigen is:

large, complex, foreign, stable, degradable, protein-like, and accessible.



8. Adjuvanticity

Certain antigens require **adjuvants** to enhance immunogenicity, especially in vaccines.

Examples of good antigens:

- Viral proteins such as **influenza hemagglutinin**
- Bacterial polysaccharides (e.g., capsules)
- Microbial toxins

VIII. Superantigens

Definition

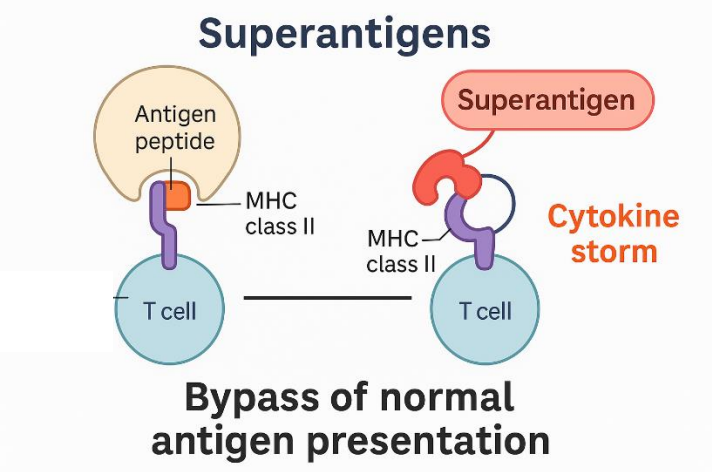
Superantigens are special microbial proteins and a unique class of antigens(**mostly from bacteria)** capable to **cause massive, non-specific activation of T cells, far beyond what a normal antigen could ever do**.

Characteristics

1. **Direct binding** to TCR and MHC-II(Bind outside the peptide-binding groove)
2. Do NOT require antigen processing
3. Activation of up to **20% of T cells**
4. Induction of **cytokine storm**, causing systemic inflammation, shock, or organ failure

Examples

- **Staphylococcal enterotoxins**
- **TSST-1** (Toxic Shock Syndrome Toxin-1)
- **Streptococcal pyrogenic exotoxins**



IX. Major Histocompatibility Complex (MHC)

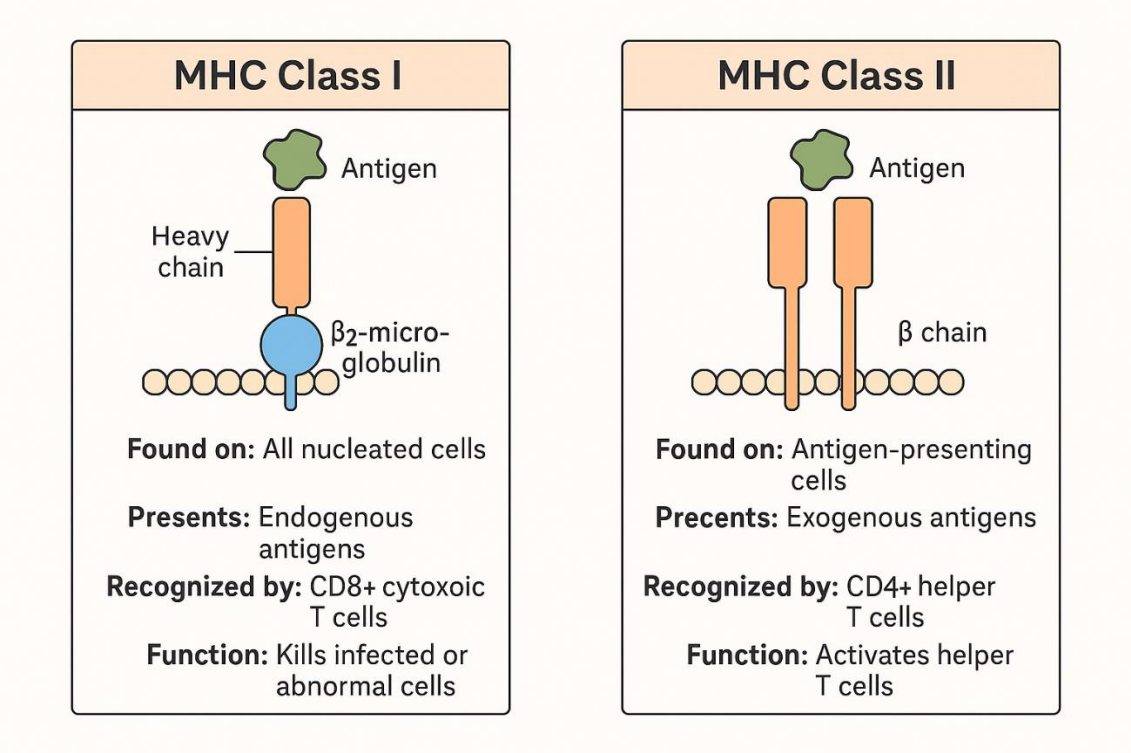
The MHC is essential for antigen presentation to T cells.

MHC Class I

- Present on all nucleated cells
- Present **endogenous antigens**
- Activate **CD8+ cytotoxic T cells**

MHC Class II

- Found only on professional APCs
- Present **exogenous antigens**
- Activate **CD4+ helper T cells**



X. Applications of Antigens

A. Vaccination

Vaccines rely on antigens to stimulate protective immunity without causing disease.
Example: Hepatitis B vaccine containing viral surface antigens.

B. Diagnostic Tests

Antigens are used in:

- Allergy testing
- Immunoassays (e.g., **ELISA**) for antigen or antibody detection