Vaccines immunology

The goal of an active immunization is to stimulate protective immunity and immunological memory. When active immunization is successful, a subsequent exposure produce heightened response, leading to the elimination of pathogen or prevention of the disease mediated by its products.

Vaccines protect by inducing effector mechanisms (cells or molecules) capable of rapidly controlling replicating pathogens or inactivating their toxic components.

Primary exposure of naïve T and B cells to pathogen or vaccine antigen results in a rapid increase in antigen-specific cells (T and B cells).

Most antigens and vaccines trigger B- responses, represented by antibody production ("humoral immunity") and T-cell responses ("cellular immunity").

An individual's first encounter with a particular immunogen leads to a relatively slow, sluggish short-lived response designated as **Primary response**. the titer of antibody is low, which does not persist longer and the antibodies formed are predominantly **IgM** in nature.

However, a portion of the antigen-specific cells (T and B cells) population survives and is maintained for long periods of time as **memory cells** in secondary lymphoid tissues and peripheral tissues.

These populations (T and B cells) rapidly expand or increase following reexposure to same antigen to generate thousands of progeny with the same specificity and are capable of providing protection and rapidly clearing the pathogen from the site of infection. This is known as **Secondary response** .

IgM may be transiently produced in the secondary response, but IgG production is increased considerably, making it the predominant antibody class.

However, *the mechanisms of vaccine protection may vary widely between different pathogens, different individuals, different doses of pathogen to which the individual is exposed and different routes of exposure .*

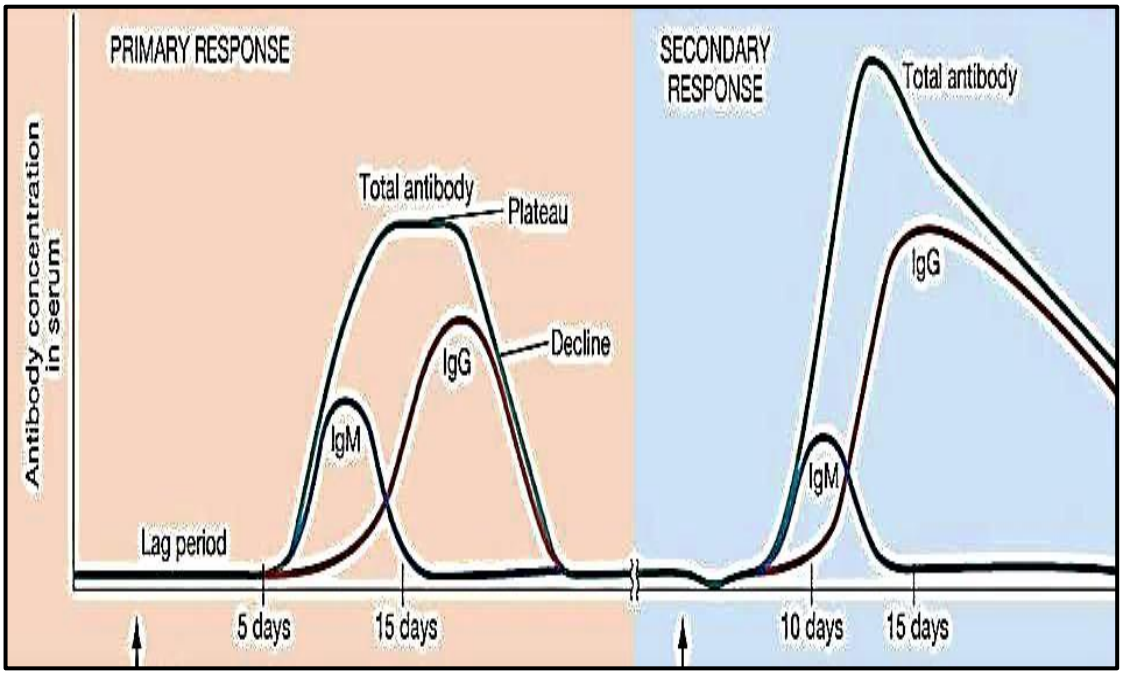

Figure -1-: Primary and secondary antibody responses

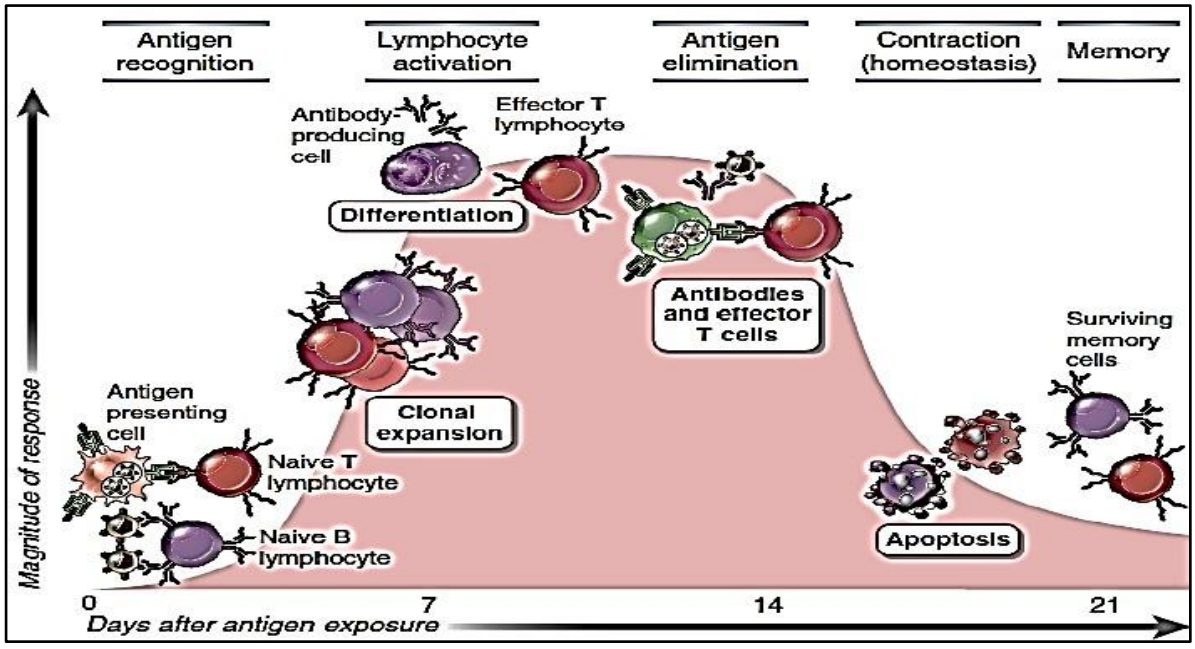

Figure -2: Development of adaptive immune responses.

❖ How Vaccines Work

1) Antigen Recognition:

Vaccines introduce antigens that are:

- Taken up by **antigen-presenting cells (APCs)**
- Processed and presented via **MHC molecules**.

2) T Cell Activation:

- MHC II → $CD4^+$ T helper cells.
- MHC I → $CD8^+$ cytotoxic T cells

3) B Cell Activation:

- With T helper cell assistance
- Differentiation into:
  - Plasma cells → antibody secretion
  - Memory B cells → long-term protection

4) Immune Memory

Vaccines stimulate the formation of:

- Memory B cells
- Memory T cells

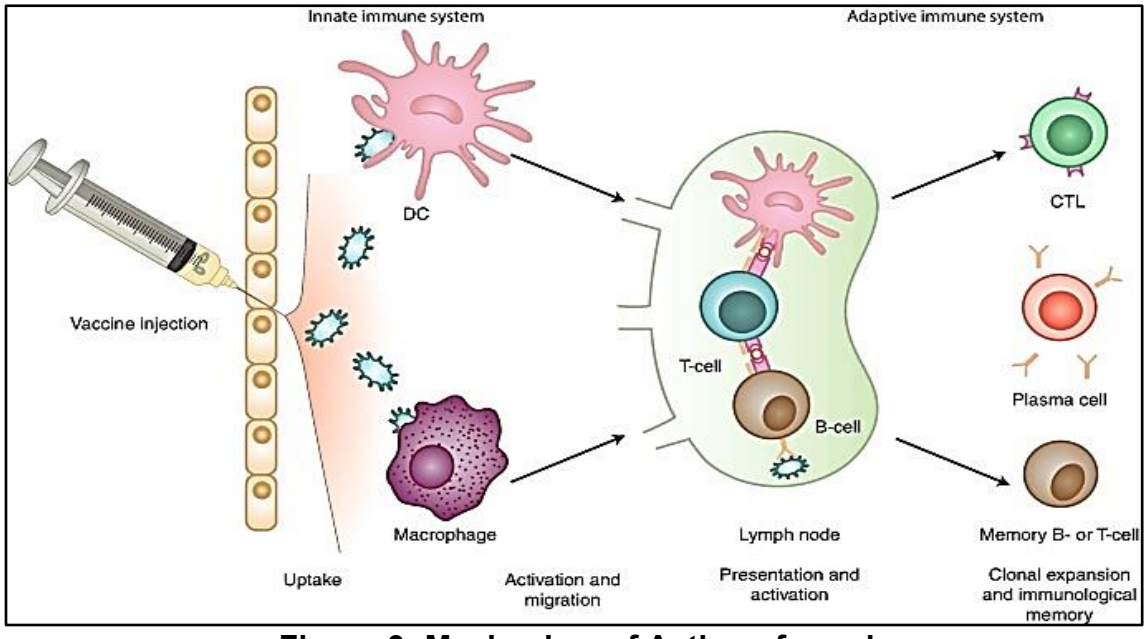

Figure-3 :Mechanism of Action of vaccines.

❖ Immunological mechanisms of vaccination.

Vaccine-induced immune effectors and the effector mechanisms triggered by vaccines summarized in the following :

1) **Humoral immunity in Vaccination (Antibodies)** :B lymphocytes recognize many different types of antigens and develop into antibody-secreting cells. **Antibodies** prevent or reduce infections by clearing extracellular pathogens through:

   a) Neutralization of viruses and toxins
   b) Opsonization → enhanced phagocytosis
   c) Complement activation
   d) Antibody-dependent cellular cytotoxicity (ADCC)

2) Cell-Mediated Immunity in Vaccination

A.CD4+ T cells (Helper T lymphocytes):

It do not prevent infection but participate in the reduction, control, Coordinate immune response and clearance of extracellular and intracellular pathogens by their cytokine-production capacities. Their main subsets include:

- **T-helper 1** (Th1) effector cells producing interferon (IFN)-γ, tumor necrosis factor (TNF) , IL-2, and mainly involved in protection against intracellular pathogens (Viruses, *Mycobacterium tuberculosis*) through activating macrophage and $CD8^+$ cytotoxic T cells.
- **Th2** effector cells producing IL-4, IL-5, IL-13, and responding to extracellular pathogens (bacteria and Helminthes) by activating B cells.

B.CD8 + T cells : It do not prevent infection but reduce, control, and clear intracellular pathogens by:

- Destroy virus-infected cells (release of perforins, granzymes, etc.).
- Indirectly killing infected cells through antimicrobial cytokine release.

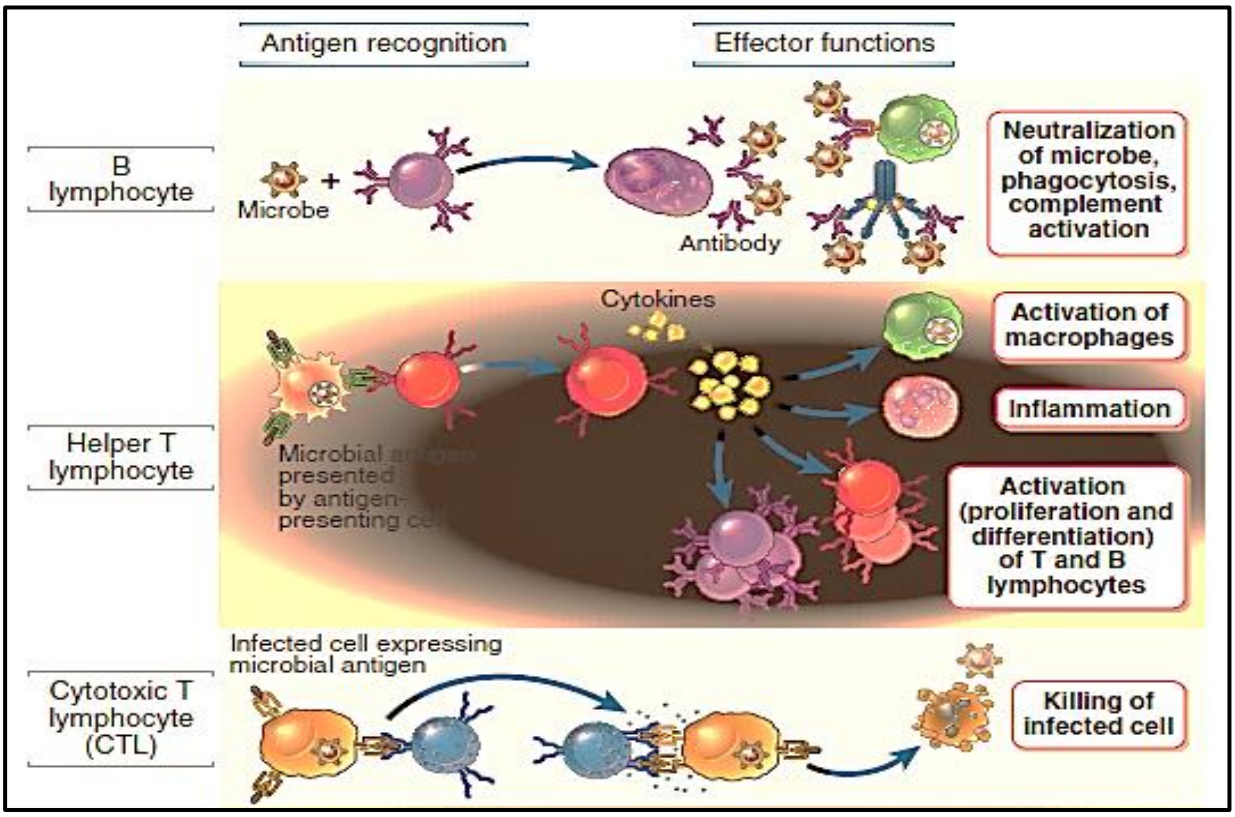

Figure-4:Classes of lymphocytes induced by immunization .

❖ Factors Affecting Vaccine-Induced Immunity

1) Host Factors

- Age (infants, elderly)
- Nutritional status
- Immune competence
- Genetics

2) Vaccine Factors

- Vaccine type
- Dose
- Route of administration
- Adjuvants

3) Environmental Factors

- Storage conditions
- Cold chain maintenance