6) Vaccines

I. Classification of Acquired Immunity

1. Passive Immunization

- **Definition**: Refers to the transfer of **"ready-made" antibodies** from one individual to another.
- **Natural**: Occurs via **transplacental transfer** of maternal antibodies to the fetus, or through **colostrum and breast milk** rich in IgA.
- **Artificial**: Induced by injecting a recipient with **exogenous antibodies** targeted to a specific pathogen or toxin.
- **Key Characteristics**: It provides immediate protection but is **not long-lasting** because it does not generate an immune response in the host.
- **Examples**: Maternal antibodies against **measles, rubella, and tetanus**; **IVIG** used for immunodeficiency; specific antibodies for treating acute infections like **rabies**.

2. Active Immunity

- **Definition**: The process of **exposing the body to an antigen** to generate an **adaptive immune response**.
- **Natural**: Occurs through **infection** with a wild pathogen and subsequent recovery, **hepatitis A virus (HAV)**
- **Artificial**: Occurs through administration of **vaccines** containing weakened or inactive pathogens.**administration of two doses of hepatitis A vaccine**
- **Key Characteristics**: The response takes **days/weeks to develop** but is **long-lasting—even lifelong**.

II. Principles of Vaccination

- **Aim**: To induce a **protective immune response** to a targeted pathogen without the risk of disease or complications.
- **Mechanism**: Antigens induce **cell-mediated immunity** by activating specific **T lymphocytes** and **humoral immunity** by stimulating **B lymphocytes** to produce antibodies.
- **Immunological Memory**: Established after the elimination of the pathogen, allowing for rapid response upon re-exposure.
- **Adjuvants**: Substances added to **enhance and modulate the immunogenicity** of the antigen.
    - They activate **innate immune responses** to broaden or extend memory.
    - Usually **not needed for live attenuated vaccines** as they replicate and self-enhance the response.
    - **Aluminium salts (alum)** are the most widely used globally.

III. Main Vaccine Categories

1. Live Attenuated Vaccines

- **Nature**: Contain pathogens **weakened, altered, or selected** to be less virulent than wild-type counterparts.
- **Production**: Often achieved through **serial passage** in cell cultures (e.g., chick embryos), where the virus loses its ability to replicate in humans.
- **Pros**: Induce robust responses and confer **long-term immunity** often after one or two doses.
- **Cons**: **Contraindicated in immunocompromised individuals**.
- **Examples**: **Measles, mumps, rubella, varicella (MMR/V), BCG (bacterial), and Oral Polio Vaccine (OPV).**

2. Non-live (Inactivated) Vaccines

- **Nature**: Do **not contain living or infectious particles**; cannot cause disease or reactivate.
- **Safety**: Excellent safety profile, even for **immunocompromised individuals**.
- **Pros/Cons**: Less immunogenic than live vaccines; usually require **repeated doses (prime-boost principle)** or adjuvants.
- **Subtypes**:
    - **Inactivated Whole Pathogen**: Killed by heat, radiation, or chemicals like **formalin** (e.g., **IPV, rabies,whole-cell pertussis, Hepatitis A).**
    - **Subunit Vaccines**: Contain **selected fragments** (proteins/polysaccharides). Examples:**HBsAg**, **tetanus toxoid, inactivated split and subunit seasonal influenza, acellular pertussis and pneumococcal polysaccharide vaccines**
    - **Toxoid Vaccines**: Produced by **detoxifying pathogenic toxins**. They induce **toxin-neutralizing antibodies** (e.g., **tetanus, diphtheria**).
    - **Conjugate Vaccines**: Purified **polysaccharides** are coupled to a **protein** to transform a T-cell-independent response into a **T-cell-dependent response** to induce memory. (eg:**Streptococcus pneumoniae, Haemophilus influenzae type b and N. meningitidis**)

IV. Advanced Concepts

- **Herd Immunity**: Indirect protection that occurs when a **large percentage of a population** becomes immune, making it difficult for a contagious disease to spread.
- **Toxoid Limitation**: Toxoids protect against disease pathogenesis but **do not prevent infection or transmission**, so they do not provide herd protection.
- **Newer Platforms**: **Nucleic acid vaccines (mRNA/DNA)** enter cells and serve as a template for the cell to synthesize protein antigens itself.

V. Summary Comparison Table

Feature	**Passive Immunity**	**Active Immunity**
Source of Antibodies	Received from another (ready-made)	Produced by host's own system
Exposure to Antigen	No	Yes
Onset of Protection	**Immediate**	**Delayed** (days/weeks)
Duration of Protection	**Short-term** (months)	**Long-term/Lifelong**
Memory Cells	None	**Present** (Immunological Memory)
Natural Example	Breast milk, Placenta	Infection and recovery
Artificial Example	Antibody injection (IVIG)	Vaccination