Types of vaccines and Antigen

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1) Live vaccines:

• Live microorganisms are attenuated by different methods.

• Attenuation results in the loss of pathogenicity without the loss of antigenicity of the microorganisms.

• Hence, it produces an infection but does not result in disease or injury.
Ex: Anthrax vaccine, Sabin vaccine (oral)

2) Killed vaccine:

• The microorganisms are killed in their virulent phase either by heat or antiseptics.

• While killing, care is taken not to denature the antigen by excessive heat or strong detergents.

• Its dead cells are introduced into the body.

• Even though the pathogen is dead, the immune system can still learn from its antigens how to fight live versions of it in future.

• Killed vaccines are short lived (less immunogenic) and it may require booster dose.

Ex: Salk vaccine, influenza virus vaccine.

3) Toxoid vaccine:

• Toxoids are preparations of toxins inactivated by formalin.

• They retain the antigenic potency and thus like toxins, toxoid can induce antitoxin formation.

Ex: Tetanus toxoid, Diphtheria toxoid

❖ Passive immunity:

• Immunity resulting from the transfer of antibodies or immune cells from an immune to a non-immune individual is known as passive immunity.

• The host cannot produce antibodies or resistance.

• It is less effective than active immunity.

a) Natural passive immunity:

• The development of resistance in foetus by the transfer of antibodies from the mother to the foetus naturally is known as natural passive immunity.

• It occurs mainly by the passage of antibodies from the mother to her unborn child through the placenta during later part of pregnancy.

• Mainly, IgG crosses the placenta.

• Human colostrum is rich in IgA antibodies.

• New born babies can absorb these immunoglobulins directly.

❖ Artificial passive immunity:

• The development of resistance in a patient by transferring antibodies or immunized lymphocytes from a donor is known as artificial passive immunity.

Artificial passive immunity is brought by following methods:

▪ Hyperimmune serum of animal or human origin:

• The serum prepared by injecting antigen from immunized man or animal is called hyperimmune serum.

• ATS (antitetanus serum) – prepared by repeated administration of tetanus toxoid to horses.
• Serum is collected by bleeding the horses.
• Now, human volunteers are used because its effect is long lasting.

▪ Convalescent serum:

• Serum collected from recovering patients contains high amount of antibodies against specific antigen.
• This serum is used in passive immunization against viral infections such as measles and rubella.

▪ Pooled sera from different healthy individuals:

• Sera of healthy adults contain antibodies against the infectious microorganisms commonly prevalent in that community.

• Sera from large number of such healthy adults in that community are collected.

▪ Combined immunization:

• Non-immune individual if suffered from tetanus wound then ATS given in one arm and tetanus toxoid in other arm for long lasting protection.

Difference between active and passive immunity

Active immunity	Passive immunity
• Exposure to antigen	• No exposure to antigen
• Immunity achieved by injecting antigens	• Immunity achieved by injecting antibodies
• Activation of immune system	• No immune system activation
• Immune cells develops over a period of weeks	• Immunity develops immediately
• Immunological memory develops	• No immunological memory develops

Difference between innate and adaptive immunity

Attribute	Innate immunity	Adaptive immunity
Specificity	Antigen non-specific	Antigen specific
Response time	Rapid response (hours)	Slow response (days)
Diversity	limited	Very high
Memory	absent	present
Major cell types	Phagocytes, NK cells and others	T and B cells, antigen presenting cells
Distribution	Found in vertebrates and invertebrates	Found only in jawed vertebrates.

ANTIGEN

- Adaptive immune responses arise as a result of exposure to foreign compounds.
- The compound that evokes the response is referred to as antigen, a term initially coined due to the ability of these compounds to cause antibody responses to be generated.
- An antigen is any agent capable of binding specifically to T-cell receptor (TCR) or an antibody molecule (membrane bound or soluble).
- The ability of a compound to bind with an antibody or a TCR is referred to as antigenicity.

• There is a functional distinction between the term antigen and immunogen.
• An immunogen is any agent capable of inducing an immune response and is therefore immunogenic.
• The distinction between the terms is necessary because there are many compounds that are incapable of inducing an immune response, yet they are capable of binding with components of the immune system that have been induced specifically against them.
• Thus all immunogens are antigens, but not all antigens are immunogens.

➢ Requirements for immunogenicity:

A substance must possess the following characteristics to be immunogenic:

❖ Foreignness:

• The most important feature of an immunogen is that an effective immunogen must be foreign with respect to the host.

• The adaptive immune system recognizes and eliminates only foreign (nonself) antigens.

• Self antigens are not recognized and thus individuals are tolerant to their own self molecules, even though these same molecules have the capacity to act as immunogens in other individuals of the same species.

❖ Size :

• The second requirement for being immunogenic is that the compound must have a certain minimal molecular weight.

• There is a relationship between the size of immunogen and its immunogenicity.

• In general, small compounds with a molecular weight <1000 Da (e.g. penicillin, aspirin) are not immunogenic; those of molecular weight between 1000 and 6000 Da (e.g. insulin, adrenocorticotropic hormone) may or may not be immunogenic; and those of molecular weight >6000 Da (e.g. albumin, tetanus toxin) are generally immunogenic.
• The most active immunogens tend to have a molecular mass of 100,000 Da or more. In short relatively small substances have decreased immunogenicity, whereas large substances have increased immunogenicity.

❖ Chemical complexity:

• The third characteristic necessary for a compound to be immunogenic is a certain degree of chemical complexity.
• For example, homopolymers of amino acids or sugars are seldom good immunogens regardless of their size.
• Similarly, a homopolymer of poly-γ-D-glutamic acid (the capsular material of Bacillus anthracis) with a molecular weight of 50,000 Da is not immunogenic.

• The absence of immunogenicity is because these compounds, although of high molecular weight, are not sufficiently chemically complex.

• Virtually all proteins are immunogenic.

• Furthermore, the greater the degree of complexity of the protein, the more vigorous will be the immune response to that protein.

• Carbohydrates are immunogenic only if they have a complex polysaccharide structure or part of complex molecules such as glycoproteins.

• Nucleic acids and lipids are poor immunogens by themselves, but they become immunogenic when they are conjugated to protein carriers.

❖ Dosage and route of administration :

• The insufficient dose of immunogen may not stimulate an immune response either because the amount administered fails to activate enough lymphocytes or because such a dose renders the responding cells unresponsive.

• Besides the need to administer a threshold amount of immunogen to induce an immune response, the number of doses administered also affects the outcome of the immune response generated.
• The route of administration also affects the outcome of the immunization because this determines which organs and cell populations will be involved in the response.
• Immunogens can be administered through a number of common routes: Intravenous (into a vein); intradermal (into the skin); subcutaneous (beneath the skin); intramuscular (into the muscle).

- Antigens administered via the most common route namely, subcutaneously, generally elicit the strongest immune responses.

- This is due to their uptake, processing, and presentation to effector cells by Langerhans cells present in the skin, which are among the most potent APCs.

- Antigens administered subcutaneously moves first to local lymph nodes.

• Intravenously administered antigens are carried first to the spleen, where they can either induce immune unresponsiveness or tolerance, or if presented by APCs, generate an immune response.

• Orally administered antigens (gastrointestinal route) elicit local antibody responses within the intestinal lamina propria.

❖ Antigen-antibody interactions

• Ag-Ab interaction is highly specific and occurs in a similar way as a bimolecular association of an enzyme-substrate.

• The binding between antigens and immune components involves weak non-covalent interactions.

• The binding forces are relatively weak and reversible and consist mainly of van der Waals forces, electrostatic forces, and hydrophobic forces, all of which require a very close proximity between the interacting moieties.

• The smallest unit of antigen that is capable of binding with antibodies is called an antigenic determinant (or epitope).
• The corresponding area on the Ab molecule combining with the epitope is called paratope.
• The number of epitopes on the surface of an antigen is its valence.
• The valence determines the number of antibody molecules that can combine with the antigen at one time.

• If one epitope is present, the antigen is monovalent.
• Most antigens, however, have more than one copy of the same epitope and are termed polyvalent.

❖ Comparison of antigen recognition by T-cells and B-cells :

The recognition of antigens by T-cells and B-cells is fundamentally different. B-cells recognize soluble antigens whereas most T-cells recognize only peptides combined with MHC molecules.

Characteristics	B-cells	T-cells
Antigen interaction	B cell receptor binds Ag	T cell receptor binds Ag and MHC
Nature of antigens	Protein, polysaccharide, glycolipid	Peptide
Binding soluble antigen	yes	no
Epitopes recognized	Accessible areas of protein structure containing sequential amino acids and non-sequential amino acids	Antigens processed internally and presented as linear peptides bound to MHC molecules
MHC molecules	Not required	Required to display processed antigen

❖ Haptens

• Substances called haptens (from the Greek hapten, which means to grasp) fail to induce immune responses in their native form because of their low molecular weight and their chemical simplicity.

• Haptens are antigenic but not immunogenic. These compounds become immunogenic when they are conjugated to high molecular weight, physiochemically complex carriers.

• Thus, a hapten is a compound that, by itself, is incapable of inducing an immune response. However, when hapten is conjugated to a carrier, an immune response can be induced against it.