Chapter 15
Adaptive, Specific Immunity and Immunization
15.1 Specific Immunity: The Adaptive Line of Defense

Third line of defense – acquired

• Dual System of B and T lymphocytes
  – Immunocompetence

• **Antigen**: Molecules that stimulate a response by T and B cells

• Two features that characterize specific immunity:
  – **Specificity**: antibodies produced, function only against the antigen that they were produced in response to
  – **Memory**: lymphocytes are programmed to “recall” their first encounter with an antigen and respond rapidly to subsequent encounters
Characteristics of Antigens and Immunogens

- **Antigen** (Ag) is a substance that provokes an immune response in specific lymphocytes.
- Property of behaving as an antigen is **antigenicity**
  - Foreignness, size, shape, and accessibility.

Figure 15.7
Characteristics
of antigens
Characteristics of Antigens

- Perceived as foreign, not a normal constituent of the body
- Foreign cells and large complex molecules over 10,000 MW are most antigenic
- Antigenic determinant, **epitope** – small molecular group that is recognized by lymphocytes
- Antigen has many antigenic determinants

![Diagram showing epitopes](image)

Figure 15.7

b. complex molecules that make good antigens

c. Poor immunogens
15.3 Cooperation in Immune Reactions to Antigens

- The basis for most immune responses is the encounter between antigens and white blood cells.

- Lymph nodes and spleen concentrate the antigens and circulate them so they will come into contact with lymphocytes.
Antibody Structure and Functions

- Immunoglobulins
- Large Y-shaped protein
- Consist of 4 polypeptide chains
- Contain 2 identical fragments (Fab) with ends that bind to a specific antigen
- Fc binds to various cells and molecules of the immune system

Figure 15.11 a. Model of antibody structure
Figure 15.12 Antigen-Antibody Binding

(a) Good fit
(b) No fit
(c) Poor fit

Hypervariable region of Ab that binds Ag
Antibody-Antigen Interactions

Principle antibody activity is to unite with the Ag, to call attention to, or neutralize the Ag for which it was formed

- **Opsonization** – process of coating microorganisms or other particles with specific antibodies so they are more readily recognized by phagocytes
- **Neutralization** – Abs fill the surface receptors on a virus or the active site on a microbial enzyme to prevent it from attaching

Figure 15.13 Summary of antibody functions
Antibody-Antigen Interactions

- **Agglutination** – Ab aggregation; cross-linking cells or particles into large clumps
- **Complement fixation** – Activation of the classical complement pathway can result in the specific rupturing of cells and some viruses
- **Precipitation** - Aggregation of particulate antigen

Figure 15.13 Summary of antibody functions
Classes of Immunoglobulins

5 classes of immunoglobulins (Ig):

1. **IgG** – monomer, produced by plasma cells (primary response) and memory cells (secondary), most prevalent

2. **IgA** – monomer circulates in blood, dimer in mucous and serous secretions

3. **IgM** – five monomers, first class synthesized following Ag encounter

4. **IgD** – monomer, serves as a receptor for antigen on B cells

5. **IgE** – Involved in allergic responses and parasitic worm infections
# Immunoglobulin Classes

**TABLE 15.2** Characteristics of the Immunoglobulin (Ig) Classes

<table>
<thead>
<tr>
<th></th>
<th>Monomer</th>
<th>Dimer, Monomer</th>
<th>Pentamer</th>
<th>Monomer</th>
<th>Monomer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Antigen Binding Sites</strong></td>
<td>2</td>
<td>2 or 4</td>
<td>10</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Molecular Weight</strong></td>
<td>150,000</td>
<td>170,000–385,000</td>
<td>900,000</td>
<td>180,000</td>
<td>200,000</td>
</tr>
<tr>
<td><strong>Percentage of Total Antibody in Serum</strong></td>
<td>80%</td>
<td>13%</td>
<td>6%</td>
<td>0.001%</td>
<td>0.002%</td>
</tr>
<tr>
<td><strong>Average Life in Serum (Days)</strong></td>
<td>23</td>
<td>6</td>
<td>5</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Crosses Placenta?</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Fixes Complement?</strong></td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Binds To</strong></td>
<td>Phagocytes</td>
<td>Epithelial cells</td>
<td>NA</td>
<td>NA</td>
<td>Mast cells and basophils</td>
</tr>
<tr>
<td><strong>Biological Function</strong></td>
<td>Long-term immunity; memory antibodies; neutralizes toxins, viruses</td>
<td>Secretory antibody; on mucous membranes</td>
<td>Produced at first response to antigen; can serve as B-cell receptor</td>
<td>Receptor on B cells for antigen recognition</td>
<td>Antibody of allergy; worm infections</td>
</tr>
</tbody>
</table>
15.5 A Classification Scheme for Specific, Acquired Immunities

- **Active immunity** – results when a person is challenged with antigen that stimulates production of antibodies; creates memory, takes time, and is lasting

- **Passive immunity** – preformed antibodies are donated to an individual; does not create memory, acts immediately, and is short term

- **Natural immunity** – acquired as part of normal life experiences

- **Artificial immunity** – acquired through a medical procedure such as a vaccine
**Figure 15.18 Categories of Acquired Immunities**

**Acquired Immunity**

- **Natural Immunity**
  - acquired through the normal life experiences
  - not induced through medical means.

- **Artificial immunity**
  - produced purposefully through medical procedures (also called immunization).

- **Active Immunity**
  - is the consequence of a person developing his own immune response to a microbe.

- **Passive Immunity**
  - is the consequence of one person receiving preformed immunity made by another person.

- **Active Immunity (same as vaccination)**
  - is the consequence of a person developing his own immune response to a microbe.

- **Passive Immunity**
  - is the consequence of one person receiving preformed immunity made by another person.
Artificial Active Immunity: Vaccination

• **Artificial active immunity** – deliberately exposing a person to material that is antigenic but not pathogenic
  
  – Principle is to stimulate a primary and secondary anamnestic response to prepare the immune system for future exposure to a virulent pathogen
  
  – Response to a future exposure will be immediate, powerful, and sustained
Principles of Vaccine Preparation

Most vaccines are prepared from:
1. Killed whole cells or inactivated viruses
2. Live, attenuated cells or viruses
3. Antigenic molecules derived from bacterial cells or viruses
4. Genetically engineered microbes or microbial agents
Qualities of an Effective Vaccine

**TABLE 15.4 Checklist of Requirements for an Effective Vaccine**

- It should have a low level of adverse side effects or toxicity and not cause serious harm.
- It should protect against exposure to natural, wild forms of pathogen.
- It should stimulate both antibody (B-cell) response and cell-mediated (T-cell) response.
- It should have long-term, lasting effects (produce memory).
- It should not require numerous doses or boosters.
- It should be inexpensive, have a relatively long shelf life, and be easy to administer.
Killed or Inactivated Vaccines

- Cultivate the desired strain, treat it with formalin or some other agent that kills the agent but does not destroy its antigenicity.
- Often require a larger dose and more boosters to be effective.

Figure 15.19 Strategies in vaccine design
Live Attenuated Cells or Viruses

- Process that substantially lessens or negates the virulence of viruses or bacteria – eliminates virulence factors

(a) **Whole Cell Vaccines**

![Figure 15.19 Strategies in vaccine design](image)

- Live, attenuated cells or viruses
  - Viulence is eliminated or reduced
  - Alive. With same antigenicity
  - Administer

Vaccine microbes can multiply and boost immune stimulation.
Attenuated vs Killed Vaccines

• Advantages of live preparations are:
  – Organisms can multiply and produce infection (but not disease) like the natural organism
  – They confer long-lasting protection
  – Usually require fewer doses and boosters

• Disadvantages include:
  – Require special storage, can be transmitted to other people, can conceivably mutate back to virulent strain
Antigenic Molecules

- **Acellular or subcellular vaccines** (subunit – if a virus)
- Exact antigenic determinants can be used when known:
  - Capsules – pneumococcus, meningococcus
  - Surface protein – anthrax, hepatitis B
  - Exotoxins – diphtheria, tetanus
- Antigen can be taken from cultures, produced by genetic engineering, or synthesized

Figure 15.19 Strategies in vaccine design
Genetically Engineered Vaccines

- Insert genes for pathogen’s antigen into plasmid vector, and clone them in an appropriate host
  - Stimulated the clone host to synthesize and secrete a protein product (antigen), harvest and purify the protein – hepatitis

- “Trojan horse” vaccine – genetic material from a pathogen is inserted into a live carrier nonpathogen; the recombinant expresses the foreign genes
  - Experimental vaccines for AIDS, herpes simplex 2, leprosy, tuberculosis

(c) Recombinant Vaccine
Genetically Engineered Vaccines

- DNA vaccines – create recombination by inserting microbial DNA into plasmid vector
- Human cells will pick up the plasmid and express the microbial DNA as proteins causing B and T cells to respond, be sensitized, and form memory cells
  - Experimental vaccines for Lyme disease, hepatitis C, herpes simplex, influenza, tuberculosis, malaria

Figure 15.20 DNA vaccine preparation
Routes of Administration and Side Effects

- Most administered by injection; few oral, nasal
- Some vaccines require *adjuvant* to enhance immunogenicity and prolong retention of antigen
- Stringent requirements for development of vaccines
- More benefit than risk
- Possible side effects include local reaction at injection site, fever, allergies; rarely back-mutation to a virulent strain, neurological effects
Recommended Immunization Schedule

Table 15.6: Recommended Immunization Schedule United States 2010*

### Persons Aged 0-6 Years

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Age</th>
<th>1 month</th>
<th>2 months</th>
<th>4 months</th>
<th>6 months</th>
<th>12 months</th>
<th>15 months</th>
<th>18 months</th>
<th>19-23 months</th>
<th>2-3 years</th>
<th>4-6 years</th>
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<tbody>
<tr>
<td>Hepatitis B</td>
<td>HepB</td>
<td>HepB</td>
<td>HepB</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Rotavirus</td>
<td>RV</td>
<td>RV</td>
<td>RV</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diphtheria, Tetanus, Pertussis</td>
<td>DTaP</td>
<td>DTaP</td>
<td>DTaP</td>
<td>DTaP</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Haemophilus influenzae type b</td>
<td>Hib</td>
<td>Hib</td>
<td>Hib</td>
<td>Hib</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pneumococcal</td>
<td>PCV</td>
<td>PCV</td>
<td>PCV</td>
<td>PCV</td>
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<tr>
<td>Inactivated Poliovirus</td>
<td>IPV</td>
<td>IPV</td>
<td>IPV</td>
<td>IPV</td>
<td></td>
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<tr>
<td>Influenza</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measles, Mumps, Rubella</td>
<td>MMR</td>
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<td></td>
<td></td>
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<tr>
<td>Varicella</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Hepatitis A</td>
<td>HepA (2 doses)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Meningococcal</td>
<td>MCV</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

### Persons Aged 7-18 Years

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Age</th>
<th>7-10 years</th>
<th>11-12 years</th>
<th>13-18 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diphtheria, Tetanus, Pertussis</td>
<td></td>
<td>Tdap</td>
<td></td>
<td>Tdap</td>
</tr>
<tr>
<td>Human Papillomavirus</td>
<td></td>
<td></td>
<td>HPV (3 doses)</td>
<td></td>
</tr>
<tr>
<td>Meningococcal</td>
<td>MCV</td>
<td></td>
<td></td>
<td>MCV</td>
</tr>
<tr>
<td>Influenza</td>
<td></td>
<td></td>
<td>Influenza (Yearly)</td>
<td></td>
</tr>
<tr>
<td>Pneumococcal</td>
<td></td>
<td></td>
<td></td>
<td>PPSV</td>
</tr>
<tr>
<td>Hepatitis A</td>
<td></td>
<td></td>
<td></td>
<td>HepA Series</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td></td>
<td></td>
<td></td>
<td>HepB Series</td>
</tr>
<tr>
<td>Inactivated Poliovirus</td>
<td></td>
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<td></td>
<td>IPV Series</td>
</tr>
<tr>
<td>Measles, Mumps, Rubella</td>
<td></td>
<td></td>
<td></td>
<td>MMR Series</td>
</tr>
<tr>
<td>Varicella</td>
<td></td>
<td></td>
<td></td>
<td>Varicella Series</td>
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