1 **Adaptive Immunity: Specific Defenses of the Host**

2

3 **The Adaptive Immune System**

Learning Objective

17-1 Compare and contrast adaptive and innate immunity.

4 **The Adaptive Immune System**

- Adaptive immunity: defenses that target a specific pathogen
  - Acquired through infection or vaccination
  - Primary response: first time the immune system combats a particular foreign substance
  - Secondary response: later interactions with the same foreign substance; faster and more effective due to "memory"

5 **Host Defenses: The Big Picture**

6

Check Your Understanding

✓ Is vaccination an example of innate or adaptive immunity?
17-1

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7 **Dual Nature of the Adaptive Immune System**

Learning Objective

17-2 Differentiate humoral from cellular immunity.

8 **Dual Nature of the Adaptive Immune System**

- Humoral immunity
  - Produces antibodies that combat foreign molecules known as antigens
  - B cells are lymphocytes that are created and mature in red bone marrow
    - Recognize antigens and make antibodies
    - Named for bursa of Fabricius in birds

9 **Humoral Immunity: Overview**

10 **Dual Nature of the Adaptive Immune System**

- Cellular immunity (cell-mediated immunity)
  - Produces T lymphocytes
    - Recognize antigenic peptides processed by phagocytic cells
    - Mature in the thymus
  - T cell receptors (TCRs) on the T cell surface contact antigens, causing the T cells to secrete cytokines instead of antibodies
    -
-

11 **Figure 17.1 Differentiation of T cells and B cells.**

12 **Dual Nature of the Adaptive Immune System**

- Cellular immunity attacks antigens found inside cells
  - Viruses; some fungi and parasites
- Humoral immunity fights invaders outside cells
  - Bacteria and toxins

13

Check Your Understanding

✓ What type of cell is most associated with humoral immunity, and what type of cell is the basis of cellular immunity?

17-2

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14 **Cytokines: Chemical Messengers of Immune Cells**

Learning Objective

17-3 Identify at least one function of each of the following: cytokines, interleukins, chemokines, interferons, TNF, and hematopoietic cytokines.

15 **Cytokines: Chemical Messengers of Immune Cells**

- Cytokines are chemical messengers produced in response to a stimulus
  - Interleukins: cytokines between leukocytes
  - Chemokines: induce migration of leukocytes
  - Interferons (IFNs): interfere with viral infections of host cells
  - Tumor necrosis factor (TNF): involved in the inflammation of autoimmune diseases
  - Hematopoietic cytokines: control stem cells that develop into red and white blood cells
- Overproduction of cytokines leads to a cytokine storm

16

Check Your Understanding

✓ What is the function of cytokines?

17-3

17 **Antigens and Antibodies**

Learning Objectives

17-4 Define *antigen, epitope,* and *hapten*.

17-5 Explain antibody function, and describe the structural and chemical characteristics of antibodies.

17-6 Name one function for each of the five classes of antibodies.

18 **Antigens**

- Antigens: substances that cause the production of antibodies
  - Usually components of invading microbes or foreign substances
  - Antibodies interact with epitopes, or antigenic determinants, on the antigen
- Haptens: antigens too small to provoke immune responses; attach to carrier molecules

19

20

21 **Antibodies**

- Globular proteins called immunoglobulins (Ig)
- Valence is the number of antigen-binding sites on an antibody
  - Bivalent antibodies have two binding sites
-

22 **Antibodies**

- Four protein chains form a Y-shape
  - Two identical light chains and two identical heavy chains joined by disulfide links
- Variable (v) regions are at the ends of the arms; bind epitopes
- Constant (Fc) region is the stem, which is identical for a particular Ig class
  - Five classes of Ig (IgG, IgM, IgA, IgD, IgE)

23

24 **IgG**

- Monomer
- 80% of serum antibodies
- In the blood, lymph, and intestine
- Cross the placenta; trigger complement; enhance phagocytosis; neutralize toxins and viruses; protect fetus

25 **IgM**

- Pentamer made of five monomers held with a J chain
- 6% of serum antibodies
- Remain in blood vessels
- Cause clumping of cells and viruses
- First response to an infection; short-lived

26 **IgA**

- Monomer in serum; dimer in secretions
- 13% of serum antibodies
- Common in mucous membranes, saliva, tears, and breast milk
- Prevent microbial attachment to mucous membranes

27 **IgD**

- Monomer
- 0.02% of serum antibodies
- Structure similar to IgG
- In blood, in lymph, and on B cells
- No well-defined function; assists in the immune response on B cells

28 **IgE**

- Monomer
- 0.002% of serum antibodies
- On mast cells, on basophils, and in blood

- Cause the release of histamines when bound to antigen; lysis of parasitic worms

29

30

Check Your Understanding

✓ Does an antibody react with a bacterium as an antigen or as an epitope?
17-4

✓ The original theoretical concepts of an antibody called for a rod with antigenic determinants at each end. What is the primary advantage of the Y-shaped structure that eventually emerged?
17-5

✓ Which class of antibody is most likely to protect you from a common cold?
17-6

31 **Humoral Immunity Response Process**

Learning Objectives

17-7 Compare and contrast T-dependent and T-independent antigens.

17-8 Differentiate plasma cell from memory cell.

17-9 Describe clonal selection.

17-10 Describe how a human can produce different antibodies.

32 **Clonal Selection of Antibody-Producing Cells**

- Major histocompatibility complex (MHC) genes encode molecules on the cell surface
  - Class I MHC are on the membrane of nucleated animal cells
    - Identify "self"
  - Class II MHC are on the surface of antigen-presenting cells (APCs), including B cells

33 **Clonal Selection of Antibody-Producing Cells**

- Inactive B cells contain surface Ig that bind to antigen
- B cell internalizes and processes antigen
- Antigen fragments are displayed on MHC class II molecules
- T helper cell (T_H) contacts the displayed antigen fragment and releases cytokines that activate B cells
- B cell undergoes proliferation (clonal expansion)

34

35 **Clonal Selection of Antibody-Producing Cells**

- Clonal selection differentiates activated B cells into:
  - Antibody-producing plasma cells
  - Memory cells
- Clonal deletion eliminates harmful B cells

36

37 **Clonal Selection of Antibody-Producing Cells**

- T-dependent antigen

- Antigen that requires a T_H cell to produce antibodies
- T-independent antigens
  - Stimulate the B cell without the help of T cells
  - Provoke a weak immune response, usually producing IgM
  - No memory cells generated

38

39 **Antigen Processing and Presentation: Overview**

40 **Humoral Immunity: Clonal Selection and Expansion**

41

Check Your Understanding

✓ Would pneumococcal pneumonia (see Figure 24.12, page 689) require a T_H cell to stimulate a B cell to form antibodies?
17-7

✓ Plasma cells produce antibodies; do they also produce memory cells?
17-8

✓ In what way does a B cell that encounters an antigen function as an antigen-presenting cell?
17-9

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42

Check Your Understanding

✓ On what part of the antibody molecule do we find the amino acid sequence that makes the huge genetic diversity of antibody production possible?
17-10

43 **Antigen–Antibody Binding and Its Results**

Learning Objective

17-11 Describe four outcomes of an antigen–antibody reaction.

44 **Antigen–Antibody Binding and Its Results**

- An antigen–antibody complex forms when antibodies bind to antigens
  - Strength of the bond is the affinity
  - Protects the host by tagging foreign molecules or cells for destruction
    - Agglutination
    - Opsonization
    - Antibody-dependent cell-mediated cytotoxicity
    - Neutralization
    - Activation of the complement system

45

46 **Humoral Immunity: Antibody Function**

47

Check Your Understanding

✓ Which antibodies may activate the complement system, and which antibodies are usually associated with agglutination?
17-11

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48 **Cellular Immunity Response Process**

Learning Objectives

17-12 Describe at least one function of each of the following: M cells, T_H cells, T_C cells, CTLs, T_{reg} cells, NK cells.

17-13 Differentiate T helper, T cytotoxic, and T regulatory cells.

17-14 Differentiate T_H1, T_H2, and T_H17 cells.

17-15 Define *apoptosis*.

17-16 Define *antigen-presenting cell*.

49 **Cellular Immunity Response Process**

- T cells combat intracellular pathogens
  - Mature in the thymus
  - Thymic selection eliminates immature T cells
  - Migrate from the thymus to lymphoid tissues
  - Attach to antigens via T-cell receptors (TCRs)
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-

50 **Cellular Immunity Response Process**

- Pathogens entering the gastrointestinal tract pass through microfold cells (M cells) located over Peyer's patches
  - Transfer antigens to lymphocytes and antigen-presenting cells (APCs)
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51

52 **Antigen-Presenting Cells (APCs)**

- Dendritic cells (DCs)
  - Engulf and degrade microbes and display them to T cells
  - Found in the skin, genital tract, lymph nodes, spleen, thymus, and blood
- Macrophages
  - Activated by cytokines or the ingestion of antigenic material
  - Migrate to the lymph tissue, presenting antigen to T cells

53

54

55 **Antigen Processing and Presentation: MHC**

56 **Classes of T Cells**

- Clusters of differentiation (CD)
  - $CD4^+$
    - T helper cells (TH)
    - Cytokine signaling with B cells; interact directly with antigens
    - Bind MHC class II molecules on B cells and APCs
  - $CD8^+$
    - Cytoxic T lymphocytes (CTL)
    - Bind MHC class I molecules

57 **T Helper Cells ($CD4^+$ T Cells)**

- TCR on the T_H cell recognize and bind to the antigen fragment and MHC class II on APC
- APC or T_H secrete a costimulatory molecule, activating the T_H cell
- T_H cells produce cytokines and differentiate into:
  - T_H1cells
  - T_H2 cells
  - T_H17 cells
  - Memory cells

58

59 **T Helper Cells ($CD4^+$ T Cells)**

- T_H17 cells produce IL-17 and contribute to inflammation
- T_H1 cells produce IFN-g, which activates macrophages, enhances complement, and stimulates antibody production that promotes phagocytosis
- T_H2 cells activate B cells to produce IgE; activate eosinophils
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60

61 **Antigen Processing and Presentation: Steps**

62 **T Regulatory Cells**

- T regulatory cells (T_{reg})
- Subset of $CD4^+$ cells; carry an additional CD25 molecule
- Suppress T cells against self; protect intestinal bacteria required for digestion; protect fetus

63 **T Cytotoxic Cells ($CD8^+$ T Cells)**

- Activated into cytotoxic T lymphocyte (CTL) with the help of T_H cell and costimulatory signals
- CTLs recognize and kill self-cells altered by infection
  - Self-cells carry endogenous antigens on a surface presented with MHC class I molecules
- CTL releases perforin and granzymes that induce apoptosis in the infected cell

64

65 **T Cytotoxic Cells (CD8⁺ T Cells)**

- Apoptosis
  - Programmed cell death
  - Prevents the spread of infectious viruses into other cells
  - Cells cut their genome into fragments, causing the membranes to bulge outward via blebbing

66

67 **Cell-Mediated Immunity: Cytotoxic T Cells**

68

Check Your Understanding

✓ Which antibody is the primary one produced when an antigen is taken up by an M cell?
17-12

✓ Which T cell type is generally involved when a
B cell reacts with an antigen and produces antibodies against the antigen?
17-13

✓ Which T cell type is generally involved in allergic reactions?
17-14

69

Check Your Understanding

✓ What is another name for apoptosis, one that describes its function?
17-15

✓ Are dendritic cells considered primarily part of the humoral or the cellular immune system?
17-16

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70 **Extracellular Killing by the Immune System**

Learning Objective

17-17 Describe the function of natural killer cells.

71 **Extracellular Killing by the Immune System**

- Natural killer (NK) cells
  - Granular leukocytes destroy cells that don't express MHC class I self-antigens
  - Kill virus-infected and tumor cells and attack parasites
  - Not always stimulated by an antigen
  - Form pores in the target cell, leading to lysis or apoptosis

72

73

Check Your Understanding

✓ How does the natural killer cell respond if the target cell does not have MHC class I molecules on its surface?
17-17

74 **Antibody-Dependent Cell-Mediated Cytotoxicity**

Learning Objective

17-18 Describe the role of antibodies and natural killer cells in antibody-dependent cell-mediated cytotoxicity.

75 **Antibody-Dependent Cell-Mediated Cytotoxicity**

- Protozoans and helminths are too large to be phagocytized
  - Protozoan or helminth target cell is coated with antibodies
  - Immune system cells attach to the Fc regions of antibodies
  - Target cell is lysed by chemicals secreted by the immune system cell
  -

76

77

Check Your Understanding

✓ What makes a natural killer cell, which is not immunologically specific, attack a particular target cell?
17-18

78 **Immunological Memory**

Learning Objective

17-19 Distinguish a primary from a secondary immune response.

79 **Immunological Memory**

- Secondary (memory or anamnestic) response occurs after the second exposure to an antigen
  - More rapid, lasts many days, greater in magnitude
  - Memory cells produced in response to the initial exposure are activated by the secondary exposure
- Antibody titer is the relative amount of antibody in the serum
  - Reflects intensity of the humoral response
  - IgM is produced first, followed later by IgG

80

81 **Humoral Immunity: Primary Immune Response**

82 **Humoral Immunity: Secondary Immune Response**

83

Check Your Understanding

✓ Is the anamnestic response primary or secondary?
17-19

84 **Types of Adaptive Immunity**

Learning Objective

17-20 Contrast the four types of adaptive immunity.

85 **Types of Adaptive Immunity**

- Naturally acquired active immunity
  - Resulting from infection
- Naturally acquired passive immunity
  - Transplacental or via colostrum
- Artificially acquired active immunity
  - Injection of vaccination (immunization)
- Artificially acquired passive immunity
  - Injection of antibodies

86

87 **Types of Adaptive Immunity**

- Antiserum: blood-derived fluids containing antibodies
- Serology: the study of reactions between antibodies and antigens
- Globulins: serum proteins
  - Gamma (γ) globulin: serum fraction containing antibodies
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88

89

Check Your Understanding

✓ What type of adaptive immunity is involved when gamma globulin is injected into a person?
17-20

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90