Host Defense Mechanisms (non-specific)

BIO162 Microbiology for Allied Health
Chapter 15
Page Baluch

Host Defenses

- **Resistance**
  - Ability to ward off disease
  - Varies among organisms and individuals within the same species

- **Immunity** - mechanisms used by the body as protection against microbes and other foreign agents; self vs. non-self

- **Nonspecific** immunity (innate, natural, inborn
  - Defenses against any pathogen

- **Specific** immunity
  - Resistance to a specific pathogen

<table>
<thead>
<tr>
<th>Non-specific Resistance</th>
<th>Specific Resistance (Responses of the Immune System, 2021)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First line of defense</strong></td>
<td><strong>Second line of defense</strong></td>
</tr>
<tr>
<td>Intact skin</td>
<td>Phagocytic white blood cells</td>
</tr>
<tr>
<td>Mucus membranes and their secretions</td>
<td>Inflammation</td>
</tr>
<tr>
<td>Normal microbiota</td>
<td>Fever</td>
</tr>
<tr>
<td></td>
<td>Antimicrobial substances</td>
</tr>
</tbody>
</table>
First line of defense – physical & chemical barriers

- Intact, unbroken skin (Broken skin = port of entry)
  - Almost all bacteria are incapable to penetrate a few helminths (hookworm & schistosoma) may
  - Skin predominantly inhabited by Staphylococcus epidermidis
- How?
  - Dryness
  - Temperature
  - Low pH (acidic) of skin;
  - Bacteriocidal secretion by the sebaceous glands
  - Desquamation – sloughing of epithelium
  - Perspiration (sweat contain lysozymes – attack bacterial cell wall)
- Exception: Staphylococcus aureus in moist area

First line of defense – physical & chemical barriers

- Eyes
  - Blinking of eyelids
  - Tears containing lysozymes
- Outer ear canal
  - Wax contains antibacterial components
First line of defense – physical & chemical barriers

• Mucus membranes – layers of mucosal cells that line body cavities that open to the outside (digestive, genitourinary and respiratory tracts)
  – Mucus is produced by the mucosal cells
    • Contains antimicrobial substance such as lysozymes, lactoferrin (sequester iron)
    • Mucosal cells are rapidly dividing → flush out of body along with attached bacteria

First line of defense – physical & chemical barriers

• Digestive tract
  – Mouth and lower digestive tract – lots of bacteria (mostly anaerobes e.g. Bacteroides, anaerobic streptococci [Streptococcus mutans in mouth] and Clostridium in colon)
  – How?
    • Mucus
    • Saliva (contains lysozyme)
    • Bile (alkaline) in small intestine
    • Stomach acids
    • Defecation (feces contains up to 50% bacteria!)
    • Mucus contain antibacterial agents, antibodies and immune cells called phagocytes

First line of defense – physical & chemical barriers

• Genitourinary tract
  – Urinary tract is sterile in a health person except the distal urethra
  – How?
    • Urination
    • Secretion (vaginal and seminal fluid)
    • Low pH of vagina (presence of several Lactobacillus sp., Candida albicans)
First line of defense – physical & chemical barriers

• Respiratory tract
  – Nose - nasal hair, mucus secretions (phagocytes and antibacterial enzymes), irregular chambers
  – ciliated epithelium (nasal cavity, sinuses, bronchi and trachea)
  – Cough reflexes
  – Alveolar macrophages

• Microbial antagonism
  – Normal flora vs. invaders
    • Compete for colonization sites
    • Compete for nutrients
    • Produce bacteriocins
  – Administration of broad spectrum antibiotics may kill only certain members of the normal flora, leaving the others to overgrow → superinfection
e.g. yeast in vagina – yeast vaginitis
Clostridium difficile in colon – diarrhea and colitis

Second line of defense

• Once beyond the protective outer barrier of the body, the invading microbes will encounter a series of nonspecific cellular and chemical defense mechanisms

• Mechanisms:
  – Inflammation – a series of events that removes or contain the offending agent and repair the damage
  – Chemotaxis – movement of cells toward a chemical influence (chemokines or chemotatic agents)
  – Phagocytosis – process in which cell ingest foreign particulate matter e.g. microbes

• Many are carried out by the white blood cells in blood
Blood Components

- **Fluid portion**
  - Serum: liquid portion of clotted blood
  - Plasma: liquid portion with clotting factors
  - "Plasma can clot; Serum cannot"
  - Contains antibodies & other proteins

- **Clotting factors (proteins)**
  - Fibrinogen
  - Prothrombin

- **Formed elements**
  - Erythrocytes – red blood cells (RBC) – carry oxygen and carbon dioxide; no nucleus
  - Leukocytes – white blood cells (WBC) - defense
  - Platelets – thrombocyte particles – clotting; no nucleus

Second line of defense – formed element in blood

Wright's stain of the peripheral blood cells can identify granulocytes based on properties of the granules. It contain two dyes:

- Eosin dye stains basic cell components → reddish
- Methylene blue dye stains acidic cell components → blue-ish

Formed Elements In Blood

<table>
<thead>
<tr>
<th>Type of Cell</th>
<th>Normally present in</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (Red Blood Cells)</td>
<td>4.5-5.5 million</td>
<td>Transport of O₂ and CO₂</td>
</tr>
<tr>
<td>Leukocytes (White Blood Cells)</td>
<td>5,000-10,000</td>
<td>Phagocytes</td>
</tr>
<tr>
<td>Monocytes</td>
<td>1%</td>
<td>Production of tissue</td>
</tr>
<tr>
<td>Neutrophils</td>
<td>75%</td>
<td>Production of tissue</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>20%</td>
<td>Production of tissue</td>
</tr>
<tr>
<td>Eosinophils</td>
<td>3%</td>
<td>Production of tissue</td>
</tr>
<tr>
<td>Basophils</td>
<td>0.5%</td>
<td>Production of tissue</td>
</tr>
</tbody>
</table>

Note: The images and tables are not transcribed here but are included in the page as visual aids.
Formed Elements In Blood

[Table]

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<th>Type of Cell</th>
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</thead>
<tbody>
<tr>
<td>Neutrophils (polymorphonuclear cells or PMN)</td>
<td>5,000-10,000</td>
<td>Phagocytic cells, involved in inflammation</td>
</tr>
<tr>
<td>Eosinophils</td>
<td>100-200</td>
<td>Involved in allergy, asthma, parasitic (helminth) infection</td>
</tr>
<tr>
<td>Basophils</td>
<td>10-100</td>
<td>Involved in immediate hypersensitivity reactions</td>
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</tbody>
</table>

Can you identify these leukocytes?

Granulocytes

- **Neutrophils**
  - Most common leukocytes in the blood.
  - Granules unstained.
  - Mobile cells and can pass through capillaries and engulf bacteria by phagocytosis.
  - Secret a fever inducing agent called pyrogen which also helps the body fight infection.

- **Eosinophils**
  - The granules of cytoplasm are stainable with eosin (red).
  - The exact function of eosinophils has been a mystery for many years, but research has pointed to its role in allergy, asthma, and parasitic (helminth) infection; some phagocytosis.

- **Basophils**
  - Rarest WBC in normal blood.
  - Blue granules contain histamine.
  - Play a role in immediate hypersensitivity reactions and in some cell-mediated delayed reactions, such as contact hypersensitivity in humans, skin graft or tumor rejections.
Monocyte (Macrophage)

Monocytes (the blood form)
- the largest WBC's normally found in blood
- horseshoe or "U" shape nucleus, or it may be folded
- travel to different tissue to mature into specific macrophage

Macrophage
- As it developed from monocytes, its size can increase 2-3 times
- Wandering – motile and travel in bloodstream; found throughout body
- Fixed (histiocytes) – attached and remain in the tissue
- Removal and engulfment of foreign particles and useless body cells/material

Lymphocytes
- The lymphocyte nucleus is usually round to slightly indented with a sharply defined edge, and deep, dense purple. Cytoplasm may be scant or form a narrow rim around the nucleus.
- Cornerstone of the immune system: antibodies production & cell-mediated immunity

Second line of defense
- Acute phase proteins
  - set of plasma proteins whose level increases during infection to enhance host defense mechanisms
  - e.g. complement proteins, coagulating factors, transferrins

- Cytokines
  - small secreted proteins produced by cells
  - Communication between different defense systems
  - Examples: interleukins, interferons
Second line of defense

• Fever
  – Pyrogens are substances that stimulate fever
    • External, e.g. bacterial endotoxin
    • Internal (endogenous), e.g. interleukins (IL-1)
  – Body temperature increases in response to pyrogens to:
    • Stimulate WBC to deploy & destroy microbes
    • Increase in immunological response (e.g. proliferation and activation of lymphocytes)
    • Slow down growth of or kill pathogens

Second line of defense

• Interferons
  – Anti-viral proteins produced by virus-infected cells (eventually died)
  – Alert system to prevent virus from infecting other cells and to stimulate certain lymphocytes
    - Has been used as experimental therapy (nowadays, many are genetically engineered) for viral infections and cancers
    - Species-specific for host cells

Second line of defense

• The complement systems
  – Consists of ~30 proteins that complement the action of the immune system
  – Functions:
    • Inflammation
    • Stimulate leukocytes
    • Lyse bacteria
    • Increase phagocytosis by opsonization
Opsonization

- Process by which phagocytosis is facilitated by deposition of opsonins
- Opsonins can be complement proteins, or antibodies
- E.g. encapsulated bacteria
- Deficiency in complement system may lead to increased susceptibility to certain infections.

Inflammation

- Four cardinal signs
  - Redness
  - Heat
  - Swelling
  - Pain
- Primary functions
  - Localize infection
  - Neutralize toxins at injury site
  - Repair damage tissue

- Major events
  - Vasodilation
  - Increase permeability of capillaries
  - Mobilization of leukocytes to site of injury (chemotaxis & emigration)
  - Phagocytosis

Second Line of Defense
Phagocytosis is the ingestion of microorganisms or other matter by a cell. Many white blood cells engulf invasive microorganisms by the process of phagocytosis. The steps in phagocytosis are:

1. **Chemotaxis** is the process by which phagocytes are attracted to microorganisms.
2. **Attachment**: The phagocyte then adheres to the microbial cell. This adherence may be facilitated by opsonization – coating the microbe with plasma proteins.
3. **Ingestion**: Pseudopods of phagocytes engulf the microorganism and enclose it in a phagosome to complete ingestion.
4. **Digestion**: Lysosomes fuse with the phagosome to form a digestive vacuole. The microbe is killed and digested.