Body Defenses

The body has three layers to its defense system: 1) the skin and mucus membranes, 2) nonspecific chemical and cellular responses, and 3) the immune system. All the layers are closely linked to one another and often respond in concert with each other. Understanding the basics of each level of the defense system provides a platform for successful prevention and intervention.

Nonspecific Body Defenses

As long as the ***skin and mucus membranes*** remain intact they provide a mechanical barrier to pathogens and toxins. They also secrete chemicals that either inhibit or destroy bacterial growth as discussed in the preceding pages.

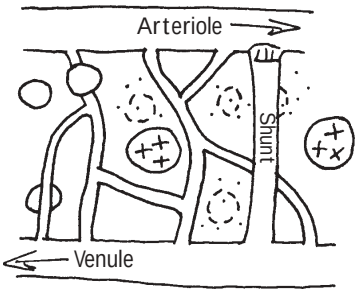
The second line of defense is also nonspecific and relies on chemical and cellular responses. ***Phagocytes*** engulf and destroy pathogens that penetrate the skin and/or mucus membranes. ***Natural killer cells*** directly attack and destroy the infected and cancerous cells before the immune system is fully mobilized. The ***inflammatory response*** (see below) isolates the damage, assists in the destruction of invading pathogens, and begins the repair process. Antimicrobial proteins, complement and interferon, are present at all times in the blood and plasma. ***Complement*** binds to the cell membrane of invading microorganisms and causes them to explode (lyse). ***Interferon*** enters virus-infected cells and interferes with the virus's ability to replicate. Phagocytes actively engaged in fighting invading microorganisms secrete chemicals (pyrogens) that stimulate the brain to raise the body's temperature. Low and moderate ***fevers*** ($\leq 102^{o}$ F) increase general metabolism, raise the effectiveness of all the body's defenses and speed repair processes; they also tend to suppress reproduction of most pathogens. High fevers are dangerous because too much heat breaks down (denatures) proteins and inactivates enzymes required for normal body processes.

The Inflammatory Response

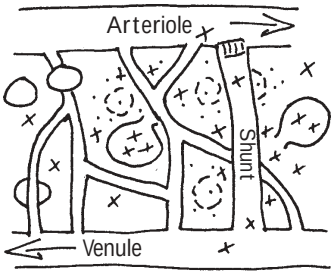
When cells are damaged or destroyed (by any MOI), a chemical "alarm" is sounded activating the immune system and a complex healing process known as the inflammatory response. Numerous chemicals (histamine, kinins, prostaglandins, complement, and lymphokines), are released locally by the injured cells, mast cells, nerve endings, platelets, and white blood cells (WBC). Together the chemicals act to increase the permeability of the local capillary network and encourage healing. Clotting proteins build a fine net designed to wall off the damaged area and keep microorganisms out of healthy tissue (see below). At the same time, specialized white blood cells, called phagocytes, move across the capillary walls and into the damaged tissue. Once there, the phagocytes begin cleaning up the cellular debris and actively devouring any bacteria or toxins present. The area remains "inflamed" until most of the damage has been repaired.

Vasodilation (a component of the inflammatory response) increases the local capillary pressure and forces plasma (fluid) to move across the vessel walls into the extracellular space. Plasma continues to accumulate in the extracellular space until the pressure is equalized. The extra fluid (edema) helps dilute any harmful substances and brings in the extra oxygen, nutrients and clotting proteins necessary for repair. The clotting proteins form a gel-like fibrin mesh that act as a protective barrier and prevents the spread of pathogens to other areas. The mesh also acts as a framework for permanent repair.

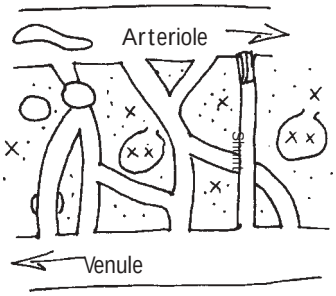
Local pain, redness, heat, and swelling are signs and symptoms of a healthy inflammatory response. The influx of fluid (edema) causes pain as local nerve endings are stimulated. Pain also results from the presence of toxins, a sudden decrease in nutrients and the sensitizing effects of prostaglandins and kinins. Non-steroidal anti-inflammatory drugs (NSAIDs) relieve pain by inhibiting prostaglandin synthesis. In addition to causing pain, prostaglandins decrease collagen production and slow surface healing. While this is helpful for deep wounds that are likely to become infected (it aids in drainage), it is not necessary for superficial ones. The vasodilation causes redness and increased heat as more blood enters the damaged tissue. Another sign of increased permeability and vasodilation is localized swelling; the edema (and therefore the swelling) is confined to the stuffsack that surrounds the leaky tissue (e.g.: muscle facia, organ membranes, skin, etc.) Generally the greater the tissue damage, the greater the swelling. *In the majority of trauma cases, clinically significant swelling due to the inflammatory response reaches its peak within 24 hours. Swelling primarily due to bleeding is much more rapid and usually occurs within six hours of a traumatic event.*



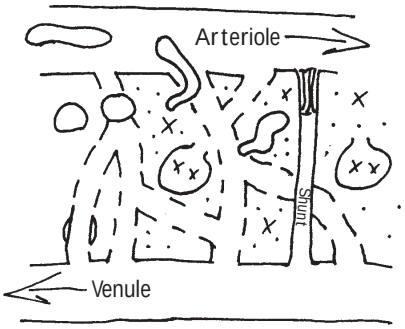
Cell injury or death sounds a chemical "alarm" triggering the inflamatory response.



Chemicals are released by the injured cells, mast cells, nerve endings, platelets, and WBCs.



The chemicals:
1) attract circulating phagocytes
2) increase local permability
3) cause local vasodilation
4) stimulate the immune system



Additional plasma, phagocytes, clotting proteins, & nutrients enter the tissue.

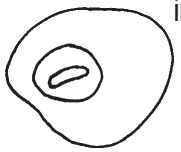
Specific Body Defenses: Immunity

Unlike the first two defensive layers, the immune system is specific and has a memory. The cells of the immune system distinguish self from non-self (*antigens*) by recognizing specific "self molecules" (MCH proteins) on the surface of the body's cells. There are two types of immune responses, cellular (or cell mediated) and humoral. Both responses occur at about the same time and both increase the inflammatory response. The cellular immune response is designed to attack invaders *inside* infected cells by chemically destroying the cell. The humoral immune response neutralizes invaders *outside* the cell and marks them for destruction by phagocytes.

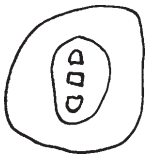
Both processes begin when an new antigen is engulfed and digested by one of several phagocytes (dendritic cells, macrophages, activated B cells, etc.). Once digestion is complete, the cell presents part of the antigen on its surface and travels through the lymphatic system until it encounters a helper T-cell (usually in a lymph node or the spleen). The helper T-cell (T_H) binds with the presenting part of the antigen, clones, and releases chemicals that stimulate the production of antigen specific B and T cells. The activated B-cells are responsible for the humoral immune response while the T-cells are responsible for the cellular immune response.

Antigens (non-self: microorganisms or chemicals) enter the body.

Phagocytes become Antigen Presenting Cells (APC) as they

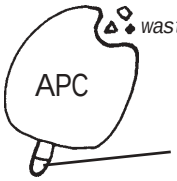


ingest,

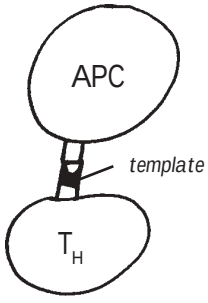


digest,

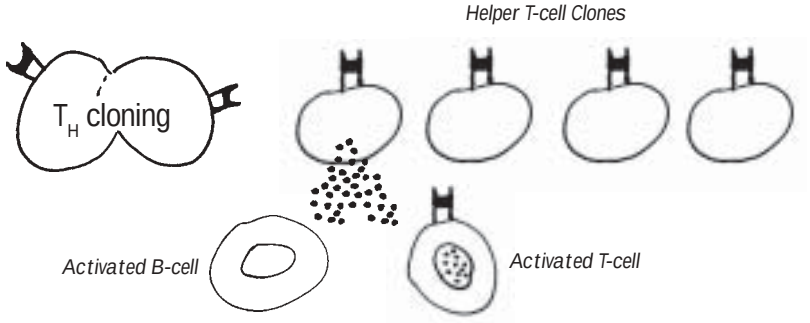
and process antigens (Ag).



The APC discards waste material into the extra-cellular fluid for later removal and presents part of the antigen on the surface of its cell membrane for Helper T-cell (T_H) recognition.



A Helper T-cell binds with the APC, creates a template of the antigen, and clones additional T-cells. The cloned T-cells release chemicals that activate the B and T-cells responsible for the humoral and cell-mediated immune responses respectively.

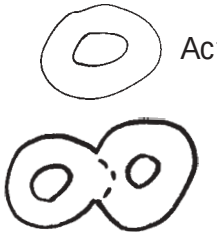


Humoral Immune Response

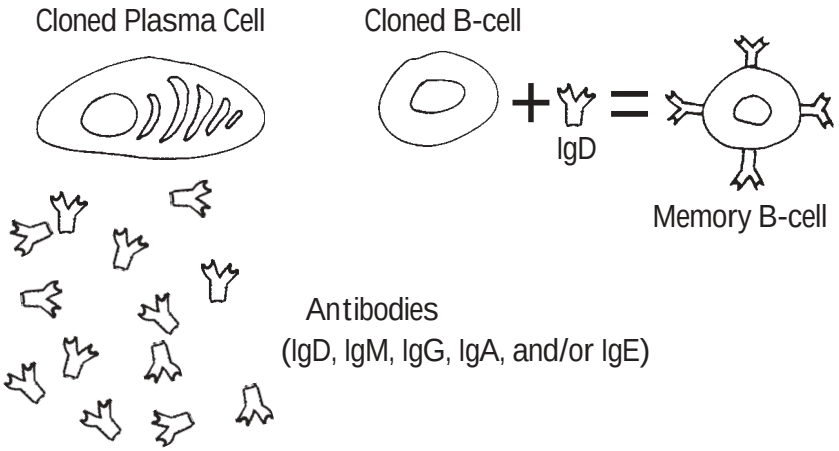
Cell-mediated Immute Response

Once activated, B-cells clone to form both memory B-cells and plasma cells. Memory B-cells have long lives (years) and are able to mount a rapid (within hours) humoral response if they encounter the same antigen at a later date. Plasma cells produce protein molecules called *antibodies* or immune globulin (Ig) at an astounding rate (about 2000 per second). Most antibodies freely circulate in the extracellular fluid spaces (outside the tissue cells) and bind to the antigens they were created to defend against. Once bound, the antigen is neutralized and targeted for later destruction by circulating phagocytes. There are five classes of antibodies (IgD, IgM, IgG, IgA, and IgE). Each class has a slightly different role in the body's humoral defense processes: IgD usually attachs to the surface of B-cells and gives rise to the memory B-cells responsible for immunological humoral memory. IgM circulates in the blood and is the first antibody to be produced by plasma cells during a primary immune response. IgG is the most abundant antibody in plasma and offers protection against viruses, bacteria, and toxins; it also crosses the placenta and transfers passive immunity from the mother to the fetus. IgA is primarily found in body secretions and prevents microorganisms from attaching to skin and the mucus lining of the lungs and gut. IgE helps neutralize gastrointestinal parasites. A single plasma cell can concurrently produce multiple classes of antibodies each specific to the same antigen.

Primary Humoral Immune Response



Activated B-cells clone and become either plasma cells or memory B-cells. Plasma cells are responsible for creating antibodies (IgD, IgM, IgG, IgA, and/or IgE). IgD binds with a cloned B-cell to produce a memory B-cell while the other antibody classes are produced depending on the location of the antigen and need.



The antibodies (Ig) bind, neutralize, and target for later distruction antigens (Ag) freely circulating in the extracellular fluid spaces.

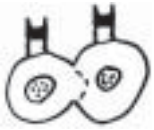
The antigen-antibody interaction also enhances inflammation, activates complement, and increases phagocytosis.

Specialized T-cells are activated at the same time as the B-cells and are responsible for cell-mediated immunity. *Cytotoxic T-cells* or killer T-cells (T_C) recognize, attack, and destroy infected cells and foreign tissue without damaging healthy cells. *Memory cytotoxic T-cells* (T_M) have a long life (years) and are able to mount an attack within hours of a secondary exposure. *Suppressor T-cells* (T_S) inhibit B and T cell activity once the invading antigens have been destroyed.

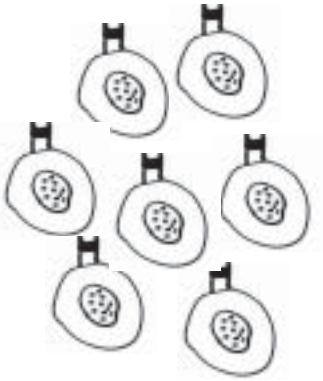
Primary Cell-mediated Immune Response

Activated T-cells clone and form cytotoxic T-cells (T_C), memory T-cells (T_M), and suppressor T-cells (T_S).

Activated T-cell

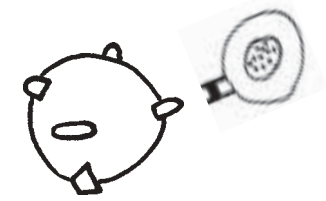


Cytotoxic T-cells



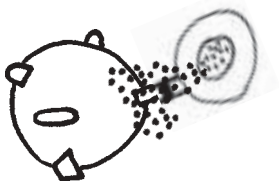
Memory T-cell

Suppressor T-cell



Infected Cell

Similar to APCs, infected cells also present parts of the invading antigen on their surface, this time for recognition by circulating cytotoxic T-cells. Once identified, the attacking cytotoxic T-cell releases chemicals that later lysis the cell and destroy both the infected cell and the antigen. Cytotoxic T-cells are assisted in their attack by non-specific Natrual Killer Cells.



Cell membrane leaks & cell dies (lysis)

Cellular and humoral immune responses act in concert to defend the body from invading antigens. A *primary immune response* takes about three to six days to activate with antibody and cytotoxic T-cell levels reaching their peak within ten days. *Secondary immune responses* are much stronger and faster due to the immunological memory of both memory B and T cells. Activation of a secondary response occurs within hours of exposure with antibody and cytotoxic T-cell levels reaching their peak within two to three days. Unlike a primary exposure, antibody levels remain high for weeks or months following a secondary exposure.

Problems with the immune system may occur in three separate areas: immunodeficiencies (e.g.: genetic defects or AIDS), autoimmune diseases (e.g.: multiple sclerosis, type I diabetes, rheumatoid arthritis, etc.), and allergies (local or systemic). Of these, allergic reactions are the most common in a wilderness setting. Acute allergic reactions are caused by "abnormal" IgE antibodies attached to stationary Mast cells or circulating basophils and usually triggered by bites or stings. Acute reactions may be either local or systemic (anaphylaxis) depending on the placement of the IgE. Subacute reactions (usually to food) are caused by "abnormal" IgG or IgM antibodies. Delayed allergic reactions (usually due to poison ivy, poison sumac, or poison oak) are not caused by abnormal antibodies but by an "abnormal" cell-mediated immune response that produces a skin dermatitis characterized by blisters and weeping.