Chapter 43
The Immune System

The immune system consists of a network of ducts and vessels called the Lymphatic System, and a set of specialized cells called Leukocytes (Greek for ‘white cells’) whose job it is to destroy microbes that invade the body. The types of foreign invaders include viruses, bacteria, yeast, fungi, protozoa, and microscopic worms. Leukocytes circulate around the body looking for these invaders (a process called ‘immune surveillance’) like police officers patrolling neighborhoods looking for criminals. They usually decide who is supposed to be in the neighborhood and who is an invader by checking proteins on the surfaces of all the things they come in contact with. They are then able to distinguish ‘self’ from ‘non-self,’ and distinguish the cells that are meant to be there because they are part of the body from those that are not meant to be there.

(Author’s note: Immunology is a very complicated subject, and I’ve attempted to simplify it for you. For those of you who go on to study immunology in greater detail, please forgive me for having ‘oversimplified’ many things!)

I Components of the Immune System:

The Human Immune System (also known as the Lymphatic System) includes the following major components:

1. The Bone Marrow
2. Leukocytes (white blood cells)
3. The Thymus
4. A network of lymphatic vessels
5. Lymph Nodes
6. The Spleen

Bone Marrow Stem Cells: are also known as Hematopoietic Stem Cells. Hematopoietic stem cells in the bone marrow are generic cells which can turn into (or ‘differentiate’ into) specialized cells (either leukocytes or erythrocytes) in response to cytokine and hormone signals sent from other parts of the body. (Hematopoietic stem cells are said to be ‘pluripotent,’ because they have the ability to turn into any type of blood cell.) For example, you learned in Chapter 42 that hematopoietic stem cells will differentiate into erythrocytes when stimulated by the cytokine erythropoietin, which is sent to the bone marrow from the kidneys. The same hematopoietic stem cells are also capable of differentiating into a number of different types of leukocytes when stimulated by different cytokines. Examples of cytokines that will stimulate bone marrow stem cells to differentiate into leukocytes include the Interleukins (abbreviated IL) such as IL-2, IL-3, SCF (‘Stem Cell Factor’), M-CSF (‘Macrophage Colony Stimulating Factor’) etc.
Lymphoid vs. Myeloid Lineages: Hematopoietic stem cells differentiate into one of two classes (called ‘lineages’) of blood cells. A) The Lymphoid Lineage, which includes the B and T cells (to be discussed below), and B) the Myeloid Lineage, which includes everything else (erythrocytes, Basophils, Eosinophils, Monocytes, Neutrophils, Megakaryocytes [which give rise to the platelets] etc.).

Leukocytes (white blood cells): Hematopoietic stem cells can differentiate into a number of different types of white blood cells, all of which have different jobs to perform.

1. **Phagocytes:** large cells whose job it is to eat invading microbes (viruses, bacteria etc.), as well as dead cells (example: worn out erythrocytes are broken down by phagocytes located in the spleen), and virus-infected cells. Phagocyte is a general term to describe cells that eat things. Depending on where they are located in the body, they may be given different names. For example, phagocytes wandering through the blood are called Neutrophils. Some of these neutrophils then take up residence in different parts of the body (ie-the Spleen) and are re-named Macrophages. Phagocytes located in the skin are called Dendritic Cells.

2. **Granulocytes:** Are members of the myeloid lineage. They include several types of cells (Basophils, Eosinophils, Neutrophils and Monocytes) that have a ‘grainy’ or spotty appearance under the microscope, and who have polymorphic nuclei (PMN Cells). The ‘grains’ are actually vesicles filled with enzymes designed to combat invading microbes. For example, one type of granulocyte called a Mast Cell has vesicles full of a chemical called Histamine (not to be confused with the amino acid Histidine) which, when released, will cause capillaries to suddenly become permeable enough to let large amounts of fluid escape into the interstitial spaces. Holes in the capillaries will actually become so big that leukocytes can also get into the interstitial spaces. The release of histamine is intended to combat a local infection or invasion of microbes. If microbes invade a certain area of the body, allowing immune system cells to leave the capillary beds and enter the interstitial spaces will help combat the infection. The increased fluid in the interstitial spaces will then be carried back to the blood stream through the lymph vessels, which have lymph nodes along the way. These lymph nodes are filled with phagocytes which will further combat the infection. Another one of the main types of granulocytes are the Eosinophils, whose main job is to combat microscopic worms, protozoans and other parasites. If a microscopic worm enters the blood, eosinophils will flock to it, bind to it, and release protease enzymes that will break holes in its skin.

3. **B Cells:** Are members of the lymphoid lineage. B cells (and a specialized form of B cell called a plasma cell) secrete “Y-shaped” proteins called antibodies that bind specifically to invading microbes. B cells are part of the immune system called ‘adaptive immunity’ (see below).

4. **T-helper Cells (T_h cells):** Are members of the lymphoid lineage that help to control and coordinate the B Cell response (secreting antibodies) to an invading microbe.

5. **Cytotoxic T Cells:** (Also known as Natural Killer Cells, or NK cells) are also members of the lymphoid lineage. Once activated (with the help of T-helper cells) they will destroy other cells in the body that are either infected with viruses, or stricken with cancer.
**The Thymus:** Is a gland that sits atop the heart (Figure 43.7). T-helper cells originate in the bone marrow, but then migrate to the thymus were they mature. (The “T” in T Cell refers to ‘thymus.’) T Cells are ‘trained’ in the thymus to be able to differentiate native cells from foreign, invading cells. Basically, this is done by eliminating any T cells that would otherwise react to and attack cells from our own bodies.

**Lymphatic Vessels:** An extensive network of vessels, similar to the blood circulatory system, called lymphatic vessels is also present in the body. As you learned in Chapter 42, lymphatic vessels also drain fluid from interstitial spaces. Small lymphatic vessels located in capillary beds drain into larger vessels which carry the lymph (the fluid carried by lymphatic vessels) upwards through the body, and eventually return it into the bloodstream at the subclavian veins, after it has been ‘filtered’ and checked for invading microbes by a series of Lymph Nodes.

**Lymph Nodes:** The lymphatic vessels are punctuated by tiny organs called lymph nodes, which contain macrophages. These macrophages check the lymph fluid for any invading microbes, and if any are found they destroy them. Lymph nodes are like police roadblocks, and police checkpoints on roads, where police are trying to catch criminals. When the macrophages located in lymph nodes find some invading microbes, they become active and multiply in an effort to destroy the invaders. This causes the lymph node to swell. When you are feeling sick, and go to the doctor, one of the first things the doctor will do is feel some of your larger lymph nodes to see if they are swollen. (The main ones they’ll check are the Axillary Lymph Nodes located under your arms, and the Submandibular Lymph Nodes located in your neck, just under your jaw.) If they are, this indicates that your body is trying to fight off an infection. These lymph nodes could be trying to destroy microbes (bacteria or viruses) that have been found in the lymph fluid, or they could be trying to destroy cancerous cells that have been found in the body.

**Spleen:** A large organ located just behind and to the left of your stomach. It contains macrophages which filter the blood to remove dead cells (ie-dead and broken down erythrocytes), as well as invading microbes (bacteria and viruses).

**II Sequence of Immune Responses to an Invading Microbe**

The Immune System (the Lymphatic System) has several lines of defense that will protect you from invading microbes. The order in which a microbe will encounter them is as follows.

1. Barriers to entry into the body.
2. The Innate Immune System
3. The Adaptive Immune System
4. Immune System Memory

**Barriers to entry:** The skin and the mucous membranes are the first lines of defense preventing microbes from entering the body. The skin contains phagocytes called Dendritic Cells that automatically try to eat invading microbes that enter through cracks or cuts in the skin. They will also send for help by producing cytokines that tell other phagocytes to migrate to the wounded area, producing puss. (Puss is the yellow coloured ‘goo’ that you see in an area of infection. It consists mostly of live and dead macrophages.) Phagocytes are activated by a class
of cytokines called the Interferons. The formation of pus is referred to as a *pyogenic* reaction. Certain types of bacteria are classified as *pyogenic bacteria* because phagocytes really ‘hate’ them, and invasion by such microbes causes the rapid formation of pus.

The mucous membranes are good sites of entry for microbes because they lead inside of us from the outside. (i.e. the mouth, the rectum, the genitals etc.) Because of this, mucous (as well as saliva and tears) contain a special enzyme called lysozyme, that attacks and destroys the walls of certain types of bacteria (specifically, the Gram positive bacteria).

**The Innate Immune System:** If microbes are able to get past the skin and mucous membranes, they will next encounter phagocytes (dendritic cells, macrophages, neutrophils) inside the body that will immediately try to eat them. Invading microbes will also encounter granulocytes that will ‘degranulate’ or dump the contents of their vesicles onto them in an effort to destroy them. As mentioned above, some of these vesicles contain histamine, while others contain proteases. This innate immune response is immediate, and non-specific. It is non-specific in the sense that it will attack a broad range of invading microbes, without distinguishing between them. It is also non-specific in that phagocytes attacking microbes will also damage the body’s own tissues!

If the adaptive immune system (discussed below) is like individual police officers driving through neighborhoods looking for specific criminals, the innate immune system is more like the Riot Police. Riot police will attack a crowd of people, most of whom are innocent, in order to drive out criminals. Calling out the innate immune system (phagocytes in particular) is like calling out the riot police. In addition to the criminals, a lot of innocent people will also get hurt. Because of this, the body’s own immune reaction to foreign microbes can sometimes do more damage than the microbial infection itself. (Example: an infection of *Streptococcus pyogenes* as a child can lead to heart problems as an adult, because the immune system’s reaction to this bacterium also damages cardiac muscle [see below])

**The Adaptive Immune System:** The adaptive immune system is more specific than the innate immune system, and tailors a specific type of response to a specific microbe. This smarter, more tailored response involves the production of antibodies that will bind specifically to the microbe in question. An adaptive immune response begins with a phagocyte ingesting (eating) a bacteria (for example). The phagocyte will then break down the microbe, and then place fragments of the invading microbe’s proteins on its own surface, combined with a class of proteins (called the Major Histocompatibility Complex proteins [MHC class proteins]) found on the surface of all cells in the body. This combination of a fragment of the invading microbe (called an antigen: an antigen is something that provokes an immune response), in combination with the native HMC protein can be ‘read’ by a T-helper cell when the phagocyte ‘presents’ this combination of proteins to it. The phagocyte is then called an Antigen Presenting Cell (APC). This combination of Antigen and MHC class protein activates the T-helper cell, as if it were a key fitting into a lock (Figures 43.12, 43.18 and 43.20).

The T-helper cell will then go to either the bone marrow, the spleen, or a lymph node (or even remain in the blood) and look for a B Cell that has a receptor that is capable of binding to this specific antigen. B Cells have receptors on their surfaces (called the B Cell Receptor) which are capable of binding to specific antigens. Each B Cell only expresses one type of receptor, capable
of binding to only one type of antigen. There are, however, several million different types of B Cells, each of which expresses a different receptor. Therefore, in your repertoire of several million types of B Cells, the T-helper cell will eventually find one that has a receptor capable of binding to this antigen that was presented to it. When the T-helper cell finds a B Cell expressing a receptor capable of binding to the antigen, this is called **Clonal Selection**. The T-helper cell will then produce cytokines that cause the B cell to multiply, and differentiate into a slightly different type of B cell called a **Plasma Cell** (Figure 43.21). A plasma cell differs from its parent B cell in that it produces mass quantities of the B cell receptor (which are capable of binding to the original antigen), but it does not hold on to them. Instead of being anchored to the cell surface, they are secreted outside. When they are secreted outside the cell, rather than being bound to the surface, they are called **antibodies**. (Antibodies are “Y-shaped” with the two ends of the Y each being capable of binding to the original antigen). Multiplication of the original B cell, followed by differentiation into antibody-secreting plasma cells is a process known as **Clonal Expansion**.

These antibodies will then swarm to the invading microbes and coat them with antibody, a process called **Opsonization**. Once a microbe has been coated with antibodies, it is easier for phagocytes to eat it. In addition, a series of 30 different proteins produced by the liver (which are collectively referred to as the **Complement** Proteins; Figure 43.19) will also bind to the antibodies coating the microbe, and proceed to punch holes in the cell membrane of the invader.

The T-helper cell will also activate cells called **Natural Killer cells (NK cells)**, which are also known as **Cytotoxic T Cells** (abbreviated T<sub>c</sub> cells) that will also flock to the same antigen, and destroy the cells bearing the antigen by releasing proteins called **Perforins**, that punch holes in the cell membrane. The adaptive immune system is better than the innate immune system in that it attacks only the invading microbes, and doesn’t damage the body’s healthy, uninfected cells. The adaptive immune system is also worse than the innate immune system in the sense that it takes about ten days to do all of this. (This is why it takes you about ten days to get over a cold.) The innate immune system may be clumsy, but at least it is fast.

**Immune System Memory:** The adaptive immune system takes longer to respond to invading microbes than the innate immune system. However, once it has mounted a successful defense against a specific microbe for the first time, it will leave some cells called **memory cells** scattered around the immune system in case that specific microbe ever dares to return. Some of the plasma cells that were created in response to the invader remain in the immune system, in large numbers, for months or even years after the original invading microbes have been destroyed. They are called **Memory B Cells**. Some NK cells that responded to the initial invader also remain, and are called **Memory Cytotoxic T Cells**. The creation of these long term memory cells is the principle behind vaccination and immunization.

**III Vaccination and Immunization.**

The Immune System will mount an immune response against an invading microbe, leading to the creation of Memory B Cells and Memory Cytotoxic T Cells that will remain, in large number, in the immune system for years. However, the immune system doesn’t distinguish between live or
dead microbes, or live or dead viruses when it mounts this response. Therefore, if you inject a person with dead bacterial cells, or non-viable viruses, they will still lead to the creation of Memory Cells that are capable of dealing with those microbes if they are ever encountered in a live state. Vaccines are simply killed viruses or bacteria, or fragments (antigens) from viruses and bacteria that are injected into a person for the purpose of creating Memory cells. When a person mounts a response to an invading microbe for the first time, the initial response takes about 10 days, and not many antibodies are produced. This is called a **Primary Immune Response** (Figure 43.15). The second time a person is exposed to the same antigens, however, the response will be much faster (about two days), and thousands of times more antibody will be produced. This is called a **Secondary Immune Response**. A secondary immune response is therefore much faster, and much stronger than a primary response.

IV  The Inflammatory Response

Part of the innate immune reaction to an invading microbe is called the **Inflammatory Response**. Inflammation also occurs in response to tissue damage. During inflammation, several cells in the innate immune system work together to trigger cells called **Mast Cells** (which usually reside underneath mucous membranes, and in soft tissues) to release histamine, which causes capillaries to become permeable. Fluid, as well as red and white blood cells then flow out of the capillaries and into the interstitial spaces. The goal is to allow the white blood cells to attack the invading microbes, and the fluid to then be cleared by sending it through the lymph system, passing through numerous lymph nodes along the way. The immediate effects, however, are that the area of inflammation becomes red (because of erythrocytes in the interstitial spaces), swollen (due to edema and anaphylaxis), and hot (due to the release of some hormones that increase the local body temperature). The three characteristics of inflammation therefore are: **1) redness, 2) swelling, and 3) heat.** While the inflammatory response is useful for combating a local infection, chronic (long term) inflammation is bad, because the phagocytes will damage the healthy tissues as well, leading to scarring of the tissues and loss of elasticity. Scarring and loss of tissue elasticity due to chronic inflammation is called **Fibrosis**.

V  Problems With the Immune System

**Chronic Inflammation and Fibrosis:** As mentioned above, chronic inflammation of an area can lead to tissue damage, scarring, and loss of elasticity. If this happens to tissues in the lungs, heart, or joints, this can cause problems. Chronic inflammation of the joints, leading to destruction of the joint tissue is called **Rheumatoid Arthritis**.

**Autoimmunity:** The terms Autoimmunity and Autoimmune Diseases refer to diseases where the body’s own immune system runs amok, and destroys its own tissues. Rheumatoid Arthritis is one example of this. Another example is when people contract a strain of bacteria called **Streptococcus pyogenes**. As it happens, one of the proteins from this bacteria (called the **M Protein**) is very similar in structure to human cardiac muscle. Thus, when your immune system makes antibodies to attack the M Protein, they will also attack your own heart, leading to heart damage. This is particularly dangerous to children who get an infection of **Streptococcus**
***pyogenes*** (called ‘Scarlet Fever’) which has the effect of damaging their heart at a very young age. This leads to heart problems in middle age.

**Evasion of the Immune System:** Some microbes are able to evade the immune system in very clever ways. Some bacteria (such as ***Streptococcus pneumoniae*** or ***Strep*** for short) surround themselves with a layer of polysaccharide called a **Glycocalyx**, in order to hide the foreign proteins on their surfaces. The immune system is very good at mounting antibody-mediated attacks in response to foreign proteins, but not very good at mounting attacks against foreign polysaccharides. Another example of immune system evasion is called **Antigen Switching**. A certain genus (family) of protozoa called the **Trypanosomes** (for example: ***Trypanosoma brucei*** or ***Trypan*** for short) have a clever way of evading the immune system. Recall that it takes 10 to 15 days to mount a successful antibody attack against an antigen. In response to this, Trypanosomes simply change the antigens on their cell surface every few days to stay one step ahead of the immune response.

**Destruction of the Immune System:** The Human Immunodeficiency Virus (HIV, or the AIDS virus) is a virus that invades and destroys T-helper cells, thus destroying the cells that coordinate the adaptive immune system. People who are infected with HIV are more susceptible to infections by other microbes because they have a compromised immune system.

**PRACTICE QUESTIONS:**

**Short Answer Questions:**

1. The cytokine Erythropoietin (Epo) stimulates Hematopoietic Stem Cells to differentiate into Erythrocytes. List one cytokine that stimulates Hematopoietic Stem Cells to differentiate into Leukocytes.
2. What is the technical term for a white blood cell?
3. What is the technical term for a white blood cell that has a granular (spotty) looking cytoplasm?
4. What is the technical term for a white blood cell that has a nucleus that is formed into several lobes, rather than simply having a round nucleus?
5. List the two major ‘lineages’ that hematopoietic stem cells can differentiate into?
6. Are erythrocytes members of the myeloid or the lymphoid lineage?
7. Are B Cells members of the myeloid or lymphoid lineage?
8. Are T Cells members of the myeloid or lymphoid lineage?
9. What is the general (generic) term used to describe a leukocyte whose job it is to EAT things (virus-infected cells, dead cells, bacteria etc.)?
10. Are Eosinophils members of the myeloid or lymphoid lineage?
11. Are Natural Killer Cells (NK Cells) members of the myeloid or lymphoid lineage?
12. Where do T-helper cells (T<sub>H</sub> cells) go to be ‘trained’ to distinguish between native and foreign cells? (Hint: it’s a gland.)
13. Where is the Thymus located in the body?
14. What is the generic name for the class of proteins that antibodies belong to? (Hint: it’s abbreviated as Ig.)
15. In which organ is the blood checked and filtered for foreign, invading microbes?
16. Which type of cell migrates through the blood, eventually takes up residence someplace in the body, and then differentiates into a Macrophage?
17. The word ‘Phagocyte’ is a general term for a type of cell. What does this type of cell do?
18. The word ‘Phagocyte’ is a general term for a type of cell. List two specific types of Phagocytes. (2 points)
19. What does MHC stand for?
20. What does APC stand for?
21. Name one type of lymph node that the doctor well check for swelling when you feel sick.
22. What is the name for a fragment of a protein or carbohydrate found on an invading microbe that will provoke an immune system response.
23. What is the main constituent of puss?
24. What is the technical term for an infection that provokes the formation of puss?
25. Which type of granulocyte is the body’s main defense against microscopic, parasitic worms?
26. What do you call the scarring and loss of tissue elasticity caused by chronic inflammation?
27. What do you call a constant inflammation of the joints, leading to destruction of the joint tissues?

Descriptive Questions:
1. What is an Antigen?
2. What is an Antigen Presenting Cell? (5 points)
3. What is a phagocyte?
4. What is a plasma cell?
5. What is a Memory B Cell?
6. What is a Vaccine?
7. What is a Glycocalyx?
8. What is a Lymph Node?

Essay Questions:
1. Describe how vaccination works, and what it is intended to do. (20 points)
2. Explain how a class of microscopic parasites called Trypanosomes (example: Trypanosoma brucei) is able to evade the immune system. (20 points)
3. Explain how some bacteria (example: Streptococcus pneumoniae) are able to evade the immune system through the use of a glycocalyx. (20 points)
4. Describe what happens during the inflammatory response, and list the three main characteristics of the inflammatory response. Also, explain the effects of chronic inflammation on tissues. (20 points)
5. Describe the process of Clonal Selection and Clonal Expansion of B Cells by T-helper cells. (20 points)
6. Explain how a bout of Scarlet Fever in childhood can lead to heart problems in middle age. (20 points)
7. Describe how HIV (the AIDS virus) is able to evade the human immune system. (10 points)
8. Describe how *Streptococcus pneumonia* is able to evade the human immune system. (10 points)

**Extended Matching: Match the term to the definition.**

<table>
<thead>
<tr>
<th>A. Antibody</th>
<th>S. Lysozyme</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Antigen</td>
<td>T. Macrophage</td>
</tr>
<tr>
<td>C. Axillary</td>
<td>U. Megakaryocyte</td>
</tr>
<tr>
<td>D. Complement</td>
<td>V. Memory B Cell</td>
</tr>
<tr>
<td>E. Cytokine</td>
<td>W. MHC</td>
</tr>
<tr>
<td>F. Dendritic</td>
<td>X. Myeloid</td>
</tr>
<tr>
<td>G. Erythropoietin</td>
<td>Y. Natural Killer Cell</td>
</tr>
<tr>
<td>H. Fibrosis</td>
<td>Z. Neutrophil</td>
</tr>
<tr>
<td>I. Glycocalyx</td>
<td>AA. Opsonization</td>
</tr>
<tr>
<td>J. Hematopoietic</td>
<td>BB. Phagocyte</td>
</tr>
<tr>
<td>K. Hematology</td>
<td>CC. Plasma Cell</td>
</tr>
<tr>
<td>L. Histamine</td>
<td>DD. Pluripotent</td>
</tr>
<tr>
<td>M. Immune Surveillance</td>
<td>EE. Pyogenic</td>
</tr>
<tr>
<td>N. Immunoglobulin</td>
<td>FF. Rheumatoid</td>
</tr>
<tr>
<td>O. Interleukins</td>
<td>GG. Spleen</td>
</tr>
<tr>
<td>P. Interferons</td>
<td>HH. Submandibular</td>
</tr>
<tr>
<td>Q. Lymph Node</td>
<td>II. Thymus</td>
</tr>
<tr>
<td>R. Lymphoid</td>
<td></td>
</tr>
</tbody>
</table>

1. The class of proteins to which antibodies belong.
2. A chemical released by a type of granulocyte called a Mast Cell, which leads to increased permeability of capillaries.
3. Term referring to scarring and loss of tissue elasticity due to chronic inflammation.
4. Refers to the process of coating an invading microbe with antibodies, making it easier for phagocytes to eat it, and complement to bind to it.
5. Name for a layer of polysaccharides that some bacteria are able to put around themselves (thus hiding the foreign proteins hiding in their outer membranes) in order to hide from the immune system.
6. Refers to a cell that ‘presents’ a piece of a foreign protein from an invading organism to another immune system cell, thus starting an adaptive immune reaction.
7. A “Y-shaped” protein (secreted by a specific type of cell in the immune system) that will bind to a foreign protein (on an invading microbe).
8. An anatomical term referring to your underarm. (Location of one of the two major types of lymph nodes the doctor will check for swelling when you feel sick.)
9. A part of a foreign protein (on an invading microbe) that provokes an immune response.
10. General (generic) term for a cell whose job it is to eat things (invading microbes, virus infected cells etc.).
11. Name for a type of arthritis that results from a chronic inflammation of the joints, leading to destruction of the joint tissues. (“__________” Arthritis)
12. Anatomical term referring to the neck area near your ear, just under your jaw. (Location of one of the two major types of lymph nodes the doctor will check for swelling when you feel sick.)
13. Refers to a class of proteins found on the surfaces of cells which allows the immune system to distinguish self from non-self, and also aids in antigen presentation.
15. Name for an enzyme that is secreted in tears and saliva, whose job it is to break down the cell walls of invading bacteria.
16. A type of cell from which platelets break off.
17. A type of B cell designed to secrete antibodies directed at a specific microbe, which remain in the immune system for months or even years after the specific microbe has been destroyed.
18. Name for the LINEAGE of cells that includes the B and T cells.
19. A term that refers to the ability of bone marrow stem cells to differentiate into any type of blood cell.
20. Refers to the formation of puss as a reaction to an invading microbe.
21. Name for the LINEAGE of cells that includes the erythrocytes and granulocytes.
22. Generic term for a class of signaling protein that signals other cells to do things.
23. Term used to describe leukocytes ‘patrolling’ the body to look for and destroy invading microbes.
24. Term referring to the study of blood, and the formation of different types of blood cells.
25. Name for a type of phagocyte that resides in the skin.
26. Large organ located behind and to the left of the stomach which is filled with macrophages, and which filters the blood to remove foreign microbes.
27. A ‘checkpoint’ along a lymph vessel (or lymph duct) which contains macrophages which destroy invading microbes.
28. Technical term for bone marrow stem cells (“___________ Stem Cells”).
29. Gland located above the heart where T cells go to ‘learn’ to distinguish native proteins and tissues from foreign, invading tissues.
30. The collective name for the 30 proteins made by the liver which circulate in the blood, and form a membrane-destroying complex in response to soluble antibodies binding to an invading microbe.
31. Generic term for a type of cytokine that causes stem cells to differentiate into different types of leukocytes.
32. A cytokine that signals bone marrow stem cells to differentiate into erythrocytes.
33. A class of cytokines that activates phagocytes and other leukocytes to either multiply, or start eating things.
34. Name for a phagocyte (or phagocyte precursor) that is wandering through the blood.
35. Name for a LARGE phagocyte that is located in a specific tissue of the body.
36. Name for a specific type of phagocyte located in the skin.

© J. Greg Doheny 2014