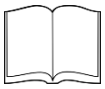
SUBJECT CODE:	Bio 1	*Fundamentals of Biology 1*
LEARNING GUIDE CODE:	4.0	*Immunity*
LESSON CODE:	4.2	*Non-specific Defenses of the Human Body (Innate Immunity)*
TIME FRAME:		*30 minutes (1 session)*



MATERIALS NEEDED

To complete this lesson, you need the following:

1. pen;
2. paper;
3. phone/tablet/laptop;
4. Moodle app;
5. Moodle (PSHS Knowledge Hub) account;
6. stable internet connection and;
7. Biology: A global Approach by Campbell et al. (2015).

TARGET

After completing this lesson, you are expected to:

1. compare nonspecific and specific defenses;
2. explain how the various nonspecific defenses function in defending the body; and
3. discuss the cellular elements of blood (basophils, lymphocytes, eosinophils, neutrophils, monocytes, platelets) that function in defense.

HOOK

SCRAMBLE RAMBLE

Can you see the five words with their letters jumbled? Arrange the jumbled letters in order to identify the mystery word.

N	I	S	K

P	H	M	L	Y

C	A	I	L	I

H	I	P	B	L	O	A	S

G	A	E	R	O	C	H	A	M	P

Are you familiar with each word? What is common among these words?

IGNITE

In the previous lesson, we have learned that the immune system or defense system is the body system which defends the body against any foreign molecule and aims to limit if not prevent many infections. We have also learned that animals utilize a variety of strategies in order to protect themselves from the threats of the external environment. We have also differentiated the two types of immunity found in animals as discussed in the previous lesson. It was also pinpointed that vertebrates possess both immunity and, in this module, we will be focusing on the nonspecific defenses of vertebrates and how each structure protects a vertebrate's body.

INNATE IMMUNITY OF

VERTEBRATES

The innate immunity of vertebrates can be classified as either barrier defense or cellular innate defense. **Barrier defense** is the first line of defense and protects against any outside invaders while cellular innate defense is the second line of defense composed of immune cells dedicated to detect, devour, and destroy pathogens which have breached the barrier defense.

BARRIER DEFENSES OF THE HUMAN BODY

How does it protect the body?

- Blocks the entry of pathogens
- Expels pathogens and foreign agents
- Provides an environment which is not suitable to the growth of pathogens.

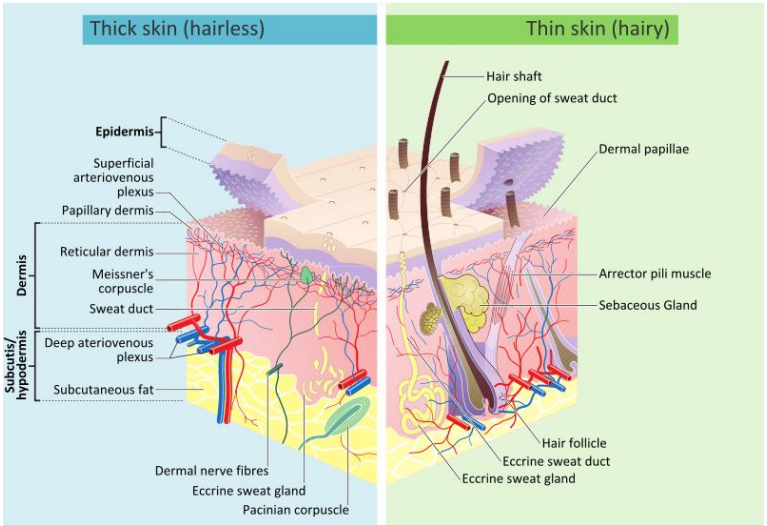


FIGURE 1: Skin as a multi-layered barrier defense

By Madhero88 and M.Komorniczak - https://en.wikipedia.org/wiki/File:Skin_layers.png, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=21986708

These defenses include the skin, respiratory tract structures, urethra, body secretions, organ pH, and **friendly microflora of some organs.**

1. The most visible barrier defense of the body is the **skin.** This organ is intact, and multi-layered as seen on Figure 1. These characteristics prevent the entry of pathogens. The **internal surface** of the organs is also made up of **mucous membrane** which acts as the first line of defense of the organs.

2. One of the most common entryways for pathogens is the respiratory tract since most pathogens can be easily transported through air. The respiratory tract is protected by a **respiratory lining** composed of nasal hairs in the nose or nasal cavity, and **cilia** from the trachea up to the bronchioles as seen in Figure 2 (take note that alveoli lack cilia). The nasal hair acts as air filters trapping dirt and large foreign molecules. The respiratory tract is also protected by several mechanisms such as **sneeze, cough reflex,** and **muco-ciliary apparatus**. These three mechanisms work hand in hand. **Sneeze** and **cough** reflex are usually experienced when dirt or any unnecessary material enters the respiratory tract as shown in Figure 3. These two can also be symptoms of respiratory tract infection because the presence of lots of mucus in the respiratory tract (a product of infection) triggers this reflex. When dirt or pathogens enter the respiratory tract, they are usually trapped by the mucus produced by the mucous membrane along the respiratory tract. The pathogen trapped in mucus will be pushed upward by the upward beating of the cilia along the lining; hence, the term **muco-ciliary escalator**. Physiologically, pathogens trapped in mucus will be pushed up to the pharynx, where it will be swallowed and will be taken care of by the acidic environment of the stomach. These respiratory structures and mechanisms are efficient air filters which are evolutionarily successful in trapping and expelling dust and germs. When the muco-ciliary escalator fails, mucus may accumulate in the respiratory tract as seen in Figure 4 and this may cause infection and disorders.

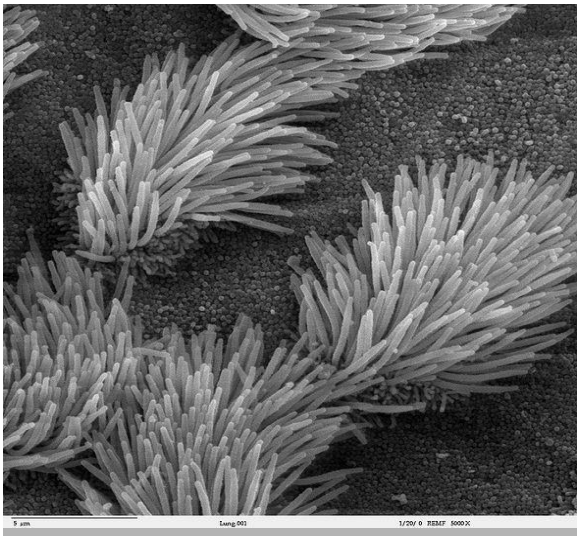


FIGURE 2: Ciliated cells in trachea

By Charles Daghlian - http://remf.dartmouth.edu/imagesindex.htmlhttp://remf.dartmouth.edu/images/mammalianLungSEM/source/9.html, Public Domain, https://commons.wikimedia.org/w/index.php?curid=1253508

FIGURE 3: Sneeze reflex in mid-action

By James Gathany - CDC Public Health Image library ID 11162, Public Domain, https://commons.wikimedia.org/w/index.php?curid=6701700

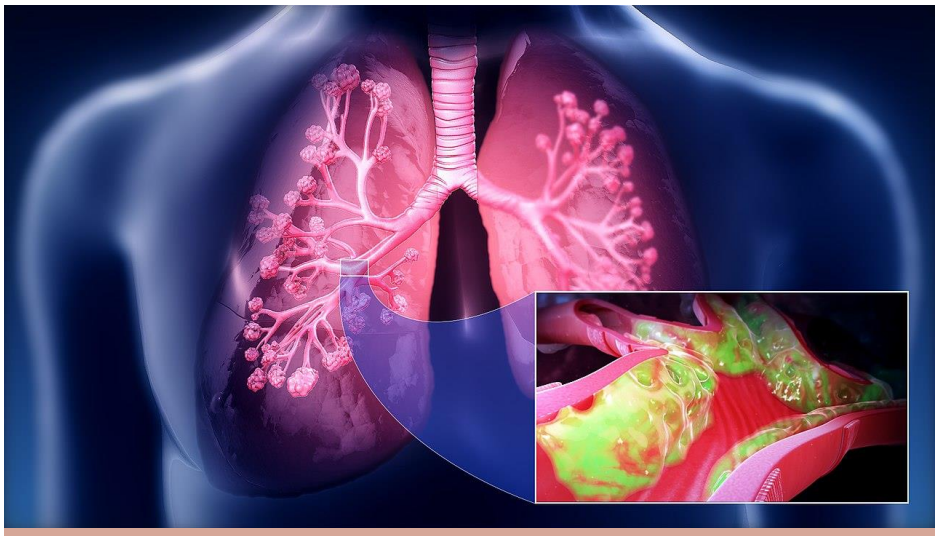


FIGURE 4: Mucus accumulation when muco-ciliary apparatus fails

By http://www.scientificanimations.com - http://www.scientificanimations.com/wiki-images/, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=81077285

3. The reproductive opening can also be an entranceway for pathogens. In terms of its anatomy, the **long urethra in males** is a first line of defense since this structure makes it hard and slower for bacteria to travel to the urinary bladder and promote urinary tract infection. This is also the reason why UTI or urinary tract infection is more common in females than in males because females have a shorter urethra than males as seen in the figure below.

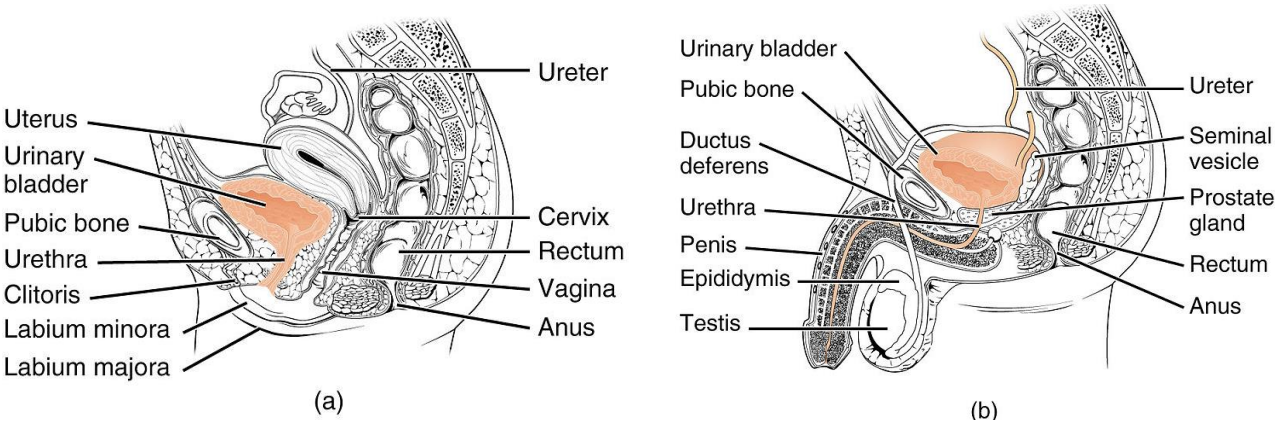


FIGURE 5: (a). Urethra in female and (b). Urethra in males (both orange extensions of the bladder and ureter)

By OpenStax College - Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013., CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=30148631

4. Aside from the intact and efficient structures, there are also **bodily gland secretions** which inhibit the growth of pathogens. These secretions include the following:

    a. **Earwax,** which are produced by ceruminous glands in the ear. This secretion traps dirt and germs which enter the ear canal.
    b. **Tears,** which are produced by lacrimal glands of eyes, contain **lysozymes, phagocytes and IgA antibodies,** which altogether protect the eyes from the entry of dirt and pathogens. **Lysozymes** are enzymes which break down bacterial cell walls. **Phagocytes** are cells which engulf foreign materials and pathogens. **IgA antibodies,** on the other hand, is **immunoglobulin A,** the function of which will be discussed in the next module.
    c. Since the food we ingest may also contain pathogens, the **saliva** produced by salivary glands also contains **lysozymes and antibody IgA.**
    d. As discussed earlier, the mucus gland of gastrointestinal and respiratory tract secreted **mucus** which protects cells against **acid** and also **traps germs.**

5. Some body organs and bodily secretions have an acidic environment. The acidity of these environments is unfavorable for the growth of bacteria since acidity has a bactericidal (bacteria-killing) effect. The stomach for instance is very acidic due to the hydrochloric acid (with a pH of 2) produced by the gastric glands in the lumen of this organ. The internal environment of the vagina is also acidic (pH: 3–4) as maintained by *Lactobacillus*. The skin is also acidic (with a pH of 3-5) due to sebum, an oil produced by the sebaceous gland in the dermal layer of the skin. Urine also is very acidic due to ions (with a pH of 6–7), adding another layer of protection to the urinary tract.

6. There are also **friendly bacteria** which grow on some parts of the body which prevent the overgrowth of harmful bacteria. *Lactobacillus,* a friendly bacterium seen in the micrograph below, usually grows in the **vagina** and **large intestine.**

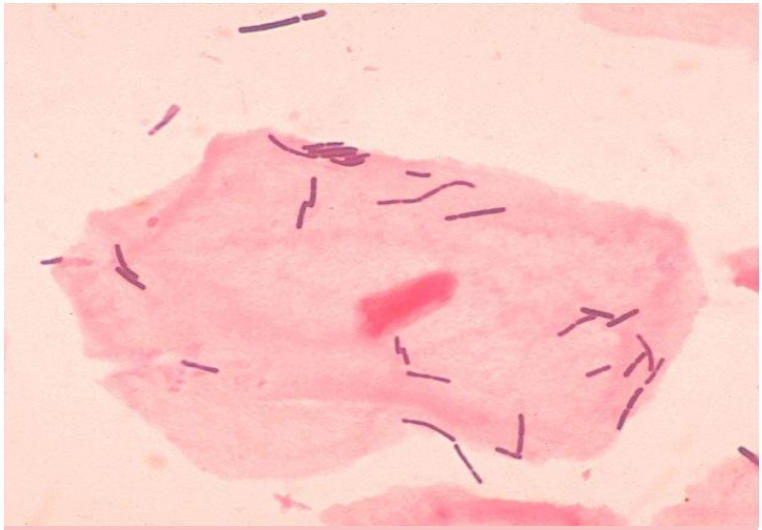


FIGURE 6: *Lactobacillus* in vaginal tissue smear

By Photo Credit: Janice CarrContent Providers(s): CDC/Dr. Mike Miller - This media comes from the Centers for Disease Control and Prevention's Public Health Image Library (PHIL), with identification number #1048. Public Domain, https://commons.wikimedia.org/w/index.php?curid=640855

What would happen if the pathogen or foreign molecule breaches the barrier defense? In the next part of this lesson, we will be discussing the cellular innate immune defenses which act against foreign molecules and substances which successfully invaded the barrier defenses of the body.

CELLULAR INNATE DEFENSES OF THE HUMAN BODY

How does it protect the body?

- Detects, devours, and destroys invading pathogens which have breached the barrier defense.

Cellular innate defenses often rely on **Toll-like receptors (TLRs),** a mammalian recognition protein similar to the Toll proteins of insects. **TLR3** recognizes *double-stranded RNA* **(**genetic material of some **viruses**), **TLR4** recognizes *lipopolysaccharide* (molecule found on the **surface of some bacteria**). **TLR5** recognizes *flagellin* (the main protein of bacterial flagella).

Cellular innate defenses can be classified as **phagocytic cells, natural killer cells,** and **anti-microbial peptides and proteins.**

1. There are different **phagocytic cells** in the blood. These are the **neutrophils, macrophages, dendritic cells,** and **eosinophils.**

   Neutrophils and macrophages respond immediately to infections caused by small pathogens like bacteria, virus, or fungus. **Neutrophils** are mature phagocytic cells which ingest marked pathogens and kill them as seen on Figure 7. Neutrophils are often attracted by signals released by infected cells. **Macrophages,** on the other hand, are large-eaters which have more elaborate phagocytic abilities than neutrophils. However, macrophages when circulating in the blood are still immature, and these immature macrophages are called **monocytes.** Monocytes only mature into macrophages when they migrate to the tissues. In the tissues, the mature macrophages can live for months; hence, providing continuous defense against infections in tissues. Upon phagocytosis, the pathogen is killed via **lysosomes** (the cellular organelle which functions in cellular digestion or breaking down of unwanted materials inside the cell)**.** Phagocytosis is illustrated in Figure 8.

   Eosinophils, on the other hand, immediately respond to **big pathogens such as big worms** and kill parasitic worms by **releasing destructive enzymes**. **Dendritic cells** often populate tissues which are in direct contact with the environment such as the skin. They also exhibit phagocytosis, but instead of killing a pathogen, they mark the pathogen and presents the pathogen for destruction by the *acquired/adaptive immunity* which we will discuss in the next learning guide.
   When pathogens enter a tissue, as in the case of splinters pinching into the skin, **basophil/ mast cells** release histamine which causes dilation of blood vessels. Macrophages residing in

the area of the injury also releases signaling molecules. Dilation of the blood vessels and release of signals attract neutrophils and allow them to accumulate in the area of tissue injury. This sequence of events is also known as the **inflammatory response** and this is summarized in Figure 9. A product of inflammatory response is the build-up of **pus –** a liquid which is a combination of immune cells, cell debris, and dead pathogens.

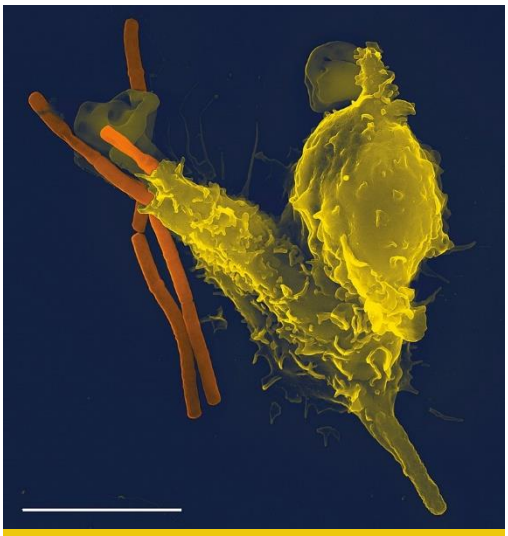


FIGURE 7: Neutrophil (yellow) engulfing a *Bacillus anthracis* (orange) seen under SEM

By Volker Brinkmann - (November 2005). Retrieved on 2009-01-04., CC BY 2.5, https://commons.wikimedia.org/w/index.php?curid=2107792

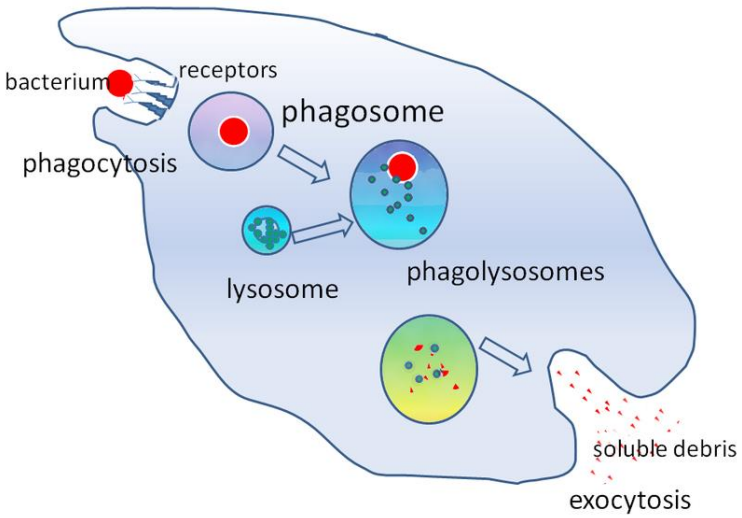


FIGURE 8: General mechanism of phagocytosis

By GrahamColm at English Wikipedia, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=6811745

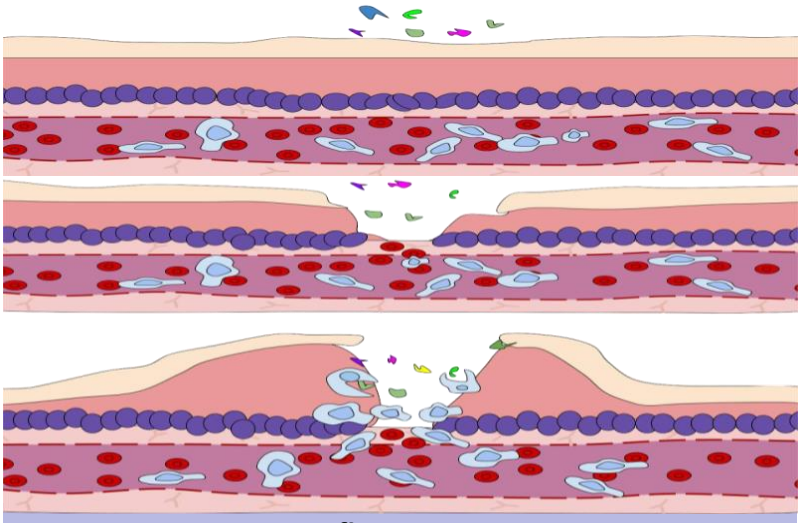


FIGURE 9: Inflammatory Response

By Nason vassiliev - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=69869239

2. **Natural killer cells** act against virus-stricken and cancerous cells not by engulfing them or phagocytosis but by releasing chemicals which lead to cell death. These cells circulate throughout the body and can easily recognize whether a cell is healthy or cancerous or infected by a virus.

3. There also substances which directly kill pathogens and impede their reproduction. These substances are also known as **antimicrobial peptides and proteins.** These are peptides and proteins that attack pathogens and impede their reproduction. **Interferons** are proteins which interfere with viral infections. **Complement system,** on the other hand, is a type which eliminates dead cell wastes, and augments adaptive immunity.

Cellular innate defenses usually circulate throughout the body and detect any possible infection. The response cells involved usually reside in the **lymph nodes,** structure which contains **lymph. Lymph** is a fluid which carries liquid and pathogens which have leaked from the interstitial fluid of the cell and the blood. At the **lymph nodes,** the response cells act against the pathogen. Lymph is distributed throughout the body by a network known as the **lymphatic system** illustrated in the figure below**.**

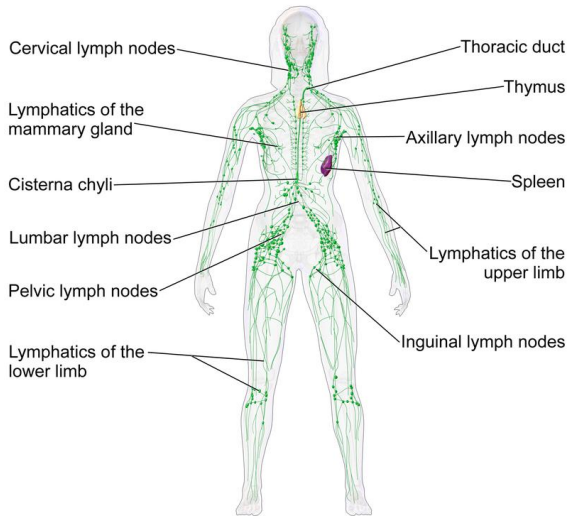


FIGURE 10: Lymphatic system

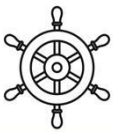
By BruceBlaus. When using this image in external sources it can be cited as:Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436. - Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=28086436

A PATHOGEN BREACHES THE INNATE IMMUNITY, WHAT'S NEXT?

As a product of coevolution across time, some pathogens evolved structures and mechanisms which made it impossible for the innate defenses to expel, acknowledge, neutralize and kill them. One example of this is *Streptococcus pneumoniae,* the causative agent of **pneumonia.** It possesses a capsule which made it hard for innate defenses to recognize them. This led to the development of drugs which can effectively eliminate these pathogens.

Now that we have discussed the different innate defenses of vertebrates, we can now proceed to the unique immune mechanism of vertebrates, the **acquired or adaptive immunity** in the next learning guide.

You may also refer to your textbook (Campbell et al., 2015) for other illustrative examples and more detailed explanations.



NAVIGATE

CBC: WHAT'S WRONG?

Complete blood count is a blood test which determines the amount of several cellular components of the blood which include the red blood cells, white blood cells, lymphocytes, platelets and hematocrit (the proportion of red blood cells in relation to the plasma). Underlying medical conditions can be deduced from a CBC report.

Analyze the CBC report below and answer the questions which follow. **THIS IS A NON-GRADED ASSESSMENT.**

Tests	Reference Intervals	Results
Hemoglobin g/L	135 - 180	141
WBC $x10^9$/L	4.00 - 11.00	12
Platelets $x10^9$/L	150 - 400	350
MCV fL	78 - 100	82
PCV	0.40 - 0.52	0.48
RBC $x10^{12}$/L	4.5 - 6.5	5.6
MCH pg	27.0 - 32.0	29
MCHC g/L	310 - 370	340
RDW	11.5 - 15.0	13

Neutrophils	2.0 - 7.5	5.6
Lymphocytes	1.0 - 4.5	3.5
Monocytes	0.2 - 0.8	0.75
Eosinophils	0.04 - 0.40	0.86
Basophils	< 0.1	0.05

ANALYZE

Based on the CBC report, which blood cell count is abnormal? Why do you say so? Based on what we have discussed, what do you think are the possible underlying medical conditions of the individual bearing this blood count? Write your answers on the space provided below.

KNOT

In summary, the immune or defense system of vertebrates is classified as either innate defense or acquired immunity. Innate defenses are nonspecific defenses which protect the body from the invasion of a wide array of pathogens. Innate defenses can be classified as either barrier defense or cellular innate defense. Barrier defense is the first line of defense of the body and protects against any outside invaders. This defense may be structural (intact skin, respiratory lining, reproductive structures), chemical (secretions, enzymes, pH), or ecological (mutualistic relationship with friendly bacteria) in nature. Cellular innate defenses, on the other hand, are composed of response cells and antimicrobial substances which act against pathogens and foreign molecules which have breached the barrier defenses.

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