



## Host-Parasite Interactions Innate Defenses of the Host

Hosts and parasites have co-evolved throughout life on Earth. The first hosts evolved in the presence of parasites, and thus, throughout their evolution, were continually developing new strategies to protect themselves from these parasites.

Each time a host defense strategy evolved, a parasite attack strategy to counter that defense co-evolved. Over time this process of co-evolution in host-parasite relationships has led to the development of a very complex system of attack and counter-attack.

### Example

Host - Human	Parasite - <i>S. pneumoniae</i>
Mucus lines nose and throat to prevent colonization by invading bacteria	<i>S. pneumoniae</i> is sometimes able to colonize the nose and throat, and can remain there transiently as part of the normal flora. It can also be aspirated into the lungs
The lungs contain alveolar macrophages, cells which engulf and destroy invading microorganisms.	Some <i>S. pneumoniae</i> have a polysaccharide capsule surrounding their surface. This makes them slippery, and the alveolar macrophages can no longer engulf and destroy them. The bacteria can now multiply in the lung.
The immune system produces antibodies that specifically recognize and attach to the polysaccharide capsule of <i>S. pneumoniae</i> . The antibody acts as a tag and calls in and helps macrophages engulf the bacteria.	

## Innate versus Acquired host defenses

There are two major types of host defenses — innate and acquired which are compared in the table below.

	Innate	Acquired
Examples	Barriers such as skin or mucus membranes Peristalsis Acid pH	Antibodies Cytotoxic T cells
Time required for response to be ready to act	Immediate — Innate host defenses are in place, ready to go, at all times.	Takes several days for the response to be generated
Specificity	Non-specific — Will attack any invader.	Specific to the microorganism against which it was generated. For example, antibodies against smallpox do not protect against other diseases such as colds or polio.

This exercise deals with innate defense mechanisms only.

## Normal Flora

The normal flora are bacteria which are found in or on our bodies on a semi-permanent basis without causing disease. There are more bacteria living in or on our bodies, than we have cells of our own. A human body contains around  $10^{13}$  cells. The human body is home to around  $10^{14}$  bacteria. One fourth of fecal weight is made of bacteria!

The normal flora are particularly important in the large intestine. Normal flora are also found in the nose, mouth, throat and skin. Our normal flora protect us against disease by

- Competing with invaders for space and nutrients
- Producing compounds (bacteriocins) which kill other bacteria
- Lowering the pH so that other bacteria can't grow

In addition to the above ways of protecting us from disease our normal flora help us in other ways. Of course, there is a down side as well...

The Good Side	The Bad Side
Help digest food	If the normal flora escape from their normal location, they can cause disease. For example, <i>Escherichia coli</i> , commonly found in the intestine, can cause urinary tract infections if introduced into the bladder.
Boost our immune system — Germ free animals (born and raised in a germ free plastic tent) are very susceptible to disease when removed from the germ free environment because their immune system is underdeveloped.	Treatment with antibiotics can kill the normal flora, leaving the host open to infections. For example, many people suffer from diarrhea following antibiotics as their normal intestinal flora is disrupted.
Produce vitamins we are unable to produce such as vitamin B12.	Immunosuppression can allow otherwise harmless bacteria to cause disease. AIDS, some cancer treatments and transplant rejection drugs all suppress the immune system and allow the normal flora to cause occasionally serious disease.

## **Defenses of the Mouth**

**Saliva** - Our mouth is continually producing saliva, which washes away potential invaders. Also, lysozyme is an enzyme found in both tears and saliva. This enzyme breaks down bacterial cell walls, which are made of a unique compound called peptidoglycan.

**Normal Flora** - See normal flora section above.

## **Defenses of the Stomach**

**Acid** - Our stomach is continually producing hydrochloric and gastric acids and has a pH of around 2. This low pH helps us to digest food. It also kills most invaders attempting to gain access to the body through the GI tract.

**Peristalsis** - Peristalsis is the wave-like contraction of smooth muscle in the intestine. This process is continually occurring in our body, and keeps food moving through our intestine. The continual movement makes it difficult for invading microorganisms to stay in place long enough to start an infection.

**Normal Flora** -See normal flora section above.

## **Defenses of the Skin**

**Keratin** - The outer layer of the skin is composed of tightly packed dead cells containing large amounts of keratin, a tough, waterproof protein. This acts as a physical barrier, or wall, which blocks the entry of invaders into the body.

**Dryness** - Skin is very dry, like a desert. Since most organisms require moisture to live, it is difficult for organisms to colonize the skin, just as it is hard for plants and animals to live in a desert.

**Sebum** - The sebaceous glands in our skin produce an oily substance called sebum. Sebum contains unsaturated fatty acids that are toxic to most potential invaders.

**Acid** - Our skin is less acidic than the stomach, with a pH of around 5. Many but not all bacteria are unable to grow at this low pH. However, fungi, including yeast, can often grow at this pH.

**Normal Flora** - See normal flora section above.

## Defenses of the Eyes

**Lashes** - Eye lashes prevent pieces of dirt and bacteria from falling into the eyes.

**Sclera** - A tough, hard layer of fibrous material covering the eye. Parts which are visible include the whites of the eyes, and the translucent **cornea** through which we see. This tough surface is difficult to infect or cross.

**Conjunctiva** - Membrane covering the surface of the eye

**Tears** - Lysozyme is an enzyme found in both tears and saliva. Each time we blink our eyes, our eyelids wash tears over the surface of our eyes, thus removing bacteria and particles that have been deposited. The enzyme lysozyme breaks down bacterial cell walls, which are made of a unique compound called peptidoglycan.

## Defenses of the Throat and Bronchi

**Mucociliary Escalator** - The mucociliary escalator covers most of the bronchi, bronchioles and nose.

It is composed of two basic parts;

1. the mucus-producing goblet cells
2. the ciliated epithelium.

The cilia are continually beating, pushing mucus up and out into the throat. The mucociliary escalator is a major barrier against infection. Microorganisms hoping to infect the respiratory tract are caught in the sticky mucus and moved up by the mucociliary escalator. Note how our purple invader has been trapped in the mucus and is being pushed upward towards the throat.

**Normal Flora** - See beginning of handout on normal flora. Note - The throat is covered with a normal flora. The bronchi and bronchioles are usually sterile and do not have a normal flora.

## **Defenses of the Nose**

Air is full of dust particles and microorganisms. We breath-in 8 microbes a minute, or 10,000 a day, and that does not include all the dust we breath. The nose is the initial filter of microbes entering the respiratory tract.

**Nose Hairs** - Hairs that act as a physical filter to trap many microbes. Additionally the nose has an active normal flora that competes for space and nutrients with potential invaders.

**Nasal Turbinates** - The pathway that air follows from the entrance of the nose down into the trachea is not a straight one. There are a series of bone plates, sinuses and baffles, called the nasal turbinates, through and around which air must pass. As air passes around a sharp corner, most particles and microbes are thrown against the walls by the air currents (shown in blue). Notice how our purple invader has been thrown against the upper wall of the nose. Once thrown against the wall, particles are trapped in the mucus layer that lines the nose and are then removed by the mucociliary blanket which pushes trapped materials towards the throat.

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**Normal Flora** - See normal flora section above.

## **Defenses of the Lungs**

The lungs are normally a sterile environment. They are not lined by a mucociliary escalator as this would slow down the gas exchange that needs to take place across the cell surfaces which line the alveoli of the lung.

Alveolar macrophages are the primary innate defense mechanism of the lung. These cells are phagocytic cells, cells that can swallow invading microorganisms and destroy them. First the alveolar macrophage grabs onto the microorganism by binding to its surface. Then it swallows the microorganism by a process called phagocytosis. The cell membrane blebs out and surrounds the invader. The invader is then pulled into the inside of the cell in a membrane bound vesicle, a phagosome, which then fuses with lysosomes. Lysosomes are specialized organelles which serve as the trash can of the cell. Lysosomes are filled with toxic oxygen compounds that kill microorganisms and degradative enzymes which break down the microorganisms.