**Environmental Chemistry and Microbiology**
**Dr. Anjali Pal**
**Dr. Sudha Goel**
**Department of Civil Engineering**
**Indian Institute of Technology - Kharagpur**

**Module - 11**
**Lecture - 54**
**Pathogens and Diseases - I**

Welcome everyone. This is our next module; this is module 11 and in the next 2 lectures, we are going to cover Pathogens and Diseases. So, this is part 1 and lecture 54 of module 11.

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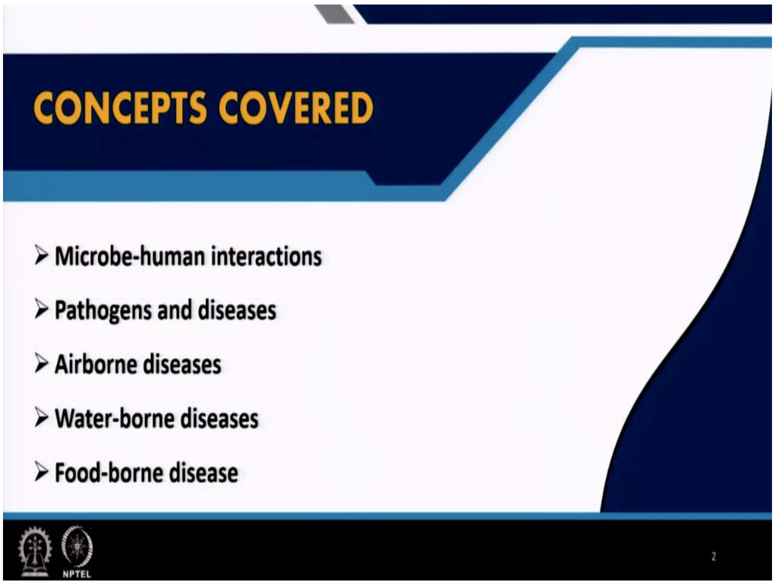


So, we will start with the first part, which is microbe-human interaction. So, what is the nature of the interaction between microorganisms, human beings and diseases. This is an extremely short review of pathogens and diseases; so, you will have to forgive me for going through it very quickly. But it is something that we need to be aware of. But at this point, I would say there is no need for us to become experts in this matter.

So, I am going to be covering these topics. We will look at the nature of how microorganisms interact with humans; are they always destructive or they can be beneficial as well. So, we will be taking a look at all these neutral, beneficial, and destructive interactions. Then we will focus on pathogens and diseases because from a public health point of view, which is a precursor to environmental engineering and science, this was the main reason for many of the things that we do. For example, disinfection in water treatment, wastewater treatment. It is all because of our knowledge of pathogens and diseases. And then we will take a quick look at some common airborne diseases, waterborne diseases, and foodborne diseases.

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So, let us come to the first point and that is, what is the nature of the interaction between microbes and humans? So, when we think about microorganisms which are inside the human body, we might say that microbes are parasites and humans are the hosts. However, it is not always the case. There are 3 types of relationships that we want to look at.

The first one is neutral, where the microorganism may either exist on the surface or inside the body, or in the external environment. If it does not affect the host, it is in a neutral relationship. If it is of mutual benefit, in the sense that when we take in food, what we are also doing is providing nutrients for the microorganisms that exist within our body. Now, if those microorganisms are also creating certain vitamins or growth factors, or they are breaking down complex foods into simple sugars which our body can digest more easily, then it becomes a mutually beneficial relationship and we call that a symbiotic relationship.

And then, the last one is pathogenic. Now, pathogenic is when the relationship is completely antagonistic. So, if the microorganism is going to cause damage to the host, either cytotoxic damage or genotoxic damage, wherein either the cells or the organs are destroyed or the DNA is destroyed. So, in either case, these are called pathogenic microorganisms.

What is the outcome of the antagonistic relationship? Now, it depends on 2 major factors. One is microbial virulence. So, the virulence of these microorganisms means the ability to damage the host cells or organs; that is a major factor. That is the first major factor. And I will show you examples as we go - about what is the difference between, let us say a highly virulent organism and a moderately virulent organism.

And then we come to host immunity. What is the ability of the host to resist attack from these antagonistic or pathogenic microorganisms? So, if the host is normal, and has a healthy immune system, then it will be in most cases completely resistant to attack by these microorganisms. There may be conditions; let us say somebody is stressed out, somebody is having poor diet, they are old or they are too young, too young, too old. These are groups or conditions under which the person's immune system is not fully resistant. So, under those conditions, they become vulnerable to attack by these pathogenic organisms. And often we call those opportunistic pathogens. So, I will come to that.

Now, the outcome of this relationship between microbes and human beings is not always constant, it depends on several factors. So, the first big group of factors is environmental conditions. Like I said, your stress level can be mental stress, it can be physical stress. If I am in an environment where it is too cold; if I am in an environment where it is too hot; or the humidity level is too high; all these are environmental factors which can cause physical distress for the human being. So, these external factors or environmental factors will also influence the outcome.

And I have mentioned this several times in the past; we are living through the COVID-19 pandemic; and these factors are being widely discussed in the media and so on. So, I think the layman is now quite aware of these factors both in the environment and within the immune system. So, if the person is vulnerable because of low immunity, then opportunistic pathogens can cause problems, can cause diseases. So, infection is what we define as the growth of microorganisms within the host.

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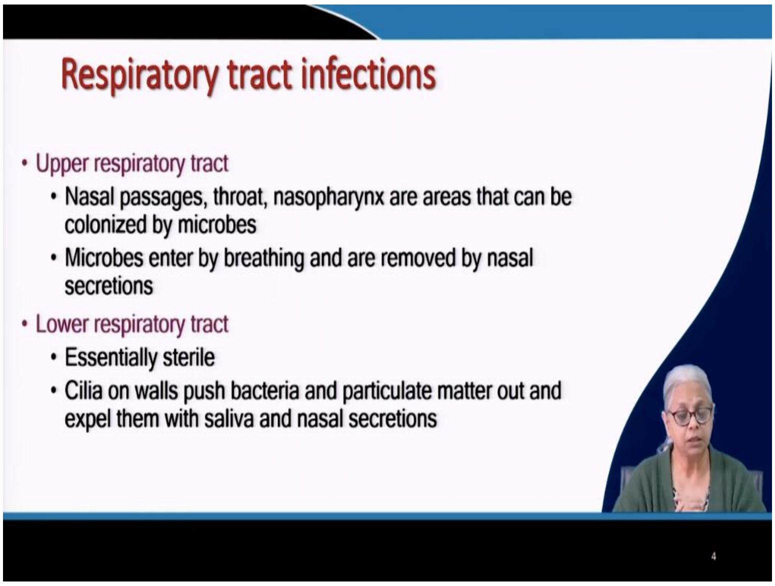


Now, I will take you through some of the different infections that can happen either in the respiratory tract or in the mouth, teeth. I will look at some of the general ones that we come across on a daily basis. Like I said, the intent over here is to make you aware of certain common types of infections. The intent is not to become an expert in microbial pathogens and diseases. We will leave that to the medical experts.

And here is just a very brief introduction to different types of infections. So, within respiratory tract infections, we have upper respiratory tract and lower respiratory tract. So, what is the upper respiratory tract? It includes the nasal passages, the nose, related to the nose, throat, nasopharynx, all the way down. And these areas are commonly colonised by microbes and bacteria, viruses, all of them.

These microorganisms are also present in the air. So, they enter by breathing and they are removed by nasal secretions. The lower respiratory tract in a healthy human being is considered to be essentially sterile. And we would hope that it would remain sterile. The cilia on the walls of the lower respiratory tract, they push both bacteria and particulate matter out. That is what you exhale and they are expelled with the saliva as well as the nasal secretions. So, this is the body's way of defending itself from attack by microorganisms.

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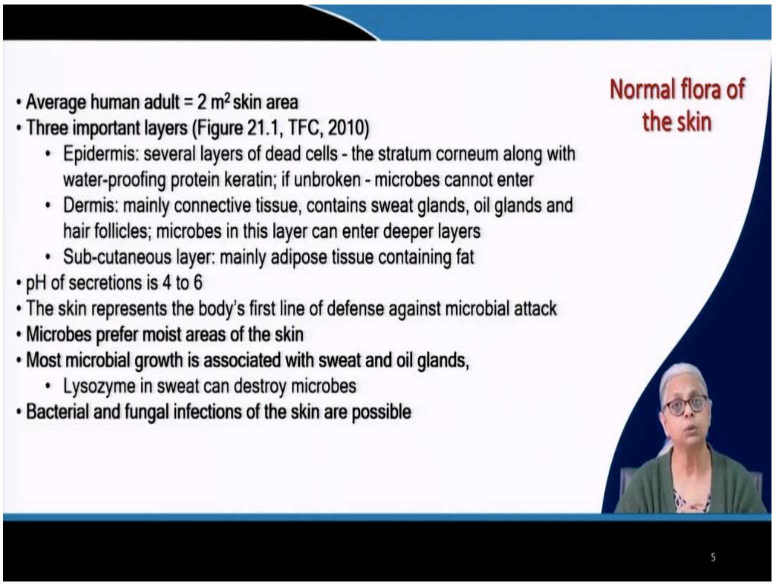


Let us now take a look at the normal condition of the skin. So, after the respiratory tract; we also have a lot of microorganisms that grow on the surface of our body. The average human adult has more than 2 square metres of surface area or skin area. If you were to take a section, a cross-section across the skin, you would find that there are 3 important layers. And I have referenced a particular figure in the textbooks, one of the recommended textbooks. You can look at any of the images that are available on the Internet, so that you have an understanding of what this is about. So, these 3 important layers are the epidermis, the dermis and the subcutaneous layer.

The epidermis is the top part. So, if you were to just look at your skin, what does it have? It has a layer of dead cells. There are several layers; it is not just a single layer. And it has nerve endings, but it does not have living cells; they are not multiplying at the surface. That is part of your body. So, several layers of dead cells are present. And there is this stratum corneum. This is called the stratum corneum. And it also contains a waterproofing protein keratin, which is also part of our hair and our nails. If this layer, the epidermis is not broken, no microorganism can enter into the body through the skin. So, this dead layer of cells has a very important function to provide, and it is our first line of defense against pathogenic microorganisms.

Below the epidermis, below the dead layers, we have the dermis. Now, this dermis is where the connective tissue is. It also contains sweat glands, oil glands and hair follicles. So, the roots of your hair, the body hair has its roots in the dermis. So, these are the hair follicles. If the epidermis is damaged, microbes can enter, they can enter into the dermis and even deeper. So, this is the entry point where, if the top layer is broken or damaged, then it can happen. Now, below the dermis, we have another layer which is called the subcutaneous layer. This subcutaneous layer is mainly made out of adipose tissue and that is mainly fat. So, it has got this yellowish colour to it, that is the colour of fat. The pH of secretions from the skin; so, you might think about sweat and oil and all of that; it has a low pH of around 4 to 6. As I already said, the skin represents the body's first line of defense against microbial attack.

Why is the skin area susceptible to microbial attack? One is that it is a moist area. It has 2 things. 1, it has moisture; and 2, it has oil and sweat. Now, oil and sweat, both contain nutrients which can allow these microbes to grow. And that is why it is so important to maintain personal hygiene, in terms of regular bathing and showering and all of that, and use of soap and water. All these things are mainly because microbial growth is associated with sweat and oil glands. And there is a particular enzyme, lysozyme, which I have shown you in previous lectures; it is present in sweat. And that is capable of destroying microbes. So, that is another line of defense. The skin is fairly vulnerable to both bacterial as well as fungal infections. And there are many examples of these types of infections.

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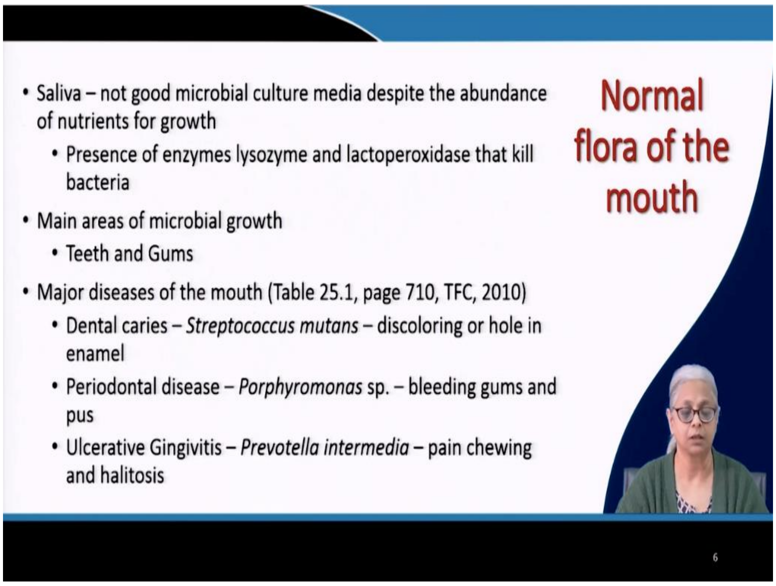


Let us take a look at another part of the human body and that is the mouth. We all know that if we do not brush our teeth, what happens. You have this horrible feeling in your mouth. And that is, you have bad breath, you have a bad taste, and you have a sense of some layer growing inside your mouth, on the surface of the teeth as well as on the surface of the tongue and so on; if you happen to forget to brush for more than a day or 2.

So, your mouth has saliva. This saliva, despite the abundance of nutrients that are present in saliva, is not a good microbial culture, mainly because of 2 major enzymes, lysozyme and lactoperoxidase. These 2 enzymes are very good at killing bacteria. So, even though saliva has lots of nutrients, the mouth is not sterile; far from it. It has a huge number of microorganisms in the mouth, and that is why brushing is so important. But it is able to provide some defenses against various bacterial infections, simply because of the presence of these enzymes.

So, what are the main areas that are susceptible or vulnerable to microbial growth? We have teeth and gums. And those of you who are old enough to have suffered through dental cavities and bleeding gums and so on, you have already some idea that all this happens because of the growth of microbial organisms in the mouth.

So, there are 3 categories of organisms that can cause diseases of the mouth. Again, I have provided a reference here, from the textbook. The first one is dental caries. Caries are also cavities. So, when you have the degradation of the tooth or its enamel and it starts with discolouration and then ends with a hole in the enamel. Very often this is due to *Streptococcus mutans.* So, that is the first one.

Then you have periodontal disease. And this periodontal disease causes bleeding gums and you might even have pus in the gums and so on. And that is caused by *Porphyromonas* species. And then you have ulcerative gingivitis, which is caused by *Prevotella intermedia*; and that causes pain when you are chewing, and it also causes bad breath or halitosis.

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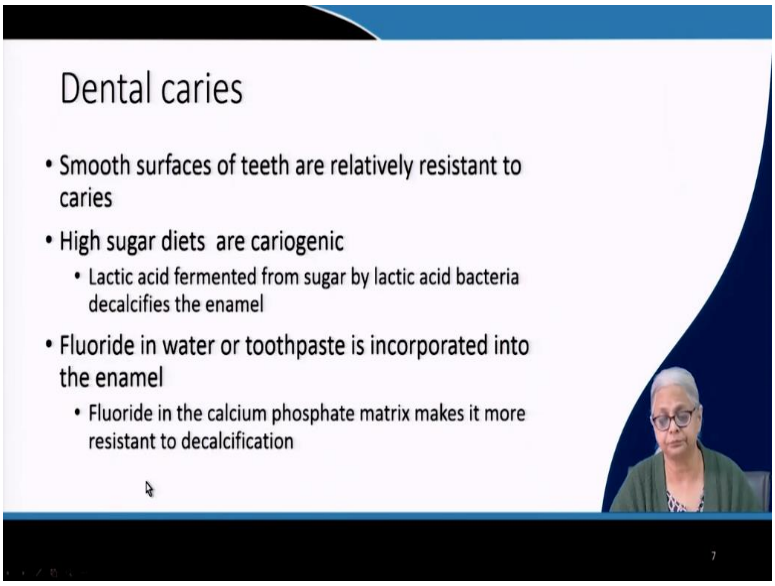


Coming to some details about dental caries. You know that in a normal human being with good teeth, normal teeth, the surface of teeth is relatively smooth, and it is resistant to cavities or caries. If the diet is high in sugar or carbohydrates, it is considered cariogenic; which means that if you have a high sugar diet, you are encouraging microbial growth within the mouth.

So, the same applies to other; sugar can come from various sources. It can come directly in the form of sugar or sucrose, and it can also come in the form of carbohydrates as well as milk products. So, lactic acid is fermented from sugar by lactic acid bacteria. And these bacteria are also responsible for decalcification of the enamel. The enamel is generally made out of calcium phosphate, carbonated calcium phosphate and this carbonated calcium phosphate is easily decalcified by acids.

And it is not maybe just lactic acid, but remember what I said in microbial metabolism; I mentioned to you that all the intermediates, the key intermediates in the first phase of metabolism are all acids. So, that itself is an indicator of the fact that your mouth is going to be slightly acidic, perhaps. And these acids are responsible for decalcification of the enamel. So, if you take fluoride in either the toothpaste or in water, that gets incorporated into the enamel. So, the matrix of the teeth is basically calcium phosphate, and providing fluoride makes it resistant to decalcification.

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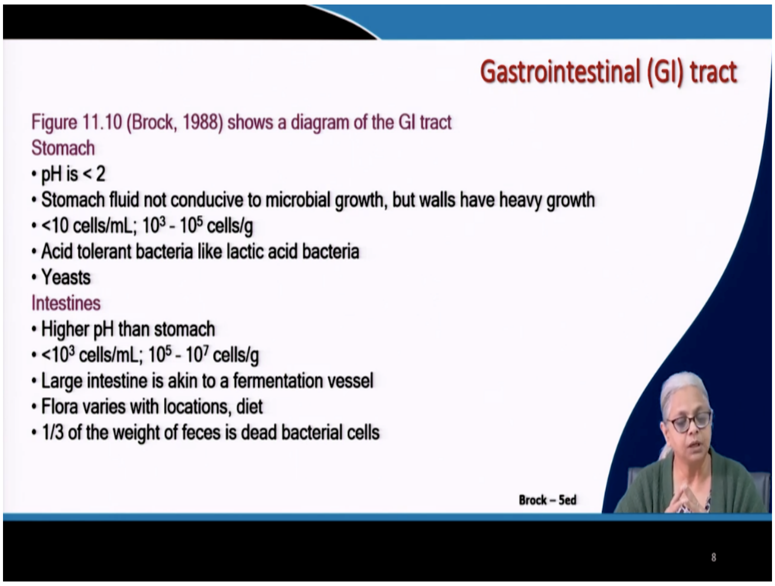


Let us now move to another organ of the human body and that is the gastrointestinal tract. So, from the point of view of digestion, this is the most important organ; or, it is not actually 1 organ, it is a set of different organs. So, it includes the stomach, the smaller and the larger intestines. So, when we take a look at the stomach, the pH of the stomach is considered to be below 2. How is it possible for an organ to have such low pH? The acidity is very high.

That is possible because of the mucosal lining. So, these mucosal linings which are part of many of these organs including the stomach and the intestinal lining, that allows the stomach fluids to have a low pH. Stomach fluid by itself is not going to allow microbes to grow. However, the walls, the mucosal lining has much greater propensity for allowing microbial growth. The number of cells in the stomach fluid is less than 10 cells per ml.

It can vary from 1,000 cells to 100,000 cells per gram at the mucosal lining. It includes acid-tolerant bacteria. Remember that, because the pH is so low, the only bacteria that can survive over here are acid-tolerant bacteria like lactic acid bacteria, as well as yeasts.

And then we come to the intestines. These intestinal organs, the smaller as well as the larger ones, they have a higher pH than the stomach. The cell number is also much higher. It is less than 1,000 cells per ml, but much higher than the stomach. And if you want to put it in terms of grams, it is $10^5$ to $10^7$ cells per gram.

The large intestine is similar to a fermentation vessel. So, a fermentation vessel is where you are generating gas and that is where you get the complete end of whatever you have eaten is; some of it is partially mineralized and some of it is converted to biomass. Some of it is old biomass, dead biomass and some of it is new biomass. The microbial flora; this flora means microbial flora, within the intestinal tract, varies depending on the location, depending on the diet, depending perhaps even on the age of the person, and so on. So, there is a huge amount of difference in the microbial species that colonise the GI tract or the gastrointestinal tract. One third of the weight of feces is considered to be dead bacterial cells.

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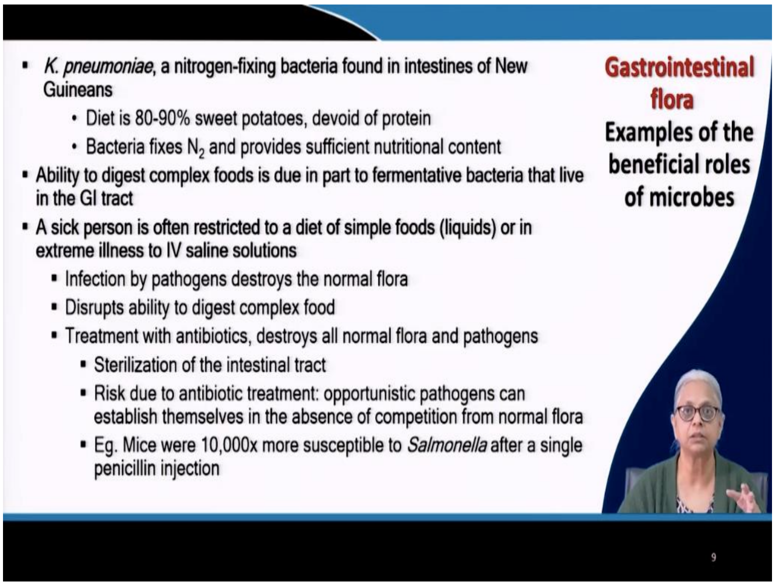


What I have here are some examples of the beneficial role that microbes play in our digestion process. So, here, the very first example is *Klebsiella pneumoniae*. Now, *Klebsiella pneumoniae* is a facultative bacterium. It is also capable of nitrogen-fixing. It can grow under aerobic conditions, but under anaerobic conditions, it can fix nitrogen. And this bacterium has been found to have a symbiotic relationship with a small group of human beings, the New Guineans. Their diet is, 80 to 90% of their diet is sweet potatoes, which are devoid of protein.

So, how can they get their protein? This bacterium has colonized their intestines and it is capable of fixing nitrogen gas and therefore creating amino acids and proteins, thus providing them sufficient nutritional protein.

Let us take another look at other examples. Our ability to digest complex foods is mainly due to fermentative bacteria that live in the gastrointestinal tract. The simplest way to kind of understand it is what happens when you fall sick. Anyone who has fallen sick knows that the first thing that seems to hurt us is the lack of appetite, the inability to digest complex food. So, when you have a stomach upset; starting from a simple stomach upset to maybe even more serious infections, what happens is, you switch to a simpler diet.

You may switch to a liquid diet, you may switch to something that is extremely simple to digest like soups, hot soups and so on. That is an example of why you are unable to digest complex foods and you are moving to liquid and simple foods. And in extreme cases, when the person is extremely ill, they may not be able to ingest any food at all, whether it is a solid or liquid, and they are put on intravenous saline solutions. So, that is an extreme condition. These sick people have been infected by pathogens that have destroyed the normal flora of their gastrointestinal tract. So, these pathogenic organisms have destroyed the ability of human beings to digest complex foods. And then when you are treated with antibiotics, that further destroys the normal flora and the pathogens.

In many cases, (if the antibiotic) dosage is high enough, it can cause sterilization of the intestinal tract which may be required to get rid of the pathogen. And the risk due to antibiotic treatment, therefore, is that opportunistic pathogens can establish themselves within the GI tract, because the normal flora which outcompetes them under normal conditions is no longer present. So, here is an example of mice that were given a single penicillin injection. And after the injection, they became 10,000 times more susceptible to *Salmonella* than before.

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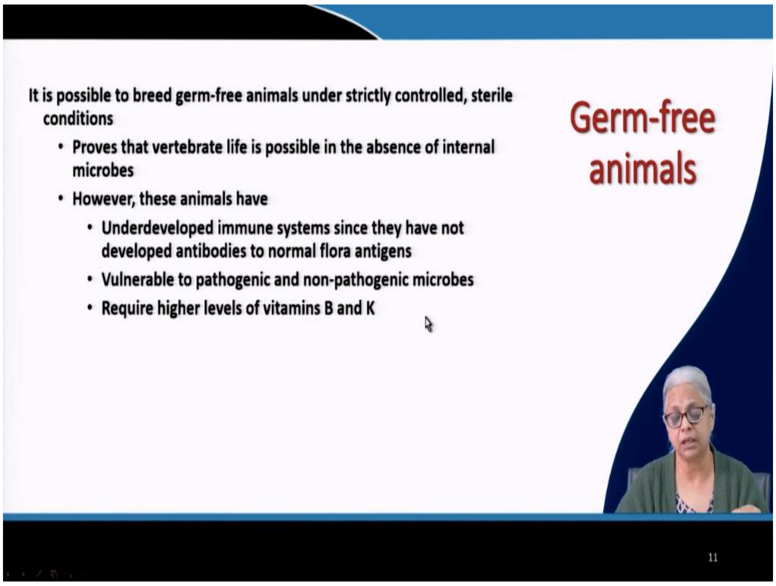


Now, many people would say, why not eliminate germs or microbes completely? Is that possible? The answer is yes. It is possible to breed germ-free animals. And they have been bred under strictly controlled sterile conditions for various experimental purposes. One set of conditions proves that vertebrate life is possible in the absence of internal microbes.

So, when I say that certain internal microbes are responsible for helping us to digest complex foods, that is true. But what is also important to understand is that, yes, we can survive without these internal microbes. What is the impact of not having internal microbes? These animals that are germ-free, that are bred under sterile conditions, have underdeveloped immune systems, because they do not have the antibodies that are required to defend themselves against attack. And they do not have antibodies for the normal flora antigens. They are also vulnerable to both pathogenic as well as nonpathogenic microorganisms. And they need higher levels of vitamins like B and K. So, these vitamins are provided by the normal flora, in many cases, depending on the animal, depending on the diet and so on.

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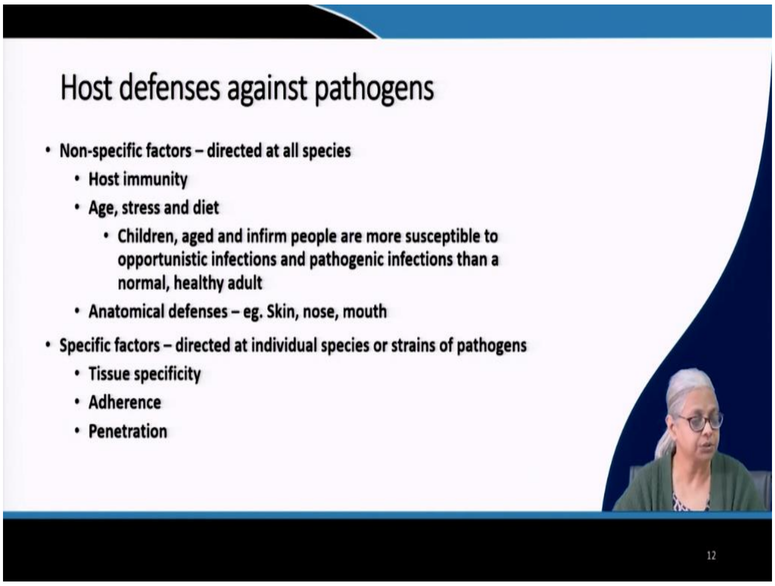


What are the host defenses against pathogens? There are 2 types of factors. One is nonspecific factors and the other is specific factors. So, we are going to take a look at all of them. Nonspecific factors apply to all species. The first thing would be the immunity of the host. So, if I am not under stress, either physical, mental, any other kind of stress, then the immune system response will be better than if the person is under stress.

So, that is the first thing. The other factors are age. Like I said, the youngest and the oldest are generally under greater stress, they are more vulnerable to attack from pathogens. And these are forms of stress. And then diet. If the diet is balanced, if it is nutritious, if it is providing all the elements that are required for the life processes to go on, then these are the kinds of factors that will determine whether the host is resistant to attack by pathogens.

I have already mentioned; there are 2 types of infections; one group is called opportunistic infections, and the second group is pathogenic infections. I will just give you a simple example of *E. coli* versus, let us say, something like *Vibrio cholerae* or *Salmonella typhi* and so on. Now, we know that typhoid and cholera are caused by certain bacterial agents (the ones mentioned above). On the other hand, *E. coli* is a normal inhabitant of the gastrointestinal tract. It normally is a beneficial microorganism that lives within our gastrointestinal tract. However, there is a particular, let us say, strain of *E. coli*, which can cause infection or stomach upset or gastroenteritis in certain people who are not immune to this particular strain. So, that is an example of an opportunistic infection.

On the other hand, when I was talking about typhoid and cholera, those would be definitely pathogenic infections. They are always destructive. It is not an opportunistic issue, and they are always destructive, and they can affect even normal healthy adults. What are the anatomical defenses against these kinds of pathogens? Our skin, nose, mouth, and several other organs of the body are part of the anatomical defenses. Specific factors are directed at individual species or strains of the pathogen. So, I have already mentioned. I have given you an example of *E. coli* versus, let us say, cholera or typhoid causing agents. These are individual species or strains that can be virulent. So, that is specific.

Then we come to tissue specificity, and adherence, as well as penetration. So, that is specific to certain individual species of pathogens or the strain. Even within *E. coli*, as I said, *E. coli* by itself is considered nonpathogenic, but it has one particular pathogenic strain. And it is also under certain conditions considered an opportunistic pathogen because if the host is already under stress, for whatever reasons, it can get affected adversely.

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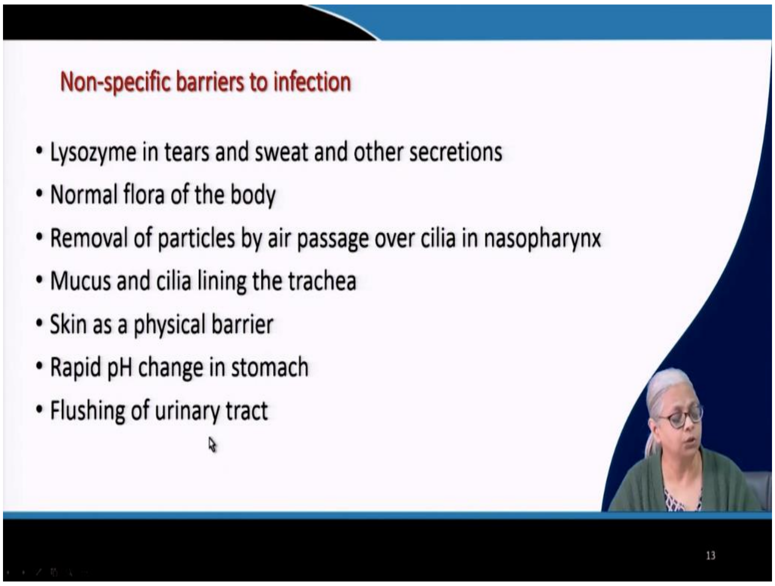


Let us come to some other nonspecific barriers to infection. So, what are the nonspecific barriers that the body has, especially the human body against infection? The first one is lysozyme in tears, sweat, and other body secretions. The second is the normal flora of the body. Remember that we have enormous numbers of microbes that live on the body as well as within it. And they are all barriers to infection because they outcompete small levels of attack by pathogenic organisms. Removal of particles by air passage over the cilia in the nasopharynx. So, if you are already aware of the fact that most airborne pathogens attach themselves to particles; they are not freely floating around; it is very rare. So, these particles, when you breathe them in, they are thrown out as you exhale and they pass over the cilia in the nasopharynx. They are thrown out by the breath as well as the nasal secretions. Mucus and cilia lining the trachea are another level of defense.

The skin serves as a physical barrier. The rapid change. So, we know that when we ingest food, it is generally not at low pH. And there is a rapid change from the pH of the food that we ingest; food, water, whatever we are taking in. That pH is dropping down to less than 2. So, that itself is also a defense against infection.

And then, flushing of the urinary tract. Most of you may be aware of the fact that often the doctors will say, drink lots and lots of water to get rid of the infection. So, simply flushing out the system helps in doing that. So, these are nonspecific barriers to infection.

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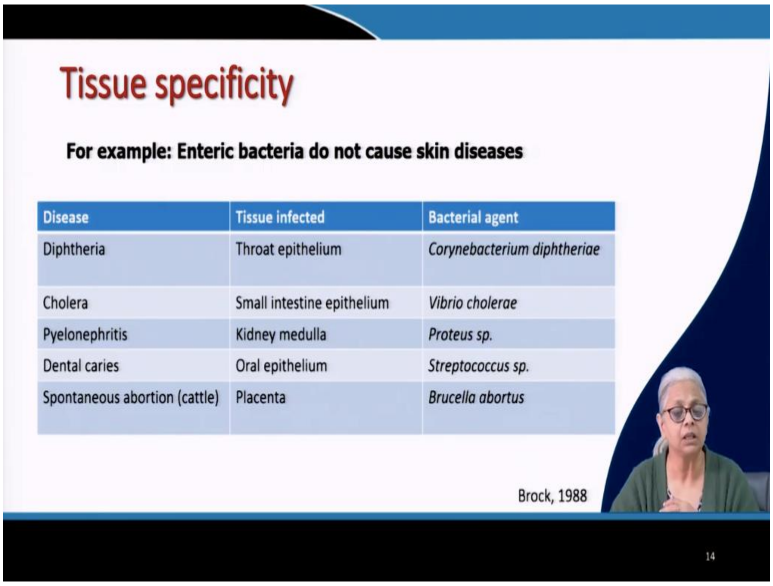


Let us take a look at tissue specificity. Now, we can have so many pathogenic organisms live in our environment. Are we vulnerable at all times to all of them? The answer is no. It depends on your stress levels, your age, your diet, all of these things. There is another aspect that is that a bacteria that is likely to cause a skin infection is not if you ingest it, is not going to cause any other problem to any other organ of the body.

So, specific pathogens will attack specific organs of the body. So, that is tissue specificity. So, the example that I have given here is Enteric bacteria will not cause skin diseases. So, if you have *E. coli*, or even if the virulent strain of *E. coli* is present in your water or food, it is not going to cause skin disease. It may cause a stomach upset, but it will not cause skin disease. So, that is tissue specificity. And here I have given you a few examples from the text.

So, diphtheria will affect the throat epithelium; and the bacterial agent is *Corynebacterium diphtheriae*. Cholera - it affects the epithelium of the small intestine; *Vibrio cholerae* is the causative agent. Pyelonephritis will affect the kidney medulla, and the species are Proteus species. Dental cavities or caries (incorrect!). *Streptococcus species* attack the oral epithelium.

You have spontaneous abortion in cattle; that happens due to an attack on the placenta of the cattle, and the causative agent is *Brucella abortus*. So, these are just some examples. I have just chosen a few examples here, but the textbook contains many more.

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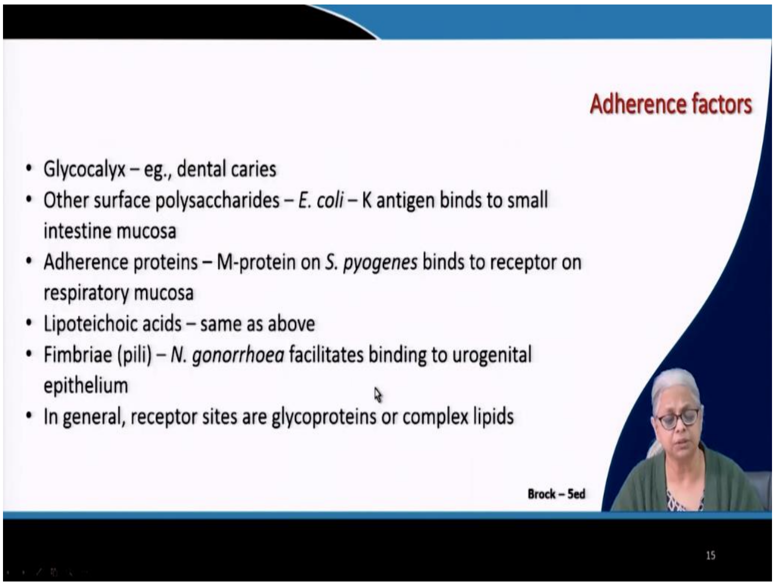


Let us look at adherence factors. One of the biggest adherence factors that we have all been kind of subject to is that; we know that the bacteria that grow within the mouth, like I said, if you forget to brush or something, you know that you get a layer of bacterial growth in the mouth and that is because of the glycocalyx that is present on the surface of the bacterial cells. They allow the cells to adhere to the surfaces.

So, the surfaces in the mouth are basically your teeth and your tongue. And that is where these bacteria are going to have a great time if you are not maintaining proper oral hygiene. Other surface polysaccharides will cause certain other bacteria to grow.

So, *E.coli* has a K antigen that binds to the small intestinal mucosa. There are adherence proteins. M proteins from *Salmonella pyogenes* bind to a receptor on the respiratory mucosa.

There are lipoteichoic acids. If you remember the section view of the cell wall of gram-positive and gram-negative cells, I showed you a schematic of lipoteichoic acids, and that is the same thing. So, *Salmonella pyogenes* binds to receptors because of these lipoteichoic acids. Fimbriae or pili are present in organisms like *Neisseria gonorrhoeae* that facilitate binding to the epithelium of the urogenital epithelium. Now, the main point here is; these are just examples. The general point to be made over here is that the receptor sites are all glycoproteins or complex lipids.

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I will stop at this point. Thank you.