

**Biology for Engineers and other Non-Biologists**  
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**Lecture Number 04**  
**Cells**

Welcome to this set of lectures on “Biomolecules and their relationship to the Cell Structure and Function”, which are important aspects? We’ll go through a set of lectures which will cover appropriately sized, so that it’ll be easy for you to assimilate aspects.

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Why are instruments sterilized before an operation  
(surgical procedure)?

To avoid infection

What causes infection? How does sterilization help?

Let’s ask the question. Why are instruments sterilized before an operation? What I mean by an operation is a surgical procedure. Why are instruments sterilized before the medical doctor cuts open the skin? All of us would know the answer to this question – to avoid infection. Okay? What causes infection? And how does sterilization help in preventing infection?

These would be the natural questions that come about, right? What causes infection? Let’s answer that first.

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Infection is caused by microorganisms such as bacteria, fungi, etc.,

What is bacteria?

Some figures:  
Anushree Santosh  
Sujin Raj



There are so many different bacteria. They are different in many fundamental ways from other life forms. It is one of the three major **domains** of life

Infection is caused by micro-organisms, such as bacteria, fungi and so on, okay? I would should say some types of micro-organisms among bacteria, fungi; there are a lot of very useful types of bacteria, fungi, which actually reside inside our body and do a lot of useful things for us, okay? We should not forget that aspect. So there are harmful bacteria, harmful fungi, viruses and so on, and they can in in terms of infection let's stick to bacteria and fungi.

They can, cause a lot of infection. Right? And, to, where is this bacteria and why should it cause infection when the surgeon is making an incision in the skin? That is because there is these micro-organisms, bacteria, and other such organisms are in the air around us. Studies have found that about ten power three to ten power four thousand to ten thousand bacterium per milliliter, okay, per cc, per cubic centimeter, are present in the air around us. They are present all the time, and they are interacting with us all the time. Our body has immune system which fights against this all the time, and as long as this balance is maintained, we don't get infection.

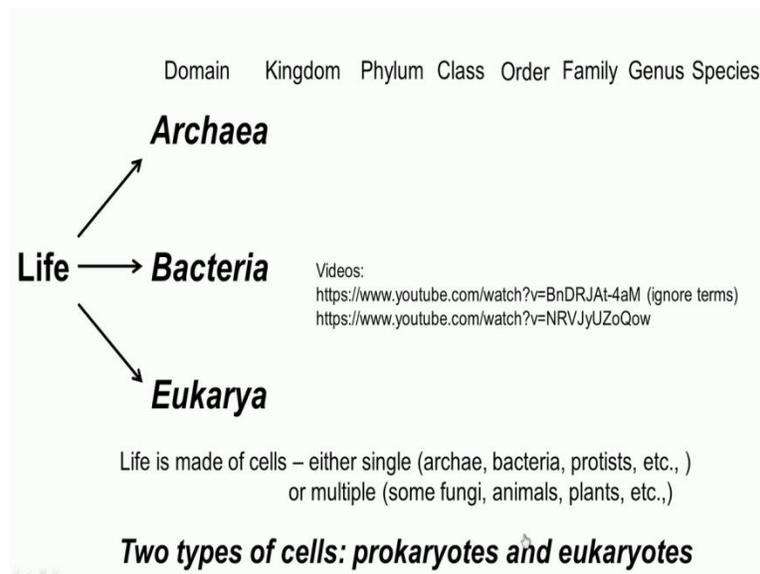
Whereas when the surgeon is operating, and when the surgeon is making an incision in the skin, if there are bacteria around, it will start settling in this wound and that will cause infection. Okay? So conditions need to be created such that there is not (bac) not much bacteria around, not much bacteria on the tables, on in the material that is in the operation theatre, certainly not in the instruments and so on. So, such things need to be taken into account, and it is it is also a nice exercise to carry out, to realize how much bacteria is present around, I did mention ten power

three to ten power four organisms per ml. You may want to do this calculation, find out the mass of air in the room that you are sitting in. Okay? You would be in for a surprise.

The density of air is one point two nine kilogram per meter cubed, if you you would need that to make an estimate, you would be very surprised as to the a mass of air that is just present in the room that you are sitting. You should do that. Okay? Now what is bacteria? Bacteria, it cc be something like this if you look at it under the microscope. You know you'll see these rod shaped structures here. This could be one of the bacteria that is present in nature. There could be other kinds of bacteria that are present with different shapes, different, slightly different size, and so on so forth. And, there are so many different (ty) kinds of bacteria. They are different from the in fundamental ways; we'd come to know what those fundamental ways are to certain extent when we go through the course.

They are different in many fundamental ways from the other life forms. Okay? And it is so different, and so big that it is bacteria is one of the three major domains of life, okay? Before I go forward, I should acknowledge that some of the figures in this course have been adapted by Anushree Santosh and Sujin Raj. Now let's get back to domains.

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Life, bacteria is one of the domains. The other major domain is archaea, and eukarya, is the other, the third major domain. This is what I call as domain. There are three major domains in life, and each domain has many kingdoms, each kingdom has many phyla, phylum, plural,

phylum, singular, phyla plural. Each phylum has many classes. Each class has many orders, each order has many families, each family has many genera, and each genus has many species.

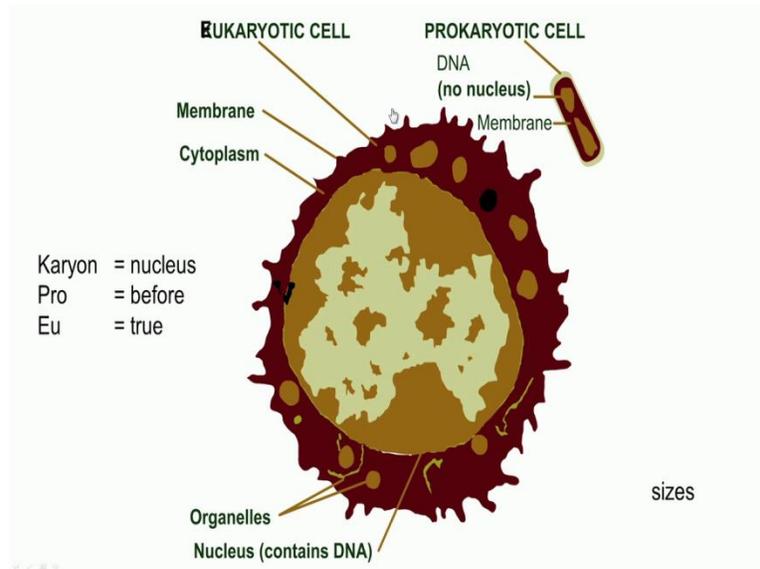
Okay? Don't worry about this. I'll give you a mnemonic, which I picked up from one of the, one of the videos that I'm going to suggest to you. I think it is the mnemonic is 'Do Kuala Prefer Cheese Or Fruit Generally Speaking', yeah. 'Do Kuala Prefer Cheese Or Fruit Generally Speaking', let us have it that way. Okay? It is the way to remember this. Anyway, if you look at these videos, there are two videos that I'd like to recommend.

The first one you can it is it is a small video you can watch. Please ignore the terms, they'll talk of DNA, RNA and so on and so forth. Please do not worry about the terms, you will know what those terms are only as a part of this course, if you do not already know them. If you know them then it's fine. And the second video is slightly longer, about you could watch about three-fifths of that video, then it gets into too much detail and this would tell you all about the domains of life and some of these aspects also. Okay.

Then life itself is made up of cells, either single cells, as the case of archaea, bacteria and some protists in the 2 eukarya family, or it could be made up of multiple cells, such as some fungi, you know mushrooms and so on so forth, the fungi, animals of course, plants, humans, and so on, okay? So life is made up of either single cells, or an organization of single cells. Can anybody guess the number of cells in the human body?

It's of the order of about  $10^{14}$ , okay?  $10^{14}$ . So you can imagine the number of cells and how they interact with each other to make life possible. There are two major types of cells; first type is called prokaryotes, the second type is called eukaryotes. What do these names mean? If you know the (name), if you know the meaning of the names, probably it's a little easier to get more comfortable.

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It so happens, karyon means nucleus. Karyon is the word for nucleus. Pro is before, this we all know. Eu means true, okay? So, prokaryote, before nucleus, eukaryote, something that has a true nucleus. That's what it means. This is a prokaryotic cell, a simple enough cell here, typically small, we'll come to sizes in a minute, it has some parts, we'll not get too much into it.

It is of course separated from its environment through a cellular envelope that could have a cell wall and a cell membrane, it could have some DNA, you know kind of strewn around here in the cell which is not limited in any way physically in the cell; and this is prokaryote before nucleus. There is no well-defined nucleus in a prokaryotic cell. Whereas in the eukaryotic cell, it's complex, it has a well-defined nucleus that contains many things including DNA, right? This is the basic difference.

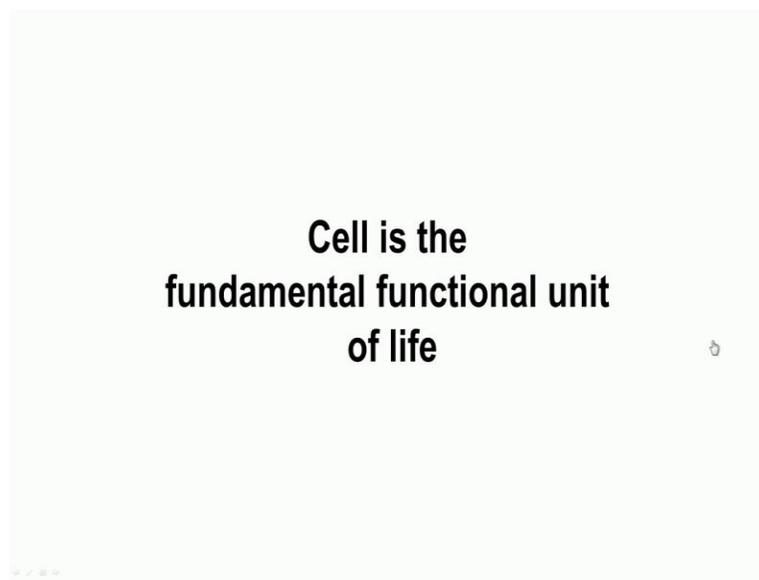
Eukaryotic cell has a true nucleus, a prokaryotic cell does not have a well-defined nucleus. This is a well-defined nucleus. This has a membrane, and inside the membrane whatever is there is called the cytoplasm, and in the cytoplasm you have a lot of organelles, small small small things, that have, each one has their own function, and of course the nucleus is here, indicated here which contains DNA and other things, okay?

So, this is good enough to know. The typical sizes, a prokaryotic cell; for example, a bacterial cell, is about five microns, typical size, okay? Five micron length two micron, diameter, or if it is spherical it could probably be about five micron diameter, and so on. Many prokaryotic cells are of that size typically speaking. There are variations of course, but we are talking of some typical sizes here. Whereas a eukaryotic cell could be of a typical size, a mammalian cell for example could be of ten micron diameter, typical size, even a human cell goes anywhere from seven microns to about twelve to fourteen microns during its lifetime. Right?

So there is variation with time in the cell size also. But we're talking of typical sizes. If we talk of fungi which are eukaryotes that could be a few microns in size, fungal cell. If you talk of mould, you know, you cannot really talk of a single cell in the mould because it branches and so on so forth, let's not get into that, we just need to, kind of, have this in the background saying 2 that the cells are not separated from each other.

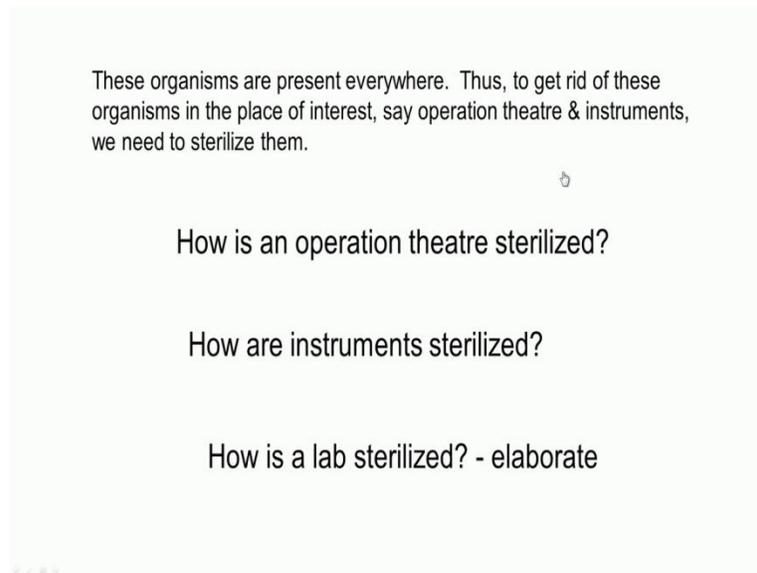
If you talk of a (neuron) neuron, which is a neural cell in humans, that could be two hundred microns, right? So it widely varies, the cell size widely varies. Typical sizes, about two to five microns this is about ten microns. These are good enough for our back of the envelope calculations. Why are we so interested in this cell? Because cell is the fundamental functional unit of life.

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What does it mean, if we understand cell, the cell, and all its functions, all its properties, then we would be able to somewhat predict what happens to life. That is what it means. Same way that a unit cell in, in its crystal structure, the properties, with those properties you could predict properties of the whole thing, and so on so forth. This is some fundamental unit of life itself. It is a biological cell. That's why we are so interested in the cell.

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As I mentioned earlier, these organisms, remember we are talking, our story is about infection, infection in during surgeries, how to prevent them and so on so forth, let's stick to that story. The organisms are present everywhere. The harmful organisms are also present everywhere, and to get rid of these organisms in the place of interest, which happens to be the operation theatre, the instruments which are used to cut the skin and so on, we need to sterilize them. Right?

How are instruments sterilized? How is an operation theatre sterilized? Instrument sterilization, that, it's rather straightforward, so let me talk about that first, and then we would get to the operation theatre sterilization, which is a whole field in itself. Instruments are sterilized by exposing the metallic instruments to high temperature and keeping it at high temperature over a certain period of time, the standard way of sterilization; autoclaving as it is called.

So the temperature is raised to about 121 degrees C, steam is used. As we all know, thermodynamic steam, you know 121 degrees C, you need a higher pressure to maintain the conditions there. So you have slightly higher than atmospheric pressure conditions in the

autoclave. So you create such conditions and you keep it at that condition, one twenty one degrees C, at say one point two atmospheres, for about 15 minutes; it kills the cells, as well as kills these pores, and so on so forth, okay? So that's a very standard method of sterilizing instruments, or sterilizing things that we use in the lab to grow organisms and so on. So instruments are sterilized that way.

But how do you sterilize operation theatres, okay, which are huge spaces? How do you sterilize labs which are huge spaces? You know in the labs you would want to grow only the cells that we are interested in. We do not want the others to grow, and compete for the food that is given to the cells of interest, okay? How is this done? It is, very interesting, the way it is done. It is done by using chemical vapours, okay? And, the procedure that I'm going to describe now, is used heavily in labs, because you can control the conditions there and kind of not let people enter the lab very strictly and so on so forth, you have a control over that, and therefore you could do that. Okay?

You will have to be careful if you are dealing with people and you want to use this procedure. It's not very safe. There could be related methods that are safer, but which are a lot more elaborated to use. The cells are killed by formaldehyde, okay?  $\text{HCHO}$ , formaldehyde. And the formaldehyde vapour is generated from, what are called formalin solutions. Formalin solution is nothing but forty percent formaldehyde in water, okay? This you get, you can buy it off the shelf. So what people normally do, let me describe the lab procedure here. First all the windows and doors are sealed except the passage through, or the door through which we need to get out.

And then, we use what are called aluminum boards, in which we have this formalin solution, forty percent formaldehyde solution. This is in the liquid, okay? This has to come out into the vapour to kill all the organisms, in the space, in the lab so that the space is made clean or the space is made clear of these micro-organisms that are present there.

And to make that possible, to generate formaldehyde vapours, what is used is the exothermic reaction between potassium permanganate, and the formalin solution. Okay? So these aluminum boards containing formalin solutions are placed in key positions in the lab, then everybody is sent out, and before you place the formalin solution, make sure that it is made sure that all the

windows and doors are shut and taped so that no vapour escapes out, because this vapour is poisonous.

And then, the person uses a mask and so on, just for those few seconds, drops a few pellets of potassium permanganate, that are carefully weighed out for, required for the stoichiometric release of formaldehyde and so on, drops in the aluminum boards, farthest first, and then keeps dropping in the boards that are closer to the door, and then quickly walks out the door, shuts the lab, and tapes the door shut. Okay? It is left there for a day or two, and may be a day more, just to make sure that none of the vapours are present, and then somebody gets in and neutralizes the present formaldehyde and so on so forth. Okay?

So it's an elaborate procedure that is used to sterilize the lab; we do it from time to time, may be once in a month or so, it is recommended that the lab is sterilized. A similar procedure can be used for operation theatres, it has been used for operation theatres. But in addition, you could swab with, let us say, seventy percent ethanol, you could use other cleaning solutions; mop the floors and so on so forth, that's normally done. That is how the space is gotten rid of these micro-organisms. The micro-organisms, some of which have the capability to cause infection in humans. Okay? That is how in operation theatre is sterilized, how the instruments are sterilized.

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How is a bioreactor sterilized?  
Before that, what is a bioreactor?

Bioreactor is a vessel, any vessel, in which bio-products are made.

For example:

Single use: <https://www.youtube.com/watch?v=GZevitDkhOg>

Large bioreactor image: <http://csmres.co.uk/cs.public.upd/article-images/g-20448.jpeg>

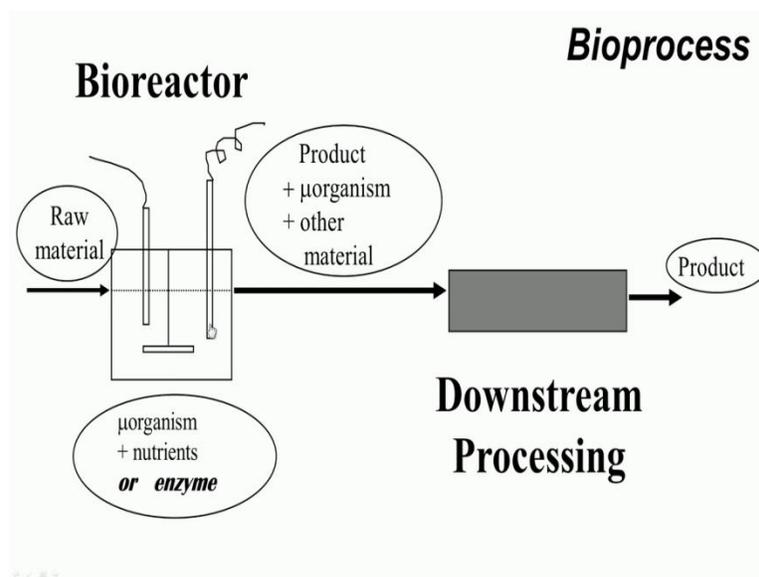
How is a bioreactor sterilized? And you would go, 'where is this bioreactor coming from'? Okay? So this question, before that. "What is a bioreactor"? Okay? This is something that people

normally used from an engineering perspective. So I thought it will be closer to you. Bioreactor, by the way, it is it is certainly closer to me, this is the area in which I used to work heavily. Bioreactor is a vessel, any vessel, in which bioproducts are made, it is as simple as that.

It is something that is used for production that uses organisms for production. These organisms produce many useful compounds, many useful substances, including a lot of medicines. For example, if you see this figure, I think this is a video, YouTube it is a video, it will tell you how a single use bioreactor looks like, and what it is used for and so on.

Bioreactors could be very large, extremely large because of the use in production of high volume products, okay? And this link here gives you an image of one such large bioreactor. And many of these water treatment facilities have bioreactors that are large. Okay? Bioreactors are the basal ones that are used for water treatment. They are very large too.

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The bioreactor is a part, an important part of what is called the bioprocess, and the bioprocess is the one that is used to produce all these products of interest to us. There are very very many products, we'll Surf Excel some of those products in this course itself, okay? We have, for a bioprocess, the bioreactor aspect, and, what is called the downstream processing aspect. In fact, the downstream processing part could have about 90 percent of the steps of this bioprocess. Bioreactor is a small part of it, okay? But it's kind of a central part.

Raw material goes into the bioreactor, either in a continuous fashion or in a batch fashion, you know, you dump everything at one time. And, in the bioreactor, you have the micro-organism of interest, along with the nutrients for it to grow and make the product. Or, there could be an enzyme that is present, okay? Just take the name on its face value, and now you might have heard of enzymes, you will actually look at what enzymes are in detail in this course. Okay?

Or an enzyme here, in the micro-organism plus nutrients or an enzyme, and the raw material is converted into the product of interest. So what comes out of the bioreactor is a mixture of the product of interest. The micro-organism that is there which is producing the product and a lot of other material which is present in the nutrients, the medium as it is called, and so on.

And maybe some other products are also produced, which may not be of much interest to us, we're interested only in the product of great importance to us, amongst the products that are present. So, this product needs to be separated out from all this to be able for its proper use, and that is done by what are called the downstream processing steps, a large number of steps, including the solution extraction and so on and so forth, till we get the final purified product, okay?

This is what the bioprocess is. The bioprocess produces a lot of useful substances, and, in the bioreactor, the cells that we talked about, the cells that are used typically the bacteria that we talked about, the fungal cells that we talked about, may be mammalian cells that we talked about, right? They are used to produce products, and in the bioreactor, the cells are subjected to shear, okay? That is the next part of the story. We will stop here for, for this lecture, this part of the story, essentially a story, when something like this, we wanted to know, what causes infection, and we said micro-organisms cause infection, and we saw how micro-organisms are organized for better understanding.

If you look at those two videos, it'll give you more reasons for, organizing it a certain way, and so on. Please look at those videos, on 'Taxonomy'. And then, we looked at the cell as the fundamental functional unit and there being two types of cells, prokaryotes, before nucleus, and eukaryotes, with a true nucleus. In other words, prokaryotes do not have a well-defined nucleus, eukaryotic cells have a well-defined nucleus. And, then we saw that the cell is the fundamental functional unit of life. Then we saw that these organisms are present everywhere, and started

looking at how to get rid of them in an operation theatre. We looked at some means of getting rid of them. And then, we looked at what a bioreactor was. Okay? Let us stop this lecture here, there is good enough new information for for you in the next lecture. Let us take things forward with shear of the bioreactor. See you then.