Biological Inorganic Chemistry
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Lecture 51
Carbon, hydrogen and oxygen

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Good morning, dear students. So, we will now move on to the 11th module where we will be talking about now, in place of the metal ions, now we will just simply talk about the nonmetallic part which are very important to our life to our biological system. So, today in lecture number 51 we will be talking about three elemental things and its compositions like the carbon, hydrogen and oxygen.

These are very simple thing what we are studying from are again from our school days, but now we will put altogether in some very complicated area where the nature is doing for us is the biosynthesis of nonmetallic biomolecules. What are those? Because you do not have the metal ions now. You can have the amine acid, you can have the protein, you can have the lipids, you can have the carbohydrates also. Then we will talk about the formation of small molecules how we can take because you all know the example of formation of the small molecules through the consumption of the dioxygen molecule is your carbon dioxide.

When I am talking when I am breathing also, I am producing lots of carbon dioxide into the air. Then, how we can get those carbon dioxides for generation of sums beautiful anions like bicarbonate and the carbonate anions that we have also studied earlier, then what are the roles of the different ion channels and the anion receptor. So, these are not basically the concepts considered them as the keywords. You read more about what is the ion channel, how the ion channel will be related to the nonmetallic biomolecules? What are the anion receptors something like that.

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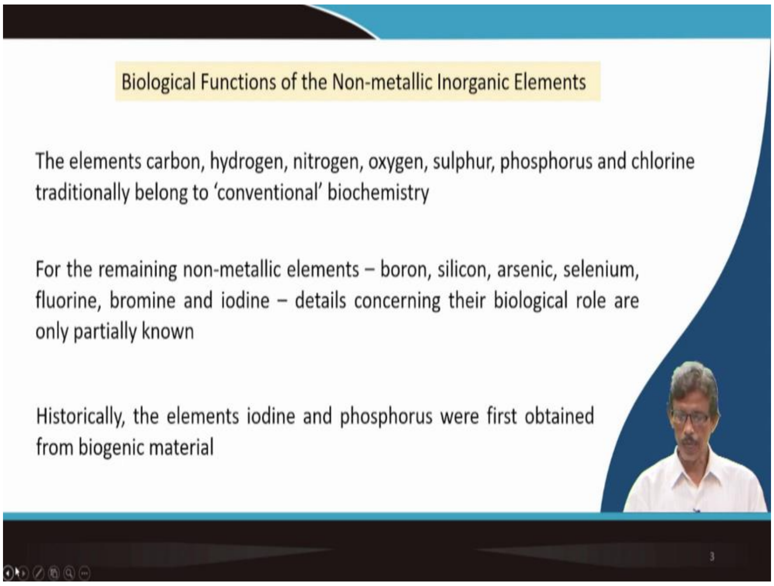

So, if we have some inorganic element like carbon, hydrogen or oxygen, so the organic chemist can debate with me no carbon, hydrogen, oxygen, they are for their thing that is they are making the organic molecules. But if you have everything, but we do not put the metal ion that is the environment what we are talking about, and that has very useful role in the biology.

So, if we consider all of them, not that the organic chemist who are interested to have the carbon, hydrogen, oxygen, nitrogen but sometimes sulfur, but occasionally will bring phosphorus, will bring chlorine will bring iodine also, the iodide arms what we know that your common salt the table salt we take iodine for the formation of good amount of thyroxin.

So, the conventional biochemistry, how this particular part or the way we are looking at it, in terms of your biological inorganic chemistry, how inorganic chemist can see from their point of view, what is the biochemistry from their eyes or their experiments? So, the remaining nonmetallic elements, like we can have also boron, we can have silicone, arsenic, selenium, fluorine, bromine iodine all these, but it is very difficult to consider all of them together one after another in this particular module.

So, I will try to focus, I will try to go for attending those parts where you can apply the basic concepts, how to get a small molecule, how to get the corresponding anions, and how those announced are useful for us. Because historically, when people identified why iodine is so important to us, why the phosphorus we know much about these were the first obtained biogenic materials because the iodine-based materials and the phosphorus base materials like the appetite and all these for our tooth, and the bone formation.

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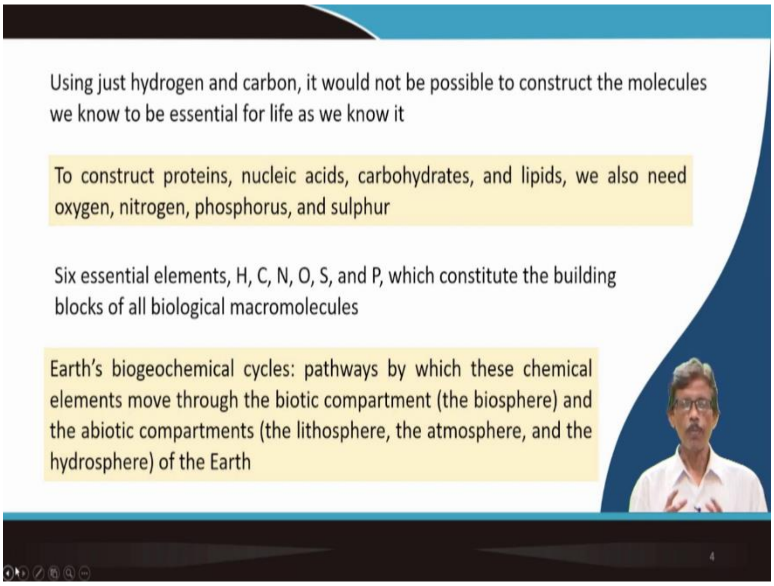

So, using just hydrogen and carbon, that means, the organic molecules, what we can have that is hydrocarbons we call. The organic people when they talk about methane, ethane, propane, butane, and all, all these gases also, they would call it as the hydrocarbons. So, if you gap the hydrogen and carbon in hand, and if you try to construct or build many complicated molecules, and these molecules are essential for life processes, any life processes the bacterial life process, the viral life process, also the human life process and the mammalian life processes.

So, how to get the protein nucleic acid carbohydrates lipid? There also we need to know about the incorporation, not only the hydrogen and carbon, but also oxygen, nitrogen phosphorus, sulphur all these things. So, the very basic things, the way we know the photosynthesis is giving us the corresponding carbohydrates. So, we are already incorporating oxygen over there is not hydrocarbon is carbohydrate. So, you have extra oxygen over there.

But it is a very simple process in a straight cut process, we are producing those glucose molecules for us, but only go for many complicated system the protein combined with glucose and all these things and the incorporation of these things in the amino acid residues. So, altogether, how many elements we can have? Altogether we have basically six essential elements, which can be considered as the building block of all biological macromolecules now, not the small molecule like carbon monoxide, carbon dioxide or even a water molecule.

Then, some balance would always be there. So, biology governed balance and the geochemically, the geological thing and the chemical thing also. So, the earth biogeochemical cycles basically where from we get the water because we are dependent on the corresponding geochemical cycle or the geological cycle and something related to the biogenic thing, which we call as the biogeochemical cycle.

So, they basically move through from one part or one compartment to the other we call it as a biosphere or we can consider as a biotic compartment or some is a biotic compartment that is biological part is not there. So, what is your lithosphere, the atmosphere and the hydrosphere, but the biological part is definitely there, but they are not controlling much about this particular movement of these cycles.

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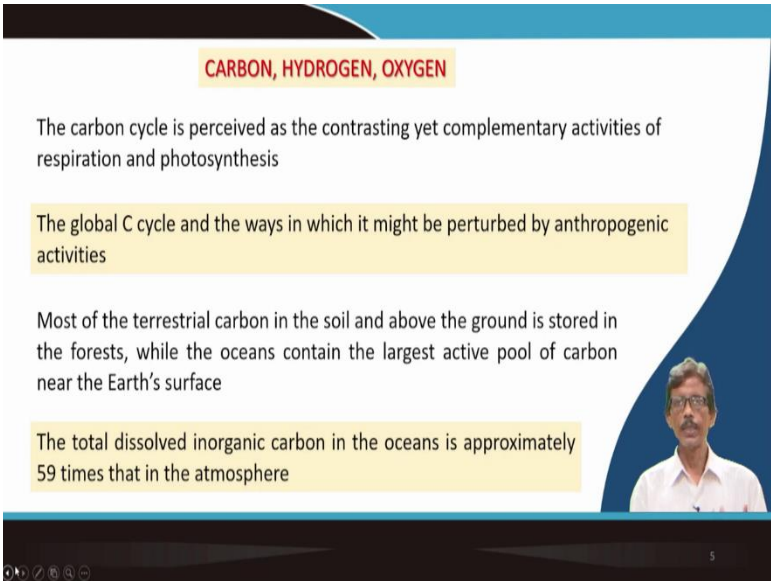

So, we know that is why we can have the carbon cycle from our school days again, we are learning these. We have, we learned about the nitrogen cycle, but in the next class we will be talking about nitrogen, so in this class today we will be talking about these three only the carbon, the hydrogen as well as the oxygen.

So, when you have the carbon cycle, how the carbon cycle is there? We are not talking about from the elemental carbon, but what we get which is readily accessible. So, readily accessible thing what we can consider that every time when I am talking in this particular class also I am giving you in the environment, the carbon dioxide. So, how quickly you can produce carbon dioxide? So, it is a very simple thing.

But if I ask you give me the detail mechanism, give me the detail catalytic processes, how you are burning your glucose molecule or the carbohydrate molecule to produce the carbon dioxide involving other metal ion and bearing important biomolecules like hemoglobin and myoglobin. So, life will be complicated in that way. But if you consider the carbon cycle, that means, how we can go for the corresponding movement of the carbon in one form to the other and then coming back again to the system, which can be from the elemental carbon also the charcoal, we know the graphite all these also.

So, you can have the corresponding activities like respiration and the photosynthesis. We know, in photosynthesis we are consuming carbon dioxide and producing O2 and the reverse is true for our respiration. So, you should always know about the very simple examples, which can contribute to your carbon cycle.

So, it basically can be part out by anthropogenic activities. When we burn fossil fuel, when we go for other activities, and even we just go for some heat treatment for something we basically disturbing all these things and we are producing more and more amount of carbon dioxide, which is the well-known greenhouse gas by doing so, we are increasing the terrestrial temperature, we are melting the ice and all these things are happening together.

So, what we can have about the availability or the amount of iron available and the terrestrial surface in the soil and above the ground, it is stored in the forest while in the ocean, it contains a largest pool of carbon near the earth surface. So, you have the oceanic pool, and you have the forest pool, because the forest all we can have because if you consider that we are talking about the corresponding lignin, the plant material and all these they are all having carbon, hydrogen and oxygen.

So, about the dissolved inorganic carbon, if some time we asked you what is that dissolved organic, inorganic carbon, is not that the elemental carbon, but is the corresponding form of corresponding species what we can have based on carbon. So, you can have the carbon monoxide, it can be carbon dioxide or it can be the different carbonates that means the inorganic anions. So, it is basically the amount is very high is approximately 59 times then that in the atmosphere, which is available to us.

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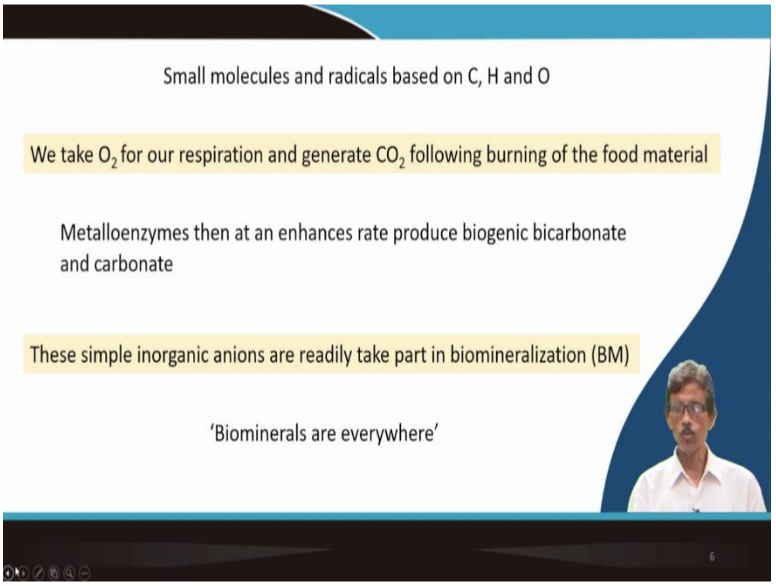

So, if you have the small molecule based on these three elements the carbon, hydrogen and oxygen what we can understand? While we are studying about the hydrogenases we have seen there is a very complicated molecule. You have iron center, you have nickel center, nickel center is surrounded by your sulphur, but your iron center have very small molecules, as the ligands. One, is your carbon monoxide the CO, another is your cyanide that is CN minus.

So, if you do not talk about the nitrogen today, if just if you talk about the oxygen and the carbon you get the carbon monoxide molecule. How we get that carbon monoxide molecule for some degradation also. So, either you can have the small molecule or the radicals. What are those radicals? The inorganic anions we call the acid radicals from our school days. We know, how to estimate the corresponding anions like the chloride anion that is also there in our body, huge amount of chloride.

The way we talk about the imbalance in terms of your sodium and potassium in your body, at the same time, we should also talk about the corresponding balance in terms of your anion or the chloride ion. We are not talking about the corresponding anion like nitrate or sulphate or any other thing related to that of your sodium salt or the potassium salt. So, when you take O2 we produce CO2, when you burn some material, when you burn our food material also we produce CO2. So, if you have the CO2 is a small molecule definitely is a linear small molecule carbon and the two ends you have the oxygen.

How to make it a carbonic acid, a bicarbonate or the corresponding free carbonic acid H2CO3. So, metalloenzymes are they are carbonic anhydrase we have studied earlier then add at enhance rate, enhances the rate of production of the bicarbonate and the carbonate molecule that means the carbonic. Anhydrase is an enzyme and is a very good catalyst for huge amount of turnover and the turnover frequency is also very high, such that, very quickly you can produce large amount of carbonates and bicarbonates in our body.

So, rightly you are getting that good examples of the inorganic anions. Only thing that when we first tried to know that how we can detect the presence of bicarbonate and carbonate in your some solution in your some food drink, the beverage is what do we take, so they are all carbonated water. So, how much solubility of that free carbonic acid is there and whether that is releasing huge amount of carbonate and that particular thing can also get some relief due to acidity in our stomach or it give some other impact on your body.

So, these simple inorganic anions. We are not going far away, we are talking about the very simple thing O2 we have consumed, we have produced CO2 and CO2 due to hydration we are producing the carbonic acid. And after deprotonation that carbonic acid will be giving you the bicarbonate and the carbonate anions. So, one important thing, we can consider. Now, if you allow some metal ions to come into this particular point that means plenty of anions are available, the carbonates and bicarbonates are available. What we can have the corresponding biomineralization process?

So, mineralization process, the typical process, we can go to a geologist to take the help to know or understand it nicely, what is mineralization. So, you have the anion, which is charged one, so carbonate and bicarbonate having charges of 1 minus and 2 minus. If you try to neutralize it by putting some cation, say, calcium, typical example we will be taking now is your calcium. So, we will be forming calcium bicarbonate and calcium carbonate.

You are going for initially the charge neutralization. And once it is charged neutralized its solubility will also be reduced, and it will try to separate out from the media. So, during that particular separation process it is not that amorphous powder material is separating, as a simple powder like charcoal powder or any other dust it will go for typical crystallization process because this growth is very slow and very in a steady manner.

So, this particular mineralization and process is directly related to your crystallization process. And we get these BM or the biomineralization, sometimes we also call it as the corresponding bio minerals what do we get from there. So, everywhere surrounding us, the biomineralization process is taking place. But what is the role of the inorganic anions for these imperialization process that we will see.

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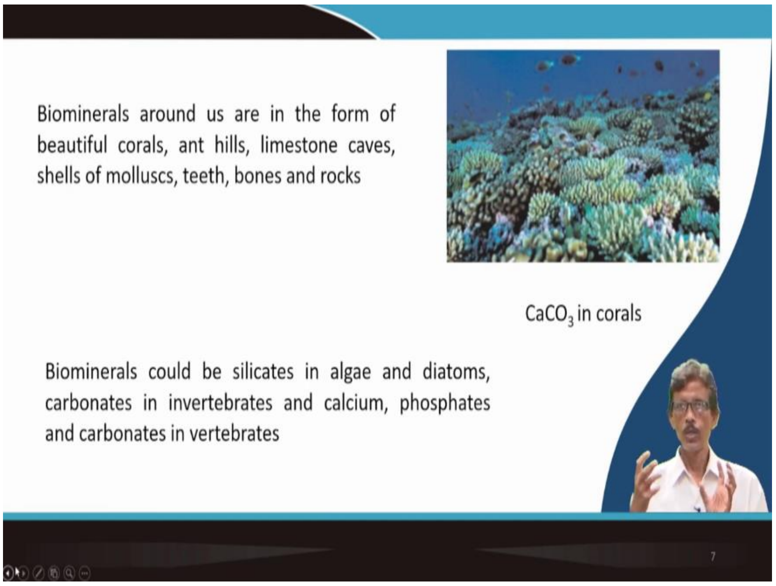

So, around us what are those simple examples? So, examples are pretty in our body also, we have teeth, we have bones. In the geological world, geologists are interested about the limestone, the limestone caves and the rocks also. Then the biologist other type of biologists who are working on it, they can be very much interested about the corals, some are interested in the ant hills.

So, this is a beautiful pictures from the natural products through these biomineralization process is nothing, but as a inorganic chemist what I see only the calcium carbonate. But other people can see the beauty of the corals, but we know, we are just trying to see through our inner eyes or our eyes, that how much calcium chloride is there within these beautiful corals. And how these calcium carbonates are forming over there through the participation of the carbonate anion what we produce in our body nature is also producing in some other ways because we are going for that inspiration in different forms.

Also, not only carbon, not only oxygen, the carbonates and bringing the metal ion species like calcium 2 plus, you can have the silicate. So, that particular form in algae and diatoms, carbonates in other invertebrates and calcium phosphates carbonates and altogether in different vertebrates.

So, we should look at about the corresponding anions. What anion in species we are talking about? Whether we are talking about the carbonates and bicarbonates or we are talking about the silicates or we are talking about the phosphates. So, we are moving basically, you see, carbon and oxygen was there, if you move it you will be getting silicon. If you move further, you will get phosphorus. So, these are the basic elemental compositions from there.

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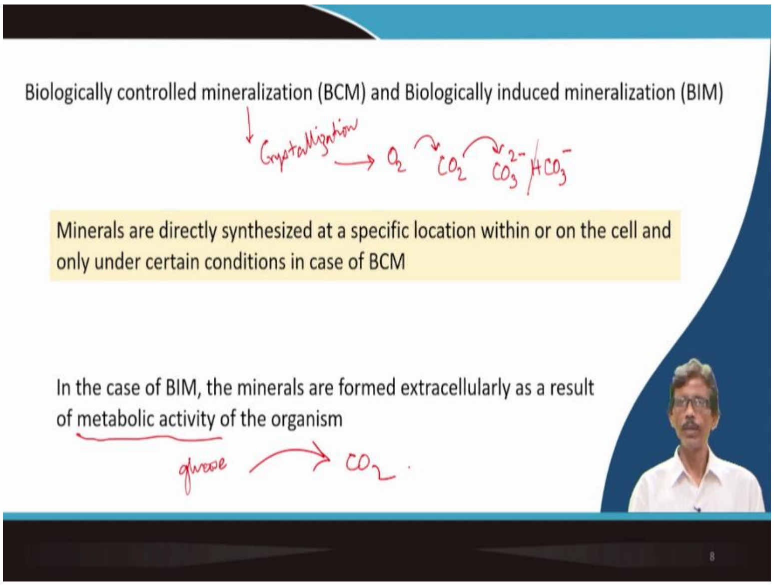

So, what we see now, is that, if you have a biologically-controlled mineralization process, what we call as BCM, and another will be considering as biological induced mineralization. That means, now, we are trying to differentiate the typical mineralization process, but we are not forgetting the role of the typical inorganic anions.

So, you should know a little bit about the mechanism of mineralization process, as I told you is a typically a crystallization process. So, that crystallization process can be there. So, if you consider that we have this mineralization process for that and we get this particular one for this mineralization. So, what we can have crystallization.

Crystallization with some saturation. What are those saturating elements? We were having O2, from auto we are getting CO2 and from CO2 we are getting CO32 minus, as well as, HCO3 minus. So, these are the processes, that means, we are looking for some saturation, that mean, supersaturated solution.

Until and unless you have the supersaturated solution, you cannot have the crystallization. We are getting is a typical natural process. So, that is why we are not giving any importance for that. When you do it in the laboratory, we are struggling for the crystallization, that means, the thing growth of the single crystals, we pay huge attention, but what nature is doing for us how the coral reefs are forming beautifully with the ambient conditions.

The temperature of the ocean water, the pressure, the water pressure, all these things are important, there is no need to go for any other abnormal temperature what we produce or give in the laboratory, abnormal pressure also. So, the natural process so, a trained mind a curious mind always try to look at the beautiful chemistry is going on around you. So, how this particular mineralization process, what we are bringing is, when you bring the biological part is typically the natural process. So, is nothing but the natural level of studying inorganic chemistry.

So, if you have the crystallization, and you have the typical anions you get. So, why we define is that when we get, what is BCM then? When they are directly synthesized at a specific location. That means, if you have the test tube, we know the test tube, and you put something some saturated solution of your carbonate or bicarbonate, then you put the calcium 2 plus what will happen, you have to have your answer with you.

Because whether your this typical surface of your test tube or a conical flux or a beaker, can be useful to allow you to grow the crystals. So, when they are synthesized at some specific locations or on the cell that is why the biology is coming into the picture. The biological cell is there, and under certain conditions we get the process of biologically controlled mineralization. So, it gives basically the corresponding cell, we call it the cellular chemistry, the chemistry which is happening within the living cell.

Then the second type how it is different, the minerals are formed extracellularly it is forming outside the cell or outside some other cavity, as a result of metabolic activity of the organisms. So, when we consider that we are talking about the metabolic activity, we can talk about our burning of the glucose. Glucose molecule when we are burning, we are producing CO2.

So, when we have that metabolic activity, we control, we study the metabolic activity, but at the same time, we should also look at the corresponding activity of the carbonic anhydrase and that carbonic anhydrase can take care of the production of carbon net bees, the corresponding anions like the bicarbonate and the carbonates. And the rate of that formation is typically very high. So, there is no dearth of availability of these ions.

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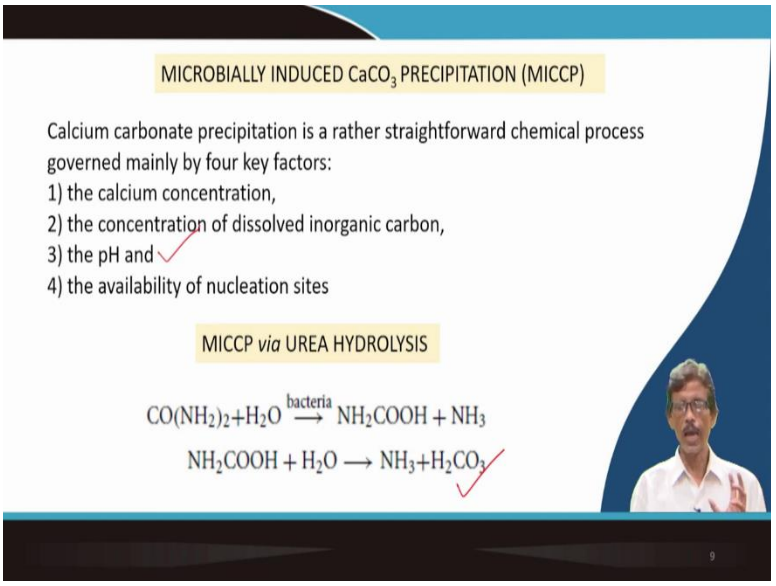

So, how we can move now? So, not going for the very big thing, what we produce in our body you go to some microbes only. So, if microbes are available. So, biologics, the biotechnologies they will come and try to tell you something where we can have the corresponding microbially induced CaCO3 precipitation, which is aggravated as MICCP or MICCP you can consider in a very good name MICCP.

So, you talk about the corresponding precipitation of calcium carbonate. So, but our anion, the inorganic part. In this class, we are not talking about the role of the metal anion, we are talking about the role of the anionic part, the inorganic part that means the carbonate part. So, it is very straightforward chemical process mainly by four important steps. Amount of calcium concentration, so availability of the calcium what we are, just now we have said that you can add externally calcium solution from outside to a solution of bicarbonate or carbonate.

So, the accumulation of calcium is important, not that you can have the corresponding formation of the carbon dioxide. So, the concentration are dissolved inorganic carbon, try to follow the language, is basically the corresponding formation of carbon dioxide followed by its dissolved form in aquas medium is your bicarbonate, carbonate as well as carbonic acid because the free carbonic acid H2CO3 can have some solubility in the aqueous medium.

pH is also important, because whether you are getting in an acidic form or in the basic form and the availability of the nucleation sites, sometime we know that the crystallization is triggered or enhanced if you have some nucleus over there. So, external seed, we consider that you put the seed and around the seed or over the seed you go the bigger amount of those crystals.

Then, not only the hydration of carbon dioxide, but also, we can think about the urea hydrolysis. Already we have studied only few days back about the urea's molecules, the nickel bearing metalloenzyme that is responsible for the production of the corresponding, the hydrolyzed form that means carbon dioxide and ammonia.

So, this ammonia is also producing not only your free H2CO3. So, when we are talking just now about the formation of CO2 then H2CO3 now, if you get from some other source the corresponding area hydrolysis. So, bacteria is there, or urease is there. So, UREA is responsible for your hydrolysis giving ultimately what? Giving ultimately, not only the free H2CO3, what we are getting through hydration of carbon dioxide, but also ammonia. So, ammonia will be controlling what? Ammonia will be controlling your pH which is important. So, now we get instead of a very free state you will having now a buffered condition so, that buffer is important and that buffer will control many things.

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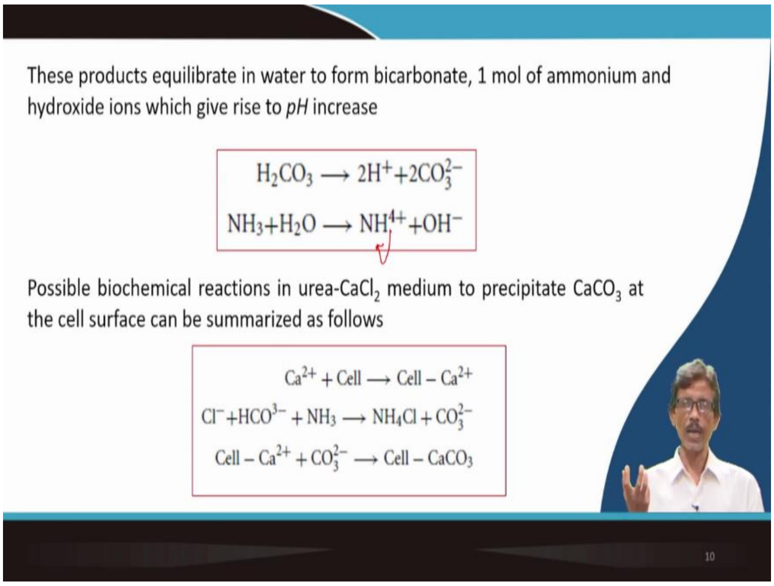

So, products basically equilibrate in water to form bicarbonate because you are producing H2CO3, and one mole of ammonium, as well as hydroxide ion will be forming which give rise to the pH increase or the change in the pH. So, is there is some error so, what has been taken from the book or journal the 4 will be here it will be NH4 plus.

So, we know the corresponding degradation of the carbonic acid, but also when ammonia is available hydration of ammonia will move also producing NH4 ion ammonium ion as the hydroxide and so that is producing the corresponding available base. So, the biochemical reaction what is now happening?

Now, you think of another anion, which is chloride. We are talking about, if you are biased, if you are focused only to the formation of the carbonate base thing the calcium carbonate base thing the medium will only precipitate calcium carbonate, but what is happening on the cell surface.

So, if you have the calcium bring the cell, the biological cell, calcium can be tagged over there or attached over there, and that is giving rise to the calcium bound to the cell. Now, you got simple reaction with chloride ion bring chloride ion and ammonia is already there and carbonate is they are forming ammonium chloride.

You are having, we are proceeding towards the ammonium carbonate ammonium hydroxide buffered medium. And also, another equilibrium due to that of your H2CO3. So, the carbonate will come now will replace those particular things is not trying to interact with the chloride ions but in interact with the corresponding carbonate. So, that gives you the cell bound, cell is your template now. The cell bound calcium carbonate. If your coral reformation is the mechanism that will be forming over the cell surface or some point.

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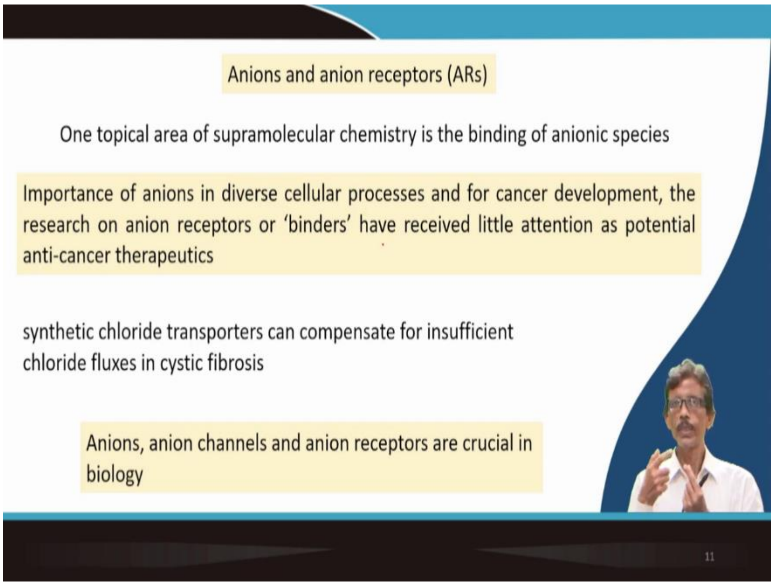

So, when you have the anion. In our body everywhere we talk about the anime receptors is when we talk about the cations, the metal ions we talk about the ligands, but when you have the anions, we talk about the receptors, Receptors are also there, which can grab, and which can bind many big molecules like transferring and others.

So, in supramolecular chemistry, which are having some weak interactions, the hydrogen bonding interactions, the other non-covalent interactions, and which is forming between the anions. So, we what we can have induce all these cellular processes during the development of cancer also what we see that is very interesting observation that anion receptors, which are nothing but the binders of anions can be studied nicely such that you can have some good anti-cancer therapeutics.

So, synthetic chloride transporters basically. So, which are moving chloride, binding chloride which is transporters means transporting, receptors is binder. Compensate for insufficient chloride influxes in cystic fibrosis. So, if there is a diseased condition is cystic fibrosis is related to the chloride imbalance or the chloride transporters. So, how that can be managed by something? So, you have anions, then you have the anon channels through which your anion is passing and your synthetic chloride transporters are also there, which is binding the anion like chloride or carbonate or bicarbonate and move from one point to the other is therefore, crucial in biological studies.

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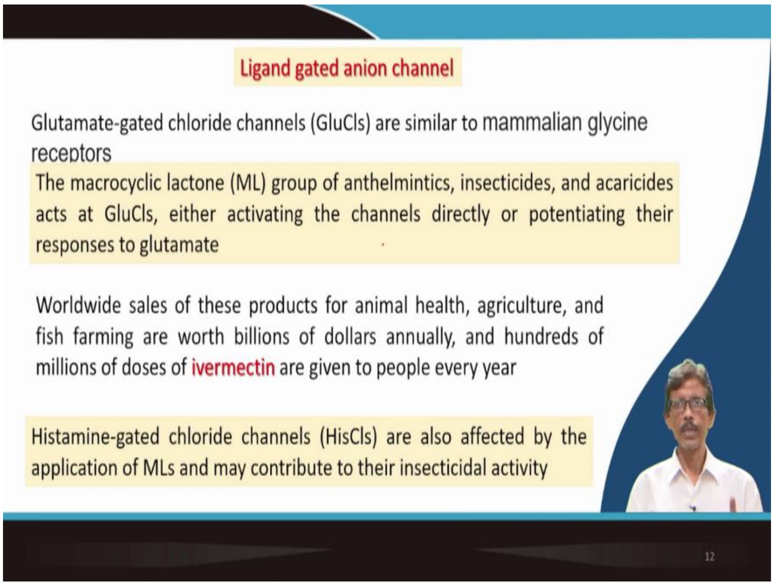

We have already seen in earlier cases also, the sodium ion potassium ion thing, now we are talking about the chlorides only, the anime channels. If your ligand is coming since is the ligand-gated anion channel, the glutamate, the simple amine acid glutamate, glutamic acid, anionic form. So, if it is there, so, ligand will be sitting over there, and ligand will opening up the channel and doing something and your chloride can pass through that channel. Sot, that is why the ligand-gated.

So, the person who is there, who is doing your that particular opening up and closing up the gate is your glutamate. Then some macrocyclic lactone, which are very useful for its activity as a drug molecule like ivermectin. So, ivermectin is their huge amount of billions of dollars people make, they are responsible for animal health, our health, agriculture, fish farming many classes, which is very useful also.

But if you know that it is related to the corresponding movement of the anions, corresponding movement of the typical inorganic anions and their corresponding effect on other things. So, in place of glutamate you can have the histamine, then histamine is also another ligand, the histamine its channels it is not histidine, it is histamine. So, remember the molecule what you can have.

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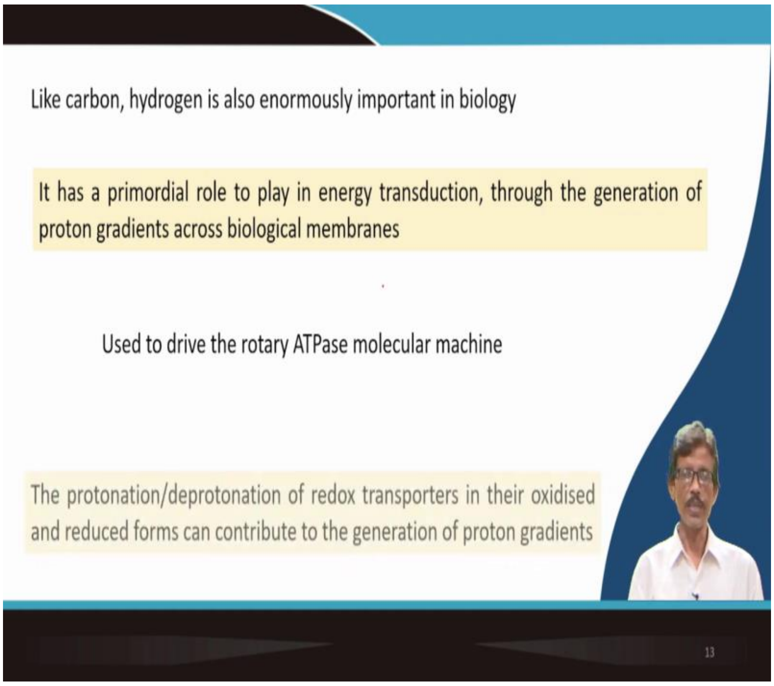

So, like carbon, hydrogen can also have enormous importance in the biology. Already we have seen the hydrogenases. I request you to study a little bit about all this hydrogen cycle, water involving water, as well as the hydrogenases through that. So, primordial role it has to play for energy transaction, generation of proton gradient in the biological membrane. We know the proton gradient then the proton transport also, ATPs also, the proton pump is required for ATPs as or ATP hydrolysis in the molecular machine. And the protonation deprotonation as well as the redox transporters are also dependent on hydrogen cycle or the proton cycle.

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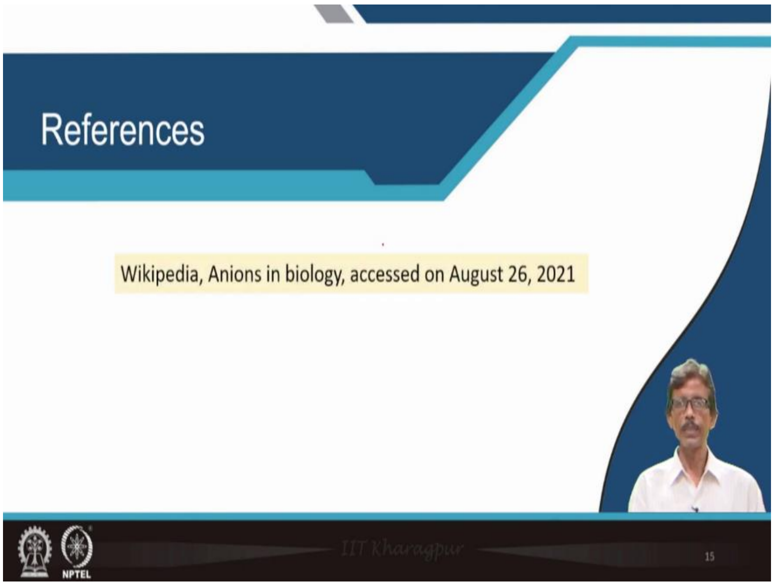

So, in conclusion, we just very briefly will now tell you should understand it nicely that what we are talking about is that how we can get it the formation of anions and their importance. So, you know the molecules when you breath we take oxygen. How it is related to the formation of very important anions or you are taking something externally, like your table salt, in your food material sodium chloride or from other foodstuff potassium chloride, how chloride will take part in all these cases or the biology of the chloride ions or the biology of the carbonate ions.

Then the connections of all these things, the anions, the anion receptors or anion channels also then how they are basically giving some helping hand to us to know about the disease, the disease conditions. You can talk about then the health, how it will be useful for our good health and the medicine whether we can produce some lactone type of thing which can bind very loosely, but is important for transportation for your all this macrocyclic lactone what I just told you as ML. So, read all these nicely from the Wikipedia page about the anions in biology and the book of Crichton. So, thank you very much for your kind attention.