Introduction to Cell Biology
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Discussion on directionality of motor Protein

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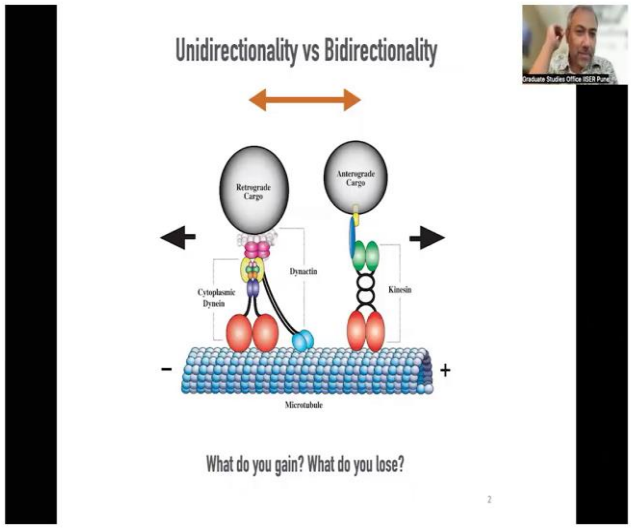

So, welcome back, everybody. We are going to pick up where we left off last time. And we are going to talk a little bit about this query that I left all of you guys with. And so we will open with a small discussion on this particular query. So, the question was very simple, that we have discussed the cytoskeleton, we have discussed motor proteins. And we have also understood that motor proteins have this very unique directionality.

Most motor proteins, either walk in one direction or the other. And there is this possibility, of course, that motor proteins could have been designed in a way that they could walk in both directions, something goes in this direction and then decides to go the other way. And the thought question here was, what kind of advantage, disadvantage does this confer having unidirectionality versus bidirectionality? So, anybody have thoughts on this? Let us have a quick discussion on what you think the pluses and minus would be.

If you have a thought that you want to share, you can post it in the chat box or you can also put your hand up and we will bring you up to speak about it. So, any thoughts, anybody? Unidirectionality versus bidirectionality. Nobody, no thoughts. Somebody is put their hand up. I am thinking one second. Sarthak, yes, Sarthak, please go ahead.

Student: Sir, bidirectionality would consume more energy as compared to the unidirectionality.

Professor: Why?

Student: Because it would require for the more coordination between the molecules to decide where they want to go.

Professor: They will walk, all energy is required only to make a step. So, if it has to make a step if it has to go 10 steps this way, 10 steps back, the amount of energy is energy per step. So, that energy consumption is going to largely stay the same. Normally, you would have had 10 steps of motor protein going in this direction and 10 steps of another motor protein going in this direction. Here, you have 10 of one and then it reverses and does another 10.

Student: It will increase the traffic now, between the…

Professor: No, that is not what you said. You said energy consumption will enclose.

Student: This will lead to the energy consumption more.

Professor: Traffic may not lead to energy consumption. Traffic will lead to other things. As I said, the energy consumption is per step. And if it wants to walk 10 steps it will use a certain amount of energy, which probably is not going to change in that sense. Let us see what some others have to say, Sarthak, give me a second. There is an ECS quiz today. Somebody has put it up and Neeraj has said less traffic in unidirectionality. That means there is no divider here in the cytoskeleton. It is not like on one particular microtubule all proteins are working in one direction.

And all work proteins are working in the other direction on another microtubule. In the same microtubule strand or actin strand, they could be walking in both directions. So, if it is unidirectionality or bidirectionality, the number of motor proteins and how they will be moving around, may not change very dramatically. So, the question here is that really going to change traffic? Amruthamshu has said bidirectionality easy to recycle motor proteins perhaps.

So, you take it to the end and they can be brought back. So, he thinks, bidirectionality is actually going to be beneficial. Sanchit has said unidirectionality gives better order but needs

more protein. So, Sanchit, what exactly do you mean by better order? Will you be able to speak.

Student: Sir, at a given time for protein to know, which side it has to go to. If we have proteins that only go to one side, that makes it slightly easier.

Professor: So, what is easier?

Student: I do not know what exactly these are, but then there must be some sort of processes if the proteins are bidirectional, there must be some sort of process which indicates in which direction the cargo should go. So, in which direction the protein should go, but I know that might be a complex process.

Professor: So, there might be more complexity in regulating a bidirectional motor protein as compared to a unidirectional motor protein. That is the point you are trying to make. Kavia said the same reason that microtubules have directionality to distinguish one direction from the other. So, both motor proteins that go in one direction as well as that have bidirectionality. We will have to have a way to tell which direction they are heading in.

As was just mentioned, the complexity of this regulation may be actually more in the context of a bidirectional motor protein because you will have to control more things to decide when that switch happens what that regulatory mechanism is supposed to be. And so, regulating or controlling a bidirectional motor protein may be more complex than a unidirectional motor protein. Deep is saying bidirectional motor protein causes less wastage. And by wastage, I think you mean that motor protein can be kind of reused or repurposed in the other direction.

Yes. So, that could be one advantage of this. Dhairya is saying that unidirectionality would require more complexity and what would show in more evolved organisms there. Dhairya could you elaborate on why you think unidirectionality is more complex than bidirectionality?

Student: It is just a simple idea that two unidirectionality would require a another protein apparatus to govern the direction of travel rate.

Professor: Bidirectionality, you mean or unidirectionality you are talking about?

Student: I am talking about unidirectionality but I may be wrong.

Professor: So, unidirectionality you are thinking requires more proteins to control it.

Student: Yes.

Professor: But if you have a unidirectional protein, you do not actually my counter argument with that would be that you do not actually need too many regulatory components because that motor protein will walk only in one direction. The only thing to worry about is putting the motor protein on the track and making sure it is bound to something. It will do what it is supposed to do, which is walk in one direction.

Bidirectionality if anything requires to know, when I sit on the track, the motor protein needs to get information saying which direction am I going now, because it could go either direction. And so, it needs some information coming in that allows for the motor protein to know this is the direction it is heading in. And similarly, if it has to go a certain distance and at some point of time change direction there has to be a mechanism to control it.

So, my sense would be that it will actually be a bit more complex to regulate bidirectional motor protein. Unidirectional motor proteins might be easier to control. Now, see, in all of these mechanisms and many of you have said things like bidirectionality can create confusion, it would spend more energy. Somebody said specialization and this term specialization is particularly interesting, which is because motor proteins are, there is a tradeoff here it is trying to make.

And the tradeoff here essentially is that there is a certain amount of specificity that a motor protein needs to have. There is a certain amount of rapidness to the delivery of a cargo that it needs to have. And then there is this element of flexibility in terms of saying, Okay, can I do more than one directions. Now, it is highly possible that a bidirectional motor protein needs one, as we discussed many ways of controlling it. And it is also possible that a bidirectional motor protein could be a bit more error prone. And somebody is alluded to this, that bidirectionality has chances of more error as compared to unidirectional motor proteins.

And that is a very important point to make. That the cell is having a trade off in being able to do something in a certain way that reduces the error of the chances of errors or mistakes happening versus something that may be a little more amenable to change and could have benefits of reusing or repurposing things. But maybe a little more error prone.

Now, the question here is this kind of choice between having something that is more energy efficient or something that is more amenable to regulation versus something that is less flexible less moderatable, less regulatable but is less error prone. And chances are, will make

less mistakes, is the kind of choice that the cell faces on multiple locations. And this is one of the reasons I raised this question, because it allows us to think about this. And there are I alluded to the thought that there are very distinct ideas in terms of thinking about cells.

One is we talked about the regulation in space and time. And in that same context, one of the ideas that cells inevitably think about is how do I reduce the chances of a mistake happening, right and there are mechanisms by which a mistake if it happens, can be corrected and there are mechanisms by which a mistake is the chances of a mistake happening are reduced. And this will depend on the process, that that component is regulating, that there are certain processes and that a certain pathway is controlling that where it can live with a certain amount of error.

And in some places, it cannot and motor proteins are particularly relevant because they regulate vesicular trafficking as we talked about. And when they regulate vesicular trafficking, they are carrying fairly important cargoes, they are the delivery of the cargo is very time and space bound, which means, things have to reach at a very specific time at a very specific place.

And the room for error, if we want to call it that might be significantly less with events and processes that motor proteins may control. And unidirectionality even though it comes at a cost might allow for that kind of specificity, that kind of time bound delivery, with minimal number of errors to happen more effectively for cells. And hence, one thought here could be that the unidirectionality allows for that in a way that bidirectionality may not. Yes, the bidirectional motor proteins with a very elaborate regulatory mechanism could also have achieved it.

And it is possible that the cells did try that out at some point of time. But it may or may not have done as well as it should have. And that is probably led to the fact that cells are now deciding to choose to use a unidirectional motor protein. Deep, you have your hand up? You have something to say please go ahead.

Deep: Sir, I was wondering like bidirectionality is one molecule moving in two directions. A unidirectional, it is two, one is used but like they move in one direction each. So, essentially, everything is still going from left to right, but it is just the number of molecules are changing.

Professor: So, everything is not going left to right, some will be going left to right and right to left.

Student: Left to right and right to left.

Professor: So, they will be going in both directions. Yes, they will be going in both directions. Yes. So, your thought or question being.

Student: No, like, that is what I was wondering because like people were saying it is like better to have unidirectionality and like better bidirectionality. If like, there are two molecules, like the number of RNA will have to increase, since, like, we have to synthesize two different complexes, instead of like in bidirectionality, we just had to synthesize one complex and just the concentration of that should increase for there to be efficient transport. So, that is why, I think, bidirectionality.

Professor: Right. So, bidirectionality could be beneficial, because of certain reasons. But what the point I am trying to make here is that unidirectionality seems to have been chosen here, because of this major factor that the regulatory system that bidirectionality would have required may or may not have the error correctness, that unidirectional system may have. So, unidirectional system may actually be less error prone as compared to bidirectional systems.

And the kind of cargo that motor proteins carry means that, that error could be very vital for the cell. So, as I said, it is possible that bidirectional proteins were tried out and given a chance they could evolve a system, that is as error correct and as less error prone as a unidirectional system and maybe at that point of time, these motor proteins will come into play. But for the moment, this seems to be the choice that cells are making. We will take one last question from Sai. Sai, you have your hand up, can you?

Shai: Yes, sir. I was just trying to imagine how the situation would be like, if we have a bidirectional motor protein, how was this regulation be as an it probably receives a certain molecule like telling it to go in a certain direction but that is also freely released into the cytoplasm.

Professor: See, the other thing to consider is bidirectional motor proteins, the base of the motor of the motor protein has to be designed in such a way that it is able to walk in both directions. And there has to be something that maybe comes and talks to the motor protein in such a way that it now asks the motor protein to kind of change its direction and walk the other way effectively. So, it will be, it will require a certain number of changes to happen in maybe the design of the motor proteins in the regulators that come and bind to the motor protein, which all need to happen for a motor protein to effectively become bidirectional.

So, it may not be just a simple on-off kind of change, that it could be that many players or many parts need to be brought together to allow for that to take place. So, but it is an important thought to have and which is one of the reasons I put this up because the idea that there is a tradeoff that the cell is constantly thinking about for many cellular events and processes is a vital thought to have that when it makes a choice, in some cases, the choice is dependent on energy requirements. In some cases, the choice could be based on how effective this pathway is going to be, what chances of error are going to happen.

And so, the cell is making decisions based on what the requirements of that particular process are. And therefore, what molecule is regulating that process is fine tuned to that particular requirement. And this is a, as I said, it is a thought to have about all cellular processes that when you look at a cellular process and you think about why something is set up this way. You want to ask this kind of a question.

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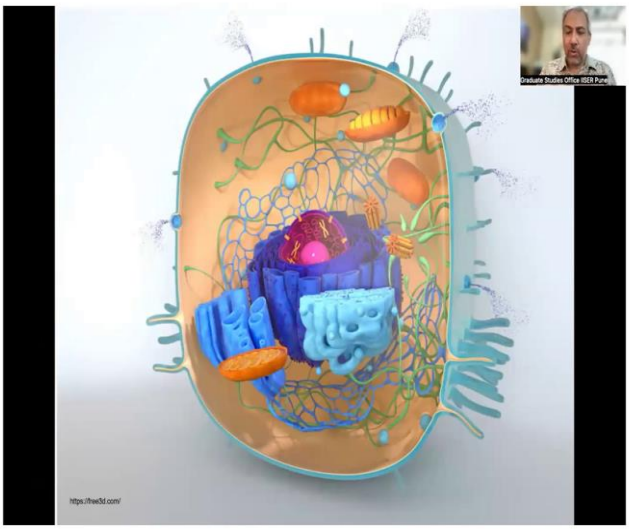

And that is essentially how all these different processes are brought together to come and work with work in a cell.