Introduction to Biomimicry
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Lecture – 26
Nature's Unifying Patterns - 1

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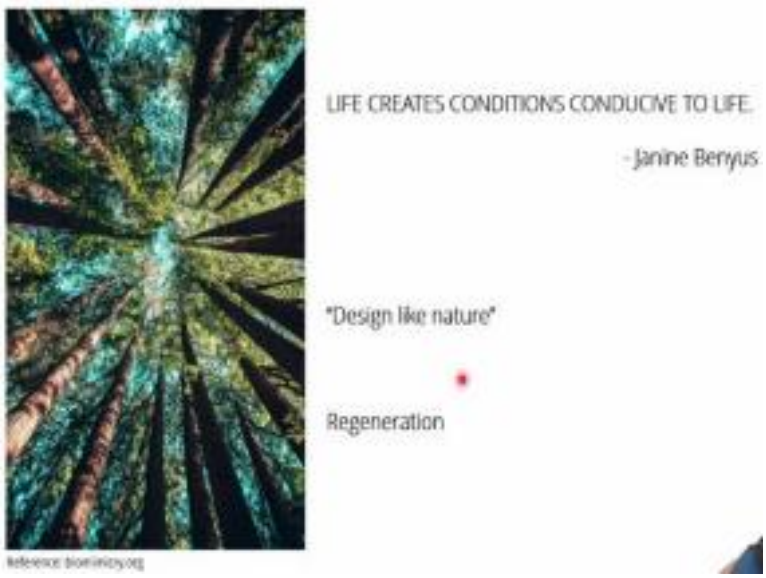

Life creates conditions conducive to life. This is a central lesson in biomimicry. The statement implies that all life forms on earth, all organisms on earth have figured out strategies over millions of years for their survival, and not just their own survival, but the survival of the next generation in the places that they inhabit. That is why you will find that in all ecosystems on the planet, the life forms that are looking up that ecosystem are always maintaining favorable conditions for the entire ecosystem.

They do not harm each other. They always create beneficial conditions for all the other life forms that comprise that ecosystem. And that is life-creating, conditions conducive to life. Now, given the state of our planet currently, rather, the dire state of our planet currently, with loss of forest cover, loss of biodiversity, the water crisis, the oceans being full of plastic, pollution, the list just goes on.

It is obvious that we are heading towards some sort of catastrophe and as responsible citizens of this planet, we have to do something globally. We have to do something within our own communities and therefore it is not sufficient if we speak only about learn from nature. It is

not enough if you just keep saying let us learn from nature. What we need to do is design like nature, not just learn from nature, but design like nature because only if you design like nature, we can reverse the adverse effects of human activity on the planet.

Of course, it is no secret that human activity has caused more destructive effects on the planet than anything else. And if you have to reverse that, we have to reverse the destructive effects and we need to actually have a regenerative effect on the planet, we need to promote regeneration on this earth then we need to design like nature.

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And with this central lesson, we are going to talk about the 10 unifying patterns of nature. Now these 10 patterns you have been introduced to them before as well. They are 10 essential lessons from nature as far as design is concerned. It does not of course mean that nature does only this as far as design is concerned, but it is a starting point for us to understand how nature designs and how we can also start designing like nature.

Also, as biomimics it is important for us to understand these principles because this is what distinguishes biomimicry from other forms of bio-inspired design. So, these patterns become important because clearly they take us to more sustainable solutions. You have been introduced to them when we spoke about the biomimicry design spiral. We spoke about coming back to these patterns every step of the spiral, especially in evaluate.

When you start assessing your solution there is this checklist, the nature's unifying patterns checklist, you can pick up each of these patterns and look at the checklist and find out if you

are able to meet those criteria in the checklist. The goal is to translate these patterns to design specifications, to quality control metrics, to process selection, to material selection, etc., because that is how we will start designing like nature.

Of course, it may not be possible to incorporate all the 10 patterns in every single solution given the current limitations of our systems and our materials, etc. But it is a good start to try and see how many we can incorporate in every solution because clearly, they lead to more sustainable solutions and that is what the planet needs right now. Of course, it would not be easy, it definitely would not be easy because nothing that is worth doing is easy, right?

Whether it is the biomimicry design spiral and actually applying the spiral to come up with a solution or it is these 10 principles, trying to figure out how to invite them and bring them into your solution, it would not be easy, but as biomechanics we have to try and that is what we are going to do. The other interesting thing about these patterns is they are not just if you are a biomimic, inventor or innovator or a creator of solutions or a designer, they can also be used by anyone looking to bring these patterns into their life and work.

They can clearly take you towards a sustainable lifestyle, a lifestyle that is more in tune with the way nature is and therefore each of us can draw our own lessons from these patterns, and find out how we can invite them into what we do and how we live. What we are going to do next therefore is look at each of these patterns one by one, so you can get started on exploring these patterns in greater detail.

You can start looking at how these patterns work, how you can design using these patterns, and how you again bring it into solutions that you create or even into the other parts of your work, etc. So, that will be the goal of these the next few modules. So, let us get started with the first one. Nature uses only the energy it needs and relies on freely available energy.

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So, this first principle that we are going to talk about is nature uses only the energy it needs which is the first part of the statement, and nature relies on freely available energy. Now, energy is an expensive resource. What it means is that in order to get energy you need to spend energy. That is what it means. That energy is an expensive resource. So therefore, if any organism uses excess energy, the effects of that can actually end up being fatal.

Therefore, you will notice that across nature, all organisms will use only the energy that is needed. There are two key expenditures of energy for any organism. Two big buckets in which you can say that they need to expend energy. One is to obtain energy. Obtaining energy is what plants do when they produce their own food using photosynthesis or animals when they look for food or find food. That is one big expense of energy for organisms.

The second is to grow their bodies, grow the materials in their bodies and build their homes. Now, these two are major expenditures of energy for all organisms and you will find in nature that all organisms will adapt their needs to the amount of energy that they have available. They will ensure that they use low energy processes for each of these. They will use energy that is easily available around them.

They will use energy that does not require a lot of energy to be spent in order to get that energy and they will make sure that this energy need not be mined from the earth, which is what humans do. So that is something that all organisms across nature will do. Also, organisms tend to have certain mechanisms to ensure that they use less energy, they use modular structural building

blocks going from smaller elements to larger elements.

They use nested structures; they use multifunctional design. In fact, one thing you will find is they always use ambient temperature and pressure, unlike humans whose processes will always be about high temperature, high pressure, heat beat and treat what we call in most of our processes. So, organisms do not do that and that is what this pattern implies that nature uses only the energy that it needs.

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The second part is nature relies on freely available energy. See, now technically no energy is free because in order to get energy you need to spend energy, so no energy is technically free. But we say that nature's energy sources are freely available because they are easily available locally. They do not have to be pulled out from the earth. They do not have to be mined like human sources of energy.

And they are regenerative, they are renewable that is why we say they are freely available and most organisms will tend to rely on these sources of energy. Now the freely available energy sources are of course sunlight, which the plants use for photosynthesis, then air currents, many large birds will employ air currents in order to fly because if they have to flap their wings and fly, it will really be using a lot of energy for them.

So what they do is they glide along the air currents in order to conserve energy, they make use of a freely available source. Similarly, dissolved minerals from deep sea vents, this is almost all marine animals. Most marine organisms make use of that decomposing organic materials. All these are freely available sources of energy in nature. Now, let us look at an example of this

pattern in nature and we will be doing this for each of the patterns as we look at them.

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This is the abalone shell. Now, abalone is a type of marine snail and this is the shell of that snail, you can see how beautiful it looks. Now the interesting thing about this shell is that it is 200 times stronger than high-tech ceramics, 200 times stronger than anything that humans have made. The best part is that human ceramics need again, the heat beat treat processes, high temperature, high pressure, need to spend a lot of energy to take out the minerals from the earth.

However, this shell is constructed at seawater temperature, seawater pressure using only the minerals that are available in seawater. The snail just pulls out those minerals and creates the shell. So that gives you an understanding of how nature uses only the energy it needs and uses the freely available energy sources available right around them. Let us also look at an example of the same pattern in the human world.

So, it is not as if in the human world such things do not exist. Teams, innovators, designers, entrepreneurs have started doing these, looking at these patterns and applying them. So, let us look at a pattern from the human world.

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This is a bicycle charger for mobile phones. Now I am going to talk about one that was made in Tanzania in Africa. Of course, you may have heard of this in other parts of the world as well. Typically, what happens is, in many parts of the world including Tanzania, people have mobile phones, but they do not have electricity to charge those phones. So, what they need to do is they need to traverse a long distance in order to get to a place that has electricity so that they can charge these phones.

So therefore, this bicycle charger was designed for such people, you can just plug in this charger or rather attach this charger to your cycle. And when you cycle around, this charger will actually charge your phone. The best part is this charger is actually using discarded bicycle and radio parts because they were anyway going to be disposed off. So instead of throwing them in a landfill of some sort, they are actually being used to do something useful.

So, this is one example of using the energy that you need and rely on freely available energy in the human world. Like this, there are several examples in the human world in the natural world. So, we are going to urge you to start looking for that. We are going to urge you to start finding out how you can apply this in your own life and your own work. And see for example, if you take the example of cooking, you go to a kitchen and you will see so much energy being spent.

On the one hand the gas and the other hand there could be an oven, there could be a microwave, all of them are taking up energy. Is it possible to take the energy from one place and reuse it somewhere else to do something else, some other part of cooking? You know there are

entrepreneurs who are looking at these questions and trying to design stuff so that the energy use is optimized in the kitchen. So, these are some questions that you can ponder over as you look at this specific pattern and find out how you can work with this. **(Refer Slide Time: 16:04)**

Next, let us look at nature recycles all materials. Before we do that, I would like to mention that there is no specific order for these 10 unifying patterns. Now, it is not as if the first is more important or anything like that. They are just in some order and we are just going through this order that is it. So, nature recycles all materials. In nature, you will clearly see that one organisms' waste becomes a source of food for other organisms. This is something that you will observe across all of nature.

And you will also, in nature what you will see more accurately can be described as upcycling. So instead of recycling it is upcycling. So if you have this, this tree and the tree is broken down by the fungi and the fungi will be eaten up by a mouse. The mouse will then be eaten up by an eagle. So, the material that are composed in one organism kind of get upcycled to another part of the ecosystem and that is what typically tends to happen in nature.

And you can see that organisms like the fungi actually breakdown complex molecules which can then be used by other organisms. So, they make it available for other organisms to utilize. Also in nature, the various elements and compounds are recycled like water, carbon, nitrogen, etc. You are well aware of how this happens and this can happen at the local, the regional and the entire earth system as an entire system.

The water cycle for example is well known, how water evaporates from the water bodies on the earth and from the plants by transpiration and it then forms clouds. These clouds then bring rain and then the rain runs into the soil and into the water bodies and so on and so forth. So, this is a cycle that happens in nature. It has been happening, it happens everywhere. Similarly, carbon and nitrogen as well. So, nature recycles all materials is an important pattern that you can observe across nature.

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An example of this would be what happens to trees, the lifecycle of trees. Now, I mentioned that there is upcycling that happens in nature, so wherein recycling in nature is not direct. So, this wood of the tree is not going to again become wood that is not typically what happens. Now as the tree starts decaying, you will have organisms like the fungi breaking this up into smaller compounds, which can be used by other organisms. Also, this decaying log becomes a place for some organisms to store their food, some organisms will take shelter over there.

So, it has been used by other organisms as well. And some organisms will start breaking down these, the log and this material will actually be used by other organisms as food or other materials for their homes, etc. So, this is the way the recycling or upcycling happens in nature. This is an example of how it happens in nature. There are several other examples of course, but this is kind of a simple example for us to understand which is why we are looking at it.

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In the human world, how does this happen? And I am going to pick up the example of zero waste city called Ambikapur in Chattisgarh, India. Of course, there are several zero waste cities across the planet now, several cities have started doing this. So, what Ambikapur has done is they have started ensuring that they do not create any new landfills for dumping waste. Most of the waste is subjected to treatment and recycling.

They have what are called garbage clinics. It is an innovative model that they have got where they bring all the garbage. They figure out what can be recycled, they extract the items that can be recycled. If they need to be processed for recycling, they are sent to various places. And biodegradable waste is also treated in a decentralized manner so that is what Ambikapur has done which ensured that they are zero waste.

And this is clearly an example of nature recycles all materials. Now you can also think about how can you bring this into your life and work and into solutions that you create. Now instead of looking at recycling as a buzzword, can we look at it as something that helps us design like nature? Can we look at it as something that helps us create conditions conducive to life? That is what we would like you to think about as you explore this pattern further.

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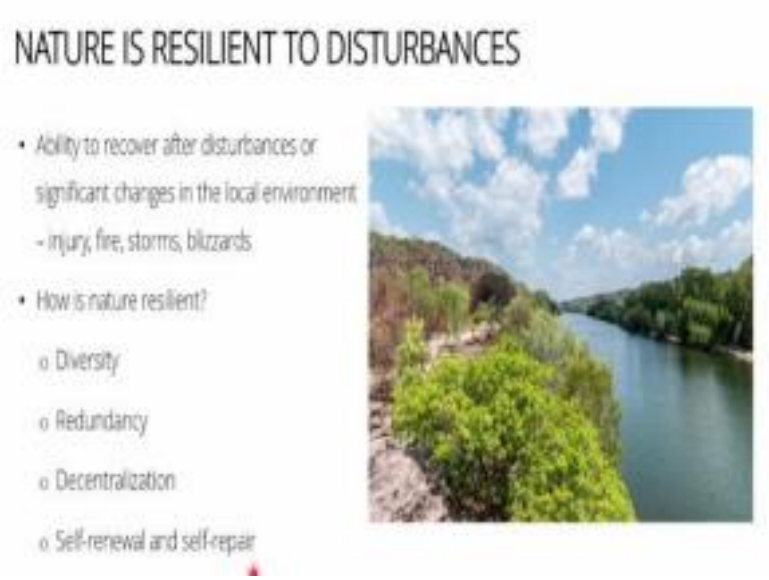

Let us now look at nature is resilient to disturbances. Now, resilience is a quality which is about withstanding difficult conditions and the ability to recover from those difficult conditions. And in nature, you will find this everywhere. Whether it is injury to an organism or it is natural events like fires or storms, nature does recover. So, how is nature resilient? How does it do it?

There are four enabling mechanisms that can be considered as the secret behind nature's resilience. This could be at the individual level, it could be at the system level as well. The four are our diversity, redundancy, decentralization, self-renewal and self-repair. What do these mechanisms imply?

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Diversity is that there are several forms, processes or systems that accomplish a single function. There is never just one form or one process that actually meets a function. We spoke about this briefly even when we discussed function and strategy. Also, in response to a change in the

environment, the responses will always be a range of responses, it would not be just one response. So that if nature is looking to see there is a response, there are a range of responses that give a clue as to a change in the environment. This is one of the enabling mechanisms for resilience.

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Then you have redundancy. Redundancy is when in a system more than one organism or species provides a function with some overlap. So, that if one representative is lost, the entire system is not destroyed. We will look at an example shortly.

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Then there is decentralization, which is the other mechanism kind of goes with redundancy and diversity as well. The mechanisms are that maintained redundant functions are not in one place, they would not be in one place so that if there is a disturbance in that one place, the whole system does not get destroyed. So, the mechanisms that maintain these redundancies are

actually spread out throughout the system so that even if there is a disturbance and if there is a loss in one local part of the system, the entire system does not get affected. So, this is another enabling mechanism for resilience.

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Then you have self-renewal and self-repair. Now, this is clearly what happens at the cellular level, at the individual organism level and the system level across all of nature. This needs no explanation because you have the ability to generate new cells, to heal injuries and damaged organs and respond to any external viral, bacterial threats. So, this is an important part of maintaining resilience in nature.

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The example from nature, we are going to look for resilience to disturbances is the lodgepole pine forest in the US. Now lodgepole pines are a type of tree that grows in the Yellowstone National Park in the USA. Now in 1988, there were large forest fires there which burned all

these forests. But these pine forests were able to grow back and how do they do that? They did that using the mechanisms for resilience that we just saw. First one is diversity.

All these trees carry two types of cones. Now cones are the structures that hold the seeds of these trees. So, what do these two types of cones do? You have the regular cones that will release the seeds in normal conditions. They split open and release the seeds in normal condition so that other trees can grow. Then you have the special cones that will not split open in normal conditions at all.

They are sealed shut with some type of resin and they open only when exposed to high heat of a fire like a forest fire. So, when that happens, they split open, and they spread so that the trees can actually regenerate. So that is how diversity works in order to enable the regrowth of the forest.

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The other part is the redundancy where each tree produces several cones. So, it is not as if there is just one or two cones, one or two special cones. So even if a small percentage of seeds sprout, the forest can still regrow and regenerate. Also, what has been observed is even if the forest is burned down completely to the ground, seeds from nearby forests can contribute to the regeneration so that the forest can come back to life. So, this is an example of resilience to disturbance from nature.

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Now let us look at an example from the human world. The example we are going to take up is self-healing concrete. Now, we know that concrete is a very important building material, the only problem with concrete is it is prone to cracking. And scientists and researchers at the Delft University of Technology in the Netherlands have created bio-concrete by mixing bacteria into the concrete.

Now, why do they do that? They did that because when the concrete cracks, the bacteria actually grow into the crack and when bacteria grow, they produce calcium carbonate as a waste product and that actually fills up the crack and therefore the concrete repairs the cracks on its own. That is why it is called self-healing concrete. And this is an example of the application of the pattern of being resilient to disturbance in the human world.

Like this, you will find other examples as well. So, please do explore this, find out resilience to disturbance, how can we create systems, how can we create solutions that are resilient to disturbances instead of systems that just collapse in case there is a disturbance that occurs.

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Next we look at nature tends to optimize rather than maximize, unlike humans of course because for human beings bigger is always better. More is what we always tend to think of. But in nature, nature tends to optimize rather than maximize. Now, we saw this a little bit in the pattern on energy. Both energy and materials are extremely valuable resources in nature. Therefore, there will be a judicious balance on the resources that are spent and used, whether it is energy or whether it is materials.

So, because what happens is if animals or plants or any other organism is going to start growing indiscriminately, there are going to be various adverse effects that happen in that organism, which is why organisms stop growing after a certain point in time, there is an optimization there, because it is not unlimited, unlimited growth is really not possible. And this is a valuable lesson for humans because we think indiscriminate growth is possible, unlimited growth is possible.

In reality, that is not possible without harmful and adverse effects. And in nature, in all natural systems you will find that there are checks and balances to prevent the overuse of resources, which is why organisms stop growing, earlier example that I gave you. So, these checks and balances are to prevent not just at the individual level for overuse of resources, but also at the system level, prevent one's life form from overusing resources.

So, this exists in all of nature. It is an important lesson that we can learn from nature. Optimizing rather than maximizing. Let us look at an example in nature.

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The example is of bones. Now, bones will respond to stress wherever, whichever part of the bone needs to take weight, it will add more calcium to it and therefore make it stronger. Now, the trade-off there is that that part of the bone will become heavier. Now, if it is heavier, then in that case what happens is the organism needs to spend more energy to carry that heavy bone around.

So, therefore what happens is the points on the bone where there is no load bearing occurring, those points will actually have less calcium, they will become lighter. So, this is the way the weight of the bone is optimized and the energy needed to carry that bone around is optimized, while at the same time ensuring that the bone is able to take all the stresses, all the loads that are placed on it. So, this is one example of nature tending to optimize rather than maximize.

So, bones it is not as with more and more calcium they just keep getting heavier and heavier and heavier. That does not happen. It is based on the mechanism of what is needed to carry the weight, what is needed to withstand the stresses that are placed on the bone. And if there are points of where it is not needed, the calcium is removed to make the bone lighter. Let us also look at a human world example.

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The example is of what is called tiny houses. All of us are well familiar with this tendency that we have to build larger houses, larger cars, larger offices, everything has to be big for us, whether we need it or not. And there is this movement therefore which is called tiny houses, where you build a house with all what you need, all the amenities, all the functionalities that you need in a very small area, everything is available to you and it is a compact, self contained unit.

Many of them, of course use renewable sources of energy, etc., as well in order to reduce their impact on the environment. But these tiny houses are one example of tending to optimize rather than maximize because just use the space that you need. There is no need for 8-bedroom houses, 12-bedroom houses, 20-bedroom houses with 2 bedrooms downstairs, 8 bedrooms upstairs, so many baths, etc.

Just look at a tiny home like this, which has everything that you will need to live, at the same time be comfortable. Now this is quite a big movement across the world now. And people are trying to do this to reduce their impact on the environment and to also remove the stress of often having to look for land and having to look for resources for people to live. Because we know that the housing crisis is quite a big crisis across all countries in the world and this is one way of overcoming that.

It is just that**,** many times if people are told about tiny houses, they will immediately start objecting saying no, but I cannot do this, I cannot do that. In order to bring these patterns into our lives, what we need to do is we need to change our perspective a bit. We need to start

thinking a little differently and that is one of the things that these patterns can help us do as well. Find out, okay, this is how nature does it, nature can do it, why not us?

And this is something that has worked, it has worked for millions of years. If that can happen, why cannot humans imbibe the same thing? This brings us to the last pattern that we are going to be talking about this week. We will pick up the other patterns in next week. The pattern we will speak about now is nature provides mutual benefits.

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Now in nature it is well known that symbiotic relationships exist where species interact with each other and benefit each other. They collaborate with each other. This is a well-known fact. Of course, it happens to the human world as well, but the intention of looking at this pattern is to find out how can we do it in order to be more like nature. So, the cooperative relationships can be looked at as two types. One is called mutualism, where both organisms actually are benefiting.

Now this is, you would have seen several such examples, you have this nearly blind shrimp that lives under the sea and then there is this fish. So, the fish and the shrimp, the shrimp make a burrow in the sand and the fish also lives in the same burrow. When there is a predator, the fish touches the shrimp. So, the shrimp and the fish kind of go into the burrow so that they can stay safe from the predator. So, both are now protected. And then fish gets away a place to lay its eggs in a safe place so that is mutualism.

There are several such examples in nature of mutualism. The other interesting one is commensalism, where one organism benefits and the other organism is neither benefited nor

harmed that is called commensalism. We will look at an example of this as well. However, one point here is that even the other types of relationships that you see in nature which is predator-prey, parasites, or competition. Even though they may look to be harmful at the individual level, obviously at the individual level a parasite can harm an organism.

Predator-prey, the prey is harmed. And in competition between two species, one specie will obviously suffer. But there are benefits that occur at the system level. So that is important thing to remember here that we are talking about mutual benefits and the kind of relationships that occur between organisms in nature. But even these relationships do have some benefits at the system level. So, let us look at an example from nature of how nature provides mutual benefits.

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The example we are going to look at is a commensal relationship which is remora and sharks. Remora is a type of fish, this fish that you see here. They have flat oval sucking discs on the top of their heads. And what they do is they use that to attach themselves to the bodies of large sharks. And why do they do that? They are carried along with the shark, they do not have to spend their own energy swimming.

They feed on the leftovers of the shark's meal, but the shark by itself is not bothered about the remora at all. So, this is a commensal relationship that happens in nature. There are mutual benefits of course, but this is an example of a commensal relationship in nature.

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An example of providing mutual benefits in the human world of course you can look at, you would have seen several examples. One example is of what we call empty miles. Now you have freight scanning trucks that go across cities, across the country and most of them do not carry loads on the return trip. Now, this is actually a problem for many transporters because the costs of transporting are higher because of that and then as these come back empty, there are unnecessary greenhouse gas emissions.

Other problems also like traffic and logistics and even other human problems occur. Now there are AI-enabled platforms. What they do is they allow shippers and carriers to actually find out empty trucks that are going to be returning empty and provide them with a load to carry as they return home. So, on the way back, if some shipper wants to send something to that location, they can just give the load to that carrier and they will carry it back.

So, this way the number of empty miles is actually reduced. So, this is an example of a platform that provides mutual benefits, a lot like what happens in nature. Again, we can say that there are several such examples already happened in the human world, but the intention is to look at nature closely, find out how we can take those lessons, how can we actually imbibe some of the specific strategies of cooperation and make our lives better, make our solutions better.