Introduction to Biomimicry
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Lecture – 18
Step 2: 'biologize' the Problem: The Biomimicry Design Spiral

So you have looked at the define step, which is the first step of the biomimicry process, the biomimicry design spiral. And you have seen that function plays a critical role in defining your problem statement. You look at what your solution needs to do and use function as the basis for doing that. And as you go through the design spiral now to the next step which is 'biologize', you will see that function assumes larger importance because you will need to understand function really well when you start doing these steps as well.

So, we are going to go to the next step which is 'biologize'. And in 'biologize', you are going to look at similar functions. You have defined a bunch of functions in your define question, one function, or maybe more than one function in your design question in the define step. Now in 'biologize', you are going to look at similar functions from nature. But before we do that, I would like to introduce to you something called biomimicry taxonomy.

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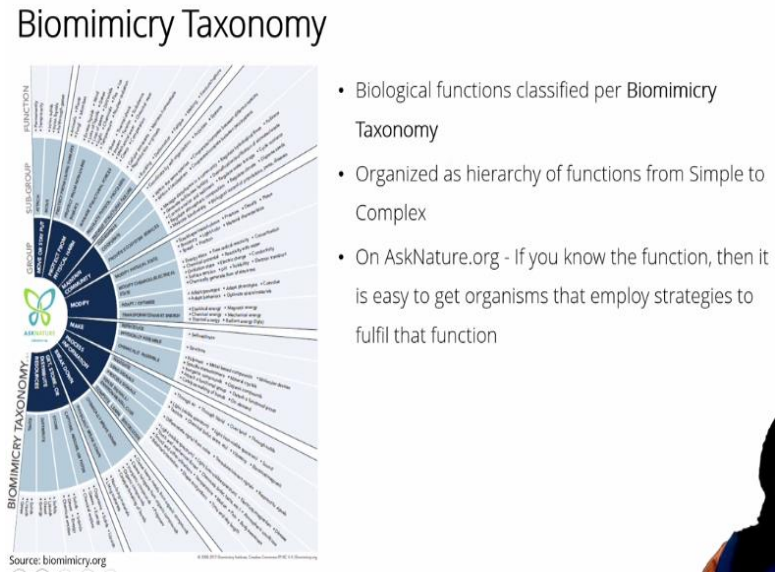

The biomimicry taxonomy is the diagram that you see right here, this one. Let me just get the pointer here. So, this is the biomimicry taxonomy. It looks complicated, but it is not really that complicated. What it is taxonomy is basically a classification. So, the biomimicry taxonomy is

a classification of functions organized as a hierarchy from simple to complex. And this taxonomy is available on AskNature.org.

You remember we spoke about AskNature.org in week 1, and I mentioned that we will look at it in greater detail subsequently. So, AskNature.org has this biomimicry taxonomy clearly spelled out. And if you once you know the function, it is very easy for you to locate organisms that perform the same function and we will see how that happens on AskNature. But first, let us understand this biomimicry taxonomy a little better.

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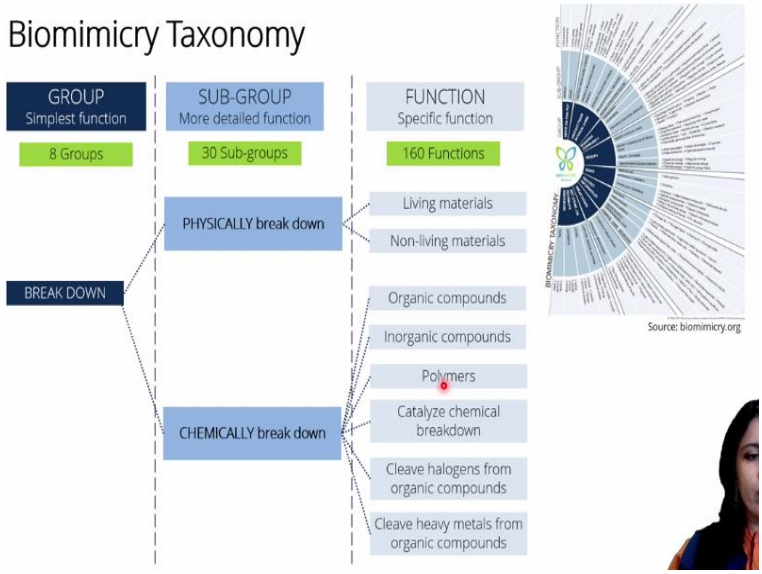

So, this is the taxonomy. As I said, a taxonomy is a classification. So, the classification of functions is from a group where the simplest function is mentioned, which is what you see here mentioned in the innermost circle. Then you have a sub-group where it is a slightly more detailed function, which is what you see here mentioned in the next set of functions. And then you have a specific function radiating out from the subgroup.

Now, you have 8 groups, 8 simple functions, 30 subgroups, 30 slightly more detailed functions, and 160 specific functions in the biomimicry taxonomy. For example, if you take one of them, which is break down which is a function that many organisms perform. Under breakdown, you will find two subgroups. The two sub groups are physically break down and chemically break down.

So, if you see, the simple function is break down, and the two subgroups under that are physically break down and chemically break down. The next specific functions would be under

physically break down would be physically breaking down living materials, physically breaking down non-living materials. And under chemically breaking down you would find specific functions.

Chemically breaking down organic compounds, inorganic compounds, polymers, catalyzing chemical breakdown, cleaving halogens, and cleaving heavy metals. Now, this looks very complicated. But if you look at AskNature and try to understand this a little better, you will see how it all works out. So, I am going to do that right now. I am going to take you to AskNature to show you this taxonomy, this classification of functions, and how you will be able to use that.

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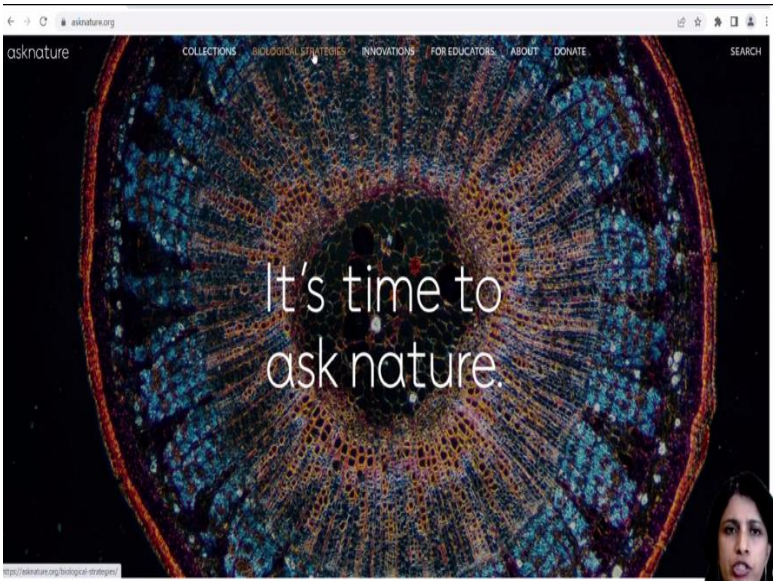

So now that you have looked at the taxonomy, I am going to show it to you on AskNature.org. Now AskNature.org is the sister website of the Biomimicry Institute and they have actually curated more than 1700 organisms on this website based on the taxonomy of functions. So, I will take you through the other parts of this website as well. But let me first start with the biological strategies, which is the part where you will find the functions.

(Video Starts: 05:26) So, remember I showed you the taxonomy where in the taxonomy you saw that there were 8 main functions and under that, there were subgroups and specific functions. So, the 8 main functions are right here. Can you see them? Break down, getting storing or distributing resources, maintaining community. So, the radiating structure that you saw in the document is translated here on the website.

So, we looked at the breakdown function. So out here if you see the breakdown, you can see the breakdown function right here and you have 87 organisms that perform this function that they have curated here. I mean, 87 organisms, not in the entire natural world, but what has been curated on AskNature. So, in breakdown, you have chemically break down and physically break down. So those are the two subgroups under break down.

And if you take the chemically breakdown, for example you can see that there are 66, organisms that are chemically breaking down in the natural world. And you can further look at specific items they are saying, let us say chemically break down polymers, 9 organisms are here. You click on that and you can let us say find these 9 organisms right here. You can click on any one of them that is of interest to you, you open that.

And this one is on how fungi can clean up pollution. So, we came here from chemically breaking down. Breaking down, chemically breaking down polymers. So, fungi are performing the function of chemically breaking down polymers. And on this page, you can actually see how they do that. So, the function is chemically breaking down, and the strategy, the biological strategy of how it does that is mentioned right here.

The AskNature page also gives you the potential of this strategy saying where could it possibly be used in the human world. And if there is an innovation that has stemmed from this strategy, they have provided a link for that. So, you can actually open up that innovation and look at how did this company Novobiom go about doing this innovation based on that strategy. So, this innovation right here, they have spoken about what they do.

They are using fungi and microorganisms for the remediation of contaminated soils. What are the UN SDGs that they have targeted using this? What is the challenge they started with? What is the actual solution they came up with? There is a short video to describe the innovation and how did they use this. And you have heard of the Ray of Hope Prize, right? The Ray of Hope Prize I mentioned in week 1.

So, if they are a finalist, they have kind of given you details about that as well. Coming back to the strategy that we started with chemically breaking down, how do fungi chemically break down contaminants? So, it is right here, the entire strategy is right here with also related

strategies given to you here. Plus, you will find some references to journal articles if you want to learn more.

So, as you can see AskNature has done an excellent job of making it easy for you to look for functions and organisms that are performing those functions and how they perform those functions. Also, on this page, you can see related functions for this organism. And if you want to look at the entire living system, let us say fungi, you can look at additional information on fungi. So, this is a pretty detailed and comprehensive view of any function that you pick up to see.

I am going to go back to this taxonomy right here. We looked at the chemical breaking down. You could also look at other parts, you can look at, let us say, physically breaking down. And in physically breaking down you have 22 organisms that are physically breaking down living materials you could click on. You could again click on any one of them. You know you have 24 organisms. You click on one, maggots let us say.

Again, you will find the basic function that they perform- scraping dead tissue. How do they do it? How do they actually do it? What is the potential for the strategy which means how can the strategy possibly be applied in the human world. And if there is an innovation that has happened based on that or there is a related function or a strategy based on that, the links to that would be given here along with references.

So, that is how the taxonomy works on AskNature.org. I am going to come back to the taxonomy here. Now, some of you must be thinking this looks highly technical, this is only for engineering students, it is for engineering people, it is for researchers in science, etc. But that is not true. Biomimicry can be used in other fields as well using the same concept of function and strategy. For example, if you look at how does nature let us say maintain community?

So you are looking at how does nature maintain community? Under community, you see 213 organisms that are maintaining community. You could say that under maintaining community, let me look at let us say providing ecosystem services. And under that there are various functions that are available. Let us say I choose one of them, which is managing disturbance in a community. How does nature manage disturbance in a community?

So, you are looking at how nature manages disturbance and you have 29 systems, 29 organisms that do that. You can scroll through them. You can look at each one of them if you like. You open one of them and you can see the details like before as to how. This is an example of the savannah ecosystem. So, the savannah ecosystem, how does it manage disturbances? So here it is how does it do it and related innovation that has stemmed from that.

So, you have a company that has created an interactive graph database based on this learning from savannah ecosystems and prediction models based on savannah ecosystems. So, as you can see this is not; the taxonomy or biomimicry is not just for engineering and design questions, it can also be used for other domains and other fields, HR, leadership, team building, conflict management.

You just have to look for the appropriate function over here. I am going to look at another example just to give you a sense. So, for example, let us say you are looking at education. So, if you are looking at education, where would education fall? Education will fall under processing of information, I guess, so there it is. So, processing of information learning. So under learning, you find there are 9 organisms that have been curated.

The learning of 9 organisms has been curated here to show you what strategies they employ for learning. So, you could look at them and find out if you can get some ideas from nature. For example, I can say let me look at this one. I open that and peer-to-peer learning spread innovation in the Bottlenose dolphin. So, I can go right down here, understand what is the strategy that the bottlenose dolphins employ in order to perform this peer-to-peer learning.

And the potential of this, there is also a nice animation here to show you how it works and how it could be applied in the natural world. And you can see the related innovations that have used this strategy in order to do something. So, there you have it the biomimicry taxonomy, the concept of function using biomimicry is not just for engineering and design, it is also for other fields and other domains.

I also want to show you the other parts of this AskNature website. And you can see right here you have something called collections. Collections are where you have themed resources on biomimicry collected here so that you can look at various themes of biomimicry. For example,

you can see a collection of how mammals came to be on earth. You can see different, for example, how does nature deal with stress?

Again, it is not an engineering kind of question. So, you could look at the collection and find out what you can learn from this. So, it is a collection of various resources. Oh, wow, look at this. Nature is always hinting at us. It hints over and over again and suddenly we take the hint. And that is what we are doing here. We are taking the hint and learning biomimicry. So, these are the collections that are available on the AskNature website.

You can also look at the innovations. When you looked at biological strategies, the related innovations were available to you right below with the links, but you could just go to the innovations tab and start looking at innovations. And these innovations are organized by sector. So, you can look at Green Chemistry, you look at manufacturing. Also, there are UN SDG goal-related innovations that are given to you, materials, aerospace.

So, you could just click on one of them, and find out what the innovation is all about. For example, this is a company called Biohm which has built insulation inspired by mushrooms. You can see what are the details of this innovation. What have they actually done? Typically, there are nice videos explaining what they have done and this is what it is. The AskNature website also has something for educators.

So, if you are looking to educate AskNature activities are available. How do you use biomimicry activities? Also, for various age groups from kindergarten to class 12, how can you use materials? So that is available as well on the website. So, this is the AskNature website for you. An absolute treasure trove of information and resources that you can use not just to go through the biomimicry process, but also to learn more about biomimicry. **(Video Ends: 17:12)**

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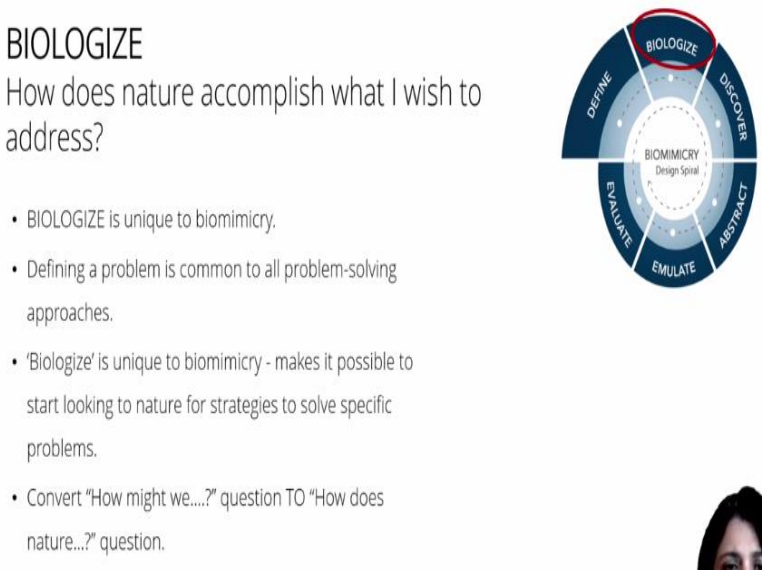

So now that you know how AskNature works, let us just pick up step number 2 of the biomimicry design spiral, which is ‘‘biologize’’. And in ‘biologize’, the question we ask is how does nature accomplish what I wish to address? Remember this is related to the function and therefore we will be working with the function that you use in your design question in order to ‘biologize’ it. Let us see how we do that.

Now, before we get into the specifics of how we go about biologizing a design question, I would like to mention that ‘‘biologize’’ is the step that is unique to biomimicry. Now defining a problem is something that all problem-solving approaches have. So, this is something that you would do in any sort of problem-solving approach, identifying what the problem is, looking at the criteria, looking at the constraints, and framing the problem statement is something that you do in all problem-solving approaches.

So that is something that we do in biomimicry as well. So that is common to other approaches and to biomimicry. However, the ‘biologize’ step is unique to biomimicry and why is that? Because in ‘biologize’, we are asking the question of how does nature do something and that is the stepping stone for us to start looking at nature for solutions. So, in ‘biologize’ what you are going to do is ask the question how does nature do something?

And you do that by looking at nature's functions and subsequently nature's strategies. So specifically in ‘biologize’, the ‘how might we’ question that you defined, you framed in the define step, you are going to convert it to a ‘how does nature’ question. Let us see how to do that.

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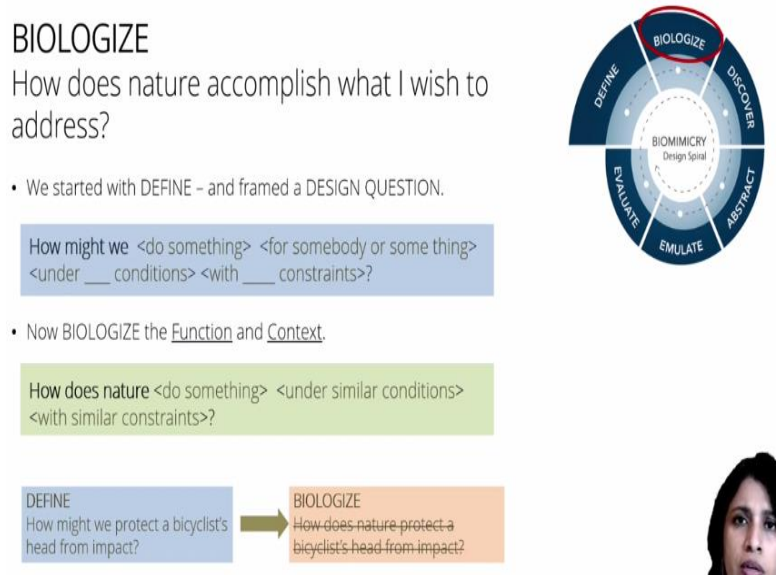

So, in 'define' you will recall that you did something like this you define the question. You defined or framed a problem statement in this manner. How might we do something for somebody or something under certain conditions and constraints. So how might we protect bicyclist's head from impact? How might we create learning opportunities for refugees? How might we make sure that surplus food is got to those in need?

So, this is the standard form of a design question. Now, how do we take that and 'biologize' it? You are going to 'biologize' it by biologizing the function and the context of the defined question. Now, what does that mean? Now you are going to create a question that looks like this. How does nature do something under similar conditions and similar constraints? Similar to what? Similar to the defined question, similar conditions, and similar constraints.

However, remember that you are looking at the function and the context based on what you did in 'define', but you will have to 'biologize' that appropriately which means that you will have to bring in the natural world conditions into that. You cannot just directly translate it. For example, if you are saying how might we protect a bicyclist's head from impact which is your defined question. You cannot say how does nature protect a bicyclist's head from impact? That sounds absurd.

It is not possible for you to look for anything in that context. So, what you will have to do is look at the defined question, identify the function, identify the context, and the criteria that you

have used, and 'biologize' it appropriately in order to frame a biologized question. And how will you go about doing that?

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BIOLOGIZE the CONTEXT

It is difficult for drivers to see cyclists on the road at night.

Design Question *How might we....*	Function(s) *Biologically relevant*	Context *Biologically relevant*	Biologize *How does nature....?*
How might we make urban cyclists more visible to drivers at night?	• enhance visibility; • produce light; • reflect light; • sense or send signals;	• dark, low light; • chaotic/busy; environment; • moving quickly;	

Of course, you will use the biomimicry taxonomy for it. So let us see how that taxonomy will work. How will you 'biologize' the function and context in order to create a 'how does nature' question? So, you start with; I mean this is a very short problem statement or opportunity to solve a challenge. But for the purpose of an example, we have kept it short. So, it is difficult for drivers to see cyclists on the road at night that is kind of the framing of the problem situation.

And based on that, the design question that we come up with could be how might we make urban cyclists more visible to drivers at night? So given that it is difficult for drivers to see cyclists on the road at night, we look at a design question which means you look at the function of what is it that you want to do in order to accomplish something and say how might we make urban cyclists more visible to drivers at night? Now, this is the design question.

This is what you have done in the define step. Now, if I have to 'biologize' this, I cannot say how does nature make urban cyclists more visible to drivers at night that really sounds ridiculous and obviously that is not going to take us anywhere. So, therefore, what we do is we will look at how do we make this? How do we 'biologize' the function and the context from this defined question? Because the defined question is from the human world, we have to translate it to the natural world.

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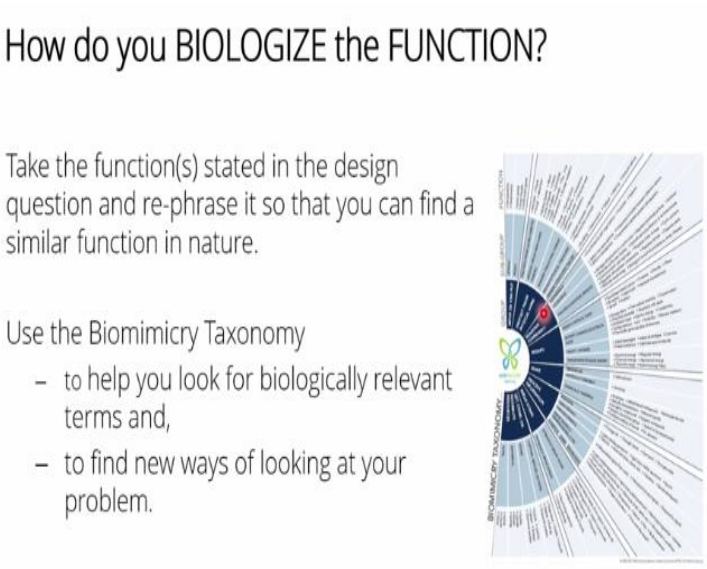

So how we go about doing that is using the biomimicry taxonomy and the biomimicry taxonomy remember you will take the help of the functions that you saw earlier, all these functions. You can take the help of these functions to look at biologically relevant functions to the function that is specified in your defined question. And also find fresh ways, fresh perspectives of looking at your problem statement. Let us look at it with an example.

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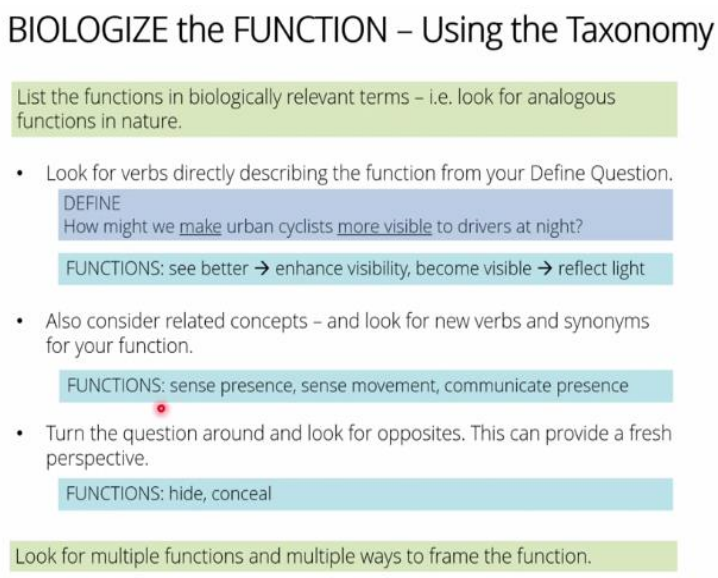

So, look at your design question and look for functions in nature. For example, you take your defined question which is how might we make urban cyclists more visible to drivers at night? And what do you do? You look at the verbs that are describing the function. Remember, the function is how you do something. So, therefore, it is an action. And the action here is making it more visible. Now what do you do, this is making it more visible.

You need to look for functions that are similar in nature and look at making more visible what could be similar functions in nature. Similar functions could be seeing better, enhancing visibility. So, you are looking at becoming visible, so other ways could be reflecting light because that is what makes stuff visible. So, you can play around with the function and look at what could it be in nature that is one way.

And for doing this, you can take the help of the taxonomy. The taxonomy gives you a bunch of functions and you could use the wordings from that in order to come up with functions that are from the natural world which are similar to what you have put in your defined question. You could also do one more thing. Look for related concepts, and synonyms to your function, synonyms are words that have the same meaning.

So, you can look at functions that are similar in nature to what you are looking for. So, in this case making more visible which is seeing better, enhancing visibility, reflecting light, etc. So, what could be similar in nature? You look at the biomimicry taxonomy and look at what is similar in nature. So, you look at what is similar, you can look at sensing presence because that makes something visible to you, sensing movement or communicating presence.

All these are concepts related to becoming more visible. Again, the taxonomy will help you do that. You do not have to pull them out of thin air, the taxonomy will help you do this. The other way you can do it to 'biologize' to function is to flip the question around, you can look for opposites, just like you looked at synonyms which are words that have the same meaning, you can look for opposites. And this can give you fresh insights into how to approach your question.

So, you look at instead of saying making more visible, you could say how does nature hide? How does nature conceive? So, this is a way of biologizing using the function which is specified in your define question. You look at verbs that directly mention the function, which means instead of saying making more visible, you look at how does nature enhance visibility? Because you cannot say see better. How does nature make things more visible?

Reflecting light is one concept. You look at similar functions, similar concepts, sensing presence, and how does nature sense movement? How does nature communicate presence? And you could also look at opposites how does nature hide? How can nature see? So, this can

give you a fresh perspective. So, this is a way of biologizing the function that is mentioned in the 'define' question.

So, one tip here would be that look for multiple ways to frame the function just like I did here. Do not just stop with making more visible, therefore enhancing visibility, let us move on. You will be very disappointed with yourself if you just do that because you will find that you are getting stuck. So, look for multiple functions and multiple ways to frame the function. So, coming back to our example, how might we make urban cyclists more visible to drivers at night? This is our defined question.

So, the function that we have extracted from it, 'making more visible' is the function of course, the biologically relevant function. Remember, you cannot just say how does nature make more visible. So, what is a biologically relevant question that we can extract from it using the taxonomy? We could extract enhancing visibility, producing light, reflecting light, sensing signals, and sending signals.

So, all these are biological functions related to what we have mentioned in the defined question. Now that you have biologized the function, you have to 'biologize' the context as well and how do we do that?

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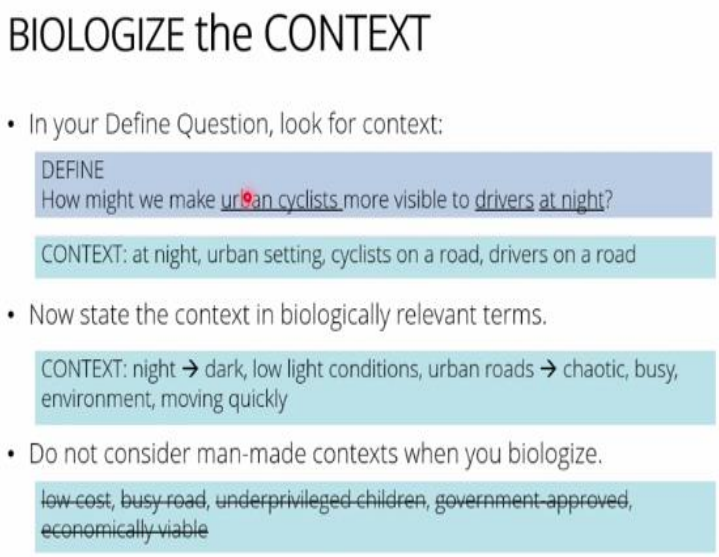

Again, first thing is to write down your defined question and look at what is the context that you have mentioned in the defined question. In this case, making visible is the function but what is the context? Remember, the context is who are the stakeholders? Whom is it used for?

Where is it used, etc. So, the context here is urban cyclists and drivers and at night, so these are contexts for the defined question.

So how do we 'biologize' this? We look at first the context which is in the human world. At night, urban settings, cyclists on the road, drivers on a road and take that forward and make it in biological terms which means that you remove the manmade settings from it. You cannot talk about roads and urban and cyclists because that does not make any sense in the natural world. So, therefore, you look at biological terms.

So, night implies dark conditions, low light conditions, urban roads could imply chaotic or a busy environment where things are moving very quickly. So, this could give you the context in biological terms. And then one important tip again to remember here is not to consider manmade contexts when you 'biologize'. This is very important when you are trying to 'biologize' your question.

Because we get students all the time who bring manmade context into their biologized questions like low cost, busy road, underprivileged children, government-approved policies, etc. Now, these are things that are all manmade and they cannot be part of your biologized question because they do not make any sense in the natural world. So, from your defined question, you will have to remove the manmade context, remove the manmade functions and state it in biological terms.

So that is what you have done here, you have biologized the context and you will rephrase the whole thing as it occurs in nature. So, therefore coming back to our example you have looked at the design question, you have biologized functions. Now you have biologized the context as well. So, the biologist context is therefore dark, low light conditions, chaotic and busy environment where things are moving quickly.

All these we got from this question by biologizing the function and biologizing the context. Therefore, how would we start writing our how does nature question which is the biologized question?

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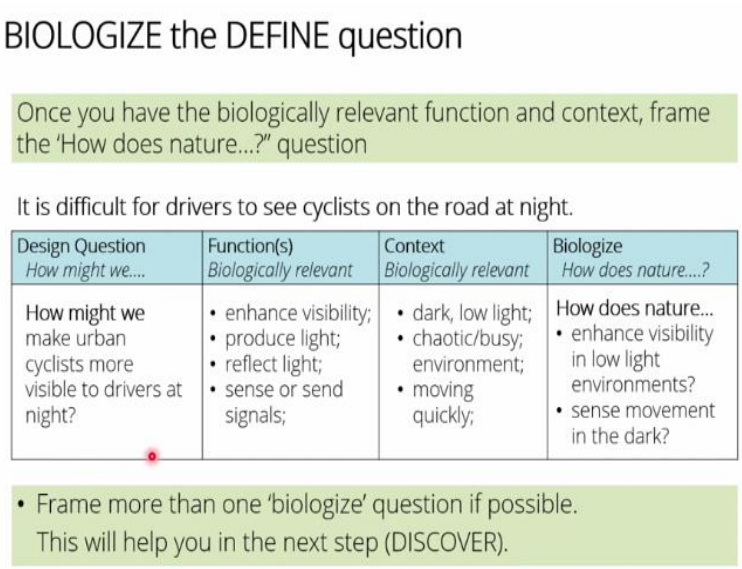

We will look at both these biologically relevant functions and contexts and state the biologized question which would be how does nature enhance visibility in low light environments? And how does nature sense movement in the dark? Now, if you notice this defined question is related to this biologized question, but at the same time you have removed all the manmade structures from this.

And you have made it relevant to the natural world and that is what 'biologize' is all about. Looking at how nature accomplishes the functions that I am looking to accomplish in my defined question. Now, you will notice that I have framed two questions here for this single defined question and that is definitely a tip that I would suggest to you that frame more than one biologized question because that will help you in your next step which is 'discover'.

So, what you have done in this step is taken your design question, biologized the function and context, and created a how does nature question. Look for more than one question because that will give you a lot of organisms to explore in the next step.

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BIOLOGIZE

Design Question *How might we....*	Function(s) *Biologically relevant*	Context *Biologically relevant*	Biologize *How does nature....?*
It is difficult for drivers to see cyclists on the road at night.			
How might we make urban cyclists more visible to drivers at night?	• enhance visibility; • produce light; • reflect light; • sense or send signals;	• dark, low light; • chaotic/busy; environment; • moving quickly;	How does nature... • enhance visibility in low light environments? • sense movement in the dark?
MY MOBILE PHONE BATTERY DIES TOO QUICKLY.			
How might we make mobile phone batteries last longer?	• conserve energy; • capture energy; • store energy;	• limited energy availability; • limited storage capacity;	How does nature... • conserve energy? • store energy?

Let us look at one more example for you to understand this a little better. You have seen this example already. Let me look at one more problem context. This is my mobile phone battery that dies too quickly. Of course, you do need more information on this problem. I have just used this single statement as an example of this. Remember that in define we said we need to understand the problem or the opportunity fully before we start defining.

But for the purposes of this example, I have just used a single sentence. So, the design question, define question could be how might we make mobile phone batteries last longer? Directly from this, this problem statement. So, I say my define question is how might we make mobile phone batteries last longer? And what do I do with that? I will have to 'biologize' it.

And as you recall we have to remove the manmade function and manmade context from this and make it relevant to the natural world and one way of doing that would be in the function. What is the function here? So, look at the function and say making a battery last longer, so, therefore, that is conserving energy, related ones could be capturing energy, or storing energy. Remember, it is not just the direct function, it could be related functions as well.

So, conserving energy, capturing energy, and storing energy are biologically relevant functions derived from this defined question. Now you have to biologize the context as well because mobile phones and batteries are not present in the natural world, so how do we 'biologize' the context? You look at limited energy availability because you are talking about mobile phone batteries dying fast and you want to make them last longer.

So limited energy availability, and limited storage capacity. Now, these are contexts that are relevant to the natural world. And therefore, using these two how do you create a biologized question? How does nature conserve energy? How does nature store energy? Very simple taking it from here to here by biologizing. Now that we have looked at examples, we are going to urge you to practice this yourself because there is nothing like practicing it yourself to understand this better.

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So, therefore, I will be giving you an exercise to practice this. But before that, a couple of tips that I want to share with you. One tip is that you need to recognize that 'define' and 'biologize' are critical to the process and difficult to do. Sometimes, as you get started, especially when you do it the first time, you will find that you are getting stuck and you will be wondering why did I even come to this biomimicry practice.

But recognize that it will be tough in the beginning, and as you do it multiple times as you practice a few times, you will get better and better and better at it. The other thing is to take some time to frame the questions. Do not be afraid of framing multiple questions and reframing those questions and iterating through those steps because in 'biologize' you might actually come up with some new insights.

As I said, do not just look for directly relevant functions, you can look at similar functions, you can look at opposite functions as well and this may actually give you some new insights. And that is what 'biologize' is intended to do for you as well. So do not get frustrated by the process,

a part of the process is to practice it multiple times and get better at it. Refine your problem statement and define question in case you find that you are getting stuck.

If you are not able to find the function properly in your biologized step, just try it a few times and you will surely hit upon something that you can take to the subsequent steps. So that is 'biologize' for you. You have looked at a couple of examples on how to do this. And the best way to understand this better would be to practice it. Therefore, we are going to suggest that you practice it using the example that I give you right here.

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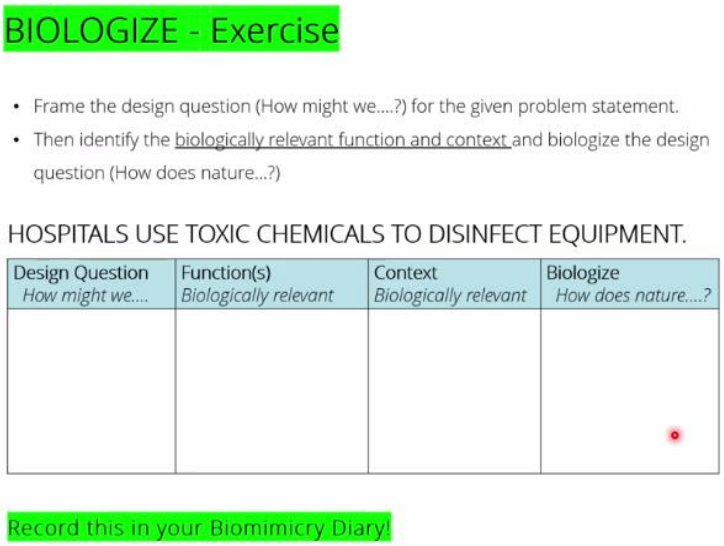

You frame the design question for the given problem statement and then identify the biologically relevant function and context and 'biologize' it. So, basically, just fill this table just like what we did before. And the problem statement that you can use is hospitals use toxic chemicals to disinfect equipment. Based on this, come up with a define question, 'biologize' the function and the context from that define question.

And write down your how does nature question based on that. And do not forget to record this in your biomimicry diary because that will help you see how you progress, how you did this, and do not be afraid to do this multiple times. You can also pick up other problem statements and try to do this step, the 'biologize' step by filling up this table and seeing how you get better and better at it.