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W1L3_Biology and the City

Hello, my name is Kaustubh Rau and I'm one of the instructors for the I-Think Biology NPTEL course. Today's lecture is titled Biology and the City. You might think it's strange that we are talking about cities in a whole course on biology. What is the connection between these two? So there are two reasons why we have chosen to follow up the first lecture, which is called What is Living with the second one, which is about cities. The first reason is a very practical one. The world is urbanizing and over 50% of the world now lives in some kind of urban area.

And India is following this trend where over 50% of India's population will live in an urban area by 2030. India also will have seven megacities, which means their population will exceed 10 million people by the end of the decade. So how do we plan for such a large mass of humanity to live in a very concentrated area and how do we give them access to things like clean air, clean water, good housing, and good roads? And the other thing to consider is now for the first time in human history, the majority of humans will, their first contact with nature will be in a city.

So how do we plan our cities so that they have enough natural spaces in the form of parks or lakes or other kinds of spaces so that humans can develop a deep connection with nature really that is the bedrock upon which all life exists and it is very important that all humans understand this. The second reason for this lecture is that we think there are certain concepts in biology that can be applied to other subjects and that will help illuminate our understanding of those subjects. Cities are one such subject to which we can apply certain topics or concepts from biology. So let's talk about those now. But before that, let us look at certain views of Indian cities.

So this is the city of Mumbai and you see in the foreground a dense mass of humanity who are living in informal settlements or slums and in the background you see all these high rises. So there are people with very different socioeconomic conditions living in proximity to each other. And you don't see a lot of green space in this image. This second picture is from the city of Hyderabad and it shows a road in Hyderabad. A road in Indian cities is not just for the conveyance of goods and people from one point to another but it can serve many other purposes.

For instance, here you see a large number of people walking on the road so people always don't have access to motorized transport and b, there are a number of shops lining the road so people as they are walking along, they are conducting business with these shopkeepers in a way that kind of enhances and is convenient for both parties. Here is the third Indian city. This is the city of Bangalore and this is from one of the smaller areas in the city where in a narrow street you see these two mature trees. So even though people have very small areas in which to live, they have managed to keep these trees, nurture them, and allow them to grow, indicating that people do feel a connection to nature and exhibit in different ways. Here is a more conventional view of nature in the city.

So this is again from Bangalore and this is a picture of one of Bangalore's many lakes. Many cities in India have such large water bodies. So the question is how do we preserve these water bodies, how do we make sure that they have clean water, a, can people have access to these spaces so that they are in contact with nature, and b, can these water bodies also serve a purpose in terms of the drinking water supply for the city or they can be flood protection areas for the city by soaking up rainfall when it rains densely in the city. Here is a more quantitative view of urbanization in India. So shown here is a time series going from 1950 to its projection in 2025 and it shows the growth of Indian cities and the size of these red dots refers to the population of the city. So if you look at 1950, we only have five Indian cities that have a population that exceeds one million and interestingly if you see at that point in time, Calcutta was the largest city in India.

But then over time if you see the population growth, you can see that Bombay grows in size and you will see that by 2025 it is expected that the population of the greater Mumbai area will be much larger than that of Calcutta. So cities also in some sense have a life of their own. There is kind of the birth of a city and its growth phase and cities in some ways can also die or see no growth. There are a few other things to notice about these maps. One is that you see really the explosion in the number of cities with over one million population and say by 2000 there are many more and by 2025 there are expected to be, I mean I haven't counted them, there must be over close to 30 of these cities within India.

There are other interesting features like the city of Bangalore didn't really show up in 1950 but it had a very strong presence by 2000 and by 2025 it will probably be bigger than Chennai in terms of population. So a very large urbanization trend will be seen in India in the next few decades. And if you juxtapose that with some of the natural areas in India, so shown here in blue are the Western Ghats which extend from Gujarat all the way to the tip of the peninsula and they actually extend, I mean the same ecosystems extend into Sri Lanka so that's also shown in blue. So the Western Ghats are of course a biodiversity hotspot. They've been designated one of the top ten such hotspots in the world and so they have a tremendous biodiversity and a very large

degree of endemism which means plants and animals which aren't found anywhere else.

So one is that we need to preserve this biodiversity and we need to make sure that all the species living there are not threatened or don't go extinct. So how do we do that? The second is that preserving the Western Ghats is very much, I mean our lives actually depend on the Western Ghats because all the major rivers in South India originate in the Western Ghats whether it's the Krishna, the Godavari, or the Cauvery. So if you look at the city of Bangalore, it gets its water supply from the Cauvery which originates in the forests and mountains of Coorg. So actually, Bangaloreans should be worried about the mountains of Coorg and Wayanad because a lot of the tributaries of the Cauvery also originate in Wayanad and we need to preserve those places so that the rivers get enough water and that water flows so that Bangaloreans and other people have access to it. So it is also very much within our interest to preserve these natural areas.

There's one more interesting feature about this image and those are the dots which are outside these rectangles which means they are outside what we would consider the Indian national boundary. So you can see here a city in Pakistan and over here you can see a city in Bangladesh. And these cities have also grown. I mean they have probably grown at the same pace that cities in India have. A question to ask is if these are cities that have the same kind of climate compared to other cities in India or if they have the same kind of habitat or ecosystems compared to cities in India, can we kind of expand our thinking and think of a kind of regional landscape in which this urbanization exists? They also face the same kinds of problems that cities in India face, things as water shortages or air pollution.

So can we think of common ways of dealing with these problems and maybe there are certain solutions from within India that could be applied to those cities and vice versa? So let me now come to the second reason why we decided to have this lecture which is the connection of biology to cities and using concepts from biology to think of the cities. So the first such concept is called urban metabolism. Urban metabolism treats the city as an organism, very much like an organism that eats, reproduces, or grows and excretes. And surprisingly this concept is quite old and it was actually applied in the 19th century.

And Karl Marx is one of the first people to have written about this where he spoke about the connection between human beings and the natural environment and here he explicitly called it metabolism. And he was referring to things like plant nutrient cycles or soil fertility and their effect on things like the economy. And actually, Engels has also written about when he was concerned about the effects of pollution in the city of Manchester. So this concept started sometime in the 19th century but it was only applied in a serious way post-1960s. So here's a question to motivate our thinking.

So first do you actually agree that a city can be considered a living organism? And to justify

your decision can you base it on certain facts so whether you agree or disagree? So we are going to try and do that exercise now. So in this table, I have shown columns for a cell or an organism and a city and there are certain categories on the left-hand side. So let's take the first category of form. So we all know that cells or organisms develop according to a defined form right? So they have a defined form and they very much grow according to a developmental program. And this applies to all organisms, right? Even an organism where you think the form is not defined say like an amoeba right? We tend to think of an amoeba as kind of having this diffused border.

But even an amoeba develops according to a specific program where genes or gene circuits decide how certain things are turned on and off and when certain organelles develop and some others don't right? So can we say the same thing about cities? Do cities develop according to a defined form? And we very much have to say in India that it is quite unplanned right? So cities don't develop according to a defined form. Of course, we have certain cities in India say Chandigarh or Auroville right? Which are planned cities yeah? The blueprint of the city has been decided and it has developed according to that. The second category is that of inputs. So the inputs are of three kinds. You have energy, water, and materials.

So what kind of energy does a cell use? And so that depends on the kind of cell it is. You know it could be an autotroph or it could be a heterotroph right? So it very much I mean ultimately all energy flows from the sun and then organisms make use of that in one form or the other. So you have the whole what you could say is a trophic cascade right? Where energy flows from one level to the next. And so what happens within the city? I mean you could say even in a city the sun is the ultimate source of energy. But more proximately we make use of fossil fuels within the city, right? And that energy used is heavily dominated by one species which is humans.

And then other species kind of make use of available resources to fuel their growth. So this could be in the form of food that we put out or garbage or sewage which could serve as an energy source for various kinds of organisms. So water again, a cellular organism will make use of water in all its natural forms. So whether you are an aquatic animal or you live in the desert, you are heavily dependent on the natural form of water. Whereas here in a city what we do is tap water right? So we either make use of groundwater or we can make use of the shallow aquifer.

And in many cases or in most cases we actually tap water directly from flowing water like rivers right? So all organisms make use of materials whether it's, I mean mostly it's for their homes but sometimes might be for other purposes. But all materials tend to be locally available. They're all biodegradable. I mean we can think of large-scale engineering of materials which things like termites do when they build their mounds right? But they make use of local materials. Sorry, just correcting my spelling.

What materials does a city use? These are materials that are not found usually within the city so we make use of steel, concrete, and plastic which have to be brought into the city, and in 99% of the cases, it's not biodegradable. So wood could be also a material that we make use of within the city. And so waste outputs, so they're all recycled. Typically I mean all waste is biodegradable or a cell or an organism. And many times what seems to happen is that waste for one organism could be a resource for another.

I mean for things like particularly in a microbiome of some kind so whether it's a soil microbiome there are different species of bacteria and RK and fungi living in proximity to each other and they work in this fashion output so the waste of a city, can take various forms so it can be sewage or it can be construction debris. It can be plastic or garbage. And typically this is not recycled in any major way in the city. Regulation so we know one very standard way of regulating which is called homeostasis.

This is a way for a body to maintain its equilibrium whether it's pH, blood pressure, heartbeat, kidney function, or things like that. So the body tries to maintain an equilibrium or as it's known homeostasis. So does the city also have some kind of regulation? And so who do we think about when we think about does the city have a regulator? So the regulator will be the city government. And so how do they regulate the growth of a city in that sense? So here if you look at this table it gives us one way to think about the city and very important ways in which cells and cities either look like each other or differ from each other and mostly this table in this table it all differs from each other. And it's shown here urban metabolism as a concept is shown here as a schematic.

So you have a city where you have inputs that can be food, energy, or goods and you have outputs. So emissions or inorganic wastes. And you can actually do this kind of analysis for a particular city. So shown here is an urban metabolism study done for the city of Mumbai and I'm not going to go through this whole image but we can just look at the water input. So the water input is about 1680 million kilolitres of water is used by the city of Mumbai and what is the output? It's sewage.

So it's 1350 million kilolitres. So almost 80% of the water which comes into Mumbai flows out as sewage. And so that's a huge problem because most of it flows out into the creeks and estuaries and mangroves of the greater Bombay area and an incredibly delicate and biodiverse environment. And so this kind of analysis allows us to kind of clarify that image that we have of a city and say can we think about bending some of these metabolic pathways so that they're circular? So instead of having these linear pathways can we have circular pathways which is what organisms seem to do? If you look at for instance we have many such cycles within our bodies such as the Krebs cycle for instance. So can we think about recycling and reusing this water so that there is less fresh water coming into the city? And this kind of analysis has been

done for other cities around the world and actually one can think about doing this for the city in which you live right now.

We can even think about doing it for smaller areas if you live in an apartment community you could do an urban metabolism analysis for your own apartment community where you look at the inputs and the outputs. Here's another way to think about cities. And so this is another concept we are taking from biology and that's the concept of ecosystems. And there is a whole field within biology which is called urban ecology and they look at a city as a valid ecosystem and they say that we can study processes that are there in natural ecosystems. In the same way, you can study processes within an urban ecosystem.

And so an ecosystem can be defined by three different components. The first component is the abiotic and biotic components, then what is the energy flow and three what are the nutrient cycles within a city. So what I thought we could do is we could look at this concept of the urban ecosystem by using a case study and we've chosen the city of Surat. And Surat is interesting in many ways because it's one of the fastest-growing cities in India right now. And so on this map, you can see the Surat has grown around the river Taapi which is shown in green here and it has this kind of characteristic bend that you can see here.

All the pale areas are the city of Surat which has grown around this river. And then the river kind of empties into a delta over here where there are mangrove systems in that delta. Here's a picture of Surat as it looks today. So you have the river Taapi in the foreground here and you have a bridge crossing the river and then you see this urbanization, dense urbanization in the background. And you can see this kind of image for pretty much any city within India today.

So now can we use some of the concepts of an urban ecosystem and apply them to a city? So if you look at some of the abiotic components of Surat, it has over 300 days of sunshine, and its yearly rainfall is shown here at about 1200 millimeters. The thing to note here is actually that Surat has a very flat landscape. So it is almost at sea level. And it has suffered three major floods since 1994.

So that's one thing to consider. Biotic, there is one species that will dominate within the city, that's humans. And actually, by the 2021 census, the city population has grown, it's 7.5 million. So it's grown a lot within a decade. And apart from humans, what are the kinds of creatures you will find there? So these would be typical of what you will see in urban areas.

And because you have this river and estuary, then you also have many aquatic and amphibian species because the salt water from the sea can enter this delta and that leads to a very interesting habitat. So you can see many kinds of, different kinds of fauna within these deltas. The other thing to ask is about the flora. So in one study done, Surat had very little green space, a study

across Indian cities, and it had only 0.5 m^2 of green space per person. And the WHO advisory is that in a city you need to have at least, every person needs to have access to at least 9 meters square of green space. And actually, only one city in India currently meets that requirement, which is Bhopal. So the city in this sense needs to do a lot more. So energy flow, you will have the standard kind of food webs, terrestrial and aquatic food webs in this case. But the main thing to note is that humans drive these food webs because they make energy-rich food available to certain species in the form of sewage or garbage.

And the problem is about also the sewage kind of flowing into the river. So the city is trying to take cognizance of this fact. For instance, they are constructing a biodiversity park. Along the banks of the river, I think it's about 68 hectares. And they're also trying to deal with the sewage and garbage by building better systems, say like sewage treatment plants or waste segregation.

So certain threatened species which are sometimes seen within the city like flamingos are not affected. Nutrient cycling not much is available, but we can look at just one, which is the carbon cycle and that will be perturbed. And that's mainly due to human activity in the form of fossil fuel emissions. One calculation given by the city government was that the per capita fossil fuel carbon dioxide emissions were about 4.46 tons in Surat. So this is quite large if you consider the all-India number. So all India's per capita emissions will be around 2 tons. But this is across India. But typically in urban areas, this number will be a lot higher.

And this is what you see in Surat. So what again the city government is saying is that they're planning a rapid transit system and much more public investment in much more public transport to bring down these fossil fuel emissions that come from transport. And finally, in looking at an urban ecosystem, we cannot ignore the socio-economic context. So typically now we call them socio-ecological systems rather than just ecological systems. For instance, the reason why Surat is growing so rapidly is because it's a hub for many kinds of industries.

And there's also a very large chemical industrial belt. So it is expected that migration into the city will continue for the foreseeable future. So then how do you plan for the growth of the city so that human beings, their well-being is looked after and then the well-being of all the other organisms which are living in close proximity, whether within the city or just outside the city in these mangroves or these deltas. So again, through the lens of biology, we can look at a city in this fashion and enhance our understanding. And we can do this kind of analysis for any city in India. Or again, as I said, we can even do this analysis for smaller areas like neighborhoods or say your apartment complex where you live.

And I urge you to do that. Finally, I'm going to leave you with one more analogy of the city. And that is not such a nice analogy and that is of a city as a cancer. So shown here on this map is the national capital region, consisting of Delhi and other cities like Gurgaon, and Ghaziabad.

And you can follow the change in the kind of land use within the NCR from 2001 to 2017. And so the different regions, the color codes refer to different kinds of land use within this region.

And so the main thing to look at in this image is that you have to follow the red, which refers to urbanization of built-up land. And so you can see this tremendous increase in the amount of red from 2001 to 2017. And so people have said that cities are like cancer. So in the way that a cancer tumor sequesters resources so that it can grow faster, in many cases it also remodels our blood supply, right? So that it increases the amount of blood flowing to the tumor. In the same ways, a city also sequesters resources from around itself and that allows it to grow.

But is the growth sustainable in any fashion? Or is it actually like a cancer that is growing on the land? And people have actually modeled this process, the process of the growth rate of cancer to the growth rate of a city. They have seen that in many cases, the growth rate of a city can equal that of a tumor or in some cases, it can even exceed it. So that's another way for you to think about a city and try and see whether we can do something to change it. So in this lecture, we looked at three ways of looking at a city. One is that of urban metabolism, where we treat the city as an organism that eats, grows, and excretes and tries to see if we can, just like in a metabolic pathway, also have a circular metabolic pathway within the city.

The second way is that of an urban ecosystem, where just as you look at a natural ecosystem with abiotic and biotic components, energy flow, and nutrient cycling, you ask what happens to these three categories within the city. The third is more one could think of it as a metaphor that helps us to understand, but we shouldn't carry that analogy too far. But that's of a city as a cancer. So using biology, we can look at a city with these three lenses and see if it enhances our understanding of these places where most of humanity is going to live. And with that, I will stop this lecture and we can pick up this conversation later during the tutorial. Thank you.