THE UNIVERSITY OF MELBOURNE
Published on *Up Close* (http://www.upclose.unimelb.edu.au)

Episode 33: Mathematics of Biology

Mathematics of Biology

VOICEOVER
Welcome to Melbourne University Up Close, a fortnightly podcast of research, personalities, and cultural offerings of the University of Melbourne, Australia. Up Close is available on the web at upclose.unimelb.edu.au. That?s upclose.u-n-i-m-e-l-b.edu.au.

SHANE HUNTINGTON
Hello and welcome to Up Close, coming to you from Melbourne University, Australia. I?m Dr Shane Huntington and today?s topic is biological mathematics. Mathematics is potentially the most cross-disciplinary research field that exists ? whether we are dealing with architecture, biology, economics or agriculture, mathematics has an exceptional role to play. As the complexity of our technological world increases mathematics is finding new and critical areas of application. A truly cross-disciplinary scientist is Professor Kerry Landman, from the Department of Mathematics and Statistics in the Faculty of Science, University of Melbourne, Australia. It is my pleasure to welcome Kerry to Up Close today.

KERRY LANDMAN
Thank you, Shane.

SHANE HUNTINGTON
When you talk about mathematics, I guess, people have an image of what a mathematician does, and I guess that these days, may be predominantly coming from films like A Beautiful Mind or Numbers, these types of programs. But day to day, what is involved in a mathematician?s job?

KERRY LANDMAN
The type of mathematics you do means that you interact with different sorts of people, or you might interact with a smaller group of people ? only people who do the sort of mathematics that you do. I do applied mathematics. And I do mathematical modeling, so a lot of the problems I work on, are problems which are of interest to people in different disciplines. But if you are a pure mathematician and are interested in say, the four colour map, often times they are old problems which are unsolved and they?re challenges to pure mathematicians.

SHANE HUNTINGTON
I see you laughing, are these problems that applied mathematicians deem not necessary to resolve at this point or ? ?

KERRY LANDMAN
No, I think it takes a different sort of mind. And a different sort of motivation to do those sort of problems. They?re not the sort of problems that I have been interested in. I like interacting with people from other fields and I like working on questions that they want to answer. So, I like to collaborate and I like my work to be used in different fields. I am not challenged by pure mathematics, just pure questions which only relate to mathematics. I am stimulated by how mathematics can be used in the wider community.

SHANE HUNTINGTON
And presumably, there are a certain range of problems from which similar mathematics or similar sets of equations are used for quite a large range of problems, is that true in your experience?

KERRY LANDMAN
Yeah, that is certainly my experience, because I work mostly with transport of material. So, in the engineering context in which I worked for many years, it would be like heat transfer or how do solid particles in a suspension move? All of those are transport of material, and you use what are called ?conservation equations?. You describe conservation of mass, if you like, or force balance, so it is essentially Newton?s law, force is mass times acceleration. And those things can be transferred to a wide variety of contexts and now I am applying them to biological areas.

SHANE HUNTINGTON
Kerry, let?s get, to the, I guess, the topic of today, which is biological mathematics, or mathematical biology, or bio-maths, there is a few ways to say it, how are mathematicians used in biology? Where does the link come from?

KERRY LANDMAN
Well, in a variety of ways. I was going to talk about the non-statistical areas which are sort of the areas which people know about or think that mathematics is used when you analyse data. So, the large area that I?ve been involved with, started about 30 years ago, was trying to understand for example, cancer growth. So, some of the early models where mathematics was used, is trying to understand the structure of a cancer. So, for example, you start off with a few cancerous cells, and say they are a sphere, all of those cells divide, and the whole thing starts to grow, but after a certain amount of time, it gets to a stage where there are cells on the inside which are no longer dividing, they?re alive but they don?t all divide, and the ones on the rim are still dividing. And so the whole thing still continues to grow. But at a certain stage you find that the inner core actually dies. There is still a ring of quiescent cells ? they?re alive but not proliferating ? and the final ring is a proliferative ring of cells, but the whole sphere has come to a steady state. And so, for example, the cancer researchers were interested, ?well, why is this happening??

And this started a whole group of mathematicians working on these sorts of problems because ? it is still a very current project in applied maths ? so, trying to understand, essentially, diffusion or nutrient limited, so, the cells, in order to divide, they need oxygen or nutrients. And the nutrients have to diffuse into this sphere and if it grows too large, the nutrient level at the centre, is obviously the lowest, and it falls below a certain level and it means that the cells will respond differently ? no longer proliferate or die, depending on the level. So, this is an example of one area where mathematicians were very helpful.

SHANE HUNTINGTON
So, I guess in that sense you would need to understand the rate at which various chemicals diffuse, which would depend on the chemicals and the environment, you would have to understand how the cells were adapting and dealing with that on an individual cell basis. It sounds like a very complex equation.

KERRY LANDMAN
There are different levels of working things. Depending on the question that you?re answering, sometimes you can model things as an average or as a population level, so you?re looking at groups of cells and how they behave, rather than looking at what is actually happening with each individual cell. You?ve raised an interesting point. At what scale are you looking at biological events? Are you looking at a scale of millimeters, like the size of a tumor, or a cell, or inside a cell which is the size of a micron, 10 to the minus six meters. So, you would see different sorts of models or you would be asking different sorts of questions, and you would respond with modelling in different sorts of scales.

SHANE HUNTINGTON
Now this brings us to the heart of the work you do, there is a very strong interaction, no doubt, between yourselves and the biological community. You guys speak quite different languages. How do you manage that process?

KERRY LANDMAN
It takes a long time to learn to speak a similar language. The hardest thing in any of this collaboration is really framing the question that wants to be answered. And often times with collaborations, you meet the person, you have discussions, it might take one or two years before you work out what you want to work on. And in some ways, the most exiting part of the project, is trying to frame the questions correctly. One of my current collaborators, he gave a seminar in our department and I was extremely interested in his problem, and we talked about it for a year and a half or two years until we started to work out what did he really want. Because when the biologists talk about these problems, they talk about all the detail, and not necessarily is all the detail necessary to understand what is actually happening. So, trying to work out what levels you want to answer the questions is the part of the mathematician.

SHANE HUNTINGTON
I guess, you have a scenario, where particularly what is important to you in your field is not necessarily important to the biologist, you have different driving forces and you

have to align your goals in such a way that you somehow come out with something consistent.

KERRY LANDMAN
Very much so. Often we would start a project and we would have the question in mind that we are interested in and we?d answer that question or come up with new hypotheses for various diseases or abnormalities or come up with ideas for experiments. But at the same time they?re interesting mathematical questions, and so we would also study the mathematical questions and do the analysis, but they wouldn?t be of interest to the biologists. So, a lot of the modelling does raise some interesting theoretical questions for us as mathematicians because we are obviously interested in it at that level as well.

SHANE HUNTINGTON
And how enabling is the current computer technology, is this the sort of thing you couldn?t do 20 years ago, this sort of modeling, or is it quite robust and independent of the computer speeds we have access to?

KERRY LANDMAN
The work that is currently being done, there is a lot of work now trying to match, really, at the same level where the experiments are at. So there is a lot of experimental work now which is tracking individual cells, so if you have a large population of cells and want to know how every cell is moving or how they divide, then you have to do large computations. And those things are much easier now on larger computers.

SHANE HUNTINGTON
You?re listening to Melbourne University Up Close. I?m Dr Shane Huntington and we?re speaking with Prof Kerry Landman about biological mathematics. Now the last issue that I want to mention, that you have been working on, which is a very serious one, is in the area of tissue engineering what is the role of mathematics there?

KERRY LANDMAN
Well, in tissue engineering, the idea is to be able to make a new organ or to make a tissue which you can implant in an organ or to have a tissue re-grow in the human body so that there is no rejection. So, I think one of the things that mathematicians will be useful for, is to try and help design the best way to seed cells into a scaffold. So, if you seed them a certain way, you want to know how their numbers will increase because you don?t put the whole tissue there, you put a little piece of tissue and you want it to grow and fill this whole scaffold. So the idea would be, how can you optimise, for example, the seeding, of those scaffolds, or how do you design a better scaffold in order to maximise the amount of tissue you have after a certain period of time. The geometry of the problem is very complex. So, at this stage the modelling is on, you have to abstract it to be simpler.

SHANE HUNTINGTON
Right. And there is some very interesting work all over the world, happening in this

field at the moment.

KERRY LANDMAN
Very much so.

SHANE HUNTINGTON
It is a hot topic.

KERRY LANDMAN
Very hot topic. And a lot of people are doing things in vitro, in the lab, on simpler surfaces because in order to something in a very complicated geometry of a scaffold in three dimensions you need to understand how cells can migrate, proliferate, even just on two dimension surfaces, so, a lot of the mathematics and the experiments at this stage are, ?how do you make sure that the cells stick or adhere to the surface and how can you predict how they are going to move??

SHANE HUNTINGTON
Now, Kerry, I guess, what is next on the horizon in mathematics? What big questions are being asked at the moment worldwide in maths? I think of yourself as, sort of, the Point A to Point B woman, a lot of your work involves transition of objects from point one to point two, and so forth. What are the big, burning questions in maths worldwide?

KERRY LANDMAN
Let me talk about mathematical biology for the moment. I think one of the major challenges in mathematical biology is going back to this scales issue, is trying to understand how to integrate at the population level to the cell level, to the intra-cell level and how to model all those three levels. How do you integrate them? And how do you put the feedback between each of those levels? And those challenges in mathematical biology are very similar to challenges in other areas, like in granular media. So, if you?re talking about granular media you have lots of particles, and again, the same idea is that you?re looking at a large group of particles, if you have a hopper with wheat or something or you?re looking at individual wheat grains, how do they interact together. And again, you have questions of scale. And I think that is one of the major challenges. And similarly, trying to work with biologists, the techniques that the biologists are now using are much more detailed than the ones they used before. They can look inside a cell and they understand information about genes and they can understand how to track individual cells with time, and what we would like to understand is how can we take their data and understand what that is telling us and how do we build mathematical models around those sorts of things.

SHANE HUNTINGTON
And I guess a big part of that is, the fact that, in a sense that the biologists at the moment, are almost in a data overload mode and dealing with that data is something that they need your optimisation to help them with.

KERRY LANDMAN

Exactly right. They collect a lot of data, but you don?t know which data is going to tell you anything. So even if you collect that data, how do you assimilate it all together and try and work out what it tells you about mechanisms. I think that is a major challenge for mathematicians and also for biologists.

SHANE HUNTINGTON
Prof Kerry Landman, from the Department of Mathematics and Statistics, I congratulate you on applying your maths in so many different areas and thank you for being our guest on Up Close today.

KERRY LANDMAN
Thank you, Shane, for inviting me.

SHANE HUNTINGTON
Melbourne University Up Close is brought to you by the Marketing and Communications Division in association with Asia Institute of the University of Melbourne, Australia. Our producers for this episode were Kelvin Param and Eric van Bemmel. Audio recording by Craig McArthur. Theme music performed by Sergio Ercole. Melbourne University Up Close is created by Eric van Bemmel and Kelvin Param. Relevant links, a full transcript and more info on this episode can be found on our website at upclose.unimelb.edu.au. We also invite you to leave your comments and feedback on this or any episode of Up Close, simply click on the ?add new comment? link at the bottom of the episode page. I?m Dr Shane Huntington and until next time, goodbye.
