Glycans : A new way to understand Aging and how to address it Transcript

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Introduction to the Anti-Aging Summit and Dr. Locke

Hi everyone. I'm Doctor Sanjeev Goyal and you'll be listening to the advanced Anti-Aging and Technology Summit. Today I'll be interviewing Doctor Gordon Locke.

Gordon Locke is a professor of biochemistry and molecular biology at the University of Zagreb. Director of the National Science Center of Scientific Excellence and Personalized Health Care.

Honorary professor at the University of Edinburgh and the King's College London. And member of the John Hopkins Society of Scholars. In 2017 he initiated the launch of the Human Glycogen Project and is one of its two co-directors.

His research team is pioneering high throughput Glycolic analysis and an application of glycan biomarkers in the field of precision medicine by by combining glycolic data with extensive genetic, epigenetic, biochemical and physiological data in a systems biology approach.

They are trying to understand the role of glycans in normal physiology and disease. Professor Logue has collected over 200 research articles that are cited over 5000 times in 2007.

He founded Genos, a biotech company that is currently a global leader in high throughput light comix research, and Gino's letter led to the development of the glycogen test of biological age.

I hope you enjoyed today's talk with Doctor Locke. Okay. Welcome, Doctor Gordon. Love. I really appreciate your time.

Why Glycans Matter in Biology and Medicine

Today, to talk about this whole new, you know, whole new field of, glycan comics. I'm not sure what the word is, but, thank you, thank you, thank you for taking the time all the way from Zagreb.

So thank you for the invitation. It's a pleasure to join you and talk about glycans, because, yes, I think glycans are something which is very important.

I work in the field for nearly 30 years now, so I'm kind of a dinosaur of the field, but unfortunately not so many people know about it because it's not being, the, presented in, high schools, not even at university level.

Very few physicians have heard about glycans and practically every protein which has been invented after we became multicellular organisms is glycosylated.

And glycans play an important role in many physiological processes. Practically, virtually everything which is above the level of a single cell involves some part of the glycans.

So, we have to learn more about them, and we have to start using this knowledge. Right. So maybe to take us back, how did you even get come up across this whole field like 30 years ago?

Like, how did you decide this was. This was an interesting thing and had such a huge impact. But it was a kind of serendipity then, because, at one point there was the novel kit to look for glycans and my boss at the time was interested for novel things.

He said, let's try this. We tried that and it was interesting. And I'm a stubborn guy. And I continued going to the direction because we were learning more and more and more, and it's becoming more and more interesting.

And so far we have analyzed over 150,000 different people from different clinical cohorts, genetic cohorts. And we are learning the glycans actually are big part of inter individual variations.

So, for example, blood groups are glycans. If you think about the A, B and O blood groups, chemically they're like us. But there are thousands and hundreds of thousands different glycoproteins which all make us different.

How Glycan Research Began and Why It Matters

And this is what is very important in this field called, precision medicine, where we are trying to identify differences between people and see why are people different and why each of us would respond differently to the same food, same type of exercise, same drug.

But people respond differently because they're different. That molecular level. And one of these differences are glycans. You're seeing the biggest inter individual variation is due to glycans.

Is that right? Yes. The huge part of individual variation are glycans. And these are these all but they haven't all been mapped out. I mean, it sounds like you're saying the 250,000 different glycans.

No, it's, it's even more complicated. So the, the individual glycan blocks are not so complicated. There are a couple of thousand of them, but they get combined in a many different ways.

And for example, immunoglobulin antibodies, which have a single polypeptide chain, can come in over 900 different glycol forms having different glycans attached to it.

And each of them is a little bit different. So it is immense complexity. It's several orders of magnitude more complicated than the genes and the proteins.

And this is actually what enabled the life of this planet to be so diverse and so complex as it currently is. Oh my God, you just I think you just blew my mind.

You're saying that this is a big. It's like the ocean. Like we just discover a whole new field of, metabolic medicine or something. Oh, something like a decade ago, I think I wrote the paper with the title that Epigenetic Regulation of glycosylation is the Quantum Mechanics of Biology.

So it's it's another layer of complexity because there are two things. First, the structural diversity. So glycans have many different structures. And the second one is, genetic complexity because normally each protein is being coded by a single gene.

So you inherit the gene to have a specific protein. But for glycans, they're encoded in a network of dozens or even hundreds of genes. So you have, a network defining a chemical structure which is being inherited as a complex trait.

But too many genes. So it's it's yes, it's entire ocean, entire universe of complexity, which are actually like us. And we are just learning a tiny little bits of it.

We, for example, one of the proteins which has been studied a lot are immunoglobulins. So we know a lot about how antibodies get glycosylated, what these, glycans do, how do they make them different.

And, you know that now many drugs are although smart drugs, many of the smart drugs are immunoglobulins. So out antibodies are drugs. And now their next generation of these drugs which are being like engineered.

So you put a different glycan and then you have a drug which is for example 100 times more effective than the original one. And the only difference is a tiny little, like an ad at the end of the structure.

And then you have 100 times more potent drug. So it's a whole new field. As you mentioned, whole ocean.

Glycans, Precision Medicine, and Biological Complexity

So that's so interesting. So let's take a step one before we get into the, into the immunoglobulins. That so hemoglobin A1 C is this. So this is a glycosylated hemoglobin.

Is that right. And so is that a type of glycan marker. Is that a type of glycan. This this is a common confusion. So chemically it is glycosylated because it does have a glycan which is chemically bound to a protein.

But the we call it glycated non glycosylated just to make a difference. And this process of glycation is a random chemical reaction between glucose, which is an aldehyde, and amino groups and a protein.

So it's a kind of, random. It's a chemical reaction which happens when the glucose is elevated. So people with diabetes would have a higher level of HbA one C.

And this, this biomarker is used to measure the the burden of glucose. So people who have high glucose will have more HB one C. But this is something biologically very different because glycated hemoglobin.

This is an error which happens when the glucose is high. Glycosylation is the enzymatic process regulated by hundreds of enzymes. Many transcription factors where the structure is designed by evolution.

So evolution decided which glycan structure to have on a specific site because it will have a biological function. So these two things are actually very different.

Biologically, functionally although strictly chemically, yes. Glycated hemoglobin is a glucose attached to to hemoglobin. While the glycans I'm talking about are oligosaccharides with 10 to 15 different monosaccharides in the different spatial distribution.

And they actually represent part of the molecule which does the work. Wow. Okay. So then so I understand. So this, this thing about the the biomarker for aging, let's, let's move on to that.

It looks like it's, it's a glycan looking at the glycans attached to an immunoglobulin G. Is that correct? Yes. So so how can you tell me a little bit about.

Yeah. So we are interested to learn how people are different in a way they glycosylated proteins. And what are the functional consequences. And we studied many large cohorts, as I said, over 150,000 people so far.

And what we learned is one of the first finding was the glycans change a lot with age. So when people are young, their immunoglobulins have one type of structures which is relatively large, has the galactose and sell it at the end.

Well, as we are getting older, these structures are becoming a little bit smaller. They're missing some of these sugars at the end. But this is not just kind of wear and tear of glycosylation, but it's a reflection of, changes with happened with aging.

And the main one of the main changes is increasing inflammation. Because we are young, we are keeping our inflammation controlled.

HbA1c vs Glycosylation and the Aging Biomarker

Although actually it's not completely true because when we are kids, inflammation can also explode. But after puberty and in our early 20s and 30s, we keep our inflammation controlled.

And one of the elements which suppress inflammation are these glycans. Globulins. So these lichens are actively suppressing inflammation. And we I think the best example of this is if there is a therapy called IVIg, intravenous immunoglobulins, which is being used in some clinical situations.

If you give immunoglobulins from a young person to an older person, you have a systemic suppression of inflammation. And this systemic suppression of this low grade chronic inflammation is resulting in the phenomenon that these older people have a lot of energy, they feel much younger, they feel much better because they're not wasting all the energy they have on this low grade, chronic inflammation.

And when we are young, this is happening naturally. So our only when the globulins are suppressing inflammation. As we are getting older, these old glycans are activating some of the molecular mechanisms which lead to inflammation.

So they're actually promoting inflammation. And by promoting inflammation. And we are talking about the low grade chronic inflammation a little bit of information everywhere.

And inflammation is a kind of like a reset button on a different location than a body. Or just like you are resetting your computer to just shut everything down and build it again, the same thing inflammation does that goes on a specific location.

Neutrophils kill everything and then everything is being rebuilt, which is extremely expensive. So we are spending huge amount of our biological energy on this low grade chronic inflammation.

And animal globulins in all people are actually promoting this inflammation. And the second thing we learned is that this change from young, kind of healthy glycans to old inflammation promoting glycans is not exactly following the trajectory of chronological age.

Some people move much faster into this old glycans, while some people go slowly. And this difference between glycan age and the chronological age associated with many biomarkers of unhealthy life.

For example, if you are obese, your glycans are going much faster to towards these pro-inflammatory old glycans. If you are under too much stress, if you are developing many different conditions, this happens also.

But the interesting thing is that these glycans actually change before people become ill. For example, we have studied thousands of people with inflammatory bowel disease with tried this with different inflammatory conditions, and they all have older glycans.

So young people with rheumatoid arthritis will have glycans of a much older person. But these glycans become old before the person developed the disease.

So it is not that the disease is driving the glycans, but the glycans change first. And actually they seem to contribute to development of disease because they promote inflammation.

So the idea we have now is not to wait until people get ill, because unfortunately, modern medicine functions in a way that you go to hospital only when you are sick, when you have pain somewhere and something is not working, then you go and say, help me, cure me.

And most of the times these are chronic diseases which you cannot cure anymore.

Inflammation, Glycan Age, and Disease Risk

So people stay, they, we call them chronic because they stay forever. So people, they just go to diagnosis and then they get therapy for most of their lives.

And we hope that if you go early and you catch this biomarker changing before any other symptoms, and we know that glycans are not only biomarkers, they're effectors.

They work toward disease development. If you can fix them, if you can repair them on time, you will develop a disease much later or not at all. And this is why I don't like to talk about glycans as a biomarkers of aging.

They are biomarkers of aging. They're actually functional effectors of aging. So if if you improve your glycans, you're actually slowing down your aging.

And we did many studies where we can actually where we have seen that there are ways to improve your likeness. So by changing your lifestyle, the diet, losing extra weight, you can actually improve your glycans.

And this is what we are now trying to understand how a given person can change their angle icons. Because we are not all the same. Not everything works for everybody.

Is there a genetic, some risk factors that put people at a higher rate of glycan, aging? Like guess there, specific genes? Snips or whatever. So this is very important question.

Of course. And genetics is an important component. And glycans are heritable. And heritability is a measure how similar we are to our parents. So if something is highly heritable, it's mostly genetic.

If it is not heritable, it's mostly environmental. And glycans are on average 50% heritable and 50% environmental. But those glycans which change with age are actually even less heritable.

They're approximately 30% heritable, while 70% is environmental. So maybe between one third and one half of our glycan composition is defined by our genes.

So some people just have genes which make their glycans older. But even in them, 50% of this, variation can be altered by, lifestyle, while in other people it's even less so.

Most of it is lifestyle. So yes, genes are important, but genes are something we cannot change. And for example, there's I also, I'm a professor of molecular biology, so I also teach genetics.

And I also have a laboratory which is doing genetic analysis. And the key problem we have would be the genetic risk factors or all the genetic analysis is that you can do a test and find that somebody has twice as high risk for, diabetes.

But whatever this person does, this risk will always be twice as high because you cannot change your genes. While lichens, you can actually see the improvement.

We can also say that, okay, based on glycans you have a higher risk to develop some diseases. Although, we cannot make these claims officially because they are not approved by the FDA.

But we can say there is a research saying that these things are linked and then people can do something to change diet, try some kind of, there are many different approaches.

Maybe we can touch it later, how you can change your glycans, and then we can say, yes, you have improved. Now your risk is lower and you are way better because you probably know if there is a paper a couple of maybe a year ago showing very clearly that by having a healthy lifestyle, habits, you can add up to ten years of healthy life to our lifespan.

So living healthy gives you ten healthy years, but people don't do it. And now, if you think about it, if you know that something you do will give you extra ten years of healthy life, why don't we do it?

And we don't do it? Because the reward comes after several decades. You know, I'm not going to suffer today to get something after 20 or 30 years. The feedback is too long.

So people, small people get obese, people live unhealthy lifestyle because, you know, the the reward or the punishment is so far away that you think about it.

Lifestyle, Genetics, and Reversing Glycan Age

Well, if or now when we have this biomarker which actually tells you, you know, you are 35, but your glycans look like you are 55 already, and then people start to think and they change and they see their glycans going down, and then they are motivated to continue doing this hard thing because, you know, living healthy life is not easy.

You know, junk food is good. People like junk food because, well, it's not good. It tastes good, but it's unhealthy. Exercise is difficult. So people avoid it, but it's healthy.

And if you do something and you see that it's working, that's great. And the other problem we have is, for example, my glycan age is horrible. I'm 20 years older than I'm my chronological age.

And when I learned that a couple of years ago, actually 5 or 6 years ago, I try to, you know, kill myself in a gym. I was exercising 3 or 4 hours a day.

I lost ten kilos just by exercising and the effect was minimal because overtraining is also a bad thing. You know, the wear and tear of training too much is actually promotion information, and you have to find the right way.

How to exercise. You have to find the optimal amount of exercise, type of exercise. Even the diet is not working in the same way for everybody. We just recently did a study, published it head on over 1000 people on five different diets for a year and for each given diet, there were some people who improved and some who did not.

So there's no magic diet. There's no one diet which works for everybody. Some people cope with carbohydrates just fine. They can eat carbohydrates. Other people have horrible reaction to carbohydrates.

Some people need a high protein diet. Other can't stand it. So it's, you know, we are all different. And these glycans are a good way to see which is working for me and what is not working for me.

So, what what is the mechanism like, let's say, for, exercise to improve glycans or weight loss, like how does it actually changing this glycan moiety on damiana globulin.

Like how is that happening. So this is something what we are trying to learn now we still don't know much. So what we have done, we have done thousands of people where we also have a genetic data for them.

And then we did something which is called the Gwas genome wide association studies, where we looked for links between genes and glycans. And now we have a network of over 40 genes which regulate IG like with deletion.

And now we are dissecting these pathways to see which of them is the reacting to which. For example, we know that some inflammatory processes affect glycosylation like IL six, interleukin six, tumor necrosis factor.

These are all proteins which affect like dilation. We also learned that the sample estrogen is very important. So hormone levels also heavily affect glycosylation.

So what we are currently doing in my lab we are trying to take each of these pathways, change activity of these genes, look what will happen and then try to find a way how to prove it.

So we still don't know the exact mechanism. So the only real, really nice designed study we have for these pathways was with the estrogen, where we had a randomized, placebo controlled trial.

And we really showed that they by removing estrogen, by adding estrogen, you have this causal link between estrogen and glycosylation. For most other things we have only correlative.

We have association. So these things are associate. But we cannot guarantee what causal. And it's for example also now we are doing many studies in the Covid field.

And we see that people when they have Covid, their glycans drastically change. We're just drafting a paper on this topic. So it's so there there's a lot of research to be done.

There's still a lot of things which we don't know, but we are trying to learn by by looking by, for example, something we are really interested. There's different studies where people change something.

They start to, go in the diet, they start yoga, they start exercising zinc, they start the specific drug. For example, we have some data indicating that when people start taking metformin like us, improve.

And so it's there's a lot of research we are doing trying to understand how and why this works. For the moment, we cannot say upfront. We cannot even I haven't sold my like, an agent or like, like energy. Hi.

So, we still don't have a magic solution, but what we can do, we can, People can try something, and then we can see whether it works for them. And for majority of people, it's relatively easy because, obesity is a big driver of, this problem.

From there, I do you like them. So, you know, first thing is lose extra kilos if you improve on your weight, your glycans will improve. And this works for most people.

But they everybody.

Mechanisms, Hormones, and Intervention Studies

But for most, it works if people are, not obese and have a better glycan age, then it's more difficult. Then it's usually either psychological, too much stress and not enough sleep.

Or it could be. It could be overtraining. Some people overtrain and then get their glycans, because we have a lot of people in different gyms, the especially the trainers who actually don't look too good because they just exercise too much and they usually get very unhappy about it.

But when you think, you know, when you think about professional athletes, we consider them old in their late 30s. A professional athlete of 30 something is an old football player or whatever.

And, we still think we are young in our 50s nowadays, so it's now too much sport. It's not something which is good for your body. That's very interesting.

We had a couple other speakers talk on that exact same same thoughts. So do you think that is there any other nutraceuticals? I know you mentioned metformin, but your thoughts about, you know, you know, potentially adaptogens because these make a difference.

Could you think, make a difference on glycans? Any I, I'm just I mean, I'm extremely cautious in making any claims in this direction because we have done many studies where we have seen correlation.

And then we realize it's actually not the effect of, of a drug, but it's the fact that the specific group of people take a drug or, the moment they start taking something, they also change some other habits and then things improve.

So to be able to claim that something really works, we need a proper placebo controlled trials. For example, we have a clinic in New York where most of the patients going to the clinic are 20 to 40 years younger.

But I don't know what it is that actually works because they're taking many different supplements, hormones, many different things. So what we are doing now, we are really trying to dissect this and do the placebo controlled trials and somehow try to predict what will work in a in every specific individual.

Not not the same things will work for everybody. So it's it's still not we have a magic pill that will in on sale save all the problems. But at least we have a metrics.

We have a tool to check whether something works or not. And then it sounds like, this is like the aging of it sounds like this better. The glycan is, increases like a sign of aging of the immune system.

At least it sounds like something like that. Does that mean that something like, you know, peptides, like, you know, time is an alpha people are giving is, you know, potentially is, to improve and restore the immune system or, or this plasmapheresis or people are taking the blood out and.

Yeah, immune system extremely complicated. There are so many different branches of the immune system. So we usually say that the glycans is aging of the immune system, but not entire immune system.

There are other aspects of the immune system which are not covered. And this glycans and immunoglobulins which we measure, but definitely it is immune system.

It is part of the process called inflammation. So with as with aging we are in increasing inflammation. And then inflammation is driving aging. And it's a vicious circle.

And it's clearly not directly linked to this. The oxidative aging DNA damage. This is not what we are measuring with glycans. It is indeed the organism level at, we can call it also part of the immune aging.

Although I would not claim that entire aspect of immune aging was covered with with the glycan on immunoglobulins because now, immune system is the most intricate system which we have is keeping us alive against all these crazy pathogens that are around.

How would you compare the glycan age, with regard to, you know, compared to epigenetic, clock methylation clock, to telomere length measurements? So if we talk about epigenetics, so definitely epigenetic clock is way more accurate for the chronological age because the way Steve Horvath developed it was that he measured, epigenetic marks, these methylation sites on hundreds of thousands of sites, and then he collected 300 and something of them which predict chronological age.

Well, and actually, his original, aging clock is a kind of, not too informative because it is too accurate for the gradual age. So he now developed this, a grim aging clock and some others.

Comparing Glycans with Epigenetic Clocks and Telomeres

And there are many other epigenetic clocks now on the market. And it's, it's it's a little bit difficult to know exactly which part of information each of these tests have.

So, epigenetic tests are interesting. The my I always say, you know, for each of these tests. So each individual test, you know, every company selling a test is selling a different test.

We have to show what are they actually measuring and what is it predicting. And can it be affected by intervention which you know are healthy. And unfortunately for most of these test it was shown that actually they do not respond to beneficial interventions.

You know, people, lose weight and the methylation doesn't change that much. I think there are only 1 or 2 papers now showing effects on methylation. I know David Sinclair had some data recently where he can actually show that you can improve methylation.

So I think ventilation is essential piece of information linked to aging, but it is still information. While the glycans glycans are effectors, they're molecules which actually do the work.

So I think methylation is key. I love methylation, we work a lot on epigenetics and it is regulating many aspects of of life, but it is still just the information.

It's the data which is sitting somewhere. While glycans are molecules which, perform function, they suppress inflammation, they promote inflammation. So if you improve glycans, you know that you are suppressing inflammation.

If you change some methylation site, you still do not know what is the consequence regarding telomeres? Telomeres are very reliable marker of cell divisions of a single cell.

So on a cell level this is the basic mechanism. How you prevent a cell of dividing indefinitely. You put some kind of a timer. You can divide so many times. And you are that.

But this is on a cellular level. We as the trillions of cells have very old cells and very young cells. And when you look at the telomere length, you can get very different telomere length if you take a different part of the same person, or if there is something on going on with, with inflammation, for example, if there is, not, some kind of, mobilization of, of a new cells of the immune system, then the younger cells come in the blood line and then you get completely different data than if you do it before.

So telomeres are great for measuring individual cells. And they give you a lot of information about the individual cells you are looking at. But it's much more difficult to interpret it on the level of an organism.

So what does it mean if at the moment I have younger cells in my blood, is this because I'm younger or just something just happened and we had to make many new cells because I don't know, cells died because of some reason.

So that's very interesting. I never thought of it that way. Are you saying that when they do the leukocyte telomere length, I guess they take an average of all the cell telomere length that they tested?

And so I guess only really depends on what sample they got that day. This is the only way you can do it. So you take the blood sample and then you measure the average length of all the cells in circulation at the moment.

Because you are not looking in the individual cells, you're looking at the full of cells. So there are some studies now we just do a single cell telomere length.

And then you get, you know, 10 or 100,000 pounds per person. But it's still you know, it's an average. The factor which is affecting the telomeres the most is the composition of the cells in your in your blood.

And they change a lot depending on the inflammatory status on some other aspects. So it's as I said, it's a very good measure at the cellular level when you're looking at a specific cell, but at the level of organism, it's very hard to interpret.

And also there's very little data that you can actually change your telomere length. And then again, it's a question whether it's good or bad. Because genetically longer telomeres are a risk factor for cancer because the telomeres are the safety switch against cancer.

So without telomeres we would have cancers all the time. So if you genetically have longer telomeres you're actually at higher risk for some type of cancers.

Really. Yeah. Because telomeres is a safety switch against cancer. So there there was a paper a couple of years ago that study hundreds of thousands of people.

And yes, genetically longer telomeres, risk factors for a number of different cancers. I thought short telomeres also put you at risk of cancer, but I guess that's not true.

Short telomeres, because that's. So there are some examples also where the short telomeres a risk for some cancers, are longer for some other cancers.

It's it's complicated right. Wow. So let's come back to the IG glycans. So I understand that it's a three month window. It gives you a three month window.

What happened in the last three months like is it is it completely recycling. Our IG glycans are recycling completely.

So it's a little bit of the half life of immunoglobulins is approximately three weeks.

So when we say three months this is the the window where we usually see the effect of the intervention. So if you decide to do something now it takes some time.

Future Research and the Human Glycan Project

For example I start losing weight, I lose a few kilos in a month. And then this is affecting my glycans. And this takes another three or 4 or 5, six weeks.

So usually the first effects we see after two months, after three months, we usually see the effect of intervention. Because immunoglobulins live, half life is three weeks.

So after three weeks orthogonal globulins are gone and the new ones are being made. Is there a complete turnover of our glycans every six weeks? Like is that is that what's happening like?

So glycans do not there's no turnover of glycans. There's a turnover of human of globulins. So entire molecule gets removed and the new molecule is made.

So it is it's not. So it's a half in three weeks and then another half another three weeks. Right. Vote not just absolutely, but more or less after six weeks, there's very little of the original immunoglobulins left.

Right. Okay. If somebody has a chronic disease already and they reduce their glycans, the glycan age, have you seen from the studies any improvement in there.

And there was, there was a lot of work on rheumatoid arthritis. And there we do see that if you improve your glycans, usually your symptoms decrease. For example, since, glycans so heavily affected by hormones, for example, woman, when they got pregnant, their glycans change a lot.

And also disease usually goes into remission while very quickly after birth it goes back because the glycans go back to this pro-inflammatory stage in the disease, it also comes back.

So yes, it is possible in some cases we have this data for we don't have unfortunately we don't have a drug which can easily improve your glycans. So if there would be a drug you take a pill and your glycans improve it would be easy to do this type of studies.

Now most of our studies are just correlative. We can look what people have done, what has changed and and how would the glycans changed? Sounds good. So what did you see the next year looking like?

What are the things that you're looking at in this whole and this whole field of, glycans that you mentioned? We already analyzed 150,000 people, but these are mostly cross-sectional studies.

So we have a group of people, a and group of people B, and then we look for differences. Now we are mostly trying to focus on intervention studies. So we have several clinical trials ongoing in different part of Europe actually also putting us where people do something and then we are looking for consequences.

People start taking different drugs, people lose weight, people go and start to meditate. People get Covid, people get influenza, and we look longitudinally within a person.

So how the glycans change within the same person with time and then try to understand what is the cause and what is the consequence. The second thing we are doing, we are dissecting this glycosylation pathway and trying to identify targets, how we could try to change it.

Because ideally I would like to have a pill, take a pill, change your glycans, suppress your inflammation. But this this is decades away. This is what we are dreaming about.

Okay. That's awesome. So I think, for our viewers, where should they go to learn more? I mean, they may see the doctor. Doctor, I guess, who's perhaps knows about glycans, but not too many of those.

How do you what do you suggest? So what we are trying to do glycan h, company to build also an education site. So there is a whole science, part of the website where we are trying to communicate this really difficult chemical research to people to try to understand it, because chemically glycans are very complicated.

But if you try to translate it in, you know, you know, language, which is easier for for non-black people, there's a lot of good data there. So I think I would start there looking at what we have written already.

There's also thing called the human glycan project. One of the two directors of this project where we are coordinating activity of over 300 researchers at the moment, where we are trying to do something similar, like what the Human Genome Project was, where the people around the world work together to understand the human genome.

Now we are trying to understand the human like them. So there's also the website of the Human Glycan project, where we also try to put all this information and just look for the word glycans.

It's, it's a, it's a fancy new word which, is bringing a lot of knowledge to us. And it became very apparent in this Covid pandemic that glycans are so important because at the beginning, even the director of knowledge was blogging about this as glycoprotein without glycans.

And actually there's more glycans on this S glycoprotein than proteins. And very quickly people understand, understood that actually glycans play a very important role there.

And actually glycans are at the frontline of this eternal war between us and viruses. And we will learn a lot more about glycans because of this pandemic, because now everybody realized, wow, a virus can come and it can stop the planet.

So we have to develop the real weapons, which we need. And these are like these mRNA vaccines, the new drugs to fight our real enemy, and not just the rockets and the bombers and the thanks to fight other people.

So I think this will become more and more prominent in the future. And that like we learned about DNA with all these CSI series, they became popular in the over 20 years ago.

Then everybody learns about the DNA with time. People also learn about glycans, but it will go slowly. It will not go very quickly. Yeah, well, thank you so much.

I mean, this opened up a whole new world for me and I'm sure for the viewers. And I'm going to become, getting my glycan test. I know it's coming in the mail and I'll be testing myself out as well.

So thank you so much.