Demetri Kofinas: What's up everybody? Welcome to another episode of Hidden Forces with me, Demetri Kofinas. Today, we speak with Geoffrey West. Dr. West is a theoretic physicist whose primary interests have been in fundamental questions in physics, especially those concerning the elementary particles. They're interactions and cosmological [00:00:30] implications.

Dr. West currently serves as distinguished professor at the Santa Fe institute where he served as president from 2005 through 2009. Prior to joining SFI, he was the leader and founder of the High Energy Physics group at Los Alamos National Laboratory. He's also the author of Scale a remarkable and timely book whose substance and theory we explore today.

In this episode, we explore and uncover [00:01:00] some of the most remarkable insights coming out of the field of computational biology, an interdisciplinary cohort consisting of theoretical physicists, biologists and mathematicians all working together to create models that explain the origins, requirements and limits of life.

What do our models tell us about nature's designs for humanity? Other limits to growth? What are the universal costs associated with our cities and our lifestyles? [00:01:30] What role do we play in the universe's inexorable procession towards entropy and how much time do we have left?

As always, you can gain access to reading lists put together by me ahead of every episode by visiting the show's website at HiddenForces.io. Lastly, if you are listing to this show on iTunes or Android, make sure to subscribe. If you like the show, write us a review and if you want a sneak peek into how the sausage is made, or for special story lines told [00:02:00] through pictures and questions, like us on Facebook and follow us on Twitter and Instagram at @hiddenforcespod.

Now let’s get right to this week's conversation.

Dr. Geoffrey West, thank you so much for coming on the program.

Geoffrey West: It's a pleasure to be with you Demetri.

Demetri Kofinas: Well I'm very excited as I was just telling you. This is perhaps the most dense, exciting and when I say dense, not difficult to read, just very packed with information book I've read in years.

[00:02:30] I want to start off by really telling the audience and you what I think is so remarkable about this book. It's really the thesis that you lay out. There's this remarkable amount of self-similarity across various types of networks or systems. Our listeners are familiar with complexity. We've had Brian Arthur on the show, we've had Christopher Cole, Erick Schadt, ect. What you do and, Eric spoke a bit about this as well in his genomics and computational biology work is you bring the mathematics [00:03:00] of modeling. The way we do theoretical physics for example to biological and socio-economics systems.

What I find particular exciting and useful about your work and the work you've done is that it allows us to try and make predictions to better conceptualize life and the systems of life at larger scales and most importantly, I think it provides a really powerful foundation for understanding why we see what we see and why we have to make serious changes [00:03:30] to our expectations about growth at least as we currently measure it and what we can expect from the next 20, 40 and if we're lucky, 100 years.

It's much easier for me to understand why the planet can't support high living standards as again, as we currently conceive of them for 10 billion people when I have models and can run through the mathematics then if you just give me statistics and correlations and have me draw conclusions from that data.

[00:04:00] This is, for me, what is most powerful about your work. You're building a model of our world, of the relevant aspects of the human world as we experience it as it affects us and as we affect it. That's the value I find in your work in the way in which I conceptualize the theory but why don't you lay out for our audience how you see and what you feel the value of your work is.

Geoffrey West: Well there's many dimensions to it and one is definitely along the lines that you articulated. That [00:04:30] was in fact one of the aims of the book. One of the aims associated with that was simply to try to present to lay audience, those that are not familiar with mathematics and even this way of thinking a way of thinking about the world around them that is embedded in science, is embedded in observation and data and as you say, in conceptual and theoretic [00:05:00] frameworks that can allow one to be quantitative about the things around us and also ultimately predictive. That was one level.

Another level was to, I don't know how to put this but in a certain sense was almost a spiritual level to show the extraordinary interconnectivity between things around us that where we tend to see them as highly complex sort of random and chaotic, [00:05:30] highly diverse and to see that underlying that, an extreme complexity and diversity. Actually, if you look at it through the right lens, there's an extraordinary hidden simplicity and even beauty.

That was also part of it. Then the other part was to address ultimately some of the big questions and ultimately the big question about the sustainability [00:06:00] of life and in particular the kind of socio-economic life that we have evolved in the last 10,000 years. The sustainability of that long term on the planet as we sort of careen ahead with this kind of open growth paradigm, which by the way has been extraordinarily successful, which many of us are privileged to participate in.

The question is, can we just go on doing that [00:06:30] ad infinitum and the image that just going on like this, things are just gonna get, so to speak better and better, bigger and bigger and smarter and smarter, or is there some limit to that. Trying to understand the science underlying that, underlying why it is the way it is, why we have this extraordinary phenomenon and whether it is a sustainable.

Secondly, how does it relate to what has happened of the last [00:07:00] two to three billion years on this planet, which has been dominated by life and its multiple manifestations, which has clearly been sustainable, that's been unbelievably sustainable, even though it's evolved and adapted. The question is, can we evolve and adapt with it.

Demetri Kofinas: You've touched on a lot of things. Of course, running through what you're saying are the super linearities and we're gonna get to that. That has to do with this open ended idea. You've talked about a sort of a hidden order essentially to this system and also to the sort of spiritual [00:07:30] component, which I think kind of speaks to the intelligence of the network.

There is an interesting way in which you draw distinctions. You talk about the scale of biological systems, you talk about the scale of cities in the physical sense of their infrastructure and you talk about companies as well, as well as the socio-economics of the cities. I actually think that the two great real distinctions are between the sub-linearities and the super linearities, specifically in terms of the systems that adhere to sort of the physical [00:08:00] laws of nature.

Every system needs to adhere to those but in so far as the intelligence derives from some kind of natural intelligence of the system in biology or in sort of the physical infrastructure of cities, the way they scale versus the socio-economic super linearities. The way in which growth and wages and disease scales in societies.

I want to get into all that stuff but maybe the best way to begin is to sort of talk about this common conceptual framework. [00:08:30] How do physical systems or physical networks scale in size within the confines of the Earth's physical space? How do we think about that? Whether we're talking about bridges or whether we're talking about containers or elephants. How does that work?

Geoffrey West: Yes. The simplest kind of scaling and scale, is called Scale, the book. That is perceived as a window onto these underlying questions, all the questions you just articulated. The [00:09:00] idea is extremely simple in principle and that is just asking the question, what does happen to a system whether it's something fairly trivial like a chair or a house, a building or something highly complex like an animal or a plant, a tree or something even more complex like a city, what happens to those systems when you scale them up, if you double the size. Does everything double in size in sort.

[00:09:30] That's kind of the primitive form of the question and remarkably, in answering it, trying to answer that question leads to some rather surprising implications and some surprising science. At the simplest level, the idea of scale goes back to the origins of science. Galileo started thinking about this question and asked the question, could you have so to speak, infinitely tall trees or infinitely [00:10:00] big buildings.

What he realized was something that is very profound and forms kind of the template for future thinking about these kinds of questions and that is that the way an area of a system scales, so the area of one's body for example. The area of a building scales differently than the way its volume does. Volume scales like a length cubed, [00:10:30] up, down and sideways so to speaks. That's three dimensions and that scales like a length cubed, whereas an area is just a length times a breadth and that scales like a length squared.

If you double the size of a system, the area only increases by a factor of four whereas the volume that it contains for example, scales like a factor of eight. It scales much faster and what Galileo realized that was so profound was that the strength [00:11:00] of a beam or the strength of limb or the trunk of a tree only scales like its cross sectional area. The strength only increases slower than the weight, which is volume basically that is supported by that beam or limb.

For example, if you double the size of a building, if you doubled all the sizes in it, the strength of all the beams would increase by a factor of four [00:11:30] but the weight that those beams have to hold would increase by a factor of eight. If you kept doing that, the system would eventually collapse under its own weight.

Demetri Kofinas: That brings us to the point of gravity, which is the importance of gravity.

Geoffrey West: Yes, it's because of gravity, exactly.

Demetri Kofinas: In physical systems. There's a similar effect in terms of heat dissipation, correct?

Geoffrey West: Sure.

Demetri Kofinas: So larger animals-

Geoffrey West: Likewise.

Demetri Kofinas: ... have smaller surface areas relative to their body weight and so have a more difficult time dissipating heat, which explains why elephants have large ears, it also explains why buildings require [00:12:00] larger cooling units the larger they are relative to their size.

Geoffrey West: Exactly. There's all these very simple scaling laws, which been known for a long time and are sort of engineering and we do engineer into our various systems that we build, that we manufacture. They obey these rules and we have to be cognizant of them in order to design effective artifacts, whatever they are, whether it's, as I say, something as simple as a chair to [00:12:30] something as complex as a building or even an entire city.

Those are sort of very simple physical laws but what is interesting is when one looks at highly complex systems, rather than these simpler systems, if you look at a complex system like an organism and you were to ask for example, if I double the size of an organism, how much more food, how much more [00:13:00] energy does it need to sustain it. You might think naively, that since you doubled the size of an organism, you doubled the number of cells, you would need twice as much energy, twice as much food. That's not the case.

It turns out, this is kind of remarkable that instead of needing twice as much, you only need 75 percent as much. Every time you double the size whether from two grams to four grams or 20 kilograms to 40 kilograms, you only [00:13:30] need 75 percent more energy. There's always a 25 percent, a one quarter savings with roughly speaking of redoubling.

Demetri Kofinas: Sorry to interrupt, that's the sub-linearity. That's the economy of scale that occurs in nature.

Geoffrey West: Correct.

Demetri Kofinas: Can we also just, I just wanted to interrupt again, because I think it's difficult of the audience to visualize these metrics. Would a good way to sort of think about a sub-linear trajectory is the way that a sort of cruise missile would off of an air craft carrier and eventually [00:14:00] reach a sort of maximum altitude where it would just fly vertically, is kind of ... I think that's the way I think of the sub-linear trajectory.

Geoffrey West: Well, that is a metaphor, that could be used as a metaphor but the economy of scale is simply that the bigger you are, the less you need per cell or per volume of tissue per cubic inch of tissue for example you need to support yourself.

The same tissue in a [00:14:30] mouse requires much more food to support it than the equivalent tissue in a human being and even less in an elephant for example. That's what an economy of scales means, it means for the same amount, I need less energy or less resources in order to keep it alive.

Demetri Kofinas: So 1,000 kilograms of cells organized as an elephant are more efficient in their energy usage than 1,000 of unicellular organisms. 1, [00:15:00] 000 kilograms.

Geoffrey West: Exactly. IF you broke down all of your cells and then put them in a little dish and tried to support them, instead of requiring the 2,000 food calories a day, it would, I'm just guessing, I don't remember, I've not done the calculation and I probably should. It would require many, many thousands more of calories per day to stay alive.

By bringing them together into the coherence of [00:15:30] our own bodies, we take advantage of this extraordinary economy of scale of having a system that operates in a highly coherent, integrated fashion. The integrated whole system, at the systemic level is completely different than the sum of its individual parts. That's the statement, which many, I'm sure, many of your listeners would have heard that the whole is different than [00:16:00] the sum of its parts applies in spades. Us and for any such complex system that we have this extraordinary economy of scale.

Demetri Kofinas: What accounts for the decrease in metabolic rate as size and mass increase. What accounts for that?

Geoffrey West: That's the question. First, let me just say something else. It turns out the scaling laws for organisms not only are true across all organisms, beginning with cells all the way up through all different kinds of taxonomic groups, whether they're mammals like us [00:16:30] or fish or birds or insects or crustacea or plants and trees. They all follow the same classic rule of saving roughly 25 percent with each doublings, extraordinary economy of scale.

It is true for any physiological characteristic of an organism in terms of the ways it scales with size. If you think of something mundane like the length of your aorta, aorta is the first tube that comes out of your heart or something [00:17:00] highly complex like a lifespan or how long it takes to grow. Any characteristic of an organism that you can measure scales in a similar systematic way with something analogous to that 25 percent savings.

This is true, as I say, across all organisms. The question that it begs obviously is where in the hell do these laws come from? They're remarkable because we believe in natural selection and natural [00:17:30] selection means not only does each organism but each part of an organism, each organ, each cell type, each genome has evolved with its own individual history and from its own individual environment ecological niche. One would not have expected any simple regularity to evolved. It would expect everything to be historically contingent. These laws say no, that's not true. Well almost everything that you could measure about organisms [00:18:00] obey these very simple laws.

I does as I say beg the question where in the hell do these laws come from. The idea is the following that they arise from the physics and mathematics of the multiple networks that sustain an organism so for us-

Demetri Kofinas: On Earth.

Geoffrey West: That would mean things like our respiratory system or our circulatory system or our renal system or our neural system, [00:18:30] even our bones. All of these system have this kind of network structure and typically they're hierarchal networks, meaning that for example your circulatory system delivers blood, something that's microscopic down through the network for hierarchically down to capillaries to feed our cells at a microscopic level. That's very typical of these networks. It is the mathematics of these networks [00:19:00] and the kind of optimization that has evolved by natural selection.

For example, one might argue that the circulatory system that we all have, we here meaning all mammals, every mammal that's ever existed, all of us have is one that minimizes the amount of energy our heart has to do to pump blood through our circulatory system [00:19:30] to supply cells with oxygen and other nutrients.

We do that in order minimize in order to optimize the amount of energy we can allocate to sex and reproduction. To so called Darwinian fitness. We minimize, if you like, the mundane challenge of supporting ourselves of living in order to maximum the amount of energy we can devote to passing down our genes to future generations [00:20:00] and to the process of the evolution process of natural selection.

If you take that idea that somehow this system has been optimized, you can apply mathematical ideas, mathematical techniques and determine the whole structure of this network. How this network actually works, not just its physical structure but how the flows of oxygen and blood and other nutrients go through these systems in order to keep the entire [00:20:30] organism alive.

Out of that comes all these interesting so called quarter power scaling laws, this 25 percent. Furthermore, what it reveals is that the structure of these networks are fractal like. So called, self-similar, meaning that if you look at any individual piece of the network and cut it off, it looks like a small version of the whole.

We have this interesting sort [00:21:00] of Russian doll phenomenon that each piece at a lower level looks like the whole. That comes partly because of this optimization. These kinds of self-similar fractal life structures have one of the major properties is they optimize delivery times and the amount in which you can deliver to individual local sites like cells.

Demetri Kofinas: That's part of the allometric scaling, right?

Geoffrey West: Exactly. That's called technically allometric scaling. [00:21:30] Allometric means same.

Demetri Kofinas: Okay so let's talk about that because then I want to get into some of the more exciting stuff on the socio-economic.

Geoffrey West: Sure and by the way, just to interrupt you for a second, by having this complete theory, two things. One is it explains from fundamental principles the origins of not just the quarter power but of the economy of scale. You ubiquitous economy of scale that transcends all of biology, but it also allows [00:22:00] one then to calculate and understand many other aspects of life like growth, why the hell the systems grow. Sleep, the structure of tumors and so on, all these kinds of things. Now once one has a sort of generic theory, one can apply it to many different things.

Demetri Kofinas: It is a remarkable thing as you said, it's almost spiritual in a way that the intelligence of this network and it is remarkable. One thing that it wanted to mention with respect to the biology just because it helps me think about it. I think [00:22:30] it's also useful to imagine an animal the size of a mouse that had the physical, the relative strength and speed of an elephant, it wouldn't survive. That's sort of the core [crosstalk 00:22:39].

Geoffrey West: Correct. Often, I say in a talk, if you take an elephant and you scale it down according to these rules, of course what this says is you end up with a mouse or to put it slightly differently, if you ask the question, why aren't there tiny elephants, the answer is, actually there are tiny elephants, we call them mice.

Demetri Kofinas: [00:23:00] Right, it's a scaled down elephant. In other words, the mouse [crosstalk 00:23:03].

Geoffrey West: We are scaled versions of each other.

Demetri Kofinas: Right, exactly. Back to the allometric scaling, 'cause I do want to touch on that, there are three features of allometric scaling. One is the space filling component, the other one is invariance of terminal units and that's very important as well 'cause I want to talk about terminal units in the context of the socio-economics later because I have some interesting questions to ask you on that and then the third is the optimization, which is sort of the intelligence of the network I think.

Could you touch on those three before we move [00:23:30] onto the socio-economics?

Geoffrey West: Yes, so I've already talked a little bit about the optimization, this minimal, for example, in our circulatory system, the minimization of the amount of energy we put into pumping blood around our circulatory system. There are two other generic principles and by the way, an important aspect of these underlying principles is that they transcend design, that is that the same principles apply to us with a beating heart as say for example, apply to [00:24:00] a tree or a plant, which of course are completely different in their structures.

The other two that you've focused on are first of all, the idea of a space filling. That simply means that the network, the end points of the network, the so called terminal units, have to end up feeding all of the cells in the body for example. Every cell in the body obviously needs to be sustained. The endpoints of a circulatory system, [00:24:30] our capillaries, have to end up close enough to a cell in order to transfer oxygen from blood to cells to sustain them.

The network, in that sense, has to go everywhere within the organism and that's called space filling. In the theory, one has to put that into a mathematical language. The second major principle that transcends design is the so called invariance of the terminal units, these terminal units like capillaries or mitochondria [00:25:00] within cells or the last branch of a plant, these are pretty much the same regardless of the size of the organism. The idea there is that when a new species has evolved by natural selection, nature has not reinvented the wheel so to speak, nature does not reinvent the specific cell or the capillary, keeps those the same, it [00:25:30] builds, has these fundamental building blocks for a given design, such as us, mammals, and it builds on those to form organisms of different sizes, adapting them to the local environment.

Things like capillaries and even cells, often leaves of trees are pretty much the same. We're very well aware of that because when you think about it, except for some obvious gross exceptions, primarily, leaves are roughly speaking, the same size [00:26:00] within a factor of two or three. They don't vary enormously in size yet the plants vary from a tiny sapling to giant oaks and so on.

There's this invariance reflecting a certain parsimonious nature of natural selection. These play fundamental roles and are the building blocks themselves of the mathematical theory.

Demetri Kofinas: Alright so I think we have a good, solid foundation thinking about sort of the physicality of these networks [00:26:30] and it's also important to reiterate that these are networks, that's the commonality here when we think about a human being, or an elephant or a building, we're thinking about a network.

Geoffrey West: Yes and by the way when one thinks of oneself, if you think of yourself underneath this wonderful, beautiful smooth skin that we have, you realize that you are a bunch of networks, you are a respiratory system, a circulatory system, a neural system. Your very brain, what you think of as your very self is in fact [00:27:00] a network of neurons sending signals.

We are networks and as I say just to repeat myself, it is the physics and mathematics of those networks and their generic universal properties that are being reflected in the scaling laws and indeed in the way life behaves around us.

Demetri Kofinas: Alright so let's get to cities. There are the physical characteristics of cities, which also a scale sub-linearly. [00:27:30] I want to actually hold off on those a little bit in the of time and I want to get to the socio-economics of cities because this is where I think it's very fascinating. You've got one dynamic, which is the sub-linear component, which is the economy of scale in the city as well. The larger the city, the more efficient it is, it scales at .85 versus the economies of scale of .75, 25 percent savings for biological systems, approximately 15 percent's savings for cities. These are approximate numbers but the socio-economic scale differently, they have a convexity [00:28:00] to them.

There are increasing returns to scale for the socio-economics. Why don't you talk to us a little bit about that. Explain that for our audience.

Geoffrey West: Sure. Yeah, so let me just back off one minute, so just as we, what you find, what you discover is that despite appearances, a whale is a scaled up elephant, which is a scaled up giraffe, which is a scaled up human being, which is a scaled up mouse. To 80, 90 percent accuracy in terms [00:28:30] of anything that you can measure about them that's a physiological interest or about their life history.

It is, it turns out with cities to surprisingly that New York, despite appearances, is in terms of everything you can measure about it, roughly speaking a non-linearly scaled up Las Angeles, which is a scaled up Chicago, which is a scaled up Boise, which is a scaled up Santa Fe, for example, obeying [00:29:00] similar kinds of scaling laws just as you said in terms of its infrastructure, cities scale much like biology, that is the bigger they are, the greater the economy of scale, the less roads they need, the less gas stations, the less electrical lines and so on. But instead of 25 percent, as you say, there's a saving of 15 percent and that's true for urban systems around the globe. The ones where you can get data. That's true in the United States but it's also [00:29:30] true in Columbia, Chile, Portugal, Japan, China and so forth.

Those are sort of the, in a certain sense the less interesting part as you've emphasized. The most interesting part of a city is its socio-economic activity, us, people, interacting with each other and doing something that became new to the planet beginning when we started building cities, when we discovered cities and forming economic and social [00:30:00] communities.

What we discovered there was that any socio-economic metric, everything from the amount of disease or the number of AIDs cases or flu cases, the amount of crime, the number of patent produced therefore the innovation in the city and so on, all of those phenomena that are socio-economic scale in a way that's different than the economy of scale instead of the less per capita, [00:30:30] the bigger you are, it's the more per capita.

The bigger you are, the fancier restaurants you have per capita, the more education institutions you have per capita and as I said, the more AIDs cases per capita, the more crime per capita, the more construction per capita, the more innovation per capita, patents per capita and so on. Or, and this was very surprising, or by about 15 percent roughly speaking with every doubling of the city's size [00:31:00] and again, being true approximately everywhere around the globe where one can get data.

There was this kind of extraordinary universality to cities transcending apparent uniqueness and individuality, not that cities aren't unique and individual but that is the minority of who they are in the same way that the whale is a scaled up giraffe despite appearances in terms of the majority [00:31:30] of things that you measure about it.

There's this extraordinary phenomenon that is coming about from social interaction among people. Again, you might ask oneself, how could it be that cities in Japan scale in the same way as cities in Portugal or the cities in the United States when there wasn't a discussion as to this is how you should build cities, they just evolved organically. That's how urban system evolved and yet they've all evolved [00:32:00] in this common fashion. You ask yourself, how can that be, what was the underlying dynamic or the underlying principles and I think just a moment's thought you realize what it must be because you have to have something that's common to all cities and the most fundamental things that's common to all cities is the fact that they are for, built by, conceived by, lived in, used by human beings.

Human beings are [00:32:30] at this level of accuracy, pretty much eh same across the globe in terms of their social interactions. We're all pretty much the same whether we're Japanese, Chinese, Portuguese, Albanian or American. That's what's being reflected in these scaling laws and the fact this increase in returns to scale, this added 15 percent on socio-economic quantities, whether they're good, bad or ugly is a reflection of [00:33:00] the positive feedback that is inherent in our social interaction.

I talk to you, you talk to a friend and then he talks to someone else then they talk to me and then we sort of have this conversation going and it is that form of interaction that leads to ideas, to innovation, to wealth creation ultimately and so on. Most of those conversations are fairly trivial and mundane but they are still generating ideas, some [00:33:30] of them are extremely profound and change the world but nevertheless they all had built into them this same underlying fundamental dynamic of positive feedback leading to more the more you interact. That's what's reflected in these cities.

Demetri Kofinas: There's this powerful inverse relationship between the scale of the infrastructure of the city and the socio-economics and I think there's also, I think in some ways there's sort of a tension there. [00:34:00] Before we get into that, I want to ask you, you were talking about this, you know where it comes from, it's people. The way I sort of thought about this [crosstalk 00:34:08].

Geoffrey West: It's people and by the way networks, social networks.

Demetri Kofinas: Exactly. Networks of people, in some ways networks of the capillaries of the terminal units if the network. In other words, I want to sort of purpose something in terms of how I thought about it and I'm curious what you have to say about it, what your thoughts are. The network in my view has a sort of intelligence and there is normally in biological systems that network intelligence dominates the system [00:34:30] but it seems in the case of human beings and human networks in cites, there's something very unique happening, which is that there is the intelligence of the city, this is the way the city scales but then there is this sort of intelligences of the terminal units, which forge another network, which has a completely different scaling propensity.

There is these diametrically opposed dynamics that both accelerate sort of power, the distribution of power and output but also create problems for sustainability. [00:35:00] Does that make sense?

Geoffrey West: Well it does and I can elaborate on that, yes there is this tension if you'd like between, on the one hand, the infrastructure, which is the city, the stage upon which we act out our lives and act out our social interactions whether it's going to the theater, having a job or committing a crime for getting sick or whatever. That's the stage. That has a certain network structure [00:35:30] and that network structure has evolved in terms of the convenience maybe even towards trying to optimize the way in which we sustain ourselves in terms of getting food and other resources to our houses and so forth, much like biology does.

Then there's this other network, which in a certain sense doesn't exist in biology, in which we are now participating in real time, you and [00:36:00] I with others that we're talking to one another and interacting and the tension is that yes, we have that and we have, all of us have this image of social networks now because of IT, whether it's Facebook or Twitter or the rest and we have this image that's somehow, I don't know in suspended animation, up there in the cloud in some cyberspace.

Yes, there's truth to that obviously because that's how those interactions actually take [00:36:30] place, electromagnetically. The truth of the matter is, we, each of us have to be some place. I have to be here in Santa Fe in a room sitting in a chair in front of this telephone and microphone and you're in maybe New York doing something similar but you are wedded to that place, not only that, when this is finished, you're going to leave the building and go to ... I don't know maybe you'll go to a bar, maybe you'll go home, maybe you'll go to your family, whatever but you're gonna move [00:37:00] and likewise me. That involves the physical infrastructure network.

Even though we're trying to interact and creating this positive feedback, we are necessarily constrained by the physicality of the city, which supports us.

Demetri Kofinas: Lets hold right there. Now you're talking about that friction, that tension. I want to hold on that because I want to get back to that but I want to stick with this sort of, this metaphysical layer, this as I thought of it, in terms of the way that [00:37:30] Dawkins talks about memetics, this sort of memetic layer of networks and the way that human beings come together to impact their environment as a result of these structures.

There are two sort of things that I've thought about with respect to this and in terms of the way that it defies the normal optimization of nature, it seems to me that nature optimizes its networks with a much larger time domain. In other words, nature values time in a different way than human beings.

Geoffrey West: Yes, absolutely.

Demetri Kofinas: Our time preference [00:38:00] is different. There are two ways in which I think of that. One with respect to the actual output, which is this notion of power equals work over time, we want more power and the way we achieve that is by putting in more energy and doing more work and trying to shrink time. That effectively gives us more power. It also gives us more output.

I also think about it in terms of interest rates, which I find fascinating. It's something that I always personally been drawn to, this notion of discount rates, discounting the future. Our interest in the [00:38:30] future so to speak is mis-priced. I think that's the case with interest rates today and in general with our economy, I think it's what leads to these sort of excessive booms and busts in financial markets.

I see this same sort of thing across the system in this case. Talk to me a little about that. How do you see all of that?

Geoffrey West: Yes, the last quarter of my book I suppose deals with some of these issues.

Demetri Kofinas: I think this is the most fascinating part of your book. I mean your whole book is fascinating-

Geoffrey West: [crosstalk 00:38:57] and it leads to the more speculative part [00:39:00] but I think the more, in some ways, maybe the more profound part in the end, I don't know. That's for readers to judge. First go to your comment about time because I think that's crucial in this.

In biology, we're sort of a meta equilibrium. I mean obviously ... which obviously things evolve and change but they change over huge time scales. Most evolutionary processes take place over a minimum of hundreds of thousands of years, [00:39:30] often millions of years. It's very slow but the important point it takes place over many generations.

The extraordinary thing about social interaction and about what we had discovered when we discovered language and then emerged from being hunter gatherers to form communities and interact with each other and discovered economies of scale that working together, each of us can get more by working for the same amount or even less. That [00:40:00] discovery was extraordinary and what that has led to is that we can affect change, adaptation evolved change in a lifetime, in one generation, nowadays in less than a generation.

Time has taken on a completely different dimension. Time in biology typically gets slower if you like. Time actually slows down the bigger you are. Elephants live [00:40:30] much longer than mice. Their hearts beat much slower than mice. Time in a sense slows down the bigger you are for socio-economic systems, cities, our very economic system. This positive feedback that comes from social network interactions speeds up time, has exactly the opposite.

We viscerally fill that. I mean, my God, in my lifetime, the pace of life has increased enormously [00:41:00] but at the most fundamental levels its meant that change and evolved change paradigm shifts take place, which originally even in socio-economic systems when we first invented them may have taken many generations, now takes less than a generation. That's a huge issue that we will have to face.

Demetri Kofinas: That speaks to the finite time singularity.

Geoffrey West: Exactly. One of the things that comes out of this in terms of the mathematical structure [00:41:30] so let me back off one second back to biology.

If you ask about growth in biology, you can understand it in this because how do you grow and how does socio-economic system grow? What happens is you have incoming resources of various kinds, which are metabolized and that resource is sent through networks to cells in biology to sustain them, to make repairs, to maintain them and then adds new ones. That's how we grow.

Then put that into mathematics [00:42:00] and what you discover is the economy of scale, which leads to the slowing of the pace of life also leads to an understanding of it is that we grow quickly when we're young and then we stop. We stop growing and then we die. It explains all of that. Why we die, why we grow, why we stop growing in a quantitative, predictive way.

When we take that idea over to socio-economic systems, which conceptually is [00:42:30] quite similar. We have input, metabolism if you like, social metabolism if you like, which is not just energy but ideas and so forth, that gets allocated between maintaining what is there and adding new stuff. What you find there is exactly the opposite to biology. Not only dos the pace of light speed up but we have instead of finite growth and death, we have open ended growth, which is fantastic, which is [00:43:00] what we discovered and what has led to this extraordinary enterprise, which we all participate in. Especially when after the industrial revolution and the discovery of capitalism and free market systems, entrepreneurship and so forth.

This has been wildly successful but it has built into it some very serious stumbling blocks, let's put it that way, and these go by the name of finite time singularities because when you look at [00:43:30] the equations that describe this and that explain this, they have built into it the idea that the system will collapse in some finite time, that is the idea of singularity is that when you approach that singularity, all socio-economic metrics will become infinity big, which is completely crazy. The theory tells you what happens under those circumstances, the system stagnates and collapses.

Now you could avoid that [00:44:00] and we have avoided it brilliantly by innovating. What you realize is that what I described a moment ago was assuming that everything sort of so to speak stays the same. That you've made some major paradigm shifts, some major innovation like, well a long time ago, discovering iron or bronze. More recently-

Demetri Kofinas: Dr. West, I just want to interrupt because I want to clarify something to the audience because when you talk about things being infinitely big, what you're really touching on, [00:44:30] please correct me if I'm wrong, is that for example, on a metric like growth, the growth required to sustain the population at paradigm X is no longer reachable given the technological foundations of that society.

Geoffrey West: Yes, exactly. That's a very good way of saying.

Demetri Kofinas: Can no longer be achieved and therefore you need a paradigm shift whether it is-

Geoffrey West: And you need a paradigm shift in order to, so to speak reset the clock and start over again. That's effectively what we do. We so to speak have to reinvent ourselves, [00:45:00] which we have done and we've done it through these marvelous innovations of various kinds. Some as profound as discovering coal in the industrial revolution and some minor things but very profound like the telephone.

Demetri Kofinas: Language, discovery of language.

Geoffrey West: Language originally.

Demetri Kofinas: Written language.

Geoffrey West: Language was the beginnings of all this. Then more recently, the invention of computers and very recently the invention of IT. These huge [00:45:30] paradigm shifts, which so to speak reset the clock and allow us to have this open ended growth. There's almost like a theorem, that is that if you want to maintain open ended growth of the kind that we participated in, then you have to have a sequence of innovations, a continuous sequence of paradigm shifting innovations.

Now the catch, there's a huge catch in this. Many people have noted this and have [00:46:00] stalled this, that it is innovation that of course gets us out of the possibility of collapse, the famous Malthusian trap. If you follow the mathematics of this, I've already said, the pace of life increases for which there is ample evidence. The data supports that very strongly but one of the consequences is that these innovations have to come faster and faster.

There is an acceleration, not just to the [00:46:30] pace of life but an acceleration of the rate in which we have to innovate and make these paradigm shifts. Something that might have taken 100 years to develop 1,000 years ago, now only takes 25 years. The next innovation may only have to take 20 years and then 15 years and so on. The question is, can we continue to make these paradigm shifts at an ever increasing rate as if we're on this accelerating treadmill. Are we gonna have [00:47:00] so to speak a socio-economic heart attack because we can't keep up with it.

From this view point, innovations certainly avoid collapse but from this viewpoint, they are a temporary fix because you're gonna have to do it again and again and again and have to do it faster and faster and faster and we have this terrible problem of being able to keep up with that and then you can take the argument even further to a kind of reduction ad absurdum [00:47:30] that eventually you're going to have to be making a paradigm shift analogous of the nature of the IT revolution every year, then every six months and so on, which is obviously crazy.

Demetri Kofinas: I want to propose a sort of dichotomy here. Two opposing arguments. One is your argument with respect to this model and then I'm gonna put forward the argument of futurist like Ray Kurzweil. I want to juxtapose those two.

What you're describing, first I want to understand, within the model, have you tried to model out, [00:48:00] and you'd have to obviously input some data her and make some major assumptions but is there a point at which you can sort of say within this range in one of these singularities, we will not be able to cross the chasm, so to speak?

Geoffrey West: I think that's incredibly hard to predict because the whole question is what stage does it become impossible to keep up with this rate of innovation? Of major innovation, it's not just ... by innovation here, I don't mean, [00:48:30] iPhone eight or some other little ... I mean a major one like IT or computers. Something that has a big conceptual implications and therefore social and economic implications.

Demetri Kofinas: Would an example be ... I just want to point this out to the audience because one of the things we didn't really touch on directly, you may have mentioned it but is the problem of entropy, the problem of disorder.

Geoffrey West: Yes, I didn't talk about that but this of course is intimately related to the [00:49:00] continuous production of entropy, meaning that those that are not so familiar, the most fundamental law of ... in science really, is the second law of thermodynamics, which say roughly speaking that if you use energy, well you have to use energy to create order and coherence. In making an organism, in making a television set and creating a city. You also have to use energy to maintain those obviously.

[00:49:30] In order to maintain and create order, you create disorder elsewhere.

Demetri Kofinas: You actually create more disorder overall. You actually create more entropy overall in the system if you try to create order than if you were to simply to let the system reach entropy on its own.

Geoffrey West: Yeah. What we try to do obviously is to minimize that kind of entropy production but it does produce entropy and, in the end, entropy so to speak kills. One of the reasons we die [00:50:00] is that the very systems that keep us alive create entropy and entropy in that sense is manifested in wear and tear, damage, damage to ourselves, damage to our DNA and so on.

Despite the ... putting energy into repair, which is what we do, eventually it becomes prohibitively expensive for us to put in that amount of energy and we can't keep up with it and we die. The question [00:50:30] is I suppose, is there some analogous thing to that in terms of the whole socio-economic enterprise. If you want to use that entropy as an example. Its more that I think that this problem that paradigm shifts have to come faster and faster and it may be that we have a paradigm shift, which gets us out of this loop, so to speak.

My thinking about it along those lines is that when we think of paradigm shifts conventionally [00:51:00] and the way I've been talking about it and I mostly talk about it in the book, most of the experts talk about it, is in terms of technological innovation. An airplane, oil, computers and so on, we think of them as technological but maybe the paradigm shift that we ultimately need to make is a kind of cultural paradigm shift. Something that really changes the way we think about growth itself.

Demetri Kofinas: I want to get into that. That's the demand side of the equation. [00:51:30] I want to ... and I do want to touch on that, Dr. West. I want to actually explore it in depth actually because I think it's essential. I'm convinced in other words by the mathematics of the model.

Before we go there, I want to entertain this opposing argument. Are you familiar with Isaac Asimov's, The Last Question and the Multivac computer?

Geoffrey West: Well I read it a very, very long time ago. I don't remember it but I should read it again because several people have asked me this question.

Demetri Kofinas: It's interesting. Well it's instructive I think for the purposes of both the entropy [00:52:00] that we were discussing before as well as the argument that Ray Kurzweil will make. The way I think of that in the context of the entropy is that the civilization built around the Multivac was the pocket of order in the chaotic disorder of the universe. That one point of shining light amidst the darkness.

The Multivac was relevant in my view in terms of bridging the connection with Ray Kurzweil because for Ray Kurzweil and futurists like Ray, they refer to a singularity as well except they don't call it a finite time singularity, [00:52:30] they call it just simply a singularity and for Ray and others, that refers to a moment in which machine intelligence will surpass human intelligence. They're also very optimistic people in so far as that is concerned because there is an argument that that sort of the end point of humanity could potentially be.

People like Nick Bostrom and Elon Musk will make that argument. Let's take the optimistic scenario that Ray Kurzweil puts forward, the idea being that you reach this moment, this singularity and that is sort of the innovation that sort of [00:53:00] breaks the function. That would actually I think in the way that he thinks about it and I'd like you to sort of follow me and tell me if I have this correct sort of in the context of the model. It seems that it would be sort of a break in this function and you would break everything. You would break the entire space time continuum because of the idea being that you would achieve this super intelligence that can solve any problem within the confines of the closed system of the universe. Basically kind of like the Multivac, you're only constrained by the entropy of the entire universe and so we would be able to expand our [00:53:30] time domain to the end of the known universe.

Putting aside the seemingly absurd fictionalized aspect of that, just simply in terms of the theoretical sort of argument, does that make sense theoretically and then please go ahead and just make your counter argument.

Geoffrey West: Well you know.

Demetri Kofinas: I really enjoyed coming up with that, I must say. It just came to me when I was sitting and reading, I said you know if I'm gonna put myself in a position of Ray Kurzweil-

Geoffrey West: I told briefly in the book about the differences between science fact and science [00:54:00] fiction. I'm a great fan of science fiction because it does allow one's imagination to run wild. Ideas could come that could conceivably be very useful and concepts could conceivably.

One of the things that I have learnt in my career is that it's much harder to do science fact than science fiction because science fact, it's a bit like Mr. Trump. If you're not constrained [00:54:30] by facts and by logic and following equations through, then of course you're allowed to say and do anything-

Demetri Kofinas: I think you're asking a great deal of our president.

Geoffrey West: That's completely fine in some ways, as it turns out I don't like the way Mr. Trump uses it but you could imagine by the way a president that does that that does something that we all think is good by ignoring all kinds of facts and so on.

It's not of itself I suppose [00:55:00] reprehensible although I happen to come with a deep commitment and philosophy towards ideas of rational thinking and following equations through and rational thought through. I can't say whether the scenario you've outlined or the scenario-

Demetri Kofinas: But at least do you think it's a creative attempt to take the position of Ray Kurzweil, at least give me that?

Geoffrey West: Yes, no, and I think that's fine. I'm all for that actually but I'm also skeptical.

Demetri Kofinas: Sure, sure.

Geoffrey West: When [00:55:30] it's totally unconstrained, it becomes not so useful. Here's the point, you can talk about singularity and you can talk about the future but if you don't understand the past and how it got here and understand not just by verbal narrative but by having quantitative predictive, conceptual structures, which you could prepare to data, that's the way science has worked and by the way, what has brought [00:56:00] us to this extraordinary time in human history because of science and technology, because of using these ideas. From Newton and Maxwell and Einstein and so on, it has all followed that and it's paid off enormously. I think we should stick with that and use that and use that as our guide.

I take an agnostic view, I'm not in any way decrying those speculations other than saying from my philosophical [00:56:30] viewpoint, I find them less interesting than-

Demetri Kofinas: Well to be clear, I think anyone who studies Ray Kurzweil and other futurists, the sort of conclusions they draw result in many more consequences than simply ... it's not simply a matter of ... in other words what I want to say is that the future that Ray Kurzweil lays out for me is besides being unconvincing when you get into the sort of ...

some of the ideas around it but also unappealing. It's not a future I'd want to live in because the idea being that we merge with machines if we want to survive.

Geoffrey West: Yes, [00:57:00] no I agree with that too. I have a reaction that way too of course.

Demetri Kofinas: I think that leads us to the sort of sustainability argument – to the demand side – because that's where I want to get to ultimately. I just want to-

Geoffrey West: Exactly. I'm glad you brought it back to that-

Demetri Kofinas: Well absolutely I would-

Geoffrey West: 'Cause that's my passion.

Demetri Kofinas: I find your argument convincing, I certainly individual your modeling convincing. Why don't you kind of lay that tout for us.

Geoffrey West: Yeah, so I just want to pick up with that because I think that's really important that independent of anything else, I too, and many [00:57:30] of us probably do too, we have this kind of anthropocentric view that we like who we are. I like our bodies. I like looking at bodies, I like sex, I like looking at people. It's a shame to think that all that might be gone. I like houses and I like cities and I like the kind of life that we've tried to develop and I want that to be for not just the seven and half billion people on this planet, [00:58:00] I want it for the possible 10 or 12 billion people that may be on this planet in less than 100 years. I want that to happen and I want to ask the question, how could it happen? Maybe it can't happen. That's a huge challenge and I think that's what we should be thinking about.

I got into this because of going back to what I said earlier is that we have this paradigm that we've [00:58:30] invented, that we've got into that has lead us to this open ended growth and to this idea that to sustain it, we need to have this continuous cycle of innovations, which have to be accelerated. That is an enormous challenge and as I said earlier, if you take that argument to its logical conclusions, the system simply can't be sustained.

One has to try to think, is there other ways [00:59:00] out of this? I'm not, by the way, just a side comment. I'm less concerned about the future of human beings on the planet than I am about the socio-economic human beings that we are now. That is I'm not so ... maybe we'll return to being hunter-gatherers, but I find that less interesting [crosstalk 00:59:21].

Demetri Kofinas: We'd have a major population collapse.

Geoffrey West: I want us to be like us. I'm very anthropocentric in this. I want us to be like us and to be able to do what you and [00:59:30] I are doing now.

Demetri Kofinas: It seems though that your model suggests that that's not possible.

Geoffrey West: Well that's the question, is it possible? The way out that maybe we can get out of it is by redefining what we mean by growth and redefining what we mean by a paradigm shift because as I said earlier, when we think of paradigm shifts and this is true of the Kurzweil's and the many Bostrom's and the Elon Musk's and all the rest is we [01:00:00] think of it technologically. We think of all these marvelous technological innovations, which will ... some of which will surely happen and some of which have already happened and we think of it that way.

For example, again, again it maybe that one of the major paradigm shifts that's gonna be upon us soon are driverless automobiles. That may be, that may have enormous consequences way beyond just simplifying transportation. That may be a major paradigm shift, maybe not.

Anyway, we do think in these technological, [01:00:30] physical terms. I would like to start thinking about changing the way of thinking about this by saying, lets transfer that to cultural shift. Let's think of a cultural paradigm shift or even a paradigm shift in which we redefine growth and this is certainly not original with me, from not just the GDP or the stock market as defining growth but some things that are a little more flakey maybe like happiness and quality [01:01:00] of life and so forth.

That's the kind of index. Wouldn't it be wonderful for example, that instead of every day where we hear how the Dow Jones average is doing, along with that, we had the whatever, some other index that tells us something about the quality of life. It just went down for example because there was a great big hurricane it Houston so obviously the quality of life went own in the United States, wouldn't it be nice to have a little metric like that [01:01:30] that competes with the hegemony of the Dow Jones average.

That's my cartoon version of asking us, can we have a major cultural shift that I don't need to own three cars and a great big house, even those there's only myself and my wife in this one dwelling. I don't need that but I have it and I want it but I don't need to have more, I don't need to have an iPhone eight and nine and ten. We need [01:02:00] to change that.

Can we move into that in a smooth way and have a soft landing. I've become very pessimistic about that possibility. I didn't even think it was possible frankly until amazingly something happened a year ago. That was Mr. Trump came along and Mr. Trump has shown us that we can have what may end up being a paradigm shift in the wrong direction in this [01:02:30] instance.

In one year, he got people to completely change their way of thinking. That we based our whole government and our civilization on rational thinking, on polite discourse, we violate these things from time to time but polite discourse, facts, understanding and so on. He showed us, he showed half of the American people that no, we don't have to believe in any of that stuff. [01:03:00] Just throw that all out of the window and just violate all of that.

Who would have believed a year ago that a large segment of the US population would go along with that.

Demetri Kofinas: I mean to sort of be fair, I don't actually think ... I think he's a product of a society that has become increasingly-

Geoffrey West: Oh of course he is. No, absolutely and that's what I'm coming to. Of course he is. It's not that these things weren't there, they're there sort of in the unconscious, of course they would, it's part of human beings.

Demetri Kofinas: I think he's the bug that's exploited those faults in the network.

Geoffrey West: [01:03:30] What he did, which was a genius move was he opened the Pandora's box and he was the ... when you put the nucleus in a super-heated or super cooled system, it freezes immediately, everything happens, that's what he did, he was like that. He was the catalyst that somehow, I don't know in the unconscious of the American people and maybe globally for all I know, set off this thing and set it off, [01:04:00] of course in my viewpoint in the wrong direction. It was a proof of concept.

Demetri Kofinas: Proof of principle. I don't know that he had shifted the social paradigm anymore-

Geoffrey West: No we don't know yet. I'm grabbing at straws here frankly. I'm hoping that if that were the case, maybe we could have a charismatic leader, someone or a group of people do a similar thing to all those wonderful things that we also have. All these people that have all these .... [01:04:30] willing to go along with that also have a whole bunch of positive things. They want to love and they want to help people. They don't want to see poverty. They don't want to have global warming, everybody feels this at some level.

We need to have some spark that really does that. We have not had that kind of leadership in the United States or on the planet for a very long time, except for Mr. Trump.

Demetri Kofinas: It's interesting, in the spirit of complexity though it's interesting to sort of consider other alternatives [01:05:00] that might shift the paradigm that are not sort of driven by in a sort of hierarchical manner where it's simply from the leadership position. In fact, I think speaking politically, that's been one of the problems in America has been the sort of search for a messiah. This focus on national politics.

Geoffrey West: Look, what I said was tongue in cheek.

Demetri Kofinas: Tongue in cheek, no.

Geoffrey West: And a cartoon but it was a point to illustrate because you're absolutely right. This is a highly complex adaptive system and [01:05:30] it is but much of the system is very close to what we call a critical point. Trump obviously at some intuitive level felt that and it's a systemic effect. It's part of the social network again, it's that social network.

The question is, is it conceivable that this social network, which is the origin. After all the origin of this open ended growth and this pressure to have accelerating [01:06:00] paradigm shifts comes from social interaction. That's what the theory is and that's what it shows.

The question is, can we use that, that framework, that idea that this systemic social network to effect significant change. And change that will be a paradigm shift but will not be necessarily technological but will be social and maybe even economic. The fundamental question [01:06:30] that it brings up is, can we have the kind of vibrant, exciting, innovative, economic community, socio-economic enterprise that we have now without the kind of growth that we've had in the past, economic growth defined by the GDP. Is that conceivable?

Demetri Kofinas: I think this show is actually ... and not to sort of toot my own horn but I think this show is ... the demand for this show is a reflection of a changing cultural [01:07:00] dynamic in society, which is driven by desire to understand better the world and is less sort of politically oriented. We don't really do much politics in the show particularly for that reason because there's so much noise pollution in the media around politics and so many people come with so loaded with opinion to all their sort of conversations. This opens the window to one question I want to ask you and then one last one before we go because we're taking up a lot of your time and the audience.

One has to do with the [01:07:30] dynamics of wealth distribution, wealth and income. That's something that's very significant for me, when I think about the future of humanity and sustainability and it's something that we talk about on the show. I thought about those dynamics with respect to solving this problem. If we had more time, I'd like to focus both on the pessimistic and on the optimistic component but I want to focus on the optimistic component because I think that tone of the benefits of the expanding divide of wealth and equality is that you have a sort of super rich elite [01:08:00] with a tremendous amount of money and power and they have an opportunity to use that money and power in one of two ways and it's actually interesting also this sort of falls into the category of the Ray Kurzweil sort of idea, which is not just as you approach the singularity do you ...

Not just with the singularity do you reach super machine intelligence but in fact there are people before we reach that point that have access to technology that allows them to sort of escalate the ladders of power. This is definitely a dynamic that's occurring. Power is concentrating [01:08:30] in fewer hands and so those fewer hands will have one of two choices and in fact, this also reminds me spontaneously of an article that Bill Joy wrote for Wired in, I believe it was Wired in 1999. The founder of cell micro systems, which had to do with this exact future. This idea of a binary outcome.

There would either be a sort of beneficent response by the powerful, concentration of power in the world or would there would be a malevolent response. You mentioned the Club of Rome, many people have seen that as of [01:09:00] sort of ... some things that came out of that as being of this issue of population control from the top down, whatever it is. Let's take the optimistic scenario that philanthropy and sort of philanthropic instincts by the wealthier members of society can coalesce to sort of create some sort of solution. Have you gamed that out at all in your head. Have you thought about that?

Geoffrey West: Well not very much frankly. I have thought about the inequality issue a little bit because there's the famous scaling law about wealth and [01:09:30] so forth. Zipf's law or Pareto's law of income and so on, which seems to be valid across almost all, well all economic systems where there is this very strong powerful distribution of wealth.

I thought a little bit about that and the implications of that and is that really a law, so to speak. Is that inevitable and how much flexibility is there in that.

Demetri Kofinas: What about the capacity [01:10:00] of wealthy sort of super elite because that's where we're at.

Geoffrey West: Yeah, so what has happened ... so yes. That leads to one of the things that has happened in just sort of relatively recent time is the explosion at the top. We've seen a violation of that law, of the income distribution law with many, many more people having much greater wealth than quote, "There should be," in quotes, and that's what you're referring to.

[01:10:30] I don't know. I have no really great ideas about how that's gonna play itself out. I would love to be optimistic about it along the lines that you're suggesting that these people will exercise their power and wealth to effect huge changes on the globe and many of them have spoken that way but history has not borne that out very well frankly.

[01:11:00] The rich want to get richer it turns out. That has been more of the rule than the rich wanting to give it away. Bill Gates has given away a lot of money but it's a tiny fraction of his entire wealth. That's true of most of the great philanthropists.

Demetri Kofinas: Right, so what I'm suggesting is that we get to a certain point where the concentration is so great and the existential crisis looming is so great that the personal interest of the elite is such that they need to fix this problem.

[01:11:30] Now you could get a Children of Men scenario. There are exzillion scenarios that you can come up with but I think the dynamic, the fact that that is the dynamic speaks to the set of solutions that are presentable and I think it's important to think about that and I always think about the wealth dynamic whether I'm just having a conversation like this or whether I'm thinking about a potential market opportunity in business thinking about the fact that the distribution of income is different so you have to think of products in a different way.

There's one last question I want to ask you [01:12:00] before we go and it's again, this is gonna sort of push the limits of what you perhaps normally think about because it isn't necessarily discussed in your book. You touched on it in the very beginning and it as this notion of spirituality. Another way of thinking about it is the intelligence of the network. Do you ever consider the source of the intelligence of networks as an important sort of question to meditate on, the way that some people meditate on the question of consciousness [01:12:30] and the way that the role of consciousness in the physical world and sort of where it comes from. Does consciousness proceed material reality.

Do you think about that incredible intelligence of the network and do you try to get in your head what that means, where that comes from?

Geoffrey West: Yes well, I do think about that from time to time. I think about it in terms of ... I actually refrain from using the word intelligence because [01:13:00] it has a somewhat different connotation or even consciousness. They're very hard to define and as I say, they carry ... they come with baggage. Of course, so does the word spiritual but that's the only word I can think of which connotes the feeling aspect of this kind of thinking.

I'm very much taken by the ideas of the philosopher Baruch Spinoza, which is kind of a more, I don't know, what's the word, animist [01:13:30] view of the universe that the universe is God so to speak, to put it in simplistic terms maybe. That's what it is. I think I even talked briefly about it in the book. I see our role, human beings our role, so to speak in terms of asking what is the meaning of the universe, where does this intelligence come from.

It's something that has evolved in order for the universe to know itself.

Demetri Kofinas: [01:14:00] There's the Multivac again, that's why people are telling you to read The Last Question. That's the Last Question essentially.

Geoffrey West: Well there you go.

Demetri Kofinas: No I didn't mean to interrupt you. It's interesting what you have to say on this because I think you're touching on the mystery on a question that we really can't answer and it does come with a lot of baggage because all sorts of people impose upon it all sorts of different things.

Yeah, for me, I think simply I would say that there's a wonder that is generated ... [01:14:30] for example, reading your book, which I will say again is remarkable is a remarkable read and I recommend it to anyone. You are sort of mystified anytime you deal with complexity and you look at fractals and you look at the complexity and the geometry and the beauty, the elegance.

You can always second guess and question and say, in some ways, I'm built to appreciate the beauty of complexity and XYZ but the elegance of the mathematics is profound and inescapable.

Geoffrey West: It [01:15:00] brings up that question, a question, which is been around for a long time, why is mathematics the language of the universe so to speak.

Demetri Kofinas: Now our listeners have to re-listen to the Ray Monk episode on philosophical mathematics.

Geoffrey West: Oh yes, you interviewed him on that, oh very good. [crosstalk 01:15:15].

Demetri Kofinas: Yeah, that was excellent and I should actually also mention we had the philosopher Mark C. Taylor on episode three, he wrote a book called Speed Limits, which dealt exactly with this issue of is time speeding up as a result of technological change.

[01:15:30] Many similarities I think for our audience who've heard some of those episodes and listened to this episode, there's a great deal to sort of stitch together. I must say, we couldn't have done this conversation in 10 hours. Like I said, your book is remarkable dense, I do highly recommend-

Geoffrey West: Well I appreciate that. Dense, I'm interpreting your statement in a positive sense.

Demetri Kofinas: In positive, very positive way. Usually density reflects difficulty and maybe almost boringly complex but no, actually I found it incredibly sort of ... as I've said [01:16:00] it's understandable it's just dense, it's fractalian, as I would say in the infinite number of epiphanies you could have depending on what branch you choose to follow along the networks of thought.

Dr. West, we've taken up tremendous amount of time, I certainly appreciate your time, I appreciate the audience's time that's still with us for the end of this episode.

Geoffrey West: If anyone's still here at the end, yes.

Demetri Kofinas: There will be, the special nerds will have gotten to this part and they'll actually-

Geoffrey West: A few will make it to [01:16:30] the very end.

Demetri Kofinas: No, [crosstalk 01:16:31] there will be.

Geoffrey West: Well Demetri, thank you for inviting me and for a very stimulating conversation, I really appreciate it.

Demetri Kofinas: Alright, thank you so much.

Geoffrey West: Take good care. Thanks a lot again.

Demetri Kofinas: And that was my episode with Geoffrey West. I want to thank Dr. West for being on my program. Today's episode was produced by me and Genevieve

Annable. Sound engineering is Ignacio Lecumberri. Edits are Stylianos Nicolaou. For more episodes, you can check out our website [01:17:00] at HiddenForces.io. Join the conversation at Facebook, Twitter and Instagram at @hiddenforcespod or send me an email.

Thanks for listening, we'll see you next time.