Science Makes our World Livable and Humane
March 14, 2012

Thanks….

for the Series of wonderful talks about wonderful people and their stories. Thanks to Mickey for having us in her home. Thanks to Room 500 personnel for feeding and drinking us so well, and dealing with my cilantro sensitivity for all these years.

This afternoon will be a little different. **This talk will be about something else.**

This talk will be about how

Science Remakes Our World

….. and we do not even notice.

Almost everyone in this room is devoted to taking care of people.

Almost everyone in this room knows that people are hard to take care of you. You don't know what they are going to do next. And even when you think you do, someone else comes along, and does something else that changes everything.

That is the real world of people.

That is the real world of medicine.

That is what our brains were evolved to deal with.

Change, uncertainty, rapid adjustment, making things work.

That is what our brains were evolved to deal with.

That is the world of the living

but it is not the world of life.

It is not the world of biology.

It is not the world of science.

Science is about the part of the world we can predict.

Most of you are skeptical. Most of you find that only a small part of the world is predictable. Many of you may not believe that ANY part of the world is predictable: you didn't believe what was taught in physics, because the experiments you did there did not work, or did not happen at all.

Most of you do not believe that a significant part of the world is predictable.

But you are wrong.

Your everyday life, your standard of living, the inventions that make it possible to be humane, are all from that tiny part of the world that is entirely and exactly predictable.

Now, that is what I said. You heard me right

Part of the world that is entirely and exactly predictable.

Entirely and exactly predictable.

What am I talking about?

Anyone want to guess in the audience? What part of the world is entirely and predictable that you use every day, some of you nearly every waking minute?

I mean the part of the world where mathematics predicts what is going to happen exactly,
and where machines can execute that mathematics to get an answer.

I mean the part of the world where anyone, and everyone, get exactly the same result for a measurement or an experiment, whether they hate each other or love each other, whether they pray for the same result or another result, and **MOST REMARKABLY even if they do not know what the symbols mean, even if they do not care what the symbols mean.**

Mathematicians get unique results without knowing what the equations mean.

Scientists make the same measurements no matter what the feelings, hopes or prayers of the scientist.

Amazingly, scientists can measure the properties of a small piece of matter, say Lake Michigan, and how it moves a tiny amount, write equations to describe that motion, check that the equations are right. Mathematicians can then take those equations and predict the waves on the Lake, and with a little more work, even the flow of air over an airplane wing.

This sounds amazing but it is done every day.

But this undoubtedly sounds like nerd talk, science speak to many of you.

You think who cares? so what? what does this mean to me?

Well, I point out that your comfort, your shelter, your entertainment, your food, comes from EXACTLY that tiny part of our world where mathematics works, where things can be predicted.

Our standard of living comes directly from EXACTLY that tiny part of our world where mathematics works, where things can be predicted.

WHEN WE CAN CALCULATE WE DO NOT HAVE TO DO TRIAL AND ERROR EXPERIMENTS TO GET THINGS RIGHT.
and nowadays we can do many of those calculations in much less than a second, that our ancestors could not do in a year.

Look at buildings, architects and contractors compute, and design on blueprints, they do not build scale models. Buildings built without math fall down, even without

earthquakes. That is why cathedrals that look so tall are actually only a few stories high.

Air and water flow are the most amazing examples because they are so complex. The flow of water out of the shower most of you took this morning can be computed exactly. Every drop, every swirl in the sink can be computed.

Air flow is much harder because it involves sound waves and shock waves and sub, trans and supersonic flow. No one can understand what will happen when small changes are made in airplane wings: little tabs, bent up corners, …..etc
No one can understand what happens when small changes are made in the walls of a concert hall. But the equations predict what happens exactly. Scale models and trial and error do not work. Direct calculation does.

In this kind of equation, small things matter
A colleague and collaborator of mine, Julian Cole, went to

Boeing in Seattle when he was a graduate student at Cal Tech, around 1947, because none of his bosses wanted the struggle of travelling in those days. He answered a question: how do you tell what kind of flow we have, below at or above the speed of sound. He answered in about 30 seconds. AND WE HAD A GENERATION OF AIRCRAFT. No kidding.

The most important thing we can calculate is electricity.

Electrical Laws are correct to 1 part in 10^20 or so.

Laws for resistors and capacitors and things we buy at Radio Shack are with a few per cent from 0.1 ohm to 100 million ohms, or if you use the equipment we designed at Rush, even to 100 billion ohms.

The laws of electricity have entirely remade our world

AND

The laws of electricity have not finished remaking our world.

How many of you have heard of a transistor? or Moore's law?

How many of you use a cell phone or a flash memory card or a digital TV?

They are part of the most fantastic intellectual revolution in the history of mankind, by a factor of thousands, more fantastic than the invention of printing, than the industrial revolution, than what molecular biology or pharmacology has done so far.

When you our students were 6 or 7 years old, we had computers but not digital TV's or memory cards.

Digital technology was about one thousand times less capable than now.

We take it for granted. This progress is called Moore's law and started around 1965. It has produced several BILLION

improvement in electronics, but that number is too large to understand.

Moore's law has produced one thousand fold improvement since many of you were in kindergarten.

We should not take this for granted.
Rather we should understand why and how this process is occurring
AND TRY TO DO A LITTLE OF THE SAME IN OUR OWN WORLDS, LIKE MEDICAL CARE.

It is not natural that this little stick can have about 16 BILLION numbers stored in it in 500 billion switches (transistors) and they are all right.

OR

that Dr. Goodman's TV has about 2,000,000 switches (transistors) in it and not one is faulty. You don't see a single

black or white pixel where it should not be. AND I (and Panasonic and Mickey and Dr. Goodman would find even one I assure you)

It is not natural that the cost of information is essentially zero (~$8 dollars on Amazon on Sunday morning)

But we are all humans and we take for granted what we do and use every day. ME TOO! I take for granted the wonderful medical care all of you have given me and my family, and the productive environment Dr. Deutsch and Dr. Goodman have created for us to do science.

We do not think through what we use every day.

If cars had improved by 1,000 times since you went to elementary school, **we would need only a few drops of gas where we need a tankful today.**

And what about medicine?

Do I have to tell you how hard you have to struggle to improve patient care by 20%?

I do not have to tell you how important imaging technology is today, than when you left kindergarten?
In essence, there was no imaging technology then.

Imaging technology is the DIRECT result of mathematics (Radon transform and the solution of inverse problems), physics (nuclear magnetic resonance, etc), and incredible mind boggling fantastic engineering.

Compassion, caring, organization of health care, and so on has had only a minor effect compared to these realities.

Even the greatest biological and medical invention, the magic white powder of penicillin and antibiotics that changed the way every human lived, has not had the quantitative continuation of modern electronics.

So that is the story I want to tel..

What does this have to do with MY STORY that I was supposed to tell?

I have wanted to apply this power of mathematics and physical science to biology and medicine since I was a teenager. I started doing it when I was 17 or 18. Not an admirable story. Who would want to work on the same thing for more than 50 years….and be frustrated and wrong (i.e., incomplete) most of the time.

I did and do and fortunately for me so do my collaborators and colleagues

I am still doing science on the same questions I started on long ago. Thanks to Dr. Goodman, Dr. Deutsch and so many others, who let me still do it.

I have always wanted to do math on biology.
But I learned when I was 20 or so, that we could only do math and physics on little pieces of biology at a time. The big methods that mathematicians used for buildings and air and water flow, called Variational Methods and Hamiltonians did not work for salt water or things in salt water. All biology occurs in salt water.

Imagine how I felt in 2009, some 47 years later, when I discovered that someone had solved that problem, had developed a general Variational Method and generalized Hamiltonians so they could work for salt water. Chun Liu had done it by math. He had corrected a mistake. He had found a way. And he did not know it applied to biology or salt water.

So I helped Chun,

by showing him what a salt solution was

(this took about 1 minute,

and then it took him two questions

and one equation from me

and another minute

to write the equations

no one had known how to write up to then).

So now I am doing what I always dreamt of doing, trying to bring the power of mathematics and physical science to bear on the general problems of biology and medicine.

It is the power of mathematics that has allowed us to live so much better and longer than our ancestors.

I hope to help apply that power of mathematics throughout the science of life.

Thanks