From Mechanistic to Social Systemic Thinking
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Why all of a sudden is everybody interested in systems? Why, all of a sudden, has quality become a big thing? Why, all of a sudden, organizational learning, or process reengineering? Why? I mean, these things have been around for a long time. There have always been consumers with expectations. Why didn't we worry about quality before? There have always been systems? Why?

Well, all of our explanations rest on certain assumptions that we make, because explanations are simply deductions from theories or sets of assumptions, and every theory rests on a more general theory. And the most general theory of all that each of us has is a theory of reality, a concept of the nature of the world, which is referred to as our world view, or as the Germans referred to it with a beautiful word, Weltanschauung, our concept of the nature of realty.

Now, there are very few people who are conscious of that set of assumptions about reality. There's no need to be, but you all have it. You absorb it by osmosis in the process of acculturation, of growing up. And the reason we share a culture is that we share world view. The world view is the cement that holds the culture together. It characterizes what the historian calls an age. An age is simply a period of time in which a culture has a single shard view of the nature of reality. And therefore a change of age is a period in which the world view is going through a transformation from one view to another.

Now the reason for all that is that the thesis of the argument I want to present it, is that we're in the early stages of a change of age. We are about to consummate, not immediately, but in time, a transformation from one world view into another. Now, in order to present that argument and defend it, I'm going to go back a little way, and talk about the preceding one.

The preceding world view, which has a long way to go before it's completely dead, because world views don't die, they fade away, began with the Renaissance. The Renaissance was a period of transformation between two ages, the Middle Age, and the Modern Era, but the significance of the Renaissance is frequently lost We all know that it represented major changes, but not what the nature of the changes were. The fundamental nature of the change in the Renaissance derived from several facts. The first fact was expected life was 27 years, before the Renaissance. 40% of the children born did not survive infancy. 95% of the people never traveled more than 4 miles from their place of birth during their entire life. And they lived in abject poverty.

Now, if you begin to amplify those statistics and develop an image of what life was like in the Middle Ages, it was pretty damn miserable, for most people. So, the fundamental question which was asked, is what is the purpose of life? Couldn't understand why we were given life it it's so punishing. Now the only institution that mattered during the day, the Catholic Church, which was the only international institution at the time, provided an answer. It said life is preparatory for death.

If you live life correctly, you've got an infinite sojourn in paradise or heaven, so why worry about 27 years? The only thing to worry about it is live it in such a way that you make the right turn afterwards. So, that was the generalized belief, and as a result, the Middle Ages focused on spiritual life and afterlife, not this life. And that's easy to see by looking at the art and the literature of the time. You don't see any realism, to speak of. You see Dante's Inferno, Milton's Paradise Gained, Paradise Lost, pictures of gods and angels floating around, but no realistic scenes of everyday life, because the preoccupation was with afterlife.

Now, two things happened that began the conversion. The first was Peter the Hermit's crusade, which for the first time, led hoards of men, (about 40,000) across the face of Europe, who, for the first time, came in contact with cultures other than the one in which they'd been born. And they observed differences and became curious about those differences, and began to ask questions Why do these people have a different set of values than we do? Why do they have different habits than we do? Different traits than we do? And that led to the movement called the New Humanism. And the new interest in the nature of man led to a new interest in the environment of man.

That was accompanied by the opening of trade out of the city-states of Italy, where, similarly, merchants began to visit other cultures as far East and West as India and China, and saw cultures, again, completely different than ours, and emphasized the question of what's responsible for those differences? And became curious about man. Now, in one obscure encyclical, during the Middle Ages, curiosity was actually declared as a sin. But despite that, like birth control today, people ignored it.

And so, they began to inquire into the nature of man and his environment. And that led to the movement called the Renaissance. And Renaissance is a French word which means rebirth. It was the reentry of man into this world. Now, when we made that reentry, we developed a completely new view of the world, which was based on three fundamental beliefs and the doctrines which were derived from them. The first fundamental belief was that complete understanding of the universe was possible, was a reversal of the assertion that man could not understand anything. He simply had to accept reality as an act of faith that God knew what He was doing, and you just believe it. But now if you look at the work of Renee Descartes, probably the first great modern philosopher,

what he was all about was declare the ability of the human mind to understand the nature of reality and to understand it completely.

That view of the complete understandability of the universe in principle, if not in practice, was reflected in the conference held in Europe in the middle 19th Century, when, you may recall, it was the habit of such conferences to issue proclamations at the end, and the proclamation would be an attempt to state what was generally believed by the people who attended the conference.

And in 1850, this conference in Europe of the leading scientists of the world, said that it was their collective belief that by 1900, our understanding of the universe would be complete. Now that is hard to believe today, but they really believed it. Which shows that scientists can't forecast one damn bit better than economists can. They completely missed everything that was to come later. But they believed it. That belief, you shall see, is very important for other things that followed.

That was the first leg of what I will call the Machine Age,, for reasons I'll explain in a moment. The second leg, derived out of the method of thought. This period developed a concept of what thought was that derived from observing children. If you look at a child who's given an object they've never seen before, not an infant, but a child, it could be a radio, a clock, a toy, whatever it is. And just leave it with them. And they want to find out what it is. What is the first thing they'll do? Take it apart, of course. So, the first step is take it apart. Second step is try to understand what the parts do. Now try to assemble the understanding of the parts into an understanding of the whole. Three-step process. That is analysis. Analysis is a process by which you take something you want to understand apart. Try to understand the behavior of each part taken separately, and then assemble the understanding of the parts aggregated into an understanding of the whole.

Now that became the dominant method of thought in the Western World. So much so, that even today, if I say those two face the same problem. She thought about and he analyzed it, and I asked you what's the difference? You'd have a lot of trouble telling me. Because analysis became a synonym of thought.

Now because it did, it led to one very important consequence. Suppose I want to understand an automobile, which I've never seen before. Well, analysis says take it apart. So I take it apart, and now I've got a carburetor. And when analysis says I can't understand the automobile until I understand the carburetor. Now the question is how do I understand the carburetor? Take it apart. So I take it apart and I've got a valve. Well, how do I understand the valve? First fundamental question: is there any end to the process of taking things apart? Now, if you believe in the complete understandability of the universe, what must be the answer be? There had to be an end; otherwise you'd never have complete understanding. And therefore, the first fundamental doctrine was, everything and every experience is reducible to indivisible parts, elements, and that is

manifested through every branch of human knowledge. In physics, the decision was that every physical object is ultimately reducible to indivisible particles of matter called the atom. The atomic theory is a reductionist theory of nature.

Most of you had a course in chemistry somewhere in high school. Do you remember the first day? I can guarantee you got a sheet of paper with a table on it. What was the table of? Chemical elements, the ultimate forms of matter. In biology you learned that every living thing reduces to a single element of life called a cell. And so on, through every science, until you reach something like linguistics, one of the most modern sciences, and what does linguistic say? All languages reduce to elements of sound called fomate.

Science was a crusade in search of the element, because we believed that understanding the universe would only be possible when we had understanding of the elements of which it was composed, and therefore we first had to identify them and understand them.

Now the third element of machine age thinking resulted after we understood the elements. See if we now had taken the table apart into the atoms and composed it, we understand the behavior of the atoms. In order to understand the behavior of the table, you've got to put the behavior of the atoms together. That means knowing how they're related. Now, it's not surprising that in an era that believed that everything that reducible to indivisible parts, that we believe that all relationships between things were reducible to one single simple relationship: that's all that was necessary, and that relationship was cause and effect. We could explain everything in the universe just using that one relationship.

Now cause and effect's such a familiar concept to us today that we don't know what it means anymore. So let's just reflect on what it meant when it first emerged. It meant two things. It said the cause of an effect is something which is necessary for the effect. The effect won't occur unless the cause does. And the cause is sufficient for the effect. That is,, if the cause occurs, then the effect must follow. So, if I do this, you just saw a light come on and a sound,and I asked you what;'s the cause, you said it's my striking this with a coin. If I had not struck it, the light would not have come on, and if I did strike it, it would come on,because I hit the switch. And therefore my striking it is the cause of that effect.

Now, our commitment to cause and effect thinking led to three very fundamental doctrines which permeated our thought for almost 400 years The first one was this. If I want to explain the phenomenon, all I have to do is find its cause. So I find this cause, and now I have a complete explanation of the phenomenon, because the cause is sufficient for the effect. But I've got an unexplained cause. So how do I explain the cause? Well, I treat it as an effect, right? Find its cause. But now I still have an unexplained cause. Question: is there any end to the causal regression? If you believe the universe can be completely understood,what must the answer be? There had to be a first cause.

You have just now heard the cosmological proof for the existence of God, because that's exactly what it was.

The official doctrine as to why God existed was derived from our commitment to causality, so God was seen as the Creator, the first cause. And therefore the only thing in the universe which could not be explained, because was uncaused. God alone had to be accepted as an act of faith, but everything else could be accepted on rational grounds once we understood what the causes were.

Now the second consequence of cause-and effect thinking was even more profound. IT enabled us to develop a theory of explanation that excluded the environment. WE didn't need the environment to explain anything. Now that's really shocking one in light of today's thought, but reflect for a moment. There's two evidences of this. First, I used to ask my students what's the most familiar law of physics? And since, they weren't physicists, they never knew the name of it, but would usually say, it's that experiment Galileo ran with the balls running down the hill. And I'd say that's the law of freely falling bodies. And some of them even knew it was $S=1/2GT^2$. I said, the important thing about that law is its name. What's the word freely doing in there? Well, what is it doing there? What does freely refer to? It's a law about a body falling in a vacuum. What's a vacuum? It's the absence of an environment. All the fundamental laws of physics tell us what will happen when there is no environment, not when there is one.

Universality doesn't derive from the fact that they apply in every environment, but from the fact they don't apply in any. All other environments are simply approximations of various degrees to the nonenvironment. But that's not the main demonstration. What do you call the place a scientist did his research? Laboratory. What's a laboratory? A place deliberately constructed to exclude the environment. If you want to study the effect of X on Y without the intervention of the environment, you build a laboratory. Because we believed that the understanding of the universe would derive from the understanding of dyadic relationships, X and Y, without the intervention of the environment. So we had an environment-free theory of explanation.

The third component that came out of cause and effect was this: Does anything ever happen by chance? Spontaneously? Certainly appear to be. Uncaused event. Well, if you believe the universe can be completely understood, what must the answer be. No, can't be. That's just another way of talking about ignorance. Chance is a statement of ignorance. If you knew enough, you would know what the cause is. And therefore, everything which occurs is the effect of a cause. That doctrine is called determinism. Everything is caused.

Now, if you take those three doctrines together, understandability, analysis as a method of inquiry, cause and effect s a sufficient relationship to explain

everything, and put them together, what do you get? You get Isaac Newton. Because Isaac Newton was the first one to synthesize all those thoughts into a single image. So, it's not surprising that Newton said the universe is a machine. He did not say it is like a machine. He said it *is* a machine. Furthermore, he said exactly what kind of a machine it was. It's a hermetically sealed clock, not like a hermetically sealed clock, it is a hermetically sealed clock, and it is. Think about it. A clock is a mechanism that operates with a regularity dictated by its internal structure and the causal laws of nature. Newton of course thought he'd formulated those laws in his laws of motion. How do we tell time ultimately? How does the naval observatory tell time? By the movement of planets. So the universe is a clock. It's hermetically sealed. It's a closed system. It has no environment. The universe is self-contained. Has no environment.

And so he saw the universe as a machine. Now the interesting thing about this giant of science was he was a very religious man. And if you look at the Pinchipia (sp?) his major work, was dedicated to the glory of God, because he thought that science demonstrated the wonder of God. And so he made an assertion that was believed and preached from every pulpit of every religion in the western world, regardless of sectarian differences. The universe is a machine created by God to do God's work. We are here to serve his will. Now,whatever the concept of God was, or the universe was, people believed that. The universe is a machine to do God's work.

Now, combine that with another belief that's much older than Newton, it goes back to Genesis. In the Bible, it says that man, meaning people, but they were a little prejudiced at that time, man was created in the image of God. Which means that we are more like God than anything else on earth. That's not surprising because we wrote it. But now put those two thoughts together, you've got the premises of a very interesting syllogism. 1. The universe is a machine created by God to do God's work. 2. Man is created in the image of God. 3. Man should be creating machines to do his work. That was the origin of the Industrial Revolution.

It was a direct consequence of our view of the world. It was man's effort to imitate God as he understood him. If there were time, we could go into details of the Industrial Revolution, but let me just do enough to show you that every characteristic of the Industrial Revolution derived out of four view of the world.

The Industrial Revolution was about the mechanization of work. There are two fundamental concepts: work and machine. Now, work, according to the Reformation, which came on the heels of the Renaissance, was real, very real. That's what Luther and the others showed. Everything that's real reduces to atoms. And atoms have only two properties, mass and energy. Therefore, it's not surprising that work was defined as the application of energy to matter in order to transform the matter.

So, if I move a chair, I change the location of the chair,and that's work, because I applied energy to changing a property of the chair. If I burn coal and create heat,that's work, because I applied energy to the coal to transform it. So work was seen as the application of energy to mater so as to change its properties.

Now what's a machine? A machine is any object which can be used to apply energy to matter. Now, let's see how good your memory is. You all learned somewhere in school that there are three elementary machines from which all other machines are derived, reductionism again. What are the three machines? Lever arm, pulley-wheel and axle, incline plane. There they are. So you take a screw driver. What's a screw driver? Well, you've got a wedge at the end (incline plane) you've got the handle, which is the wheel and axle, and if you take the length, you've got the lever, you've got all three combined to create a screw driver.

Now, the problem was, to deal with work so we could mechanize it, apply machines to it. So here's a job to be done. How do we do it? First thing you've got to do to anything is analyze it, so we took it apart. Took the task apart. How far down do you take it? Well if you read Frederick Taylor, he'll tell you. He says, reduce work to its elements. Work elements. How is a work element defined? It's a task so simple that no two people can do it at the same time. It can only be done by one person at a time. I can remember my father trying to tighten the same screw as I was working on. Didn't work. Tightening a screw is a work element. Moving a 500-LB. table isn't, but lifting this watch is a work element, because it only takes one person to do it, and two would only obstruct it.

What we tried to do then, is by analysis of work, and it was called work analysis by Taylor, we reduced work to elementary tasks. Now, the next job was to mechanize those tasks. You can see why we reduced it to elements, because the simpler the task was, the easier it was to mechanize and in many cases, we could use elementary machines to do it. However, for one of two reasons, we couldn't mechanize all of them. Either we didn't have the technology for some of these tasks, or it was cheaper to use human labor than machines. So what we did is assign these tasks to people, we mechanized the others. And now, following the analytical procedure, we aggregated all of them, so what we had was a sequence, or a network of elementary tasks performed by men and machines to produce a product. And what do you call that network today? That's the modern factory.

The production line and assembly line is simply the result of the analysis of work and its mechanization. Direct consequence. Now that has two very important implications for what we're about. The first is this: if there turns out to be another way of thinking other than analysis, then there must be another way of organizing and designing work. And by God, there is, and it doesn't look

anything at all like Ford's assembly line or production line. They already exist. And when they were looked at for the first time by the deans of American production, they denied its validity. Of course they did. They couldn't understand it. We'll come back and look at that in a moment.

The second thing it did was not intended by any means, but nevertheless occurred. In the process of the mechanizing of work, we reduced work to elements that were simple enough to mechanize. Those that we couldn't mechanize we gave to people. And therefore, we made people behave as though they were machines. WE dehumanized work, which ultimately led to its alienation, the alienation from work, which has been a major phenomenon of the twentieth century, according to the Dept. of Health, Education and Welfare, it's the most serious problem confronting this country. Because despite all the productivity figures you see, when you separate the productivity of capital from the productivity of labor, the productivity of labor has been going down.

Well, the Industrial Revolution was the technological manifestation of Machine Age thinking. Now what happened? Well, what happens to any age is the appearance of certain problems that challenge the validity of the world view. Those problems are called dilemmas. A dilemma is a problem which cannot be solved within the prevailing view of the world. All hundreds of them appear over time, and you have to develop a critical mass before anything really occurs. Now I'm not going to go through hundreds of them, but let me give you a sample of some of the more important ones.

First critical one that arose was this. The Machine Age view of the world says that everything which occurs is the effect of a cause. That means there is no free will. No choice. Everything you do is determined by something that preceded it. Now we don't believe that, obviously we don't. We believe we make choices, that we have freedom, but that's incompatible with the view of the world. That's a dilemma. That was a central problem of western philosophy for 300 years, and we only began to approximate some kind of agreement or consensus at the turn of this century, when, largely through the influence of logical positivists, which became the dominant mode of philosophy at the time, we came to a conclusion that free will was an illusion granted by a merciful God who realized how dull our life would be if we didn't have it. One philosopher who had two very unique gifts - brevity and clarity--said it in two sentences. He said man is like a fly riding on the trunk of an elephant who thinks he's steering it. The elephant doesn't mind, and it makes the ride more interesting.

Now, despite all that, we continue to believe we have freedom of will, and therefore the dilemma persisted. The second one really rocked the machine age, and produced the first chink in its armor. 1923, a young physicist in Germany by the name of Heisenberg came out with an incredible finding. Remember the atom has only two properties, mass and energy. If you want to determine those two properties for a given atom in a given moment in time, it turns out you can't

do it. Because what Heisenberg showed is that the more accurately you can determine its mass, the less accurately you can determine its energy or vice versa. And you can only know one of its properties perfectly when you know the others completely imperfectly. Now which belief did that challenge?

The understandability of the universe. It said the universe cannot be completely understood. John Dewey, America's leading philosopher of the day, immediately with his classical book called *The Quest for Certainty* He said understandability of the universe is an unattainable end but an ideal which we can continuously approach but never attain. It is unattainable in principle, like 0 error in science. You can continuously reduce the error of any observation, but you never reduce it to zero. You can always make it smaller. So, gradually, in the 1920's and 30's, we began to think of understandability as an ideal,not as something that was attainable.

Now, the dilemma that actually broke the back of machine age thinking is an interesting one. Its origins go back into the 30's but it only reached consciousness in the 50's. But there was a great deal of apprehension and anxiety and awareness that something was about to happen. In 1946, I returned from 4 years in the military, and went back to the university to complete my graduate work, and shortly thereafter, in 1947, a book appeared that really shocked everybody the academic circles I was in. Because we knew that something was up, we didn't know what it was. Something fundamental was being challenged. The book was Norbert Weiner's *Cybernetics*. Something was really up, but we couldn't tell what it was. And the first insight into what it was, I think occurred in 1954, when Vonbertalongfee's book appeared. Now the content of Von Bertalonfee's book was not particularly important, but the concept around which it was built was. That was systems. The book was called General Systems Theory. Now why? That's the critical question.

Why, all of a sudden, did systems break the bank of machine age thinking? Well, let's take a look. We've got a system, I don't care whether it's a hospital, a school, a conference, corporation, and we want to understand it. We have to analyze the system in order to understand it. Now before we can understand the consequences of analyzing a system, we have to understand what a system is. So let's look at that first. A system is a whole which consists of a set of two or more parts. So it's not an atom, not an irreducible thing. It's not an element. It can be divided into parts. Three requirements are imposed on part s: each part can affect the behavior of the whole. So you are a system, a biological system, an organism. Your heart can affect your behavior, your lungs, your stomach, your pancreas, your liver, you name the part , it can affect you. Unfortunately, I said that to a group of doctor a while ago, and one of them immediately rose and said, "that's not true. There's at least one part of the body that is known to have any effect on it at all." I pretended surprise and said, what is it? And he said the appendix. I said, what does the word appendix mean? "added on or attached to" but it's not a part of.

You see, if the medical sciences ever find a use for the appendix, they'll have to change its names. Because as soon as it has a function, it's a part, it's no longer an appendage. So the first requirement of a system is every part of a system is capable of affecting its behavior.

2. The way each part affects the behavior of the system depends on what at least one other part is doing. Now there's several different ways of saying that. It says no part has an independent effect on the system. It depends on other parts. Or if you're a logician, you would say simply that parts constitute a connected set. They all interact. No part is isolated. So it says the way your heart affects your behavior depends on what the brain and lungs are doing. You all know that. What the lungs are doing depends on what some of your nerves are doing in the brain, and so on. The parts are all interconnected, is all the second part says.

The third part says if you take the parts of a system and line them up in any order at all, doesn't matter how you do it, and then divide it up into groups, subsets, the subsets, no matter how you create them, will have the same properties as the parts. That is, every subset of parts can affect the behavior of the whole, and no subset of the part has an independent effect on the whole.

So, when you take the human body and break it up into motor system, nervous system, metabolic system, and so on, these subsystems interact, and each one can affect your behavior.

Now, if you take those three properties, put them together, we get a poetic definition of the system. It's a whole, which cannot be divided into independent parts. Now, that doesn't sound radical and revolutionary, does it? Sounds almost trivial until you reflect. Because a system following from its definition has certain very critical characteristics. First one: the essential properties of any system, the properties that define a system, are properties of the whole which none of its parts have. Now that's not obvious, but it is on reflection.

Take an automobile. Mechanical system you're all familiar with. What's its essential property? It can take you from one place to another. Right? What part of an automobile can carry you from one place to another? A wheel? A seat? The axle? Of course, nothing. Not even the motor. A motor can't even carry itself from one place to another. The automobile can, though. You walked into this room earlier, I looked at you and decided you were human beings, perhaps in error, but nevertheless I did. Because I saw you do characteristically human things, like your writing. You can write. Your hand can't write. Cut it off and put it on the table. Watch what it does. Your eye doesn't see. You see. Your brain doesn't think. You think. Those are instruments you use in the process, but they are properties of you as a whole. And therefore, when I take a system apart, it loses its essential properties.

If I bring an automobile into this room, and disassemble it, although I have every single part in this room, I don't have an automobile. Because the automobile is not the sum of its parts. It is the product of their interactions. Therefore, when I take a system apart, the whole loses its essential properties and furthermore, so do its parts.

What does the engine of an automobile do? It moves the car, right? If you take the engine out of the car, it can't move. But if I take the engine out of the car, it can't do anything. It just sits there. It has lost its capacity to move when it's separated from the system of which it's a part.

The steering wheel determines the direction of the automobile, right? Take it off the steering column, put it on a table, what does it steer? Nothing. The hand separated from the arm just sits there. And so, when a system is taken apart, the system loses its essential properties, and so do the parts. Now comes the systems dilemma that broke the back of the machine age. We want to understand it. Analysis says what's the first thing we do? Take it apart. What happens when you take a system apart? It loses all of its essential properties. Analysis in the second step says try to understand what each part does taken separately. What happens when you take the parts of a system separately? They lose their essential properties.

And so the great discovery in the 50's was that you cannot understand the nature of a system by analysis. And that's a fundamental revolution. Another method of thinking was required. And it was developed in the 50's. Not surprisingly, it came to be called synthesis. And it's exactly the opposite of analysis. In analysis, if this is a system we want to understand, the first step is take it apart. In the first step of synthesis, we do exactly the opposite. Consider a university, for example. If you're an analyst and you want to explain a university, you first say it consists of colleges, and colleges consist of departments and depts.. consist of students, faculty, and subject matter, and you can drive it all the way down to the element. And then you try to build it up again into an understanding of the university.

If you're approaching a university synthetically, the first step is the opposite of taking it apart. And that's seeing the university as a part of a larger system, the educational system.

The second step of analysis you try to understand each part taken separately. In the second step of synthesis, you try to understand the containing system, the larger system, not the parts.

In the third step of analysis, you try to aggregate the understanding of the parts into an understanding of the whole. In the third step of synthesis, you dis-aggregate the understanding of the whole into an understanding of the part by identifying its role or function in the system of which it's a part. Now, what analysis reveals about a system is how it works. If you want to know how an

automobile works, you have to analyze it, take it apart, and see what each of the parts does. If you want to repair it, you've got to analyze it to find what part isn't working. So the product of analysis of a system is know-how. Psychologists don't like common language, so that became knowledge. But that's not understanding. Knowledge is what's contained in instructions, not in explanations. Understanding is what is contained in explanations. And what synthetic thinking does is tell you the role or function of the system in the larger system in which it's a part, and that explains it and yields understanding. Analysis reveals structure, how it works. synthesis reveals understanding, why it works the way it does.

For example, you all know the British drive on the wrong side of the street. Why? I'll give you all the English automobiles you want and all the American automobiles, you can take them apart from now till Doomsday and never get the explanation. Because the explanation does not lie inside the vehicles; it lies outside them. In the role or function which they perform. Now, I don't know the truth,, but there is a book that appeared recently explaining this. It said the knight in shining armor riding on a horse down a road in England was normally right-handed and wielded a sword with his right hand. What he was concerned about was an attack by a highwayman coming in the opposite direction towards him, and he wanted to be in a position to defend himself. So he rode on the left, so that this sword-wielding arm would face the oncoming person. And when the British developed their automobiles, they simply followed the knight.

Well, we didn't have knights in shining armor when we designed the automobile. What we designed it for was a lot of right-handed people who would prefer to shift gears with the right hand, not the left, so we moved them over to the other side. See, the explanation doesn't lie inside, but outside in the role or function. The automobile was originally developed for six passengers. Why? You can take them apart from now till Doomsday and you won't tell. No amount of analysis will tell you why, or lead you to understand six passenger. Why not seven, fifteen, nineteen, three? The answer lies in the fact it was designed for the average American family, which happened to be 5.6 at the time. The reason it's getting smaller is it's now 3.2, so the car is contracting. The explanations always lie outside. So, the machine Age began to die when we gave up the principle of understandability. And when we substituted synthetic thinking for analytic thinking when we try to understand, not when we try to know.

Systems thinking is the fusion of analysis and synthesis, depending on whether our objective is knowledge or understanding. But now let's look at the other consequences.

This says that if I want to understand the university, I've got to first understand the educational system of which it's a part. So here's the university; here's the educational system. Now how do I understand the educational

system? What's the answer to that? You've got to take the larger system that contains it, don't I? Society. How do I understand society? Here we are in the same question that we had with reductionism in reverse. Everything I try to explain depends on a larger system. Is there any end, is there one system that contains everything? Be careful, this is your midterm exam.How many of you think there is? At least two brave people. How many of you think there isn't? A few. Most of you are not thinking. The answer is you're both wrong. And it's important to understand why.

Look, you've given up the notion the universe can be understood. Now, given that the universe cannot be understood, if there were one hole that contained everything, you could never know it, because if you did, you would understand the universe. And if there isn't, how do you ever prove that there isn't? Now, the fact is, that this then scientifically becomes a meaningless question. Scientifically, but not psychologically. So you don't have to be ashamed of having raised your hand. Because people feel very uncomfortable. When Evington wrote the book that proclaimed the so-called expanding universe, there were almost riots in England at its reception, because people believe firmly one way or the other.

Now, it's interesting that in the 1960's when these ideas began to emerge, a very interesting phenomenon occurred. And let me get to it by revealing an incident that occurred to me a while back. I was in 1968, we were having a sit-in at the Univ. of Pennsylvania, and there was no use hanging around doing nothing, so I went to visit Berkeley. My colleague Churchman was there, and so I went out to see him, and arrived on the morning that their sit-in broke out. So we spent all the time sitting in the faculty club, chewing the rag, and among the people who were there was the faculty member who was chairman of the board of the Univ. of California bookstore. Which is the largest university based bookstore in the world, because as you know, there are about 60 branches, they're all over the place.

In the middle of lunch, he turned to me, and said, "Russ, what do you think is the largest selling book in the bookstore of the University of California?"

And I thought for a moment, and I said, "the Bible."

He said, "No. The Bible is a big seller, but it's not the biggest, by any means. Try again."

So I thought a little more, and I said, "the dictionary. A dictionary."

He said, "No, that's a big one, but not the biggest. Try again."

I said, "Look, I'll take one more shot at it, and that's the end. Rand & McNally road maps."

He said, "No, that's another big one, but it's not the biggest."

I said, "What is?" Now, the amazing thing that happened, was he told me, and it was a book I'd never heard of. Now, here I am a professor in a major university, in the 1960's, and the book being most read by students was one I never heard of. It was called the I Ching. A lot of you recognize it. What was it about? Zen Buddhism. Why, all of a sudden, did the 60's generation turn to Zen Buddhism? Do you remember the Beatles? What did they do? They ran off to India to meet the guru, and spent a couple years with him. Why? Because the first generation born after World War II into systemic thinking were disturbed by the incompatibility of a concept of a God distinct from the universe who created it as opposed to one that was the universe. And so they looked for a religion in which the conception of God is God as the universe, as the whole. And where did they find it? In Eastern religion.

And so we get the tremendous emergence of interest in eastern religion. The interesting thing about that concept is in the machine age view, you are distinct from God. You are a creature of God. But in this view, you are part of God. Very different. Your stomach is not something you created. You didn't create your brain or your liver or your pancreas. You are your stomach, liver, pancreas. So, this view of God was conceived that way, as consisting of the whole, and if you wanted to sense your participation in that wholeness, you needed a new way of doing that, which was meditation. That was what the whole meditation movement was all about, how a person could lose his self-consciousness and awareness of the whole of which he was a part. That was what the effort was.

So what we get is the doctrine of expansionism instead of reductionism, which says to understand anything, you have to get to larger systems, you will never reach a complete explanation or understanding of everything, but your understanding increases, the larger the system that you comprehend. Now your knowledge increases the smaller the element that you comprehend. Knowledge goes from the whole down to the parts; and understanding goes from the whole up to the larger wholes.

So expansionism comes. Now what happens to the rest of it?

End of Side One.

Well, the story of what happened to cause and effect is in many ways, the most interesting part of the transformation, and also the most technical, so I'm going to have to give you a feeling for it.

The man who is the first responsible for this transformation, to the best of my knowledge, was a remarkable man by the name of Arthur Singer, Jr., who in 1898, graduated from Harvard. He had been the assistant of William James, a professor of psychology and philosophy. He was an unusual young man, because he got his first degree in civil engineering, his second in psychology, and

his doctorate in philosophy. He got an appointment in Penn, and came there as an instructor in '96, and in '98 published what has been subsequently seen as the most revolutionary article in science in the last hundred years.

What he showed was that science has been cheating for one hundred years. How? He said, consider an acorn and an oak. Is the acorn the cause of an oak? Clearly it isn't. Why not? Well, although an acorn is necessary for the oak, it's not sufficient. That's easy to demonstrate. How? Throw an acorn in the ocean, you don't get an oak tree. Throw it in the desert, or an iceberg, you don't get an oak tree. It's necessary, but not sufficient.

Now science knew that. This was no discovery of Singer's. And in the late 19th century, science began to be concerned with that type of relationship, and gave it a special name. They called this relationship either probabilistic causality (this was the foundation of statistical mechanics) or non-deterministic causality. These two terms were used. What Singer did was show that these are contradictions.

If a cause is defined as something which is sufficient for the effect, if the cause occurs, what is the probability of the effect? One, and it can't be anything else. Therefore, non-probabilistic causality is a contradiction, is to say that the cause is not sufficient. So it's not causality. Nondeterministic.

See, causality implies determinism. That's what we saw. Now the first law of logic, according to Aristotle, is if in an implication, you deny the consequence, you must deny the precedence. Therefore nondeterminism implies non-causality. It's a fundamental law of logic. So if I say all men are mortal, and then say you are not mortal, then it follows, that you're not a man. So Singer said, this is a different relationship, and he gave it a name. He called it producer-product. A producer is necessary but insufficient for its product.

Now let me say, by way of a footnote, this was written in 1898 and was completely ignored. No one saw the significance of it until 1954, when, in the context of cybernetics, a cybernetician in Europe, Gird Sumerhoff at Oxford, published a book called Analytical Biology in which he rediscovered exactly the same thing, but gave it a different name. He called it directive correlation, but it was the same thing.

Now, Singer said, let's look at the world through producer-product instead of cause and effect. What happens? Well, a series of things happen. First of all, if I want to explain this oak, which I have over here, what I do is look for the acorn which produced it. Do I have the complete explanation for the oak? Of course not, because it's not sufficient. Well, what else is necessary to become sufficient? Well, what is? A certain amount of moisture, a certain kind of soil with nutrients, and so on. I have a list of the other necessary conditions. The sum of these is called the environment. Lo and behold, all explanation now requires the

environment. We have an environment-full, not environment-free, theory of explanation.

Nothing can be understood independently of the environment. What a shocker this was. AS a child, I learned there are lots of universal laws, and the first one I learned was that everything that goes up must come down. That's not true. It's true within the gravitational pull of earth, but go out beyond it,and go up ad infinitum. Every law is constrained by the environment within which it applies. There is no such thing as the universal law. They are all environmentally relative. It was the first consequence of producer-product thinking.

The second one is very technical; it is what happened to determinism, and I can't take you through that argument, but I want to give it to you by analogy. Have you ever gone abroad and seen a fruit or a vegetable that you never saw before? Most of you are shaking you heads that you have. I remember the first time I saw kiwi many years ago when I visited Australia; I'd never seen one before. Or a mango, or a papaya, it's happened to many of us, at least if you're my age. Imagine this. Somebody from a strange part of the planet visits you and while visiting you, walks into your dining room table. We have a bowl of fruit on it. And he looks at the fruit, and he points to one, and says, "my God, what's that? I've never seen one of those before."

And you look at him in complete surprise and say, "That's an orange."

And he says, "What do you do with an orange?"

"We eat it' it's a fruit."

He says, "Well, what's it like?"

And you say, "Wait a minute; I'll show it to you."

So you go into the kitchen, get a knife, slice it, cut it in half, and what does he see? You know have two circles with a white strip down the middle, and an orange segment on both sides. Hold it up to him. Now just about that point in time, your spouse, or whoever else occupies your house with you enters the room. And they do something that is characteristically annoying. They say, "What are you doing?"

And you say, "He's never seen an orange before, and he asked me what it's like, so I sliced it to show it to him."

Then, he or she says, "Why don't you slice it the other way?"

Well, after the profanity is over, you figure that for the sake of peace in the household, you either get another orange, or you take the two halves, put them

together, slice the orange the other way, and now what happens? What I see is this: same orange, but two entirely different views of it.

What Singer showed, and this was his life work, is that cause and effect is a way of looking at reality. There are an infinite number of ways. Because reality is not two-dimensional, it is multi-dimensional, and every slice through it will give you a different view. And therefore producer-product is not an alternative to cause and effect, but is complementary. This is Borne's principle of complementarity. It's another way of looking at the universe. And it turns out that when you look at it this way, free will, purpose and choice are compatible, and so he developed a teleological view of the universe, a purposeful one vs. the deterministic one. And they're completely compatible. They are simply two different on the same thing. The question is, which one is the more useful for what type of research?

So there we are, every fundamental belief the Machine Age has been going through a transformation. It still is not widely conscious, but we're gradually catching up with it. And we now see the world differently than we did before. We don't see it as a machine. We've come to recognize that even the machine is a system, a particular kind of a system. A machine is a system which has no purpose of its own; it has a function which is to serve the purposes of something external to it, its god.

Now the universe was seen that way, but so was early business. Who was the god of the early business? The owner who created it. He was president an all-powerful; he could do any damn thing he wanted. There were no labor laws; no restrictions; no registration; he was god. And the business existed to serve his purposes. It had no purposes of its own. And his purpose was to make a profit. And so Milton Friedman, who was always behind times, comes out and says, the only legitimate business of business is business. That's a complete mechanistic view of a business. It's a machine. And as a machine, the business is an instrument of its owners, and the only responsibility of a business is to maximize the value of the machine to its shareholders. So Rappaport and Friedman go off on maximizing shareholder value.

Machine as a system has no purpose of its own, and therefore, neither do its parts. Now, when Von Berlanti came along, and began his papers in '30, but they were written in German so they didn't' get known on this side of the Atlantic until the 50's. He said, the organism is a very different kind of a system. It's a system, but it's different. Because an organism has purposes of its own. What is the principle purpose of any organism? Survival. And in order to survive, it must grow.

So we now have a system which is survival-seeking, or viability and growth is seen as necessary for it. Now what about its parts? Its organs? They don't' have any purpose; they have a function. So your heart doesn't have a purpose of its own, your lungs, stomach, and pancreas. They have functions, but not

purposes. And this exists in an environment that's a passive receiver of the output of this and its waste, and a supplier of the resources. But you don't have to worry about the environment. It takes care of itself in the biological view. Now, it's interesting, if there were time, we could go through the history of the concept of an enterprise,and see it went through this transformation right after World War I, for a very interesting reason. Up until W.W.I, most enterprises in the U.S. were owner-managed. And they were owned, either by an individual or a family, and he was God.

Unions were just beginning to appear to challenge the power of the owner, but several important things were occurring, like the education of the workforce. In 1900, the average educational achievement of an American worker was three years; they were barely literate. By World War I , it had gotten up to 8 years because of public education, and so on. But the critical thing that occurred that produced this transformation in the way we looked at an enterprise, was the fact that our economy was so healthy that the opportunities for growth exceeded the amount of growth an enterprise could achieve even by reinvesting all of its profits. If an enterprise took all of its profits and reinvested it in its own growth, it still could not grow as fast as possible. And therefore the fundamental problem confronting the owner of enterprises in this country in the 20's was do I retain exclusive control, do I remain God, and constrain growth, or do I share control with other contributors of capital and unconstrained growth?

Now the corporations that survived, the companies that survived, you know what they did: they went public. So Ford went public, General Motors, all the big corporations went public to raise the additional capital so they could grow. And in that process, God disappeared. Now there's a marvelous passage in the early word of Peter Drucker who recognized all this. He said God has disappeared; has become an abstract spirit out there. And we have created an institution to facilitate communication between man and God who are now the shareholders.

How, though, do the clergy, called managers, know the will of God? By revelation. But the interesting thing that happens is the whole language of business became biological. The chief executive of a new firm, the senior manager got to be called the what of the firm--the head. Head is a biological concept. You never talk about the head of a machine. Stafford Beer wrote two wonderful books, one is called The Brain of the Firm, and the other is called the Heart of the Enterprise, biological analogies. The firm was seen that way. The firm got to be called a corporation, not a company. What's the stem for corporation? Corpus. What's corpus? Body. Biological.

Now in W.W.II, we went through another transformation for a series of reasons. The principle one was this: the bulk of the American workforce was drawn into the military; they were drafted. Voluntarily or not, and I can attest to that. AT a time when we demanded greater productivity from our industrial

machine than we ever had in the past, which means we had to get substitutes. Who did we get to substitute for the men who were drawn into the services? Tilly the Toiler, Rosy the Riveter. If you want to have fun, go back and look at the movies of W.W.II. What were they about? They were all about the feminine heroine who picked up the welding machine and filled the spot that her boyfriend left when he went to fight the war and kill the enemy, and he eventually returns and they reunite, and she goes to her suburban house. It was a whole mythology of the war, that women were drawn into the workforce, the elderly and the young. And that was the first time in the history[of enterprise that the workforce was not primarily motivated economically. Why?

When we were inducted in the army, our pay, you wouldn't believe it. $21. a month. Now you couldn't support a family on $21/month, even in 1942. You didn't have to, because you got an allowance for each dependent. So your dependents could live above the poverty level, but not luxuriously while you were in the service. You didn't have to worry about them, and they didn't have to worry. So the people who went to work in the workforce did not have to work in order to survive. And it was the first workforce that didn't. And therefore it had a different attitude towards work.

They said, "if you want me to work, you're going to have to pay attention to me. I am not a machine that you can use as you see fit and discard when I don't serve your purposes. Because I'm here because of patriotism and loyalty to a national cause, and you better pay attention And for the first time, management had to begin to think of the workforce as human beings.

Now that was augmented in several ways. All kinds of curious things broke out at the end of the war. Here's the corporation here. Or society. Or a hospital or a school. It's a system. What happened were two movements. One is parts of systems began to organize to protest the way that the system was affecting them, the system of which they are a part. They said, hey look, I've got purposes of my own. And I want you to pay attention to them. And if you don't, I'm going to screw you up.

Do you recognize this? Of course you do. This was the race movement, where minorities protested the way society was serving their interests. It was women's liberation, where people differentiated by sex were protesting the way society served their interest. It was the generation gap problem, the alienation from work problem. There are a whole series of problems that go under the name humanization, which had to do with the fact that society was becoming aware of the fact that the employed people are human beings with purposes of their own.

Now simultaneously, groups are forming outside, were protesting the way the organization is affecting them and saying you serve my purposes better or I'll mess you up. Do you recognize them? Of course you do. That was the ecological movement, and the consumerist movement. All of a sudden, managers of systems found themselves confronted with three different levels of

purpose. The purpose of the organism itself, the enterprise; the purposes of its parts, and the purposes of the larger system of which it is a part , and the other systems in that environment. And in none of these levels were the objectives compatible. The nature of management went through fundamental change. WE haven't caught up with that yet. That's the problem that confronts management, because it's still managing biological organism. It's still acting as thought the corporation is an organism.

What happens is there are systems that are machines; there are systems that are organisms; and there are systems that are social systems. You can treat a machine as an organism. If you do, it would be stupid. You don't treat an automobile as though it has as its objectives survival and growth. But you do treat organisms as though they are machines WE do it all the time.

We have a tendency to treat organisms as machines, and even social systems as machines That has a certain usefulness, but it is not nearly as useful as looking at a social system as a social system. And the way to look at an organism, a person, is not as a social system but as an organism. And the way to look at a machine is as a mechanical system. That's one of the things we're learning.

One last point. The machine Age had the industrial revolution as its counterpart. What's the technological counterpart of the systems age? It's fascinating, because it goes back to about 1850. Remember the definition of work, the application of energy to matter so as to transform the nature of matter. About 1850, we began to use electricity as the source of power for the first time. Electricity was known for at least a hundred years, but it had been used as a toy. Remember Benjamin Franklin used it with kites to goose himself. But he never tried to use it productively. But in the middle of the last century, we did. And we started to use it, we had the problem of measuring it. Now, it turns out you need to know how much electricity is flowing through a wire and you can't see it. Turns out you can feel it,but that's quite dangerous. So we had to develop devices which would measure it for us. So what you get is ometers, ameters,etc. Now the interesting thing about those instruments is they were not machines. why not? They had nothing to do with the application of energy to matter to change the nature of matter. But nobody recognized that we called them machines.

So, let's just accumulate that. What we have are instruments which do not do work. What they do, when a human being does it, we call it observation. So, the gas gauge in your car looks inside the tank and tells you how much gas is there. Believe it or not, when I was a little boy, when my father bought his first car, when he wanted to know how much gas there was, I had to go out, go back, take the cap off and look in. A great technological advance came a couple of years later, when they gave us a wooden stick that I could put in and read the wet

mark. Observation is symbol generation. They were devices that generated symbols. But we thought they were machines

Very shortly thereafter the telegraph was invented. Then came the telephone, and the wireless, then radio, television, then the laser, you know that. They weren't machines. What did they do? They don't apply energy to matter. What they do is transmit symbols. So they're symbol transmitting devices. WE have a name for that What do you call it when a human being transmits symbols? Communications. So these are observing, these are communicating. Now, for a hundred years, these two sat around being treated as though they were part of the industrial revolution, and it wasn't until 1946 that we recognized that something fundamental had happened.

What we were doing, in effect, is building a whole new culture on an arch that had three stones. We put observation in one side, then communication, but we didn't have a keystone until 1946. Now some people who come from Boston argue that it was here in 1944--that's not true. It was at the Univ. of Pennsylvania in 1946. And it was called the Univac. The first electronic digital computer which was not a machine. What is it? It's a symbol manipulating device, but it manipulates symbols according to rules, and that's called logical. So it's logical, symbol manipulation.

Now we have a word for that, too, but it's not quite as obvious unless you know John Dewey, because John Dewey wrote a book before the computer about the logical manipulation of symbols. He called it how we think. And so it came to be called a thinking machine. Wasn't a machine, but a thought.

Now, a very remarkable young lady, remarkable first of all because she was a lady,and secondly because she was a professor of philosophy, observed that we had three technologies out there that had one thing in common. What was it? They all had to do with the manipulation of symbols in one way or another. Her name was Suzanne Langer,and her book was called *Philosophy in a New Key*. And she turned attention to the processing of symbols.

Now, remember, synthetic thinking was beginning to emerge, and so for the first time, people began to ask what happens when you put things together instead of taking them apart? And when you put these three things together,what do you get? Lo and behold what you get is a mind. The first Industrial Revolution was about muscle,about the application of energy to matter to transform it. Here is a whole new technology which is a substitute for mind, because it communicates and observes and it can think. And so, automation, rather than mechanization, becomes the key concept of the post-Industrial Revolution or the systems age.

Now, I don't want to take any more time, but it's easy to show that the interest in design and quality and learning, all derive from the same transformation in our concept of the nature of reality.

Thank you.