A Complexity Science Primer:

What is Complexity Science and Why Should I Learn About It?

Adapted From: *Edgeware: Lessons From Complexity Science for Health Care Leaders*, by
Brenda Zimmerman, Curt Lindberg, and Paul Plsek, 1998, Dallas, TX: VHA Inc.
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This paper is called a 'primer' because it is intended to be a first step in understanding complexity science. In house painting, the primer or prime coat is not the finished surface. A room with a primer on the walls often looks worse than before the painting began. The patchy surface allows us to see some of the old paint but the new paint is not yet obvious. It is not the completed image we want to create. But it creates the conditions for a smoother application of the other coats of paint, for a deeper or richer color, and a more coherent and consistent finish. As you read this primer, keep this image in mind. This paper is not the finished product. Ideas and concepts are mentioned but only given a quick brush stroke in this primer. You will need to look to the other resources in this kit to get a richer color of complexity.

Complexity science reframes our view of many systems which are only partially understood by traditional scientific insights. Systems as apparently diverse as stock markets, human bodies, forest ecosystems, manufacturing businesses, immune systems, termite colonies, and hospitals seem to share some patterns of behavior. These shared patterns of behavior provide insights into sustainability, viability, health, and innovation. Leaders and managers in organizations of all types are using complexity science to discover new ways of working.

Why would leaders be interested in complexity science? In a recent research project with health care executives, we uncovered two inter-related reasons for the interest: frustration and resonance.

> *"At first learning about complexity science and what it suggested about leadership was confusing, even stressful. Once I began to learn it, to understand it, and to discuss it with other professionals, it began to make sense... I really believe in it... In complexity science I'm learning that leaders of modern organizations have got to take on a different roles - especially in this health care revolution."*
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> *John Kopicki, CEO,*
> *Muhlenberg Regional Medical Center,*
> *Plainfield, NJ.*

There is a frustration with some of the traditional clinical and organizational interventions in health care. The health care leaders in the study said they no longer trusted many of the methods of management they had been taught and practiced. They didn't believe in the strategic plans they wrote because the future was not as predictable as it was depicted in the plans. They saw intensive processes of information gathering and consensus building in their organizations where nothing of substance changed. They were working harder and feeling like much of their hard work had little or no impact. Complexity science offered an opportunity to explore an alternative world view. Complexity science held a promise of relief from stress but also suggested options for new interventions or ways of interacting in a leadership role.

The second "hook" for health care leaders was resonance. Complexity science resonated with or articulated what they were already doing. It provided the language and models to explain their intuitive actions. By having a theory to explain what they 'knew' already, they felt they could get better leverage from their intuitive knowledge and use it more confidently.

Although we are in the early days of deliberately applying complexity science inspired approaches in organizations, we are gathering evidence of leaders applying the ideas to general management and leadership, planning, quality improvement, and new service development. Some of the application projects have generated positive results while others are still works in progress. Complexity science holds promise to have an important impact on organizational performance.

Comparing complexity science with traditional science

Complexity science addresses aspects of living systems which are neglected or understated in traditional approaches. Existing models in economics, management and physics were built on the foundation of Newtonian scientific principles. The dominant metaphor in Newtonian science is the machine. The universe and all its subsystems were seen as giant clocks or inanimate machines. The clocks or machines can be explained using reductionism - by understanding each part separately. The whole of the machine is the sum of the parts. The clockware perspective has led to great discoveries by focusing on the attributes and functioning of the 'parts' - whether of a human body or a human organization. The parts are controlled by a few immutable external forces or laws. The parts are not seen to have choice or self determination. The 'machines' are simple and predictable - you need only understand the few guiding external rules which determine how the parts will behave. There are limits to this perspective when understanding living systems, and in particular human organizations. Clearly humans are not machine parts without individual choice and so clockware is a necessary but not sufficient way of understanding complex systems.

The Newtonian perspective assumes that all can be explained by the careful examination of the parts. Yet that does not work for many aspects of human behavior. We have all experienced situations in which the whole is not the sum of the parts - where we cannot explain the outcomes of a situation by studying the individual elements. For example, when a natural disaster strikes a community, we have seen spontaneous organization where there is no obvious leader, controller or designer. In these contexts, we find groups of people create outcomes and have impacts which are far greater than would have been predicted by summing up the resources and skills available within the group. In these cases, there is self-organization in which outcomes emerge which are highly dependent on the relationships and context rather than merely the parts. Stuart Kauffman calls this "order for free" and Kevin Kelly refers to it as "creating something out of nothing."

Complexity science is not a single theory. It is the study of complex adaptive systems - the patterns of relationships within them, how they are sustained, how they self-organize and how outcomes emerge. Within the science there are many theories and

> *"I found a lot of what we did [in management] was really dumb. It was very impersonal. We treated people as if they were one-dimensional. If you figure them out, give them strict rules, put money in front of them, they will perform better...it was very linear."*
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> *James Taylor*
> *President and CEO*
> *University of Louisville Hospital*
> *Louisville, Kentucky*

concepts. The science encompasses more than one theoretical framework. Complexity science is highly interdisciplinary including biologists, anthropologists, economists, sociologists, management theorists and many others in a quest to answer some fundamental questions about living, adaptable, changeable systems.

From physics envy to biology envy

There has been an implicit hierarchy of sciences with physics as the most respectable and biology as the conceptually poor cousin. Physics is enviable because of its rigor and immutable laws. Biology on the other hand is rooted in the messiness of real life and therefore did not create as many elegantly simple equations, models or predictable solutions to problems. Even within biology there was a hierarchy of studies. Mapping the genome was more elegant, precise and physics -like, hence respectable, whereas evolutionary biology was "softer," dealing with interactions, context and other dimensions which made prediction less precise. Physics envy was not only evident in the physical and natural sciences but also in the social sciences. Economics and management theory borrowed concepts from physics and created organizational structures and forms which tried (at some level at least) to follow the laws of physics. These were clearly limited in their application and "exceptions to the rules" had to be made constantly. In spite of the limitations, an implicit physics envy permeated management and organization theories.

Recently, we have seen physics envy replaced with biology envy. Physicists are looking to biological models for insight and explanation. Biological metaphors are being used to understand everything from urban planning, organization design, and technologically advanced computer systems. Technology is now mimicking life - or biology - in its design. The poor cousin in science has now become highly respectable and central to many disciplines. Complexity science is a key area where we witness this bridging of the disciplines with the study of life (or biology) as the connecting glue or area of common interest.

For organizational leaders and managers, the shift from physics envy to biology envy provides an opportunity to build systems which are sustainable because of their capacity to "live". Living organizations, living computer systems, living communities and living health care systems are important because of our interest in sustainability and adaptability. Where better to learn lessons about sustainability and adaptability than from life itself.

Complexity questions

The questions asked by complexity scientists in the physical, natural and social sciences are not little questions. They are deep questions about how life happens and how it evolves. The questions are not new. Indeed, some of the 'answers' proposed by complexity science are not new. But in many contexts, these 'answers' were not explainable by theory . They were the intuitive responses that were known by many but appeared illogical or at least idiosyncratic when viewed through out traditional scientific theories. Complexity science provides the language, the metaphors, the conceptual frameworks, the models and the theories which help make the idiosyncrasies non-idiosyncratic and the illogical logical. For some leaders who are studying complexity, the science is counterintuitive because of the stark contrast with what they had been taught about how organizations should operate. Complexity science describes how systems actually behave rather than how they should behave.

> *"It is a curious thing... at least for me it has been. It is both mind expanding because of new notions but it also seems like it is affirming of stuff you already know. It is quite paradoxical."*
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> *James Roberts, MD,*
> *Senior Vice-President,*
> *VHA Inc., Irving, Texas*

Complexity science provides more than just explanations for some of our intuitive understandings. It also provides a rigorous approach to study some of the key dimensions of organizational life. How does change happen? What are the conditions for innovation? What allows some things to be sustained even when they are no longer viable? What creates adaptability? What is leadership in systems where there is no direct authority or control?

What does strategic planning mean in highly turbulent times? How do creativity and potential get released? How do they get trapped? Traditional management theories have focused on the predictable and controllable dimensions of management. Although these dimensions are critical in organizations, they provide only a partial explanation of the reality of organizations. Complexity science invites us to examine the unpredictable, disorderly and unstable aspects of organizations. Complexity complements our traditional understanding of organizations to provide us with a more complete picture.

That is the good news about complexity science. There is also some bad news. Complexity science is in its infancy. It is an emerging field of study. There are few proven theories in the field. It has not yet stood the test of time. But it has become a movement. Unlike some other movements in the management arena, the complexity science movement spans almost every discipline in the physical, natural and social sciences. There is often a huge schism between those who study the world using quantitative approaches and those who use qualitative methods.

> *"Out of nothing, nature makes something. How do you make something from nothing? Although nature knows this trick, we haven't learned much just by watching... [Life's] reign of constant evolution, perpetual novelty, and an agenda out of our control... is far more rewarding than a world of clocks, gears, and predictable simplicity."*
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> *Kevin Kelly*
> *Out of Control*

Complexity has created a bridge or a merger of quantitative and qualitative explanations of life. It has attracted some of the greatest thinkers in the world including some of the most highly respected organization theorists and Nobel prize winners in physics, mathematics and economics. It has also attracted poets, artists and theologians who see the optimism implicit in the science. By examining how life happens from a complexity perspective, we seem to have increased our reverence for life - the more we understand, the more we are amazed.

Definition of Complex Adaptive System

The next two sections of the paper need a "warning to reader" label. They are filled with the new jargon of complexity science. Each new term is a quick brush stroke in this primer but is explained in greater detail in other sections of this resource kit. For the reader new to the field of complexity, read the next two sections to get the overall sense of complexity science. You do not need to understand every term at the outset to start the journey into understanding complexity.

Complex adaptive systems are ubiquitous. Stock markets, human bodies, forest ecosystems, manufacturing businesses, immune systems and hospitals are all examples of CAS. What is a complex adaptive system (CAS)? The three words in the name are each significant in the definition. 'Complex' implies diversity - a great number of connections between a wide variety of elements. 'Adaptive' suggests the capacity to alter or change - the ability to learn from experience. A 'system' is a set of connected or interdependent things. The 'things' in a CAS are independent agents. An agent may be a person, a molecule, a species, or an organization among many others. These agents act based on local knowledge and conditions. Their individual moves are not controlled by a central body, master neuron or CEO. A CAS has a densely connected web of interacting agents each operating from their own schema or local knowledge. In human systems, schemata are the mental models which an individual uses to make sense of their world.

Description of complex adaptive systems

CAS have a number of linked attributes or properties. Because the attributes are all linked, it is impossible to identify the starting point for the list of attributes. Each attribute can be seen to be both a cause and effect of the other attributes. The attributes listed are all in stark contrast to the implicit assumptions underlying traditional management and Newtonian science.

CAS are embedded or nested in other CAS. Each individual agent in a CAS is itself a CAS. In an ecosystem, a tree in a forest is a CAS and is also an agent in the CAS of the forest which is an agent in the larger ecosystem of the island and so forth. In health care, a doctor is a CAS and also an agent in the department which is a CAS and an agent in the hospital which is a CAS and an agent in health care which is a CAS and an agent in society. The agents co-evolve with the CAS of which they are a part. The cause and effect is mutual rather than one-way. In the health care system, we see how the system is co-evolving with the health care organizations and practitioners which make up the whole. The entire system is emerging from a dense pattern of interactions.

Diversity is necessary for the sustainability of a CAS. Diversity is a source of information or novelty. As John Holland argues, the diversity of a CAS is the result of progressive adaptations. Diversity which is the result of adaptation also becomes the source of future adaptations. A decrease in diversity reduces the potential for future adaptations. It is for this reason that biologist E.O. Wilson argues that the rain forest is so critical to our planet. It has significantly more diversity - more potential for adaptation - than any other part of the planet. The planet needs this source of information and potential for long-term survival. In organizations, diversity is becoming seen as a key source of sustainability. Psychological profiles which identify individuals' dominant thinking styles have become popular management tools to ensure there is a sufficient level of diversity, at least in terms of thinking approaches, within teams in organizations. Diversity is seen as a key to innovation and long term viability.

Many of us were taught that biological innovation was due in large part to genetic random mutations. When these random mutations fit the environment better than their predecessor they had a higher chance of being retained in the gene pool. Adaptation or innovation by random mutation of genes explains only a small fraction of the biological diversity we experience today. Crossover of genetic material is a million times more common than mutation in nature according to John Holland. In essence, crossover suggests a mixing together of the same building blocks or genetic material into different combinations. Understanding this can lead to profound insights about CAS. The concept of genetic algorithms is paradoxical in that building blocks, genes or other raw elements which are recombined in a wide variety of ways are the key to sustainability. Yet the process of manipulating these blocks only occurs when they are in relationship to each other. In genetic terms, this means the whole string on a chromosome. Holland argues that "evolution remembers combinations of building blocks that increase fitness." It is the relationship between the building blocks which is significant rather than the building blocks themselves. The focus is on the inter-relationships.

In organizational terms, this suggests that it is not the individual that is most critical but the relationships between individuals. We see this frequently in team sports. The team with the best individual players can lose to a team of poorer players. The second team cannot rely on one or two stars but instead has to focus on creating outcomes which are beyond the talents of any one individual. They create outcomes based on the interrelationships between the players. This is not to dismiss individual excellence. It does suggest that individual abilities is not a complete explanation of success or failure. In management terms, it shifts the attention to focus on the patterns of interrelationships and on the context of the issue, individual or group.

CAS have distributed control rather than centralized control. Rather than having a command center which directs all of the agents, control is distributed throughout the system. In a school of fish, there is no 'boss' which directs the other fishes' behavior. The independent agents (or fish) have the capacity to learn new strategies and adaptive techniques. The coherence of a CAS' behavior relates to the interrelationships between the agents. You cannot explain the outcomes or behavior of a CAS from a thorough understanding of all of the individual parts or agents. The school of fish reacts to a stimulus, for example the threat of a predator, faster than any individual fish can react. The school has capacities and attributes which are not explainable by the capacities and attributes of the individual agents. There is not one fish which is smarter than the others who is directing the school. If there was a smart 'boss' fish, this form of centralized control would result in a school of fish reacting at least as slow as the fastest fish could respond. Centralized control would slow down the school's capacity to react and adapt.

Distributed control means that the outcomes of a complex adaptive system emerge from a process of self-organization rather than being designed and controlled externally or by a centralized body. The emergence is a result of the patterns of interrelationships between the agents. Emergence suggests unpredictability - an inability to state precisely how a system will evolve.

Rather than trying to predict the specific outcome of emergence, Stuart Kauffman suggests we think about fitness landscapes for CAS. A CAS or population of CAS are seen to be higher on the fitness landscape when they have learned better strategies to adapt and co-evolve with their environment. Being on a peak in a fitness landscape indicates greater success. However, the fitness landscape itself is not fixed - it is shifting and evolving. Hence a CAS needs to be continuously learning new strategies. The pattern one is trying to master is the adaptive walk or capacity of a CAS to move on fitness landscapes towards higher, more secure positions.

The co-evolution of a CAS and its environment is difficult to map because it is non-linear. Linearity implies that the size of the change is correlated with the magnitude of the input to the system. A small input will have a small effect and a large input will have a large effect in a linear system. A CAS is a non-linear system. The size of the outcome may not be correlated to the size of the input. A large push to the system may not move it at all. In many non-linear systems, you cannot accurately predict the effect of the change by the size of the input to the system.

> *"Some people really want to stop controlling, but are afraid. Everywhere things are changing, creating high degrees of uncertainty and anxiety. And the more anxious you are, the more in control you need to be. Making all this even worse, we've bought into the myth that leaders have all the answers. Managers who accept this myth have their levels of anxiety ratcheted up again. ...If complexity theory can begin freeing managers from this myth of control, I think you'll see people a whole lot more comfortable."*
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> *Linda Rusch*
> *Vice President of Patient Care*
> *Hunterdon Medical Center*
> *New Jersey*

Weather systems are often cited as examples of this phenomenon of nonlinearity. The butterfly effect, a term coined by meteorologist Edward Lorenz, is created, in part, by the huge number of non-linear interactions in weather. The butterfly effect suggests that sometimes a seemingly insignificant difference can make a huge impact. Lorenz found that in simulated weather forecasting, two almost identical simulations could result in radically different weather patterns. A very tiny change to the initial variables, metaphorically something as small as a butterfly flapping its wings, can radically alter the outcome. The weather system is very sensitive to the initial conditions or to its history.

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An example in an organizational setting of non-linearity is the huge effort put into a staff retreat or strategic planning exercise where everything stays the same after the 'big push'. In contrast, there are many examples of one small whisper of gossip - one small push - which creates a radical and rapid change in organizations.

Non-linearity, distributed control and independent agents create conditions for perpetual novelty and innovation. CAS learn new strategies from experience. Their unique history helps shape the path they take. Newtonian science is ahistorical - the resting point or attractor of the system is independent of its history. This is the basis of neo-classical economics and is the antithesis of complexity.

Complex adaptive systems are history dependent. They are shaped and influenced by where they have been. This may seem obvious and trivial. But much of our traditional science and management theory ignore this point. What is good in one context, makes sense in all contexts. Marketers talk about rolling out programs that were effective in one place and hence should be effective in all. In traditional neo-classical economics, there is an assumption of equifinality - it does not matter where the system has come from, it will head towards the equilibrium point. Outliers or minor differences in the starting point or history of the system are ignored. The outlier or difference from the normal pattern is assumed to be dampened and hence a 'blip' is not important. Brian Arthur's work in economics has radically altered this viewpoint. For example, he cites evidence of small differences fundamentally altering the shape of an industry. The differences are not always dampened but may indeed grow to reshape the whole. Lorenz referred to this in meteorology as sensitive dependence to initial conditions which was discussed earlier as the butterfly effect. In economics, in nature, in weather and in human organizations, we see many examples where understanding history is key to understanding the current position and potential movement of a CAS.

CAS are naturally drawn to attractors. In Newtonian science, an attractor can be the resting point for a pendulum. Unlike traditional attractors in Newtonian science which are a fixed point or repeated rhythm, the attractors for a CAS may be strange because they may have an overall shape and boundaries but one cannot predict exactly how or where the shape will form. They are formed in part by non-linear interactions. The attractor is a pattern or area that draws the energy of the system to it. It is a boundary of behavior for the system. The system will operate within this boundary, but at a local level - we cannot predict where the system will be within this overall attractor.

A dominant theme in the change management literature is how to overcome resistance to change. Using the concept of attractors, the idea of change is flipped to look at sources of attraction. In other words, to use the natural energy of the system rather than to fight against it. The non-linearity property of a CAS means that attractors may not be the biggest most obvious issues. Looking for the subtle attractors becomes a new challenge for managers.

> *"In the past, when managers have tried to implement change, they'd find themselves wasting energy fighting off resistors who felt threatened. Complexity science suggests that we can create small, non-threatening changes that attract people, instead of implementing large-scale change that excites resistance. We work with the attractors."*
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> *Mary Anne Keyes, R.N.*
> *Vice President, Patient Care*
> *Muhlenberg Regional Mediacal Center*
> *Plainfield, NJ*

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CAS thrive in an area of bounded instability on the border or edge of chaos. In this region, there is not enough stability to have repetition or prediction, but not enough instability to create anarchy or to disperse the system. Life for a CAS is a dance on the border between death by equilibrium or death by dissipation. In organizational settings, this is a region of highly creative energy.

Why is complexity science relevant now?

The seeds for complexity science have been around for a long time. The founding parents of complexity science were often far ahead of their time. Why is now the right time for complexity science? More specifically, why is this the time for complexity science studies of human organizations? Turbulence, change, adaptability and connectedness are not new to the late 20th century. There are at least four reasons why now is the time for complexity science:

1. the limit to the machine metaphor
2. the coming together of biology and technology
3. the connections between studies of "micro" and "macro" phenomena,
4. the apparent compressions of space and time.

The first three reasons will be outlined briefly in this section. The last reason, the compression of space and time, will be described in the next section.

Complexity science is a direct challenge to the dominance of the machine metaphor. Since Newton, the machine metaphor has been used as the lens to make sense of our physical and social worlds, including human organizations. The machine metaphor has been a powerful force in creating manufacturing, medical and organizational advances. However, its limits are now becoming more obvious. It is as if we have collectively learned all we can from the machine metaphor and will continue to use that knowledge where appropriate. But we have more and more instances where the machine metaphor is simply not helpful. For example, it does not explain the emergent aspects of an organization's strategy or the evolution of an industry. Complexity science, with its focus on emergence, self-organization, inter-dependencies, unpredictability and nonlinearity provides a useful alternative to the machine metaphor.

In addition to changing the metaphor to interpret events, complexity science is gaining momentum because of the coming together of biology and technology. Biologists are using technology to understand biology, for example, in biotechnology. Computer technologists are using biology to create computer software which has some life-like characteristics. Without the technological advancements, due in part from the machine metaphor, we would not be able to replicate nature's fractal forms, or understand the implicit process rules that allow flocks of birds to move as one, or explain the chaotic heart rates of healthy humans. Complexity science is understandable to us now because of both the advances in technology and the increased respect for biological lessons.

Complexity science brings together the two solitudes of micro-studies and macro-analysis. For example, the micro studies of the human genome and the macro studies of evolutionary biology are coming together with complexity science. The lessons from the micro studies are informing the macro analysis and the lessons from the macro studies are informing the micro. This second learning - the macro informing the micro - has been underplayed in our search for applying Newtonian scientific thinking to life. A Newtonian perspective suggests that the parts can explain the whole. Therefore, the quest is to study the parts in greater and greater detail. Complexity science suggests that the whole is not the sum of the parts. Emergent properties of the whole are inexplicable by the parts. In complexity, studies of natural and human systems are explained by both kinds of analysis - micro (or analysis of the parts) and macro (or holistic analysis).

Murray Gell-Mann, a Nobel Prize winner, discovered and named the quark - clearly a study of micro parts. But his journey of discovery into the tiniest parts led him to a path of holistic understanding and an appreciation for ecology. His book "The Quark and the Jaguar" exemplifies this coming together of the appreciation of the micro and macro analysis. E.O. Wilson, a renowned biologist, argued that we are seeing the confluence of the two major foundations of biology: (1) the molecular basis of life, and (2) the evolutionary basis for human (and ecosystem) behavior. This has profound impacts on our understanding of organizational health. Some interventions are seen to be context dependent - we cannot explain the micro functioning without understanding the macro context. The health of a community or organization impacts the well-being of the individuals within them. Complexity provides us with the opportunity to look at problems with multiple perspectives, studying the micro and macro issues and understanding how they are interdependent.

This section provided some explanations for the complexity science movement in the physical and natural sciences. But there is an additional explanation for its power in social systems - the compression of time and space. The next section describes this seemingly esoteric issue. Some readers may not feel the need to understand the roots of complexity from this perspective and may skip ahead to the section which addresses the paradoxes of complexity.

The compression of time and space

One of the unique dimensions of the late 20th century is the apparent compression of space and time. Why should health care leaders care about something as seemingly esoteric as the compression of space and time? Most of the models of organization, methods to improve performance, and measurement concepts which dominate the management field today were created with the implicit assumption of space and time lags. In other words, they were designed for a world which in many instances no longer exists. When these approaches are tried in contexts where there is this space-time compression, the results are often frustration, stress and lack of improvement. This section of the paper will demonstrate the compression of space in time using examples from manufacturing, banking and health care.

Dee Hock, the founding CEO of VISA, refers to the major impact the compression of time has had in financial markets. In the past, there was an expectation of a time lag (or 'float') between the initiation and completion of most financial transactions. For example, if you purchase an item on credit there is a time lag between when you make the transaction and when the cash is paid to the supplier. We have elaborate systems designed to take advantage of this float. This luxury of a time lag (or 'float') disappears with the use of debit cards or equivalent systems of real-time transfer of funds.

Hock argues this same reduction of time lags happens with information today. We used to have the luxury of a time lag between the discovery of an idea and the application into practice. This time lag is almost non-existent in many aspects of society today. In health care, medical research is reported on (often in 'sound bites' on the news). The public access to medical research has often created a push to put the ideas into application immediately.

An example of a time lag reduction that has had a remarkable impact on manufacturing around the world is the idea of 'just in time' inventory systems. The idea was a simple one, eliminate the need for storing, financing and managing inventories by creating real-time order and delivery systems between suppliers and producers. When the concept was first introduced there were many skeptics. Yet in a very short period of time, this was standard practice in many (perhaps most) manufacturing industries. Just in time inventory changed the relationship between suppliers and producers. It was both facilitated by the improvement in technology and shaped new improvements in technology to get the most benefit from the concept. Boundaries became blurry between what was "in the organization" and what was "outside". Networks were created to minimize the potential problems if a supplier could not provide the needed goods on time. The definition of success for a supplier was altered and new skills of flexibility were needed in the employees and the physical production systems.

Case Study: Time & Space Compression

At a large hospital in Montreal, a change in procedures demonstrates this compression of time and space. Recently the hospital administrators made a decision to eliminate all radiology film from the hospital. Instead, x-ray images were stored in computer files and doctors viewed them on their computer screens. Films which traditionally needed to be handled, processed and delivered through intermediaries were now directly available from the radiology department to the surgeons or other direct service providers. After hearing how quickly and radically this changed the ability of the radiology department to serve the patient care physicians, several hospitals in Toronto are planning to eliminate radiology film. In this example, film and all of its associated people and systems were intermediaries which created both time and space lags between the tests and the reading or interpretation of the tests.

In terms of compression of space, we can now bypass many of the intermediaries in our society. Intermediaries play the role of a bridge between organizations or individuals. When we can access the organization or individual directly rather than through an intermediary, we are again witnessing a compression of space.

The financial service industry is another case where this compression of time and space can be demonstrated. Technology has allowed us to bridge huge distances and create connections which permit simultaneous creation and dissemination of information. We see this reduction of time lags in banking where the currency float of a few years ago has shrunk to a point of being virtually non-existent. Money can be transferred instantly between individuals, organizations and countries. The increased degree of connectedness aided by technology has eliminated some of the intermediaries in our society. One of the banks' prime roles was to be the intermediary between those who had money to loan and those who had need to borrow money. For a price, the banks would match the players. Today, this is becoming less significant. When the information of who has money and who needs money is more widely available, many corporations are bypassing the intermediary role of the bank. This is not unique to financial services. Due to the technology which allows increased connectedness, in many industries one can go directly to the source of the information, product or service.

In our organizations, intermediaries are often layers of management or supervision. Part of their job is to bridge the gap between the providers of service or front-line workers and upper management. Bridging the gap creates time lags in our organizations. These lags provide the information float and hence the luxury (and sometimes the frustration) of time delays. But these intermediary positions are being eliminated in many industries through downsizing. If the positions are eliminated but the role of intermediation and the expectation of float still exist as old mental models, we will simply see over-worked employees trying to fulfill the same roles but with less resources and less success.

> *"The tendency of people in positions of power is to believe that they can control and they believe in the power of 'let us figure it out.' 'Let's hire the experts, let us sit in a room, figure it out and then it'll happen.' That is a common theme and it's one that I just don't believe in."*
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> *James Taylor*
> *President and CEO*
> *University of Louisville Hospital*
> *Louisville, Kentucky*

Intermediaries also imply external 'designers' of a system. The designers are distanced from the deliverers of the service. This is a separation of thought and action in both space and time. The planners plan and others implement - a separation in space. The plans are created first and predetermine the action steps to take - a separation in time. Complex adaptive systems have the capacity to adapt and evolve without an external designer. They self-organize without either external or centralized control.

In highly interconnected contexts, where there is a compression of time and space, the assumptions of float, intermediaries and external designers are problematic. Many management models, such as traditional strategic planning processes, are built on the assumptions of float, intermediaries and external designers. When these assumptions hold, the models are relevant and useful. They can improve effectiveness and efficiency in organizations. When the assumptions are invalid, these models can lead to an illusion of control but an actual loss of effectiveness and adaptability.

Some of the paradoxes of complexity

Complexity science is highly paradoxical. As you study the world through a complexity lens you will be continually confronted with 'both-and' rather than 'either-or' thinking. The paradoxes of complexity are that both sides of many apparent contradictions are true.

The first of these paradoxes is that the systemic nature of a CAS implies interdependence yet each of the elements which are interdependent are able to act independently. Interdependence and independence co-exist.

Another paradox in complexity is that simple patterns of interaction can create huge numbers of potential outcomes. Simplicity leads to complexity. CAS operate in a context that is frequently unpredictable; not merely unknown but unknowable. Yet it is the agents' propensity to predict based on schema of local conditions that allow them to act in an apparently coherent manner.

Complexity science is the study of living systems but living systems die. As a metaphor associated with life, it needs to encompass all aspects of the life cycle. Death is part of this cycle. The traditional management literature's depiction of the life cycle begins at birth and ends at decline. Complexity also includes the study of death and renewal.

"As a physician, I learned to think from a biological perspective. When I went into management, traditional organizational theory seemed artificial, foreign to my experience. So when I started studying complexity, I was stunned. Here was a way of thinking about organizations hat compared them to living things. That makes sense to me, intuitively."

Richard Weinberg, MD
Vice President,
Network Development
Atlantic Health System
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Complexity is a metaphor

A recent article in a popular magazine argued that we needed to distinguish between complexity researchers who were using the 'theory' from those who were using the 'metaphor'. What that statement missed is that all science is metaphor, as Gareth Morgan argues. It is metaphor which shapes our logic and perspective. Metaphor influences the questions we ask and hence the answers we find. A powerful metaphor becomes deeply rooted in our ways of understanding and is often implicit rather than explicit. In biological terms, a metaphor is the schema by which we make sense of our situation.

Complexity science presents a contrast to the dominant scientific and organizational metaphor and thereby challenges us to see what other questions we can ask about the systems we are studying or living within. The metaphor of systems as mechanical or 'machines' has shaped our studies in physics, biology, economics, medicine and organizations. Complexity is about reframing our understanding of many systems by using a metaphor associated with life and living systems rather than machines or mechanical systems. Viewing the world through a complexity lens means understanding the world from biological concepts.

The inquiry continues

It is normal to finish a paper with a conclusion - to end with a summary of the key points and implications. Yet consistent with both the science of complexity and the state of its development, it seems more appropriate to end with questions. The questions can be viewed from five levels of analysis:

1. sector
2. regional network
3. institution or organization
4. division, department or work group
5. individual person

Some of the questions below are aimed at one of the levels but most can be used for any level. We invite you to participate with us in this inquiry as it applies to Your organization or sector health care. **The overall question is, how can complexity science improve management and the health of organizations?**

Some of the other questions to ponder are:

- ☐ How does co-evolution impact the role of a leader? If everything is changing and I am part of that change, how do I plan?
- ☐ If a CAS self-organizes, what is the job of manager or leader of a CAS?
- ☐ Can we use ideas of self-organization to unleash the full potential of our staff?
- ☐ Can we create the conditions for emergence as two or more organizations are coming together in a merger?
- ☐ What do we have to change to improve the quality of our services and reduce costs? Can complexity science provide us with any insights to this question?
- ☐ If an organization is a CAS, what does this imply about strategic planning?
- ☐ Can we use insights from complexity to improve the health of communities?
- ☐ If the edge of chaos is the area of greatest innovation, how do we stay on the edge of chaos? What are the risks of staying on the edge?
- ☐ What organizational structures, designs, processes etc. are consistent with a complexity science perspective? How would implementing these 'complex' ideas improve organizations and the services they offer?
- ☐ How can we ensure complexity science enhances and complements proven management approaches? Where and when does complexity science add most value? Where are "traditional" approaches more appropriate?