American Journal of Systems Science 2013, 2(1): 13-22
DOI: 10.5923/j.ajss.20130201.03

System Theories: An Overview of Various System Theories and Its Application in Healthcare

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Abstract Throughout the course of human evolution, humans have been solving complex problems. In this paper, various system theories such as General Systems Theory, Chaos Theory, Complex-Adaptive Systems, and Integral Theory are described and discussed within the context of the human body. Different systems of varying context, such as: (1) when facilitating sustainable changes in organizations; (2) when promoting the unification of health care teams to enhance patient care; and (3) when explaining treatment principles in oncology, are also described and discussed in this paper, using systems theory as a framework. Systems theory has many applications, not only in leadership and organization, but also in oncology. Leaders need to be systems thinkers in order to facilitate sustainable change in their organizations.

Keywords Systems Theories, Health Care, General Systems Theory, Chaos Theory, Complex-Adaptive Systems, Integral Theory, Oncology

1. Introduction

Throughout the course of human evolution, humans have been solving complex problems. There are multiple, hierarchical, and complex systems that exist in the world, which make problem solving challenging. Philosophers like Aristotle and Descartes have conceptualized how to best address systemic complex problems. Aristotle described the importance of looking at systems as a whole, and introduced the notion that the whole is greater than sum of its parts. Descartes, on the other hand, introduced the idea of solving problems by breaking down large complex problems into smaller manageable portions. Over the years, these philosophies have evolved, and various theories about systems have emerged.

It is important to understand how systems work, in order to affect sustainable change. There are many different types of systems, ranging from mechanical systems such as clocks, to computer systems, and natural/organic systems. Systems involving humans tend to be the most complicated.

The goal of this paper is to provide healthcare professionals with concrete examples of how system theories can be used in analyzing complicated issues in health care.

In this paper, a definition of a system is provided, and various types of systems are identified. Various systems theories such as General Systems Theory, Chaos Theory, Complex-Adaptive Systems, and Integral Theory are described and examples are provided within the context of the human body. Finally, using systems theory as a framework, various issues within the health care system is discussed in detail such as: (1) when facilitating sustainable changes in organizations; (2) when promoting the unification of health care teams to enhance patient care; and (3) when explaining treatment principles in oncology.

2. Systems and Systems Thinking

A system is defined as "a regularly interacting or interdependent group of items forming a unified whole"[12], and as "a group of devices or artificial objects or an organization forming a network especially for distributing something or serving a common purpose[12]. Meadows (2009) defined system as "a set of things–people, cells, molecules, or whatever – interconnected in such a way that they produce their own pattern of behavior over time"[11]. These definitions are consistent with other existing definitions of a system, as they share four common elements: (1) having a group of objects, molecules, or forces; (2) the relationships and interactions between the groups within their environment; (3) how these groups make up a larger whole; and (4) the function or purpose of the elements within the group, that affects the function or purpose of the group as a whole. Understanding how systems work, and the various factors that affect a system, have been an area of interest for leaders and researchers in the field of social sciences, biology, human and organizational psychology, business, and in other disciplines.

There are different types of systems. Systems may be open or closed, simple or complex. A complex system is one that

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Published online at http://journal.sapub.org/ajss

includes many other micro-systems, or a network of systems, thus forming a much larger and complex system. Bertalanffy identified various systems and listed them in hierarchical order of complexity[17]. Examples of systems, listed in hierarchical order includes, static structures, clock works, control mechanisms, open systems, lower organisms, animals, man, socio-cultural systems, and symbolic systems [17]. Atoms, molecules, and biological structures at the microscopic levels are called static structures[17].

Conventional machines, like clocks, are another example of a simple system. Control mechanisms, which include feedback loops such as thermostats, are a little bit more complex as it involves a flow of communication between the structures in the system[17]. Humans are a much more complex system, as the human body involves multiple systems. For example, the human body is comprised of several organ systems, such as the digestive system, cardiac system, respiratory system, muscular system, nervous system, circulatory system, reproductive system, integumentary system, and excretory system. These systems work together and communicate with each other, to create homeostasis or balance. Each system has a function, and it interacts with other systems. These systems also react to the environment or the external forces that lie outside of the body. The flight-or-fight response mechanism in humans is an example of a well-developed and complex system. For example, when an external stimulus such as a lion, is introduced in a person's immediate environment, a network of interconnected nerves within that person's nervous system picks up this signal and sends it to the brain. The brain, in response, interprets the information as a threat, releases hormones, and the nervous system sends this information to other parts of the system. The network of nerves, are connected to all of the systems in the body. The cells within the systems are also connected to the nerves. When the signals are received by the cardiac system, it will respond to the signal by causing the heart to beat faster. The rest of the systems will also receive the signal, and will elicit specific physiological responses. As a result, physiological changes such as hyperventilation, sweating, and feeling hot, may occur.

Although the body's response to the stimulus initially follows a basic pattern, the response of the different systems may vary, causing a different reaction or behaviour for different people. The flow of information between the systems causes decision points and action points[11]. Some people might feel the need to run away from the lion, while others might feel the need to fight the lion. Different people, depending on their past knowledge and experience, will react differently to the stimulus presented.

When a group of people are interacting together in an environment, much more complicated systems develop. These systems include socio-cultural systems, and symbolic systems. In addition, information systems, as part of this larger and complicated system, also become much more complicated as new structures emerge, new relationships and social systems are formed, hierarchy and rules develop, and intangible elements, such as culture and beliefs, are created. Despite the complexities, all of these elements are interconnected and play a role with within a larger system. Systems also have the ability to "change, adapt, respond to events, seek goals, mend injuries, and attend to their own survival in lifelike ways" (Meadows, 2009, p. 12).

According to Meadows (2009), a system can lose its 'system-ness' when the multiple inter-relations that held it together no longer function and dissipates[11]. Again, looking at the biological structure of a man, if the interconnected nerves stopped functioning, then the transfer of information and signals to the other organ systems will also not occur. For example, if the nerves that innervate the respiratory system and the cardiac system stopped sending signals to the heart and lungs, the heart and lungs will cease to function, ultimately causing death.

One of the greatest attributes of a system is its ability to change and adapt[11]. Again, using the human body as an example, if the nervous system is only partially functional, then other interrelated systems will find ways to compensate for this partial loss, to make the larger system, which is the body, to continue its function. To elaborate on this further, if a small part of the nervous system is affected, such as damage to the 5th thoracic vertebrae of the spinal cord (T5 spinal cord injury), then the flow of information to parts of the body that are innervated by the nerves in that area will also be affected[3]. As the flow of information from the nervous system to other systems, such as the musculoskeletal and excretory system is incomplete, full function of the body will also be incomplete. Depending on the severity of the injury, individuals with this type of injury usually have complete bladder incontinence, and paralysis of the lower body and legs[3]. Although the upper body will try to compensate for the loss of function, other elements, such as a wheelchair, will need to be introduced to the system for the body to maintain homeostasis. In this context, homeostasis means preserving the person's ability to mobilize. Ultimately, the musculoskeletal system in the lower body will continue to deteriorate, and the wheelchair will take its place within this new system. The result is a new functioning system, that is adapted, but not quite the same as the old system.

When new factors or elements are introduced into a complex system, the system behaves differently. Virtually every biological thing in this universe is inter-related and is a part of a system. Understanding how various systems work is a fascinating concept for many theorists, philosophers, and pragmatic thinkers. There are many existing theories on how systems work. Over time, the systems thinking movement emerged, as a way to address problems[8].

2.1. Systems Thinking

Systems thinking is an approach or a methodology to addressing problems[8]. It follows two basic premises, which include looking at reality in terms of wholes, and acknowledging that the environment is an essential part of the system, as it interacts with the system[8]. System thinkers, such as Senge[16], Wheatley[18], Bertalanffy[17], Wilber[19], and Meadows[11], all asserted that in this organic world, where everything is inter-related, there are no linear systems, and that former approaches to solving complex problems by breaking it down into smaller manageable elements are no longer sufficient. Various theories on how systems work, and how a system mends itself to adapt to change, exist. As with many contemporary theories, early documented assertions on systems theory originated from the works of early philosophers such as Aristotle and Descartes.

3. The Evolution of Systems Theory

Systems theory is not a new concept. The notion of thinking about things in wholes rather than parts, have been discussed by early philosophers. Even then, some philosophers have varying perspectives on ways to view the world. For example, Aristotle pondered about the notion of wholeness, whereas Descartes supported the notion of breaking things down into smaller parts. Aristotle and Descartes viewed the living human body in different ways. Aristotle[5] argued that the whole body is much more than the sum of its parts, while Descartes viewed the body as separate from the mind[9].

Aristotle was an ancient Greek philosopher, born in circa 384 B.C, whose work highly influenced western philosophy [1]. According to Aristotle, all things have several parts, and that the whole is different from its parts. Aristotle also talked about connections between bodies or elements that creates unity and one-ness[4]. This is evident in the following passage from *Metaphysics*, written by Aristotle:

In the case of all things which have several parts and in which the totality is not, as it were, a mere heap, but the whole is something beside the parts, there is a cause; for even in bodies contact is the cause of unity in some cases, and in others viscosity or some other such quality. And a definition is a set of words which is one not by being connected together, like the Iliad, but by dealing with one object. What then, is it that makes man one; why is he one and not many[4].

Furthermore, Aristotle argued that there is much more to the living body than just its body parts[5]. He made the comparison between a living body with a dead body; although both have the same composition, they function and exist differently. He also discussed that individual body parts, such as a finger, although part of a whole, cannot function on its own. He argued that there is more to 'being', which means existing in the world in a living body, than just having all of the parts in place. He identified the notion of having a soul, as an essential substance of a living being. The following passages below derived from the work of Aristotle, *On the parts of animals,* describes the notion of a living being:

And yet a dead body has exactly the same configuration as a living one; but for all that is not a man. So also no hand of bronze or wood or constituted in any but the appropriate way can possibly be a hand in more than name. For like a physician in a painting, or like a flute in a sculpture, in spite of its name it will be unable to do the office which that name implies. Precisely in the same way no part of a dead body, such I mean as its eye or its hand, is really an eye or a hand. To say, then, that shape and colour constitute the animal is an inadequate statement, and is much the same as if a woodcarver were to insist that the hand he had cut out was really a hand…

If now this something that constitutes the form of the living being be the soul, or part of the soul, or something that without the soul cannot exist; as would seem to be the case, seeing at any rate that when the soul departs, what is left is no longer a living animal, and that none of the parts remain what they were before, excepting in mere configuration, like the animals that in the fable are turned into stone;[5].

What this passage means is that a hand, with movable fingers and a thumb, when attached to a living person, has its own function. However, that same hand when severed from a living person, although still has the exact same components as the previous hand described, will not function the same way. Similarly, that same hand, if attached to a dead person, will also not function the same way. If the hand was severed and detached from a living person, and then later reattached to the very same person, it may not function as well as it had, in its original form. Additionally, Aristotle also argued that the hand is much more than just its components, and that although it could be replicated using wood, and may look exactly the same, it is not necessarily the same hand. With these postulations, Aristotle was able to argue that the whole living body, is much more than the sum of its body parts[5].

Conversely, Descartes, a French mathematician, physicist, and philosopher, born in circa 1596 A.D., had a different view about the body[2] According to Descartes, the mind is separate from the body; and that they are two separate entities. Descartes compared the body to a machine, and that although the body is more complex, "the movements of this machine can be explained in the same way as the movements of clocks, fountains, or mills"[7]. Descartes was the first to introduce reductionism to western thinking[9]. According to Descartes, "the world can be regarded as a clock-work mechanism; to understand it, one need only investigate the parts and then reassemble each component to recreate the whole"[9]. This reductionist approach to science, informed the work of Newton, and the development of Newtonian epistemology. This worldview states that complexities in the world can be resolved by analyzing and reducing phenomena to their simplest components[9]. Contrary to Aristotle's view, reductionism is a worldview that asserts that a complex system is nothing but the sum of its parts, and that it can be described by describing its individual constituents[12]. In the reductionist approach, individual factors within systems can be analyzed to get a better understanding of the larger whole. The reductionist approach also provided scientists and biologists with a practical approach to understand living organisms in relation to its physical and chemical properties, and it allowed scientists to understand basic cellular and molecular processes[9]. However, it seems that the reductionist approach is inadequate when dealing with organic, complex systems, as these types of systems are always changing. Additionally, there seems to be much more to complex-organic systems than just being the sum of its parts. Thus, the holistic perspective as originally introduced by Aristotle, has been revisited, and various theories on how systems work have emerged.

4. Various System Theories

4.1. General Systems Theory

General systems theory (GST) was developed by a biologist, named Ludwig von Bertalanffy which refers to "a general science of 'wholeness'[17]. According to Bertalanffy, it is important to look at systems as a whole, because in the past, science tried to explain observable phenomena by reducing them to an interplay of elementary units investigable independently of each other. Conceptions appear in contemporary science that are concerned with what is somewhat vaguely termed 'wholeness', i.e., problems of organization, phenomena not resolvable into local events, dynamic interactions manifest in the difference of behavior of parts when isolated or in a higher configuration, etc.; in short, 'systems' of various orders not understandable by investigation of their respective parts in isolation[17].

Bertalanffy identified the need to develop a general theory that can be applied to any system, regardless of the properties or elements of the system[17]. As a result, GST was developed. According to Bertalanffy, the goal of GST is to integrate various sciences such as natural sciences and social sciences, in order to address the metaphysical fields of science[17]. GST was developed in order to identify universal principles applying to systems in general[17]. In addition, GST was needed to avoid duplication because there have been "many instances where identical principles were discovered several times because the workers in one field were unaware that the theoretical structure required was already well developed in some other field"[17].

In GST, there are two different types of systems: closed systems and open systems. Closed systems are systems that are isolated from its environment, and open systems are systems that interact with its environment[17]. For example, all organisms are generally considered an open system as there is import and export of material[17]. Conversely, a closed system, is a system where no material enters of leaves it[17]. An example of a closed system is a computer software program, such as Microsoft Word ®. Although users can enter text to use the program, entering text or data into the system, does not alter the system in anyway.

As every living organism, from simple unicellular organisms to complex multicellular organisms such as humans, requires some sort of input, such as oxygen to survive, and some sort of export to remove its metabolic products, then all living organisms are open systems. Complex systems may include a combination of open and closed systems. For example, in creating Microsoft Word ®, the programmer would have to enter commands to create the program, thus making this process an open system. However, the final product, which is the Microsoft Word ® program, is a closed system. This is because although the end user interacts with the program, the user cannot alter the system's functionalities.

Principles of GST can also be applied to explain current treatment practices in oncology, to prevent tumour lysis syndrome. One of the principles in GST is that organisms in an open system usually strive for equilibrium, such that temporary changes in its environment will cause the organism to react to compensate for the change, in order to maintain equilibrium[17]. Cells, within an organism, are open systems as they are constantly interacting with its environment. Minerals and chemicals travel into the cells (intracellular) from outside of the cells (extracellular), and vice-versa. This exchange of minerals and chemicals are done under a tightly-controlled mechanism to maintain equilibrium. Certain levels of minerals intracellularly and extracellularly are maintained for equilibrium, which enables normal cell function and organ function. For example in normal cells, intracellular potassium levels range between 3.5 – 5.0 mmol/L, calcium levels range between 2.20- 2.62 mmol/L, and phosphate levels range between 0.80 – 1.40 mmol/L[6]. If there is a deviation from these values, such as an increase or decrease of the values, mechanisms are in place to compensate for the changes to maintain equilibrium. For example, low calcium levels in the cells will cause calcium from the extracellular space (such from the blood) to enter the intracellular cells, resulting in low calcium levels in the blood. A signal will be sent to the body to either slowdown in using up, or breaking down the calcium, or to develop more calcium. If unresolved, long-term effects of this mechanism could cause the organism to have weak bones. The whole process entails components inside and outside of the cells to work together to maintain equilibrium, and to interact with its environment. This in turn, affects the larger organ system, thus causing the organs to react, and the whole body to react.

Similarly when a cell dies, all intracellular components (or minerals), including deoxyribonucleic acid (or DNA), leave the cells and enter the blood stream[14]. Cancer cells, which are mutated cells from normal healthy cells function the same way. Cancer therapies like chemotherapy and radiation therapy, are used to target and kill cancer cells. This results in the release of intracellular components into the blood stream. When a high number of cancer cells are killed, vast changes in the components in the blood, such as increased potassium (hyperkalemia), increased uric acid levels (DNA is broken down and turns into uric acid, this is called hyperuricemia), and increased phosphates (hyperphosphatemia), occur[14]. Phosphates tend to have an affinity to calcium, and when released in the blood, they bind to free floating calcium ions, thus causing low calcium levels (hypocalcemia). When all of these changes in the blood stream occur at the same time, the organs are affected significantly. For example, hyperkalemia causes cardiac arrhythmia and renal failure[14]. Hyperphosphatemia and hyperuricemia will also cause renal failure, and hypocalcemia will cause changes in muscle function. Having this in mind, cancer treatment then becomes a fine balance between killing the cancer cells, while controlling for tumour lysis syndrome (TLS). This is why cancer treatments, such as chemotherapy and radiation therapy, are administered in small doses over time. When TLS is inevitable, certain procedures and medical interventions are done to prevent renal failure and other adverse events associated with TLS from occurring. For example to manage hyperkalemia, medications are administered to decrease the amount of potassium in the bloodstream, and the patient is hydrated aggressively with saline via intravenous route to prevent renal failure[14]. GST can be applied in various systems. As demonstrated in this example, GST can be applied in medicine and can be used as a guiding principle in cancer therapy.

4.2. Complex-Adaptive Systems

Some systems, with various levels of hierarchies, networks, and layers of complexities, have the ability to learn to adapt to its changing components and environment. The complex-adaptive systems (CAS) "are made up of interacting components (the system) whose interactions may be complex (in the sense of nonlinear) and whose components are diverse and/or have a capacity for learning that generates reactive or proactive adaptive behavior"[13]. CAS are also sometimes referred to as, complexity science.

Like all systems, complex-adaptive systems start off as a simple system. According to Norberg and Cumming, The story of how life on earth developed is about a gradual increase in the complexity, organization, and information-processing capabilities of organisms, from single cells with largely reactive behaviors to interactive multi-celled organisms with elaborate senses, learning capabilities, and proactive behavior. This story is paralleled in the development of human societies, which have grown from autonomous foraging groups of early humans to highly interconnected[13].

CAS, however, is different from complexity theory because it includes the term adaptive and its focus is on the capacity and ability of the system to change and adapt itself through self-organization, learning, and reasoning, as a response to variations in its conditions or environment[13]. In humans, the immune system, and more specifically the adaptive-immune system, is an example of CAS. The immune system, is a system that protects humans (or hosts) from pathogens that could lead to infections, and if not controlled or destroyed, could eventually cause for the host to die. Usually, immune cells have the ability to directly destroy pathogens, or recognize pathogens and send signals to other immune cells to destroy it. In some situations, certain pathogens are able to able enter the host unrecognized as a threat. Eventually, the immune system will learn that the pathogen is a threat, and will send off signals to other cells to react and destroy the pathogen. Certain cells have the capacity remember this new type of pathogen, and will store this information in its memory. This is to ensure that if the same pathogen enters the host in the future, the cells will be able to recognize this pathogen faster, and will remember the steps it took to destroy the pathogen much faster. In adaptive immunity, the immune cells reorganize itself, after learning about a new pathogen, in order to respond to it and ultimately suspend its growth in the system. Self-organization leading to an adaptive process is the underlying principle in CAS. CAS are also distinguished by "their diversity of components, nonlinear behaviors, complex (typically hierarchical) organization, multi-scale nature, and homeostatic feedbacks; they are also unique in their ability to self-organize, or adapt, in response to environmental demands[13]. These principles are all demonstrated in the adaptive immune system.

To obtain reliable information about a system, Norberg and Cumming discussed the importance of identifying system boundary, which include the largest area or time period where the system exists[13]. This is because there are smaller systems that are interconnected that make up larger complex systems, and when looking at the smaller system, it is important to take into context the larger system that play a role within the smaller system. Similarly, it is equally as important to identify how each of the smaller systems affects the larger complex system.

4.3. Chaos Theory

Another theory that has been used to describe how organic systems respond to change is chaos theory. According to Wheatley, "chaos is necessary to new creative ordering"[18]. One of the underlying principles in chaos theory is the notion that there is order that emerge out of chaos, and that everything is interrelated.

There is a relationship between order and chaos, and these forces are not only mirror images of each other, they are inherent within each other[18]. At first glance, a system when responding to change, may look chaotic and unpredictable. However, upon closer examination, in "that state of chaos, the system is held within boundaries that were well-ordered and predictable. Without the partnering of these two great forces, no change or progress is possible" (p. 13). Through the exercise of individual freedom and autonomy, order and form are created from a few guiding principles that acts as a feedback mechanism on itself[18]. In addition, organic systems have a self-organizing capacity known as autopoiesis, which is life's fundamental process for creating and renewing itself[18]. This is process is exhibited at the basic level of life, in the cell's DNA. A snap shot of the DNA sequence may seem random, and chaotic. However, a deeper examination of the whole process, reveals that it is a complex system that is tightly controlled, and has the ability to repair and renew itself. Therefore, to "see how chaotic processes reveal the order inherent in a system requires that we shift our vision from the parts to the whole"[18].

In organic systems, very slight variances that may not seem obvious at first can amplify into completely unexpected results[18]. Complex and organic systems are non-linear with feedback loops causing it to amplify and grow[18]. Therefore, slight variances may cause enormous impact, if left unnoticed over time. This principle is demonstrated in cancer development and growth.

In the cellular process, the cell has the ability to repair, renew, and replicate itself. When a DNA mutation in a cell occurs, the DNA in the cell is first repaired before the cell is allowed to divide. If a mutated cell is unable to fix itself, it is destroyed. For a normal cell to divide its DNA must first be replicated. Every time the cell divides itself, it doubles in size, and this process is constant. For example, when one cell divides, it turns into two cells, these two cells then divide, and turn into four cells, thus exhibiting an exponential growth in size. This process, however, has a built in mechanism, that controls the overall size of the cell, otherwise the cells would continue to grow uncontrollably. In cancer, all of the mechanisms in place to control the normal cellular process are defective[14]. Mutated cells are not fixed, or destroyed, and they are allowed to divide uncontrollably. The small mutated cell though insignificant at first, will continue to grow, and over time, will invade its surrounding organs and enter the blood vessels. This mutation can occur anywhere in the body. It may start off as one mutated cell in the colon that ultimately replicates itself. The ball of mutated cells, known as a tumour could get as big as a baseball, and could end up blocking the colon. In addition, in order to sustain itself, the tumour will use up the oxygen supplies and nutrients originally meant for the normal cells. As a result, the organism, which is depleted of oxygen and nutrients with a blocked colon, may feel weak, fatigued, and constipated. This feeling of malaise may prompt the affected person to seek medical attention, and subsequently receive a cancer diagnosis. From this example, a mutated cell that is initially harmless and minute, has amplified itself causing a profound effect on the overall complex system—the human body. In this example, it seems that the occurrence of cancer is merely a random incident. However, it is the result of a repeating pattern.

Patterns in the present can determine that future, however, it cannot predict the future[18]. This is because organic systems are always changing, and may never react the same way even if given the exact same conditions. This deterministic condition is the reason why scientists, researchers, and oncologists are able to make breakthroughs in cancer treatment, but are not fully able to eradicate all cancers.

In describing systems theory, Wheatley also discussed fractals, which are repeating patterns that describe any object or form[18]. Fractals are organic, and when allowed to exercise freedom, it may look as if the pattern that is developing is random and chaotic. However, it is important to look at the whole system, the interconnectedness of things, and its relationship with the environment. For example, in lung cancer, a genetic mutation within the lung cells occurs. There are various factors, such as environmental and hereditary that allows for this to happen. The person's susceptibility to cancer may have been inherited; or the person's lifestyle choices, such as smoking tobacco, or high alcohol consumption might have also contributed to the emergence of the cancer. Some of these factors need to interact and come into play for the person to be afflicted with cancer. This is the reason why some smokers, also do not develop lung cancer, and some non-smokers do[14].

In systems with interconnected networks, slight disturbances in one part of the system may create major changes far from where they originate. In this highly sensitive system, the most minute actions can blow up into massive disruptions and chaos[18]. However, it is also a world that seeks order, such that when chaos occurs, it not only disintegrates the current structure, it also creates the conditions for new order to emerge[18]. Perhaps this is the reason why cancer is hereditary. It is a fault within the human race, and familial lines that carry the genes are not permitted to continue. Cancer plays a role in the human evolution process. Those who carry the mutated genes live shorter, and are 'weeded out' of the human race. Now that scientists are learning more about this, certain groups of people who are carriers of the afflicted gene are opting to not have children, thus their familial lineage is removed. Using Chaos Theory as a framework for analysis, it seems that death from cancer is not merely a random act or disease, but rather, it is the order within a higher order in human evolution.

4.4. Integral Theory

Another theory that has been used to describe systems in higher order is Ken Wilber's Integral Theory[19]. According to Wilber, everything is interconnected and integrated in a larger scheme of things[19]. Wilber also described another element in systems, which is reality. Reality, which has a dimension of time, occurs in a continuum and is a segment within a larger whole[19]. Reality must always be taken into context, and exists as a simultaneous whole/parts, also known as holons. Holons are originally coined by Koestler[19], which means wholes that exist in other wholes, or systems within systems. For example, before "an atom is an atom, it is a holon. Before an idea is an idea, it is a holon. All of them are wholes that exist in other wholes, and thus they are all whole/parts, or holons, first and foremost"[19]. In addition, according to Wilber, holons have the ability to self-preserve, self-adapt, self-transcend, and self-dissolve. There is a hierarchy of holons, called holarchies. Cells are an example of holons within holarchies. Each cell, like a hepatic cell, contains a chromosome (DNA), nuclear membrane, mitochondria, and ribosome. Each part of a cell has its own function, and is independent, but interacts with each other and belongs to a larger whole, a cell. This hepatic cell, belongs to a larger whole, and when hepatic cells are grouped together, they form a kidney. The kidney belongs to a larger network of systems that make up the human body. The human body, however, is more than just a group of cells and organs. It thinks, and interacts with others. On a different level, the whole living body belongs to a family, which belongs to a society, within an ecosystem, which is part of earth, within the universe. When a group of people come together, belief systems, languages, and cultures develop[19]. However, this network does not end here, but it does not start with the parts of the cells either. It starts with holons, and ends with holons[19]. This arrangement plays an important part in systems, as it provides the foundational structures in complex systems. Larger holons cannot exist without the lower holons. Destroying lower holons, will destroy everything above it[19]. For example, destroying cells, a lower holon, means that the organ systems which is a higher holon in the holarchy, will cease to exist. Similarly, a society cannot exist without humans, humans cannot exist without cells, and cells cannot exist without molecules.

Wilber also discussed other aspects of holons, such as its ability to take on different perspectives and behaviours[19]. For example, in human behavior, one's actions can be informed by one's internal perspective, and also from a collective perspective, which include social and cultural perspectives[19]. The various perspectives enable the connection between other existing systems that are at a higher level in the holarchies, such as cultures, beliefs, and spirituality[19].

5. Application of Systems Theories

5.1. Theory U

Theory U is an organizational and leadership theory that has is similar to Chaos and Order theory. The concept of presencing, or being in the moment, is the overarching principle that informs Theory U[15]. Otto Scharmer discussed ways to lead from the future as it emerges[15]. Learning from the past, connecting with current situations, creating sustainable structures and support systems are some strategies that enable organizations to thrive. The U-shape provides a visual representation of the five core stages in Theory U: co-initializing, co-sensing, co-presencing, co-creating, and co-evolving[15]. The co-initializing stage, involves listening to one's calling in life, and connecting with people and contexts related to that call[15]. This is an important step, as it sets the context the primer for actions and interactions that are meaningful for all individuals, and for the organization. The co-sensing stage involves identifying places with the most potential, observing, and listening with the mind and the heart[15]. This step helps to create room for the emergence of new knowledge. It involves letting go of old ideologies, beliefs, and knowledge, and accepting new ideas to emerge[15]. The third stage is the co-presencing stage, which involves opening up one's self to a deeper source of knowledge by reflecting, and allowing for the inner knowledge to emerge[15]. This is a crucial step, as it enables the present to connect to the future that is slowly emerging. The fourth stage is the co-creating stage, which involves building structures, and creating a prototype of the new future[15]. The final stage is the co-evolving stage, which involves the co-development of a larger system that connects people across boundaries by seeing and acting from the whole[15]. This five stage process, allows the leader of an organization to see, hear, and act, in a way that incorporates and affect all levels, including the micro, meso, macro, and mundo systems level[15].

5.2. The Learning Organization

According to Senge, businesses and human endeavours, which are the major constituents of many organizations, are also systems because they are bounded by interrelated actions[16]. As some of the interrelated actions are invisible, their imminent effects on the whole are not immediately evident, and thus often ignored, causing drastic organizational changes to occur over time. These drastic changes may have compounding and detrimental effects to an organization, and may ultimately cause it to collapse[16]. Similar to complex-adaptive systems, Senge discussed how complex organizations today need to be able to transform into learning organizations in order to thrive in the future[16]. By becoming a learning organization, an organization has the ability to continually enhance its capacity to achieve their highest aspirations and potential[16]. Senge identified five disciplines, or five capabilities, that an organization must possess in order to become a learning organization[16]. These include: (1) systems thinking, (2) personal mastery, (3) mental models, (4) building shared vision, and (5) team learning. Organizational leaders must have an understanding of the five disciplines in order to affect meaningful and sustastainable change within their organization.

Senge emphasized the relationship between all of the disciplines, and the importance of integrating all of the disciplines, as a whole, rather than implementing only parts of it. Senge also identified systems thinking as the discipline that acts like a glue between all of the disciplines, as it enables the holistic integration of all the disciplines[16]. Senge referred to systems thinking as a conceptual framework developed to clarify patterns, describe the relationships between the forces that make up a whole, so that changes to problems can be made more effectively[16].

Senge described personal mastery as a special level of proficiency, beyond competence and skills[16]. Personal mastery is also not about dominating others, or being superior to others, but rather about having the ability to delve deeper into one's self, to identify what is truly meaningful and important; and being able to perceive patterns objectively to see reality for what it is. Being able to perceive reality in its true form, without bias, is important in order to keep focus, resolve organizational challenges effectively, and avoid creative tension[16]. Creative tension occurs when there is a difference between a vision and the current reality, which causes a reality gap[16]. When creative tension occurs, making meaningful and sustained changes in an organization becomes difficult.

Mental models are other factors that influence and affect behavior and decision making. Mental models are deeply entrenched ideologies, beliefs, generalizations, and assumptions that influence how one perceives the world[16]. Mental models may not be overt, and at times may also be shared by leaders and front line staff, that it becomes widespread throughout an organization[16]. When leaders or organizations possess mental models, personal mastery is inhibited; and new insights are not implemented into practice because it conflicts with their deeply embedded worldview, which limits their thinking, decision making and acting. People with various mental models, when experiencing the same event, will describe their experiences differently because they have paid attention to different details of the situation[16]. When people are unaware of their mental models, it could become detrimental to an organization. Unexamined mental models in the midst of an always changing and evolving world creates a widening gap between reality mental models, leading to counterproductive actions[16]. In addition, unexamined mental models can impede learning, block new insights, and freeze organizations into out dated practice. According to Senge (2006), mental models must always be examined, and re-examined, as the potential power of mental models in learning can be insurmountable. In learning organizations, the best possible mental models can be achieved by helping leaders to clarify their assumptions and also through reflection. Reflection facilitates the discovery of internal contradictions within deeply embedded assumptions, which enables new insights and creative thinking to occur[16]. It is only through reflection and in challenging mental models that having a shared vision for an organization can be achieved.

Having a shared vision is important to learning organizations, as it promotes focus and energy for learning[16]. When people within an organization have a shared vision, they are working towards something that is meaningful with a larger purpose, as it is deeply embedded within them thus making the achievement of the shared vision possible. Shared vision also changes people's relationship with each other and with the whole organization, as the vision is not about doing something for the organization, but rather, it is about doing something that is a part of their being, which eliminates competition and mistrust with one another[16]. Shared vision also fosters risk taking and experimentation to achieve the overarching goal. However, the experimentation is not ambiguous because there is a focus, and in return, learning and innovations happen[16]. A shared vision can emerge from an individual vision that is shared by leaders[16]. However, each person has their own interpretation of the vision that embodies the organization at its best. Each person shares responsibility for the whole, and although they may have different perspectives, their vision represent the whole. Therefore, a shared vision is similar to a holon.

The ability of a team to develop the capacity for coordinated action, or team learning is also a fundamental aspect in a learning organization. In order to do this, team members must enter into a dialogue, by suspending all of their assumptions so that they can all start to think together and all members of the group can discover insights together[16]. Individuals also align themselves with the team vision, such that they "do not sacrifice their personal interests to the larger team vision, rather, the shared vision become an extension of their personal vision"[16]. Team learning also means that each member of the team is performing their best, and their individual contribution enhances the performance of others, thus the group is functioning as a whole. Therefore, team learning is a team skill, necessary to reach the team's highest potential.

According to Senge, all five disciplines need to be implemented together for an organization to become a learning organization[16]. However, becoming a learning organization is not an end-point, but rather, the goal is to learn how to be a learning organization. Organizations must always examine, and re-examine its current state and reality, and compare it with the organization's direction and vision. Team members must also learn how to learn with each other, know their own function so that they can perform beyond their best and into a phase called personal mastery[16]. Through this, meaningful actions are taken, everyone is working synergistically, and the group is performing as a whole. By suspending all of their assumptions, and mental models, they can gain new insights together and build a shared vision. Systems thinking play a large role in this process, as it links all of the disciplines together, thus making learning organizations possible.

5.3. The Health Care System

The Healthcare System is a system with various levels of complexities. It involves decision makers, policy makers, and groups of people in institutions, organizations, and agencies that shape the way in which health care is delivered to society. The Health Care system also encompasses different levels of care, from providing services for the prevention of diseases, to providing palliative/end-of-life care. Healthcare is provided by multiple health professions, such as physicians, nurses, social workers, occupational therapists, pharmacists, and many other types of professionals. In Canada, the healthcare system has become so complex, not only for the patients, but also for health care professionals, that the 'patient navigator role', has emerged. This new role, seen as highly innovative, and a necessary service to meet the needs of the patients during their illness trajectory, aims to better connect patients with their healthcare providers in a more timely manner. It also enables better coordination of care, as it improves communication between healthcare professionals. The healthcare system has become so complex, and health care professionals have become so specialized, that another health professional is needed to help patients, and health care providers to navigate the healthcare system.

The various epistemological perspectives of the different health disciplines, has created silos and diverse clinical foci when addressing patients' clinical[10]. For example, physicians with a predominantly biomedical model, uses objective information to address patients' problems, whereas nurses, tend to have a more humanistic and holistic approach and sees patients as persons[10]. The different education, and socialization that occur in each of the disciplines during their training also lead health professionals to focus on different aspects of the patient care needs, even though they are presented with the exact same information[10]. These differences in perspectives may be one of the reasons for the communication breakdown between nurses and physicians, as each discipline have different clinical foci for the patients. However, it is also these epistemological differences that ensure the holistic care needs of the patients are met.

The silos between the various health professionals are a challenge that leaders have tried to address. To address this issue, it has been suggested that the various members of the interdisciplinary team need to share their knowledge with each other so that professional boundaries are blurred and members think more alike[10]. Another suggestion has been for health professionals to learn to make their values become more apparent to one another[10]. McMurtry has suggested an alternative solution[10]. He suggested the need to encourage various health professionals to develop a relationship with each other, work together, and to adapt their contributions in relation to one another, thus enabling them to come up with more and better solutions[10]. These strategies however, seem flawed. The hierarchies that exist between health professionals is one of the biggest barrier for health care teams to work together effectively. Additionally, asking health care team members to adapt their contributions in relation to one another could be problematic, especially in a culture where physicians tend to have the dominant view. This results in health care professionals working independently, and in silos.

Using systems theory, silos between the various healthcare professionals can be addressed, which can also help in identifying an overarching goal to enhance patient care. To do this, members of the interdisciplinary team first need to be unified as a team, and identify as a team an overall clinical goal for the patient. One of the challenges with this strategy is the power dynamics between the various members of the team. To work effectively as a team, members must be willing to suspend any previous beliefs that one discipline is superior to others. In addition, they must all be willing to buy-into the following principles: (1) Like holons, each of the health disciplines have their own unique sets of knowledge, skills and expertise, but are interconnected with each other to make up a greater whole; (2) Each member of the team are valuable, and members must recognize not only their own contributions, but also others' unique contribution as part of the larger whole; (3) Members must have the ability to step back, in order to reflect, and understand how their own contributions sustains the overall goal for the patient; and (4) Members must learn how to learn together, learn from their mistakes, and identify ways to overcome their challenges together. Changes, however, must be made at all levels. For example, changes must be instituted at the individual (micro) level by health leaders, and also introduced in the training and curriculum of students in various health disciplines. Changes must also occur at the meso-level (or organizational level) so that the practices of the various members of the health care team reflect the principles and ideals that are being taught in school. Changes at the micro and meso levels will serve as catalysts to the changes that needs to happen at the macro-level (health care system), and globally.

Unfortunately, the structural inequalities in the healthcare system exist, which make it difficult for health care teams to be unified. Various health disciplines are still focusing on highlighting the magnitude of their contribution to healthcare by minimizing the expertise other health professions, in order to remain in power.

To facilitate change, health care providers and leaders must be system thinkers. They need to be able to identify the different elements and units, large or small that affect way care is provided to patients. They also need to be able to mobilize the health care organization into learning how to become a learning organization.

6. Conclusions

Humans and organizations are complex systems. Systems theories can be used as a framework to solve many complicated problems and system issues. When looking at systems, it is important to look at the smaller components of the system, within the context of the larger system. Fundamentally, a system is made up of components that are interdependent of each other. By looking at the components in isolation, and without looking at the larger system as a whole, the whole system could collapse. The interdependency of each of the component means that minute changes to any of the component could result in a domino effect, thus ultimately changing the system as a whole. This is also true of large and complicated systems that are composed of smaller systems. Changes to the smaller systems cannot be made without taking into consideration its potential effect on the larger system.

Systems theories are also helpful in understanding organic systems, or systems involving living beings. As organic systems are always interacting with each other and with their environment, the system is always changing. Systems theories can help us better understand how changes in nature occur, for example in evolution. Systems theories can also be used to help us better understand how humans interact with each other, and with their environment, and the intricacies that exists within their systems. In healthcare organizations, which involve people, processes and structures, there are multiple types of systems that are involved. Each of the systems are inter-related with one another. Leaders need to be systems thinkers in order to facilitate sustainable change in their organizations. For example, in some systems dealing with change, the process to reorganize itself, in order to adapt, may seem chaotic. However, going through the process of ‘chaos’ is important, in order to find a new order. The principles of order within chaos underline Chaos Theory. General Systems Theory is another that provides universal principles that applies to systems in general. When complex systems have the capacity to adapt to its changing environment, it is considered a complex-adaptive system. Systems, such as beliefs, culture, and religion are also a part of a higher order systems in humans, and are best described using Wilber’s Integral Theory[19]. As discussed in this paper, systems theory has many applications, not only in leadership and organization, but also in healthcare and in oncology.

ACKNOWLEDGEMENTS

I would like to acknowledge Dr. Kathy Tiner for her wonderful support with the development of this paper.

REFERENCES

[1] A+E Television Network. (2013a). *The Biography Channel website: Aristotle*. Retrieved, Jun 07, 2013, from http://www.biography.com/people/aristotle-9188415.

[2] A+E Television Network. (2013b). *The Biography Channel website: Descartes*. Retrieved, June 10, 2013, from http://www.biography.com/people/ren%C3%A9-descartes-37613

[3] Apperelyzed. (2013). Spinal cord injury levels-Functionality of T5-T9 spinal cord injury. Website. Retrieved June 03, 2013, from http://www.apparelyzed.com/support/functionality/t5-t9.html

[4] Aristotle. (2009a). *Metaphysics.* (W.D. Ross, Trans.). The internet classics archive. (Original work written 350 B.C.E). Retrieved June 28, 2013, from http://classics.mit.edu/Aristotle/metaphysics.mb.txt

[5] Aristotle. (2009b). *On the parts of animals.* (W. Ogle, Trans.). The internet classics archive. (original work written 350 B.C.E.). Retrieved June 28, 2013, from http://classics.mit.edu/Aristotle/parts_animals.html

[6] Cordon, C., & D’Angelo, S. (2005). Understanding blood counts. Retrieved July 07, 2013, from www.uhn.ca/docs/HealthInfo/.../Understanding_Blood_Counts.pdf

[7] Hattab, H. (2001). *Descartes's Body-Machine.* Retrieved June 15, 2013, from http://www.folger.edu/html/folger_institute/experience/textures_hattab.htm

[8] Kramer, N. J., & de Smit, J. (1977). Systems thinking: Concepts and notions. Leiden, Netherlands: H.E. Stenfert Kroese B. V.

[9] Mazzochi, F. (2008). Complexity in biology. Exceeding the limits of reductionism and determinism using complexity theory. *European Molecular Biology Organization Reports, 9*(1), 10-14.

[10] McMurtry, A. (2007). Reinterpreting interdisciplinary health teams from a complexity ccience perspective. *University of Alberta Health Sciences Journal*, *4*(1), 33-42.

[11] Meadows, D. H. (2009). *Thinking in systems. A primer*. London, UK: Earthscan.

[12] Merriam-Webster. (2013). Dictionary. Retrieved June 03, 2013, from http://www.merriam-webster.com/dictionary/system

[13] Norberg, J., & Cumming, G. (2008). *Complexity theory for a sustainable future*. New York, NY: Columbia University Press.

[14] Otto, M. E., Langhorne, J. S., & Fulton, S. E. (2007). *Oncology nursing*. (5th ed). St. Louis, MO: Mosby.

[15] Otto Scharmer, C. (2009). *Theory U. Leading form the future as it emerges*. San Francisco, CA: Berrett-Koehler Publishers.

[16] Senge, P. (2006). *The fifth discipline*: *The art & practice of the learning organization.* (2nd ed.) New York, NY: Double Day.

[17] Von Bertalanffy, L. (1968). *General system theory*. New York, NY: George Braziller.

[18] Wheatley, M. J. (2006). *Leadership and the New Science: Discovering Order in a Chaotic World.* San Francisco, CA: Berrett-Koehler Publishers.

[19] Wilber, K. (2000). *Sex, ecology, spirituality*. Boston, MA: Shambhala Publications.