The science and theory of complex adaptive systems, also known as complexity science, has emerged as an alternative to existing paradigms. Complex adaptive systems demonstrate identifiable characteristics: embeddedness, self-organization, non-linearity, unpredictability, and others. These systems exhibit emergent behavior that arises from simple rules and interconnections among diverse elements with porous boundaries, as they interact with and respond to the environment. The health system and the profession of nursing can be viewed as complex adaptive systems, and when done so, new insight can be gained. While several authors have stated they believe nursing is indeed a complex adaptive system, a visual model has not yet been advanced. This article offers a model of nursing viewed as a complex adaptive system, a discussion of key properties of a complex adaptive system, and potential implications of the use of complexity science in nursing and health care.

The nature of the whole is always different from the sum of its parts.
Frithof Capra, The Web of Life

The science of complex adaptive systems (CASs), also known as complexity science, has emerged as a powerful force influencing many fields and has great potential for use in nursing. Complex adaptive systems are characterized, according to Anderson and McDaniel, as a number of elements interacting locally in a dynamic, non-linear manner. Interactions in the system are intricate; system activities are a function of what has previously occurred and are open to energy and information from the environment.1 Complexity science has value in examining systems during times of rapid change—a situation in which the health system is currently.2 The purpose of this article is to examine how complexity science can be applied to the profession of nursing and to offer a visual display of the model.

WHAT ARE COMPLEXITY THEORY AND SCIENCE?

Complex adaptive systems are not merely complicated systems that change over time. Glouberman distinguished “complex” from “complicated” by explaining that a complicated system, like a car, has many parts. Changing the oil doesn't affect the tire pressure. He contrasts the complicated system of the car with the complex system of the car as mass-produced transportation and its influence on society, health, law, behavior, insurance, and other systems.3

Complexity theory attempts to explain complex behavior that emerges from dynamic, non-linear systems. Complexity theory is not a single theory but is a collection of overlapping and complementary theories from a variety of sciences. These include chaos theory, self-organization, and fractal geometry.4 The Plexus Institute5 regards complexity science as the intellectual successor to systems theory and chaos theory.

Complexity science is focused on CASs—the patterns of relationships within them, how they are sustained, how they self-organize, and how outcomes emerge.6 Evolving over 40 years, complexity science emerged in response to the unpredictable activity of phenomena under study in many scientific disciplines. It is highly multi- and inter-disciplinary, and its proponents include biologists, chemists, anthropologists, economists, sociologists, physicists, and many others. These diverse disciplines have turned to complexity theory and science in a quest to answer some fundamental questions about living, changeable systems.7 Complexity theory attempts to explain why some systems show patterns of adaptability and progress in response to an ever-changing environment, in contrast to others that wither and die. Examples of complex adaptive systems include bee hives and the stock market.

The work of groups such as the New England Complex Science Institute, the Santa Fe Institute, and others have brought researchers together to study how patterns emerge from seeming randomness (see Figure
The work of these groups, including research, education, and application, has advanced the science and spurred interest. Researchers are developing tools and applying them to the examination of CASs of all kinds including biological, economic, and social. Not-for-profit groups and commercial entities are using complexity science to find solutions to challenging problems.

**DESCRIPTION, PROPERTIES, AND CHARACTERISTICS OF A COMPLEX ADAPTIVE SYSTEM**

Complexity science provides a framework to study systems that display perplexing behaviors if looked at through the lens of traditional thinking. What might appear chaotic may really be progressive and adaptive. And what might have been seen to be good because it was stable, orderly, and predictable, may in fact be evidence of an impending death spiral.

Complex adaptive systems are exemplified by a number of identifiable characteristics (see Figure 2). Relationships are critical to understanding the system. The behavior in a CAS grows out of interactions between the agents within the system. They contain a network or group of related diverse elements that respond in a positive way to the environment. The elements (or agents) are independent but interconnected to other agents. An agent might be a person, a cell, or an organization. The reactions of an agent can have wide-ranging influence because of the many relationships within the system. And the agents can have different or changing roles as the CAS evolves and the environment changes. The interconnections are important because they allow a diverse system response in an adaptive way. Interconnections make learning and co-evolution possible. A system does not evolve independently from its environment and the larger systems in which it is nested. The systems co-evolve.

In a CAS, one action does not cause a single expected result (as one would see in a mechanical system), but the effect can spread in unpredictable ways. This is the property of **non-linearity**—one action may result in a variety of subsequent actions. A small change may have an extensive effect and a large change may have a small effect.

Complex adaptive systems are not controlled by a central authority but, instead, react to their local environment. **Self-organization** occurs in CASs, where order is created through patterns of organization that follow **simple rules**, such as occurs in a school of fish.

### Table: Properties of a Complex Adaptive System (CAS)

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>DESCRIPTION OF PROPERTY</th>
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<tbody>
<tr>
<td>Adaptable elements</td>
<td>Elements in a CAS can evolve.</td>
</tr>
<tr>
<td>Attractors</td>
<td>Catalysts in a CAS that allow new behaviors to emerge.</td>
</tr>
<tr>
<td>Co-evolution</td>
<td>Progress in the CAS occurs with constant tension and balance.</td>
</tr>
<tr>
<td>Context and embeddedness</td>
<td>The CAS resides within and interacts with other systems that influence it.</td>
</tr>
<tr>
<td>Emergent behavior</td>
<td>New behavior is a feature of the CAS represented by constant innovation and creativity.</td>
</tr>
<tr>
<td>Inherent order</td>
<td>Order is maintained in a CAS even without central control.</td>
</tr>
<tr>
<td>Nonlinearity</td>
<td>Implies that in response to a stimulus a variety of behaviors are possible, and the cause and effect relationship is not directly evident or linear.</td>
</tr>
<tr>
<td>Porous boundaries</td>
<td>The boundaries of the elements in a CAS are blurry and porous, allowing exchange and movement between them.</td>
</tr>
<tr>
<td>Self-organization</td>
<td>Process where many local interactions create order without direction from above.</td>
</tr>
<tr>
<td>Simple rules</td>
<td>Local application of simple rules can result in broad, complex outcomes.</td>
</tr>
<tr>
<td>Unpredictability</td>
<td>Forecasting is inexact in a CAS because elements change, behavior is emerging and activities are nonlinear; the trajectory of a system is unknowable.</td>
</tr>
</tbody>
</table>

Data from references 9 and 27.

**Figure 2.** Properties of a complex adaptive system (CAS).
This portrayal of activities on a hospital nursing unit illustrates the principles of a complex adaptive system as defined by Plsek (25) and how they can be identified within a nursing system.

Every bed in the 16-bed intensive care unit (ICU) is filled as the day-shift nursing staff arrive, including the day-shift charge nurse. The nurses, medical interns, residents and attending physicians begin their patient assessments (inherent order). Nurse Breckinridge tells Medical Resident Blackwell his drug order for an intravenous antibiotic is incorrect. Grumpy from little sleep, he pulls out his reference book. Realizing his error, he changes the order to the correct dose—preventing potential harm to the patient (co-evolution).

There are three critical patients in the emergency department likely to be admitted to the ICU and a surgical procedure scheduled with a planned admission to ICU. Because no patients are stable enough to be transferred to other units, the ICU charge nurse consults with the Director of Operating Room Services and a decision is made to cancel the elective surgery (adaptable elements).

A small area of tissue in the left ventricle of the Patient Stewart is becoming irritable. A few irregular heartbeats appear on the EKG monitor before sustained ventricular tachycardia ensues—throwing the heart into an ineffective rhythm as the patient lapses into unconsciousness. Nurse Dix drops a phone as he glances up at the cardiac monitor and says in a loud voice, “Call a code in room 6.’ Like bees heading to a

(Continued)
boundaries between different elements of the system and between the CAS and its environment are ill-defined and porous. This allows exchange of information, matter, and energy, and interaction between the components of the elements.\textsuperscript{10} Attractors, values or behaviors people are drawn towards, exhibit influence in a CAS.\textsuperscript{11}

Emergent (new) behavior arises from the co-evolution resulting from the relationship between the CAS and the environment, where change is constantly in evidence as the two co-exist and influence one another. Emergence may be viewed as the sudden appearance of unpredicted phenomena due to myriad interactions and the self-organization of agents.\textsuperscript{12} As a result of the

Figure 3. Continued
reactions to and interaction within the environment, a CAS is resilient and robust. In addition, CASs are history dependent; they are shaped and influenced by their past. Figure 3 provides an application of the characteristics of CASs as they might appear on a clinical nursing unit.

THE COMPLEX NATURE OF CONTEMPORARY HEALTH CARE

For most of the period of time that humans have inhabited the earth, health care has been fairly uncomplicated. Until recently, there were quite simply few effective strategies to deal with the diverse maladies and traumas that befall human beings. But fast-forward to today—past the development of homeopathy, the establishment of medical societies and medical licensing, the development of anesthetic techniques, the discovery of the microbe, the flourishing of surgical procedures, and the transition from general practitioner to board-certified medical specialist. Continue past the urbanization of America and the introduction of vaccinations, public health measures, and visiting nurses. Consider the birth and growth of the hospital—the built environment that became the womb of sophisticated clinical and technological advances. As treatment options expanded, requiring diverse care providers and equipment, patient care moved into the hospital until the end of the 20th century. The burgeoning hospital economy demanded trained workers—especially nurses.

As the possibilities for help, health and healing expanded, patients demanded the best the system had to offer. In the 20th century, the government entered the health care arena through the direct delivery of care and the financing of patient care, health care provider education, and health research. As health costs skyrocketed in the late 20th century, care moved into ambulatory care centers, hospices, dialysis centers, birthing centers, and returned to the home. Financial and organizational restructuring measures were enacted as control mechanisms. Federal and state laws were passed in an attempt to regulate behavior in the increasingly complex system. This evolution has resulted in a hugely complex system that provides the context for the practice of nursing today.

THE COMPLEX NATURE OF CONTEMPORARY NURSING

Modern nursing practice, grounded in nursing science, has evolved significantly since its birth in the late 19th century. The “trained” nurse of the late 1800s had a narrow scope of practice most often in a hospital near the bottom of the paid labor hierarchy. The American Nurses Association estimates there are nearly 2.9 million licensed, registered nurses in the US today. These nurses conduct their practice in diverse organizations and at varying points in the process of care.

Nursing roles and scopes of practice have expanded; over 100 specialty nursing associations serve their members. Nurses are positioned in every part of the health system providing and coordinating care for people, in government agencies including the military and Congress, in the private sector as executives and consultants, as well as in academia, not-for-profit agencies, faith-based organizations, legal firms, and research institutes. Multiple entry points to practice exist; at least 10 educational degrees in nursing are available and graduate programs span specialties from neonatal nursing to geriatric care, from oncology to disaster nursing, and from informatics to forensics.

THE CASE FOR VIEWING NURSING AS A COMPLEX ADAPTIVE SYSTEM

The authors contend that nursing is, indeed, a complex adaptive system and that the profession demonstrates the characteristics of a CAS. Therefore, it is desirable to present a model of nursing as a CAS. When nursing is viewed through the lens of the CAS model, it is possible to visualize key components and relationships within the system, and then to develop new approaches to nursing science, practice, leadership, research, and education.

ADOPTION OF COMPLEXITY THINKING IN HEALTH CARE AND NURSING

A number of disciplines have adopted complexity science thinking and have recognized the value of the CAS model. Complexity science has begun to appear sporadically in the health care literature (see Figure 4 online at www.nursingoutlook.org). The nursing literature contains a small number of articles about complexity science and its applications (see Figure 5 online at www.nursingoutlook.org). Though these publications are disseminating critical aspects of complexity science and thinking in the nursing literature, a conceptual model that represents this thinking has not yet been advanced.

Why should nurses be concerned with complexity thinking? Complexity science may be of value to many nurses—certainly it may be an appropriate theoretical framework for nursing research. But it may also be valuable to a nurse manager who finds that her organization is not behaving as she expected. Looking at employee behavior and organizational activity through the lens of complexity science may assist that manager in making decisions that are not futile. Clinicians may find value in complexity science as they work to plan sophisticated nursing care in an unstable environment. Indeed, any nurse who works in a fluctuating, confusing environment may understand that environment better and, thus, be able to be more effective if he considers that he is in a CAS.

THE VALUE OF A CONCEPTUAL MODEL

A conceptual model is a powerful tool for organizing, shaping, and guiding thinking. Just as a microscope offers a view of microbes, a conceptual model provides a lens through which ideas and relationships come into focus. Wilson\(^1\) wrote that outside our heads there is a freestanding reality, and inside our heads is the reconstitution of that reality based on sensory input and the self-assembly of concepts. A conceptual model can be considered part of the sensory input that guides the assembly of concepts.

Fawcett\(^2\) defines a conceptual model as a set of relatively abstract and general concepts that address the phenomena of central interest to a discipline, the propositions that broadly describe those concepts, and the propositions that state relatively abstract and general relations between 2 or more of the concepts.

THE COMPLEX ADAPTIVE SYSTEM MODEL APPLIED TO NURSING

The New England Complex Systems Institute (NECSI) is an independent educational and research institution dedicated to advancing the study of complex systems. One of NECSI\'s initiatives is to advance the understanding, dissemination, and advancement of complex systems science by displaying key concepts in visual models. Clemens\(^1\) created a graphic model for the NECSI that demonstrates the major characteristics of a CAS (see Figure 6).

VIEWING NURSING WITH THE NECSI COMPLEX ADAPTIVE SYSTEMS MODEL

The NECSI CAS Model is an elegant graphic that effectively illustrates the properties that are resident in CASs. When the graphic is adapted to display the concept of nursing, a powerful image emerges (see Figure 7).

The health system, appearing at the top of the graphic, is a CAS, and within it are numerous other CASs—including nursing. The 3 subsystems (or agents) selected for use in the model are societal elements, other health system elements, and nursing. Societal elements are portrayed as a CAS within the health system and may include such things as financing strategies. Other health system elements might include medicine, dentistry, and pharmaceutical research. Nursing is portrayed as the third entity at this level but other agents could exist. All of these entities have porous

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*Figure 8. An exploded view of the metaparadigm of nursing as a complex adaptive system as proposed by the authors. (Graphic by Marshall Clemens – Visual Modeling and Facilitation for Complex Business Problems, www.idiagram.com)*
boundaries; information, personnel, and patients move in complex patterns within them and between them. Each action within the system has many possible outcomes and can influence many other elements within the system.

NURSING’S METAPARADIGM VIEWED AS A COMPLEX ADAPTIVE SYSTEMS MODEL

A metaparadigm identifies and describes the global concepts of interest to a discipline and the global propositions that describe relationships between or among the concepts. Four concepts emerged from the early grand theories of nursing to become the metaparadigm of nursing: man, society, health, and nursing. Scholarly debate has ensued about these concepts and resulted in the refinement of the labels: “Man” evolved to “person” and then to “human being.” “Society” became “environment.” The authors chose to use the 4 concepts of human being, environment, health, and nursing in the application of the CAS model to nursing. The exploded view of the CAS model demonstrates these 4 concepts and proposes the next level of subsystems that may comprise them.

THE “EXPLODED” MODEL OF NURSING AS A COMPLEX ADAPTIVE SYSTEM

Using complexity theory supports a view of nursing as a system that contains subsystems and that each, in turn, contains other subsystems—all displaying the properties of CASs. The exploded view of the CAS model applied to nursing includes a visual display of the concepts that form the metaparadigm of nursing:

Human Being

The hallmark of most nursing models is the individual person as the primary focus of the profession. Fawcett has proposed that “human being” is the most appropriate concept to employ due to Leininger’s argument that “person” is not a globally understood concept. Nursing

Nursing

Nursing is a discipline and practice that has been socially constructed to meet human health-related needs according to Thorne et al. Meleis described nursing as a human science as well as a practice-oriented, health-oriented, caring discipline. Many definitions of nursing have evolved since the first put forth by Florence Nightingale in 1859—and much debate has occurred. Thorne et al proposed a unifying definition that reflects a philosophic middle ground, and that definition was used to guide development of the nursing subsystem in Figure 8:

Nursing is the study of human health and illness processes. Nursing practice is facilitating, sup-

Health

The definition of health has been the source of significant debate and has evolved as a concept within the nursing literature. While its definition has been argued, health has been a phenomenon of central interest to nursing. Recently, quality of life has gained interest as a central focus, but neither health nor quality of life has been clearly conceptualized in nursing. In her metaparadigm of nursing, Fawcett broadly defines health as the human processes of living and dying. This definition was used to develop the nursing subsystem of health in Figure 8.

Environment

Originally identified as “society”, “environment” was felt to better describe phenomena relevant to “person” (and, later, “human being”). Two views of the concept of environment in the nursing metaparadigm exist. The first is a narrow view of the environment as the immediate surroundings or circumstances of an individual. The second is a broader view that presents the person and environment as contiguous. This second view is more consistent with complexity theory and was adopted by the authors for use in development of Figure 8. The concepts identified in Figure 8 depict the phenomena that are relevant to understanding the environment in which human beings exist.

INSIGHTS FOR NURSING FROM COMPLEXITY SCIENCE

Applying complexity science and theory in nursing, and using a graphic model to assist their application, offers intriguing insights and opens up new avenues of thought and scholarship. The essence of leadership is bringing about change in complex systems. Clancy advocates for viewing nursing as a CAS and indicates that leading in a complex environment requires managers to understand new concepts such as emergence and self-organization.

Relationships Rule in a CAS

A system is seen as a social entity, and behavior in a CAS occurs due to interactions among the agents in the system. The quality of relationships among agents needs more attention than the quality of agents in the system. Leaders who adopt complexity thinking will focus on building and nurturing relationships with their colleagues.
A model of nursing as a Complex Adaptive System

Chaffee and McNeill

“Machine Model” Thinking Won’t Work in a CAS

In a mechanical system, outcomes of actions can be readily predicted. Mechanical systems rarely produce surprising behavior (like CASs). When an employee in a health care agency behaves “unpredictably” and is considered inappropriate or unreasonable, perhaps it is the administrator’s view of the system that is not appropriate.1

Old Dogs and New Tricks

Health care executives, managers, and other professionals must consider adopting a new mental model of the health system if they desire to succeed in the rapid, ongoing change in health care organizations. Because mental models are engrained from years of use, change is not easy. But, change is critical if entrenched views that no longer work are to be replaced with views that permit innovation and creative action.1

Unpredictability must be Expected in a CAS

The complexity and characteristics inherent in CASs make unpredictability an expectation. If we accept that this is the case, we can learn to appreciate unpredictable results. Tension, paradox, uncertainty, and anxiety are healthy in a CAS.

Silo Thinking is Inconsistent with Complexity Science

The boundaries of a CAS are porous and blurry. Exchange of people, energy, resources, and other components that make up the elements of a CAS are going to happen. The interactions that take place among the elements make it impossible to operate in a silo mindset. Whatever one element does will have impact elsewhere in the system—and this will happen in a non-linear fashion. For example, changing routine medication times on a unit will have obvious impact on the pharmacy. It may not be quite so evident that timing of laboratory tests may have to be adjusted, which will impact scheduling in another department, which could fuel discontentment, decrease retention, and increase costs.

Autocratic Leadership Doesn’t Work in a CAS

Self-organization does not imply a lack of leadership; leadership is required at all levels. Leaders who adopt complexity thinking will equip all people to be leaders so, when something happens, they can respond in an innovation and independent way at their level. Freedom for the agents or elements in a CAS to act in ways that are not predictable and controlled by others is what makes a CAS adaptive and allows creative behavior to emerge.

Decentralization and Empowerment Thrive in a CAS

Leaders who adopt complexity thinking will create conditions that allow systems to evolve and adapt over time. The agents must be given the tools to develop creative solutions, and the authority and power to implement them. Leaders should formulate the vision and allow creativity at local levels in its implementation.

It’s Good to be on The Edge of Chaos

Complexity scientists believe CASs move between 3 states: chaos, stasis, and the edge of chaos. The edge of chaos is viewed as the state where the system is most ready for adaptation. Organizations in this state are ripe for unexpected movement and new ideas.5

Recognizing Patterns is Important in a CAS

Complex organizations produce patterns but they can be difficult to discern.12 Patterns are simply sequences of events, ideas, or behaviors that have significance. They are logical in hindsight but can be tough to spot as they are taking shape. James26 has identified 6 ways to identify patterns: extension, elaboration, recycling, pattern reversals, strange attractions, and chaos. Having these tools to assess an environment for patterns may support successful leadership and action in a CAS.

CONCLUSION

On September 11, 2001, when the first airliner struck the World Trade Center, most people viewed the event through a traditional lens and believed it was an accident. But it was necessary to view the events of September 11, and others since, through a very different lens. It became apparent that well-financed and highly skilled religious extremists had attacked the US. If the events were still viewed through traditional thinking, current action would probably involve new measures to improve aircraft safety near tall buildings. Only with a much broader interpretation of the complex and related facts that have emerged concerning September 11 can appropriate efforts move forward.

Complexity science is a very different method of considering nursing and its function in the health system. It offers nurses a powerful opportunity to design research, leadership decisions, policy, and clinical practice in new ways. Begun and White2 suggest that adopting complexity science thinking in nursing may be vital for the profession’s survival, as nursing is often intransigent and held in place by inertial forces.

While some professions are embracing the concepts of complexity science, they are few. Nursing has a remarkable opportunity to adopt complexity thinking and alter its worldview.27-31

The views in this article are those of the authors and are not necessarily the official views of the US Government, the Department
of Defense, the Department of the Air Force or the Department of the Navy.
The authors wish to acknowledge the effort of Marshall Clemens of idia.png in the preparation of the graphics for this article.

REFERENCES

<table>
<thead>
<tr>
<th>Agency</th>
<th>Purpose</th>
<th>Weblink</th>
</tr>
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<tbody>
<tr>
<td>Center for the Study of Complex Systems, University of Michigan, Ann Arbor, MI</td>
<td>Founded in 1999, the Center encourages CAS research, expands educational opportunities and explores the boundaries of CASs and more traditional approaches.</td>
<td><a href="http://cscs.umich.edu">http://cscs.umich.edu</a></td>
</tr>
<tr>
<td>New England Complex Systems Institute, Cambridge, MA</td>
<td>NECSI conducts research, education, knowledge dissemination, and community development to promote the study of complex systems and their use to better society.</td>
<td><a href="http://www.necsi.org">www.necsi.org</a></td>
</tr>
<tr>
<td>Plexus Institute, Allentown, NJ</td>
<td>Plexus is a not-for-profit group formed in 2001 to foster the health of individuals, families, communities and organizations and the environment by helping people use concepts emerging from the science of complexity.</td>
<td><a href="http://www.plexusinstitute.com">www.plexusinstitute.com</a></td>
</tr>
<tr>
<td>Redfish Group, Santa Fe, NM</td>
<td>Founded in 1991, Redfish Group is an organization of complexity researchers, software developers and business experts who apply CAS to business and government problems.</td>
<td><a href="http://www.redfish.com">www.redfish.com</a></td>
</tr>
<tr>
<td>Santa Fe Institute, Santa Fe, NM</td>
<td>The Institute is a private, not-for-profit, independent research and education center founded in 1984 that encourages multi-disciplinary collaboration. CASs are seen as critical to addressing complex social challenges.</td>
<td><a href="http://www.santafe.edu">www.santafe.edu</a></td>
</tr>
<tr>
<td>ThinkVine, LLC, Cincinnati, OH</td>
<td>ThinkVine is a consulting firm that offers decision and business support; complexity science is used to design business and consumer strategies.</td>
<td><a href="http://www.thinkvine.com">www.thinkvine.com</a></td>
</tr>
<tr>
<td>UCLA Human Complex Systems Program</td>
<td>Academic program that explores complex systems inhabited by human beings; offers a minor degree in human complex systems.</td>
<td><a href="http://www.hcs.ucla.edu">www.hcs.ucla.edu</a></td>
</tr>
</tbody>
</table>

**Figure 1.** Institutes, centers, and agencies involved in the research and application of complex adaptive systems science.
• McDaniel, Jordan and Freeman assert that health care organizations are complex adaptive systems. They suggest that when that is recognized, health care organizations can be seen in new ways and new management approaches can be devised (27).

• Glouberman and colleagues analyzed the health of city dwellers from a CAS perspective. They indicate their approach can serve as the basis for innovative and effective health promotion (3).

• Minas identified characteristics of CASs in Australia’s mental health system (10).

• Stroebel and colleagues used complexity theory to inform a series of studies designed to understand and improve primary care practice (24).

• Plsek offered guidance on redesigning a safer health system using complexity science in the Institute of Medicine’s ‘Crossing the Quality Chasm: A New Health System for the 21st Century,’ (25).

• Brown applied CAS theory to the clinical practice of rehabilitation in an effort to demonstrate its relevance (28).

• The Plexus Institute presented ‘Improving the Health of the Chronically Ill: Insights from Complexity Science’ in December 2004; sponsored by the Agency for Healthcare Research and Quality (AHRQ).

**Figure 4.** Health care applications of complexity science and theory.
• Begun and White indicate nursing may be considered a complex adaptive system but they identify characteristics of the profession they believe do not wholly fit (2).

• Anderson, Issel and McDaniel used complexity science to explain the results of a study of nursing homes as complex adaptive systems. The purpose of the study was to test complexity hypotheses concerning the relationship of management practices and resident outcomes (29).

• Walls and McDaniel explored how nurse managers could use a CAS approach to cope with a health care merger or acquisition (30).

• Sitterding described the use of CAS theory by a clinical nurse specialist to prevent surgical site infection (31).

• Rowe and Hogarth analyzed how change in the performance of public health nurses was instituted using a CAS approach (11).

• The Plexus Institute presented ‘Complexity Science: Opportunities for Nursing Education’ in August 2005; hosted by the University of Kansas School of Nursing.

Figure 5. Nursing applications of complexity science and theory.