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Traditional knowledge of Western herbal medicine and complex systems science

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ABSTRACT

Traditional knowledge of Western herbal medicine (WHM) supports experiential approaches to healing that have evolved over time. This is evident in the use of polyherb formulations comprised of crude plant parts, individually tailored to treat the cause of dysfunction and imbalance by addressing the whole person holistically. The challenge for WHM is to integrate science with traditional knowledge that is a foundation of the practice of WHM. The purpose of this paper is to provide a plausible theoretical hypothesis by applying complex systems science to WHM, illustrating how medicinal plants are complex, adaptive, environmentally interactive systems exhibiting synergy and nonlinear healing causality. This paper explores the conceptual congruence between medicinal plants and humans as complex systems coherently coupled through recurrent interaction. Complex systems science provides the theoretical tenets that explain traditional knowledge of medicinal plants while supporting clinical practice and expanding research and documentation of WHM.

1. Introduction

Western herbal medicine (WHM) is a clinical practice of healing using naturally occurring plant material or plants with little or no industrial processing. Medicines or extracts from crude plant material, such as root, bark, and flower, are used in multiple plant formulations to treat persons with disease and dysfunction and to promote health and well-being (Bone, 2003; Hoffmann, 2003, p. 71; Mills and Bone, 2000; Tilburt and Kaptchuk, 2008). WHM is a title recently used to differentiate herbalism based on Anglo-American traditional herbal medicine (Casey et al., 2007) from other systems of herbal medicine such as Ayurveda or Traditional Chinese Medicine (TCM). Representing varied and diverse groups of practitioners, WHM is also referred to as traditional Western herbalism, herbal or botanical medicine, medical herbalism and phytotherapy. WHM is practised in Australia, Canada, New Zealand, the United Kingdom, the United States and Western Europe.

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Complex systems science (CSS) is a transdisciplinary approach to science (Morin, 2008) offering descriptions and explanations of how collective behaviors of whole systems arise from the parts and how whole systems interact with environments (Bar-Yam, 2009). CSS as an epistemology (Morin, 2008) includes the theories of complex adaptive systems and nonlinear dynamic systems. CSS has been applied to living interacting systems and the natural world. It appreciates the nonlinearity of reality and has been used to explain the unpredictability of weather, repeated patterns of shorelines and mountain ranges, the activity of ants, and the fractal or self-similar patterns of embedded plant structures (Capra, 1996). In human systems, complexity has been used to study and research the interacting network of human biology, information exchanges in social networks such as organizations (Capra, 1996; Zimmerman et al., 2001) and Ayurveda and homeopathic systems of medicine (Bellavite, 2003; Rioux, 2012). CSS may also be applicable to the study of WHM. By examining the congruence between crude medicinal plant medicines and CSS, perhaps a more comprehensive understanding of WHM may emerge. Using CSS plants as living organisms, may be considered self-organizing and environmentally adaptive. In this respect, medicinal plants are complex systems.

This paper explores the proposal that medicinal plants as complex adaptive systems have synergetic properties, are coherently coupled with humans, and give rise to nonlinear healing causality (Koithan et al., 2012; Spelman, 2011). The purpose of this paper is to provide a theoretical description, applying tenets of CSS to WHM, illustrating how medicinal plants are complex adaptive systems. Furthermore, using CSS to explain traditional knowledge of WHM provides relevant considerations related to the healing process and the practice and research of herbal medicine.

2. Current challenge for herbal medicine

The practice of WHM is based on traditional knowledge or received wisdom acquired over time through observation and real-life experience (Dods, 2004; Evans, 2008; Johnson, 1992; Mills and Bone, 2000). Traditional knowledge of WHM is evident in the use of individually tailored crude plant extracts in multiple plant formulations. Treatments directed at the cause of the problem, focusing holistically on the whole person with the intent to strengthen the overall constitution (Klein and Dunkel, 2003), shift causal and global patterns of dysfunction and imbalance (Casey et al., 2007; Mills and Bone, 2000). Holism in WHM refers to the fundamental unity of parts where the whole is greater than the sum of the parts and is not predicated by the parts (Mills and Bone, 2000). WHM practitioners apply concepts of holism to persons and plant medicines where plants and persons are multidimensional, interacting and interconnected living organisms. The assumptions of holism contrast the mechanistic view of humans and plants where causation and constituent parts are viewed as isolated or separate from the experience of the whole, resulting in a singular therapeutic focus on symptoms or disease (Hoffmann, 2003; Johnson, 1992; Whitelegg, 2003).

Tension exists between contemporary biomedical research and traditional knowledge-based WHM (Evans, 2008; Jagtenberg and Evans, 2003; Nissen and Evans, 2012). Biomedical research of herbs has concentrated on bioactivity of highly processed herb products, including singular mechanisms of action of single herb parts, isolated fractions, and purified extracted active ingredients. This is in contrast to traditional uses of entire medicinal plant portions as composites of activity on multiple levels. Furthermore, biomedical research is often conducted with delivery forms, doses and applications inconsistent with WHM. This research is incongruent with the approaches and reported experiences of WHM and is often not generalizable to polyherb formulations utilizing entire medicinal plants. This tension is illustrated with research of the herb *Hypericum perforatum* or St, Johns Wort (SJW).

Practitioners of WHM, based on experience have long used the fresh flowering tops of SJW in formulations as a nervine particular to nervousness and neuralgic pain and for its antiviral, astringent and expectorant actions (Grieve, 1931/1996; Hoffmann, 2003). Biomedical research, focusing on singular mechanisms of actions, showed antidepressant effects in SJW due to the hypericin constituent (Bladt and Wagner, 1994; Thiede and Walper, 1994). This finding resulted in multiple clinical trials and the standardization of SJW products to hypericin with the identification of SJW as the herbal antidepressant. This research-based biomedical application is contrary to the infrequent use of SJW for depression originating in traditional knowledge of WHM (Hoffmann, 2003) and presents as a new application specific to the standardized extracted or concentrated product used in the research.

A first concern is whether biomedical research on highly processed and possibly enhanced or synthesized plant parts or constituents is generalizable or applicable to the traditional uses of herbs as teas and tinctures. Teas, tinctures and liquid extracts represent a relatively intact “close-to-the-natural-state” herbal medicine. The behavior of a molecule may be a function of its environment. If the molecule is removed or the chemical is extracted from the chemical matrix of the plant, it may not be the same. This does not conclude that the products, mechanisms and outcomes researched are not valid, but instead poses the consideration that because crude intact plants used in WHM are complex the reductionist method of research may have limited applicability to the practice of WHM.

A second concern, illustrated with the SJW example, is that current research designs focusing on singular mechanisms and constituents rather than the entire plant threaten to change the definition and applications of herbal medicines. Instead of defining herbs as whole living organisms and applying herbal medicines close to their natural state according to tradition, herbal medicine will be defined as highly processed products comprised of isolated and concentrated herb constituents. These highly processed and concentrated pharmaceutical-like products, having no history of use and a body of knowledge limited to product-specific research, potentially present new and unique patient safety issues. Likewise, new and different clinical applications of herbs threaten to supplant traditional time-tested applications of herbal medicine.

The danger biomedical thinking poses for the complementary and alternative medical (CAM) practitioner is the eventual replacement of traditional herbal knowledge with incomplete conclusions from current research. Consequently, this relocates knowledge and practice from a holistic traditional empirical framework to a reductionistic framework and recasts traditional herbal practitioners with practitioners prescribing standardized herb products according to protocols designed to consistently treat people presenting with similar symptoms in the 10-min consultation. This conventional medical approach contrasts with the WHM approach where individualized treatments are used to treat the whole person, including root causes of dysfunction and symptoms.

The challenge for herbal medicine is how to integrate science with traditional knowledge of WHM. Research has not accounted for the holistic practice of herbal medicine using individually tailored crude plant material compounded in polyherb formulations. Shaped by traditional knowledge, this practice encompasses the binding connection and inseparability of humans and the natural world (Casey et al., 2007; Dods, 2004; Durie, 2004; Johnson, 1992) and is congruent with CSS where plants are viewed as complex adaptive systems. CSS provides the theoretical tenets needed to explore and expand practice and research models for herbal medicine.

3. Medicinal plants as complex adaptive systems

Traditional knowledge grounds WHM in the treatment of the whole person with crude medicinal plants having little or no industrial processing (Tilburt and Kaptchuk, 2008). This practice has emerged from lived experiences of the interconnectedness of life forms (Bourque et al., 1993; Dods, 2004; Johnson, 1992) and infuses and enriches WHM with holism and dynamic complexity (Bone, 2003; Brinker, 2004b; Wood, 2004). CSS offers an understanding of living systems as whole systems representing complex integrations of interconnected subsystems or parts adaptively linked to and enfolded in their environments (Koithan et al., 2012; Zimmerman et al., 2001). Complex systems are irreducible and indivisible, intricate enough so that parsimony and singularity in cause and effect are not applicable (West, 2007). This perspective is consistent with traditional knowledge of WHM. See Table 1 for tenets of CSS.

Complex systems are self-organizing, dynamic and open with emergent properties (Koithan et al., 2012). Complex systems are whole systems with multiple structures and functions existing in relationship with information networks and information exchange. This integration in complex systems creates a system, as a whole, that is greater than any isolated part (Bar-Yam, 2003; Capra, 1996; Zimmerman et al., 2001). Complexity represents new, potentially unpredictable or nonlinear order and configurations expressed as properties, behaviors or outcomes. This order or global coherence is emergent from multiple interactions of self-organizing systems and changes over time (Koithan et al., 2012). Internal interactions, within the organism, and external interactions, with the environment, exist at multiple levels of scale and are nested from local or specific to global or general with bidirectional information pathways (Gilbert and Sarkar, 2000; Pincus and Metten, 2010).

While medicinal herbs can be seen as structurally complex in morphology with embedded structures of taxonomy, it is integration within the chemical mixes (matrixes) of each plant from which complex adaptive properties emerge (Spelman, 2006). Every medicinal herb is a unique weave of potentially thousands of chemicals patterned for plant diversity, growth, protection, health, and beauty (Ganora, 2009). These chemical patterns evolved out of adaptive interaction with the environment and work together to ensure self-regulation, resistance to or protection from predators, and intraspecies communication (Macies et al., 2007; Rosenbloom et al., 2011). For example, secondary plant metabolites, such as berberine, alkaloids, and tannins, are defensive against predators while flavonoids act to attract or signal beneficial microorganisms. Oils may be secreted to attract pollinators, whereas amino acids, sterols and phenolics participate in plant repair (Mills and Bone, 2000; Spelman, 2008). Likewise, the chemical matrixes of plants may result in network-like effects of medicinal plants in interaction with human organisms (Spelman, 2011). As illustrated with *Echinacea* spp., the unique phytochemical weave coordinates multiple complex patterns of interaction and activity. *Echinacea* spp. has multiple immunomodulation activities relating to the complex matrix of alkylamides (including 14 different isobutylamides), polyalkynes, phenylpropanoids, polysaccharides, and glycoproteins (Ganora, 2009). Thus, while plants are environmentally interactive, it is the chemical matrix that provides a profile of plant complexity and self-organization with emergent environmental adaptation assuring plant stability and flexibility.

Furthermore, plant complexity exists to the greatest degree in the intact natural state of the plant and this complexity is reduced the further away from that natural state the plant moves. A fresh structurally intact plant is more complex than a tea of dried plant parts which retains more complexity than a chemically purified plant product (Brinker, 2004a). Therefore, the best way to use medicinal plants for their complexity would probably be to consume them while in their natural state.

3.1. *Medicinal plants and synergy*

Plant synergy, an adaptive strategy of emergence, occurs because the interactive effects of the whole plant as chemical matrix, consisting of plurality and diversity of chemical constituents, are greater or more effective than the additive effects (potentiating synergy) of individual constituents (Ganora, 2009; Spelman et al., 2006). Plant synergy gives rise to modulation of biochemical pathways, changes in membrane potentials, receptor selectivity and protein shifts (Spelman, 2011). Thus, plant activity emerges from the synergistic relationship and interaction of the parts and cannot be predicated from what is known about individual constituents (Ganora, 2009). Laboratory studies are replete with research on plant synergy, including research on *H. perforatum*, *Mahonia* spp. (Ganora, 2009; Spinella, 2002), *Artemisia annua* (Spelman et al., 2006), *Valeriana officinalis* (Brinker, 2004b; Spinella, 2002) and *Piper methysticum* (Spinella, 2002). Whole plants are comprised of multiple diverse chemical components (potentially

Table 1 – Conceptual definitions from complex systems science.

Attractors	A fixed point or inducer that pulls the trajectory toward it giving rise to dominant phase states ranging from equilibrium to chaos. Basic attractor types include point, periodic, and strange.[a]
Bifurcation	A sudden change in the dynamics of a system leading to unpredictable behaviors.[b]
Complexity	Nonlinear interactive parts giving rise to unpredictability and change over time.[c] Order and randomness existing together. Tightly coupled elements where nonlinear multiplicative emergence represents dynamics and fluctuations.[b] Emergent from self-organization when systems are far from order and on the 'edge of chaos'.[c]
Embeddedness	Systems nested within other systems.[a]
Emergence	Properties and structures that arise, draw forth, or manifest at a particular new complex level from self-organization of complex systems or from inseparable relationships of the whole system that are not connected in time to a priori occurrences.[a,c]
Fractal	Self-similar repeated patterns or structures at different scales.[c]
Level of scale	Repeated structures at different levels. Determines variability.[b]
Nonlinearity	Change in dynamic whole systems where relations among elements within systems cannot be represented or predicted with a line. Self-organization into patterns with emergent properties that cannot be understood through the individual parts. Nonlinearity gives rise to unpredictability due to sensitivity to initial conditions where small changes can produce disproportionate effects.[b,c]
Robustness	Property of complex systems enabling plasticity with system functioning in the face of perturbations and uncertainty yet allowing for the flexibility to adapt and evolve.[d] A robust system exhibits small responses to large stimuli.[e]
Self-organization	Non-centralized, distributed, and spontaneous emergence of ordered patterns, new structures, and new behaviors dependent on energy and interconnectedness within systems occurring when systems are 'far from equilibrium'.[a,c]
Sensitivity	Property of complex systems enabling flexibility in relation to environmental changes. A sensitive system has large responses to small stimuli. Sensitivity is complementary to robustness.[e]
Systems	Integrated wholes with essential properties emergent from the relationship of the parts. Parts are patterned in the web of interconnections. Phenomena within context (Capra, 1996, p. 25, 32). Complex adaptive systems (CAS) are open, nonlinear, dynamic, environmentally adaptive systems.[c]
Trajectory	An arching or curved path[b] describing motion in relation to attractors.[a]

[a] Capra (1996).
[b] West (2007).
[c] Zimmerman et al. (2001).
[d] Kitano (2004).
[e] Bar-Yam (2009).

thousands) embedded together in the intact plant part yielding multiple effects from chemical interactions within the plant (Ganora, 2009; Spelman et al., 2006).

While effects from intact plants are emergent, it is still unknown how compounds interact and work together (Brinker, 2004b; Ganora, 2009). Synergy manifests when multiple tannins in one plant bind to alkaloids in another to offer protection from alkaloid toxicities (attenuating or negative synergy). Attenuating synergy is illustrated in the protective use of *Glycyrrhiza* spp. with *Aconitum* spp. thereby reducing the toxicity of the *Aconitum* spp. Phytochemical synergy, both potentiating and attenuating, emerges from interactions within dynamic complex intact medicinal plants (Ganora, 2009).

In addition to potentiating and attenuating phytochemical synergy, physiological synergy, otherwise called complementation, arises from the interactions of complex living systems such as medicinal plants interacting with humans (Ganora, 2009; Spelman, 2011). While synergy creates effects beyond what there would be with single constituents added together, complementation occurs when plant constituents work together to enhance and facilitate absorption, elimination, bioavailability, and metabolism and in turn reduce potential adverse effects (Spelman, 2011; Spinella, 2002). Complementation is illustrated with *Taraxacum officinale* folium or Dandelion leaf. The diuretic action in Dandelion leaf is complemented by potassium as a natural component of the herb, thus reducing hypokalemia as a side effect (Duke, 1994). The effects of combined phytochemicals, due to chemical interactions and multiple human affinities, enable patterns of response resulting in emergent order and coherence (Bell et al., 2013). Complementation by influential chemical partners contributes to emerging global or whole-person effects with herbal medicine (Brinker, 2004b).

3.2. *Medicinal plants and environmental adaptation*

From recurrent interactions and exchanges of information over time, assuring the sustenance of plant and human life, coevolution or environmental coadaptation has joined the dynamic self-organizing plant and human in coherent coupling (Spelman, 2006, 2011). Plants and humans are enfolded and inseparable, sharing coupled histories of change (Spelman, 2011). While plants draw nutrients from the earth and convert them into bioactive phytochemical matrixes, they also utilize the carbon dioxide that humans exhale. Likewise,

humans need the oxygen and water plants exude. Humans are bound and biologically receptive to plants through sensation and perception, respiration and digestion, and in turn, nurture and preserve the plants (Ganora, 2009; Scalzo and Cumberford, 2012). Plants and humans transform each other in dynamic coadaptation. Changes in one system prompt changes in the other. The constant perturbation from coherent coupling demands ongoing system reorganization and dynamic responsiveness. Therefore, plants and humans as coadaptive self-organizing systems are shaped by mutual environmental interactions through time (Spelman, 2011).

Coherent coupling can explain the broad range of safe herbal medicines used in WHM (Duke, 2000; Spelman, 2006) and is exemplified with berberine-containing plants. Berberine is one of the multiple bioactive chemicals that in low concentrations assure plant survival by defending against microbial invasion and resistance (Klein and Dunkel, 2003; Spelman et al., 2006; Stermitz et al., 2000). Likewise, humans have used berberine-containing plants to treat infections for centuries and, in turn, select and distribute the plants, thereby assuring coexistence and adaptation of plant and human (Ganora, 2009).

Coevolution accounts for structural changes in both plants and humans resulting from interactions and information exchange over time. In humans, multiple biochemical pathways, detoxification processes, cell receptors, cell membranes, DNA, and proteins are primed for herbal medicine (Spelman, 2006, 2011). This ongoing interaction through time constitutes a deep biological-knowing or cellular memory of herbal medicine. (Duke, 2000). The connection between plants and humans is one of constant exchange and can in most cases provide a foundation for health and wellbeing. The interactions between humans and plants ultimately manifest expressions of humanity. Expressions of humanity are inextricably bound to plants due to coherent coupling in coevolution. Humans embody the success of coevolution and dependence on a rich and varied exposure to phytochemicals (Scalzo and Cumberford, 2012).

3.3. *Nonlinear healing causality with medicinal plants*

Healing with traditional herbal medicine is often a nonlinear process where local engagement may result in whole person or global effects. The effects, extending beyond a reduction of symptoms, may be non-sequential, disproportionate, and unexpected in relationship to the cause (Koithan et al., 2012; Morin, 2008). When herbal medicines interact with the human organism there are nonlinear transitions from illness to health that are often evidenced by subjective, qualitative and often subtle changes in awareness (Koithan et al., 2012, 2007; Zimmerman et al., 2001). Persons taking herbal medicines may report they "just feel better" or perhaps they may say they "feel more balanced" or can "handle" things or "cope" better. Or it may be that with herbal medicine the person may report a transformative or life-changing experience. These are unpredictable qualitative changes. The concept of nonlinear causation is demonstrated when a small perturbation from herbal medicine results in a global shift and occurs because the local is embedded in the global with a bidirectional flow of information.

Whole plant medicines interact with human biology to generate self-organization and coherent health patterns relative to the timing of the information exchange and flexibility and responsiveness of the organism (Capra, 1996; Pincus and Metten, 2010). While having multiple low affinities, in contrast to a high affinity for a singular site, traditional herbal formulations may provide a broad impact at the root and network of human dysfunction or imbalance resulting in a whole person shift and, to a lesser degree, a local focus on physiological pathways for symptom alleviation (Klein and Dunkel, 2003; Spelman, 2011). Herbal medicine is similar to a "nudge" or analogous to "internal acupuncture" (Mills, 2005) where herbal activity is broadly specific (Agoston et al., 2005) and healing emerges from engagement with multiple networks within a system. Healing is nonlinear and not always predicable with static measurable endpoints.

The traditional language of WHM used to delineate the classifications and indications of herbal medicines reflect the nonlinear nature of herbal medicines, where small and local perturbations may yield global and widespread non-specific effects. Historically and foundationally, herbs are classified according to nonspecific healing activity, which is descriptive of herbal properties and effects (Brinker, 2004b) where one herb with multiple constituents provides multiple informational exchanges with humans (Spelman, 2011). Examples of traditional herb classifications include alterative, vulnerary, tonic, adaptogen and trophorestorative. Alterative herbs are restorative while vulnerary herbs have a healing activity. Tonic herbs build up and are supportive. Adaptogenic herbs are normalizing, promoting adaptation to stress (Hoffmann, 2003) and are potentially valuable in restoring complexity reduced by aging and disease. Trophorestorative herbs are nutritive, providing needed vitamins and minerals. Traditional herb classifications and views of causation are consistent with a CSS perspective.

WHM practitioners believe herbal formulations mobilize personal strengths and support adaptive functioning by enabling or "nudging" self-healing, thus indirectly addressing the dysfunction or imbalance (Frances, 2002; Mills, 2005; Mills and Bone, 2000; Winston and Maimes, 2007). Explanations of how homeopathic remedies work in human organisms suggest that rather than end-organ pharmacological action, these medicines may instead act through interactive mechanisms of adaptation to stress at multiple levels and that the human organism mediates patterns of response as a result of network interactions (Bell et al., 2013). This may also describe how medicinal herbs act to perturb inherent healing patterns or self-organization. This nonlinear, indirect and interactive mechanism in herbal medicine can be illustrated with the treatment of fatigue. Fatigue is often treated with herbs that act on the gut and promote gut healing and elimination first, followed by tonics, adaptogens and trophorestoratives to promote constitutional strengthening, restoration and nurturing. Thus, herbs acting synergistically, at multiple targets or within a network-like framework set into motion self-organization. Likewise, skin disorders are typically treated with herbs that assist liver detoxification, improve the lymphatic system, and stimulate circulation. Focusing on the cause of the dysfunction and treating the whole person, herbal formulations in WHM are traditionally viewed as nurturing,

supporting, and strengthening. This may be interpreted as the interaction of medicinal herbs with multiple target or network affinities thus moving the human system to self-organize (Hoffmann, 2003; Mills, 2005; Wood, 2004). Traditional applications of herbal medicines initiate person-wide, broad systemic changes (Pincus and Metten, 2010).

Individually formulated multiple plant medicines display phytochemical diversity and plurality that supports complexity and globally shift dynamics (Ganora, 2009; Kitano, 2004). In CSS, disease is often considered the loss of complexity in the human organism likewise, humans as complex systems respond to complex and multicomponent treatment approaches like herbal medicine (Kitano, 2007).

The practice of WHM encompasses interactions between medicinal plants and people. The perspective of plants and people as complex adaptive systems, with plants acting synergistically, coherently coupled in environmental adaptation and characterized by nonlinear healing causality, provides practitioners and researchers of WHM a dynamic tool to enrich the knowledge base and evolve the practice of WHM.

4. Implications for research

Research is beginning to address traditional preparations of herbal medicines and individual prescribing practices of WHM practitioners in the treatment of disease. (Brush et al., 2006; Clare et al., 2009; Grant, 2010; Hipps et al., 2009; Picon et al., 2010; Wahl et al., 2008; Zwickey et al., 2007). Likewise, research that investigates patient outcomes with herbalist-prescribed personalized polyherbal formulations, reflective of real life applications of WHM, is emerging (Green et al., 2007; Hamblin et al., 2008). While still not addressing the complexity of whole plant herbal medicine, these studies begin to demonstrate the value of an individualized approach using polyherbal formulations in real-life treatment of disease.

Yet, current research dialog on traditional knowledge and practice of WHM is minimal. The lack of research and documentation of traditional knowledge-based herbal medicine places WHM in peril of loss to society as a whole and specifically, to the scientific healthcare community. The loss of biodiversity and the extinction of plant species are appropriate analogies to express the potential loss of traditional knowledge of WHM. Similar to an extinct plant that may have provided great healing power, a failure to document and research WHM may represent a loss of significant consequence. This is, in essence, an ethical issue with potential repercussions for society and healthcare.

Significant research issues emerging in herbal medicine include a bias in favor of a linear biomedical research model or researching plant parts as isolated fractions, extracted active ingredients, and manufactured botanical products. This results in the tendency to generalize findings from research on the chemical parts of a plant to the whole medicinal portion of the plant. Similar to a carpenter attempting to pound a nail with a feather, the biomedical approach may be the wrong tool to research WHM. The result is a failure to grasp the nonlinear complex nature of WHM and, thereby, neglect to adequately research and document WHM (Fonnebo et al., 2007; Mills, 2011). In other words, if WHM is diluted or hybridized and merged into a pharmaceutical model, it is no longer WHM and, therefore, no longer available.

Careful consideration of the traditional knowledge informing the foundations and practice of WHM is essential to valid and reliable research about medicinal plants. Relevant research for WHM would include studies on entire medicinal plants in individualized polyherb formulations including immediate and long-term effects of herbal medicines, timing factors and variables of individual receptivity. How herbs interrelate with and shift physiologic networks, genes, metabolic pathways, cell membranes, receptors and proteins needs greater understanding. New insights are needed that capture the complexities of the ancient practices of WHM to assure continued coevolution of plants and humans and emergent healing and well-being from medicinal plants (Spelman, 2006). Flexible research models examining systematic connections including multi-scale coupling, mutuality and cross-communication, and whole system responses over time should take precedence over models that reduce herbal medicine to components or linear inputs and outputs (Pincus and Metten, 2010). CSS offers research possibilities uniquely different than conventional biomedical approaches (Mills, 2011).

CSS shifts research away from a focus on the parts or active ingredients and products for a global herbal market (Tilburt and Kaptchuk, 2008) to consideration of interactive wholes, integral relationships, patterns within systems, and emergent changes. While traditional knowledge, as indigenous and ecological empiricism, is legitimate and valid (Dods, 2004), exploring WHM with CSS moves research to the context of how WHM is currently practised. This will highlight the value of a healing system rooted in time-tested, individualized, complex, whole-person approaches. Explorations of WHM can lend depth and richness to complexity science recursively while complexity science explains and gives greater understanding to traditional practices of WHM.

5. Implications for practice

Contextualizing medicinal plants and WHM with the tenets of CSS provides a whole systems perspective that is congruent with traditional knowledge of plant–human interactions. CSS offers herbal practitioners a pragmatic framework for the clinical practice of herbal medicine encompassing the whole plant–human connection. Partnering between plants and humans forms the foundation for practising herbal medicine with individualized formulations where the whole medicinal portion of the plant is used. The herbal practitioner benefits from viewing time-tested practices of WHM through the lens of CSS. The deep well of knowledge and experience in WHM supports the practitioner in the application of herbal medicines and provides an empirically based materia medica. Likewise, CSS provides the practitioner with appropriate tools to filter research findings and new information about herbal medicine. A CSS perspective will help the practitioner identify and eliminate incomplete biomedical research conclusions and claims that ultimately, if incorporated into a clinical practice, may do greater harm than good. CSS can broaden perspectives of herbal medicine and provide an awareness of

unexpected and global outcomes and potential benefits from individually tailored herbal formulations.

Throughout history, scientific claims have been made that eventually proved to be untrue or harmful. Current biomedical research findings on herbal medicine are primarily linear, reductionistic, and outside of the context of the natural healing processes of plant medicines. The question arises whether the practice of isolating, purifying and concentrating active constituents is truly the best way to study and apply herbal medicines or if, in time, this too will prove useless or harmful. While processing herbs for mass production negates the complexity of the whole plant, research simplifying outcomes to measurable, static and observable parameters negates human complexity (Spelman, 2011). Instead, it may be more valuable to see that individual health and wellbeing emerge from therapeutic plurality and phytochemical diversity (Spelman, 2011).

Acknowledging healthcare demands for options and medical pluralism and approaching herbal medicine from tradition and CSS offers practitioners a perspective for interpreting and differentiating research findings on herbal medicines. It brings added value to applications of herbal medicines according to traditional materia medicas containing experientially derived information on medicinal plants. WHM coupled with CSS allows for the development of practice-based theories in herbal medicine and new models to explain clinical outcomes with personalized whole plant medicines.

6. Conclusion

The metaphor of machine has infused science and healthcare since Isaac Newton described the universe as a great machine (Audi, 2006; Zimmerman et al., 2001). This infusion is evident in the linear, mechanistic models of biomedical research and product development in herbal medicine. Complexity science offers an alternative to the predominant machine metaphor (Zimmerman et al., 2001) by viewing the universe as an interconnected, living, dynamic system. CSS provides an opportunity to document, research, and coevolve traditional knowledge of WHM with an organic, whole systems perspective.

Learning to live and flourish in health is a great journey. WHM as a living tradition, based on the interactive relationship between plants and humans, continues to evolve and adapt through time. While building on the strength and wisdom of experience, new insights are requisite for new growth in WHM. Traditional WHM and CSS provide the practitioner with a wealth of solid, time-tested herbal medicine knowledge and a whole systems science approach to thoughtfully address new insights and perspectives of whole plant healing. Framing the application and research of WHM in complexity science represents an integral trajectory of exploration where science and herbal medicine intersect.

Conflict of interest statement

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