

The Ocean Inside Us

**A complex adaptive systems approach to considering the role of
marine ecosystems in sustaining human health**

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Introduction

Complex adaptive systems are characterized by a dynamic network of interactions among elements and the capacity to adapt and self-organize when individual or multiple elements are exposed to an event or events that trigger modification of the system's structure (Holland, 2006; Gell-Mann, 1994). The study of such complexity and adaptation is one approach within the field of systems theory, having the goal of identifying principles that can pertain to many types of systems, at many scales and in many fields of research. The ocean is one of the largest entities studied in systems ecology, which concerns interactions between an organism and its surroundings. Systems biology, by contrast, tends to focus on interactions within biological systems such as the human body. However, both the ocean and the human body can be considered as complex adaptive systems. In the context of such a systems-theoretical approach, we question how and to what degree the systems principles and structures pertaining to the ecosystem of the ocean could, at the same time, be relevant to the human body. Could the body be regarded as a microcosm of the ocean and, if so, by studying the sustenance of life in the ocean might we find implications for the maintenance of human health and wellbeing?

There is abundant evidence that land-based organisms evolved from the ocean (Lane and Martin, 2012; Russell et al., 1994) and that marine ecosystems continued to play a major role as human evolution progressed (Cunnane and Crawford, 2003). Given this close relationship, we are responding to the hypothesis that humans (along with other animals) internalized the sustaining matrix of minerals and trace-minerals found in ocean water in order to support intracellular and extracellular fluid conditions. We further hypothesize that, to this day, we depend on characteristics of this matrix for the sustenance of optimal health. Therefore, by analogizing the ocean to the human body, we posit that the systematic study of one system may support the understanding of the other, and vice versa. This approach prompts more general exploration of principles and methods for studying complex adaptive systems on different spatial scales. We hope to determine which approaches may be appropriate and adequate for investigating relationships between functioning marine ecosystems and a healthy human body.

Background

The link between marine ecosystems and human wellbeing

Water and the elements are essential for the development and survival of all biological systems. According to current theory, life on earth originated near hydrothermal vents on the bottom of the ocean about four billion years ago. (Lane and Martin, 2012). The Primordial Ocean contained 92 elements that formed the building blocks for those protocells from which all five kingdoms of life evolved. The fluid terrain (blood, extracellular fluid, etc.) of marine and early terrestrial life most likely contained all of these elements. Today we can identify 84 elements and 6 inert gases (two elements have decayed out of existence) that are present in seawater (Slovak, 2005; Crompton, 2006; Jacobs Thompson, 2006). For optimal functioning, the blood of animal species should be similar to isotonic seawater, with similar relative ratios of most elements. That, however, is no longer the case because soils that grow human foods are nutritionally depleted of many elements. A stable dietary source for most of the Periodic Table of the elements does not exist from land. A continuously sufficient supply of all minerals and trace minerals found in seawater appears the basis for the wellbeing of all living organisms (Sempere et al., 2012).

With regard to human evolution, a second factor might lead to the belief that an environment providing abundant marine nutrients could be particularly important for sustaining human health. As human beings emerged from *homo erectus* about 1.8 million years ago, living conditions in the early Pleistocene era might have propelled an adaptation to coastal dwelling. An abundance of seafood (shellfish, fish and seaweed) allowed, for example, for the fast growth of the human brain, resembling the brain structure of only two other mammals, dolphins and whales (Hof and van der Gucht, 2007; Crawford and Broadhurst, 2012; Kruse, 2012). This evolutionary step separates us from all other apes and may have profound implications for our dietary needs until this day.

Today, we find that a diet rich in omega 3 fatty acids – as well as minerals such as iodine, selenium or iron and vitamins such as vitamin E or B12 – promotes overall wellbeing and longevity (Calder and Yaqoob, 2009; Ahad and Ganie, 2010; Rayman, 2000; Brito et al., 2012). These findings support the assumption that a regular supply of seafood, which is particularly rich in minerals and trace minerals, supports a foundation for human health. It is possible that a decline in the consumption of seafood, along with the depletion of minerals in soils as a result of modern agricultural practices (Davis et al., 2004; Ahmad et al., 2012), have led to a decrease of minerals, trace elements and vitamins in our diets – nutrients that would be the building blocks for our cells and the basis for functional intercellular

communication. Furthermore, the steadily rising concentrations of toxins and pollutants in our environment increase our body's need for minerals, trace elements and vitamins, as our bodies experience ever-increasing detoxification demands. Minerals, trace elements and vitamins support these detoxification processes. Food choices with poor nutrient density but high anti-nutrient and sugar content stress our metabolism further (Cordain et al., 2005; Kant, 2003; Drewnowski and Darmon, 2005; Roos et al., 2013). As a result, an over-stressed human immune system may no longer be able to successfully fight infectious diseases, sustain autoimmune responses, or keep cancer cells in check. Restoring the balance of minerals, trace elements and vitamins in the human body not only supports the nervous system, but might prevent or even reverse chronic illness or fatal health conditions (O'Keefe and Cordain, 2004; WHO, 1990; Gaziano et al., 2012; Liu and Ames, 2005; Honey, 2013).

Appendix A includes additional information on the Marine Therapeutic Method. Appendix B contains definitions and historical background to help clarify and contextualize this work.

Matrix conditions and environmental contexts drive health outcomes

Dating back to the 1800s, Claude Bernard, considered the father of modern physiology, hypothesized that the *Milieu Interieur* (the Internal Terrain) is a physical reality that is responsible for preserving the liquid primordial marine basis of the organism:

Within the organism, cells behave like small aquatic creatures, submerged in a warm and dark environment... Cells form societies we call tissues and organs... The structure and function of cells are determined by the physical, chemical and electrical properties of the liquid surrounding them... One cannot conceive of the existence of the tissues without the existence of a liquid environment... (Carrel 1935).

With this paradigm, understanding the human body and its diseases is a reflection of the environmental conditions of the terrain. This “terrain” consists of the marine-derived fluids of the body, serving as the cellular “ocean.” When balanced in homeostasis, this *milieu interieur*, or the matrix conditions, support healthy immune function to ward off harmful microbes and disease.

This hypothesis – that the primary cause of disease is a function of environmental conditions of the terrain, or matrix – differs from the current medical model of Western medicine, which rests instead on Germ Theory. In its simplest form, the early Germ Theory proposed by Louis Pasteur (1822-1895) states that disease and illness result from microbes we encounter in the environment. Since Pasteur’s time, this thinking has become widely accepted – and for good reason. The medical community has successfully

identified microbes and developed extensive medicines, such as antibiotics, to kill microbes and control disease. This concept and approach have become ingrained in medical research and paramount in treatment protocols today. However, these treatments often fail to adequately deal with complex, chronic diseases and autoimmune deficiencies.

Germ Theory is not wrong, but it is incomplete and might improve through contextualization within a complex systems framework. Germ Theory will advance as it increasingly accounts for the importance of environmental contexts at the cellular level (i.e., *milieu interieur*), which is the scale at which microbes live.

Analogous to the false dichotomy of “Nature vs. Nurture,” both Germ Theory and *Milieu Interieur* hypotheses are correct to some degree. Neither one is 100% accurate, so neither extreme can answer all needs. A hybrid approach is warranted to account for the science of microbiology and microbes in addressing causes of disease, as well as to acknowledge the crucial importance of environmental context and host conditions. Through such a hybrid approach, we may be able to better understand complex illnesses such as chronic infections and autoimmune diseases.

We propose that the *Milieu Interieur*, hereafter referred to as the Matrix, is best thought of as a separate vital system of the body. The Matrix is well articulated by Dr. Stefan Kuprowsky (2013):

It begins where the capillaries release oxygen and nutrients into the extracellular fluid and moves through the connective tissues to the edge of the cell membranes where the nutrients and oxygen are absorbed. At the same time the cells release wastes which are transported through the matrix to the lymphatic system on its way back to the liver. At the same time the Matrix is connected to the hormonal endocrine system through hormones released in the blood of the capillaries. The Matrix is also connected to the central nervous system through the peripheral nerves that terminate here. As well the white blood cells of immune system hang out in the Matrix on call to attack invaders and communicate back to the rest of the body through a network of information molecules. This network of hormones, nerves and info-molecules creates a sophisticated feedback system throughout the entire body and forms the basis for what we know to be the mind-body connection.

The whole of the Matrix is greater than the sum of individual body parts. Emerging from this whole, key functions of the Matrix include (Kuprowsky 2013):

- provide nutrition to the cells;
- remove wastes from the cells;

- regulate the internal environment of cells through water balance, oxygenation, acid-base balance and mineral electrolytes;
- support cellular defense through free radical scavenging;
- maintain communication via the immune, endocrine and the autonomic nerve fibers; and
- form an energetic communication system via subtle electrical currents and ionic gradients (which is also known in acupuncture as the meridian system).

Through a variety of direct and indirect mechanisms, the Matrix is responsible for all the basic functions of the body. Health, disease, and healing all begin in the Matrix (Kuprowsky 2013).

Matrix thinking is not yet mainstream in Western medicine, but is undergoing resurgence in the 21st century, more than 200 years after these concepts were initially articulated. This resurgence is a result of the theory's ability to explain and heal complex, chronic illness when conventional Western medicine fails. Also, with advances in technologies, modern instruments, and 21st-century science, we are able increasingly to detect very small-scale changes and energetic properties of the Matrix that, collectively, make up the unified whole of a healthy physiological system.

We posit that this Matrix paradigm will become mainstream as science further contextualizes Germ Theory and today's Western medicine paradigm into a complex systems approach that accounts for broader environmental conditions, genetic predispositions, and other contextual factors.

Optimizing wellness through a complex adaptive systems paradigm

Complex adaptive systems can be regarded as systems that involve many components, which adapt or learn as they interact with each other and their environment (Holland, 2006). The ocean is an example, as it responds to an external environment that is continuously changing through influences of planetary configurations, atmospheric composition, etc. Another example is human blood, the makeup of which results from the availability of nutrients to the Earth-bound organism. Just as the whole of a living organism must react and adapt to the marine environment in which it develops, cells in the human body react and adapt to the fluid environment that supports them. Figure 1 illustrates the general structure of complex adaptive systems, which can pertain to both the macrocosm of the ocean and the microcosm of the human body. As noted in the Background section, the chemical composition of both environments has remained remarkably similar until today. A better understanding of the evolution of terrestrial life from origins in the ocean might therefore help, further, to comprehend processes on the micro-level of the human cell. A complex adaptive systems perspective could help to address how cells adapt to their

environment and what components may be necessary for optimal performance, and hence for the sustenance of human health from an evolutionary perspective.

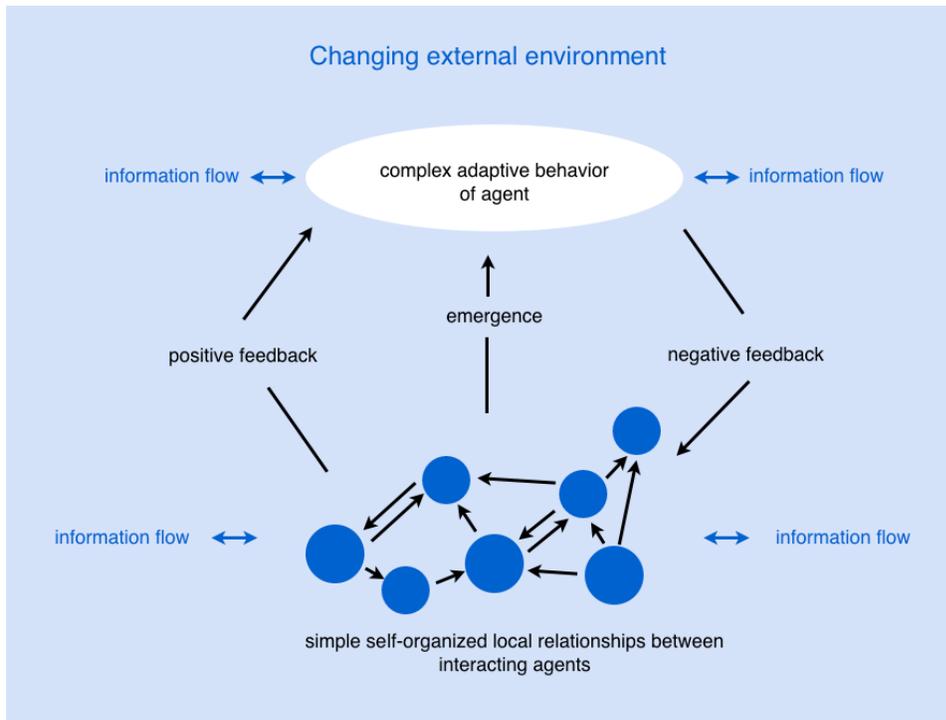


Fig. 1: Properties of complex adaptive systems

Research Areas for Study

The following topics are highlighted to encourage further discussions and scientific research into the Matrix and related concepts.

(1) Matrix Matters! The whole is greater than the sum of its parts

As this paper emphasizes, complex systems have emergent properties that make the whole greater than the sum of its parts, which is true for the human body as a system. There is a physical reality to the Matrix, as internal conditions through a network of hormones, nerves, cells, and nutrients that create a sophisticated feedback system throughout which all mind-body functions flow. Increasing recognition and scientific understanding of the Matrix – the interconnected background conditions and holistic context – will advance Western medicine.

(2) Modeling lipid bilayers as step towards better understanding of cellular systems

One way to explore the Matrix is by diving down into a small microcosm of the whole. Cells, like any entity, must respond to their environment in order to survive. Considering how these particular internal processes and external conditions relate calls attention to the questions of what elements, nutrients, and trace minerals may be able to enter and exit a cell, and how they do so. The cell membrane, as the structure defining the inner and outer realms, acts as a kind of gatekeeper – indeed, some would say it is so crucial as to be the functional “brain” of the cell.

Cellular membranes of almost all living organisms consist of lipid bilayers, which are thin polar membranes with electrical properties. These bilayers influence extracellular Matrix conditions and intracellular fluid composition and dynamics (Lipton 2011). Lipid bilayers surround the cell nucleus and other subcellular structures, forming a semipermeable membrane that regulates ions, proteins, and other molecules into and out of a cell. The availability and composition of nutrients in the form of ions in the environment determine the permeability of the lipid bilayer and, therefore, the cell’s performance. Understanding these dynamics and their implications from a complex systems perspective may be achieved by modeling the lipid bilayer and individual proteins at high resolution. Dynamic models can simulate the variable conditions and demonstrate the importance of marine nutrients and nutrient composition for human cells.

Example research of efforts completed or currently underway to explore such dynamics are:

- A simple NetLogo model simulates self-emergent properties of lipid bilayers and how the effects change with different charges and/or different molecules that are present under changing environmental conditions: <http://ccl.northwestern.edu/netlogo/models/MembraneFormation> (Head and Wilensky 2013; Wilensky 1999).
- Modeling of high-resolution 3-D protein folding, dependent on intracellular and extracellular conditions.

(3) Oligotherapy

Oligotherapy is the use of small doses of minerals for therapeutic support. Oligotherapy is one tool to help restore balance and homeostasis of the Matrix conditions. Minerals are essential catalysts that allow enzymes, vitamins, and other nutrients to perform their necessary roles to support immune system

functions, physical health, and mental health. A range of ailments, including lack of vitality, can be traced to imbalanced ratios of minerals, trace elements and vitamins (Muller 2002). Oligotherapy – especially oligotherapy with bioavailable minerals from marine sources – provides the body with the necessary building blocks (e.g., elements) it needs for healing and long-term wellness. Simply taking standard mineral supplements may not correct imbalances, since not all mineral forms are digestible and usable to the human body (i.e., bioavailable) (Muller 2002). Much research remains to integrate this naturopathic approach to wellness, oligotherapy, with the science taught in Western medicine. Perhaps research and efforts could begin with an increased emphasis on nutritional courses taught in medical, nursing, and veterinary schools?

(4) Nanomineral treatments as an emerging medical frontier

Nanominerals are nanoparticles made of naturally occurring minerals of less than 100nm in diameter. Scientists and engineers only recently discovered ways to detect, measure, and create nanoparticles, which exhibit new or enhanced size-dependent properties when compared with larger particles of the same material. Generally, the smaller the size of the nanoparticle, the more reactive it is – up to a threshold point, as particle stability decreases at very small sizes. With rapid developments in nanotechnology, novel aspects of the healing potential of minerals are emerging as a new frontier in medicine. Emerging research in silver and gold nanoparticles shows potential to revolutionize gram-negative bacteria treatments (e.g., Lyme disease), autoimmune disorders (e.g., arthritis), and cancer diagnosis and treatments. For example, silver nanoparticles or “nanosilver” has potential to target multiple disease organisms simultaneously (Qu et al. 2005); destroy gram-negative and Lyme bacteria, even in the cystic and cell-wall deficient forms (Song et al. 2006; Ghazvini et al. 2008; Ruparelia et al. 2008; Wasif and Laga 2009); prevent biofilm formation (Gibbins and Warner 2005); synergistic antibacterial effect to increase antibiotic efficacy (Shahverdi et al. 2007); does not give rise to drug-resistant forms of the bacteria; and is not toxic to human cells in therapeutic doses. Peer-reviewed science exists to mechanistically understand how minerals and nano-minerals facilitate antibiotic delivery across the blood-brain barrier, combat intracellular infection, and dissolve biofilms (Rai et al. 2009; Baratchi et al. 2009; Estevez and Erlichman 2011; Morones-Ramirez et al. 2013). Nonetheless, this science about the relationship between nanominerals and human health is in its infancy. This has significant potential, yet unknown risks, so research is needed.

Conclusion

This paper summarizes a relatively new approach to human health maintenance by applying the conceptual framework of complex adaptive systems and combining it with an evolutionary perspective that acknowledges persistent underlying biochemical structures stemming from the origin of life on earth. Next steps could include:

- publication of this work (or aspects of this work) in peer-reviewed journals.
- development of models to simulate the composition and conditions of outer matrices and inner organismal cells, and control mechanisms of the boundaries between them; and
- creation of educational programs to bring into broader consciousness the scale-transcending concept of internalization of the ocean substrate. We see opportunities in the widespread requirement for physicians' ongoing professional development and in current capabilities for and fascination with online learning programs.

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