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NUTRIENT SYNERGY AND COMPLEXITY THEORY: A NEW PARADIGM?

Annemarie Colbin, Ph.D.

Abstract

This paper suggests that there is need for an amplified paradigm in nutrition, going beyond biochemistry, to accommodate new research on the effects of whole foods and complex dietary systems. It offers a brief history of nutrition science, an overview of successful applications of the reigning nutritional paradigm and a rationale for a paradigm expansion. It is suggested that complexity theory can offer the theoretical framework for such an expansion. As an example, the author offers examples for applying complexity theory to understanding food and the human body as complex adaptive systems, rather than mechanical constructs. Complexity theory brings strength to concepts such as *whole foods, food synergy,* and *nutrient synergy*. Examples are given for practical applications of the paradigm.

Introduction

There is a new paradigm cautiously appearing in the field of nutrition: the concept of food synergy.[1] This concept holds that dietary systems, as combinations of foods consumed by individuals, are a fitting field of study for the increased understanding and dissemination of useful knowledge about the effects of food on human health.

This complex view may not fit into the reigning paradigm, as it is understood or assumed by nutritionists, funders, and other scientists.

What is the current theoretical framework of nutrition? Sizer suggests, ". . . (it) is a science – a field of knowledge composed of organized facts.[2 (p. 2)]It appears to be biochemistry, although one may be unable to find this concept expressly stated anywhere. According to the definition of Garrison and Somer, nutrition is the study of foods and their constituents – their ingestion, digestion, absorption, transport and utilization. The term nutrition includes the action, interaction and balance of food constituents as they pertain to human health and disease.[3 (p. 3)] In addition, Nutrition is the study of how food nourishes the body.

The salient points in this definition are the following: nutrition studies food and *the components of food*, which qualifies the approach as *reductionistic*, seeking to identify the parts that contribute to the whole effect. It is a science, albeit a relatively young science when compared to astronomy and physics. As a science, it is purportedly based on facts, although nutritionists Frances Sizer and

Eleanor Whitney do agree that no such thing as a *fact* exists in science. Science consists of *hypotheses* that can always be challenged and revised. [2 (p. 3)]

While the *science* of nutrition may be young, the *study* of how food affects the body is as old as humanity, and as widespread. Every culture has its food habits, customs, and taboos, which are based on the culture's cosmology and world views. The importance of food as a contributor to good health has been known for at least 7000 years, according to Egyptian pictographs.[3] Among the 70 works of the Hippocratic collection from medical treatises of the 4th Century BCE in Greece, there is one on Nutriment that has been attributed to either Hippocrates, Thessalus or Herophilus (according to the translator, W.S. Jones). In it, the author speaks in aphorisms that say, in essence, that food can be nutritious or not, that milk or meat are good for some people and not others and that food influences all parts of the body, both fluid and solid. Jones points out that there is a theory of relativity expressed in this approach. It clearly implies that the effects of foods are relative to the consumer: "Food has power . . . but power in its various forms is manifested only in relationship to other things." Further, he states that "In *Nutriment* relativity is made to apply, not merely to the knowledge of properties, but to the properties themselves." [4 (p. 337-41)] Thus it could be said that the Hippocratic position is that the qualities of food can be helpful or not depending on their context and the condition of the person consuming them – – not just on their composition. The foods considered at the time were the natural foods, and their influence was viewed as pervasive throughout the body. This venerable viewpoint is experiencing a renaissance in the contemporary wholistic approach to food and diet.

This paper argues that the biochemical paradigm needs expanding in order to accommodate such an approach, and examines the possibilities of incorporating complexity theory into a more generalized and broader paradigm of wholistic nutrition.

A brief history of nutrition science

As chemistry replaced alchemy in the 16th century, it took only a short step to apply it to the human body. The first scientific investigations into the chemical nature of digestion are credited to Renè de Rèamur (b. 1683). Later, the study of energy metabolism in laboratory animals was established by Antoine Lavoisier.[3] The age of exploration by sea, from the 1500's on, brought attention to scurvy, one of the first of what were later determined to be deficiency diseases. Scurvy causes exhaustion, tooth loss, hemorrhages, severe diarrhea and muscle pains. The first remedy for scurvy was given to French explorer Jacques Cartier, who had sailed with a crew to what is now Quebec in 1536, where they made camp. A few months into the winter 25 of his men had died and others had become seriously ill. A local native showed Cartier how to make tea from the bark and leaves of the yellow cedar tree (*Thuja occidentalis),* and on this tea the men recovered. Later it was found that the tea contained a high amount of Vitamin C. However, this remedy did not become generally adopted.[5]

In 1747, Dr James Lind devised a controlled study with twelve peope who had scurvy. He put them all on identical diets but gave each pair of participants one of the six reputed scurvy cures, which included cider, vinegar, seawater, oranges and lemons, a drug mixture and diluted sulfuric acid. After six days, only the citrus eaters had recovered completely. He recommended that all sailors be given citrus rations. Famed captain James Cook followed his advice and also instructed his men to find fresh fruits and vegetables wherever they went. The result was that in all his travels from 1768 to 1780, Cook did not lose one man to scurvy.[5 (pp92-3)] Nevertheless, it wasn't until 1795 that the official policy of including a daily portion of fresh lime juice was adopted by the British Navy, a policy that eventually let to British sailors being called limeys.[3]

Justus von Liebig, a German scientist, was among those who pioneered the study of heat and oxygen/CO_2 production in humans in the early 1800's.[3] Emil Abderhalden and other researchers established that protein would break down into amino acids during digestion.[6] His work established the importance of the macronutrients – – protein, carbohydrates, and fats – in energy production.[7] Wilhelm Stepp performed studies that showed the presence of an unknown substance essential to life and health in fat-containing foods such as milk, egg yolk, and butter. Casimir Funk also found such a substance in water-soluble foods, and in 1911 named it vita-amine[7] from whence comes the contemporary term vitamin.

Successful applications of the nutrition paradigm

The scientific theory of nutrition has been very successful in clarifying one particular aspect of food: its composition, and how its various components affect health and the functioning of the human body. The vitamin deficiency theory, building also on the successful elimination of scurvy, led to the eradication of other common diseases such as pellagra, beri beri, goiter and rickets through the implementation of public health measures that included the fortification of refined white flour with B vitamins and iron, of milk with Vitamin D, and the addition of iodine to salt.[8, 9]

In contemporary Western biomedicine, dietary therapies are most commonly used in very specific diseases or conditions where certain deficiencies and metabolic defects are found. The dietary therapies aim to correct these deficiencies or to eliminate food components that patients cannot utilize because of metabolic defects.

The following are some of the diseases and conditions treated with diets that aim to correct nutrient imbalances in the medical model:

- *cardiovascular disease or CVD* (to lower blood cholesterol[10] and high blood pressure[11]);
- *diabetes* (to reduce blood glucose by reducing the intake of refined sugar and other simple carbohydrates[12]);
- *hypoglycemia* (to bring up blood glucose levels through small and frequent carbohydrate feedings);
- *phenylketonuria* or *PKU* (to eliminate the ingestion of phenylalanine[13, 14]);
- *coeliac disease* (to eliminate the ingestion of gluten[15]);
- *central nervous system or CNS injury* (to increase protein and calorie intake[16]);
- *allergies* and *food intolerances* (to eliminate the offending foods[17]);
- *chronic renal failure* (to lower protein intakes[18]; *diarrhea and constipation* (to regularize intestinal function[19]);
- *obesity* (to restrict calories and, in some cases, to re-educate the patient in correct eating habits[20]);
- *renal stone formation* (to prevent its occurrence[21]);
- *lactose intolerance or lactase deficiency* (to provide lactose-free diets[21]);
- *nutritional deficiencies* including but not limited to protein-calorie malnutrition; and *seizures* (the high-fat ketogenic diet[21]).

These diets generally manipulate the amount and proportion of macronutrients (protein, carbohydrate, and fats) and micronutrients (vitamins and minerals).

Rationale for a paradigm expansion

The uses of food for medicinal purposes has a long history[22] but there is no firm underlying theory that connects all these approaches in terms of a cohesive contemporary Western viewpoint. There is, however, what Murray Gell-Mann has termed an assumed theory,[23], which is scientific reductionism, and that theory guides both researchers and funders.

The lack of a theory of wholeness is beginning to interfere with the progress of contemporary scientific studies of nutrition. During a conference on Food Synergy in May 2001 attended by this author, a number of academic researchers presented papers that showed the importance of using whole foods, rather than individual nutrient supplements, to obtain one's complete nutrition and to prevent chronic disease.[24],[1] However, it was mentioned several times by participants that it is difficult to obtain funding for studies of foods because the funding agencies, including the National Institutes of Health (NIH), are firmly entrenched in the biochemical model and prefer to fund studies of the effects of individual nutrients and biochemical pathways. It would seem therefore that expanding the model of nutrition beyond biochemistry, to include in it other theories that support studying the complex interactions of foods, dietary systems and human health, could provide a theoretical rationale for the funding agencies to support such research projects.

Classic biochemistry has its place but over-reliance on this reductionistic model deprives the field from many useful and exciting new ideas. One field that can greatly illuminate and expand the conceptual framework for studying the effects of food on health is complexity theory.

Complexity theory

According to Coveney and Highfield, "Through its emphasis on the study of the whole, rather than individual parts, complexity [theory] offers a means for transcending the materialistic limitations of reductionism and allows us instead to build a bridge between science and the human condition."[25 (p. 14)]

A precursor of complexity theory is the work of Belgian chemist Ilya Prigogine, who won the 1977 Nobel Prize in chemistry for his work on nonequilibrium thermodynamics, and particularly for his theory of dissipative structures – those that exchange both matter and energy with their environment; Prigogine states that they are "essential in the understanding of coherence and organization in the non-equilibrium world in which we live."[26(p84)] Living beings, and certainly humans, are obvious examples of dissipative structures. They exhibit cyclic and oscillating behaviors that nevertheless keep them at a level of order far from thermodynamic equilibrium. "Biological order," writes Prigogine, "is both architectural and functional; furthermore, at the cellular and supercellular levels, it manifests itself by a series of structures and coupled functions of growing complexity and hierarchical character."[26 (p. 83)]

Living systems, which are dissipative structures, are not random: they are self-organizing systems that depend on the self-reinforcement of useful small effects as the system keeps flowing.[27 (p. 33-34)] Similarly, complex systems are entities composed of many relatively independent parts that are highly interconnected and interactive.[28(p2)]

The major characteristics of complex systems are self-organization, replication or reproduction, learning and adaptation. They "never stop at fixed points. They are forever dynamic and can be considered dead and of little interest when they come to thermodynamic equilibrium." [28 (p. 3)] Because of their inherent capacity for adaptation, complex systems have also been called Complex Adaptive Systems (CAS), and in fact this is their most popular name. Bunk describes CAS as systems that exhibit random variation and selection, which then results over time in learning or evolution. A CAS can be microscopic like bacteria, a function like the immune system, an organ system like the central nervous system; it can be an organism that includes those systems; it can even be a composite of such organisms, like a termite mound, an ecology, a corporation or an economy. Most importantly, a CAS can self-organize, and the various phenomena or behaviors that emerge from this self-organization cannot be fully understood by analyzing parts of the system and then combining them.[29]

Applying complexity theory to food and the human body

Nutrition is embedded in biology, which has been based on chemistry, and chemistry studies the behavior of elements or small particles, an approach which ultimately comes from classical physics. Physics has been called the root science, the one on which all the others are based. The paradigm that reduces biology to chemistry and physics has ”taken living phenomena down into the realm of the nonliving and tried to explain them in its terms.” [30 (p. 28-9)] Futurist Willis Harman and biologist Elizabet Sahtouris call for ”a more holistic biology, characterized by recognition of wholes being more than the sum of their parts, by ë*emergent*’ qualities not reducible even in principle to the physical sciences.”[30 (p/ xiv)]

Human beings could be viewed as *nested wholes* (genes, cells, tissues, organ systems) that are clearly self-organizing and thereby self-healing. They exhibit what Varela and Maturana have called *autopoiesis*, or self-creation. Fritjof Capra explains it as a ”network of production processes, in which the function of each component is to participate in the production or transformation of other components in the network. In this way the entire network continually rëmakes itself.’ It is produced by its own components and in turn produces those components.”[31 (p/ 98)]

In this process, it could be argued that food provides the raw materials from which the system can continue to produce itself. The system breaks down the food into its constituent particles, and then reassembles these as needed for its own functions.

Whole foods and nutrient synergy

Just as a human being is a complex system, so are all the elements that nature provides for its food, be they plants or animals. This paper proposes that the body’s hardware is designed to interact with the complex software of natural vegetable or animal systems, with only salt (NaCl) as a habitual mineral element. For 100,000 years or more humans consumed natural foods like vegetables, tubers, natural cereal grains, fruits, nuts, fish, fowl, mammals, insects and so on. Each of these whole foods comes with a team of nutrients that are complementary and synergistic in their action, and this wholeness is what makes them both nutritious and effective in maintaining health.[32] This changed during the late 19th and all through the 20th centuries. European societies started consuming bread and pasta from flour that was stripped of its bran and germ (because then it didn’t attract rodents or insects), instead of the traditional coarse brown bread; they turned to sugar refined from the sugar cane instead of fruit or honey for sweeteners. In Asia, brown rice was replaced by white rice, depriving the local populations of its habitual source of fiber and B vitamins.

The reductionist study of vitamins and its associated industry flourished, so that what was taken from the food with one hand was returned with the other in the form of supplements or enrichment. Nutrients were considered chemicals ”separable from food.”[33 (p. 25-29)] The ultimate success story of the reductionist view of nutrients is in Total Parenteral Nutrition (TNP), used in hospitals to keep people alive when they cannot eat because of surgery and other conditions.

Recent studies have found that things are not so simple. Whole foods, or the intake of certain nutrients within foods, have been found to be more effective in the prevention of disease than supplements.[24, 34] One well-publicized study found that supplementation of beta carotene to smokers not only failed to provide protective benefits, but might actually have deleterious effects. Therefore, the author says, it seems unjustified to advocate supplementing a smoker's diet with beta carotene.[35]

Applications and Conclusion

As a complex adaptive system, the human organism is not only constantly changing, it is also constantly learning and adapting. All its parts work together synergistically, and they communicate with each other instantaneously. Studying the effects of whole foods on a complex human system is extremely valuable and can be classified as studying *nutrient synergy*. Studying the effects of a combination of foods, as in dietary systems such as the Mediterranean diet, could be classified as *food synergy*. Both these points of view can be justified by the inclusion of complexity theory into the nutritional paradigm. Computer modeling is one methodology that would allow such studies, and is beginning to be used in systems biology, in such institutions as Oxford (England) and Stuttgart University (Germany)[36]. It is to be hoped that such a broader theoretical framework will give new impetus to original research and its subsequent clinical applications.

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