Review Article

Ecosystem Health Disorders - changing perspectives in clinical medicine and nutrition

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The inseparability of people from their ecosystem without biological change is increasingly clear. The discrete species concept is becoming more an approximation as the interconnectedness of all things, animate and inanimate, becomes more apparent. Yet this was evident even to our earliest Homo Sapiens sapiens ancestors as they hunted and gathered from one locality to another and migrated across the globe. During a rather short 150-200,000 years of ancestral history, we have changed the aeons-old planet and our ecology with dubious sustainability. As we have changed the ecosystems of which we are a part, with their opportunities for shelter, rest, ambulation, discourse, food, recreation and their sensory inputs, we have changed our shared biology and our health prospects. The rate of ecosystem change has increased quantitatively and qualitatively and so will that of our health patterns, depending on our resilience and how linear, non-linear or fractal-like the linkage. Our health-associated ecosystem trajectories are uncertain. The interfaces between us and our environment are blurred, but comprise time, biorhythms, prokaryotic organisms, sensory (auditory, visual, tactile, taste and smell), movement, endocrine with various external hormonal inputs through food and contaminants, the reflection of soil and rock composition in the microbes, plants, insects and animals that we eat (our biogeology) and much more. We have sought ways to optimise our health through highly anthropocentric means, which have proven inadequate. Accumulated ecosystem change may now overwhelm our health. On these accounts, more integrative approaches and partnerships for health care practice are required.

Key Words: ecohealth and econutrition, geobiology, connectedness, species, food and health systems

INTRODUCTION

One of the most powerful arguments for conceptualising ill-health and practising health, including nutritional, care from an integrative ecosystem point of view is that the best health outcomes are evidenced at the community and household level[1-5] and because it is difficult to account for much of the variance by reductionist approaches, certainly in regard to diet.[6,7] Food systems and the cuisines which they support go some way to capturing the information we need to account for and optimise human health, evidenced across cultures from the Mediterranean to Asia, the Antipodes and Africa.[3,6-9]

In this review, integrative and reductionist evidence is brought together about ecohealth to make the case for the place of an 'ecosystem disorder' appreciation within the health and nutritional care systems. From clinical nutrition experience, a different perception of nutritional disorder obtains if the question is asked, is there an ecosystem connection? This applies to a range of situations from the material, inert or so-called inanimate parts of the ecosystem, as with major and minor elements,[10-12] through to its most complex animate parts, our plant and animal-derived foods.[13] Wahlqvist has argued previously that 'connectedness' between animate and inanimate is basic to our well-being.[14] Lieff, a neuroscientist and psychiatrist, currently explores the relationships between the mind and the material world which includes all manner of ecosystem and food-related components as a way to understand health and wellbeing.[15]

From a more mechanistic point of view, an ecosystem in all its animate and inanimate parts combined, acts in its own interests and, where humans are a part, to modulate fundamental biological pathways of activity (energy acquisition and expenditure) transduction, cell differentiation and proliferation for growth together with development and repair, defence and repair involving immunity

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and inflammation, reproduction and family welfare, mind and behaviour with interpersonal and societal association. Well-being and health are services which an ecosystem can provide, provided its ability to do so is not thwarted by the beneficiaries themselves. The problem now faced is that ecosystems have been plundered in such an anthropocentric fashion that their sustainability is precarious and our health with it.

CHANGING PERSPECTIVES OF DIET AND HEALTH

Nutrients-essential and otherwise, foods, food patterns

Nutrients may be 'macro-' (protein and amino acids; carbohydrate being mono-, di-, oligo- or polysaccharides starch and non-starch; fat and fatty acids, water) or 'micro-' (vitamins, minerals and trace elements). They may be essential, conditionally essential or non-essential; irrespective of this status, their intake needs to be optimised lest it be too little or too much.[16,17] *The concept of nutrient essentiality* has served nutrition science and the nutritional advancement of health well for more than two centuries, but it is limited. That of the *elements* carbon, oxygen and nitrogen, basic to life, was evident to European scientists in the late 1700s. At various historical time points other inorganic essential elements were recognised and included sulfur, phosphorus, calcium, potassium, sodium, iron, iodine, copper, zinc and selenium. These continue to account for perturbations in health in various locations, but which are difficult to resolve without systems or food-based approaches.[16,18-20]

Although itself not essential for humans, since we can synthesise it, the discovery of *a compound*, an amino acid, asparagine, in asparagus in 1806 by the French chemists Louis Nicolas Vauquelin and Pierre Jean Robiquet set the scene for the concept of organic nutrient essentiality. Asparagine is widespread in both animal and plant-derived foodstuffs and required in many metabolic pathways including ones affecting growth and development, especially for liver, muscle, heart and brain, and is likely to have an optimal intake, perhaps even essential in some species during growth,[21] depending on the background diet and other environmental factors, but that has remained inadequately investigated, as is likely for most dietary components. For example, asparagine as a principal contributor to the formation of acrylamide, a carcinogen, in baked and fried foods has only been a consideration since 2002;[22] does this mean there should be more or less in some diets? This illustrates how that what may be considered an established fact about essentiality is challengeable in the light of environmental change. Yet such dilemmas may be manageable by a dietary pattern approach to risk management.

The chemistry and biology of proteins (Berzelius in 1838) and carbohydrates (Von Liebig in the mid-1800s) was not appreciated until the 19th century. That of fats, other than as an energy source, was not identified until the 1920s by George and Mildred Burr when they demonstrated the essentiality of certain fatty acids.

Indeed, *what we usually mean by essential* is that we cannot live without intake of the nutrient in question in the short to medium term, possibly weeks. That we can sustain patients who cannot eat, by way of enteral or parenteral feeding for these durations does not mean that this is optimal or commensurate with the life expectancy experienced by the population-at-large. Other nutritional factors are required and we are beginning to understand what they are. They include *a number of health protective bioactive compound*s, many of them from plants (phytonutrients) and others from animal (zoonutrients) or fungi (phyconutrients) or our microbiota in the gut, on the skin, in the respiratory or reproductive tracts.[23-27] Their essentiality on a one-by-one basis is arguable,[28-30] but collectively or with complementarity between each other and other nutrients they do confer health advantage. Yet this advantage can be rapidly or slowly gained or lost in ways that involve the concerted action of both dietary pattern and the microbiota.[24-26] What then becomes essential is the integrated performance of environmental factors, food systems and microbiological systems along with the locality and personal behaviours which affect them.

The most successful way to achieve the spectrum of bioactive elements and compounds required for human biology, given that we are omnivorous with a plant food bias for optimal health, is for the food intake to be characterised by diversity.[28-33] This also dilutes out potential adverse food components and contaminants. However, there does need to be a sufficient energy throughput, allowed by being physically active enough, in order to gain the health-protective bioactive adequacy which diversity can provide.

Studies which demonstrate the value of dietary patterns over individual foods[6,30] or nutrients[6,29] generally find that the patterns represent dietary diversity.[28,31,33] The exception is that legumes seem, cross-culturally and within cultures, to be life-extending food stuff;[34,35] beans also enhance the nutritional value and efficacy of other food commodities in regard to amino acid, phytonutrient and physicochemistry profiles.[36] In turn, these observations argue for biodiverse ecosystems as the basis for good health.[33,37,38] The measurement of this food diversity can be achieved in various ways: by food group as with the dietary diversity score (DDS)[26,34] or on the basis of biologically distinct foods.[27,32,33,37,38] The approach described by Briggs and Wahlqvist[32] and developed as a personal or clinical check-list by Savige et al is shown in Table 1. In this latter case the different kinds of foods eaten across a week is assessed with a maximum score of 64- a good score is one above 20 and approaching 30. With 6 food groups, 4 or more on any day is desirable, judged by health outcomes.[30] Across a week, it is encouraged to diversify within each group.

The generalisability of nutritional biochemistry and physiology among different forms of life implies that the presence and well-being of species is ecosystem dependent and inter-dependent. The essentiality of these dependencies has seemed immaterial to many until ecosystem loss and compromise has become extreme and rapid.[39-41] The geobiological interplay between soil-derived elements for the food chain and health problems has been most obvious for I, Zn and Se deficiencies and present, but less clear-cut, for Fe, Mg and Ca, since their nutritional status is dependent on quite complex environ-mental inputs other than soil and including parasitosis in the case of Fe. The imminent limits to agriculture are with geological P, N and K. Deposits of P are increasingly exhausted and

Table 1. Food variety checklist (developed for Australia)

Grains and cereals

1.□ WHEAT
- Cracked
- Burghul
- Semolina
- Wheat germ
- Couscous
- Flour
- Breads (white, whole-meal)
- Pasta
- Ready-to-eat (Weetbix)
- Cakes
- Biscuits
- Muffins

2.□ RICE
- Flakes
- Noodles
- Ready-to-eat cereals (Rice bubbles)
- Cakes
- Biscuits/crackers

3.□ OATS
- Flakes
- Rolled
- Instant
- Bran
- Ready-to-eat cereals (porridge, muesli)
- Cakes
- Biscuits/muffins

4.□ CORN
- Sweet corn
- Maize
- Polenta
- Ready-to-eat cereals (Corn flakes)
- Corn bread
- Biscuits

5.□ RYE

6.□ BARLEY
- Pearl
- Rolled
- Flakes

7.□ OTHER
- Buckwheat
- Millet
- Quinoa
- Sago
- Tapioca
- Triticale
- Matzo Meal

Fruit (fresh or dried)

8.□ STONE
- Apricot
- Avocado
- Cherries
- Nectarine
- Olive
- Peach
- Plum
- Prune/dried plum

9.□ CITRUS
- Grapefruit
- Lemon
- Lime
- Mandarin
- Orange
- Tangelo

10.□ APPLES

11.□ BANANAS

12.□ BERRIES
- Blackberry
- Blueberry
- Boysenberry
- Cranberry
- Cloudberry
- Currant
- Gooseberry
- Mulberry
- Raspberry
- Strawberry

13.□ GRAPES
- Purple
- Green
- Raisin
- Sultana

14.□ MELONS
- Honeydew
- Rockmelon (cantaloupe)
- Watermelon

15.□ PEARS, NASHI

16.□ TROPICAL
- Custard apples
- Durian
- Guava
- Jackfruit
- Loquat
- Lychee
- Mango
- Papaya/pawpaw
- Pineapple
- Rambutan
- Star fruit
- Tamarillo

17.□ KIWIFRUIT

18.□ PASSIONFRUIT

19.□ DATE

20.□ FIG

Vegetables

21.□ ROOT
- Beetroot
- Carrot
- Cassava
- Ginger
- Jerusalem artichoke
- Lotus root
- Parsnip
- Potato
- Radish
- Sweet potato
- Swede
- Turnip
- Yam

22.□ CRUCIFEROUS (Flower)
- Bok choy
- Broccoli
- Brussels sprouts
- Cauliflower
- Cabbage
- Kale
- Kohlrabi

23.□ GREEN LEAFY
- Endive
- Lettuce
- Rocket
- Silverbeet
- Spinach
- Watercress
- Vine leaves

24.□ MARROW
- Cucumber
- Eggplant
- Pumpkin
- Squash
- Zucchini

25.□ STALKS/STEMS
- Celery
- Rhubarb
- Stalks from green leafy vegetables

26.□ BULBS
- Chives
- Garlic
- Onion
- Leek
- Spring onion
- Shallots
- Water chestnuts

27.□ PODS
- Beans
  - Green
  - Broad
- Okra
- Peas
  - Green
  - Red
  - Snow

28.□ CAPSICUM/PEPPERS
- Green
- Red
- Yellow

29.□ SHOOTS
- Alfalfa sprouts
- Asparagus
- Bamboo
- Bean sprouts
- Cress

30.□ TOMATOES

31.□ SEAWEES

Legumes/pulses (dried beans and peas)

32.□ DRIED BEANS
  - Adzuki
  - Baked beans
  - Black-eye
  - Bortolli
  - Cannellini
  - Kidney
  - Lima
  - Lentils
- Dried Peas
- Chickpeas
  - Hummus
  - Flour (Beans)
- Split Peas

33.□ SOY
- Soybeans
- Soy bread
- Soy cereal
- Soy grits
- Soy cheese
- Soy ice-cream
- Soy milk
- Oil
- Tempeh
- Tofu
- Yoghurt

34.□ NUTS & SEEDS
  - Almonds
  - Brazil
  - Cashew
  - Coconuts
  - Hazelnut
  - Macadamia
  - Peanuts (including peanut butter)
  - Pecan
  - Pistachios
  - Pine nuts
  - Walnut
- Poppy seeds
- Pumpkin seeds
- Linseed/flax seeds
- Sesame (Tahini paste)
- Sunflower seeds

Meat

35.□ BEEF, LAMB, VEAL

36.□ PORK
- Ham
- Bacon

37.□ POULTRY
- Chicken
- Turkey
- Duck

38.□ GAME (BIRD)
- Emu
- Pheasant
- Pigeon
- Quail

39.□ GAME (ANIMAL)
- Crocodile
- Goat
- Kangaroo
- Rabbit
- Venison

40.□ LIVER
- Lamb's fry
- Pâté de foie gras
- Liverwurst

41.□ BRAIN

42.□ OTHER ORGANS/OFFAL
- Heart
- Kidney
- Oxtail
- Tongue
- Tripe
- Sweetbreads

Seafood and fish

43.□ CRUSTACEANS
- Bugs
- Crabs
- Crayfish
- Prawns
- Lobster
- Scampi
- Shrimp
- Yabbies

Table 1. Food variety checklist (developed for Australia) (cont.)

44.□ SHELLFISH/MOLLUSCS
- Abalone
- Clams
- Cockles
- Cuttlefish/calamari
- Mussels
- Octopus
- Oysters
- Pipis
- Scallops
- Squid/calamari
- Whitebait

45.□ FATTY FISH
- Anchovies
- Eel
- Herring
- Kippers
- Mackerel
- Pilchards
- Salmon
- Sardines
- Tuna

46.□ FRESH WATER
- Trout
- Carp
- Murray cod
- Perch
- Red fin

47.□ SALT WATER
- Blue grenadier
- Bream
- Dory
- Flathead
- Flounder
- Garfish
- Gemfish
- Shark/flake
- Snapper
- Sole
- Trevally
- Whiting

48.□ ROE (FISH EGGS)
- Caviar
- Taramasalata

Dairy

49.□ DAIRY
- Milk
- Cheese
- Yoghurt
- Ice-cream

50.□ DAIRY WITH LIVE CULTURES
- Milk (fermented)
  - Yakult
- Yoghurt
  - Acidophilus
  - Bifidobacteria

Eggs

51.□ EGGS
- Chicken
- Duck

Water

52.□ WATER
- Tap
- Mineral
- Soda
- Tonic

Beverages

53.□ NON-ALCOHOLIC
- Cocoa
- Coffee
- Tea
- Milk drinks
  - Chocolate
  - Flavoured milks
  - Horlicks
  - Milo
  - Ovaltine
  - Quick

54.□ ALCOHOLIC
- Beer
- Wine
- Fortified wines
- Spirits
- Liqueurs

Herbs and spices

55.□ HERBS/SPICES
- Basil
- Bay leaf
- Chives
- Dill
- Fennel
- Marjoram
- Mint
- Oregano
- Parsley
- Rosemary
- Sage
- Sorrel
- Tarragon
- Thyme
- Cardamom
- Cinnamon
- Cloves
- Coriander
- Cumin
- Fenugreek
- Garam masala
- Ginger
- Mustard seed
- Nutmeg
- Paprika
- Saffron/turmeric
- Vanilla

Yeast

56.□ BEER
- Cider
- Baker's yeast
- Brewer's
- Torula
- Spreads
  - Vegemite
  - Marmite

Mushrooms and truffles

57.□ MUSHROOMS
- Cultivated (champi-gnons)
- Field
- Enokitake
- Shiitake
- Straw
- Truffles

Sugar and confectionery

58.□ TABLE SUGAR
- Chocolate
- Soft drinks/lollies
- Molasses

Insect, insect products and other delicacies

59.□ HONEY
- Sugar ants
- Grasshoppers
- Snails
- Frogs legs

Fats and oils

60.□ HARD
- Butter
- Margarine
- Nuts and nut spreads

61.□ SOFT
- Oils
  - Corn
- Cottonseed
  - Olive
  - Peanut
  - Rapeseed (Canola)
  - Safflower
  - Sesame
  - Sunflower

Fermented foods

62.□ BEAN
- Miso
- Natto
- Tempeh
- Soya sauce

63.□ VEGETABLES
- Kim chi
- Sauerkraut
- Pickles

64.□ OTHER FERMENTED FOODS

Milk products
- Liquid
  - Buttermilk
  - Sour cream
  - Yakult
  - Yoghurt
- Cheese
  - Camembert
  - Blue vein
  - Cheddar
  - Gouda
  - Neufchatel
- Bread
  - Sourdough
- Vinegar/cider
- Alcoholic
  - Beer
  - Sake
  - Liqueurs

Maximum total food variety score 64

Total food variety score	Dietary adequacy
30 or more per week	Very good
25-29 per week	Good
20-24 per week	Fair
Less than 20 per week	Poor
Less than 10 per week	Very poor

†The concept of dietary adequacy embraces that of essential nutrient adequacy, but also takes into account other food components and food properties.
From: AgeFit. Melbourne: Pan McMillan; 2001.

giving way to sources which are less safe because of their cadmium and radionuclide content.[12] N fertilisers come too often from the inappropriate use of fossil. Traditionally, K came from the ash of sea and land plants, especially wood. The largest deposits of K in old sea-beds and salt deposits are in Canada, Russia and Belarus which have mostly been traded by monopolies, pushing up prices, although these cartels are presently in flux, and other significant sources are likely to emerge or improve.[12] Political factors may also insert into the supply chain of these critical fertilisers. Again, no matter how successful is plant breeding for greater food yields, the plant needs nutrients commensurate with its productive capacity. Together, these observations and developments underscore the growing need to recognise the extent to which ecosystem health and the biodiversity on which it depends[39,40] is intrinsic to our own and our descendants' health.

Systems

In almost all areas of human endeavour, systems approaches are now preferred. This is because the point at which a problem or opportunity is identified is not often the point of origin or for intervention. In the case of human illness, we usually concentrate on the person's biology and at least the immediate family, household, school or workplace. By working in a community as primary health care workers do, wider possibilities will be taken into account and reflect a more clinical epidemiological approach to patient care.[42]

A food system approach to health considers all points in the food chain from production (farm location, water source, fertiliser; orchard; garden; pasture; feed lot; fishery), to transport, processing, packaging, storage, retailing, cooking, domestic handling, serving, eating and drinking, waste generation and disposal.[43] Problems at any stage may affect health and their recognition requires diagnostic acumen sensitive to each stage; familiarity with the stages can expedite the clinical enquiry and trigger an interest when the unusual is encountered in the public health arena or in clinical practice.

New Nutrition Science

In 2005, the IUNS (International Union of Nutritional Science) released a review of its science and recommendations that the science be more integrative and comprehensive, with coverage of the biomedical, societal and environmental sciences.[44,45] This had practical relevance for public health and clinical practice[46] as it had become clear that the changing pattern of nutritionally-related disorder and disease (NRD)[47] was largely a reflection of social[48,49] and environmental factors.[50,51]

Evidence-Based Nutrition (EBN)

Underpinning the shift towards more econutritional thinking about health was its articulation,[33] the growing body of evidence for food intake patterns as a basis for ill-health[52] and the opportunities for clinical application.[53,54] However, the resources that an ecosystem approach to health requires will extend into unfamiliar domains for most public health workers and clinicians. The UN System has developed manuals to evaluate ecosystem services and to relate them to health, although not only health.[55,56] There are numerous web-sites which deal with food security and health[57] as do some landmark papers.[58,59] For food safety in particular, most developed economies have a food regulatory web-site (eg, FSANZ, Australia and New Zealand). The UK government has an alert system for foods which present risk through the Horizon website.[60] Within public health, occupational health, maternal and child health and school-child practice, guidelines for environmentally-oriented best practice are to be found, but usually lack the efficiency and customisation required for case-specific practice.[61] A framework for 'food security in clinical practice' has been published.[62] Nevertheless, the field is poorly developed.

In general, the evidence points to varied and plant-based diets as relatively favourable to ecosystem integrity and sustainability,[63-65] but since we are omnivores and small amounts of low fat animal-derived foods can add markedly to overall nutrient density, situations in which animals can be bred and fed with minimal or recoverable ecosystem damage must be entertained.[66]

DEPENDENCY OF HUMAN HEALTH ON ECOSYSTEM INTEGRITY

The interfaces between us and our environment are blurred, but comprise time (referred to as chronobiology or biorhythms solar, lunar, seasonal, cosmological),[67] microbiomic prokaryotic organisms without nuclei (as opposed to less than 10% of our apparent biology which is eukaryotic), sensory inputs (auditory, visual, tactile, taste and smell), movement, endocrine factors (hormonal inputs by light and dark, environmental extension of reproductive hormonal pathways through food and contaminant oestrogenicity),[68-70] the reflection of soil and rock composition in the microbes, plants, insects and animals that we eat (our biogeology which is comprised of a biosphere, lithosphere and atmosphere) and much more.

Locality

There is a general feature of those who keep gardens that they remain in better health and for longer.[71,72] This is also in keeping with attention to personal hygiene and food safety. On a community scale, access to the natural environment, whether coastal or inland, native or parkland, health status also is advantaged.[73,74]

The reasons for the association between a closeness to *nature* and well-being are undoubtedly complex. But a good indicator is sensory function and the physiology beyond the sensory apparatus be it visual, olfactory, taste, auditory or tactile.[75] It has been known for a long while that memory is enhanced by smell, aromas and fragrances.[76,77] When it comes to food, its appreciation involves sight, touch, smell, taste, texture and sound as we eat, each most varied; the brain amygdala in particular can organise this information in a way that allows very detailed distinction to be made between wines, cheeses or whatever- food memory we may call it. But this may be extinguished by salt and the subtleties in the food experience lost.[78] And, therefore, how and what we eat affects us in ways well beyond the nutrient physiology which usually preoccupies us, to say nothing of the social value of food in health.[79] Now it is evident that sensory receptors are present throughout the body affecting tissues and functions from brain to heart to kidney to testes and more.[75,80,81] What is even more, the gut microbial interface between ingested food and systemic physiology itself alters the presentation of food components to sensory receptors in the gut wall and elsewhere in the body[81,82] and also with disease as in chronic renal failure.[81,83,84]

There are many foods which have unique localities and play a role in overall nutritive protection. These are often seeds (including beans, grains, nuts), fruits (non-fatty and fatty as with olives, avocadoes, red palm fruit, coconut, cacao pods with cocoa 'beans') or culinary herbs and infusions (as in teas made with Camellia Sinensis or from the mint genus of the Lamiaceae family of plants) and beverages like coffee or cocoa. Small quantities of animal-derived foods as eggs, lean flesh or milk products add to nutritional security because of their relatively high nutrient density.[85-87] Seed and fruit crops and cuttings could migrate with people and so are often found along migratory or trade routes. For others, like coconut, they could transplant by sea to be used by coastal communities like those in Kerala, India, or West Sumatra, Indonesia or by island communities.[88] Used in local cuisines these local foods have not in general been associated with the adverse health outcomes, like ischaemic heart disease with coconut consumption, as had been extrapolated from metabolic studies in advanced economies,[88] perhaps because their use encouraged the consumption of protective foods like local vegetables and fish. An econutritional disorder conceptualisation, therefore, allows for local ecological complexity, advantage and disadvantage, to be reflected in health program delivery.

A number of potentially adverse health outcomes are mitigated by dietary patterns, especially those which are biologically varied and reflect ecosystem integrity. Examples include diabetes and mortality risk reduction for the cognitive impairment by way of dietary diversity,[89,90] as well as the reduction in learning difficulties among lower birth weight girls who have a more nutritious and varied diet.[91]

The evidence is not only that dietary diversity is a preferred way of eating for health, but that it is also an index of food security adopted by the UN system.[92] Yet most of the world's population have little choice but to depend on a single staple which is a precarious food habit.

It is worth knowing, however, that even diverse cultivars of a staple like rice, wheat, maize and/or potatoes can provide for enhanced food security in the event of pestilence or adverse weather conditions. One of the principal rationale for the biofortification of staples with micronutrients in the Harvest Plus program is to reduce the nutritional adversity evident with food monoculture (http://www.harvestplus.org/).[93,94] This does not diminish the parallel efforts to develop mixed farming and diverse home gardens. It is, moreover, an unfortunate reality that increased food production, whether in emerging economies like India or many advanced economies falls short of meeting the dietary quality required for health and which could be met by dietary diversity and attention to supportive ecosystems.[95]

Healthy localities and communities, as espoused by WHO,[96] the Ontario Healthy Communities Coalition and the US Department of Health and Human Services, are ones which encourage all forms of activity- social, physical and mental and fitness in each of these respects.[37] As they say:

The World Health Organization defines a healthy city or community as "one that is safe with affordable housing and accessible transportation systems, work for all who want to work, a healthy and safe environment with a sustainable ecosystem, and offers access to health care services which focus on prevention and staying healthy.

The healthy community initiative is based on the concept that "health is more than the absence of disease, and, in this context, health is defined broadly to include the full range of quality of life issues."

The healthy city strives to provide a thriving economy and opportunities for individuals and families while adequately addressing public health, medical care, and other essential needs of its population. In addition, a healthy community demonstrates an element of interconnectedness. When a healthy community initiative is undertaken, a communal spirit develops, linking public, private, and non-profit sectors to address the underlying causes of poor health. Healthy community participants represent the wide spectrum of interests and roles that make a community work.

The Coalition for Healthier Cities and Communities, a partnership of organizations collaborating to focus attention and resources on improving the overall health and quality of life of local communities, defines a community "to include all persons and organizations within a reasonably circumscribed geographic area in which there is a sense of interdependence and belonging".[96]

One of the most effective ways to trigger all healthy activities is through leisure time physical activity (LTPA). Even small amounts of LTPA, 15 minute per day over and above a sedentary background, are enough to improve survival, and once this is in the vicinity of 30-40 minutes per day, the risk of almost all major causes of death is reduced.[97] This makes ecological and human biological sense; the least walking we might expect to be compatible with living at all would be that to get out of bed, go to where we might obtain food and meet others, and return to our bed to sleep. This would be 20-30 minutes one way and the same in reverse, which is 40-60 minutes each day! It is, therefore, understandable that almost every study of human health indicates that we need to walk 30-40 minutes a day for optimal health. In so doing, we engage with our ecosystem and expend enough energy to require enough food energy intake to deliver the amounts of food components required for basic biological functions, provided the foods are sufficiently diverse and nutrient dense.

Ethnicity-indigenes

Awareness and engagement with indigenous peoples and their cultures provides not only the opportunity to enable their survival in a period of high vulnerability, but also to learn from the myriad of different ecosystems how the rest of us might cope with the rapidly emerging environmental limitations of megacities and their associated population density coupled to ecosystem deprivation.[41,98]

Some of the key indicators of ecosystem-related health problems among Indigenes are provided by the work of

O'Dea et al among Aboriginal Australians whose increased prevalence of diabetes can be mitigated by resumption of some hunting and gathering of bush foods.[99] While the full value of these exposures may not be realistically re-established at-large, the opportunities presented for links with the natural world of a diverse diet and of physical and can be fostered. Each of these ecosystem engagement dimensions can be measured, at least qualitatively, for preventive and management purposes. They are what are ultimately reflected in various risk factors for disability and reduced survival. An example of such a pathway is provided by the body compositional disorders of fat distribution and sarcopenia among indigenous Taiwanese.[100]

Migration

The extent of migration is growing with large and small populations being displaced by conflict and climate change.

We know that it may also arise in unintended ways and consequences by the introduction of novel crops and food-stuffs which change habitable terrains and population size.[13]

Where possible, migrants will do what they can to resume traditional food practices, but this may take years, as with Greek migrants to Australia.[101] In addition, migrants can add diversity to the host-majority diet and, thereby, improve the health status of the hosts as well as themselves by selective adoption of food practices and other personal behaviours in the new environs.[102,103] Thus, healthy ecosystems will need increasingly to acknowledge and optimise migration.

ECOSYSTEM ASSESSMENT

There are many settings in which ecosystems may need to be evaluated, including the home, school and education system, work-place with its peculiarities of exposures in location, work-force characteristics, and patterns like shift-work,[104] the operational health care system and access to it, along with the communication and transport systems and places and facilities for recreation.

As indicated elsewhere in this article, the UN System has developed measurement tools for ecosystem services, most of which have a bearing on health, to allow these assessments to be made and to monitor the variables.[55,56] Nevertheless, their utility, practicality, reliability, and management value will need customisation and focus when it comes to a particular community and its health needs. Ever part of these assessments will be indices of food security in amount and quality.[3,5,30,31,92,105,106]

ECOSYSTEM HEALTH DISORDERS

1. ***A Characterisation*** *(which identifies both contributory and operational domains and where personal wellbeing, absence of disability and survival are accompanied by ecological and community sustainability)*

- **How biodiverse the habitat:** there is growing evidence that living in a biodiverse environment is conducive to health;[15,25,40,74] and each form of life is more resilient when it is within itself diverse.[33,100] The overall resilience of an ecosystem is critical and, while once sufficient, as an example, as a buffer for infectious agents, may not remain so because its characteristics have changed (eg with nearby deforestation, as was the case with the Nipah virus in Malaysia,[107] or altered net nutrient flows with their distant interruption by industrial waste).[43] It is salutary to consider latent and changing infectious agents, like plague,[108] influenzual pathogenicity in selenium deficient areas[109,110] or antibiotic resistant commensals in livestock[111] which have in the past or could in the future kill a large proportion of the human population. Such events are more likely where the inhabitants are poor and malnourished with compromised immune systems and ecosystem degradation.
- **How hygienic are the household and community facilities?** Are the sewerage and drinking water separate and the water potable, both microbiologically and chemically?
- **Is exclusive breast-feeding for 6 months possible and practical?:** Traditional foods may support successful breast-feeding like the green leafy vegetable known as torbangun used by Bataknese women in North Sumatra.[112] The maintenance of traditional agricultural practice and conditions plays an important role in the continuation of this practice of proven value. There is now evidence that colostrum's fatty acid patterns can vary by region which may have implications for maternal dietary and environmental exposures.[113] Attitudes[114,115] and support[116] for breast-feeding in the community also contribute to its success.
- **Livelihoods:** how are the basic needs of people who live in a particular ecosystem(s) serviced?
- **Social network and activities:** what are the domestic, work and recreational activities and their environmental compatibility? How frequent are they? Do they encourage networking, responsibility and obligation, opportunity for recognition and barter for livelihood.[117-121]
- **Compatibility with biorhythms:** sleep patterns including waking naturally, napping in safe circumstances (not when on the road);[122,123] sunlight exposure and health (see below). Shift work is an example of how impaired energy regulation (IER) can be associated with body compositional disorders.[104] Months and seasons are also biorhythms to be taken into account.[124]
- **The food system:** how distant is the origin of the food from consumption? what are the steps along the way?[125] is it known where and how the crops are grown , the fish caught or farmed, the animals fed? the transport used/the packaging used? the processing methods? the preservation and storage conditions? how much is wasted? where does the waste go?[43,126]

  Since both shopping[127] and cooking[128] have been shown to be associated with longer survival in cohort studies, can they be activated or improved where lacking?[129]
- **Energy disequilibrium:** physical activity levels and type; eating environs and occasions; sources of fuel and power
- **Personal security:** eg, lighting, at night, for women and children, transport
- **Form of transport:** walking, cycling, public, private cars.

  The role of cars in the pathogenesis of obesity is

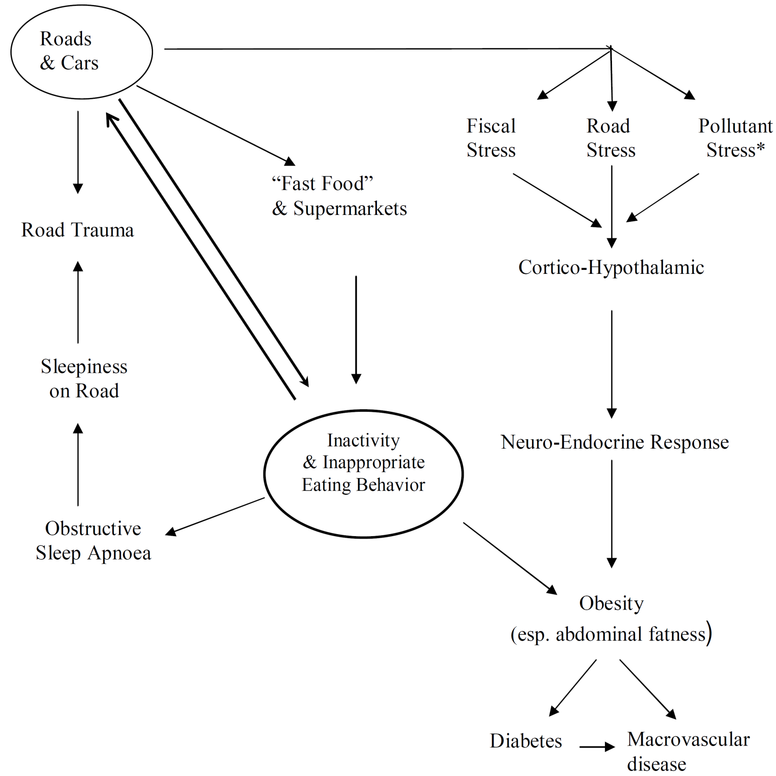

Figure 1. Fundamental and intermediate causes of ecologically and nutritionally-related disease (END): the example of eating, activity, cars and the road. (From: J Med Sci. 2006;5:157-64.)

portrayed in Figure 1.

We need an environment conducive to walking safely 30-40 minutes each day.[37,97]

- **Sunlight exposure:** enough for diurnal rhythm and seasons, for vitamin D[130,131] but not so much as to increase actinic damage and skin cancer risk.[132]

  How protective foods might minimise actinic damage is shown in Figure 2.
- **Whether soil-based:** type of farming; whether mixed or monoculture; use of fertilisers; use of weedicides, pesticides, antifungals, antibiotics.[133] Surveillance can evaluate the extent to which the overall ecosystem can behave with an acceptable risk profile for essential and detrimental elements or other compounds.[133]
- **Whether water-based:** source of water, adequacy, contamination
- **Whether plant-based:** biodiversity, horticultural methods, seasonality, food choice, storage and wastage.
- **Whether animal-based:** how fed, population density, use of growth promotants, especially antibiotics)
- **Whether microbe-based:** crop-dependence; food source itself; role in recycling; fermented foods.[134]
- **Whether anti-microbial agents being used in animal husbandry as growth promotants:** risk of antibiotic resistance in livestock microbiome, both commensals and pathogens with transmissibility to humans and loss of antibiotic therapeutic armamentarium.[111]
- **Atmospheric:** climatic attributable to temperature, precipitation, wind, allergens/pollen, pollutants
- **Natural disaster:** earthquake, volcanic, rising sea levels, typhoons/cyclones/hurricanes/tornados[138]
- **Conflict-based:** history or risk of conflict; displaced persons; use of defoliants
- **Ecosystem service compromise:** housing, clothing, heating, food, livelihood
- **Ecosystem governance:** ecosystem service measurement; guidelines, rules and laws; collective decision – making; ecosystem record and memory, tracking and surveillance.

2. Mechanisms

A difficulty in the acceptance of an ecosystem basis of disease is that a few peculiar components or factors are expected to account for a particular biological error, dysfunction or illness. While this may be so, few illnesses are unifactorial in their origin, being instead the product of multisystem and multi-organ failure, both exogenously various from the environment and endogenously various from the biological creature in question. This misunderstanding often leads to preventive and therapeutic approaches which are single or, at best, several-factor interventions, characterised by medications like antibiotics or nutrient supplements. No one can discount the enormous contribution to human health that antibiotics have played since their discovery and introduction in the 1940s, but their ultimate effectiveness has depended on the under-valued immune response of the infected host. Now we face multiply-resistant micro-organisms in farm animals and ourselves that no currently available antibiotic can eradicate; this is not least because of their misuse as growth promotants in livestock for human consumption,[111] which now presents a major threat to food security and human health. Better ecosystem management is likely

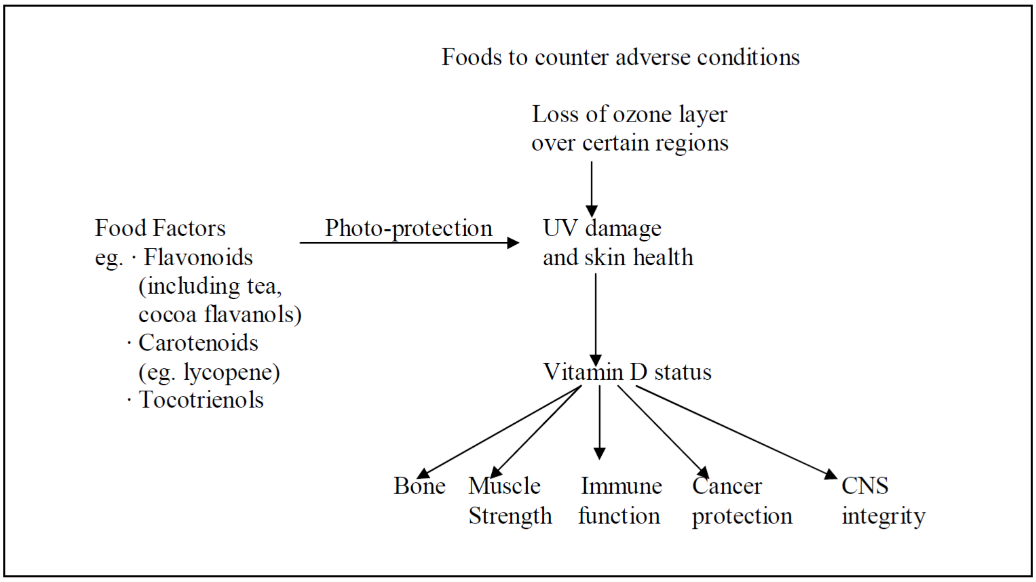

Figure 2. Counteraction of regional health adversity by local foods. (From: Asia Pac J Clin Nutr. 2007;16(Suppl):2-7.)

to be one of the few solutions available to this imminent crisis. Again, nutrient supplementation in apparently healthy individuals has not proven of benefit, and has increased morbidity and mortality in some situations.[139-141]

The finding by Zhang et al (2011)[142] that exogenous plant microRNAs (miRNAs) may be acquired through food intake and be functionally relevant indicates that cross-species, even cross-kingdom, genomic control is not only possible, but a way in which ecosystems operate. It is one of many available mechanisms which, if disrupted, pose health threats.

It does not follow that isolated food components will provide a safe and reliable approach to rectify these problems. For example, even though anti-oxidative processes are essential to oxygen-dependent living organisms like us, so is oxidation as a mechanism of defence against invasive species.[140] We are learning how excessive ingestion of so-called antioxidant nutrients (albeit multifunctional) can activate and increase tumour growth antioxidants accelerate tumour growth by , for example, disrupting the ROS-p53 axis.[141] antioxidant supplementation may also suppress endogenous antioxidant responses and adaptations. By contrast, food and foods systems provide antioxidant capacity with complimentary diversity and delivery vehicles which ameliorate adverse effects if we are in biological accord.

As mentioned earlier, physical contact with soil micro-organisms,[143,144] the ingestion of hormonal-like food components[70] and the fact that our various microbiomes interface with the environment[15,145] provide additional regulatory frameworks and connectedness with our ecosystems.

We may miss the connection with our environment if the life stage at which it is most influential is earlier than the one at which it is expressed. This is the nature of intergenerationalism,[5] epigenetics[146,147] and the place of early life exposures on later life health, as with obesity.[148,149]

Even more historically distant and striking is the evidence that Homo Sapiens sapiens has a small percentage of DNA which is that of our once co-existent (until about 28,000 years ago in Europe) related Neanderthal species. It is of particular relevance to skin and hair, and to the proneness to inflammatory disorders like Crohn's disease, immunological disorders like SLE (systemic lupus erythematosis) or biliary cirrhosis and metabolic disorders like type 2 diabetes in non- Africans, since Africans do not appear to have Neanderthal DNA.[150,151] At the same time, about 100,000 mutations of Neanderthal origin have been discovered in Europeans. Notwithstanding these findings, the prevalence of type 2 diabetes is increasing rapidly in sub-Saharan Africa against a different genomic risk profile.[152] This suggests that environmental factors are of overwhelming importance in rapid fashion and even where the genomic predisposition is absent by comparison between ancestries. The questions arise, therefore, as to what our so-called species is, how distinct from its ecosystem it is, how it is and will respond to ecological change and what is its foreseeable future.

There are ways in which we may adapt to ecosystem change, but they are unlikely to be infinite. We require measures of resilience and an understanding of the available mechanisms so that they might be enhanced, shifting the preventive health paradigm. Broadly speaking, the mechanisms could include a change in our genome as apparently happened with the selective acquisition of Neanderthal genes by inter-breeding during migration or through mutation from among single-nucleotide polymorphisms, but these processes are relatively slow. The even partial modulation of our genomic expression by miRNAs from foods is much more rapid and potentially adaptive as are epigenetic mechanisms which alter gene expression or the surveillance and environmental synchrony offered by the genomic extent of non-RNA producing DNA. Our genome is much more than had been thought when confined to eukaryotic nuclear and mitochondrial DNA, and even includes self-replicating RNA and proteins.

Our microbiome comprises most of our cells, is almost entirely prokaryotic and might have abundant resilience given its vast and diverse metagenomic connectedness to the environment through soil, water and air and all living things.[153] The core human gut microbiome appears to exist in 3 enterotypes which are not ethnically or continentally specific and probably acquired and determined maternally and early in life.[154] But the gut microbiome can change rapidly, in days, with dietary pattern, as with a shift between animal and plant-derived foods.[26,155] Since most human physiology is affected one way or another by an individual's microbiome (see above), a large part of our genome is changeable on a daily basis and in response to environmental change.

3. Recognition and Diagnosis

While not peculiar to the argument for an ecosystem approach to health and wellbeing, the accustomed public health and clinical rubrics for recognition and diagnosis of needs and problems apply to this approach with adaptation;

- Index of suspicion
- Ecosystem characteristics
- Local conditions: eg soil and biomass, diversity, fragility, resilience
- Food system: use indices across the food chain from production (origin of food, feeding practices, soil health through to measures of quantity and quality at point of consumption; consider affordability in relation to other health investments and costs).[156-158]
- The community and households
- The individual's ecology and engagement
- Vulnerable groups: 1st 1000 days, adolescence, reproductive years, later life and intergenerationalism.

4. Prevention and Management

It follows from recognition and diagnosis that effective preventive and management strategies need development and evaluation in accordance with evidence-based principles. These will take account of integrative and qualitative methodological requirements.[54]

In a rapidly changing environmental world, the relevant research and development will often be best advanced as research-in-progress. Methodology available for this purpose includes that referred to as ZOPP.[159]

CONCLUSIONS

The awareness that much of past, present and future health patterns are ecosystem-dependent grows. The utility of this knowledge is evident, if not explicit, in public health. Considerable opportunity exists for it to be more a part of clinical practice than at present. The strengthening of clinical epidemiology within health care would help. There is now a need for preventive, diagnostic and management strategies for ecosystem disorders and diseases. But perhaps most of all, the personal environmental engagement of clinicians in their own locality of residence and work would provide the required role models and leadership.

AUTHOR DISCLOSURES

The author has no conflict of interest in regard to this paper.

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Review Article

Ecosystem Health Disorders - changing perspectives in clinical medicine and nutrition

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衛生生態系統失調–改變臨床醫學及營養的觀點

在沒有生物學變化下，人類與其生態系統不可分性，日益明顯。當所有有生命及無生命的事物，相互關聯性日趨明顯時，分立物種變成只是一個近似概念。有證據指出，即使是人類早期的祖先，他們從一個地區狩獵及採集到另一個地區，甚至在整個地球遷徙。在相對短暫的 150-200,000 年間人類歷史，我們毫不猶豫的改變了億萬年的星球和生態。當我們改變我們所屬的生態系統，以取得居所、休息、活動、交談、食物、娛樂及感覺輸入機會的同時，我們也改變了我們共享的生物學及我們的健康前景。生態系統改變的速率已呈現量性及質性的增加，因此我們的健康型態，將取決於我們的應變能力，以及線性、非線性或不規則的關連性。我們的衛生相關生態系統的軌跡是不確定的。我們和我們的環境之間的介面是模糊的，包括時間，生物節律，原核微生物，感官(聽覺，視覺，觸覺，味覺和嗅覺)，關聯運動，透過食物和污染物內分泌與各種外部荷爾蒙，微生物，植物，昆蟲和我們吃的動物(我們的生物地質學)等等，反映土壤和岩石成分。我們透過高度的人類中心主義的手段，尋求優化我們的健康的途徑，但已被證明是不夠的。生態系統累積的變化，現在可能壓倒我們的健康。據此，健康照護實踐需要更加統合的方法和夥伴關係。

關鍵字：衛生生態與營養生態、地球生物學、聯絡性、物種、食物與衛生系統