Review Article

New nutrition science in practice

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A number of imperatives require a re-think of science in general and of nutrition science in particular. Nutrition science has never been a body of knowledge in its own right and many other sciences have been nutritional in their orientation. At its best "nutrition science" has been integrative as well as reductionist. It has worked across disciplines. The IUNS, (International Union of Nutritional Sciences) undertook to re-examine nutrition science from a policy point of view and to do so with knowledge-makers in general and with the International Science Council. There is now a Sciences for Health and Wellbeing (SHWB) initiative involving all branches of science. It is expected that innovative, integrative, sustainable, and cost-effective approaches to human well-being and health will emerge. Some of the pressing needs for such collaboration have been in the areas of sustainable food systems, potable water, more nutritious crops, food and human behaviour, to reduce the burden of nutritionally-related disease (NRD) and make health care affordable. An IUNS Task Force met in Giessen in 2005. It concluded that nutrition science should develop on 3 fronts, the biomedical, societal and environmental. This will encourage new and more effective initiatives for nutrition and its partners to address local, regional and global concerns about planetary and personal health and well-being. Some important and critical areas already require collective attention. Unlike our predecessors in nutrition science, we will be unable to fulfil the expectations of us unless we progress this wider and less anthropocentric form of our science.

Key Words: Nutritionally-related disorders, eco-systems, eco-nutrition, food systems, integrative nutrition, historical lessons, critical issues, nano-nutrition

NUTRITION SCIENCE

Nutritional Science is the study of the assimilation of and functions dependent on molecules derived from any organism's environment.[1,2] Yet, by its very nature, it must always be in a dynamic state, as must all science.

At *its core*, it may be narrowly focused, whilst deep in its concepts at the molecular, cellular and organismal levels. This has been the case with its traditional chemical, biochemical and physiological pursuits, albeit with quite profound and wide ramifications for human health, most notably with deficiency disorders, both macro-and micronutrient, which have be-set large sections of humanity.

However, a number of imperatives require *a re-think of science* in general and of nutrition science in particular.

THE BIG AND CRITICAL ISSUES FOR A NEW ERA AND FUTURE FOR NUTRITION SCIENCE

Having been through some two centuries of intense elaboration of the concept of energy, the energy value of foods and of energy requirements; of the definition of essential nutrients; and of the relevance of macronutrient intake relationships for human health and disease, we need to gather new support and *re-invigorate nutrition science*. Curiously, even the concepts of energy balance, dietary deficiency and inadequacy and of food compositional quality are themselves still scientifically fragile at the beginning of the 21st century.

Inevitably, these findings, reflected in policy, have directed people towards *commodities with greater perceived nutritionally-related health value*, as long as they could afford and obtain such foods.

We may not have imagined that, before consolidating basic nutrition science, we might have been disturbed and even dismayed that *climate change* is increasing food scarcity and prices. This is a new, if hitherto unrecognised, threat to human security. It has spawned belated enquiry into what might be termed *eco-nutrition*.[3] *Biofuels* now compete with food as arable crops. For these and other reasons, *shortages of healthy food commodities* are apparent and the foods less affordable e.g., fish, dairy, fruit.

Food safety is of different kinds - microbiological, chemical (additives and contaminants) and nutritional. In each case, there are new issues whether, for example, new food borne illnesses, interactions between food additives, like food colorants and MSG (mono-sodium glutamate), or the nano-compositional programming of food characteristics.[4]

Appropriate *infrastructure for food systems* (agriculture, biotechnology, water, food logistics, transportation, energy, food systems, health systems, information systems) is a collective responsibility of governments and the private

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sector. It is often wanting on account of poor governance and non-optimal mixes of local and traded food stuffs, placing unrealistic and unhealthy demands on communities and individuals.

Integrative local (community) development can alleviate poverty and hunger & deal with a changing NRD (nutritionally-related disorders and diseases) spectrum. This is because it can

- recognise the value of communities as globalization proceeds
- enable education to reflect relevant Nutrition Science (NS)
- facilitate care through the humanistic & clinical face of NS
- be involved & respectful, according participation, dignity & autonomy in the conduct of 'Sensitive Science'
- aim for effective, safe, productive, affordable and sustainable food systems with improved health outcomes and prosperity

Another major force to be reckoned with, to advantage, is the rise in *consumer expectations* about food system information. This will increasingly require a 'paper'/IT (information technology) trail for food-stuffs and a point-of-purchase facility to provide customized information. In these respects, consumers will drive NS.

A heightened level of creativity in NS with an ability to find solutions where we need them most will be sought. It is hard to ensure creativity, but in NS the human contact dimension is essential and a reason to meet and be stimulated by others.

NUTRITIONAL PRINCIPLES FOR OPTIMAL HEALTH: ACHIEVABILITY

There are *4 principles* which underpin *nutrition-for-optimal-human-health* and they are the need for well-nourished parents at conception and during fetal life, to be breast fed, to have regular physical activity, and to have an adequate intake of bio-diverse foods (for a species which is omnivorous).

Biodiversity and Food Variety are key indicators of the state of nutritional resilience in human habitats.[3] A critical issue is that only a minority of the world's population can expect, with the present socio-economic situation, to obtain or afford a bio-diverse food supply. In turn, this pre-sages the sustainability or otherwise of the local and global food supply.

There are some food systems which have, even in adversity, and partly to overcome it, achieved relatively greater food diversity. For example, southern and south-eastern coastal Chinese in China and their emigrant counterparts to Australia, have greater food biodiversity than their new majority hosts on migration (Anglo-Celtic Australians). To a lesser extent this also applies to South Asians who migrate to Australia.[5,6]

At the same time as some Asian food cultures have maintained and even developed their food diversity on migration, they have contributed to the diversification of the diets of their hosts.[5] The documentation of this is somewhat indirect. It is represented by the progressive introduction of new food crops, especially Chinese vegetables and fruits at the time of the Gold Rush to Australia in the 1850s and onwards, by the advent of Chinese market gardens, by novel cooking methods (e.g. stir-frying), Chinese family restaurants and, indeed, by changes in the whole food system, notably in food trade, conducive to food diversification. These became more entrenched with successive waves of migration, especially of a growing Asian student population in Australia from the 1950s where fellow students and host families acquired new tastes and expertise to widen the culinary experience of Australian born people. The range of climates and terrains also facilitated these dietary changes as did growing affluence. It can be argued that this diversification has contributed to Australia having consistently amongst the best (top 10) HALES (Health Adjusted life Expectancies).[7]

IUNS (THE INTERNATIONAL UNION OF NUTRITIONAL SCIENCE) AND ITS RESPONSIBILITY TO ITS SCIENCE

In IUNS, during my presidency, we undertook to re-examine nutrition science from a policy point of view and to do so with knowledge-makers in general and with the International Science Council of which IUNS is a member scientific union.

There is now a *Sciences for Health and Wellbeing (SHWB) initiative* involving all branches of science - earth, atmospheric, biomedical and engineering. It is expected that innovative, integrative, sustainable, and cost-effective approaches to human well-being and health will emerge from this process.

Some of the pressing needs for such collaboration have been in the areas of sustainable food systems, potable water, more nutritious crops, food and human behaviour, each with its prospects to reduce the burden of NRD and make health care more affordable.

An IUNS Task Force met in Giessen in 2005 to critically review the nature and relevance of nutrition science and to identify directions in which it ought to go. It concluded that nutrition science should develop on 3 fronts, the biomedical, societal and environmental.[8-11] This is now referred to as the Giessen Declaration.[12] Undertaking this exercise in Giessen had historical significance. It was in Giessen that Justus von Liebig (1803-73) developed the basic understanding of how food chemistry related to metabolism and so the conceptualisation of nutrients advanced. Impressively, the relevance of chemistry to agriculture, therapeutics and industry was also elucidated and promoted from Giessen and, over a 100 years later, this still constitutes a huge economic force through the corporations founded as a result. But IUNS is not alone in asking questions about how this nutrition science trajectory has gone and where it might and should go.

A noted populist writer, Randall Fitzgerald, has recently written a book which, in effect, looks at the veracity and social consequences of this period of nutrition science history.[13] The book critically probes the purported benefits and identifies many risks. If paraphrased conservatively, it points to problems with the culture of science in society in these respects:

- The arduous 150 year (rather than 100 year) evolution of risk science and policy and the slow appreciation of the unintended consequences of science and technology.

- The power of literacy and freedom of expression in the checks and balances within enlightened societies.
- The nature of mis-placed trust in authority and indifference to evidence.

LESSONS

There are a number of historical lessons to be learned from the time-course to impact of nutritional phenomena and interventions. Examples include:

- Introduction of Potato from the Andes and Famine in Europe.[14] The initial benefits to the food supply allowed a population explosion which, in turn encouraged migration, colonization and loss of many indigenous food cultures.
- Introduction of Sweet Potato as Pig Feed into Okinawa and development of a longevity food culture.[15]
- Food-based scurvy prevention and European colonisation of Australia.[14] Interestingly Chinese expeditionary and diplomatic fleets during the early Ming dynasty had probably solved this problem by onboard cultivation of vitamin C containing foods without the need to have preserved foods; reference is made to this in the controversial book by Gavin Menzies.[16]

Contemporary Lessons about the time-course to the public health relevance and consequence of nutrition science include:

- Slow recognition of the nutritional significance of n-3 fatty acids and fish consumption, whilst fish stocks became depleted and more polluted. Fish will need to be rationed for human consumption, stocks better managed, and alternatives found.
- Need for Public Health Nutrition in WTO agreements[17] (http://www.fao.org/docrep/meeting/x2638e.htm). Food regulatory arrangements, national and international (Codex Alimentarius in particular) acknowledge the relevance of food trade and the converse is also required in regard to the health dimensions of food regulation. This is more than food safety, the first requisite, and includes the nutritional characteristics of food. 'Dumping' by economically advantaged nations of fatty, salty meats and sugary refined foods in Pacific Islands, already overwhelmed by the health problems of obesity, diabetes and cardiovascular disease is a case in point of inappropriate food trade. So also is the over-fishing by other nations around economically-compromised Pacific Islands where fish was an abundant and health-protective food.
- Failure in concerted action when increasing obesity prevalence and its societal origins became clear in the 1980s. In countries like Australia, 20 years before the present crisis levels of obesity, it was evident that the problem was looming despite Dietary Guidelines and various food and nutrition policies.
- The re-emergence of micronutrient deficiencies like iodine[18] and vitamin D,[19,20] in part because of successful public health campaigns. These have discouraged sodium (and inadvertently iodised salt) intake for prevention of hypertension and discouraged sunlight exposure (and inadvertently decreased skin synthesis of vitamin D) because of atmospheric ozone depletion and increased risk of skin cancers. In Australia both of these phenomena are occurring, but revised public health nutrition strategies are wanting. Interestingly, foods and food factors (certain flavonoids, carotenoids and tocotrienols from plant foods and beverages) may protect against actinic skin damage to some extent and allow some tolerance to climate change.[21-,23]
- Increasing life expectancies and HALES as so-called chronic diseases increase: understanding and exploiting this phenomenon. This apparent paradox may be more a matter of time lag as a new wave of NRD awaits us. Or it may hold some answers to how health advantage might be gained in the face of apparently threatening risks.
- Securing the socio-economic advantages that nutritional & exercise interventions offer over or as well as the pharmaceutical approaches to health. The former are more likely to be cost-effective, sustainable and health-comprehensive than the latter.

SCENARIOS

Emerging Scenarios whose time-course may be shorter than we would like are:

- Limits to food trade and implications for food security

  The entire food chain depends on energy and clean water, both of which are in increasingly precarious supply in various parts of the world
- Renewed dependence on local food production and re-definition of optimal food patterns

  In many places, people have become used to a greater variety of affordable food, and to its health advantage, but coming from far and wide. This is likely to change and, to achieve comparable health benefits, we will need to optimize the food supply in new ways. This will involve new foods produced in new ways. Access to what we have regarded as simple traditional foods will be more of a treat and privilege.
- Scarce resources for food production, namely water, fertiliser, fuel, arable land, and labor (new conflicts further exacerbating scarcities)

  Increasingly skilled and competent governance will be required to manage scarce food resources in a sustainable way without conflict.
- Eco-system collapse (according to non-linear models, fractals, fuzzy logic)

  Regrettably, the likelihood of dramatic change in food systems is more and more likely as climate change becomes more evident. To some extent, collaboration between the nutritional geographical and mathematical sciences may assist prediction and management of these possible scenarios
- Nutritionally-related nano-disease and nano-treatments with a rapidly changing food supply (nano-nutrition)

  Molecular science now enables us to use molecules themselves as if they were machines. The corollary of this is that what once was thought to be relatively inert, can be biologically powerful. This offers new explanations for disorders and diseases and also new

ways of managing them. In both cases, foods and nano-food particles could play a role or be caused to do so. Because this is already the stuff of micro-chips in the computer world, it is possible to program foods to behave in different ways. It will be possible for them to be programmed for effects on human health (and on the intermediate animal derived foods).[4] One serious limitation to these new directions is the relative lack of human and environmental toxicological studies. Early evidence from the National Health Research Institutes in Taiwan indicates that the kinetics of nano-particles in mammalian systems are extremely slow.

New understandings of disease are likely as a result of nano-science and technology, providing related insights into the nutritional modulation of such pathology. For example, petrochemicals, behaving as nano-compounds may accentuate the development of pulmonary disease, certain cancers and cerebral palsy. These are afflictions seen more commonly in intense petrochemical producing areas like DaQing in north-eastern China and Kaohsiung in southern Taiwan. At the same time, inadequate intakes of plant foods[24] and vitamin D deficiency[25] may increase propensity to pulmonary disease. Thus there may be nano-chemical and nutritional synergy (nano-nutrtional phenomena) in the same way as was demonstrated belatedly for the link between infection and nutrition by Scrimshaw.[26]

- Biotechnologies to create new food stuffs

  Because of new threats to food systems, biotechnology will be tuned to provide alternative analogues. Some will be pressing and include the ongoing global problems of micronutrient deficiencies (iron, zinc, iodine, selenium, folacin, vitamin B_{12}, vitamin A and its carotenoid precursors, vitamin D), macro-nutrient related deficiencies (e.g. dietary fibre, oligo-saccharides essential fatty acids) and excesses (eg. trans fatty acids, some saturated fatty acids) and phyto-nutrients (e.g. polyphenolics, carotenoids). The problem with these deficiencies is that they are food contextual and most, sooner or later, present problems of adverse effects when used in isolation. Thus food-based approaches to them will be required. Encouraging in this respect is the biofortification program, Harvest Plus, which looks to the breeding of more nutritious plant staples as a safer, more effective and sustainable approach.[27-30]

  Perhaps one of the most pressing nutritional needs for biotechnological solutions will be the use of seaweeds (algae) to produce safe, clean and sustainable sources of n-3 fatty acids, dietary fibre and iodine, along with some bio-active carotenoids.

- Need for Cost-effective solar power

  The most valuable energy source is that derived as directly as possible from the sun. The opportunity to power urban and remote communities with solar cells or batteries would revolutionalise the earth and its life forms for as long as there is a sun. This is because no other form of energy is less disruptive to eco-systems, as universally available, or as limitless. It has the prospects of decreasing conflict over not only energy resources, but also water and food stuffs. Recent advances in solar cell efficiency are of orders of magnitude using iridium and nano-technology (nano-structured metal colloids), with more prospects on the horizon (Suntech, using technology developed in Sydney, Australia, is now, within a few years, one of China's most successful companies).

- The case for Environmentally–Sensitive Nutrition Policies and Guidelines is now urgent. It requires a conjunction between the several cognate sciences as espoused by the IUNS New Nutrition Science initiative.

THE DIMENSIONS OF NUTRITION SCIENCE

What is new about the agreed IUNS dimensions of Nutrition Science, biomedical, societal and environmental? It is:

- the relative importance of these dimensions
- what each of these dimensions now means
- the need for more effective action

Let us consider these dimension by dimension:

(1) Biomedical

Nutritionally–related disorder and diseases (NRDs) are:

- changing
  e.g. the profile of nutritionally-related cancers is now more related to physical inactivity and obesity.[31] The impact of certain nutritional states is also different as with the impact of lesser degrees of abdominal fatness in Asian populations than in Caucasians.[32]

or

- still largely unrecognized
  e.g. affecting several body systems; involving unifying disease pathways; the growing recognition of the inflammatory basis of disease and the ability of food to modulate inflammatory processes is increasingly recognized.[3,33,34]

or

- becoming intransigent
  e.g. abdominal fatness and sarcopenia with metabolic syndrome

or

- even overwhelming
  e.g. intestinal helminthiasis, HIV/AIDS, diabetes

or

- incipient and serious
  e.g. environmental nano-particle disease; emerging pathogens; endocrine disruptive industrial chemicals and environmental contaminants entering food and water supplies; altered sources and efficacies of micro- and phyto-nutrients

One reason for the current level of uncertainty about NRDs and their future is that we do not seek with sufficient assiduousness the fundamental and intermediate causes and pathways of these problems which are a mix of individual, societal and environmental or ecological factors.[23,35,36]

Illustrative of the point is the complex role roads and cars play in the acquisition of food at a distance from place of production and living abode, need for income to support this form of personal transport with associated fiscal stress, and its metabolic consequences, reduced levels of physical activity contributing to obesity,

exposure to pollutants as endocrine disruptors, use of fossil fuels with eco-system degradation, proneness to accidents and trauma through obesity-linked obstructive sleep apnoea. Without this form of analysis, the nutritional connections between modes of transport and road trauma would not be appreciated, nor would important underlying causes of obesity and related disease.[37]

This represents more integrative nutrition science and is more likely to provide effective and lasting solutions to problems.

The theme can also be applied inter-generationally by incorporating maternal nutrition and intra-uterine gene programming for abdominal obesity into the analysis.[32]

(2) Societal

Food systems and social systems are intricately related. In general, cohesive societies with good governance and developed agriculture, infrastructure including transport and communication systems, education, and health care achieve food security and improve disability adjusted life expectancies amongst citizens with a sense of well-being and conflict avoidance.

These requirements now apply not only locally, but regionally and internationally.[23] The inter-connectedness of Food Habits, Socio-economics and Health amongst Individuals is most evident when it fails. A current example is the global decline in tea consumption and the related increase in child malnutrition in tea-growing regions of south Asia.[39] Not only are the health patterns of beverage consumers at uncertain risk but so is the NRD status of the producers and their employees.

This example could be multiplied for almost any commodity where there is little diversity in consumption or production. What is interesting is that these commodities, by their social pattern of consumption, have a health (often mental health) role of their own irrespective of nutritional composition- the social role of food and beverage.[40]

(3) Environmental

A growing array of environmentally and climate related changes in both food systems and susceptibility to NRDs can be expected in the near future given rapid economic development in Asia especially, but very likely in Africa too, with persistent challenges to eco-systems and climate from economically advanced nations as well, because of energy demands and waste production in consumerist societies.

The list will include new kinds of food insecurity because of current dependence on food produced and delivered from a distance at great environmental cost; because of changed habitats for microbial pathogens and the link between pathogenicity and host nutrition, as with selenium deficiency; because of changed nutritional needs as with reduced skin synthesis of vitamin D and because of altered food patterns with uncertain medium to long term effects.

The case of vitamin D is particularly poignant because, until recently, its functions were thought to be primarily to do with bone health, but are now known to include muscle function, immune function, central nervous system integrity,macular function, pulmonary function, proneness to the Metabolic Syndrome and diabetes, and regulation of cell differentiation with reduced risk for certain cancers, possibly breast and prostate. The vitamin D situation is, as already pointed out, a product of successful public health campaigns to avoid sunlight exposure because of skin cancer risk, exacerbated by the adverse greenhouse gas effect on the ozone layer; and, more or less at the same time, but by a different public healthy sector, discouragement of intake of the few food sources of vitamin D which are basically animal-derived, namely liver, eggs and meat because of their perceived role in cardiovascular disease. Fish and fortified margarines, and in some countries, fortified milk if low fat, also useful sources of Vitamin D, were excluded from this strategy. But there have also been public health concerns about trans fatty acids in margarine and contamination with mercury, dioxin and PCBs (polychlorinated biphenyls) in fish. Yet again, newer occupations which involve most hours indoors, as with computers, have meant little UV light and often diets which are devoid of vitamin D - some such workers have unmeasurable vitamin D levels in peripheral blood (Author's clinical experience).

In regard to new sources of food insecurity, biofuels deserve comment. In the quest to minimize use of fossil fuels, crops have been considered a potential source of renewable energy. Ethanol from sugar (cane or sugar beet) and oil from seed crops (rapeseed, otherwise known as canola, and palm fruit) are examples. Unfortunately, further eco-system degradation is underway to enable this to happen as in the Brazilian Amazon and the Indonesian rain forests at terrible cost to biodiversity and endangered species including one of the closest relatives of the human species, the orangutan in Borneo.[41] Fuel crops now earn more profit than food crops, sometimes because of misplaced government subsidies, which is forcing up the price of food and making some crops increasingly scarce. When it is remembered that this is often happening in developing economies and in some of the most biodiverse-rich localities on earth, where rapid climate change is already in evidence, the future of human food systems and of planetary health must be in some doubt. Future nutrition science will need to engage actively in this situation.

There are alternatives to the world's energy requirements. More efficient solar cells have already been discussed. Designer petrol ('biopetrol') is possible using enzyme systems produced by biotechnology with a 'molecular evolution' model to make, for example, octanol. Biodiesel could also be produced through a similar approach to fatty acid production.[42] Such fuels, of course, will still produce their carbon and there is no substitute for energy conservation and efficiency with environmental conservation unless it be solar.

HOW CAN WE MAKE PROGRESS WITH NUTRITION SCIENCE FOR THE HUMAN CONDITION AND PLANETARY HEALTH?

There are various ideas and strategies which are available:

- Identify and address critical points (obstacles) in the food system
  e.g. Gates Foundation approach to the 'Grand Challenges' as applied to 'Harvest Plus' crop biofortification.[43]

- Find the most efficient, cost effective fuel cells with 'Inexhaustible Energy' sources like solar power (not simply renewable) with nanotechnology. This could have a limitless flow-on to food security and health.
- Be passionate about our science and its potential to make a difference for the better. Passion about scholarship, science and technology and what it can do for the better has been encouraged by the notable scholar and Chief Librarian of the Alexandra Library in Egypt Ismail Serageldin. This is an unusual plea to scientists but one which will likely resonate with those who are committed to their science and otherwise reluctant to be seen as other than restrained.
- Bring our science closer to the problems - global, local and individual- as much as possible by our own experience and engagement.
- Adapt our teaching and mentoring to the changing needs and aspirations of our science
- Implement the science through our personal behaviour, whether it be socializing, walking, gardening, cooking, eating out, working, or enjoying and supporting the creative arts.

A NEW NUTRITION SCIENCE LITERATURE

It is an interesting question as to the nature of future books, texts, reviews, proceedings and more, in science in general and in nutrition science in particular, because of information science and the internet. This is also apparent with Journals which are increasingly electronic. Yet every body of knowledge and scholarly discipline needs its 'literature' in some form or another.

Professional authenticity of this 'literature' will remain important and achieved through transparent critical appraisal and peer review. However, the interface between 'food and nutrition professionals' and scientists is more grey than in many scholarly areas. The Wikipedia approach, rather than the Encyclopedia one, is growing and embraces all shared knowledge and people well beyond the usual reaches of the science.

For policy –setting and budget expenditure on food security and nutritionally-related preventive and therapeutic nutrition, evidence is increasingly essential. This is reflected in the development of EBN (Evidence-Based Nutrition), an extension of the EBM (Evidence based medicine approach, although more requiring of portfolios than hierarchies of evidence.[44-47]

EXPECTATIONS OF NUTRITION SCIENCE

Unlike our predecessors in nutrition science, we will be unable to fulfil the expectations of us unless we progress a wider and less anthropocentric form of our science.

AUTHOR DISCLOSURES

Mark L Wahlqvist, no conflicts of interest.

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