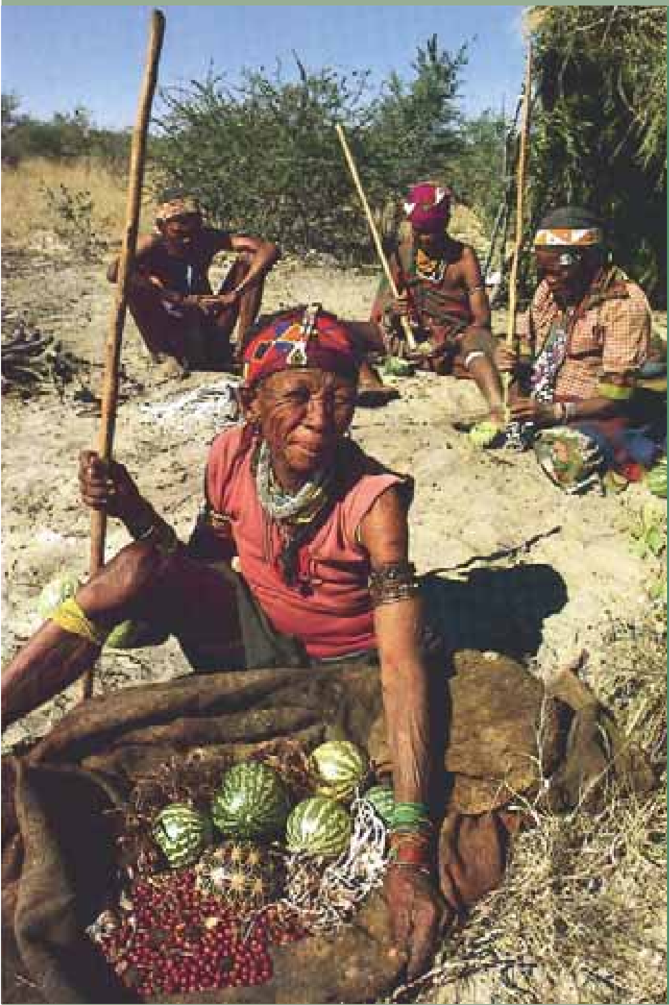


Diet and Human Evolution

what are the health implications for the 21st century?

SEMINAR HIGHLIGHTS

BROUGHT TO YOU BY MEAT & LIVESTOCK AUSTRALIA

JANUARY 06

MEAT & LIVESTOCK AUSTRALIA

Diet and Human Evolution seminars

Chairperson Professor Jennie Brand-Miller and presenters Professors Stephen Simpson, Michael Richards and Loren Cordain at the Sydney seminar, Australian Museum.

Strong evidence of a direct link between our genetic makeup and diet has emerged in recent studies which examine our ancient genome, and the discordance between our ancestral and modern Western diets. They ask: What are the health implications of our reliance on highly processed and refined foods? Is there a link between low-protein diets and poor health? How do Australian diets compare with countries such as the US?

How do these findings challenge our dietary guidelines?

The answers were given in two seminars on diet and human evolution held by Meat & Livestock Australia, in conjunction with the Nutrition Society of Australia and the Dietitians Association of Australia, in Sydney on 23 November and in Melbourne on 29 November last year.

Presenters

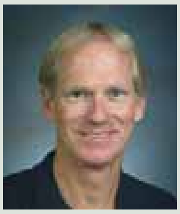
Professor Michael Richards

DEPARTMENT OF HUMAN EVOLUTION, MAX PLANCK INSTITUTE FOR EVOLUTIONARY ANTHROPOLOGY, GERMANY

Professor Michael Richards obtained his BA and MA at Simon Fraser University in Vancouver, Canada and his PhD at the University of Oxford, UK.

Professor Richards is currently a Research Professor at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and Professor of Archaeology at the University of Durham in the UK. At Leipzig, he directs a research group on 'archaeological science', which is the application of methods developed in the physical and biological sciences to fossils and artifacts to answer archaeological and anthropological questions.

His main research interest is in the application of chemical methods (isotope analysis) to human fossils to determine past diets, and especially how those diets evolved over time. The main research articles he has written in this area are on Neanderthal diets (Richards et al. 2000), Neanderthal and early modern human dietary differences in Europe (Richards et al. 2001), and the dietary changes at the Neolithic revolution in the UK (Richards et al. 2003).



Professor Loren Cordain

DEPARTMENT OF HEALTH AND EXERCISE SCIENCE, COLORADO UNIVERSITY, USA

Professor Loren Cordain is a world expert in the investigation of nutrition throughout our evolutionary history. For the last 10 years, his research has focused on the evolutionary and anthropological basis for diet, health and wellbeing in modern humans. Professor Cordain's scientific publications have examined the nutritional characteristics of hunter-gatherer diets worldwide, as well as the nutrient composition of wild plant and animal foods consumed by foraging humans.

More recently his work has focused upon the adverse health effects of the high dietary glycaemic load that is ubiquitous in the typical western diet. A number of his recent papers have proposed a common endocrine link between dietary induced hyperinsulinaemia and acne, early menarche, certain epithelial cell carcinomas, increased stature, myopia, ancanthosis nigricans, cutaneous papillomas, polycystic ovary syndrome and male vertex balding.

Professor Cordain is the author of more than 100 peer review publications, many of which were funded by both private and governmental agencies. He is the recent recipient of the Scholarly Excellence award at Colorado State University for his contributions into understanding optimal human nutrition. He has lectured extensively on the 'paleolithic nutrition' concept worldwide, and has written a popular book (The Paleo Diet, John Wiley & Sons) summarising his research findings.

Associate Professor Neil Mann

DEPARTMENT OF FOOD SCIENCE, RMIT UNIVERSITY

Dr Mann is an Associate Professor of Human Nutrition in the School of Applied Sciences at RMIT University in Melbourne. He has worked extensively in the field of dietary fat intake and the effects on vascular function through eicosanoid formation, as well as in general nutrient intake patterns and lifestyle diseases. Dr Mann has multiple qualifications in chemistry, biology, genetics, biochemistry and nutrition. He has studied and worked extensively in the field of nutritional biochemistry at Deakin University and undertaken advanced study and collaborative work in eicosanoid function at the University of Iowa in the USA and at Munich University in Germany.

His present area of special interest is diet evolution and its relevance to current lifestyle diseases. This is an area in which he collaborates with numerous international researchers in anthropology, nutrition and exercise physiology. He has been involved in numerous publications of clinical studies on diet and cardiovascular diseases, fatty acids in the diet and evolution and human diet, and has spoken at numerous international conferences in a variety of nutritional science fields.

Dr Mann is chairperson of the Nutrition Society of Australia, Victorian branch, a council member of the Australian branch of the American Oil Chemists Society and an active member of the UK Nutrition Society.

Professor Stephen Simpson

SCHOOL OF BIOLOGICAL SCIENCES, UNIVERSITY OF SYDNEY

Professor Stephen Simpson did his undergraduate degree at the University of Queensland, majoring in entomology, before undertaking his PhD on locust feeding behaviour at the University of London as a University of Queensland travelling scholar. He then moved to the Department of Experimental Psychology at Oxford University, where he worked as a Medical Research Council post-doc on the neural bases of feeding in monkeys, before moving to the zoology department at Oxford as a departmental lecturer in entomology, animal behaviour and neurobiology.

While at Oxford he began a project to explore nutrient balancing in insects – a project which continues today and has resulted in a set of nutritional models that are currently being applied to other animals, including humans. In 1986 Professor Simpson was appointed University Lecturer in the department of zoology and Curator of Entomology in the University Museum of Natural History, University of Oxford; then in 1998 he was appointed Professor of the Hope Entomological Collections, University of Oxford.

During the early 1990s he established a research program on swarming in locusts, which is still underway. He has been Guest Professor in insect behaviour at the University of Basel (1990), Distinguished Visiting Professor at the University of Arizona (1999), Fellow of the Wissenschaftskolleg (Institute of Advanced Study), Berlin (2002–03) and is currently an ARC Federation Fellow in the School of Biological Sciences at the University of Sydney and a Visiting Professor at the University of Oxford.

The **evolution** of human diets

by Professor Michael Richards

Hominid fossils showing morphological changes, archaeological remains, and direct chemical analysis of fossilised bones can help reconstruct the evolution of subsistence, particularly the introduction of animal protein in the diet.

Fossil evidence of the four main hominid categories – from *Australopithecines* (and *Paranthropines*), to *Homo habilis*, to Neanderthals, to *Homo sapiens* – shows major morphological changes over four million years. These include an increased cranial capacity, loss of a sagittal crest, a reduction in mandible size, the introduction of brow ridges and chins, and a smaller face.

The increasing gracilisation of mandibles and larger craniums are the two changes believed to be linked to diet – and point to the introduction of meat. The most widely accepted model used to explain the changes is the 'expensive tissue hypothesis' (see breakout box).

The hypothesis is supported by various lines of evidence. Firstly, archaeological remains indicate that the first stone tools for butchering animals appeared at the same time as *Homo habilis* and became more sophisticated over time; faunal remains show butchering marks; and there is evidence of cooking, such as fireplaces.

"To cope with this 'expensive tissue', recent hominids were after a high quality, more energy efficient food – meat"

Second, we can compare hominids to other living primates. The larger mandibles and smaller brains of *Australopithecines* were similar to gorillas, which are vegetarian; while *Homo habilis'* smaller mandibles and larger brains were closer to chimpanzees, which eat a little meat.

Third, the hypothesis can be supported by comparing our digestive systems to herbivores and carnivores (see breakout box).

Finally, the newest and most reliable test is direct chemical analysis of fossil remains – Professor Richards' area of expertise. This method examines the bone protein using carbon and nitrogen stable isotope analysis. Collagen can be extracted to get a long-term record of dietary protein; carbon analysis helps distinguish between marine and terrestrial protein; and nitrogen analysis distinguishes between animal and plant protein. As collagen is preserved in bones of only up to 100,000 years, the earliest hominid that this analysis can be carried out on is the Neanderthal. Professor Richards' analyses show that Neanderthals were top-level carnivores with protein derived from meat. Bones of Paleolithic humans show similar protein ratios. The main source of protein in European Upper Paleolithic humans was animal meat, but also included fish.

Effects of the Neolithic revolution

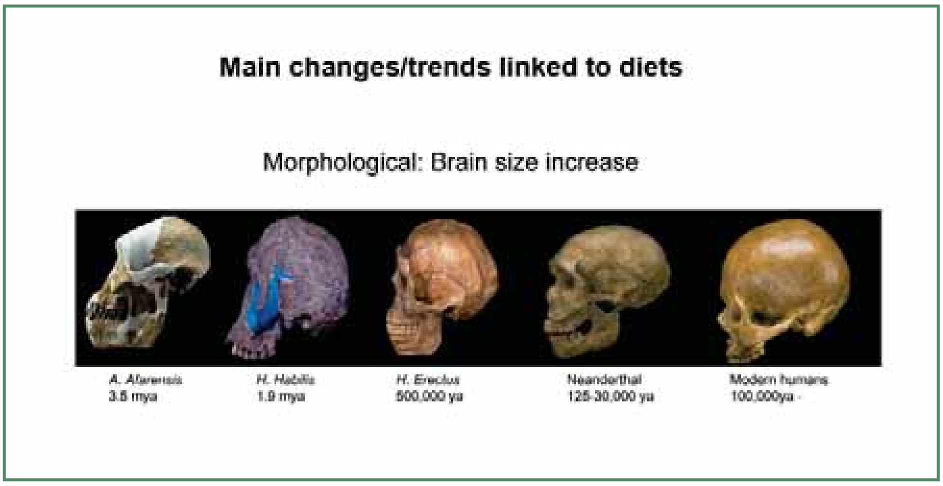
The Neolithic revolution, around 10,000 years ago, brought about the next major dietary change within our species. Humans began domesticating plants and animals. "What happened with this was the move to the domination of lower quality [protein- and fat-proof, but carbohydrate-rich] plant foods, such as cereals, maize and rice. This dietary change led to a sedentary lifestyle within villages and urban centres.

"While this is associated with our decreased stature, and a decline in health, it's led to a major expansion of our species – geographically and in population size," Professor Richards says.

The expensive tissue hypothesis

When comparing ratios of organ masses to brain size between humans and other primates, our much larger brains – which are more 'expensive' in terms of energy needs – should require a large digestive system. However, although humans have the largest brains, they have the smallest digestive systems. To cope with this 'expensive tissue', recent hominids were after a high quality, more energy efficient food – meat. Meat contains a lot more energy and amino acids than plant foods, and essential nutrients important for cognitive function. As our brain size and hence intelligence increased, we became more sophisticated in hunting, which led to further growth in brain size.

Archaeological evidence to support the diets of past hominids - stonetools



HUMAN DIGESTIVE CHARACTERISTICS SHARED WITH HERBIVORES AND CARNIVORES

Herbivores	Carnivores
Cannot make vitamin C	Cannot make taurine, which is found in meat
Slow gut transit time	High-volume large intestine and low-volume small intestine – optimal for low fibre, easily digestible food
Colons made up of a series of pouches to better digest high fibre food	Low levels of enzymes that make 20 and 22 carbon fatty acids found in animal food sources
	Low levels of enzymes that make vitamin A, which is abundant in offal

Origins and evolution of the Western diet: health implications for the 21st century

by Professor Loren Cordain

Many nutritionally related diseases in Western societies are not observed in hunter-gatherer populations. Professor Cordain argues that these diseases are due to environmental changes over the last 10,000 years, which were too recent on the evolutionary timescale for the human genome to adjust.

Pre-agricultural hominins* were omnivorous hunter-gatherers whose diets relied on minimally processed wild-plant and wild-animal foods. Foods virtually unknown to them were breads, refined cereals, rice, pasta; dairy; added salt; refined vegetable oils; refined sugars (excluding honey, available seasonally); fatty meats; and alcohol. In contrast, today these highly processed and refined foods make up more than 70 per cent of the typical Western diet. These food staples, and current food-processing procedures, were slowly introduced during, and after, the Neolithic and Industrial revolutions.

Professor Cordain argues that if the Neolithic revolution began just 10,000 years (500 human generations) ago, and the first genus *Homo* appeared two million years ago, then the above foods weren't eaten for 99.5 per cent of the time our lineage has existed. "So our genome is very well adapted to wild-plant and animal foods, and these giant come-latelys have potential effects of being discordant with our genome," he says.

From the Industrial revolution onwards (from around 1800, or 10 human generations ago), sucrose, feedlot-produced meats, refined grains, refined vegetable oils, hydrogenated oils and high fructose corn syrup (HFCS) were introduced.

By default, the inclusion of these food staples in the modern Western diet *displaces* minimally processed, wild-plant and wild-animal foods.

Key nutritional factors that have changed since our ancestors' diets

1. An increase in the glycaemic load of the diet
2. A shift in fatty acid composition to higher omega-6 and lower omega-3 fats
3. A shift from a predominantly protein-based diet to a carbohydrate-based diet
4. A decrease in micronutrient intake
5. An increase in the acidity of the diet
6. An increase in sodium intake and decrease in potassium intake
7. A decrease in fibre intake

Professor Cordain identifies seven key nutritional factors that are hugely influenced when this occurs. These factors, in turn, underlie virtually all chronic diseases in Western civilisation.

The higher-quantity, lower-quality carbohydrates in our modern diets have increased our glycaemic load. According to Professor Cordain, grains make up a quarter of our total energy, and 85 per cent is refined. "Most of the highest GI foods are refined cereal grains," he says.

The fatty acid composition is another altered nutritional factor, with lower levels of omega-3 polyunsaturated fats and higher levels of omega-6 fats. This is particularly the case in the US, where beef is grain fed, producing fattier meat with lower omega-3 and higher omega-6 fats. Pasture feeding, which is predominantly used in Australia, produces leaner meat with higher omega-3 and lower omega-6 fatty acid levels.

The macronutrient composition and micronutrient density of our diets differs markedly from our ancestors. From analyses of hunter-gatherers worldwide, Professor Cordain found that 19 to 35 per cent of their total energy was derived from protein. (In contrast, current dietary guidelines recommend we consume 15 per cent of our energy as protein.) Refined grains, sugars and vegetable oils have reduced our micronutrient intake because the latter two "are empty calories," Professor Cordain says, "often displacing the nutrient-dense foods our ancestors ate, such as fruits, vegetables, lean meats and seafood."

Professor Cordain also considers the acid-base balance of our diets. Cereal grains (acid producers) make up a quarter of our dietary energy – they are the largest single nutritional source of acid-yielding foods. "Refined sugars and oil are neutral, but displace alkaline-producing fruits and vegetables. So the typical Western diet produces a slight chronic metabolic acidosis."

'today these highly processed and refined foods make up more than 70 per cent of the typical Western diet'

Sodium-potassium ratio is linked to our increased consumption of salt – 400 per cent since the Neolithic period. "Virtually all Westernised diets comprise about 10g of salt a day, mostly hidden in highly processed foods," says Professor Cordain. These foods displace potassium-rich foods such as fruits and vegetables.

Fibre content has been greatly reduced since Paleolithic diets, with now close to 50 per cent of our energy intake as sugar, dairy, alcohol and vegetable oils (all fibre-free).

"So what are the recommendations?" he concludes. "Reduce processed foods, and increase fresh fruits, vegetables, nuts, lean meats and seafood."

*The newer term for hominid, used throughout Professor Cordain's paper.

Paleolithic Diet (Protein: 19 to 35% total energy)

Modern Diet (Protein: 15% total energy)

Omega-3 fatty-acid composition of habitual diets in Australia

Professor Cordain explained how the wild game meat our ancestors hunted was high in omega-3 fatty acids and lower in omega-6 fatty acids. However, today in the US, most cattle and some sheep are subject to lot feeding on various grains, producing fattier meats. In his presentation, Associate Professor Mann showed how Australian pasture fed beef and lamb is closer in fatty-acid profile to wild game meat, as it is significantly lower in total fat and is a valuable source of omega-3.

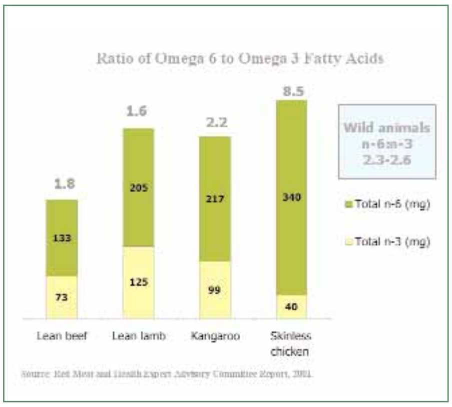
"Grass and leaves contain some omega-3 fatty acids," Associate Professor Mann explains, "whereas grains contain mainly omega-6 fats. US farmers feed lots of grain, so this beef has 60 per cent more fat and almost 50 per cent more omega-6 fat than pasture-fed beef, and no omega-3 fats. Europe, too, produces a lot of grain fed meat. Pasture-fed cattle and sheep walk around more and eat less, so are leaner."

According to the 2001 *Red Meat and Health Expert Advisory Committee Report,* Australian lamb and beef have similar omega-6 to omega-3 ratios as kangaroo. "A lot of Australian red meat has the same omega-3 as, say, white fish," explains Associate Professor Mann. "Offal, such as brain and liver, contains even higher levels of omega-3."

"…. indicates that red meat from pasture-fed animals contributes significantly to long-chain omega-3 fatty acid intake in the Australian diet, especially since 'historically', Australians are not big fish eaters"

In a study by Associate Professor Mann published in the European Journal of Clinical Nutrition in 1999, the daily intake of long-chain omega-3 fatty acid intake in four dietary groups in Australia was calculated. Vegans consumed virtually no omega-3; ovolacto vegetarians (eggs, dairy and plant foods) consumed just 10mg; moderate meat eaters (50-260g/day, including white meat and fish) consumed 140mg; and high meat eaters (more than 280g/day, including white meat and fish) consumed 290mg.

"The 1999 study above indicates that red meat from pasture-fed animals contributes significantly to long-chain omega-3 fatty acid intake in the Australian diet, especially since 'historically', Australians are not big fish eaters," says Associate Professor Mann.



Novel insights into human obesity

by Professors Stephen Simpson (and David Raubenheimer)

Professor Simpson's presentation highlighted the key role for protein appetite in the obesity epidemic with a simple geometric model he developed (along with Professor Raubenheimer) from studies of insects. Locusts and caterpillars were confined to diets of varying ratios of protein and non-protein (carbohydrate and fat) foods. Carbohydrates were overeaten on low-protein diets to a greater degree than carbohydrates were overeaten on high-protein diets, while protein intake was near constant. Over several generations, caterpillars evolved to store excesses as fat in a high-protein environment. When protein was low, they evolved to not store excesses as fat, but this made them prone to starvation if they ran out of food. Professor Simpson described how this pattern fit the 'thrifty genotype hypothesis', which suggests that humans have a genetic drive to eat more than they need for the present in order to store energy for future, helping early humans survive feast-or-famine conditions.

Studies on the rat (published in a 1984 and 1992 paper) and other human data from over 45 years of research, including his recent analysis of the 1995 National Nutrition Survey, all show a very similar nutrient intake pattern. "Protein intake is prioritised when the diet forces a trade-off between protein and fat/carbohydrate," Professor Simpson says.

Professor Simpson's hypothesis – 'the protein leverage hypothesis' is based on his model which indicates that a very small decrease in percentage protein results in a substantial excess of carbohydrate and fat intake. Professor Simpson says "the role of protein in obesity has been generally ignored because its intake during the obesity epidemic has remained largely unchanged. Non-protein foods have increased. So it can't be the protein itself that's causing obesity – it's our protein appetite within our processed Western diets."

Professor Simpson showed the vicious cycle that can occur when overeating non-protein energy on a low-protein diet. Overeating non-protein energy leads to insulin resistance, which increases the concentration of free fatty acids in the bloodstream. This, in turn, inhibits the production of glucose, which causes the body to burn up protein to release glucose. The body now needs more protein, increasing our consumption of carbohydrate and fat even more – leading to obesity.

"Protein intake is prioritised when the diet forces a trade-off between protein and fat/carbohydrate"

He concludes that there is strong evidence that protein intake is regulated by animals and humans. As protein also comprises a minor part of our total energy budget, it has considerable leverage over food intake. Low-protein diets may be a reason for the obesity epidemic.

Q&A with the presenters

Expert Panel in Sydney consisted of (from L-R) Professors Stephen Simpson, Loren Cordain, Michael Richards and Ms Lisa Yates who represented DAA.

Q What is the evidence that our ancestors' diets led to long-term health, when they died at an early age – from battles, or infections?

Professor Richards: "It's a myth that people died at 25 or 30. There were certainly older people."

Professor Cordain: "It is certainly true that hunter-gatherers studied during modern times did not have as great an average lifespan as those values found in fully westernised, industrial nations. However, most deaths in hunter-gatherer societies were related to the accidents and trauma of a life spent living outdoors without modern medical care, as opposed to the chronic degenerative diseases that afflict modern societies. In most hunter-gatherer populations today, approximately 10-20 per cent of the population is 60 years of age or older. These elderly people have been shown to be generally free of the signs and symptoms of chronic disease (obesity, high blood pressure, high cholesterol levels) that universally afflict the elderly in western societies. When these people adopt western diets, their health declines and they begin to exhibit signs and symptoms of 'diseases of civilisation'"

Q If hunter-gatherers did live longer, the quality of their life is important. They would have had plant-based foods to get antioxidants, phytonutrients etc. How does that fit into the whole protein-carbohydrate scale?

Professor Cordain: "We never said humans are carnivores. Their diets were dominated by animal foods, but up to 35 per cent of energy was from fruits and vegetables."

Q Our omnivorous nature has made us adaptable. Does this mean there are lots of different ways to eat? Would it make a difference if our weight was okay and we were very active?

Professor Cordain: "You can argue that Okinawans are the planet's longest-living people not so much because of their healthy diet but because of their caloric restriction (they consume 30 per cent less calories than Japanese mainlanders). The only known way nutrition can extend life is through restriction. We are not suffering from diseases of under-consumption but from diseases of over-consumption. One of the potential ways to reduce over-consumption has to do with protein."

Q The 'expensive tissue hypothesis' suggests we wouldn't have got taller bodies and bigger brains if we were suffering from regular periods of food scarcity. Your opinion?

Professor Richards: "The evidence is pretty scarce. Enamel hypoplasia in Neanderthals – lines in teeth indicating nutritional stress – is argued to be periods of starvation. But a recent study argued that Neanderthals wouldn't have had more food stress than modern hominids. Generally, enamel hypoplasia indicates a lot of trauma, a very hard life."

Q How long did early hominids live for? Did they suffer from arthritis and any other degenerative diseases?

Professor Richards: "It's hard to age skeletons over the age of 30. Some did suffer from arthritis, but not diseases like scurvy or rickets."

Q Could high-carbohydrate nutritional recommendations over the last decade be one reason for the rise in obesity?

Professor Simpson: "If this advice resulted in a lowering of percentage protein, then yes. But not if the shift to carbohydrate was associated with lowered fat intake, since, gram for gram, fat contains more kilojoules than carbohydrate."

Q If the Western diet continues on its reliance on processed foods, what will be a likely impact on the human race?

Professor Simpson: "We will evolve resistance to obesity – for example, through having less efficient fat deposition. The main route for selection will be the premature death of children due to obesity-related disorders."

Associate Professor Mann: "There will be a health affect – obesity, diabetes, cancers and cardiovascular diseases. This is worsening every year."

Q The message seems to be to eat less processed foods and more fresh foods. How can this approach be made easy and convenient within our time-poor society?

Professor Simpson: "Making it easy to follow: remove one portion of high-carbohydrate food daily (bread, pasta, potatoes), don't consume high-sugar drinks or snacks, eat less fat and eat high-quality protein."

Associate Professor Mann: "We can advocate healthy food choices through the media and lobby government agencies to regulate labelling laws and nutrition/health claims to promote healthy choices."

Q What are the implications of your study on current dietary guidelines?

Professor Simpson: "Firstly, eat a varied diet to ensure adequate intake of micronutrients and a balanced intake of amino acids. Secondly, increase the percentage protein in the diet slightly. And do more exercise."

Associate Professor Mann: "That we have for too long over-emphasised grain carbohydrate foods, mainly because meats were considered high fat. However, there isn't enough fish or meat available for everyone on the planet to get the recommended levels of omega-3. Eventually, genetically engineered crops will have to be a dietary source of omega-3 fats."

Q Is Australian meat more sustainable that Australian wheat production?

Associate Professor Mann: "Meat and wheat are mutually beneficial food production strategies for our long-term health, survival and prosperity through export incomes – if produced wisely in the right places under well researched land-management systems. Much of our land and climatic conditions unfit for cropping are more suitable for a human food return by grazing animals."

Key references

Aiello LC et al, 1995, *'The expensive tissue hypothesis',* Current Anthropology, vol 36; 199-221.

Cordain L et al, 2004, '*Origins and evolution of the Western diet: health implications for the 21st century*', American Journal of Clinical Nutrition, vol 81; 341–54.

Mann N, 2005, *'Omega-3 fatty acids from red meat in the Australian diet',* Lipid Technology, vol 17(4); 79–82.

Richards MP et al, 2002, *'A brief review of the archaeological evidence for Paleolithic and Neolithic subsistence'*, European Journal of Clinical Nutrition, vol 56; 1262–1278.

Simpson SJ et al, 2005, *'Obesity: the protein leverage hypothesis',* Obesity Reviews, vol 6; 133–42.