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'Meat or wheat for the next millennium?' Plenary Lecture

Animal *v.* plant foods in human diets and health: is the historical record unequivocal?

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An ideal diet is one that promotes optimal health and longevity. Throughout history, human societies have developed varieties of dietary patterns based on available food plants and animals that successfully supported growth and reproduction. As economies changed from scarcity to abundance, principal diet-related diseases have shifted from nutrient deficiencies to chronic diseases related to dietary excesses. This shift has led to increasing scientific consensus that eating more plant foods but fewer animal foods would best promote health. This consensus is based on research relating dietary factors to chronic disease risks, and to observations of exceptionally low chronic disease rates among people consuming vegetarian, Mediterranean and Asian diets. One challenge to this consensus is the idea that palaeolithic man consumed more meat than currently recommended, and that this pattern is genetically determined. If such exists, a genetic basis for ideal proportions of plant or animal foods is difficult to determine; hominoid primates are largely vegetarian, current hunter–gatherer groups rely on foods that can be obtained most conveniently, and the archeological record is insufficient to determine whether plants or animals predominated. Most evidence suggests that a shift to largely plant-based diets would reduce chronic disease risks among industrialized and rapidly-industrializing populations. To accomplish this shift, it will be necessary to overcome market-place barriers and to develop new policies that will encourage greater consumption of fruits, vegetables and grains as a means to promote public health.

Optimal diets: Dietary recommendations: Plant-based diets: Palaeolithic diets

An optimal diet, by definition, is one that maximizes health and longevity and, therefore, prevents nutrient deficiencies, reduces risks for diet-related chronic diseases, and is composed of foods that are available, safe and palatable. Throughout the course of human history, societies have developed a great variety of dietary patterns that take advantage of the food plants and animals available to them as a result of geography, climate, trade or economic status. It is evident that the ancestral diets of societies surviving to the present era must have provided sufficient energy and nutrients to support growth and reproduction. Whether they adequately promoted adult health is more difficult to determine, but seems unlikely given the sharp increases in human life expectancy observed in this century.

At issue is the precise composition of an optimal diet, particularly, for the purposes of the present discussion, its relative proportion of foods derived from plant or animal sources. Industrialized countries throughout the world currently recommend diets based largely on foods from plant sources (Cannon, 1992), yet in developing countries plant-based diets are associated with extreme poverty and poor health. Indeed, when economic conditions improve, low-income populations tend to increase consumption of meat, display fewer signs of nutritional deficiencies, and

Abbreviations: USDA, US Department of Agriculture.

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develop chronic disease patterns typical of wealthier populations (Drewnowski & Popkin, 1997).

From the standpoint of nutrition policy, it would be helpful to identify the mix of foods from plant or animal sources that could best prevent nutrient deficiencies as well as chronic diseases. To that end, the present paper reviews the status of current dietary recommendations for health promotion in industrialized countries, using the situation in the USA as an example. Since one unanswered challenge to such recommendations is their evolutionary basis, the paper addresses issues related to the diets of our palaeolithic ancestors and their modern hunter–gatherer descendants. Finally, it describes the ways in which food systems in industrialized countries create barriers to consumption of foods from plant sources.

Dietary recommendations: plants *v.* animals

US government views on the relative proportions of plant and animal foods in healthy diets have shifted markedly during this century. Beginning in the early 1900s, US Department of Agriculture (USDA) scientists and nutrition staff developed dietary recommendations to prevent disease conditions caused or exacerbated by deficient intake of essential nutrients. From 1913 to 1979, USDA dietary guides advised daily consumption of specified numbers of servings from varying numbers of food groups. These guides deliberately encouraged people to eat more of a greater variety of foods chosen from the full range of American agricultural products (Nestle & Porter, 1990). They were designed to present first, or most prominently, food groups from animal sources (meat and dairy products) and to emphasize meat as the central focus of meals and menus.

The need to 'eat more' to prevent nutrient deficiencies became especially evident during the Second World War (1939–45), when large numbers of military conscripts were revealed to suffer from poor nutritional status. Dietary guides developed during and immediately after that era continued to advise people to eat more foods in greater variety. From 1958 to 1979, for example, the USDA's principal food guide, known colloquially as the 'Basic Four', advised people to eat approximately equal numbers of daily servings of foods from four groups, presented and illustrated in the order: meat, dairy, fruits and vegetables, and grains (US Department of Agriculture, 1958). Thus, for approximately 70 years, US federal agencies promoted diets that emphasized consumption of foods from animal sources, suggested eating more of foods from all groups, and made no qualitative distinctions among foods within or between groups.

Beginning in the mid-1950s, scientists increasingly recognized that chronic diseases had replaced deficiency conditions as the principal diet-related health problems in the USA, and that dietary advice should be emphasizing ways to reduce risks for CHD, certain cancers, stroke, diabetes and other chronic conditions that had by then become leading causes of death (Page *et al*. 1957). By the late 1970s, federal dietary recommendations for prevention of chronic, as opposed to deficiency, diseases were advising Americans to reduce intake of energy, fat, saturated fat, cholesterol, sugar, salt and alcohol, but to increase intake of foods containing complex carbohydrates and fibre (Select Committee on Nutrition and Human Needs, United States Senate, 1977; US Department of Agriculture, 1979).

It was no accident that this advice was phrased in terms of nutrients, not foods, as the shift in message from 'eat more' to 'eat less' proved highly controversial. The principal sources of 'eat less' nutrients in US diets are meat, dairy and processed foods; for example, foods from animal sources (meat, dairy, eggs, and table fats and oils) contributed 36 % of the total energy, but 63 % of the total fat, 77 % of the saturated fat and 100 % of the cholesterol in the US food supply in 1990 (Gerrior & Zizza, 1994). US dietary goals, however, suggest that at least 58 % of dietary energy should be derived from complex and simple carbohydrates and, therefore, fruits, vegetables and grains (Select Committee on Nutrition and Human Needs, United States Senate, 1977). To meet this goal, as well as additional goals for reduction of total fat to 30 % of energy or less and of saturated fat to 8–10 % of energy or less, it is necessary to replace energy intake from animal foods with energy from plant foods.

Such advice elicits protests. Scientists have objected to the research basis of such recommendations, and clinicians to their applicability to individuals with no known chronic disease risk factors. The strongest objections, however, have come from food producers and companies concerned about the effects of such advice on sales of their products. In the 1970s, protests by meat producers, for example, led the government to change its initial advice to 'eat less meat' to the current 'choose two or three servings per day' (Nestle, 1993*a*). More recently, the USDA withdrew its *The Food Guide Pyramid* (US Department of Agriculture, 1992) from publication in response to complaints from meat and dairy producers about the position of their products on its design; the agency re-issued the guide only after extensive additional research supported its original design (Nestle, 1993*b*). Despite the fact that the 'eat more' components are fruit, vegetables and grains, producers of these foods have provided only weak support for dietary recommendations; fruit and vegetable producers view each other as competitors, and most grain in the USA is fed to livestock.

Since concerns about uncertainties in the scientific basis of the recommendations are most troubling, three separate groups in the USA and Europe reviewed the full range of evidence available at that time linking dietary factors to chronic disease risk. Their reports (James, 1988; US Department of Health, 1988; National Research Council, 1989), published in the late 1980s, provided strong support for the view that public health would improve if people increased their intake of plant foods relative to those from animal sources. By 1993, more than 100 reports of committees in more than thirty countries had come to similar conclusions (Cannon, 1992).

Since that time, research has increasingly supported the benefits of largely plant-based diets for prevention of CHD (Krauss *et al*. 1996), cancer (American Cancer Society Advisory Committee, 1996; World Cancer Research Fund and American Institute for Cancer Research, 1997), and diabetes mellitus (American Diabetes Association, 1996). The importance of consuming more plant foods is illustrated by observations that disease conditions related to patterns of

personal behaviour account for an estimated 800 000 (or 38 %) of annual deaths in the USA, at least half of them attributable to the combined interaction of diet and activity patterns (McGinnis & Foege, 1993).

Current US nutrition policy, however, continues to focus on nutrients rather than foods. The most recent dietary guidelines for Americans (US Department of Agriculture and US Department of Health, 1995) include advice to choose diets that contain a variety of foods, are balanced with physical activity, include 'plenty of grain products, vegetables and fruits', are 'low in fat, saturated fat, and cholesterol', and are 'moderate' in sugars, salt, Na and alcohol (if consumed at all). Implicit in such recommendations is an overall dietary pattern lower in animal foods but higher in plant foods than currently consumed. The USDA's implemention guide to the dietary guidelines, *The Food Guide Pyramid* (US Department of Agriculture, 1992) engendered controversy precisely because its emphasis on plant foods is explicit. Its design illustrates the grain, vegetable and fruit groups as the basis of healthful diets (suggesting six to eleven, three to five and two to four servings/d respectively), recommends meat and dairy foods in much smaller quantities (two to three servings of each/d), and advises only sparing use of fats, oils and sweets. In total, *The Food Guide Pyramid* recommends eleven to twenty daily servings of foods from plant groups as opposed to just four to six daily servings of foods from the meat and dairy groups (US Department of Agriculture, 1992). Such proportions reflect the views of scientific advisory committees in consensus that consumption of largely plant-based diets would improve the health of the population.

Benefits of plant-based diets

Although arguments about dietary guidelines related to fat, salt, sugar and alcohol have been especially contentious (Nestle, 1996), guidelines for grains, fruits and vegetables have remained relatively unchallenged, perhaps because their message is to 'eat more', and is so well supported by research. Foods of plant origin are significant sources of energy, protein, vitamins and minerals in American diets (Gerrior & Zizza, 1994), and are unique or principal sources of vitamin C, folate, fibre and phytochemicals strongly associated with prevention of cancer (Steinmetz & Potter, 1991*a*,*b*; Block *et al*. 1992) and other chronic diseases. Information about the health benefits of plant foods is derived from studies of the diet and health patterns of vegetarians, and of modern Mediterranean, Asian and other ethnic populations who consume traditional diets that are largely, although not exclusively, based on food plants (Nestle, 1994).

Vegetarian diets

Vegetarian populations often are reported to display lower rates of chronic diseases than non-vegetarians (Johnston, 1994), although evidence for protection against CHD is strongest (Key *et al*. 1998). Since many vegetarians also do not smoke cigarettes, drink alcohol, or engage in other unhealthful lifestyle practices, their good health cannot easily be attributed to avoidance of meat or dairy foods (Dwyer, 1994). Nevertheless, even the most conservative nutrition professionals agree that the evidence is sufficiently compelling to overcome their concerns about risks for nutrient deficiencies and that '. . . appropriately planned vegetarian diets are healthful, are nutritionally adequate, and provide health benefits in the prevention and treatment of certain diseases' (American Dietetic Association, 1997).

Mediterranean diets

Information about the diets of people living in Mediterranean regions 2000 to 5000 years ago derives from an extensively-documented archaeological record of food debris, art, artifacts, tools and inscribed tablets, and from analysis of the more recent writings of Homer and other classical authors. Although the limitations of such sources must be considered carefully, this evidence suggests that hundreds of plant and animal foods were available and consumed. The balance between food categories, however, is difficult to determine. Homer characterized his warriors as meat-eating, but scholars have concluded that the typical diet must have been based on plant foods, with meat and seafood consumed only occasionally, just as they observed it to be early in this century (Seymour, 1907; Vickery, 1936). Whatever the dietary composition, scholars suggest life expectancy in ancient Greece and Rome was 20–30 years (Wells, 1975), but that this short lifespan was more likely to have resulted from infections and wars than nutritional deficiencies (Darby *et al*. 1977).

In the modern era, the largely plant-based diets of people living in the Mediterranean region have been associated with unusually long life expectancies and low rates of chronic diseases (Nestle, 1995). Such good health cannot be explained by factors typically associated with disease prevention in industrialized countries, such as educational levels, economic status, or health care expenditures. In the early 1960s, for example, the overall life expectancy among Greeks at age 45 years exceeded that of any other known population. Today, risk factors for chronic diseases are increasing among Mediterranean populations, at least in part as a result of undesirable changes in dietary practices (Kafatos *et al*. 1997). Even so, life expectancy at age 45 years in Greece was 32·5 years in 1991, second only to Japan at 33·3 years, and exceeding that of the USA (30·8 years), the UK (30·9 years), and Canada (32·1 years; World Health Organization, 1994).

Much information about Mediterranean dietary practices derives from an extraordinarily comprehensive study of the population of post-Second World War Crete (Allbough, 1953), from the Seven Countries Study of diet and heart disease risk (Keys, 1970), and from subsequent studies correlating dietary intake to rates of CHD, cancer and other chronic diseases. The dietary data from such studies identify high consumption of vegetables, fruits, legumes and grains, moderate consumption of dairy products, and low consumption of meat products (Trichopoulou & Lagiou, 1997). Indeed, some studies have reported plant foods to comprise more than 60 % of the total energy consumed, and animal foods less than 10 % (Allbough, 1953). Thus, Mediterranean diets can be considered as near-vegetarian and, as such, to convey the benefits of vegetarian diets

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as well as preventing the occasional nutrient deficiencies associated with them (Johnston, 1994).

Asian diets

The population of Japan continues to lead the world in several important indices of health, and to display especially low rates of CHD and breast cancer, for example. This extremely good health has been attributed to a diet based on rice and other grains, fish, shellfish and seaweeds, and quite low in use of land animals and dairy foods. With increasing Westernization, this traditional pattern has given way to increasing use of red meats, poultry, dairy products and processed foods and drinks. From 1955 to 1990, *per capita* use of cereal grains in Japan declined from 118 kg (344 lb) per year to 104 kg (228 lb), whereas use of meat increased from 5 to 29 kg (7 to 63 lb), and fish from 26 to 37 kg (58 to 82 lb). Such changes have been associated with rising rates of CHD, although such rates are still well below those of more industrialized countries (Lands *et al*. 1990). One possible explanation for continued protection is that annual *per capita* availability of fruits and vegetables also increased during that period, fruit from 12 to 37 kg (27 to 82 lb), and vegetables from 83 to 118 kg (182 to 236 lb) (Taha, 1993). Data from a comprehensive epidemiological survey of diet and health in China also support the idea that as dietary and other lifestyle patterns have become more Westernized, so have disease patterns (Junshi *et al*. 1990).

Despite such evidence, the assignment of the designation 'optimal' to largely plant-based diets remains subject to challenge on the grounds that animal food products provide essential nutrients not otherwise readily available (Dwyer, 1994), that eating food plants 'tracks' with other lifestyle practices that may have a more important impact on health (Marshall, 1995), and that the benefits of such diets are only apparent in situations of great overproduction of food and overconsumption of food energy. Although these criticisms have some validity (Nestle, 1996), the preponderance of evidence strongly supports the health benefits of largely plant-based diets (Kushi *et al*. 1995).

Evolutionary considerations

A more interesting challenge to this view, however, derives from evolutionary considerations. Current dietary patterns derive from the changes in food production that started with the industrial revolution approximately 200 years ago, and from the more recent effects of the global food economy. Human nutritional requirements, however, date from the Stone Age. Eaton & Konner (1985) have proposed that from the appearance of modern *Homo sapiens* approximately 45 000 years ago until the beginnings of agriculture approximately 10 000 years ago (Table 1), man evolved to consume larger proportions of meat than currently recommended, and that the palaeolithic balance of animal and plant foods represents the dietary pattern that human subjects are genetically programmed to consume (Table 2). In their view, meat intake was high, but lean, and plant foods provided levels of fibre and vitamin C that exceed current recommendations. As evidence, these and other researchers cite the diets of hominoid primates, of early man as deduced from archaeological investigations, and of modern populations who still engage in hunting and gathering as principal means of subsistence (Bogin, 1997). This challenge raises issues germane to present-day efforts to assess dietary intake; it is difficult to determine what groups of individuals ate yesterday, let alone 30 000 years ago. Inherent in these lines of evidence are assumptions that cannot be tested with methods currently available.

Hominoid primates

It is reasonable to think that the diets of closely-related primates might give some indication of the evolutionary basis of optimal diets. Thus, anthropologists have studied the dietary habits of gorillas (*Gorilla gorilla*), orang-utangs (*Pongo pygmaeus*), chimpanzees (*Pan troglydytes*), and other hominoids in the wild, through direct observation as well as through examinations of teeth, stomach contents and faeces (Harding, 1981). Such observations have suggested that gorillas are almost exclusively herbivorous, but that other species eat amounts of animal matter that constitute up to 150 g/kg diet. In general, primates appear to eat whatever is convenient, mainly plants, but also insects, eggs, crustaceans and carrion. The structure of the primate digestive tract suggests that the predominant foods should be plants, particularly fruits and soft parts that are not too fibrous (Harris & Ross, 1987). Thus, although primates mainly consume a plant-based diet, approximately 70 % of all such species eat some animal foods (Harding, 1981). The assumption that primate diets establish a genetic basis for human diets, however, remains untested (Harris & Ross, 1987).

Table 1. Stages of evolution of human diets (Adapted from Eaton & Konner, 1985)

	Time period elapsed (years)
Pleistocene: Stone Age	1·6 million
Homo sapiens: Archaic	400 000
Neanderthal	80 000
Modern	45 000
Holocene: Agriculture	10 000
Industrial revolution	200
Global food economy	50

Table 2. Comparison of palaeolithic diet with US dietary recommendations

	Palaeolithic diet*	US dietary goals†
Protein (% energy)	34	12
Carbohydrate (% energy)	45	58
Fat (% energy)	21	30
Cholesterol (mg)	591	300
Fibre (g)	46	20–35
Vitamin C (mg)	400	45

* Adapted from Eaton & Konner (1985).
† Select Committee on Nutrition and Human Needs, United States Senate (1977).

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Palaeolithic man

In the absence of written records, knowledge of ancient diets must be inferred from the various kinds of evidence available. Such evidence is derived from studies of fossilized skeletons and teeth of human subjects and animals, shell mounds, artifacts for food acquisition and preparation, the chemical composition of fossilized bones, teeth and plant remains, and the topography of archaeological sites. Recent isotope and molecular techniques, have been used to indicate dietary composition (Schoeninger *et al*. 1983; Sallares, 1995). Among these kinds of evidence, however, faecal food remains and stomach contents constitute the only unequivocal proof of actual ingestion (Isaac & Crader, 1981).

Archaeology provides considerable evidence for meat consumption by early man. Fossil animal bones at archaeological sites have been found to display cut and hammer marks, teeth marks and breaks that are consistent with meat consumption (Bunn, 1981). Stone artifacts found at such sites are also consistent with meat-eating (Potts & Shipman, 1981). Some archaeologists judge certain pathological changes in fossil human skeletons to be similar to those found in the skeletons of people who suffer from vitamin A toxicity, a condition that could only have occurred if early man ate animal liver (Walker *et al*. 1982).

One difficulty with such observations is that findings of ancient human and animal bones occur only rarely. Such sites are scattered, poorly preserved and incompletely recovered, and sampling is necessarily biased (Cohen, 1989). Since bones are better preserved than vegetable matter, they give the impression that hunted animals must have been primary food sources (Mann, 1981). For this reason, archaeological techniques tend to underestimate plant consumption and to overestimate animal consumption (Hastorf, 1988). Furthermore, the finding of animal bones or fossilized seeds at a site does not prove that they were used as food. Thus, although some authorities continue to argue that the early relatives of man ate little but meat (Dorozynski & Anderson, 1991), others view the archaeological evidence as consistent with meat-eating (Isaac & Crader, 1981) but far too ambiguous to make broad generalizations about the dietary balance of animal and plant foods (Freeman, 1981). Regardless of that balance, the life expectancy of early man has been estimated as about 25 years (Cohen, 1989), suggesting that the palaeolithic diet, among other conditions of life, must have been considerably less than ideal (Garn & Leonard, 1989).

Surviving hunter–gatherers

Underlying the interest in existing populations that hunt and gather as primary means of subsistence is the idea that such populations are survivors of prehistoric ways of life. The few hunter–gatherer societies that have survived into the twentieth century are largely confined to marginalized regions not well-suited to agriculture. The life expectancy at birth of such populations has been estimated to be 25–30 years, with infant mortality rates of 40–50 % (Cohen, 1989). By the 1970s, anthropologists found these groups to be so radically changed from their original societies that it was difficult to reconstruct practices of 25–50 years earlier, let alone thousands of years ago (Lee & DeVore, 1968, 1976).

Dietary information is available for only a few of these groups, and much of it lacks precision (Harris & Ross, 1987), perhaps because the investigating anthropologists were more concerned about gender roles than dietary intake, hence, *Man the Hunter* (Lee & DeVore, 1968) as opposed to *Woman the Gatherer* (Dahlberg, 1981). From the dietary standpoint, gender distinctions may not be very important. Studies of the San and !Kung peoples of the Kalahari indicate that they relied heavily on gathering, a practice that did not take much time or effort in an environment of abundant plant resources (Sahlins, 1968). More than 150 plant and 100 animal species were consumed by these groups, with much of the diet derived from just twenty-three plant species. Plants were observed to provide a dependable food source, whereas game was scarce, difficult to find, and hard to kill, and snakes, lizards and insects were not eaten. Thus, about 800 g/kg diet consisted of foods from plant sources (Lee & DeVore, 1976). Eaton & Konner (1985) summarize the proportion of plant foods in the diets of hunter–gatherer groups as 500–800 g/kg in inland semi-tropical habitats, 500–900 g/kg in coastal areas, but less than 100 g/kg in the northern-most Arctic. Overall, these studies can be interpreted as providing substantial support for the predominance of plant foods in hunter–gatherer groups living in areas where plants could grow.

The Arctic exception

The one exception to this predominance of plant foods occurs among indigenous people who live in Arctic North America, the extreme of human (and plant) habitation. In the 1920s, Arctic Eskimos were reported to rely completely on hunting for their food, but to do little or no gathering (Balikci, 1968), particularly at latitudes above 49° (Hayden, 1981). Instead, the population depended on marine and land mammals and fish for 80–100 % of food intake and, therefore, on a diet based almost entirely on animal protein and animal fat (Harris & Ross, 1987).

If such observations are correct, the population must have been able to survive to reproductive age on a diet containing only minimal amounts of nutrients for which plants are main sources. Since vitamin C is found almost exclusively in plant foods, a source of vitamin C must have been available to prevent scurvy. Analyses of the nutrient content of raw game meats indicate that raw bison (*Bison bison*), caribou (*Rangifer tarandus*), moose (*Alces alces*), and variety meats contain 5–15 mg vitamin C/kg portions (US Department of Agriculture, 1989), an amount that should be sufficient to prevent scurvy in most people. Whale skin, organ meats, and the stomach contents of animals also would be expected to contain vitamin C. No information is available, however, on life expectancies, infant mortality rates, and other health indices of pre-contact indigenous peoples (HV Kuhnlein, personal communication).

Despite the short growing season, plant gathering is quite possible in the Arctic. Kuhnlein & Turner (1991) have identified more than 1000 edible plant species in Arctic areas, and found evidence for consumption of at least 550 of them (seaweeds, lichens, fungi, ferns, conifers and flowering plants). Their observations of present-day indiginous populations reveals considerable gathering, processing and

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preservation of edible plants. Thus, it seems likely that pre-contact indigenous people consumed enough plant foods to provide needed nutrients, and gathered and stored plant foods for use during seasons when they were not available.

Despite their almost exclusive dependence on meat, indigenous Arctic people have less atherosclerosis (Newman *et al*. 1993) and lower rates of CHD than are found among non-natives, even though they display higher rates of cigarette smoking, obesity (among women) and hypertension (among young men), have lower levels of blood cholesterol and triacylglycerols (Young *et al*. 1993), and have more alcoholism (Kuhnlein, 1991). This 'Eskimo paradox' has been attributed to high levels of beneficial fatty acids in marine mammals and fish (Kuhnlein *et al*. 1991; Kuhnlein & Soueida, 1992; Young *et al*. 1993). As market foods replace traditional foods in Arctic diets, however, rates of heart disease, cancer, diabetes and tooth decay are increasing, suggesting that additional intake of fruits and vegetables would convey substantial health benefits (Nobmann *et al*. 1992; Kuhnlein & Receveur, 1996).

Market-place barriers

In theory, increases in plant-food intake over current levels should not be difficult to accomplish, as current dietary patterns leave much room for improvement. In the USA, for example, dietary intake surveys find the average American adult to consume just over the minimum number of daily servings of grains and vegetables recommended in *The Food Guide Pyramid* by the US Department of Agriculture (1992), but under the minimum for fruit and dairy foods (Food Surveys Research Group, 1997). A dietary intake survey run by a meat-industry group identified even greater shortfalls in intake of foods from plant sources (MRCA Information Services Inc., 1994). Even when vegetable servings appear adequate in such surveys, at least half were derived from garnishes that accompany 'fast' foods (potatoes, canned tomatoes, iceberg lettuce and onions). When 'french fries' (chips) are excluded, the number of vegetable servings falls below three per day (Borrud *et al*. 1996; US Department of Agriculture, 1997). It must be noted that the sizes of servings counted for this purpose are quite small in comparison with amounts usually consumed. Average consumption of meat, however, is at least twice the number of recommended servings (Food Surveys Research Group, 1997). Although the *per capita* availability of beef in the US food supply has declined in recent years, poultry production has more than compensated, and the overall supply of meat has increased since 1970 (Putnam & Allshouse, 1997).

Explanations for consumer resistance to dietary recommendations generally centre on personal and social issues related to taste, convenience, cultural values and education (Nestle *et al*. 1998). The current food system, however, creates environmental barriers to choosing diets centred on plant foods. In the USA, for example, food and beverage sales earned $862 billion in 1995, of which nearly half was spent on meals and drinks consumed outside the home. This amount reflected a growth rate of about 1 % (Gallo, 1996). The food supply provided 18·2 MJ (3800 kcal)/d for every man, woman and child in the country, an increase of 2·0 MJ (500 kcal)/d since 1970 (Putnam & Allshouse, 1997). This level is nearly twice the amount needed to meet the energy requirements of most women, one-third more than that needed by most men, and far higher than that needed by babies and young children. These findings alone describe a fiercely competitive but slow-growing food market place, one in which food companies must find ways to sell more of their more-profitable foods.

In 1995, only 22 % of food expenditures (the 'farm value') went to food producers; the remaining 78 % constituted added value in the form of labour, packaging, transportation, advertising and profit (Elitzak, 1996). Because value-added products are more profitable than farm products, US food manufacturers introduce large numbers of new food products into the market place each year (17 000 in 1995). Three-quarters of these new food products were candies, condiments, breakfast cereals, beverages, bakery products and dairy products, and nearly 2000 were designed especially to be reduced or low in fat (Gallo, 1996). The current food market place includes 240 000 packaged foods from US manufacturers alone (US Department of Agriculture, 1996). These and other foods are advertised through more than $10 billion spent annually on electronic and print media, and another approximately $20 billion on coupons, games, incentives, trade shows and discounts (Gallo, 1996). Advertising for a typical candy bar, for example, requires a $25–50 million annual expenditure (Advertising Age, 1998). Such amounts are vastly in excess of the million-dollar cost of the US Department of Agriculture (1992) *The Food Guide Pyramid* (Nestle, 1993*a*,*b*) or any other federal dietary advice to eat more fruits, vegetables and grains.

Conclusion

From the evidence reviewed here, it is not possible to identify the precise proportions of foods from plant and animal sources that best promote health, nor is it possible to identify the composition of a genetically-determined optimal diet, if such exists. What does seem clear is that diets based largely on plant foods are most associated with health and longevity, at least under conditions of food abundance. Substantial and compelling evidence supports the idea that people in industrialized and industrializing economies could reduce risks for chronic disease if they increased their intake of fruits, vegetables and grains in proportion to animal foods (Kushi *et al*. 1995).

The food system, however, provides little incentive to promote consumption of low-value-added farm products. Furthermore, increasing plant-food consumption to recommended levels would affect agriculture and the environment in complex ways, some beneficial but others likely to be undesirable (Gussow, 1994; O'Brien, 1995). If public health is to be improved, new and more creative policies will be needed to promote plant-food consumption. Such policies might address the development of more direct and less ambiguous dietary guidelines, incentives for producers and consumers, national advertising campaigns supported at competitive levels, and encouragement of value-added marketing, such as that of pre-washed and pre-prepared fruits, vegetables and salads, that benefits producers as well as the health of the public.

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