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The McDonald's Equilibrium

Advertising, Empty Calories, and the Endogenous Determination of Dietary Preferences

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Abstract. A comparison of accepted nutritional advice with actual American dietary practice suggests that many people fail to eat well in spite of well-documented health consequences. Popular culture often labels the worst offenders as lacking in "self-control," and many blame the aggressive advertising campaigns of the fast-food and snack-food industries for manipulating consumers into poor diets, but these conclusions are not easily reconciled with a neoclassical approach to economic decision theory. This essay considers the consumer's "diet problem" in light of emerging evidence from the medical and behavioral sciences. In particular, it is argued that human evolution in the distant past resulted in an elegant solution to this problem (of search for a suitable diet in an uncertain environment), which any neoclassical economist would recognize. In modern environments, however, the signals that formerly provided information in the consumer's search problem are subject to manipulation by food-producing firms. Confirmation by molecular biologists that many human responses to these signals are firmly encoded in our genes suggests a need to re-evaluate the welfare economics of the food industry.

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1 Introduction

1.1 Deciding what to do

> Economics, which has traditionally been concerned with what decisions are made rather than how they are made, has more and more reason to interest itself in the procedural aspects of decision.
>
> Herbert A. Simon (1978a, p. 494)

Economic search theory is often used to model consumer choice when product quality and/or price is uncertain. In such models, the consumer might, for example, engage in sequential search for the lowest-price product. Typically, search is costly, and the consumer uses prior knowledge of the price distribution to derive a "stopping rule" that specifies the conditions under which search will be terminated (i.e., what constitutes a satisfactory price).[1]

Herbert Simon and others have noted that the information processing requirements of even the simplest search problems can be formidable, suggesting that cognitive constraints ought to be modeled directly. The resulting theories of *bounded rationality* posit that consumers in fact use relatively simple decision rules to solve search problems. In the simplest situations, a stopping rule derived without cognitive constraints can be observationally equivalent to the so-called *satisficing* behavior of the boundedly rational consumer, but certain peculiarities of consumer behavior have led some to argue that the latter approach has more descriptive power.[2]

This essay is an attempt to further delve into the question posed by Simon in the opening quotation. By asking *how* consumers choose products of uncertain quality and making use of the growing body of knowledge on the subject in fields outside the traditional purview of economics, it is my hope that new insights will result that lend both descriptive power and parsimony to consumer theory. It is within this larger context that I focus attention here on a very narrow class of the consumer's decision problem. Specifically, I ask how people choose foods.

1.2 Choosing foods

As an individual decision problem, dietary choice can be dauntingly complex. All but the poorest of the poor have a wide variety of foods available for inclusion in daily meals, each of which has unique nutritional and gustatory characteristics. In addition to the obvious constraints of cost and availability, the chosen diet must meet basic nutritional requirements. These requirements

[1] See, for example, Stigler (1961), McCall (1965, 1970), or Hirshleifer (1973).

[2] See Simon (1978b) and the recent survey by Conlisk (1996).

are age- and gender-specific, are not fully understood by modern science, and include many more compounds than can be found on product labels.[3] And – as if it were not enough that nutritional information is incomplete, complex, and sometimes contradictory – the foods that *taste* best are often reportedly the *least* nutritious.[4]

1.3 Human nutritional requirements

There is no question that diet has consequences for health and quality of life. Deficiency in any one of a long list of essential micronutrients can quickly cause illness or death,[5] and there is growing evidence that the proportion of macronutrients such as dietary fiber can be important determinants of health outcomes. For example, a 10-year prospective study of 75,000 women showed that those with the highest intakes of dietary fiber (in the form of 2.5 servings of whole grain foods per day) were 30% less likely to develop heart disease (Liu et al. 2000); similarly, a 6-year prospective study of 65,000 women showed that those with the highest intakes of dietary fiber were 30% less likely to develop type 2 diabetes (Salmeron et al. 1997); both of these diseases can be debilitating and/or deadly. So the diet problem is literally a matter of life or death.

[3] Essential nutrients (i.e., nutrients without which humans cannot sustain life) are known to include not just the obvious calories, protein, vitamins, and minerals, but also, for example, omega-3 and omega-6 fatty acids, and the amino acids leucine, isoleucine, valine, lysine, tryptophan, threonine, methionine, phenylalanine, and histidine (Groff and Gropper 2000, p. 125, p. 170). There are, of course, non-essential nutrients (i.e., compounds that the human body can synthesize via the biochemical transformation of essential nutrients) without which health may be adversely affected; examples include carbohydrates, omega-9 fatty acids, and the non-essential amino acids.

[4] Indeed, dietary indulgence is often cited as evidence of the consumer's more general problem of "self-control". A number of technical definitions of the self-control problem have been proposed; see, for example, Strotz (1956), Ainslie (1991), Becker and Mulligan (1997), Laibson (1997), Samuelson and Swinkels (2000), and Gul and Pesendorfer (2001).

[5] Smith (2002) lists the health consequences of twenty-one dietary micronutrient deficiencies. For example, a dearth of ascorbic acid results in scurvy, the symptoms of which are bleeding gums, hemorrhages under the skin, and joint pain; insufficient iodine can cause goiter (large swelling in the throat; and birth defects including mental retardation, deafness, dwarfism, and paralysis of the limbs); and those who fail to ingest enough thiamine are likely to come down with beriberi (anorexia, enlarged heart, cardiac failure, mental confusion, quivering of the hands or limbs, paralysis of the muscles of the eyes, and coma). Any of these "diseases of malnutrition" can cause death if not corrected through dietary modification or artificial supplements.

1.4 Making an "optimal" decision

The complexity and uncertainty associated with dietary choice are not so different, perhaps, from other choices the average consumer faces on a daily basis: consumers face a trade-off between immediate gustatory pleasure and future health consequences, and given available information, the consumer chooses the best diet from a menu of affordable diets. Indeed, people everywhere go about their daily lives giving little attention to their choice of diet, and appear nevertheless able to solve the diet problem reasonably well. An observer of this outcome might conclude that markets for food products are remarkably efficient at delivering products to consumers. To be sure, consumers have incomplete information[6] when making dietary decisions, but there is also a market for nutrition information, and to the extent that the marginal benefit of learning more about nutrition can be balanced against the marginal cost of obtaining the information, we might expect that consumers are in fact choosing an optimal level of knowledge with respect to nutrition.[7] The efficiency argument could also apply to private-sector producers of food: the amount and proportion of foods produced necessarily reflects both consumer demand and available food production technologies, and new technologies would presumably be developed and adopted only to the extent that they better serve to satisfy consumer demand.[8] So perhaps there's not a problem: consumers may be making uninformed decisions with respect to the composition of their diets, but they do so by choice, implying by their actions that the *status quo* allocation of foodstuffs is Pareto optimal.

[6] The cause of the information constraint need not be due to a contractual failure on the part of the supplier as in the excellent work of Akerlof (1970) and Stuart (1981); for most common food products, relatively comprehensive nutritional information is readily available in the nearest public library. Indeed, "information" here is taken to include not just the nutritional content of a given food item, but also more general knowledge of nutrition science and one's personal nutritional requirements.

[7] This is not to say that the marketplace will provide an optimal level of basic nutrition research, which is an important input to the consumer's decision problem. Basic research is generally thought to be a public good, and thus will be insufficiently provided by the private sector. On the other hand, if consumers were willing to pay, at the margin, for additional information with respect to the health consequences of eating a particular diet, then perhaps they would demand that government fund the relevant research until the uncertainties were sufficiently resolved.

[8] Again, there is the sticky question of whether the "right" amount of research and development in food production technology might be undertaken when spillovers (benefits to other producers who are able to "borrow" innovations for free) are likely. Nevertheless, innovation happens, and it seems reasonable to expect that the familiar mechanisms of supply and demand will ensure that only those innovations that improve the lot of the consumer will survive in the marketplace.

1.5 Health consequences of the modern diet

The first clue that there might be a flaw in the standard efficiency argument comes from a closer examination of the foods people *actually* choose in modern choice environments, and how changing food technologies affect market outcomes.

If consumers were concerned *only* with health outcomes, the consensus of modern nutrition science is that they should choose a diet comprised largely of whole grain foods, with ample fruits and vegetables, sufficient amounts of protein and calories, and limited amounts of sugar and saturated or processed fats. This "consensus" diet has been advocated, with minor variations, for the better part of a century, and is now supported by a substantial body of scientific research.[9] But in spite of this triumph of modern science, the average American diet looks nothing like the consensus diet. For example, adults in the U.S. reported in a recent survey consuming an average of 6.7 servings of grain products per day, only 1.0 of which was whole grain[10]; the same survey showed that on any given day, approximately 50% of Americans consume *no* fruit or fruit juice, and only 10-15% will consume the dark-green or deep-yellow vegetables touted by nutrition scientists (Enns et al. 1997, Tables 2 and 4). Just as revealing are analyses of the components of caloric intake: Americans obtain 16% of calories from added sugar, and 60% of adults obtain more than 10% of calories from saturated fats (Tippett et al. 1999, p. 43). Results such as these – combined with epidemiological evidence linking diet to diseases such as type 2 diabetes, cancer, and obesity – has led at least one public health advocacy group to proclaim that "…nine out of ten adults are at increased risk of diet-related chronic diseases…" (American Public Health Association 1993).

It is worth noting that many of the excesses of diet are related to the food processing technologies of the industrial age. For example, it has been the goal of wheat milling since prehistoric times to separate the bran and germ from the endosperm, in order to make white flour. Over the course of thousands of years, millers have become increasingly efficient at this task, successively developing millstones (ca. 8000 B.C.), papyrus sieves (ca. 5000 B.C.), quern stones (ca. 800 B.C.), windmills (ca. 1100 A.D), steam engines (1769), screw conveyors and bucket elevators (1808), roller mills (1878), middlings purifiers (ca. 1900), and air classifiers (ca. 1960). Compared to simple stone-ground wheat flour, today's white flours have many desirable properties, including an extended shelf life (crucial to an efficient system of

[9] For an excellent and accessible survey of the current state of knowledge in nutrition science, see Willet (2001). Nestle (2002, Chapt. 1) provides a summary of the history of nutrition science.

[10] A sample of 9,323 adults over the age of 20 was drawn from the U.S. Department of Agriculture's 1994-1996 Continuing Survey of Food Intakes by Individuals. Reported in Cleveland et al. (2000).

distribution) and a delicate flavor when baked into pastries, breads, or cakes. But the protein, vitamins, and essential fatty acids in wheat are mostly concentrated in the germ, and the bulk of the fiber is contained in the bran, leaving the carbohydrate-rich endosperm (and hence white flour) with a wealth of calories, but little else.[11,12]

The overwhelming evidence that the average person fails to choose a healthy diet does not, in and of itself, imply that he is making a *mistake* when he disregards the dictates of modern nutrition science. Diet, after all, is a highly personal choice, and – as noted above – consumers must weigh future health consequences against the immediate pleasure of consumption. Who better to make such a decision than the consumer himself? But the severity and ubiquity of the health consequences of the modern diet and the apparent role of food production technology in aggravating the problem suggest that perhaps something has gone awry in the market for foodstuffs. At the very least, a closer look at the problem seems warranted.

1.6 How people choose

> . . .an emigrant tends to forget the language of his fatherland before giving up his native food habits.
>
> Max Rubner (quoted in Renner 1944, p. 58)

As discussed above, the complex and uncertain nature of the diet problem does not preclude the sufficiency of free market mechanisms in helping consumers solve it. That consumers see a trade-off between *taste* and *health*, however, presents a more difficult problem, on at least two counts. The first difficulty stems from the fact that food preferences in humans are dynamic, a product of culture and habit. That food preferences are determined in part by the society in which one lives and – once determined – are resistant to change raises the question of *equilibrium selection*. Specifically, we might ask whether one "equilibrium" (i.e., *status quo*) diet is superior to another, *ceteris paribus*, and whether a given society might be better off if the local culture were to dictate some alternative diet.

The second, more troubling difficulty stems from the fact that food preferences are at least partly *genetic* in nature. As I have argued elsewhere

[11] An excellent history and nutritional analysis of wheat and milling is provided in Ensminger et al. (1983, pp. 767-769 and 2301-2321).

[12] A similar story could be told about granulated sugar – first produced in 1795, with average annual consumption in the U.S. subsequently increasing from less than 9 pounds per person in 1850 to nearly 100 pounds today (Ward 1941, p. 494; Ensminger et al, 1983, pp. 2061-2068) – or beef cattle, which have become progressively richer in saturated fat over the years as selective breeding and practices such as castration and grain (feedlot) fattening have been adopted in the quest for a more tender, better-tasting cut of meat (Coyle 1982, pp. 65-67).

(Smith 2002), when preferences are passed on genetically the corresponding genes necessarily imply certain assumptions about the choice environments in which they were formed. If these assumptions prove to be in error, then the decision-maker will make mistakes in a systematic way.

These two peculiarities of consumer behavior, the influences of culture and genes on dietary choice, are the subject of this essay.

2. Solving the diet problem: Culture and genes

2.1 Omnivory and imitation

In the parlance of the biological scientist, humans are *omnivorous*, an ambitious term suggesting we will eat just about anything. A survey of world foodways leads one to think this characterization is not far from the truth: in addition to the familiar Western habits of eating roots, leaves, seeds, and animal flesh as well as fungus, spoiled milk, tree bark, and unmentionable body parts[13], one need not look far to find instances of peoples obtaining nutrition from the likes of insects, grubs, soil, or even human corpses.[14] But the relative uniformity of diet within a given culture (which gives meaning to phrases like "Thai food" and "Mexican food") raises the question of what determines dietary preferences.[15]

It is not difficult to explain cultural differences in cuisine in terms of historical differences in locally available ingredients (see, for example, Harris 1978; Harner 1977; Johns 1991). A more puzzling observation, given the demonstrated versatility of the human palate, is resistance to change among those of us old enough to have become accustomed to a given diet. This tendency manifests itself, for example, in immigrant communities, which – in spite of the nutritional equivalence of the local cuisine – have a strong tendency to bring their dietary habits with them. A striking example of the stubborn nature of food preferences is found in the earliest New World colonists: in the 17th century settlements at Jamestown and Plymouth, the newly arrived European colonists' stubborn taste for familiar imported wheat over the novelty of corn took them to the brink of starvation before local foodstuffs were reluctantly adopted (Root and de Rochemont, 1976). Of particular interest, therefore, is the process by which cultural dietary habits are conveyed to individuals.

Humans are not alone in the animal kingdom in their dietary adaptability, nor do they hold a monopoly on social behavior. These facts, together with

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[13] Examples of such foods include potatoes, lettuce, rice, steak, mushrooms, cheese, cinnamon, and hot dogs, respectively.

[14] See, for example, the review by Stinson (1992) and cites therein.

[15] Birch (1999) provides an excellent recent survey of the literature on this subject; see also the classic treatise of Rozin (1976).

the economic and ethical disadvantages of conducting experiments directly on humans, have resulted in a literature replete with evidence of how animals select foods in social settings. Rat pups, for example, are able to identify flavor cues in their mother's milk, which allow them to preferentially select their mother's diet at weaning, and they show strong preference, *ceteris paribus*, for feeding sites at which an adult (or even the scent of an adult) is present (Galef and Henderson 1972; Galef and Clark 1971; Galef and Heiber 1976; Laland and Plotkin 1990; 1993). Though housecats will typically refuse to eat bananas, Wyrwicka (1978; 1981) was able to train mother cats to do so by electrical stimulation of the hypothalamus; when their kittens observed this novel behavior, they too began to lick and eat bananas, and continued to accept bananas four months later. Similar experiments with sheep yielded similar results: weaning lambs offered wheat for the first time ate much more wheat if it was offered in the presence of their mothers who had been trained to eat wheat; and again the effect was long lasting (Lynch et al. 1983; Green et al. 1984). Hatchling chicks can be induced to peck at foodlike objects that are first "pecked" at by a mechanical pointer (Turner 1964; Suboski 1989). Older chickens, after observing either an adolescent chicken or its television image feeding at a visually distinctive site, actively sought out and fed from similar sites two days later (McQuoid and Galef 1992; 1993).[16]

Though experimental evidence on imitative behavior in humans is much more limited, available data indicate a pattern similar to that described for other social species. Some evidence suggests that distinctive flavors such as garlic and vanilla (when present in the maternal diet) can be detected by infants both *in utero* and via mother's milk, and that such early experience can shape later dietary preferences (Mennella and Beauchamp 1996). Slightly later in life, children from 1 to 4 years old are twice as likely to taste a novel food if a friendly adult "visitor" eats it first (Harper and Sanders 1975). Children from 3 to 5 years old with demonstrated aversions to certain foods are reportedly more than four times as likely to eat the aversive food when a group of peers chooses to eat it first (Birch 1980; see also Duncker 1938).

The process of learning about new foods necessarily involves the interplay of fear of new foods or *neophobia*, and curiosity about new foods. As might be expected, these attitudes (as indicated, for example, by both breadth of diet and incidence of accidental poisonings) vary in a predictable way throughout the life cycle, with curiosity holding sway during the first two years of life and neophobia reaching its zenith around age 5 (Cashdan 1994; 1998). A similar pattern was observed in a study of free-living Japanese macaques: when candy was introduced to the group, only 10% of adults ate candy on initial presentation, whereas 50% of monkeys less than three years old did; a year after the initial introduction, 100% of 1-year-olds continued to eat candy, while only 51% of older females and 32% of older males did (Itani 1958).

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[16] For an excellent survey on the subject of social influences on dietary preferences in animals, see Galef (1996).

2.2 The physiology and genetics of taste

Culture certainly plays a role in determining the foods we choose to eat, but there are also aspects of human dietary choice that are undoubtedly influenced by our genes. From the day they are born, infants demonstrably prefer sweet tastes and avoid bitter and sour tastes (Nisbett and Gurwitz 1970; Desor et al. 1973; 1977; Desor et al. 1975; Steiner 1977), and by four months of age a preference for salt reliably develops (Beauchamp et al. 1994). These "four basic tastes" have a well-known physiological basis, with receptor cells in the tongue responding to the presence of specific classes of chemicals (simple carbohydrates, many structurally unrelated compounds, acids, and sodium, respectively) by stimulating taste-specific neural pathways and brain regions (Carlson 2002, pp. 211–216). [17]

In some cases, the genes that code for receptor cells and their associated neural machinery have been identified (see Sullivan 2002 for a recent survey), and there is also much evidence that taste perception varies within human populations, and that this variation is heritable. For example, it has long been known from family studies that sensitivity to the bitter taste of the indicator compounds 6-*n*-propylthiouracil (PROP) and phenylthiocarbamide (PTC) follows a simple (single-gene) Mendelian inheritance pattern (Blakeslee and Fox 1932; Snyder 1931). Sensitivity to PROP and PTC is measured by a threshold method that sorts people into the three genetically distinct categories of non-tasters, medium-tasters, and super-tasters (Drewnowski et al. 2001). The PROP/PTC studies, however, test sensitivity to only a single class of bitter-tasting compounds; many other compounds (chemically unrelated to PROP and PTC) are perceived as "bitter" by human subjects, and recent evidence suggests there may be as many as 60 distinct bitter receptors – all of which appear to transmit the same message to the gustatory regions of the brain (Adler et al. 2000). Nevertheless, the simple PROP screening test has been used to demonstrate that (genetically determined) variation in taste perception translates into predictable variation in dietary choice behavior (Drewnowski et al. 2001; Duffy and Bartoshuk 1996).

The basic tastes of the gustatory system are but a small fraction of what we experience as "flavor". In particular, the human olfactory system (the second "chemical sense") gives us the ability to recognize up to 10,000 different odors (Shepherd 1994). None of these, however, appear to trigger innate, unlearned responses in humans, and the number of receptor types are thought to be much smaller than 10,000. Rather, any given odor molecule appears to activate several different types of olfactory receptors, and it is the

[17] Recent evidence has suggested that humans may have at least two additional "basic tastes", one for *umami* or "savory", triggered by monosodium glutamate, and one for fats, triggered by the essential fatty acids. There is not yet a consensus that these deserve "basic taste" status, and research on their effects on ingestive behavior is much more limited than for sweet, salty, bitter, and sour. Current research is summarized in Carlson (2002).

pattern of activation that is learned and recalled later (Carlson 2002, pp. 219–220). This in turn can translate into learned dietary preference: for example, people given unfamiliar teas (presumably distinguishable mostly by aroma), some sweetened and some unsweetened, show an increased preference for the tea that had been sweetened, even when it is subsequently presented unsweetened (Capaldi 1996; Zellner et al. 1983).

2.3 Nausea aversion and other postingestive consequences

Another demonstrated determinant of food preferences is *postingestive consequences*. For example, it is generally the case that when humans or animals experience nausea or gastrointestinal distress after eating a particular food, they subsequently avoid that food. Food aversions will develop even when *subjects are fully aware that the food is clearly not the cause of the nausea*, as when subjects are treated with a nausea-inducing drug or radiation treatment, or when the subject just happens to be ill. Such aversions can last for years, and will develop even if nausea occurs only several hours after ingestion.[18]

There is also evidence that the postingestive consequences of eating high-calorie foods can increase preference for a given food. For example, Kern et al. (1993) fed 3- and 4-year-old children flavored yogurt drinks, and surreptitiously amended certain flavors with additional dietary fat. After six weeks of conditioning (of two drinks per week), subjects again tasted the various flavors, this time without added fat; they strongly favored those flavors that had been served with added fat. Experimental evidence such as this suggests that people choose foods not just for flavor or by habit, but also by caloric density, as measured by postingestive feelings of satiety.

2.4 Culture, genes, and decisions

It is tempting to emphasize the dichotomous nature of the evidence on dietary choice. After all, some of this behavior can only be described as innate – preference for sweets, for example – while there is also a demonstrable role for culture and learning.[19] But the goal here is to develop a single,

[18] See Sclafani (1971), and the recent survey by Schafe and Bernstein (1996); the phenomenon is also discussed by Romer (2000).

[19] It is important to note, as I have argued elsewhere (Smith 2002), that it is logically impossible for *any* behavior to be classified as the sole product of either culture or genes. On the contrary, all behaviors are necessarily the joint product of an individual's genes and his life history. It is legitimate to ask whether population-level variation in a given behavior is due to variation in genes or in environment, but there is a strong sense in which it is unnecessary to establish the genetic underpinnings of behavior.

parsimonious theory that brings these seemingly disparate behavioral phenomena together.

One obvious difficulty in applying conventional neoclassical economic decision theory to dietary choice is that some cases – nausea aversion, for example – seem better described as emotional or biological than as the conscious, rational deliberation typically implicit in neoclassical theories. But this does not necessarily preclude the usefulness of neoclassical principles in describing dietary choice. Indeed, the standard defense of the neoclassical approach (which generally views behavior as a tool for the decision-maker to achieve his goals, whatever they might be) is that no alternative approach provides a superior positive theory of *behavior,* regardless of what might be happening within the mind of the decision-maker (Friedman 1953). In what follows I argue that neoclassical decision theory can provide insight by providing a formal framework in which biology and culture both have a place.

3 Subjective decision theory

> ...the troubles of the neoclassical theory begin as soon as we introduce uncertainty...
>
> Herbert A. Simon (1992, p. 15)

3.1 The basics

The classic exposition of modern decision theory is Leonard Savage's *The Foundations of Statistics* (1954). Though many variations on (and alternatives to) Savage's approach have been proposed since its publication, it remains the standard against which alternative theories are measured and will serve as a useful starting point here.

The primitive elements of Savage's theory of subjective expected utility are:

S, the *set of states* of the world, with elements $s_1, s_2, \ldots$;
Z, the *set of prizes* or consequences, with elements $z_1, z_2, \ldots$;
A, the *set of actions*, functions mapping from S to Z; and
$\succ$, the *preference relation*, a binary relation on A.

By assuming certain properties on each of these four elements, Savage (and many subsequent authors) showed that choice behavior within this framework will implicitly assign a unique probability $p(s_i)$ to each state s_i of the world, and a unique (up to a positive affine transformation) utility $u(z_i)$ to each prize z_i, and that choices will maximize the expected value of utility, $\mathbf{p}(S) \cdot \mathbf{u}(Z)$. In other words, it is not necessary for an expected utility-maximizing decision-maker to "know", *a priori*, the probability of each state and the utility of each prize: as long as he is able to choose among available actions, he is implying by his actions his own personal, subjective judgment of both probabilities and utilities.

That both probabilities and utilities may be taken as subjective is Savage's greatest innovation, as it reconciles the theory of expected utility with the fact that virtually no one, if you ask them, can tell you with any confidence the probabilities of the multitude of various states of the world they face, much less assign numerical values to all possible consequences of their actions. After all, people face uncertainty every day, and make choices nevertheless, and the theory of subjective expected utility allows the behavioral scientist to focus on actions, with little deference to "black box" comprising the inner workings of the mind.

Another part of the appeal of the theory of subjective expected utility stems from the fact that it allows the behavioral scientist to infer both $\mathbf{p}(S)$ and $\mathbf{u}(Z)$ simply through observed behavior. For example, a subject might be offered a choice of a \$10 prize if Team A wins the Super Bowl or a \$10 prize if Team B wins. If the subject chooses the first contingency, he is implying by his choice that he believes the winner is more likely to be team A than team B – i.e., the two states of the world being "Team A wins" and "Team B wins", an observer could infer that the subject's subjective probability of the former is greater than his subjective probability of the latter. On the other hand, utility might be inferred by observing behavior in situations involving known objective probabilities. A subject might be offered, for example, the choice of an ice cream cone if the toss of a fair coin comes up heads or a bowl of cherries if it comes up tails. A subject choosing the ice cream would reveal by his actions that he assigned a higher utility to the prize "ice cream cone" than the prize "bowl of cherries". The relative sizes of the utilities of the two prizes could then be more clearly revealed by adjusting the probabilities of receiving each prize (i.e., by decreasing the probability of ice cream and increasing the probability of cherries, perhaps by employing another randomizing device such as balls in an urn) until the point is reached at which the subject is indifferent between the chance of winning an ice cream cone and the chance of winning a bowl of cherries.[20]

The examples employed thus far may make the decision environment described by S, Z, A, and $\succ$ seem overly simplistic. This framework, however, can be used to describe much richer decision environments; a few relevant examples are offered in the next section.

3.2 Information, signals, and contingency

The subjective probability measure $\mathbf{p}(S)$ is often referred to as the decision-maker's "beliefs" about the world. Because we might expect subjective probabilities to change when the decision-maker receives new information, it can be useful to explicitly define a collection of information sets I, each

[20] One might well ask how an observer knows exactly what the decision-maker cares about and which "states of the world" he considers relevant; i.e., what are the elements comprising Z and S? In principle, these too might be inferred from behavior, by examining an individual's sensitivity to variation in Z and S.

element I_i of which is a set of signals providing information about the world such that $\mathbf{p}_i = \mathbf{p}(S|I_i)$.

Making preferences endogenous in this way adds a significant complication to the theory, and Savage himself (1954, pp. 82-90) was quick to emphasize that his theory of decisions must necessarily be applied only in the "small world" of an individual decision-maker acting at a given time with a given amount of knowledge or information. But people are undoubtedly sensitive to new information in many ways, and the point here is that subjective decision theory can still be applied – as long as the application is limited to settings in which preferences are not altered by the arrival of new information.[21]

In principle, making behavior dependent on I does not preclude the behavioral scientist from inferring preferences directly from behavior; he merely needs to identify those informational aspects of the world to which behavior is sensitive, and control for them accordingly. In practice, of course, the data required to construct such measures in detail are prohibitive. And even when the information problem is neglected, merely distinguishing **p** from **u** by behavioral observations alone can be problematic: most applications of expected utility theory instead employ *a priori* knowledge of probability distributions, and draw inferences about utility from observed behavior. There is no reason, however, that the reverse approach shouldn't be employed: the observer might just as well begin with *a priori* knowledge of utilities and attempt to estimate subjective probabilities.

3.3 Evolution of preferences by natural selection

> Nothing in biology makes sense except in light of evolution.
>
> Theodosius Dobzhansky (1973)

As noted in Sect. 2 above, evidence from a variety of sources documents the link between human genes and dietary choice. That genes might influence behavior suggests a biological or evolutionary interpretation of subjective decision theory,[22] which opens the door, in turn, to a rich and diverse body of theory and evidence.

The elements of subjective decision theory fit nicely with the theory of evolution by natural selection. One could imagine natural selection choosing among members of a population of foraging animals on the basis of the

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[21] A related complication that often arises is the case of sequential decision-making, perhaps with new information arriving over time. Savage and others have argued that this problem can be reduced to a single decision problem in which the decision-maker chooses an optimal sequence of decisions, contingent upon the arrival of new information (Savage 1954, pp. 15–16).

[22] The notion that biology and evolution can inform theories of economic behavior has been developed by a number of authors. See, for example, Hirshleifer (1977, 1985), Rogers (1994), Bergstrom (1996), and Robson (1996).

relative success of the (genetically transmitted) behavioral algorithms employed. The measure of "success" in evolutionary biology is Darwinian fitness, loosely defined as the number of descendants surviving in the distant future. In an uncertain environment – evolution doesn't make a lot of sense without elements of uncertainty – the proper maximand is the expectation of Darwinian fitness.[23] The parallels with subjective decision theory follow immediately: the behavioral algorithm upon which natural selection acts might be represented as a binary (preference) relation on the set of possible actions; under fairly general conditions, the preference relation chosen by natural selection (i.e., surviving in the long run) will be that which maximizes expected fitness $\mathbf{p}(S) \cdot \mathbf{f}(Z)$, where $\mathbf{p}$ is a vector of actual probabilities over states of the world and $\mathbf{f}$ is a vector of Darwinian fitnesses. An observer, of course, could infer both $\mathbf{p}$ and $\mathbf{f}$ from behavior alone, as above, in the process learning something about the environment (as characterized by the Darwinian prize space, state space, and probability distributions) in which the decision-maker evolved. But the reverse is also true: an observer with knowledge of the environment in which the decision-maker evolved could make predictions about the nature of the preference relation.

Explicitly acknowledging the evolutionary origins of human behavior and the fixed nature of the genetic code that apparently underlies it casts subjective decision theory in a new light. Making sense of modern dietary choice in this light requires the informed behavioral scientist to have some understanding of the decision environment in which humans evolved. This is the subject of the next section.

4. Whence the solution: Shadows of human evolution

> I believe the main reason habitual behavior permeates most aspects of life is that habits have an advantage in the biological evolution of human traits.
>
> Gary S. Becker (1996, p. 9)

4.1 Signals and shifting priors

For an animal foraging in the wild, the problem of choosing foods is not only information-constrained, it is downright dangerous: a novel object might well turn out to be tasty and nutritionally valuable, but on the other hand it could be toxic, contain deadly poisons, or be tainted with infectious microorganisms. The same was true, of course, for humans living in small-scale preagrarian societies – as humans have for most of our collective evolutionary

[23] An important qualification to the expected (i.e., arithmetic mean) fitness hypothesis is the requirement that risks must be independent. If, on the other hand, uncertainty is the manifestation of environmental fluctuations (i.e., risks that affect the entire population) evolution will tend to select agents that maximize the *geometric* mean fitness (see, e.g., Houston and McNamara 1999; Bergstrom 1997; Robson 1996; or Smith 2002).

past. So we might expect Mother Nature (i.e., the process of evolution by natural selection) to have endowed us with behavioral algorithms that help us to nourish ourselves without doing ourselves in. The way Mother Nature has done this, it will be argued here, is to take advantage of regularities in the environment that provide clues as to which novel items in the local environment are likely to have nutritional value.

If, for example, foods with characteristic X are more likely than not to be nutritionally valuable and toxin-free, then individuals favoring foods with characteristic X would, on average, be favored by natural selection. Consider the decision problem faced by the omnivore: when presented with food X, and the choice of actions at hand is "eat item X" or "don't eat item X," the states of the world correspond to possible degrees of nutritional value for item X, with the prizes being the various possible health consequences of eating (or not eating) item X. Then we would expect Mother Nature to choose the preference relation such that the utilities implied by behavior correspond to the actual (fitness) value of eating nutritious foods, just as we would expect the probabilities **p** implied by behavior to correspond to the actual probability distribution on nutritional quality. In effect, when signal X is received with respect to a given potential food, the corresponding **p** shifts to reflect a higher (subjective) probability of nutritional value, thus increasing the expected (fitness) value of eating item X.

In keeping with Savage's tradition of focusing analysis on a "small world" of decision-making, I will limit analysis here to the simple problem described in the previous paragraph. This decision problem is implicitly framed within the context of the problem of "assembling a menu". That is, the decision-maker's larger task is to search for and adopt foods to be included in his diet in the future.[24] For foraging omnivores this is an important adaptive problem: although dietary flexibility conveys obvious advantages, it also increases the possibility of poisoning early in life, when the young animal must learn which objects are good to eat and which are to be avoided. Given what is known about how animals actually solve this problem (discussed in Sect. 2 above), the signals upon which they rely can be divided into three groups: cultural signals, chemical signals, and postingestive signals. Roughly speaking, these signals might be thought of as arriving in sequence: first the young omnivore observes his peers eating item X (a cultural signal), then he tastes X (a chemical signal) and finally he waits to see how he feels after eating X (a postingestive signal). The evolutionary rationale for relying on these particular signals will be discussed briefly in the next section. The applicability to modern human decision environments will then be considered.

[24] This is a much simpler problem than that of choosing an optimal diet. The complete diet problem might be thought of as a two-stage problem: i) assembling a menu of acceptable foods and ii) choosing a diet from that menu. George Stigler's classic study, "The Cost of Subsistence" (1945) and the large literature it spawned emphasize the second stage.

4.2 Three important signals: culture, taste, and aftereffects

4.2.1 Culture as information

The simplest method of search for foods in a natural environment would perhaps be trial-and-error, sampling the local flora and fauna and accumulating knowledge of their various physiological aftereffects. But given the inherent risks of sampling new foods – including death from poisoning or infectious disease – a better strategy would be to take advantage of cues in the local environment that signal which potential foods are more likely to be toxic and which are more likely to be nutritious. An obvious example of such a strategy is to make use of the accumulated knowledge of your conspecifics, observing what they eat and selectively consuming these same foods yourself.

As Sect. 2.1 established, humans and other social species clearly make ample use of imitation early in life, learning to eat foods they see others eat. But is this always a good idea? Might it not be possible, in the course of human evolution, that the established food habits of others might overlook valuable resources, so much so that the benefits of trying something new would outweigh the risks? Perhaps, but surveys of the traditional diets of modern hunter-gatherers and subsistence farmers suggest most cultures have been very successful at developing well-rounded diets from local foodstuffs (Eaton and Konner 1985). One striking example is found in the ancient American practice of alkali processing of corn: Katz et al. (1974) have argued convincingly that this process has been adopted in areas in which the local population would otherwise be subject to outbreaks of pellagra. Pellagra (the symptoms of which include severe dermatitis, fissured scabs, diarrhea, dementia, and death) is caused by a dietary deficiency of niacin; corn is very low in niacin, but treatment (boiling the corn with calcium oxide) greatly increases the amount of biologically available niacin. The origins of the practice are unknown, and traditional practitioners are reportedly unaware of the nutritional benefits: they claim to process the corn into masa simply because it improves the taste. Other examples of the wisdom of traditional local cultures include Asian soy processing techniques, which remove potentially harmful compounds (Katz 1987), and *geophagia* (soil consumption) in areas where the local organic diet provides a dearth of essential minerals (Hunter 1973; Danford 1982).

A related question is why people might rely on imitation rather than collecting information directly from peers and parents, by asking questions about the known properties of various foods. It may make sense for animals – which cannot speak or read – to rely on observation of others, but wouldn't humans be better off relying on oral or written histories of food? Perhaps they would, and no doubt some information has always been transmitted this way, but judging from the content of contemporary children's television advertising (discussed further in Sect. 5.2.1, below), many young people are indeed susceptible to the influence of visual representations of food consumption. The evolutionary rationale for this seemingly irrational behavior is simple: in assigning relative weights to social experience (i.e., visual observation) and asking around (or its modern equivalent, reading about nutrition) in determining dietary behavior, Mother Nature has the benefit of eons of experience. It is not hard to imagine scenarios in which peers or parents might give false testimony with respect to the merits of a highly valued treat (all the more for themselves…), so perhaps such information should be discounted accordingly; a more reliable signal of nutritional value in human evolutionary history might have been the observation of a couple of peers fighting over a coveted fruit or piece of meat.

4.2.2 Chemical signals

The fact that humans – via the senses of taste and smell – have the ability to test directly for specific classes of chemical compounds is evidence that the evolution of sophisticated chemical sensing systems is possible. But how sophisticated *should* such systems be? That is, given the metabolic costs of sensing, storing, and processing additional information with respect to the chemical makeup of a given food, at what point do the costs of additional information exceed the benefits? The usual answer in economics and behavioral ecology – the point at which marginal (fitness) cost equals marginal (fitness) benefit – is complicated by the fact that the chemicals of interest are not distributed at random in natural environments. While some important nutrients – pantothenic acid, for example – are found in virtually all foods of plant or animal origin, making a specific sense perception perfectly useless, others are to some extent grouped neatly into packages of deadly toxins and valuable nutrients, for reasons to be discussed below. A good strategy in such an environment would be to identify compounds that serve as reliable signals of toxicity and/or nutrition, and test for these, relying on the fact that other important nutrients typically coexist with the signals.

For many years plant toxins such as alkaloids, quinones, and terpenoids were thought to be secondary metabolites, waste products of no particular use to the plant that made them. But further study made it clear that these energetically costly compounds were made for a reason: as a defense against herbivorous foraging animals. By a process known as *coevolution*,[25] the production of plant toxins is now thought to have arisen because the toxins protect the plant from being eaten. The logic of coevolution can also lead, however, to precisely the opposite strategy.

[25] Coevolution refers to the evolution of two or more interdependent species, each adapting to changes in the other. The term is also sometimes used to describe the interdependence of social environment (culture) and individual (genetic) strategies within the same species (e.g., Durham 1991).

There are instances in which consumption by animals can serve to pollinate a plant's flowers or disperse its seeds; in these cases, the plant typically generates pollen or a fruit free from toxins and rich in simple carbohydrates and other valuable nutrients.[26] In both the case of protective toxins and the case of seed or pollen dispersal, plants often couple the biochemical signal with a visual signal (distinctively shaped and/or brightly colored flowers, fruits, or leaves), reinforcing the lesson for the offending animal and facilitating future identification (see, e.g., Raven et al. 1999, pp. 546–551).

The chemical signals upon which Nature seems to have settled in the coevolutionary game between humans and their foods are suggested by the (genetically programmed) sensitivities of our tongues: sugars and salt are perceived as sweet and salty, respectively, and are sought after; whereas acids and chemically complex toxins are perceived as sour and bitter, respectively, and are avoided. In natural settings, sugars are rare and found only in ripe fruits and raw honey, both of which reliably contain a host of other valuable vitamins and minerals; likewise, salt is rare in most natural settings but metabolically necessary, so an attraction to salty foods would have been likely to serve humans well over most of their evolutionary history. The sour and bitter compounds found in immature fruits and other plant (and some animal) materials are often themselves toxic, imposing an immediate metabolic cost on those unfortunate enough to sample them.[27]

4.2.3 Postingestive consequences

The evolutionary logic of avoiding foods that make you vomit is perhaps obvious, but the inflexibility of this response is perhaps less so. Why should people develop such aversions when they have objective knowledge that the nausea was not caused by the food? The answer is that for most of human evolutionary history, such objective knowledge was presumably not very reliable, and the risks of eating poisonous toxins too great. In choosing the information states on which to condition behavior, Nature gave greater weight to postingestive nausea and less to objective knowledge because in the long run this must have resulted, on average, in better health outcomes.

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[26] A similar story emerges in the prehistory of agriculture, as described in Diamond (1997, pp. 120-121): It is thought that pre-agrarian human foragers inadvertently selected for beneficial traits in harvesting wild grains. Such foraging would naturally have favored those grasses whose seeds were larger and more readily harvestable. Over time, the resulting human-facilitated seed dispersal resulted in the evolution of a handful of wild predecessor species into domesticated wheat, barley, and other grains upon which the emergence of agriculture ultimately depended.

[27] For early expositions of this hypothesis see Garcia and Hankins (1975, 1977).

It has also been suggested that nausea aversion plays a role in the omnivore's difficult task of choosing a well-rounded diet. In a series of classic experiments (described by Rozin 1976, pp. 38–48), laboratory rats fed thiamine-deficient diets to the point of malnutrition were subsequently given opportunities to try other foods. Rats, like humans, lack the ability to detect thiamine (vitamin B_1) directly via the chemical senses, but after becoming ill on a thiamine-deficient diet, they develop an aversion toward the diet, preferring to eat their own feces (which, in fact, contain trace amounts of thiamine) or any alternative diet offered, even if the alternative diet also lacks thiamine. This simple algorithm ("seek out new foods when ill") might go a long way toward helping foraging animals solve the diet problem in natural settings.

4.3 Evolutionary equilibrium: Dynamic consistency and "as-if" rationality

When one considers the environment in which humans evolved, with the inherent dangers of unfamiliar foods, the convenient distribution of sugars and toxins, and the valuable accumulation of local dietary knowledge, it begins to become apparent why people choose foods the way they do. It is not hard to imagine an ancient environment in which there was no contradiction between one's dietary tastes and future health consequences. Behavior in this environment would have looked a lot like the behavior generated by neoclassical economic models, in which choice (specifically, dietary choice under conditions of uncertainty) is a means to an end (good health).

In particular, in the evolutionary equilibrium described here there is no problem of self-control in choosing foods. An individual might actively seek out and gorge on sweet foods, but doing so would not be inconsistent with expected future health outcomes; he would not, on average, regret his actions, and he would have no reason to employ commitment devices that restrict his freedom of choice.

4.4 Conscious deliberation and bounded rationality

This essay began with the stated purpose of investigating exactly *how* consumers solve the search theoretic problem of choosing a diet. The careful reader may have noted that in the evolutionary equilibrium described above, the actions of the decision-maker are not explicitly constrained by his information-processing capabilities. Though the equilibrium strategy might be described in terms of simple heuristics ("choose sweet over bitter," "eat what others eat," etc.), these rules were generated by an optimizing process more akin to neoclassical search than to boundedly rational search. This is not to say that an *individual* decision-maker deliberately performs all the necessary calculations, much less goes out and collects the information upon which the resulting strategy is based. He merely finds pleasure in sweet-tasting foods, or feels curiosity after watching his companions eagerly consume a novel food. He experiences these emotions, and acts upon them, because in the countless generations who came before those who were similarly predisposed enjoyed an advantage when it came to solving the diet problem. In other words, the computational heavy lifting of optimization is left to the process of evolution by natural selection.[28]

Evolutionary analogies are often invoked in defense of the (unboundedly) rational consumer, as exemplified by the following passage:

> This approach is…consistent with the view that tastes or preferences are competitively selected. Tastes are not arbitrary "givens": they evolve in a crucible of continual competitive testing. In a nation of island dwellers, it is unlikely that we will find many persons who dislike fish. Nor are we likely to find many vegetarians in lands well suited to grazing animals. Tastes so expensive as these are simply not likely to survive. The environment places limits on the variability of tastes among the residents of that environment. In one sense, the aim of civilization (including the growth of income) is to widen the tolerance of the environment.
>
> George J. Stigler (1987, p. 33)

But a deeper understanding of exactly how preferences for food are influenced by genetic predilections and childhood experience raises uncomfortable questions about this particular conclusion. It is indeed true that tastes are not arbitrary, and that they are the product of an evolutionary process. And it is also true that fish are likely to be eaten on islands, and meat in regions with productive grasslands. It does not follow, however, that tastes are *completely* malleable within spans of time that interest economists. Consumers' innate reactions to sweet, bitter, sour, etc., being encoded in their genes, cannot be altered within the span of a single lifetime. Nor does it follow, as Stigler implies, that the observed malleability of preferences ensures that advances in technology will always make us better off. This is the subject of the next section.

5 Biological legacy meets modern technology: The McDonald's equilibrium

5.1 Food in the modern marketplace

Today we live in a world of rapidly changing technology, nothing like the pre-industrial (and even pre-agricultural) world that characterizes most of human evolutionary history. But an understanding of human dietary choice in light of an evolutionary view of our species yields a rich descriptive theory of how

[28] Hirshleifer (1987) and Frank (1988) offer similar explanations of human emotions in the context of social behavior.

we might expect consumers and firms to interact in modern markets. It has been argued here that we can think of consumer behavior as being guided by a preference relation that is literally written into our genes. To the extent that this is true – and acknowledging Savage's demonstration that such a preference relation must implicitly incorporate *beliefs* about the world – it is necessarily true that consumers can usefully be thought of as making "mistakes" in modern market economies.

Specifically, evolution seems to have conditioned human dietary choice on the three information states discussed in Sect. 4.2: we prefer foods that are i) eaten by others, ii) taste sweet or salty, or iii) are associated with postingestive satiety – presumably because in the course of human evolution each of these cues was associated with a higher probability of the food in question being nutritionally valuable.

A profit-maximizing firm seeking to bring food products to the market would be foolish to ignore the effects of these dietary proclivities on consumer demand. And indeed, even a cursory look at the marketing practices and products of the largest U.S. food producers confirms that these firms are no fools.

5.2 Marketing and design aspects of fast foods and snack foods

5.2.1 Television advertising

Consumer advocates have long argued that much advertising, especially television advertising, manipulates consumers into buying products that are detrimental to health or well-being. In particular, television advertisements aimed at children are rich in imagery and action but rarely convey substantive information about the characteristics of the product being advertised.[29]

The apparent lack of direct information in these ads would seem to make them good candidates for the compelling and influential theory of uninformative advertising developed by Nelson (1974) and Milgrom and Roberts (1986). In this view, advertisements may serve as valuable signals of product quality even if they convey *no* descriptive information about the product. It might well be argued that most food ads aired during children's television programming fit into this category. But closer scrutiny of the visual information presented in these ads – together with knowledge of the decision algorithm employed by young children in choosing foods – makes it clear that information is indeed being conveyed. And knowledge of the evolutionary problem this particular decision algorithm is intended to solve suggests that

[29] A current sample of food ads aired during children's television programming is described in Smith (2002). See also Rajecki et al. (1994).

the information conveyed in television ads is in a sense *misinformation*, to the extent that it induces the young consumer to act on the basis of biased subjective probabilities.[30]

In the most common treatment, the food product being advertised is shown inducing a dramatically improved mood or state of health in the actors eating it. In another, the product is presented visually as a prize being scuffled over by two or more individuals. Other themes include presenting the product as a reward for athletic merit, or associating it with social success (Smith 2002). It doesn't seem too much of a stretch to suggest that such scenarios could have provided valuable information about the relative merits of local foodstuffs for most of our collective evolutionary past. In other words, the themes emphasized in television advertisements for foods appear to be providing information that once served as a signal of nutritional value. When children preferentially choose the foods they have seen (on TV) healing the sick or being coveted by others, they are unconsciously following an ancient algorithm for choosing a healthful diet. Unfortunately, the actual nutritional quality of advertised foods is typically poor (Kotz and Story 1994).

Not surprisingly, there is indeed evidence that advertisements are effective in influencing dietary choice. Children often request specific food products after seeing them advertised on television, and their parents often buy them.[31] The diets of children exposed to more television advertising mirror the types of food products – generally high in fat, sugar, and/or salt – emphasized in

[30] This is not to imply that advertisers are necessarily aware of the biological underpinnings of the psychological mechanisms governing consumer behavior; all that matters for their purposes, of course, is that their advertisements are effective. It is interesting to note, however, that "advertising men" have long been aware of the strength of human "instincts". The following passage from the classic advertising textbook of Tipper et al. (1915, p. 75), though written nearly a century ago, could well have been drawn from a modern text on evolutionary psychology: "In the past experience of the (human) race certain objects or situations have stood out as fundamentally important in the struggle for survival, supremacy, and comfort. Definite modes of reaction have been found to be most appropriate in dealing with these particular objects or situations. Individuals who have reacted promptly and definitely in these appropriate ways have been successful, have flourished, and have left offspring who possessed the same inborn tendencies to reaction. Individuals who failed to react in these appropriate ways perished and left no progeny. So there has been a long process of selection, in which only those individuals have survived…who displayed mechanical tendencies to react in the ways which (human evolutionary) history has proved most expedient." The authors also indicate an awareness that human instincts might no longer serve their original purpose (p. 67): "Even if there is no longer any biological necessity for the activity of the instinct mechanism, the psychological need is still present, and this is a real factor in the life of the individual. In this way arise many specific modes of reaction to particular objects in the world."

[31] Borzekowski and Poussaint (1998) report that in a survey of mothers of Latino preschoolers, 55% had been solicited (within the previous two weeks) by their children to buy advertised foods, and 67% had fielded requests to go to an advertised store or restaurant. Taras et al. (1989) report similar results, and also that more than half of requested food items were subsequently purchased by the child's parents.

Table 1. Average calorie density and sodium content of selected foods

Food	Calorie density (kcal/g)	Percent sodium
Burger King sandwiches	2.42	0.45
KFC chicken	2.85	0.76
McDonald's sandwiches	2.39	0.51
Pizza Hut pizza	2.40	0.62
Taco Bell tacos	2.33	0.47
Wendy's sandwiches	2.14	0.51
Wild game	1.26	0.06
Wild plant foods	1.09	0.01

Sources: Burger King Corporation (2002), KFC Corporation (2002), McDonald's Corporation (2002), Pizza Hut, Inc. (2002), Taco Bell Corporation (2002), Wendy's International, Inc. (2002), Eaton et al (1997).

television ads.[32] And in laboratory settings, children show a strong preference for advertised products after viewing a video with embedded ads.[33]

5.2.2 Designer foods: Sugar, salt, and caloric density

Similarly, a look at the nutritional content of popular foods (Table 1) suggests that food producers have learned to isolate the chemical signals and calorie density that once helped human foragers choose nutritionally valuable foods. The McDonald's menu, for example, features a variety of sweetened, salty, and calorie-dense foods: sandwiches have an average calorie density 90% greater than the average game meat consumed by modern hunter-gatherers, and 119% greater than the average plant food; and a single sandwich provides 40% of USDA's maximum recommended daily intake of

[32] In a survey of foods advertised on television, Taras et al. (1989) find that 68% are high-sugar, 35% are high-fat, 17% are high-salt, and only 11% are low in sugar, fat, and salt. Foods requested by children followed a similar pattern (66% high-sugar; 36% high-fat; 19% high-salt; and 7% low-sugar, -fat, and -salt), as did (requested) foods actually purchased for children by their parents (58% high-sugar; 34% high-fat; 22% high-salt; and 10% low-sugar, -fat, and -salt). More generally, the authors find a significant correlation between weekly viewing hours and both reported requests for and subsequent purchases of advertised food products. This is consistent with the findings of Ortega et al. (1996) that among a sample of Spanish adolescents, those who watched television for two or more hours per day ate less fruit, legumes, fiber, and Vitamin C than those who watched less.

[33] Such an experiment is described by Borzekowski and Robinson (2001): Forty-six 2- to 6-year-olds were shown an animated video either with or without embedded advertisements, then asked to choose between two similar products. Compared to the choices of the control group, the likelihood of choosing the advertised product was greater for 7 of 8 food products, and in most cases dramatically so.

sodium; soft drinks and shakes (excluding diet drinks) average 9% and 18% sugar, respectively.[34]

5.3 Misinformed search

Each of these aspects of the modern food industry – television advertising, addition of sugar/salt, and increased calorie density – can be viewed as an instance in which technological advances have altered the probability distributions underlying the information state each once represented for pre-industrial humans. The information that children once gleaned from watching their peers fight over a prized fruit is today replaced by television images of cartoon characters fighting over a brightly colored candy; the information once provided by the sweetness in ripe fruits is today replaced by sugar refining technology, which allows the sugar to be presented without the fiber, vitamins, and minerals that accompany it in nature; and caloric density, once a signal of the likely presence of essential fatty acids and other valuable nutrients, is today replaced by processed fats and refined flour. In the language of subjective decision theory, in the modern environment **p** (and hence behavior) is conditioned on signals that no longer convey information. That is, we are no longer able to solve the diet problem in an optimal way.[35]

6. Some implications for welfare economics

> Quite a lot of high-brow economics…accepts the appropriateness of the standard general equilibrium model, with everyone pursuing their self-interest, given tastes and technology… But the high ground is not secure at all. The most basic element of such modeling, namely the motivation of human beings, is not well addressed.
>
> Amartya Sen (quoted in Klamer 1989, p. 147)

One way of approaching the consumer's dietary choice problem is to ignore the biology and to treat it as a conventional economic choice problem. The peculiarities of how people choose food (in particular, the sensitivity of choice behavior to television imagery and temporally related nausea) are hard to reconcile with a strict neoclassical interpretation, so the analysis would probably employ the descriptive emphasis of behavioral economics. But it would be tempting, even within a behavioral-economic framework, to model

[34] See Table 1 for data and sources. For a broader comparison of modern dietary habits with the prehistoric human diet, see Eaton and Konner (1985) and Eaton et al. (1997).

[35] This conclusion, though never given serious treatment in the economics literature, has long been accepted as a stylized fact by biologically oriented social scientists. See, for example, Ng (1991).

each of the three choice situations discussed herein (interpreted here as cases of social, chemical, and postingestive signals) separately; and to treat the problem as one of deterministic intertemporal choice rather than one of information and uncertainty. Imitation, for example, might inspire a theory of social preferences in which one's own consumption is complementary to the consumption of others (or the television image of others). Strong preferences for sugar or high-calorie foods might be modeled as simple rankings of product qualities (i.e., the sugar and calories themselves becoming the objects of desire) or, if consumers claim lack of self-control, are found to regret their actions and/or to seek means of restricting their own dietary choice, then a behavioral model of dynamically inconsistent preferences might be applied. Nausea aversion – with its strong influence on dietary behavior even when the consumer is aware of the irrationality of the response – poses a particularly difficult problem even for behavioral economics; it would be tempting to dismiss such behavior as "emotional" and perhaps outside the purview of a rational theory of behavior.

But this approach to economic theory would fail to make use of all the evidence from biology: the many strong similarities between human and animal food selection behavior, the demonstrably genetic basis for (and hence constraint on) the chemical senses, and the parsimonious evolutionary theory into which all these features fit so neatly. It would also fail to generate *ex ante* detailed predictions about how food is produced and marketed.

The approach applied here, on the other hand, begins by placing the behavior in question in its proper biological context, and draws on a firm foundation of scientific knowledge in answering the question (of *how* consumers solve the diet problem) posed at the beginning of this essay.

The conclusions reached here have profound implications for the theory and practice of welfare economics. To suggest that people choose foods on the basis of biased subjective probabilities is to call into question the doctrine of consumer sovereignty. Although popular opinion has long been sympathetic to the notions that children are subject to manipulation by television commercials and that people have a weakness for sweetened high-calorie foods, conventional economic theory has largely ruled these ideas out with first principles.

Weakening the equivalence between individual *choice* and individual *welfare* that serves as the foundation for welfare economics need not imply drastic changes in public policy. Indeed, many existing policies could find a sounder theoretical foundation on the basis of the findings presented here: advertising for products such as tobacco and alcohol (which, it could be argued, share many features with candy and soft drinks) is already severely limited in the U.S. by federal regulation; producers of ("enriched") wheat flour are now required to add a long list of B-vitamins to their product after the milling process has removed them; many states levy product-specific taxes on soft drinks and snack foods (Jacobsen and Brownell 2000); and Coca-Cola recently withdrew from its nationwide network of exclusive school vending contracts under pressure from consumer advocacy groups concerned about the dramatic rise in childhood obesity (Coca-Cola Company 2001). Such policies, though difficult to justify in a neoclassical framework, make sense in light of our growing knowledge of the biological underpinnings of human dietary choice.

But if *some* restrictions on advertising or on food product characteristics are justifiable, at what point do such policies become *too* restrictive? There is no simple answer to this question. It is not clear, for example, that the world would necessarily be a better place in the absence of refined sugar. It may be true that the pleasure we get from the act of eating sweets is no longer proportional – as it once was, according to the evolutionary theoretic explanation – to the expected future health consequences of that act.[36] But this doesn't necessarily mean that the very real pleasure of eating sweets should be ignored by the welfare economist interested in maximizing human well-being. The evolutionary view does, however, imply that people – left to their own devices, in a market environment of cheap sweets and lacking education in matters of human nutrition – will fail to solve the intertemporal pleasure/health tradeoff in an optimal manner.

Last but not least, there is the important question of equilibrium selection. In light of the overwhelming evidence that culture influences diet and diet influences health, it seems a reasonable exercise to consider the feasibility of various combinations of cultural practice and public health.[37] Health and well-being are intimately linked, after all, and culture can be influenced by such things as education and the media. Might we all be better off, for example, if – given our unfortunate tendency to choose foods that make us sick – we were better schooled in matters of human nutrition? Might we all be better off if, as children, we had been exposed to television images of actors grappling over a ripe apple, or a green salad, in place of Big Macs and Cokes?

Food for thought.

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[36] More precisely, in evolutionary equilibrium we would expect such pleasure to be proportional to $\mathbf{p}(S) \cdot \mathbf{f}(Z)$, the expected future *Darwinian fitness* of the act of eating sweets. Here the prize space Z (i.e., the vector of inputs to the fitness function $\mathbf{f}$) would presumably be comprised of the health consequences of eating the food item in question; the states of nature S correspond to the possible nutritional qualities of the food.

[37] A complication that arises in such considerations is uncertainty with respect to the relationship between diet and health. Though there is considerable agreement about what constitutes a healthy diet, research on the subject is ongoing. And when science finally does pinpoint the perfect diet, it is not likely be the same for everyone: individual genetic and developmental differences may imply fairly dramatic differences in dietary recommendations. It is interesting to note, however, that current dietary recommendations – as well as existing regulation governing the food industry, mentioned in the preceding paragraph – represent steps backward, toward a diet that more closely mimics the diet of our ancestors.

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