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THE FUTURE OF FOOD: HOW SCIENCE, TECHNOLOGY, AND CONSUMERISM SHAPE WHAT WE EAT

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Can you envision one day having the ability to interact vocally with a machine to request food, which is then instantly produced for you? You would have no need to bother with cooking, nor wonder whether your meal is "good" or "bad" for you, as it has already been perfectly prepared to suit your lifestyle and nutritional needs. Such is a familiar future of food as portrayed in Gene Roddenberry's popular television series, *Star Trek: The Next Generation* (1987-1994). In the 24th century, cooking as we know it is obsolete. An order is conveyed to the computer—a technologically advanced, artificially intelligent descendant of today's drive-thru fast-food servers—and the food is immediately synthesized and prepared for consumption. Roddenberry's vision represents a sort of nutritional utopia: 24th-century diners are guaranteed optimal nutrition with regards to both macronutrient proportion (i.e., fat, protein, and carbohydrate) and micronutrient content (e.g., vitamins and minerals). There appears to be no incidence of nutrient-related diseases, since food is purposely enriched to prevent such illnesses. By this point in time, our continuing efforts at culinary improvement have given rise to the ultimate finished product, the perfect food itself. It resembles the foods of today in appearance and taste (at least, in this galaxy) but possesses a subtly altered composition. In this idealized future, not only has the problem of supply been solved, with the traditional Malthusian anxieties about food shortages having been permanently alleviated; production of perfectly nutritious "superfoods" has even obviated the need for prudent dietary habits. Food and nutrition sciences and technology have enabled us to allay our fears of consuming anything unhealthy; the "perfect food" has made such common worries in our own less-than-perfect-world a thing of the past.

Is this the future of food?

In this essay, I deconstruct the question into its dual components of food production and consumption, demonstrating how science, technology, and consumerism shape the future of food, hence what we eat. Using the United States as an example, we will see how advances in food production are engendered through the inter-relation of scientific research and industrial innovation. Ultimately important is the individual food consumer, who chooses what to eat and drives what industry will produce. In the past two centuries, advances in the agriculture and food industries industrialized food production while concomitant advances in science enabled greater understanding of food, nutrition, and disease. As we begin the 21st century, we are in the midst of a revolution in food and nutrition science. The practice of nutrification, in which nutrients are added to food to improve the dietary intake of the population (1), has evolved from traditional fortification to genetic modification, that is, from simply adding nutrients to food to changing the very genetic composition of food itself. These scientific and technologic advances have forced a paradigm shift in the way we think about diet and health, and, specifically, the potential of food to change forever the nutrient-disease relationship. Industrialists and scientists will continue to nutrify foods using the latest science and technology today and long into the future—until, perhaps, we have achieved our goal of producing the perfect food. But is this idealistic future of human nourishment, as envisioned in science fiction like *Star Trek*, a realistic fate of our own?

Examining the roles of food producer and food consumer today and in American history raises philosophical and ethical questions surrounding the roles of science, individualism, and technology in food production. These questions are manifold and difficult and should be considered when reviewing past and present choices of food production and contemplating future directions, as the kinds of foods produced and consumed have important implications for public health. Such questions are posed because they encompass not only what we eat, but also who we are and what we value as individuals and as a society. After all, no custom is more ancient or universal than the consumption of food and drink, deriving as it does from a basic human need. Analyzing how that need is met in today's world will shed light simultaneously on our attitudes toward technology, as well as the economic structures that have evolved to link the supply with the demand of a basic commodity.

Food production: industrialization and nutrification

Past and present food production practices have shown that creating a healthful world food supply involves combining agricultural technology

with knowledge of nutrition (1). In particular, industrialization and nutrification have both profoundly impacted food production throughout history. Improvements in food manufacturing through industrial and technologic advancement led to increases in the quantity and overall quality of food, while scientific advances in nutrition enabled improvements in its healthfulness, both of which are further discussed in this section.

Early in the nation's history, and centuries before then, agriculture was based on abundant land and scarce labor. The Industrial Revolution of the 19th century changed the landscape of farming to focus on gains in land and labor productivity through mechanization and other advanced technologies. Urbanization and industrialization led people away from individual food production and into other growing manufacturing sectors of the early industrial revolution. In 1900, 39% of the labor force lived and worked on a farm, decreasing to 11% in 1950 and less than 2% in 1990 (2). The shrinking role of the individual in food production throughout the 20th century is reflected in these numbers, as agricultural technology increased and the food industry developed. A growing population in numbers and distance required technologies to produce enough food to feed people, and processing was required to preserve foods during distribution. Agricultural efforts and inputs intensified during and following World War II so as to secure an adequate food supply. These efforts led to the Green Revolution, which began around 1950 and was dedicated to improving seed varieties and crop yields. Over time, agribusiness, which married the science of supplying the raw material for agriculture with the subsequent production, processing, and distribution of food and fiber (3), began to dominate agriculture itself. This led to the development of global mega-corporations that generate not only food products but also the inputs for those products, such as seeds, insecticides, and fertilizers for raising crops.

The gains in food and fiber productivity made possible through the Green Revolution, however, came at a high price to the environment, the focus of Rachel Carson's seminal book, *Silent Spring* (4). Carson's book warned of the environmental downside of using heavy chemicals and pesticides to increase crop efficiency and led to a backlash against industrial (i.e., conventional) agriculture. With Carson's book, the modern environmental movement was born and continued to grow during the later decades of the 20th century, from which developed the concept of sustainable agriculture. I return to this concept later in the paper.

Along with a host of environmental problems, the production gains in the past century created an abundant food supply, redirecting industrial efforts of the late 20th century to focus on problems related to quality, rather than quantity, of food. (The pervading pandemic of hunger is a result of social, political, and economic problems related to food access, distribution, and cost, not food supply itself; this is still true today.) Many food production efforts were dedicated towards creating foodstuffs to meet diverse consumer needs, the focus of the next section. As American civilization developed, the post-modern global supermarket gradually replaced the local family farm of the agrarian era, offering the consumer a cornucopia of processed, exotic, and imported foods. By 1995, the total number of food products in the US food supply was approximately 250,000, and 17,000 new food products were produced that year alone (5).

While industrialists continue to seek myriad ways to create new foodstuffs that improve the variety and overall quality of food (e.g., taste, convenience, and safety), nutrition scientists continue to work on elucidating the role of nutrition in health and disease. The evolution of nutrition science followed a path similar to the evolution of food industrialization, focusing first on quantity and then on quality. Early nutrition research efforts throughout the 19th and first half of the 20th century focused on problems of vitamin deficiency and growth, often related to inadequate food intake. Although vitamin research still continues, research efforts in the later part of the 20th century shifted to focus on problems of overall dietary quality in relation to general health and chronic disease prevention. Throughout the history of modern nutrition science, food technologists have applied nutrition knowledge to create more healthful foods for the population at large. In fact, the practice of nutrification, in which food is purposely modified to improve its nutritional quality, is almost two centuries old, when it was first suggested in 1831 that iodine should be added to table salt to prevent goiter (1).

Since its conception, nutrification efforts have continued to develop and take advantage of contemporary technology, such that today we have the ability to nutrify food not only through the direct addition of nutrients, but also via alteration of the genetic composition of the food sources themselves. The revolution that occurred in molecular biology during the latter half of the 20th century, leading to the discovery of DNA and the eventual mapping of genes, irrevocably changed the face of food. Genetically modified (GM) foods are created by switching genes on or off within the same plant—such as in the Flavr Savr™ tomato, the first GM food to come to market in 1994—or through the direct movement of genetic material between unrelated plant and/or animal organisms. GM foods will be seen in greater numbers and variety in coming years. This most recent advance in nutrification, which uses the powerful tools of modern biotechnology to engineer foods genetically to augment their nutritional benefits, holds great potential to impact

human health. Genetic engineering can be applied to obtain a vast array of desired traits and, as such, can be used to make many changes in food beyond nutritional quality alone. In fact, molecular techniques for the production of new varieties of plants is simply a new methodology applied to a very old human activity (6), which is genetic recombination of plants through traditional cross breeding. The many applications of food biotechnology (e.g., increasing crop yields, improving pesticide resistance, or producing a vaccine), and the implications of GM foods on public health and the environment, are indeed profound. So much so that a complete discussion of the many facets of this important topic in and of itself is beyond the scope of this essay.

The objective here, rather, is to argue, from the perspective of the evolution of food production, that food produced through genetic modification is the next logical step—the next revolution, as it were—in the nutrification and industrialization of food. The impact of the Genetic Revolution on food production is no less profound than were the Green and Industrial Revolutions of the past two centuries. GM foods are the genetic offspring, so to speak, of functional foods, denoting foodstuffs that have been modified to provide greater health benefits through the addition of nutraceuticals (naturally-derived bioactive compounds), a common example being the phytochemicals, like beta-carotene, found in plants. (The treatment and/or prevention of nutrition-related diseases with nutraceuticals can be regarded analogously to the treatment of medical illnesses with pharmaceuticals.) Functional foods are designed to meet specific health and medical needs, thus blurring the line between food consumer and patient, supermarket and pharmacy. Foods modified genetically to be more healthful are therefore a variant of functional foods, different only in the scientific methods that are employed to achieve essentially the same effect, which is more nutritious food. Whether genetically modified or not, functional foods are cousins, in turn, of foods that have been enriched, fortified, and supplemented, a process that will be familiar to anyone who has read the label on a box of breakfast cereal.

In summary, while functional foods may be the most visible sign of the roles science and technology have played in food production, it can be seen that nutrition scientists have had a longstanding collaboration with industrialists in deciding what makes it to our dinner tables in the United States and abroad. Nutrification has taken on the form of whatever methods are available to improve food, whether fortification, enrichment, restoration, supplementation, or genetic modification. Industrialization has led food production from the family farm to global manufacturing plants and, increasingly, to the laboratory Petri dish, leading to novel food inventions. These trends will continue into the foreseeable future: Scientists will continue to make discoveries in nutrition and other sciences, while technologists and industrialists will continue to apply the resulting increased fund of knowledge and methods to improve the healthfulness and overall quality of the food supply by changing the nature of food itself.

In conclusion, science and technology will continue to evolve and improve the quality of food, especially its nutritional quality. However, the ability to modify foods genetically presents a whole new set of questions about what role such technologies should play, which leads us to another player governing the nature of food production in our modern world: the global consumer. The rapidly moving science of nutrification constantly creates new choices for consumers to make in selecting a diet. At this critical turning point in food production, with a plethora of foods on supermarket shelves and increasing numbers of GM foods on the horizon, what will consumers choose?

Food preparation and food consumption: convenience is key

Technological advances in food production have created an enormous market of traditional, natural, processed, and refined foods available to the consumer, as well as convenience, pre-fabricated, and entirely novel foods (1). Consumers must somehow assemble a diet from all of these options. Food meets many human needs, including those that are physiological, psychological, and sociological, and the types of foods selected for dietary consumption will impact not only health, but overall well-being. In general, consumers seek a balanced diet through extremes, wanting nutritious foods that are healthy, but desiring indulgent foods that provide hedonic pleasures, which are generally unhealthy. Furthermore, individuals are increasingly aware of moral and ethical dilemmas posed by food production and diet selection, such as environmental issues, animal rights, and world hunger. In essence, Americans in particular want it all: Taste, cost, and convenience are the predominant considerations in food purchases, but to these have been added the demands for foods that are healthful, pleasurable, fun, and even socially conscious (7, 8). The complex role food plays in our lives leads to a consumer conundrum: How can we resolve our food wants and desires to choose a diet that simultaneously meets taste, health, safety, convenience, cost, ethical and other needs, especially since these so often conflict? Food choices are, in fact, political acts that allow consumers to "vote with their forks" (9)—although it is doubtful that most Americans view eating in quite this way. Of course, food preferences conflict not only within an individual, but between individuals, and nations, and how these conflicts are resolved ultimately determine what is produced.

A complete discussion of consumer behavior as it relates to food

choice is a complex topic that is beyond the space of this paper. Nevertheless, we can summarize the cardinal factors as taste, cost, healthfulness—and convenience. In this section, I will focus on two aspects of consumer preference for convenience, first as it relates to food preparation and second as it relates to food consumption.

Food preparation practices have evolved alongside those related to production. Home-cooked meals on the family farm have been slowly replaced by fast and convenient food preparation techniques. Americans increasingly lack the time, energy, and knowledge to prepare food and few Americans cook from scratch. Indeed, cooking is becoming a lost art. Those who do cook at home tend to use 'speed-scratch' convenience tactics to decrease meal preparation time (7), taking advantage of products such as frozen foods, pre-packaged fresh foods (e.g., the familiar pre-washed salad in a bag) and the microwave oven. As at-home cooking and meal consumption have decreased, dining out at fast-food establishments and restaurants has risen (10). Yet even as Americans welcome the convenience of fast food at drive-thru windows, we demand more as we still bemoan the human element involved in the transaction and the time we had to wait in line. Recalling the instantaneous replication of food in *Star Trek*, consumer proclivity for faster and more convenient food production suggests that American consumers, at least, would be in favor of more technology in the future of food preparation, not less.

Alongside their desire to have food prepared more quickly and efficiently, and not by their own labor, consumers are increasingly demanding more nutritious choices, as they know more today about the relations between nutrition and health than ever before, a trend accelerated by the spread of information on the Internet. However, as noted above, this interest in healthfulness is balanced alongside desires for taste, cost, and convenient food preparation. Given that home-cooked meals are generally healthier than those at fast-food or restaurant establishments, along with the fact that Americans are less inclined to prepare their own food, a market has sprouted up for foods that are easily prepared as well as healthy. Cooking itself has been redefined, as consumers are able to increasingly achieve the healthfulness of at-home cooking while limiting the labor traditionally involved in cooking. And it would be of little surprise if some enterprising entrepreneur, somewhere, is working to create a tasty gourmet chocolate cake, in which the unhealthy ingredients are limited or eliminated and the nutritional qualities are enhanced, such as, for example, by imparting the nutritional abundance of broccoli and other vegetables. The overriding principle could best be stated as follows: Americans desire good health and nutrition with minimal change to their behavior and little compromise to taste and lifestyle. This desire leaves industrial roads open to create foods that people seek for their taste buds, and need for their health.

Is this, ultimately, what consumers are demanding? If so, would our perfectly nutritious chocolate birthday cake ever be something practical? The next section addresses these questions.

Technologic dreams and consumer demands: a technologic future of food?

In the first section of this essay, I focused on how industrialization changed food production and nutrification changed food itself. Together, the food and agriculture industries and nutrition scientists have created a more plentiful, more nutritious food supply. In the second section, I introduced the food consumer, who is driven by multiple factors when choosing a diet and is especially desirous of food that is both convenient to prepare and healthy. In this section, I will focus on genetically modified (GM) foods from the perspectives of both food producer and consumer, arguing that through genetic modification, a technologic future of food could fulfill consumer demands for health and convenience, applying planned technological innovation to more effectively meet our most basic human need.

I previously addressed consumer food demands, but have thus far not related these factors to the new technology of genetic modification. In light of the many factors that drive food selection, will consumers accept and choose GM foods? How does this new technology meet consumer needs—or doesn't it? From a technical standpoint, genetic technology is uniquely capable of addressing, in rapid fashion, the threefold desires for nutrition, taste, and convenience in what we consume, not to mention expediting the production of crops and increasing crop yields in enough quantity to feed often impoverished populations. But will these purported advantages be sufficient to override people's inherent concerns about such alterations?

Human health behavior is a complex topic, and one fraught with frustration at human resistance to change manifestly unhealthy behavior. People choose to eat unbalanced and unhealthy diets, smoke cigarettes, ride bicycles without helmets, and drive cars without seatbelts, to name just a few, despite known risks to health. Perceived health risks don't always deter poor health choices, and many individuals who take these risks end up treating rather than preventing disease. Indeed, in the battle over lifestyle and health, lifestyle usually wins.

The consumer desire for better health, in spite of the frequent reluctance to take simple steps in that direction, brings to light philosophical questions concerning what role individuals and government should play in caring for their health, given the costs to themselves and society; the answers to such questions depend very much on personal

and political beliefs. Nonetheless, consumer desires often create a unique opportunity for industrial innovation. As discussed, consumers prefer to obtain nutrition in ways that are least disruptive to their lifestyle and least compromising to their taste buds, and food technologists thrive on creating foods to meet these needs. As a result, there is an ever growing market of healthier (relatively speaking) junk and snack foods, including fat-free potato chips, low-fat snack cakes, and sugar-free soda, and an increasing array of functional foods, including nutritional bars, shakes, and snacks. There is, furthermore, the opportunity to gain better health from nutrified foods commonly consumed, such as fortified juices and supplemented cereals. These foods may allow the consumer to meet nutritional needs with minimal or no change to their behavior and enough choices to satisfy many palates.

Market solutions are not always palatable to nutrition scientists and public health professionals, however, raising the quintessential question: If most consumers are concerned with their health and many relations between nutrition, health, and disease are known, how best can this knowledge and its benefits be conferred so as to improve public health? What can be done to prevent unnecessary morbidity and mortality from nutrient-related diseases? As discussed, the opportunity to create healthier food products is enjoyed by both the food and agriculture industries and nutrition technologists. Yet, unlike many of the food products described above (e.g., low-fat items), which consumers may choose or reject, many nutrition alterations to foods are made in scientific and regulatory circles, without consumer consent or knowledge. As a result, people consume healthier food without having to change their behavior.

For example, flour contains B vitamins to prevent diseases such as beriberi and pellagra, cereals contain folic acid to prevent neural tube defects in babies, orange juice contains calcium to promote bone health, and the list goes on. The eradication of many vitamin deficiencies in the developed world is, in fact, due completely to nutrification of commonly eaten foodstuffs, not increased consumption of specific vitamin-rich foods. (Sadly, many vitamin deficiencies continue to plague the developing world and lead to considerable morbidity and mortality, despite the relatively inexpensive solution of fortification.) This is because nutrification of foods is the most rapidly applied, most flexible, and most socially acceptable form of public health intervention designed to improve the nutritional health of a population *without requiring nutrition education or behavior modification* [emphasis added] (1). Thus while many other types of interventions can be used to solve nutrition problems, these efforts are often undermined by the human factor: People are slow to learn, and even slower to change.

A well-known but still under-appreciated fact concerning nutrition education is that change in knowledge does not necessarily lead to change in behavior. The proverbial magic bullet of modern medicine is sought also in nutrition. This magic pellet, as it were, comes in various shapes and sizes, and takes the form of pill (vitamin supplement) or food (enriched, fortified, or functional). Increasingly, solutions to public health problems look to change food because promises of behavior change have been insufficient or inadequate. The advent of novel foodstuffs meets consumer desires for healthy foods with minimal behavior modification, and the extent to which foods are nutrified limits the health risks, costs, and ramifications of poor dietary choices. This is not to say that all foods should be promoted as "nutritious" simply because nutrients have been added: Fortifying food to combat a deficiency is not the same as supplementing food to add value to it where no clear nutritional deficiency exists (11). These authors further warn that "adding or subtracting...is a technologic quick-fix, where success depends on the assumption that scientists already know enough about human nutrition and its relation to health and longevity" (11, page 1303). In the future, however, it is likely that nutrition scientists *will* know enough about nutrition, health, and longevity to inform technologic changes; this is, after all, how science evolves. Indeed, this is why fortification with micronutrients required both the scientific understanding of vitamin biochemistry (specifically, the role of vitamins as essential enzyme cofactors in metabolism, cellular respiration, and tissue synthesis, for example) alongside, of course, the ability to synthesize these vitamins. Likewise, as technologies advance, methods of nutrifying food will improve. In time, functional foods will become more functional, containing more nutrition and yielding greater health benefits.

Yet even in the wake of functional foods, alongside more traditional fortified, enriched, and supplemented foods, consumers still need to choose among an ever-widening array of more or less nutritious foods to enjoy better health. In any case, the Genetic Revolution, eventually, will forever change the role of human choice in obtaining good nutrition, in part simply by introducing some distance between the choice itself and the production processes which introduce the choices, similar to the effect of traditional fortification. Genetic modification technology will lead to a new era of nutrification, in which nutrients are not simply added to foods, but in which the genetic composition of the food itself is altered to become more nutritious. For example, so-called "Golden Rice" plants have been modified to contain beta-carotene by inserting two genes from a daffodil (lending its "golden" hue) and one from a bacterium. This rice could potentially play a pivotal role in preventing Vitamin A Deficiency (VAD) among many millions of children in the

developing world, although the current levels at which the plant produces beta-carotene appear insufficient to provide the necessary vitamin A to prevent VAD (12) and may not be bioavailable to malnourished children (13), among other limitations (13).

The methods of biotechnology clearly demand considerable research and development input before they can be successfully applied toward the reduction or eradication of a nutritional disease, but the potential is great. And, as knowledge accumulates and methodologies are refined, genetic technology will likely make possible the dream for food technologists to create foods that impart through genetic modification the nutrients of vegetables into virtually any food. That is to say, one day we will move beyond simple gene modification, such as that used currently to create transgenic rice to produce a single provitamin, beta-carotene, to a place where nutrition scientists have a much greater understanding of the myriad nutritional benefits of vegetables, which can then be used to enhance a variety of foodstuffs—even chocolate cake—to produce multiple nutrients.

Analogous to crop modifications such as Golden Rice, a number of investigators have been seeking ways to nutritively or pharmaceutically enrich the milk from common dairy livestock. This was an expressed aim, for example, of Dr. Ian Wilmut's team at Scotland's Roslin Institute, whose work on transgenesis and nucleus transplantation led to the birth of Dolly, the famous cloned sheep. Milk from such livestock could be used to supply clotting factors missing in hemophilia, for example, or conveniently administered oral vaccines. There are many other potential applications of biotechnology to improve human health (14, 15, 16), which are beyond the scope of this paper. The remaining issue, then, in determining the future of food, is consumer choice. Will consumers choose GM foods?

New technologies always will and always should create new questions and spark new debates. Pasteurization and irradiation technologies, designed to improve the safety of the food supply, are debated still today. So, too, will genetic modification be debated for decades to come. The debate is strongest among scientists and politicians, global agribusiness executives and farmers, but, whereas scientific and political arguments are often abstract and theoretical, individual food producers are generally the only people who have hands-on experience working with transgenic seeds and crops. Therefore, farmers in particular have a unique voice in the discussion, as it is this group of traditional food producers who are most closely and physically tied to the land where food is produced. Farmers in the United States and abroad initially resisted planting transgenic seeds, but conversion of farmers to genetically modified crops has been steady for the last five years; this change in attitude and behavior is likely due to direct observation of how transgenic seeds have reduced herbicide costs and increased crop yields by reducing crop losses caused by pests (17). In fact, a variety of insect-resistant GM cotton has become so popular with farmers in several Asian countries that a black market has emerged for the seeds, which have not yet been approved for use (18).

Of course, consumers are also contemplating what role, if any, genetic engineering should play in the food supply. European consumers have rebelled against genetically modified "frankenfoods" (19), while consumers in the US do not seem to take as much issue (20). In fact, recent reports indicate that GM foods are already widespread and pervasive in the United States and around the world, and most consumers have already unwittingly consumed GM products (20). Regardless, the debate will continue. Eventually, a panoply of GM foods will appear on supermarket shelves and, likely, anti-GM sentiments and diversity of consumer preferences and values will give rise to even more choices in the form of non-GM foods.

The answer to whether or not consumers will choose GM foods, in particular, lies in the manner in which the individual consumer rectifies food politics with food preferences. Consumer preferences (at least, in some cases) are deeper than their taste buds, and include moral, political, ethical, and philosophical issues concerning contemporary food production. Moreover, these preferences will vary considerably between a manager in a first-world country, in which the availability of varied and plentiful food itself is not a concern, and a destitute laborer in a third-world nation, for whom small improvements in the nutritive value of a staple foodstock could substantially enhance his own health and that of his family. The introduction of GM foods into the marketplace has been and continues to be hotly debated and highly contentious because it forces both food scientist and food consumer to examine their basic values and beliefs about eating, an activity that is usually taken for granted. In the end, as long as taste, cost, and convenience remain as the main determinants of food choice, the selection or rejection of GM foods will ultimately depend on their function, that is, the consumer benefit they provide. In fact, research has shown that consumers were more likely to choose a GM food if it provided a tangible benefit to the consumer or environment (21, 22), even in the face of ethical uncertainty (22).

Whether modified genetically or created through some other, as yet undiscovered method, technology will likely be capable of one day creating the superfoods to which I alluded in the introduction. These techno-foods will meet consumer desire for better nutrition without behavior change and, if successfully employed, create improved nutritional health. Is this technologic vision truly the future of food? In this section I have discussed consumer demands, based upon what I see as dominant consumer behavior and desires. Yet there are obviously many different types of consumers with varying political, cultural, and ethical predilections who, if their voices are loud enough, will play a role in shaping the future of food. These differences create many alternative markets of food production and paint a contrasting picture of the future of food, next discussed.

Alternative futures and competing paradigms: an ecologic future of food?

Thus far this essay has presented the opinion that science and technology together create the future of food, while the consumer ultimately decides what to eat. The section on food preparation and consumption asserted that consumers were in fact demanding more convenient foods with more nutrition, and the previous section described how consumer proclivity (Americans in particular) for quick-fix solutions with minimal behavior change results in a growing market for functional foods—including those potentially made through genetic modification. A work such as this would be remiss if it did not, however, acknowledge that different visions of the future exist. Therefore, in this section, I describe briefly what I believe is the major alternative future, an ecologic future of food. I will first define the concept of sustainable agriculture and then discuss how sustainable and conventional agriculture arise from competing scientific paradigms. I finish the section by returning to the consumer, asking the final question as to whether sustainable agriculture can meet consumer demands.

As previously discussed, the production gains of industrial agriculture have come at a high cost, and it is now widely recognized that industrial agriculture is not sustainable because it is eroding natural resources faster than the environment can regenerate them and because it depends heavily on resources that are non-renewable (23). The concept of sustainable agriculture was developed to provide an earth-friendly alternative to conventional agriculture and is defined by the US Department of Agriculture as "an integrated system of plant and animal production practices having a site specific application that will over the long-term: (1) satisfy human food and fiber needs; (2) enhance environmental quality and the natural resource base upon which the agricultural economy depends; (3) make the most efficient use of non-renewable resources and integrate, where appropriate, natural biological cycles and controls; (4) sustain the economic viability of farm operations; and (5) enhance the quality of life for farmers and society as a whole" (24).

Sustainable agriculture embraces concepts of organic and local food production. Organic food, as defined by the National Organic Standards Board of the US Department of Agriculture, is produced "without using most conventional pesticides; fertilizers made with synthetic ingredients or sewage sludge; bioengineering; or ionizing radiation" (25). Not necessarily organic, local agriculture supports local farming efforts, thereby stimulating local communities; it also reduces the environmental costs of transporting food across long distances. Consumption of both organic and locally produced foods has increased substantially in the past decade and will likely continue. Though sustainable agriculture often employs organic methods, the concept has progressed in the past 10-15 years from a focus on low-input, organic farming of fruits and vegetables to a broader-scale approach adopted into mainstream animal and plant production (26). Nonetheless, the degree to which government and industry have employed sustainable methods is likely unsatisfying to the strongest believers in this approach.

In essence, the struggle between sustainable and conventional agriculture is not only a product of their methodological differences, but a consequence of their roots in fundamentally different scientific paradigms, a topic elegantly discussed by Lyson (27). In his article, he points out that industrial agriculture has its foundation in neoclassical economics, which is reductionist in nature and focuses on increasing efficiency and profitability by balancing land, labor, capital, and management. Conventional agriculture essentially focuses on increasing output and is increasingly incorporating biotechnologies to achieve this end. Contrarily, sustainable agriculture stems from a non-reductionist, ecologic paradigm that is based upon community centered problem solving and social collaboration, containing the economic, environmental, social, and community dimensions in its definition.

In practice, while there may be some overlap in these paradigms (e.g., a proponent of sustainable agriculture may or may not agree with traditional fortification of food to prevent a specific vitamin deficiency), the ecologic and technologic paradigms are, generally speaking, competing and produce different futures. An ecologic future, for example, promotes foods that are minimally processed ("whole") and/or fortified, which contrasts with a technologic future that promotes nutrification. The ecologic paradigm emphasizes nutrition education as the means for improved health rather than nutrification, therefore relying upon the consumer to choose a healthy diet. The strongest advocates of sustainable agriculture generally believe that conventional agriculture and the food industry have harmed, not helped, the food supply and are likely to be skeptical of the ability of technology, including genetic modification, to improve upon nature.

In summary, an ecologic future of food produces it in an environmentally sustainable way and provides an alternative future of food production to the technologic future of food previously described. But what about the role of the food consumer in shaping this future? Clearly sustainable agriculture meets a specific consumer demand for environmentally friendly food, but can it meet additional consumer needs of taste, cost, nutrition, and convenience, as previously discussed? Are the technologic and ecologic futures of food described mutually exclusive? Will one paradigm ultimately prevail? The concluding section of this essay answers these final questions.

Conclusion: the best of both worlds

This essay began by questioning whether a technologic future of food like that portrayed in *Star Trek* would represent a realistic future of our own. The paper wended its way through the history of food production and nutrition science and examined consumer trends in eating behavior, and in its final sections put forth two seemingly competing futures of food. At one end of the spectrum lies a technologic future with nutritionally perfect superfoods, maybe even synthesized by a food replicator. At the other is the bucolic picture of the family farm of yesteryear, perhaps a home-cooked meal waiting on the family dinner table. Like politics, views of the future are colored both by perspectives on the present and hopes for a better future; the conflict often arises from how individuals define "better." It is easy to see, then, how divisive the perceptions about the future of food can be and why the discussion about biotechnology continues unabated, given that it is just the latest example that allows us as a society to evaluate what role modern technologies should play in our lives and our future. Individuals—scientists, politicians, farmers, and consumers—have strong feelings about the means used to produce food and by whom their foodstuffs are produced. These opinions are important, and their reconciliation—or lack thereof—will determine the future of food. In this final section, I recapitulate the major points of the essay and summarize my own vision of the future of food.

American history demonstrates that we have been industrializing food production and modifying food to be more nutritious for the past two centuries, using the latest scientific methods and technologies to do so. There will be a day, probably far in the future, when the most pressing challenges of today regarding the nutritive quality of our food will be met, with the solution quietly incorporated into the perfectly nutrified food. This would effectively constitute the end of nutrition science as we know it today. The creation of these foods will likely be in stages, occurring as slow steps in the evolution of nutrition knowledge and food technology, but history suggests that the ultimate nutrification of food is inevitable. And if traditional fortification or genetic modification fails to deliver the perfect food, or if the implementation of biotechnology is killed in the current trade war between the US and European Union, another, as yet undiscovered technology will one day provide us with the futuristic superfoods familiar from science fiction. Many scientists and science fiction aficionados alike would agree with Stephen Hawking's note that "today's science fiction is often tomorrow's science fact" (28, page xiii).

What, then, of sustainable agriculture? Is such a future compatible with technologic superfoods if, for example, such foods were created through genetic modification or some other advanced method of nutrification? Science often progresses through paradigm shifts, or revolutions, in which one paradigm completely replaces another because of fundamental incompatibilities (29). Framing the alternative futures presented in this essay in their respective scientific paradigms is a useful way to explicate that different futures arise from distinct sets of theories, beliefs, and methods. Unlike scientific advancement, however, technology does not necessarily require an either/or approach. New technology may replace older technology, older technology that has proven effective may remain, or various technologies may be combined. Therefore, although biotechnology is rooted in the paradigm of conventional agriculture, given that it is by definition reductionist in nature, biotechnology need not necessarily be mutually exclusive with sustainable agriculture practices. Biotechnology may contribute to sustainable development, for example, through increasing crop yields per area of land or reducing the use of fertilizers or pesticides (30). Phillips (31) summarizes that proponents of biotechnology believe it will overcome food shortages and improve human and environmental health while opponents believe it will exacerbate food insecurity and endanger individuals and the planet. These contradictory beliefs are rooted as much in scientific interpretation of limited data as well as political beliefs about what role technology should play in food production, which is perhaps why Lyson (27) predicts that future food production will see two distinctly different food supplies, one produced through conventional means, including biotechnology, and the other through sustainable agriculture.

I believe that the future of food will likely contain elements of both futures, creating an eco-technological food supply that retains the best elements of each. Sustainable agriculture practices are critical in preserving our natural environment, but biotechnology or traditional nutrification methods may also provide environmental and health benefits. Moreover, both biotechnological and traditionally sustainable approaches will likely have to rely, in the near future, on renewable energy sources to a rapidly increasing degree. Environmental damage from pollutants, dwindling supplies, and severe geopolitical costs from overreliance on supplies from the Middle East are collaborating to

encourage a shift away from dependence on fossil fuels. Thus biotechnology will have to drive itself increasingly through wind farms, solar panels, and tidal sources out of sheer economic necessity—thus dovetailing with a sustainable agriculture model that already emphasizes these sources as part of its basic model. Nature and nurture, gene and environment, sex and gender: all are false dichotomies entrenched in competing paradigms and political agendas. Rigid adherence to a single paradigm or political belief closes doors to the possibility that two ostensible opposites may in fact be inter-related, even complementary. My vision of the future of food is eco-technological, containing the best of both worlds.

Nutrition science has discovered many relations between nutrition, health, and disease, but resistance to altering dietary behavior prevents us from enjoying better health through more nutritious choices alone, as indicated by the current epidemic of diet-related chronic diseases, including heart disease, diabetes, and obesity. Nutrition education should not be dismissed but cannot, for a variety of political reasons and aforementioned consumer preferences, compete with nutrification in delivering nutrients to consumers. The technology and science to improve the food supply exist as they never did before, but the existence of this knowledge does not in and of itself imply that it should be used. The use of new technologies must be fully and deeply considered and debated as science and industry move slowly, cautiously forward. The truth is that all revolutions radically change the scientific methods of discovery and the production of goods. New science is almost always perceived to be risky, even dangerous, and resistance to new technologies is inevitable, perhaps a salutary means of inspiring the debate that is essential to ensure a technology's judicious and productive application. Gradually, these technologies and their applications are accepted into society, almost always leading to a combination of expected benefits and unforeseen externalities that constitute the hallmark of progress.

As nutrition knowledge and food technology advance, both will be used to create more nutritious foods, and whether these are accepted or rejected by consumers depends on their ability to meet consumer needs. Food produced through sustainable agriculture can meet the environmental and ethical needs of some consumers and this market will continue to grow. The average consumer, however, is interested in eating for health, but not at the expense of taste, cost, and convenience; the degree to which foods produced through sustainable agriculture can meet the host of other consumer demands will in part determine how large a role they will play in the future. Convenience is key, and faster lives pave the way for faster, more convenient foods. Although *Star Trek's* energy-to-matter converting food replicator may be a while away, past and present practices of food production and consumption indicate that the notion of technologically produced superfoods is not a distant concept.

Those familiar with *Star Trek* will recall that, even in such a technologically advanced society, some people choose to cook, and this also will be true in our own future. In fact, there are individuals in *Star Trek's* cast of characters who maintain that replicated food does not compare to home-cooked meals, and we can see these sentiments mirrored in current attitudes comparing today's mainstream food supply with, for example, organic and whole foods produced through sustainable agriculture. Differences in politics and taste will likely ensure that both choices are available. Even so, I believe that the proportion of individuals possessing skill and interest in cooking will continue to decrease, and cooking will exist mainly as an art form among those who choose it as vocation or hobby. On a society-wide scale, therefore, it is doubtful that the consumers in the main will continue to follow the expectations of healthy eating as they are currently conceived—namely, the daily preparation of home-cooked meals from individual ingredients selected by the consumer, based on his or her personal knowledge of nutrition. There will likely be a sizable minority who still choose this path, however, if for no other reason than they trust their own nutritional instincts more than those of a faceless, distant agricultural corporation.

In conclusion, the future of food is created through the interplay of science, technology, and consumerism. What we eat is shaped not only by how food is produced, but the lifestyle surrounding food itself, including both preparation and consumption. The extent to which food can safely meet health needs, while minimizing demands to modify behavior, will provide the best index for its acceptability, and ultimately desirability, by consumers. Over time, it will become less important what methods were used to modify food and more important what benefits such foods hold for health and longevity. Given consumers' propensity for quick-fix solutions and resistance to changing their behavior, it is argued here that GM foods will play an increasingly important role in meeting that need, as will other functional, non-GM foods. The future will see more and more technologies dedicated to meeting these consumer needs, not only because it is a consumer's desire to eat chocolate cake as nutritious as broccoli; it is a food technologist's dream to produce it. Eventually, consumers will have their cake and eat it, too. Likewise, for those who prefer to keep their vegetables and desserts in their separate traditional courses, they may also do so—but this will not stop the scientific research and industrial innovation in the quest to create the perfect food.

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