Human Food Intake and Choice: Biological, Psychological and Cultural Perspectives

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Abstract

Human food choice is richly multidetermined. The fact that humans are food generalists means that most food choices are determined by experience, since it is not possible to identify on sensory grounds alone whether a potential food is nutritive or not, and whether it is toxic or not. There are some universal biological predispositions, including preferences for sweet and fat texture; avoidance of irritation and bitter and strong tastes; a tendency to be interested in and suspicious of new foods (the generalist's dilemma); and a set of genetic learning predispositions. Most of the determinants of human food choice fall in the domain of psychology (individual experience) and either direct or indirect cultural influences. I will briefly review what we know about the acquisition of food preferences, the way culture influences how we think about food, the psychological distinction between food and medicine, the conflict between eating for health and eating for pleasure, and the way moral issues are involved in food choice.

Introduction

The psychological study of humans and their foods is structured around two questions: What do we eat? And how much do we eat? Almost all of the research is about the controls on how much is eaten. This is probably because, at least in the modern Western world, particularly the United States, there is great concern about overweight and, at the same time, an increasing incidence of eating disorders. In respect to both questions, there are some universal aspects of human relations to foods, and there are many human-food relations that vary both within and between cultures. The universal aspects include the existence of meals and the liking for sweet tastes. Variations include the wide range of body shapes and amounts of food eaten, different ways of eating, different cuisines, and the wide range of differences in preferences within cultures.

Biological Determinants

Given the centrality of obtaining adequate nutrition for survival, significant biological, that is, innate, determinants are to be expected. In any vital biological system, we expect predetermined solutions when it is possible to anticipate the contingencies an organism will face in the world. In fact, there is good evidence, over a wide range of animals including humans, for a system that regulates energy intake. Although we still don't know how it works, we have a great deal of evidence that it exists. The most compelling evidence is that adult weight is surprisingly constant over months and years. In addition, explicit studies have shown that, under laboratory conditions, humans and rats will compensate for a dilution in caloric density by increasing volume intake. The energy regulation system is complemented by an innate ability to sense and prefer two characteristics associated in nature with high energy density. These two characteristics are sweet taste and fatty texture. So, at a minimum, we seem to be born with a system that indicates our energy deficit and with some clues about what things in the environment are likely to satisfy this deficit.

In the case of food choice, the role of predispositions is constrained, as a consequence of the fact that humans are generalist feeders. Generalists, such as humans, rats, and cockroaches, thrive because they consume a wide range of foods. They explore their environments frequently for potential foods. The pro-

blem they face is that it is difficult to predict, on sensory grounds, whether an encountered substance has nutrient value, and also whether it contains harmful micro-organisms or toxins. It is necessary to sample many of the encountered entities, to bioassay them, in order to determine their appropriateness as foods. As a result, although food selection is vital to survival, it is basically an open system for generalist animals. Experience has a powerful influence on food choice.

There are some innate predispositions in the domain of food choice, for humans, rats, and some other mammalian generalists. These include the following:

- A special, long-delay learning system allows the organism to learn to associate particular foods with their delayed negative or positive consequences.
- There is ambivalence to novel potential foods—an interest in new foods (neophilia) paired with cautiousness about sampling them (neophobia). I have called this the generalist's dilemma, and it plays out in many ways, including the cautious sampling of new foods, and the gathering of information from conspecifics about the properties of new foods.
- Certain taste biases correlate ecologically with the presence of nutrients. The two most prominent are the liking for sweet tastes and for fatty textures. On the other side is the avoidance of bitter tastes and oral irritation, and the avoidance of strong sour tastes. The bitter avoidance is clearly related to the bitter tastes of many natural toxins. However, neither the irritant avoidance nor the sour avoidance is clearly related to natural dangers to humans. Their presence is a puzzle. So far as I know, there are no innately positive or negative odors for humans; in particular, there is no convincing evidence that the odor of decay is innately aversive for humans.
- Salt receptors, though not tightly tied to a preference system, are clearly related to our nutritional needs, in particular the need for sodium.
- Corresponding to the nutrient-related receptor systems for sweet, bitter and salt, there are a few innate internal detector systems that report on levels of nutrients in the body. Hunger is generally tied to energy deficit, and thirst to water deficit. There is some evidence for a third system tied to sodium deficit.

Innate and Acquired; Universal and Variable

One of our aims in understanding human-food relationships is to identify those aspects that are universal for Homo sapiens, or perhaps all mammals, and those that vary substantially both within and between cultures. For example, the existence of some sort of regulation of energy intake, the liking for sweet, and the existence of meals constitute some of the universals. On the other hand, the balance between interest in new foods and fear of new foods (or preferences for particular culture-specific foods) would seem to be highly variable. As a general rule, it is probably the case that the universals are more likely to be genetically programmed or at least highly influenced by genetic predispositions, and that the highly variable manifestations are more likely to be influenced by experience. Of course, there are universal features of the environment that may induce universal acquisitions, and there is some evidence for a genetic basis to some individual differences in food choice, as for example, bitter taste sensitivity.

Food Intake: Biology, Psychology, Culture

One could reasonably expect a larger role for biological factors in monitoring energy intake than in monitoring choice. There is strong evidence for such regulation in non-human animals, such as rats, and the open-endedness consequent on the generalist food selection style would constrain the importance of genetic influences. The great majority of research on food, within psychology, is about the nature of the regulation of food intake, and its apparent failures in obesity and eating disorders. The more basic research has focused particularly on the discovery of the determinants of meal onset and meal termination, since the meal is the obvious “unit” of intake.

There are two sources of evidence that there is an energy regulatory system at work in humans. The first and more convincing is the fact that adults typically hold their weights within a narrow range without dieting or attending to their weight. The second is the laboratory studies that indicate that in highly refined conditions, usually with food of uniform caloric density, and in the absence of the usual contextual aspects of eating (such as its social setting), people do seem to regulate energy intake. For example, they will consume more of a more calorically dilute liquid or solid diet. Of course, the evidence for water regulation in humans is even

stronger. These results lead to two questions: 1. How does the energy regulation system work? 2. How does it operate in real, contextualized situations? The first question is the focus of virtually all of the attention in the field, even though the answer is far from clear. I will consider only the second question.

For a general discussion of the psychology of the meal, see Pliner and Rozin, 2000 (9). Common sense and a range of data suggest that how much a human consumes in a meal would be a function of

- degree of hunger, or energy deficit
- the amount of food available (as an upper limit, at least)
- the palatability of the food
- the variety of the food (10)
- the social setting (2)
- the appropriateness of the food for the occasion (19)
- cultural rules about appropriate amounts to eat and times to eat
- time and competing activities
- memory of recent eating (15)

Common sense suggests that in any given meal, perhaps the two major determinants are amount of food available and palatability. It is necessarily true that the amount offered puts an upper limit on the amount consumed. This is of considerable importance, but of little psychological interest. However, it is also true that considerable satisfaction derives from consuming a served portion, such that people are inclined to stop eating after consuming a portion, even if additional portions are easily available. Perhaps the major reason that the French are thinner than Americans has to do with portion size; whether it is restaurant portions, or size of commercially sold portions as in yogurt or soda, the standard is smaller in France (17). Amount available has another, more subtle effect. Brian Wansink (1996) (26) has shown that when people are asked to produce individual portions from a larger amount of food, beverage, or household product, they produce larger portions when the amount available to them is larger. Thus, for example, when asked to pour out cooking oil to prepare a fixed amount of chicken, they pour out more from a large oil bottle than from a smaller one. The presence of "giant-sized" food packages thus probably encourages larger individual portions.

The effect of palatability on food intake is powerful and is within the experience of every person. It really does not need to be documented.

Subtler, but also powerful, are cultural rules about the size and appropriateness of meals. A major determinant of whether someone will eat lunch, given that it is served, is whether it is lunchtime and whether the person remembers having already eaten or not eaten. We have recently shown (14) that amnesic people, who do not remember that they have just eaten, will accept and consume a second and even a third full lunch.

The Paradox of Regulation

The preponderance of evidence, along with common experience, strongly suggests that the principal determinants of how much is eaten in the meal lie outside the domain of the consumer's energy deficit. It has, in general, proved difficult to demonstrate quantitative regulation effects in humans in single meals. Yet, we know that there is an energy regulation system that operates in humans, based on both experimental data and on the fact of the very low variation of weight in adults from week to week or month to month. So energy deficit is monitoring our total intake and is, at the same time, a minor factor at individual meals, those occasions at which we accomplish almost all of our intake. The study of the regulation of food intake has focused almost entirely on the meal as an isolated unit; this appears to have been a serious error. In recent work on regulation of intake in children, Birch, Fisher and Grimm-Thomas (1996) (1) have shown that the evidence for regulation is much better if units of intake larger than a meal (such as a day) are employed.

The Biological Mismatch: Intake and Choice, and the Contrast Between Our Ancestral and Current Food Worlds

The vast differences between the environment in which humans in the developed world now live and the ancestral environment accounts for much of the inadequa-

cy of genetic predispositions to explain contemporary food-related behavior. Our biological predispositions evolved to deal with an environment very different from that of the contemporary developed world.

- In the ancestral environment food was relatively scarce; now it is abundant.
- In the ancestral environment, the natural variety of foods was rather limited; now we can get an enormous variety of foods, representing many of the world's cuisines, at our neighborhood supermarkets.
- The ancestral environment contained foods that were only modestly fatty or sweet; now we have foods with much higher fat content and higher sweetness, and we have created types of food that never existed, super-foods that appeal directly to our taste predispositions. Chocolate is a prime example of such a food.
- In the ancestral environment, one had to work, forage or hunt to find food; now it is virtually at our fingertips, as we order from a computer keyboard.
- In the ancestral environment, death typically occurred at what we now call middle adulthood; the cause was often acute injury or infectious diseases. Now we live much longer and tend to die of slow-onset, degenerative diseases (the epidemiological revolution).
- In the ancestral environment, information about food risks was minimal and based primarily on direct experiences with such outcomes as food poisoning; now, as a result of the epidemiological revolution, the links between our behaviors and their health consequences are much more subtle and long-term. As a result, we read or hear about behaviors or food choices that entail long-term health risks, risks that we cannot individually perceive.

Humans in the developed world are unprepared to deal with low risks

There is nothing in our evolutionary history that would select for an ability to evaluate and act upon very low risks. An increase in risk of 1:1 000 000 has absolutely no meaning in terms of a single human life, the unit that formed the basis for our evolution of self-protective behaviors. Yet, the epidemiological revolution has produced a situation in recent decades in which it is just such risks that have come to

our attention. The degenerative diseases that cause most deaths are subtly influenced by many variables, and it takes decades of careful accumulation of statistics to isolate the often large number of factors that exert small influences. Unfortunately, our system of education has not kept pace with our advances in the health field. As a result, we do not train people in school to understand risk, risk-benefit analysis, or even probability. We do not give people an idea of how epidemiology or science in general operates, including the idea that false theories can arise and last for a while. As a result, we face abstract, low-risk information, and are both biologically and culturally unprepared to deal with it. When people are confused or overwhelmed with information, they typically resort to processes that simplify the situation, and employ rules of thumb and biases. One such bias in the domain of nutrition is the division of foods dichotomously into "good" and "bad," independent of amount consumed. Fat, calories, salt and sugar are "bad." (But how long could we live without them?) Complex carbohydrates and fiber are "good". (At least, in this decade.) I offer here two examples of how this type of thinking expresses itself in a sample of Americans (13). About 31% of the sample agree with the statement that "A diet completely free of fat is healthier than a diet of the same number of calories with a pinch of fat added every day." About 45% disagreed with the statement that "One ounce of chocolate has fewer calories than 5 ounces of bread." A consequence of the mismatch between our ability to deal with the new world of health risks and the available information is frequent over- or under-reaction to reported food risks, with consequent removals from our diet of very pleasing foods that would reasonably form a modest part of our diet.

The Synergism and Antagonism of Biology and Culture in the Food World

Human food choice has surely been influenced by the predispositions we bring to this important task from our long history as precultural primates. Cultures have developed elaborate ways of selecting and preparing foods. These systems, which we can call cuisines, have no doubt been influenced by our innate dispositions, along with other cultural forces, including social needs and advances in technology. The result is that cuisines have aspects that can be related to our precultural life,

as has been shown by scholars such as Marvin Harris (1985) (5) and Solomon Katz (1982) (7). On the other hand, food has also taken on a life of its own in cultures, with many functions other than nutritional, such that in some cases our food predispositions have been ignored or even reversed. Leon Kass (1994) (6), in *The Hungry Soul*, provides an excellent portrait of how food has become part of culture, including manners and religion, throughout Western history. Here, I propose to review some cases that illustrate the varied fates of our food predispositions; most of these case histories appearead in an earlier analysis of biological and cultural influences on cuisine (11).

Sugar: Biology drives culture

The well documented innate sweet preference accounts directly for one important line of culinary evolution (8). Initially, this predisposition motivated the search for the sweet taste, particularly in fruits. The preference then motivated the cultivation of sweet foods, such as fruits. Attempts to maximize the desirable sweet taste led to the isolation of sugars and the cultivation of sugar beets and sugar cane. The search for sugar was a major driving force in the colonization of the Americas. Sugar then became available as an additive, to sweeten other foods and to mask less desirable tastes. Finally, with the surplus of calories, the preference for sweets became maladaptive in some contexts, and this led to the development of artificial sweeteners. While the coupling of sweet tastes with calories adaptively guided our ancestors, culture has now acted to separate the sweet taste from its caloric associations; we switched from using sweet as a signal for energy, to using sweet for its own sake.

Chocolate: Biology drives culture to produce a superfood

The sugar story involves the isolation and refinement of a natural entity. The chocolate story is more about the invention of a new food. The chocolate bean in its natural setting is an unlikely source of a super food. It is bitter, not sweet, not terribly aromatic, and does not exhibit the silky, fatty texture that is the hallmark of chocolate. Through an elaborate set of discoveries about the processing of chocolate, including roasting, combining it with sugar and milk, then stirring and heating to develop the smooth texture, chocolate emerged as a super food. It caters to two powerful human predispositions, for sweet tastes and for fatty textures (3)

and emits an aroma that is one of the most attractive in the world to humans. It has been shaped over the millennia, but especially in Europe in the last few hundred years, to optimize its taste, texture and aroma. Unlike the case of sugar, its outstanding sensory properties have yet to be uncoupled from its rich caloric endowment. Driven by our biology, humans have created a food that melts in the mouth; chocolate stands currently as the most craved food in the United States.

Chili Pepper: Culture Reverses a Biological Predisposition

The story of chili pepper is the opposite of the sugar and chocolate stories. Culture has promoted a product and a preference for it that opposes a biological predisposition. For whatever reason, oral irritation seems to be innately aversive. (It is not obvious what irritating substances in the real world pose a threat to humans.) However, culture has arranged a set of circumstances that cause the innate aversion to irritation to become a liking for this same sensory input (see 12 for a full review). We don't know how this happens; possible accounts include a certain type of social pressure or context, some type of opponent process that may be mediated by endorphin secretion, or the development of a desire to have negative experiences in contexts in which they are not actually threatening ("benign masochism"). All three of these mechanisms may be simultaneously operative; in all three cases, it is essential to encourage repeated sampling of an innately negative substance. These multiple experiences set the stage for the preference reversal. One of the roles of culture is to encourage multiple samplings of something that is initially not appealing, largely under the influence of social pressure. Across cultures, humans develop preferences for innately unpalatable substances such as black coffee, ginger, chili pepper, beer, and tobacco. One culture's favorite, innately unpalatable food may be strongly rejected by another. Chili pepper is a remarkably successful example; it is used and liked daily by literally billions of people.

Milk: Biology directs culture, but culture also directs biology

Prior to the evolution of culture, milk was a food limited to infant mammals. The availability of milk for adult consumption, consequent to the development of dairying traditions, has produced some remarkable changes in both culture and human biology. Milk is perhaps the best example in any domain of the interaction

of culture and biology. The basic facts and formulations of this phenomenon were developed by Frederick Simoons (22-23).

Milk sugar (lactose) constitutes a substantial part of the energy value of milk, and until the onset of dairying, was indigestible to all but young mammals. Lactase, the enzyme that breaks down the disaccharide, lactose, into two utilizable monosaccharides (glucose and galactose), is deprogrammed at about the time of normal weaning. This genetically based change makes adaptive sense, since it is inefficient to continue to manufacture an enzyme when its substrate is completely unavailable. Intake of substantial amounts of milk by lactose-intolerant adults causes fermentation of the lactose in the hindgut (where the products cannot be absorbed), with resultant cramps and diarrhea. The results are not fatal, but produce both discomfort and sharply reduced nutritional value of the milk. Once animal domestication occurred (at various points in human history), it afforded the possibility of dairying, and hence the availability of milk to human adults. This availability set the stage for adaptive changes in both culture and biology. We do not know how and when these changes occurred, but we do know the end point.

Culture accommodates biology. The cultural response to the discomfort produced by milk consumption and the compromise in its nutritive value has been to culture milk by digesting the lactose outside of the body, before ingestion. Cheese, yogurt, and a variety of other fermented milk products accomplish this end. Today, many principally lactose intolerant cultures, such as those in South Asia and the Mediterranean, accomplish a substantial milk product intake without consuming significant amounts of lactose. The commercial development of lactose-free milk (again, by culturing outside of the body) is the most recent step in this cultural evolution.

Biology accommodates culture. The availability of raw milk and its apparent attractiveness led to selection for genetic changes at the population level in some dairying groups, particularly those originating in Northern Europe. The genes at a single locus accomplish the deprogramming of lactase production. An allele that blocks this deprogramming exists, in low frequency, in lactose intolerant cultures. In some way, the consumption of raw milk established a selection pressure for this

allele, the result being high frequencies of this allele, and hence lactose tolerance, among Northern Europeans and a few other groups. A cultural change produced selection pressures, and resulted in a change in the human gene pool, for a minority of humans. (see 11 for a more detailed discussion on cultural and biological aspects of human relationships to milk).

Meat: The cultural fate of a biological super food.

According to many accounts, the shift from a predominantly plant diet to a diet with a substantial amount of meat was a major feature of human evolution. Meat has an extraordinary nutritional advantage over other foods; because human nutritional requirements are similar to those of other animals, the meat of other animals is very likely to be a nutritionally complete food. Carnivores are not particularly susceptible to nutritional deficiencies (unless their prey is consistently deficient). Nutritional balance plus high energy value makes meat an ideal food. The two shortcomings of meat as a food were its greater potential for microbial contamination and the fact that it is generally harder to obtain than plant foods. In light of the great advantages of meat, it is not surprising that humans find it generally tasty and appealing, and that it is generally the favored food of humans. When it is in short supply, it is traditionally made available selectively to the most powerful members of a group. Domestication made meat much more abundant, easier to obtain, and cheaper. However, throughout most of history, meat has remained an expensive food.

There is a long history, certainly over thousands of years, of ambivalence to consuming animals. Vegetarian traditions are associated with Buddhism and other belief systems, and were present in ancient Greece. Furthermore, across cultures, meat has been the focus of the majority of taboos (21-25). This seems to derive in large part from complex belief systems that teach the sacredness of life, and from our similarity to many of the available edible animals. Meat seems to be an almost perfect example of an ambivalent object. In the later 20th century, in the developed world, two sets of additional culture-based concerns have added to the reluctance to consume meat. One is a concern for the world and its future, in that meat is an inefficient means to provide energy to humans, in comparison to plants. The second is the rising concern for degenerative diseases, and in particular the puta-

tive contribution of animal fats to cardiovascular disease. Thus, for ecological/moral, health, and animal-rights-related moral reasons, there is an increase in partial or full vegetarianism in some parts of the developed world. Cultural concerns have compromised the attractiveness of meat, biologically suited to traditional humans as a super food.

The Effects of Abundance and Variety of Food on Two Contemporary Cultures

In the developed world, particularly in the United States, efforts to improve nutrition have brought attention to concerns about consuming excessive amounts of food, or non-optimal types of foods. The abundance of foods and the availability of super foods have conspired to increase intake and change the nutritional profile of what we eat, while the development of the cultural value of thinness and the explosion of information about long-term risks of particular diets have caused grave concerns. The result has been widespread dieting and eating disorders, especially in middle- and upper-class women. Ironically, at the same time there has been an increase in obesity. In short, in the United States, food is an ambivalent entity for many, especially women.

Food Ambivalence in Some Americans

My students Rebecca Bauer and Dana Catanese and I have documented food ambivalence using American college students from six college campuses around the United States (Pennsylvania State University, University of Pennsylvania, and the Universities of Wisconsin, Texas, Arizona, and California (14). For example, averaging across the six schools, 71% of females agree with the statement, "my thighs are too fat." Only 11% of males answer affirmatively to this same question. In response to a question asking about being "concerned about being overweight", 57% of females answer "often" or "almost always", in contrast to 21% of males. Chocolate is, in many ways, a focus for ambivalence, on account of its highly desirable sensory properties and high caloric value. Many American women show overt ambivalence to chocolate; for example, about 25% of American females, when asked to offer the three first words that come to mind in thinking about cho-

colate, suggest both positive words (e.g., delicious) and negative words (e.g., fat) (18). Perhaps the most striking symptom of this is the fact that our six-campus survey revealed that 14% of females respond "true" to "I am embarrassed to buy a chocolate bar in the store."

Food as Pleasure and Poison: A Different Balance in the USA and France

France and the United States, as relatively affluent Western countries, are similar in many ways. Each has a long history of concern with fashion and body shape. Yet, with respect to attitudes to food, these countries appear to be quite different (see 24 for a detailed historical treatment). On the surface, at least, the French seem to have a more relaxed attitude to food. At the same time, with about the same life expectancy as Americans, and substantially lower cardiovascular disease, they seem to have their cake and eat it, too. They seem to have a somewhat higher fat level in their diet (4), but eat substantially less than Americans, and hence, by Newton's laws, are thinner. The lower food intake seems, in part, to result from smaller food portions, but also from a tradition of moderation (24). Eating is viewed more as an unconflicted pleasure in France, not typically opposed by health concerns. The French focus is on the experience of eating, and the American focus is more on the consequences of eating.

Claude Fischler and other colleagues have worked with me to document some of the fundamental differences between the French and the Americans (16). A survey given to French and American college students and a sample of adults revealed that the French consume less of foods that are adjusted to be lower in fat, and value eating as a pleasure (thus preferring a gourmet hotel with average accommodations to a luxury hotel with average food, in comparison to Americans). They tend to think of food more as an experience; so, for example, they associate "cream" more with "whipped" than with "unhealthy", in contrast to Americans. And although the French are less inclined to modify their culinary experience for health concerns, they consider themselves healthier eaters than Americans. It is hard to resist the conclusion that, in the domain of food, the French have created a more pleasant and relaxed pattern of interactions, without paying a health price. Food used to be fun for most people in the world; it is perhaps the Americans, or

more accurately, substantial numbers of upper-middle class Americans, who are anomalous and have compromised one of the great pleasures of life.

The French solution is represented in a fanciful extension of the famous French motto:

"Liberté, égalité, fraternité, manger".

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Biography
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Paul Rozin was born in Brooklyn, New York. He attended the University of Chicago, under the Hutchin's General Education System, and received a PhD in both Biology and Psychology from Harvard, in 1961. His thesis research was sponsored by Jean Mayer. He spent two subsequent years working with Jean Mayer as an NIH postdoctoral fellow at the Harvard School of Public Health. Since then, he has been a member of the Psychology Department at the University of Pennsylvania, where he is currently the Edmund J. and Louise W. Kahn Professor for Faculty Excellence, in the Department of Psychology. Past scholarly interests include food selection in animals, the acquisition of fundamental reading skills, and the neuropsychology of amnesia. Over the last 20 years, the major focus of his research has been human food choice, considered from biological, psychological and anthropological perspectives. During this period, he has studied the psychological significance of flavorings placed on foods in different cuisines, the cultural evolution of cuisine, the development of food aversions, the development of food preferences, family influences in preference development, body image, the acquisition of liking for chili pepper, the weaning process, addiction, chocolate craving and the experience of flavor. Most recently, major foci of attention have been the emotion of disgust, the entry of food issues (e.g., meat, fat) into the moral domain in modern American culture, and the growing American tendency to worry more about food and enjoy it less. Much of the recent research has been carried out in France, Japan and India, as well as the United States.

Paul Rozin is a member of the Society of Experimental Psychologists, and has twice been a fellow at the Center for Advanced Study in the Behavioral Sciences. He was an editor of the journal Appetite for ten years.

Paul Rozin is the psychology advisor for the publisher, W. W. Norton. He has been teaching introductory psychology for about 30 years, has chaired the psychology department at the University of Pennsylvania, directed the university-wide undergraduate honors program, and is now involved in developing policies and teaching materials to guarantee a minimal competence in quantitative skills and critical thinking in University of Pennsylvania undergraduates. He is also co-director of the new Solomon Asch Center for the Study of Ethnopolitical Conflict, at the University of Pennsylvania.