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Thank you for inviting me to speak this morning. Just for the record, I am 5' 10" tall and weigh 175 pounds. When I am home, I eat a light breakfast of juice, milk, and cereal, a bagel and water lunch, and then a healthy dinner prepared by my wife, who is an excellent and knowledgeable cook and concerned about my health. I walk to and from the Metro stops near my apartment and my workplace, and frequently walk to meetings in the Washington area. When I am traveling, this careful regimen goes out the window. Fortunately, my health has held up to the chaotic life of Washington so far, but I owe that to my wife and my genes more than to any special knowledge I have of what is good for me.

Part of the stress of modern life is the growing awareness of the risks we take each day. Some risks are obvious, like driving, sports, and childbirth. Others are less obvious. The risks of alcohol consumption are well known, but socially acceptable. Likewise the risks of smoking, but that is growing less acceptable. These risky acts are more or less well defined and totally discretionary. We know when we are doing them, and we can choose not to, or at least choose to seek help in stopping if we feel we must.

Eating, however, is not discretionary. And eating well, for most Americans, does not appear to be well defined. As we speak, the U.S. Department of Agriculture is updating its Food Guide Pyramid. According to a recent press report, more than 600 people and organizations wrote in with suggestions on how it should be changed. Most seem to think a change is needed, and crafting a response is one of those thankless tasks we ask Federal Agencies to perform. Probably no one will be satisfied with the final result.

The Food Guide Pyramid is to many Americans what nutrition is all about. It serves at least three purposes: to advertise the importance of nutrition, to convey current knowledge about a healthy diet, and to encourage good nutrition behavior. This reminds me of a poster I saw recently with three steps to stop smoking: 1) Notice this ad, 2. Read it., 3) Call an 800 number. These three dimensions of *awareness*, *knowledge*, and *behavior* are components of many issues for which government is expected to provide stewardship of resources it does not control. I am speaking here of resources such as our environment, the health and education of our people, and the protection of their assets. In each case preserving and enhancing the value of the resource depends on responsible actions by informed individuals. Government's role is to determine good strategies through objective studies, including scientific research, to make the public aware of them, and then to take appropriate actions to encourage behavior that optimizes the value of each resource.

It is no accident that government's role in these areas is controversial. Environment, health, education, and security are complex multi-dimensional issues whose many variables are

not easily controlled and therefore awkward for scientific investigation. Rarely does science provide an unambiguous path to improve or protect any of these basic societal resources. It cannot even produce consensus on a Food Guide Pyramid.

Nutrition is part of health – a major part. We understand today that proper nutrition helps our bodies defend and recover from the various assaults of daily life: disease, physical and mental stress, and accidents of all kinds. It also has important impacts on our mental health and our capacity for work and the pursuit of happiness to which all people are entitled. So it is distressing, especially for us to whom some measure of responsibility for public health is entrusted, when indicators of poor nutrition are high and rising.

You are closer to these statistics than I am, but it is worth stating here that nearly two-thirds of all Americans are overweight, and more than 30% are medically obese. About 15% of children aged 6 to 19 are overweight – twice the rate of twenty years ago. A recent study shows that poor diet and physical inactivity are about to surpass tobacco as the leading cause of preventable death in America. About 400,000 deaths and $100 billion in health care costs are associated with heart disease, diabetes, cancer, and other serious chronic diseases related to poor nutrition and lack of exercise.

These figures are enough to justify a major national effort to improve nutrition – the international statistics, as you know, are even worse. In a few moments I will list some of the governmental initiatives and expenditures related to such an effort, but first let me say a few words about science.

Nutrition has special significance for a physicist because it refers to the system by which every bodily process receives the energy it needs to function. Energy to a physicist is what money is to an economist. To most people, however, the current revolution in biology is strongly associated with the storage and transmission not of energy, but of *information*. The bio-information revolution began fifty years ago with the Crick-Watson discovery of DNA structure which launched the genomic era. The genomics revolution has been enhanced by the simultaneous growth of technology for storing and transmitting information of a higher order in physical structures based on silicon, magnetic and optical materials, which is causing revolutionary changes in the way we work and live our daily lives, and makes it possible to manage the huge amount of information in the genome.

This preoccupation with genomics and information has somewhat overshadowed the equally fascinating and important system for storing and transmitting energy throughout our bodies. I wish there were a better term than "metabolomics" to describe this system. I personally like the term "bioenergetics" for the corresponding field of study. It deserves a catchy title because the story of energy in plants and animals is as deep and significant and multifaceted as that of information.

Who can fail to be impressed by the fact that the cell's energy plant, the mitochondria, are remnants of ancient bacterial forms absorbed into our host cells, complete with their own mitochondrial DNA and proteome, inherited (almost) entirely from the mother's side? Or that the production of ATP which is the primary function of the mitochondria is a double-edged

sword, providing both beneficial energy and appalling destructiveness within the cells? British researcher Guy Brown, whose award-winning book "*The Energy of Life*" is the best introduction to this subject I know for lay readers, calls mitochondria "the monsters within." When I speak with groups concerned about the health impacts of toxic chemicals or radiological materials in the environment, I try to alert them to the hazardous waste generated by our own metabolism. The mitochondria leak electrons and protons into the cellular environment, creating free radicals and uncontrolled oxidation that wreak havoc with cellular machinery and nuclear DNA. Our remote ancestors had to evolve repair mechanisms as they absorbed and exploited the mitochondria, a billion years ago, so they could survive the very processes that make life possible for plants and animals. Our health depends on which side is winning in the constant war between self destruction and self repair.

The story of mitochondria and energy links more directly to issues of daily life than the parallel story of DNA and information. The energy processes are sensitive to what we eat and responsible for how we feel. They are directly related to the regulation of temperature, weight, and general health. Only energy, among the many attributes we can measure, has the scope and power to illuminate every aspect of nutrition. But to use the energy concept, we have to know many other things about the human body and its physical and social environment.

Science attempts to isolate the minimum number of variables needed to specify a system. Physicists have it easy: we can talk about nuclei without knowing about atoms, and atoms with little reference to nuclei or molecules. We break nature down into self contained systems with weak links to an environment that can be described by just a few parameters like temperature and pressure. Set the environmental parameters, and develop a predictive model for the behavior of the system. The systems that are studied by nutrition science are not so simple. At the cellular level are the mitochondria and ATP plus the soup of nutrients and waste products. In the next layer outward lie the systems of transport for fuel and exhaust. Then there are the ways that energy is used – the functions of the parent cell. Within the individual, the variables of nutrition must include mental as well as physical conditions. But the variables of nutrition go beyond the human body. Nutrition extends to issues of the supply and attractiveness of food, to economic factors, to social attitudes and lifestyles. Of the health sciences, nutrition is one of the most interdisciplinary.

A conceptual framework for the nutrition sciences of the necessary broad scope was proposed more than a decade ago by M.N. Kazarinoff and J.-P. Habicht, (J. Nutr. 121: 1498-1499, 1991) and I heartily endorse this broad and systematic approach to the field.

Nutrition is the ultimate interdisciplinary health science. The Long Range Planning Committee of your organization called it *A Reservoir for Integrative Science* in a 2001 paper. The paper cites the example of "the integration of our understanding of the molecular signals that control appetite and energy expenditure with the metabolic phenomena underlying lipogenesis and with the behavioral modulators of eating, ending with the development of a range of therapies for obese individuals." – that is to say, everything from appetite to exercise. The Committee urged that "ASNS must sell the concept that the integration of molecular, metabolic and behavioral events using a nutrition perspective is the next hot area once the genome has been

sequenced. We must make it clear that the complexity of our grant proposals is a virtue and not a weakness." (S.H. Zeisel, et al. ASNS J. Nutr. 131: 1319-1321, 2001)

I think it is a mistake to argue that this kind of integration is just the "next hot area" after genomics. Nutrition is not just another step in the march of scientific progress, it is an *endless* endeavor that must integrate present and future advances in many fields. The complex system that is the object of nutrition science is neither steady nor stable. Someday perhaps we will completely understand the mechanisms of infectious diseases and learn how to deal with them. That completeness is unlikely ever to be achieved with nutrition because of the huge variability of the external factors upon which nutrition depends. Few realms of science must face up to the real impact of cultural behavior in quite the way nutrition science must. What tastes good, what is available, what is easy to prepare, what others are eating or not eating, are questions that must be understood and answered in a systematic way as part of the science of nutrition. I was struck by the opening lines of a 1999 paper by James Blaylock and colleagues at the Economic Research Service at the US Department of Agriculture on "*Economics, Food Choices, and Nutrition*" (Food Policy 24: 269-286, 1999) – "Consumers make dietary decisions based on economic, physiologic, sociologic and even spiritual considerations, with hardly a nod to societal implications. ... Eating in a developed country such as the United States becomes a social and family event, an act of pleasure, that goes far beyond the ingestion of the necessary nutrients to sustain life. People eat for *both* pleasure and as a biological necessity. This must be remembered if we are to understand the complex world of food choices, dietary quality, and change." This cultural significance of eating is of course not restricted to developed countries

From the perspective of public policy, understanding the body as a black box that responds to certain inputs with certain outputs is not enough. If the field of nutrition is not defined to include societal and cultural issues, it will indeed become just "another step," and will eventually be superseded by some new field that does integrate the challenges of human behavior.

This brings us back to the realm of governmental action, in which nutritional aspects of public health have been current for a long time. The Departments of Agriculture and Health and Human Services have been publishing "*Dietary Guidelines for Americans*" since 1980, and are on schedule to issue the next edition, the sixth, in mid January 2005. The development of the Guidelines is coordinated by the HHS Office of Disease Prevention and Health Promotion, and the USDA Center for Nutrition Policy and Promotion, and the Agricultural Research Service.

The US Department of Agriculture will spend more than $670 million dollars this year in programs devoted to nutrition education and research, most of it (80%) on Nutrition Education and Promotion Programs, with the next largest share (9%) going to Nutrition Requirements. About 1% goes for Economic, Social and Behavioral Factors Affecting Diet.

The Guidelines program is a broadly focused, generic nutrition initiative. A similarly broad initiative in this Administration is HealthierUS, launched a year ago last Tuesday by HHS Secretary Tommy Thompson at a "Health Summit" in Baltimore. Nutrition is one of four themes of this initiative, along with physical fitness, prevention, and lifestyle risk reduction. In my view physical fitness is strongly linked to nutrition by the energy theme. President Bush is a highly

visible role model for healthy lifestyle choices, and has strongly supported HealthierUS in particular, and federal health programs in general.

I am sure everyone here is aware that President Bush followed through on his commitment to complete the doubling of the research budget for the National Institutes of Health in five years, ending in Fiscal Year 2003. Since then, NIH has enjoyed larger increases than the averages for other science agencies. The NIH budget currently consumes about half of all U.S. funds for non-defense research and development. Not all funds related to nutrition are tracked at HHS, but I can tell you that for FY2005 the President has requested funds for obesity research and targeted prevention amounting to $612 million, up 25% from FY2004. Of this, $170 million would go to prevention programs funded through the Centers for Disease Control, and $440 million would go for NIH research. "This includes a targeted, $22 million, trans-NIH initiative that will seek to better understand the neurobiological, genetic, behavioral, and environmental basis of obesity and its co-morbid conditions; improve strategies for maintaining healthy weight in adults and children, particularly in primary care, school, and workplace settings; and develop new therapeutic anti-obesity modalities to complement lifestyle interventions."

These are substantial investments, and they will continue to grow in the future because the symptoms of nutritional disorders are likely to persist. As I explained earlier, I think nutrition problems are a permanent fixture of our society. They reflect changing lifestyles associated with the continually evolving technological basis of the economy. Anthropologists give us insights into the lifestyle changes that occurred when agriculture emerged in prehistoric times. Even greater changes occurred during the industrial revolution and the mechanization of agriculture, as mass occupations changed and became less dependent on manual labor. That trend is accelerating with advances in information technology, robotics, miniaturization, and the dramatic re-engineering of all manufacturing processes.

These changes imply that the physical exercise humans need to maintain good health no longer comes automatically from the work they perform to sustain their livelihood. It is conceivable that in the future essentially all physical exercise will be "artificial" for a large fraction of the world population. That is, exercise will become purely discretionary and not motivated by any short term necessity. This presents an enormous challenge to nutrition science. It is not simply a question of understanding how our bodies consume nutrients and produce energy. We need to invent and motivate entirely new strategies for maintaining health.

I have tried to convey my sense of the excitement and the opportunities in the inherently interdisciplinary science of nutrition, and of its importance in helping humans adjust to their inexorably evolving environment. The American Society for Nutritional Science has an important role to play in maintaining a healthy population in the face of inexorable changes in economies and environments throughout the world.

Thank you for inviting me to speak to these issues this morning.