SCIENCE, PRECAUTION AND FOOD SAFETY:

HOW CAN WE DO BETTER?

A Discussion Paper for the US Codex Delegation

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Introduction and Background

An international debate is under way, in various committees of the Codex Alimentarius Commission, on the use of precaution in making food safety decisions. The debate about precaution is part of an important larger discussion of what Codex calls "Risk Analysis," the principles and concepts that define its approach to decision-making. Codex has been working for a decade to spell out these principles, to standardize its decision-making as much as possible and to make the basis for decisions more transparent.[1] Within the Risk Analysis framework, there is a sub-discussion on "the role of science and other legitimate factors" in decisions. The basic principles on which Codex operates recognize that both science and "other factors relevant to the protection of consumers' health and the promotion of fair trade in foods" are a legitimate basis for safety decisions. But to date neither "science" nor "other factors" have been precisely defined. Efforts to do so are ongoing at the Codex Committee on General Principles (CCGP), and several Codex committees that set food safety standards are working with CCGP to define how science and other factors are applied in their own work.

Within that broad discussion, the role of *precaution* as a legitimate basis for food safety decisions has now begun to be debated. So far, this debate has been relatively shallow. Some governments have asserted that the so-called "Precautionary Principle," developed for environmental policymaking, can and should be applied in making some food safety decisions. Other governments (notably the U.S.) have argued that the "Precautionary Principle" is vaguely defined, that "precaution" can be misused as a disguised barrier to trade, that food safety decisions based on Risk Analysis are inherently precautionary in nature, and that no additional, separate precautionary "principle" is needed.

While the initial stage of the debate has been somewhat polarized, there is, nevertheless, a substantial agreement that precaution is a legitimate element in food safety decisions. Where progress is needed, it seems, is on better defining where and how precautionary judgments *are now used* in food safety decisions, and how precaution *should legitimately be used*. By clarifying these issues, Codex should improve the quality and transparency of

its own decisions, and could provide a reference point to help make similar decisions by national governments sounder, more consistent and more transparent as well. These improvements, in turn, should help reduce the risk of unwanted outcomes—the misuse of precautionary decisions as disguised barriers to trade, on one hand, and unjustified trade challenges against legitimately precautionary food safety decisions, on the other. To help avoid costly disputes, both national governments and the international community need better yardsticks than they have now to measure precautionary action, so they can agree when it is legitimate and done right, and when it is not.

This paper will examine the ways precaution is used now in food safety decisions, and try to develop some principles about how to make better use of precautionary approaches. While precaution is an inherent element of many currently accepted approaches to food safety, some approaches are much more precautionary than others. The predominant paradigm now in use for most decisions seeks to base decisions as much as possible on rather narrowly defined risk assessments; explicit rules calling for precautionary actions are rare. But Risk Analysis is certainly compatible with making precautionary choices, and precaution is part of most food safety decisions. As we will see, precaution is not an alternative to risk assessment, or antagonistic to risk assessment; both are essential, and they are interrelated in complex, inseparable ways.

A goal of this paper is to help develop a conceptual framework, an intellectually rigorous vocabulary for thinking and talking about the use of precaution in food safety descisions. Such a framework is needed both as the U.S. develops its own positions on this subject, and to help shape the ongoing international discussions.

What is "Precaution" in a Food Safety Context?

At the simplest and most general level, a precautionary approach means taking action to protect health or the environment, before there is conclusive scientific evidence that harm is occurring. This concept, whether it is called a "principle" or not, has been expressed many times in many different contexts, mostly associated with environmental protection.

The familiar definitions were not written with food safety in mind, and they are too broad and general to guide officials making day-to-day decisions.

At the same time, some U.S. food safety laws take a precautionary stance toward human health risks. A common standard for what "safe" means, in U.S. laws, is "reasonable certainty of no harm" (generally, to public health). When a requirement for "reasonable certainty of no harm" is coupled with a prohibition on using a substance unless that safety standard is met, the law is inherently precautionary. The U.S. law on food additives, for example, is precautionary in this way.

In other cases, the same safety standard can be applied, in a non-precautionary way. For example, pesticide residues and environmental contaminants are present in foods because they are dispersed in the environment. When safety limits are set for such contaminants, the goal typically is also to ensure "reasonable certainty of no harm." But when current uses create vested economic interests in the status quo, risk assessments may readily be biased toward declaring current practice "safe." Quite often, in cases of this nature, the standard applied in practice is not "reasonable certainty of no harm," but rather "lack of certainty of harm," which is not the same thing at all. (One Swedish official at a recent Codex meeting humorously called this the "Bodies-in-the-Street Principle," in contrast to the "Precautionary Principle."[2])

Most U.S. food safety laws are less precautionary in their approach. Until recently, for example, U.S. law governing pesticide uses required the government to balance public health risk and benefits to agriculture in setting safety limits for residues in foods. Uses valued by agriculture were permissible unless they were found to pose an "unreasonable risk" to public health. In practice, this standard required convincing proof of substantial risk to justify risk-reducing steps; it was the "Bodies-in-the-Street Principle" made law. Past application of this approach in laws on the use of most chemicals allowed dispersal of many of those chemicals in the environment, with the result that some are now serious food contaminants. In general, laws governing the use of foodstuffs other than additives,

and the provisions that apply to microbial risks in foods, require the government to make a positive funding of hazard in order to block the sale of a food.

"Reasonable certainty of no harm" ordinarily means, "based on the available scientific evidence." Determining "reasonable certainty of no harm" requires both scientific and non-scientific judgments. ("No harm" is a question for science, but what is "reasonable certainty" is a subjective decision that scientists alone should not make.) "Reasonable certainty" is not an absolute guarantee of safety, and "no harm" does not mean "zero risk." In most cases, neither zero risk nor absolute certainty are attainable, or at least not without costs society may not be willing to bear. The standard does mean, using the best science available to be as certain as we can reasonably expect to be that foods, additives, ingredients and production methods will not harm public health.

Over the last two decades, the phrase "reasonable certainty of no harm" has taken on a new and not entirely welcome nuance. Today, the term usually can be taken to mean, "Reasonable certainty that the risks are no greater than a socially acceptable level." The determination that risks fall within the "acceptable" range is based on quantitative risk assessment, but the determination of what is an "acceptable risk" (e.g., a 1-per-million added lifetime risk of cancer in an exposed population) is obviously a value judgment.

Many thoughtful citizens are not fully at ease with using risk assessment to determine "reasonable certainty of no harm." There are several good reasons for this discomfort. One is that risk assessments can be and frequently have been be manipulated to obtain desired results. Also, quantitative risk assessment ordinarily, almost by definition, can be done only for comparatively well-understood risks on which good data exist. Less adequately understood risks may be heavily discounted, even if they are possibly more serious than the risks for which we have good data.

Experience has also shown that risk assessors frequently tend to equate lack of proof of harm with proof of lack of harm. Despite the obvious illogic of that attitude, and often, despite the precautionary bias of the food safety laws, the practical reality has too often been that the government must prove harm in order to curtail economic activity, rather

than that those who engage in risk-generating activities must convincingly show safety. In practice, the "Bodies-in-the-Street Principle" is alive and well and the basis for many decisions. The use of "risk assessment" to justify such decisions has bred deep distrust of risk assessment as an objective tool.

Another reason some participants distrust the current risk analysis paradigm is that not everyone agrees with the widely used definitions of "acceptable risk." We all recognize that drawing lines at, say, one–in-a-million, and declaring that risks that can be shown by risk assessment to be smaller than that meet the legal standard of "reasonable certainty of no harm," is a political exercise, not a scientific one. Many in the consumer sector, at least, believe that the public as a whole was not asked to ratify this definition of socially acceptable risk, especially not with respect to food safety, which touches on deeply held, very personal concerns. If asked what "acceptable risk" means, most consumers would probably choose a standard like "As low can reasonably be achieved," or more simply, "If a risk can be avoided at a reasonable cost, it should be avoided." They would not see that choice as irrationally risk-averse; they would view it as common sense.

Put this way, the average citizen's intuitive definition of "acceptable risk" seems more inherently precautionary than the way the "reasonable certainty of no harm" standard, coupled with risk assessment, has often been used, in practice.

From this brief discussion, it is clear that different food safety laws and regulatory practices in the U.S. (and abroad) use precautionary approaches in some cases, and less precautionary approaches in others. Some laws allow government to prevent harm in a strict sense, by prohibiting new activities unless they are convincingly shown to be safe. Most of our food safety and environmental laws give government more limited authority to regulate risk, by setting standards to keep the risks of permitted activities within the socially "acceptable" range. Some particularly hazardous chemicals have been banned, after they were in wide use, but such preventive actions ordinarily require convincing proof of actual harm. More commonly, regulation aims to limit risk to a relatively low level. This approach has some precautionary elements, such as use of "safety factors" to

keep permissible exposure levels well below levels known to be harmful; but post-market regulation is less preventive or precautionary than pre-market approval.

Often, the approach prescribed by law and regulatory practice reflects the nature of the risks being managed. But there appear to be opportunities to take more consistent, and more consistently precautionary, approaches to a wide range of food safety decisions.

A significant question with respect to the use of precaution in a food safety context is whether setting permissible limits for toxic or potentially harmful ingredients, additives and contaminants in foods is an appropriate way to apply precautionary measures. Some analysts have argued that such decisions are too narrow. For example, they are usually concerned only with public health risks. Many food contaminants are also environmental contaminants, and food production methods such as chemical pest control and genetic engineering of crops have potentially serious environmental effects, which may outweigh their public health risks. The indirect effects on human well-being and economic costs of ecological damage are generally outside the scope of food safety decisions.

Some authors writing on precaution have suggested that, rather than try to set "safer" limits for potentially harmful substances in foods, which tend to ignore the environmental risks posed by the same substances, we should be redesigning food production systems to eliminate toxic chemicals and other risky practices. Rather than try to define safe levels of exposure to myriad different potentially toxic substances in foods, we should eliminate unnecessary uses of chemicals and minimize exposure to chemicals in foods. A preferred precautionary approach, they argue, is to seek least-harmful alternative ways of achieving food quality and food production goals, as a general, over-arching strategy.[3,4]

These are worthy concepts and they deserve extensive discussion. But I have chosen to limit the scope of this paper to the narrower food safety context. The approaches are not mutually exclusive. As the transition to more sustainable food production advances, it will generate new, more preventive approaches to ensuring food safety. And, while our society pursues that transition, we still need to make food safety decisions—in Codex, and here in the U.S. Those decisions need to provide "reasonable certainty of no harm," and

to the extent possible, they should be proactive and preventive. As we improve our ability to use precaution in setting food safety standards, we will inevitably increase our awareness of ways to build precaution into food production systems. The two streams of progress should reinforce each other. Learning how to make smarter and better use of precaution in food safety decisions, then, is an important first step.

All Governments Use Precaution

Some governments speak openly about their use of the "Precautionary Principle." The European Commission has issued a "commentary" on the Precautionary Principle and how it should be used, focused largely on food safety decision-making.[5] Some recent European decisions on high-profile food safety issues—bans of British beef imports (now lifted), of hormone use in meat production, and of specific genetically modified crops—have been justified as based on the Precautionary Principle. Actions on these issues, by Europe *vis a vis* the U.S., or by individual European countries *vis a vis* their E.U. trading partners, have been challenged as trade barriers (which they unquestionably are). The key question is whether they are also justified safety decisions under the Sanitary and Phytosanitary Standards (SPS) agreement, which in this author's view, they may well also be. These challenges highlight the need for increased clarification of how precaution is used and should be used as a basis for food safety decisions.

Some in the U.S. have asserted that the Europeans have used the Precautionary Principle primarily as a trade weapon; the implication seems to be that the U.S. would *never* do anything like that. In fact, the U.S. has developed many recent food safety policies based clearly on the need for precaution. We don't call it a "principle," but we have used it in much the same way, and if we were challenged over the trade impacts, we undoubtedly would defend our decisions just as vigorously as the Europeans have defended theirs.

Recent examples of precaution-based U.S. food safety decisions include:

- U.S. policy on preventing Bovine Spongiform Encephalopathy (BSE). In response to the outbreak of Mad Cow Disease in the United Kingdom, the U.S. banned imports of British beef. Later, the ban was extended to all European countries, including both a few that had also reported BSE cases, and others whose BSE surveillance efforts the USDA judged to be inadequate. Domestically, the U.S. banned feeding of rendered protein from ruminant food animals to other ruminants. Although some NGOs feel this policy could be stronger, its clear rationale is to prevent the possible spread of BSE, if BSE ever were detected in the U.S. No BSE cases have been convincingly shown to have occurred here—this action is purely precautionary. In recent months, flocks of sheep in Vermont and a herd of ranch-raised elk in Montana have been quarantined or slaughtered, because there is a reasonable suspicion that they *might* harbor a TSE that *might* be spread to U.S. cattle.[6] There is no evidence of disease in these sheep, no evidence yet that the TSE disease endemic in elk can spread to cattle, and no basis for a quantitative risk assessment in either case. The U.S. policy here is clearly, "Better safe than sorry."

- US response to the Belgian dioxin contamination incident. When Belgian meat and poultry were discovered to contain dioxin from contaminated animal feeds last year, the U.S. demanded assurances from the Belgian government that foods imported here from Belgium were not contaminated. When Belgium could not immediately provide that assurance, we banned the imports. The basis was not a risk assessment showing an unacceptably high risk, but rather lack of proof that there was not an unacceptable risk—an inherently precautionary decision. (When we later received solid evidence that the problem had been corrected, we lifted the ban.)[7]

- Food Quality Protection Act. The FQPA, passed unanimously by both houses of Congress in 1996, substantially updates the way the EPA sets limits for pesticide residues in foods. It establishes a uniform standard of "reasonable certainty of no harm," which replaces the previous risk-benefit-balancing standard. It requires EPA to set standards that meet the "reasonable certainty of no harm" test, and that protect infants and children as well as average healthy adults. It says that, in the absence of

adequate scientific data to ensure "reasonable certainty" that residues are indeed safe for children, EPA must use an additional 10-fold safety factor in setting safe exposure limits. This explicitly precautionary step gives public health primacy over "business as usual" when data are insufficient to show convincingly, for example, that standard safety margins will adequately protect against damage to the developing brain. In the past, EPA has had to postpone action on pesticide tolerances while research to fill data gaps was conducted, dragging out final decisions for a decade or longer. Under the FQPA, the agency must take prompt precautionary action.[8]

- Limits on Listeria. *Listeria monocytogenes* is a comparatively uncommon foodborne pathogen sometimes found in dairy products and processed meats. Although Listeria infections are rare, they are serious, resulting in death in a relatively large fraction of cases, and increasing the risk of miscarriage in pregnant women. *Listeria* can grow at refrigeration temperatures; ordinary hygienic practices, such as keeping opened food packages refrigerated, are not adequately protective. Methods for quantitative risk assessment for microbiological agents are not capable yet of defining a "safe" level of *Listeria* in foods. Thus, the U.S. has adopted a "zero tolerance" standard for *Listeria* in ready-to-eat foods, a clearly precautionary policy.

Food safety is not the only context in which the U.S. government has made decisions to protect public health based on precaution. In late 1998, the Consumer Product Safety Commission urged companies that make chewable plastic teething rings and toys that are mouthed by babies to stop using phthalate plasticizers to soften the plastic. (The CPSC charter requires it to seek voluntary action by industry before considering a ban or other regulatory steps.) Major manufacturers and retailers promptly agreed to phase out the phthalates. In statements to the public, both CPSC and the industry emphasized that there is no concrete proof that the chemicals are harmful to babies, or that infants who chew on plastic items could get a harmful dose. But they agreed that this change in products was still desirable "as a precaution."

In summary, while European governments may claim to be applying the "Precautionary Principle," and the U.S. has argued that such a principle is not needed, our government has also made precautionary decisions, which seem similar to those made by certain of our trading partners. I have given four recent food safety examples, and a detailed search would no doubt reveal many others.

To focus the discussions at upcoming Codex meetings, an agreement is needed that all governments will from time to time encounter food safety decisions that are legitimately based on precaution, as well as on science. Codex can then begin a concerted effort to develop consensus principles for when and how to use precaution in decisions.

Being Scientific About Science

Some commentators on the Precautionary Principle view it as separate from, and even antithetical to, science. Hathcock, for example, has said the Precautionary Principle can "negate the input of science" and "overrule risk assessment," and allow "arbitrary" food safety decisions whenever there is any uncertainty about a risk.[9]

With all due respect, this characterization of the role of precaution in decisions reflects fears (perhaps fed by perceptions of the unjustified nature of certain decisions, such as the beef hormones case) about how precaution might be *misused* to block trade. But it is not an accurate description of the proper use of precaution in food safety decisions. Not only is this view mistaken about what precaution is, it may lead us to misperceive what science is as well. My view is that the need for precaution and the need for scientific rigor are inseparably connected. You can't have one without the other.

Everyone who participates in Codex seems to agree that decisions must have a sound basis in science. But there has not been much discussion of what "sound science" is. Perhaps we all think we know it when we see it. In this author's view, for science to be a *credible* basis for decisions, *science has to be treated scientifically*.

What does that mean? Isn't science always treated scientifically, and how else can it be treated? To answer the latter questions first, I believe it is actually rather difficult to be scientific about science, in the political arena. To treat science scientifically is to be rigorous about what we *know,* what we *don't know,* and what we *can't know* through scientific methods.

The natural focus in risk assessment is on the data we have. However, what we "know," scientifically, includes awareness of questions we can pose but can't answer with current data. There are also typically questions we don't know enough to formulate, beyond the boundary of what we can "know" at any particular point in time. An artist's conception of the relationship between what we know and don't know is presented in Figure 1.

A distinguishing characteristic of much of the science underlying food safety questions is uncertainty. Uncertainty is not simply ignorance; there are different types and degrees of uncertainties, and they have different impacts on ability to accurately assess risks. Some uncertainties are familiar—differences between laboratory animals and humans, lack of data on actual exposures of people to substances, and lack of toxicity data at low doses, for example. For most of these uncertainties, risk assessors have, over time, developed approaches that they believe compensate adequately for knowledge gaps: mathematical models for extrapolation, default assumptions, "safety" factors, and so forth.

But there are other types of uncertainties that are not accounted for well by current risk assessment methods. For instance, we have few data on interactive effects among the multiple residues that occur simultaneously in diets. Consequently, risk assessments typically look at the effects of single agents and ignore possible interactions. Some effects, such as endocrine effects of hormonally active agents, are plausible risks because they have been observed in wildlife.[10] But mechanisms of action, dose-response relationships, and relationships between timing of doses and harm are not well understood for these effects, and there are few satisfactory bioassay methods and no consensus models for assessing these risks in humans. Consequently, risk assessments generally ignore them. Some analysts have argued that the traditional 100-fold "uncertainty factor," applied in

setting many safety standards, provides an adequate "margin for error" to protect against all these and other (unknown) risks. But many qualified experts find that assertion less than credible.

In still other cases, such as possible unintended effects of gene transfers in genetically modified crops, or the TSE diseases, caused by an entirely new kind of disease agent, our basic biological understanding of the problems is too crude to support quantitative risk assessment. Consequently, assessments are primarily qualitative, and we are far less sure how accurate they are than we can be with older, more familiar risks, where experience provides a basis for verifying and calibrating our predictive models.

Risk assessment tends to be reductionist—to simplify problems, to treat cause/effect relationships as linear. Many scientists (including many toxicologists) understand that health and environmental risks are responses to changes in much more complex systems, and require less linear, more holistic assessments. In general, current risk assessment methods are not very good at modeling complex systems. Making the effort to do so is one way to highlight all the things we don't know, but would like to know, about a risk. However, the most common response is not to try holistic assessments, because finding out how much we don't know is usually not a very satisfying answer. Decision-makers (and risk assessors) tend to prefer questions that appear to have clear answers—even if the result is getting a precise answer to the wrong question.

While Figure 1 probably exaggerates the relative state of knowledge and ignorance for well-studied toxic effects such as carcinogenicity, for some of the newer and emerging hazards to our food supply, Figure 1 is probably a fair representation. The accompanying quote by Schopenhauer reminds us of the need for scientific humility. In assessing risks we need to examine with equal rigor what the known facts show, where the uncertainties lie, the amount and nature of the uncertainties, and alternative interpretations of the data that are also plausible, given what we know, don't know, and can't know. Assessments that lack this rigorous attention to uncertainties are not fully "scientific" exercises, and in this author's view, they are not a particularly credible basis for public policy.

Within the Codex community, while all agree that science is essential, more discussion undoubtedly would be useful on what exactly we mean by "science."

Science and scientific knowledge differ from legal facts, as established in a courtroom, or from legislative decisions, based on majority votes. Scientific knowledge is inherently tentative. Einstein is reputed to have once said, "A single experiment could prove me wrong." Truth, in science, is determined by an iterative process of assertion, criticism, challenge and reassessment, as data accrue. While there is often a prevailing view among experts in a field as to the best interpretation of the evidence on a question, well qualified scientists often favor different interpretations, and vigorous debate among competing views is the norm. Often enough, as evidence expands, a minority view turns out to be correct. What is heresy this year can be orthodoxy next year, and things we believe are true today can be shown to be wrong tomorrow, or a few years from now. One medical researcher has mused, "I know that half of what I teach as fact will be proved false in 10 years. The hard part is that I don't know which half."[11]

When scientists are being scientific, they welcome debate, because debate is the engine that drives science. They don't mind being shown to be wrong, because that's how scientific truth advances: Hypotheses are proposed, tested, rejected, replaced by better ones. Arpad Somogyi, Head of the Health Risk Evaluation Unit in the Directorate on General Health and Consumer Protection of the European Commission, has written some thoughtful recent papers on the role of science in food safety decisions.[12,13] Professor Somogyi emphasizes that scientific knowledge is hardly ever complete, and never static, and that it is often extremely hard to determine what, in fact, "current science" on a particular question actually is. This may be good news for researchers—there is always more work to do—but it is sobering news for risk managers. It means they are likely to get a somewhat different answer from each expert they ask for an opinion.

When science is used as a basis for regulations and national policies that have economic impacts, it is applied in a more adversarial atmosphere, and it is far harder to be scientific about science. Human and institutional tendencies are to treat scientific knowledge more

legalistically in the regulatory arena, to use it to defend positions. The tentative nature of knowledge is ignored; what is known is stressed, what is unknown is overlooked; debate is curtailed; science is used to prove that an existing or proposed policy is correct.

When the stakes are high, as they often can be when potential public health hazards are concerned, questions that are still being intensely debated among scientists are generally resolved politically. A scientific "consensus" may be obtained, based on the opinions of a small group of sometimes not-very-well-selected experts. Once such expert statements exist, pressure grows for other experts to "get in line." There is a tendency to declare the scientific debate "closed," to act as if all the important questions have been answered—no matter how vigorously the evidence is actually still being debated, or deserves to be. Votes may be taken, policy may be adopted by a majority or by consensus. The science that supports the chosen policy is then often presented as conclusive. Does this represent sound, science-based decision-making? No, I'm afraid, quite often it does not.

These phenomena are in large measure unavoidable. Decisions must be made; society can't grind to a halt while research answers every question that needs to be answered. As Donald Kennedy, former Commissioner of the U.S. Food and Drug Administration, was heard to say, "Often you have to decide when the data are not as good as you would like." (See Figure 2.) And by and large, our society has a good track record of making sound, occasionally precautionary, food safety decisions. But at least a few decisions have been wrong. The most poignant recent example is the British government's chain of decisions on BSE. A risk assessment concluded that BSE was unlikely to be transmitted to humans from cattle. That conclusion was wrong, and 51 citizens have so far died of new-variant Creutzfeldt-Jacob Disease, linked to eating beef from BSE-infected cattle.[14]

The vast majority of food safety decisions are not mistakes—at least, as far as we can tell. But the public knows that mistakes can be made, and that experts and science-based risk assessments can be wrong. Consumers are skittish. They need reassurance that decision-making principles and scientific methods for assessing risks are as sound as possible.

One good way to make better decisions, and to avoid making mistakes, is to be rigorously scientific about science. While that may sound like something we think we already do, it is in fact very difficult, especially when intensely debated policy choices are on the line. It is very hard for risk assessors to say, "We honestly don't know." And risk managers, for their part, are often frustrated by proper scientific equivocation. Senator Edmund Muskie, the author of most major U.S. environmental laws in the 1960s, after hearing expert witnesses say, "On the one hand…but on the other hand…." too often, exclaimed, "What this country needs is more one-armed scientists!" Scientists who advise policy-makers can face considerable pressures to offer simplified, one-sided interpretations of the evidence. We must all remember that there is always an "other hand," and that sound decisions require that both hands be kept in view.

Being scientific about science in assessing a risk enables risk managers to define the appropriate degree of precaution in managing that risk. The link between good science and precaution is thus fundamental, and straightforward. By putting proper emphasis on what we *don't* know or *can't* know, risk assessors can put what we think we *do* know in perspective. A thorough and rigorous analysis of uncertainties and their implications is also essential to define needed types and degrees of precautionary measures.

Summing up, at the start of this section I cited the view that precaution is antithetical to science. The opposite is in fact true, and we must avoid the misleading implications of the perceived dichotomy between "science" and "precaution."[4] Precaution is grounded in scientific analysis, and applying precaution to decisions requires rigorous scientific input from a range of disciplines. At times, precautionary approaches, with their emphasis on what science does not know as well as what is known, may in fact require more rigorous science than risk assessment, which has been known to brush aside uncertainties in order to answer too narrowly-drawn questions.

Hathcock's quote could be turned around: Risk assessment can also be used to "overrule" science-based precautionary judgments. But neither scenario represents sound decision-

making. Done properly, Risk Analysis uses risk assessment and precaution together, as inseparable and essential components of science-based decision-making.

Precaution and Research

Most testing in support of food-safety decisions is rather narrow in scope and linear in concept. Controlled tests in lab animals are typically done, to identify toxic effects and define dose-response curves. These experiments are designed to get reliable data on the relationship between one substance and one effect, by eliminating confounding variables. The results of such studies typically provide the basis for quantitative risk assessments, which are used, in combination with precautionary steps such applying arbitrary but long-accepted "safety" factors, to define maximum safe exposure levels for humans.

While such simple experiments are necessary to isolate the effects of the variable being studied, they unfortunately don't represent the "real world." Rather than be exposed to large doses of single substances, people, through their diets and through other everyday activities such as work, breathing, drinking water, and using consumer products, are in fact exposed to varying combinations of many potentially harmful substances, usually at very low doses. Simultaneously, humans are exposed to a variety of other stresses that arise from physiological states—rapid growth and development (as in early childhood or puberty), pregnancy (both maternal and fetal conditions), aging, various disease states—and to medications, alcohol, tobacco, "recreational" drugs, and so forth. These "host factors," plus genetic variability, contribute to very wide differences in the sensitivity of individuals to harm from potentially hazardous substances in their foods.

Current toxicological test methods cannot come even close to modeling the complexity of the actual systems that determine the health risk from any particular food-borne chemical substance. For microbiological agents, the link between pathogen and disease is often far easier to demonstrate, but the effects of potential interacting variables are just as hard to model. In fact, it is probably fair to say that, for most food-borne hazards, it approaches being scientifically impossible to model the actual conditions of risk, and will remain so for

the foreseeable future. This is one reason that decisions need to be precautionary, of course, and it suggests a need for more holistic models of "real world," complex risks.

To the extent that food safety decisions are based on rigorous scientific assessments of what we don't know about risks, as well as on what is known, such decisions can guide research. More precise scientific definitions of knowledge gaps and uncertainties can help focus the search for improved methods to assess subtle, complex, multi-factorial causative processes.

On the other hand, awareness that causality is complex and that better models are needed is far from new. Over the past 25 years, many expert committees defining environmental health research needs have called for multidisciplinary attacks on this problem.[15] But progress has been slow. If these knots could be untangled easily, more answers would be in hand by now. Experience suggests that in addition to seeking to design and carry out better testing and modeling, we also need to more clearly spell out the limits of current scientific methods, and to acknowledge that our basic condition is ignorance. For some risks we must manage now, precaution will undoubtedly remain an important basis for decisions for many years to come.

A realistic appraisal of the vastness of the darkness and the feeble light research can often shine upon it is also essential *after* precautionary safety decisions are made. One widely accepted belief about precautionary decisions is that they are "temporary" measures, and that precautionary actions should be tied to research to reduce the scientific uncertainties. This implies that research should produce sufficient data in a reasonable time to supplant a decision based on precaution with one based on a quantitative risk assessment. In fact, this expectation is written into the SPS Agreement, which permits governments to take precautionary action in the face of incomplete scientific evidence, but calls such actions "provisional."[16] In an important test case on this principle, the World Trade Organization overturned a national decision on the grounds that research had not been done to answer the questions that had prompted the initial precautionary action.

It is easy to see the value of research for reassessing and, if need be, modifying decisions (whether they are precautionary or non-precautionary). Sometimes, research can confirm a hazard—i.e., demonstrate that the decision was sound. But it is also important to have realistic expectations for what research can achieve. In many cases, precautionary action is needed because there are questions science can't answer—not just because we don't have all the data we need, but because science currently has no valid methods for getting the needed data. In other cases, we may have the tools we need to measure harm, but precautionary action will prevent our knowing how much harm would have occurred if we had not acted. In still other cases, it is feasible to collect data, but society would be much better off simply replacing a risk-generating activity with a safer way to meet the same technical or economic need. Before deciding that research must be pursued to get more precise estimates of risks of using an inherently risky food substance, governments should be permitted to do a comparative cost/risk analysis. If there are lower-risk and lower-cost alternatives, research to refine risk assessments for a substance rejected on precautionary grounds is a bad investment. For either reason—the inability of science to eliminate uncertainties, or the economic irrationality of research to make a risky choice more acceptable when there are obviously better alternatives—it can be bad policy to *require* research as a condition of precautionary decisions.

Putting "Principle" Into Practice

While most governments agree that some food safety decisions currently are and should be based on precaution, not much is agreed to beyond that point. Especially needed are better practical definitions of the circumstances that justify taking precautionary action, and clearer guidelines for how to make and how to explain such decisions.

Precaution is not a single decision invoked at the end of a risk analysis; it is an element of multiple decisions at many stages of the process. Precautionary decisions are not just choices to permit or to ban a substance or activity; they come in many varieties, from asking difficult questions, to weighing incomplete or inconclusive evidence, to looking for safer alternatives, to setting wider safety margins, and many other forms as well.

Notwithstanding that, much discussion of the "Precautionary Principle" to date seems to assume a linear model of decision-making. A common description asserts that a risk assessment should be attempted first; if scientific uncertainty precludes a decision based on that risk assessment, risk managers can then invoke the precautionary principle.[17]

This model vastly oversimplifies Risk Analysis. When properly done, it is an iterative process, with myriad decision points along the way, most or all of which may call for a precautionary choice. For instance, defining the nature of the food safety hazard, posing questions risk assessors should answer, and developing risk assessment policy are just a few of the steps of a Risk Analysis in which risk managers and risk assessors (and other stakeholders) should interact, and where precaution can come into play.

When risk assessors are instructed to assess the impacts of unknowns and uncertainties, precaution becomes a more prominent element of risk assessment. When risk assessment policy includes guidelines on how to weight uncertainties, default assumptions to use if data are insufficient, and what sorts of "safety" factors to apply, it makes precautionary steps more explicit.

Even more fundamentally, the choice of questions that are within the scope of the risk assessment is intimately linked to precaution. A risk assessment that includes questions that sound scientific insight says are relevant and important, but that are not currently likely to have conclusive answers, will tend to support a precautionary decision. A risk assessment that focuses on questions that can be convincingly answered with current data is much more likely to support a non-precautionary decision—one in which precaution is less needed because knowledge is relatively complete, or one based on the "Bodies-in-the-Street Principle."

Not only are there myriad points in the decision process at which precaution comes into play; there are also a wide variety of different kinds of uncertainties, which may call for different kinds and degrees of precautionary responses.[18]

In practice, food safety decisions fall along a wide continuum. At one end are the easiest, most straightforward decisions, where we have all the scientific data we need and there is little controversy about the soundness of decisions. At the other end are the most difficult food safety questions. These are issues on which the science is so incomplete and subject to legitimate debate among experts that government decisions, no matter how much effort went into them, can be challenged as unsupported by the evidence, while observers with no interest in the outcome cannot tell who is right. Between these two extremes lie many different types of decisions, each with their own degrees and types of uncertainties.

To illustrate the nature and degree of uncertainties and precautionary steps encountered, I will describe five more-or-less arbitrarily defined categories of food safety decisions, below. My point is not to argue that there are five categories, as opposed to, say, four or six, but rather to demonstrate the variety of circumstances that require precautionary responses, and some of the many ways precaution is appropriately used.

My categories range from cases in which there is ample scientific evidence and a firm consensus on "reasonable certainty of no harm" (Type 1), to cases in which the odds of a consensus that an activity is safe approach zero (Type 5). Figure 3 summarizes the five categories. Interestingly, precautionary steps are not limited to the latter categories—widely accepted precautionary measures are applied in *all five categories*. The problem is not deciding which categories should use precautionary decisions, but using them appropriately, consistently and transparently in every category.

Type 1. *Cases in which the science is straightforward and there are ample data; we can be reasonably certain something is safe, and permit its use, or can be reasonably certain it does not meet safety criteria, and ban it.*

Examples in this category include GRAS substances (food ingredients that are "generally recognized as safe"), and numerous food additives that were shown to be safe before they were allowed to be used (flavors, thickeners, stabilizers, many preservatives, etc.)

On the other side, the synthetic estrogen diethylstilbestrol (DES) was banned from use as a weight-gain promoting drug in beef production after studies showed that women whose mothers took DES to prevent miscarriage during early pregnancy had a sharply increased risk of a rare form of vaginal cancer. Previously, animal studies had also shown that DES was a carcinogen, but since existing analytical methods could not detect DES residues in foods, FDA had concluded that there was no risk requiring regulatory action. During the 1970s, improved analytical methods revealed residues; this advance, combined with solid evidence of carcinogenic effects in humans, led FDA to conclude that it had no choice but to ban DES use.[19]

These examples reflect *both* the sufficiency of scientific data in many cases *and* the use of precaution as a basis for decisions, and show that the two often occur together. Food additives, under U.S. law, must either be determined to be GRAS or be shown to be safe before their use is allowed, an inherently precautionary approach. The Delaney Clause, part of the food additive law, prohibits the deliberate addition to foods of any amount of a substance "found to induce cancer" in humans or animals. Although that also sounds like a precautionary stance, the question of when something "induces cancer" can be difficult to resolve, since the causes of cancer are complex, and science is rarely certain about the role of single factors. In fact, the Delaney Clause has seldom been invoked to ban a food additive, even when there is considerable suspicion that it *might* increase cancer risk (see Type 3 cases, below). The DES case, however, was unusual, in that convincing human data supported applying the Delaney Clause as a precautionary action in that instance.

Type 2. *Cases in which there is a great deal of scientific data, good risk assessments can be done, and reasonably reliable estimates of "safe" exposure can be agreed upon, but in which precautionary measures are still justified and applied in various ways.*

The examples I have chosen in this category include regulation of lead levels in foods, and food-additive uses of caffeine.

Lead. Three decades ago, lead levels in U.S. foods were much higher than they are now, because lead emissions from automobiles using leaded gasoline contaminated the food

chain, and because most food cans were sealed with lead solder, which increased the lead content of canned foods. Lead poisoning associated with lead paint and other sources is a major public health hazard, and massive amounts of research have been done on exposed human populations, attempting to establish safe exposure limits. Based on such research, public health officials repeatedly lowered the definition of the amount of lead in a child's blood that was associated with measurable adverse effects. By 1980, studies had shown that even "average" exposure, with no clinical symptoms, was associated with some risk of adverse effects on nervous system development, learning and behavior in children.[20]

In the 1970s, the FDA determined that food lead levels needed to be lowered, as part of an overall effort to reduce exposure to lead from all sources. Rather than attempt to set "safe" upper limits for lead in specific foods, the FDA pressed the canned foods industry to take feasible steps to keep lead out of foods. The industry accepted the need for such steps, and infant formula producers switched over to lead-free cans almost immediately. The canned foods industry as a whole completed this transition over a decade or so, and achieved substantial lead reduction with "good manufacturing practices" in the interim.[21] In combination with the EPA's phase-out of leaded gasoline, the phase-out of leaded cans reduced lead levels in the American diet by about 95 percent between the early 1970s and the early 1990s.[22]

The phase-out of lead-soldered food cans was a precautionary strategy. The FDA and the industry might have argued endlessly over what was a "maximum safe limit" for lead in foods. But the multi-source nature of lead exposure made the margin of safety for many children too small; lead in foods contributed to an unacceptably high overall risk, and all practical steps to reduce lead exposure needed to be pursued. The most sensible strategy was to keep lead out of foods to the maximum extent feasible, by removing a key source of contamination, lead-soldered cans.[23]

In the international arena, the Codex system is currently considering the problem of lead in foods, and is taking the opposite approach. The Codex Committee on Food Additives and Contaminants has asked the Joint Expert Committee on Food Additives to identify safe

upper limits for lead in specific foods, and is planning to set standards (maximum residue levels) based on JECFA's recommendations. This narrower approach ignores the multi-source nature of lead hazards, will not ensure safe exposures even through the diet, and is decidedly non-precautionary, compared to the U.S. experience.

Caffeine. Caffeine is widely consumed, in coffee and other beverages and in over-the-counter drugs, for its stimulant effects. It is also added to soft drinks as a flavor modifier. In the late 1970s, studies showed that caffeine fed to pregnant rats in large doses caused birth defects. Concerns also existed about the stimulant effects of caffeine on the nervous system and behavior of children, who consume large amounts of soft drinks, especially in proportion to their body weight.[24] The Center for Science in the Public Interest asked FDA to ban the use of caffeine in soft drinks, based on these concerns.

Subsequent research on women who drank large quantities of coffee while pregnant did not confirm a risk of birth defects, and FDA ultimately decided that the safety margin for food additive uses of caffeine was adequate. FDA applied no precautionary steps beyond those built into its long-standing approval of caffeine use. But the market soon produced a far more precautionary response. Soft-drink manufacturers noted consumers' concerns about caffeine and quickly developed caffeine-free versions of their caffeinated products, enabling consumers who wanted to avoid caffeine to do so easily. Precaution was not the basis for government action, but came into play through consumer product choices.

In summary, in both Type 2 cases the risks were relatively well understood. In the lead case, it was not possible to define a level of lead exposure that was "reasonably certain to cause no harm." But convincing data showed that many children's total exposure to lead was unsafe, and that food cans contributed moderately but significantly to total exposure. A consensus was reached that exposure should be reduced as much as feasible, and food canners voluntarily phased out the use of lead-soldered cans over ten years or so. In the second example, the evidence suggested that caffeine use in soft drinks posed a minimal risk of birth defects, but many consumers expressed preferences not to give their children caffeine in soft drinks. The soft-drink industry responded by offering consumers a choice

of caffeine-free colas, enabling parents to make their own precautionary decisions. In both cases, perhaps by coincidence, comparatively precautionary actions were taken by the private sector, not by government regulators.

Type 3. *Cases in which the science is not complete enough to support consensus risk assessments or resolve every important question, but decisions have to be made. Some such decisions have been precautionary in nature, and some far less so.*

There are many examples in this category, including many of the most controversial food safety debates of recent decades. Generally, those charged with doing risk assessments have believed they had a valid basis in science for their decision, but that view has been disputed by others with both expertise and a stake in the outcome—industry or consumer organizations. The cases I have chosen include:

Artificial sweeteners. In the 1960s and '70s, two of the most widely consumed sugar-substitutes, cyclamate and saccharin, came under suspicion as possible human cancer risks based on results of animal feeding studies. In 1969, when cyclamate was shown to produce tumors in high-dose rodent studies, FDA banned its use and also recalled all cyclamate-sweetened foods. These precautionary actions were at least in part based on recognition that a "safer" alternative existed—saccharin.[25,26]

It wasn't long, however, before saccharin also was under fire, for producing bladder tumors in rats. FDA had resolved, in the wake of the cyclamate case, not to let itself be forced to ban a familiar, long-used food substance simply because new safety questions had been raised. In effect, the FDA found the precautionary stance of the food safety law too restrictive, and wanted more flexibility to consider both the quality of the scientific evidence and the practical implications of a ban. The agency reclassified saccharin as an "interim food additive"—a novel category, not provided for in the law, which FDA had invented to allow questioned substances to remain on the market while further studies were conducted. FDA thus took upon itself the burden of proof, permitting saccharin use to continue while it sought to determine whether the safety questions that had been raised amounted to a clearly demonstrated public health hazard.[26]

Intense debate over saccharin persisted for several years, during which expert committees of the National Academy of Sciences reviewed the evidence several times, and the issue was publicly controversial. Advocates who favored permitting saccharin use pointed to scientific uncertainties, while public-interest groups and many in Congress pressured the FDA to act in the precautionary way they felt the law required. Ultimately, the FDA was prepared to ban saccharin, but Congress intervened and blocked the FDA ban, reaching a political decision to override the precautionary requirements of the food safety law. The reasons Congress gave for its action were that the evidence that saccharin posed a cancer risk in humans was inconclusive, that sugar-free foods had perceived benefits, and that there was no acceptable alternative for saccharin.[26] Congress required FDA and the NAS to further study the risk issues and required saccharin-sweetened foods to carry a warning label—a precautionary action, though far less effective than a ban.

More recently, additional non-caloric sweeteners, including aspartame and acesulfame-potassium, have been approved by FDA for use in specific foods. In each case, there has been controversy over whether the testing done by manufacturers demonstrates safety, or raises unanswered risk questions.[27] The focus of the debate on Aspartame, the next major sweetener approved after the saccharin debate, was primarily on effects on the brain and on other non-cancer risks, which made it appear to be a safer alternative for saccharin, at least in that there was little reason to consider it a suspected carcinogen.

Color Additives. Like the artificial sweeteners, many dyes used to color foods began to be suspected of posing risks of cancer and various other toxic effects during the 1960s and ‘70s. As it had with artificial sweeteners, the evidence came from high-dose animal experiments, and risks to people consuming the dyes in actual diets were unknown. A few dyes were banned, while others for which the evidence was not strikingly different were not. Some dyes banned by the U.S. remained in use in Canada, and vice versa. The science was too incomplete and uncertain to support a consensus approach or consistent decisions on these risks.[28]

After several frustrating attempts to resolve these issues consistently, FDA backed away from a strict application of the Delaney Clause to food colorings, taking the position that mere evidence from animal tests that an additive might cause cancer was not sufficient. FDA set itself a higher standard: It wanted to be reasonably certain that an additive posed a *significant* risk of cancer, based on a quantitative risk assessment, before banning its use. This policy shift led to a protracted dispute between FDA and the public-interest community, but the agency held its course.[28]

Thus, early experiences with efforts to take precautionary action on possible cancer risks from sweeteners and food dyes spurred greater subsequent emphasis on risk assessment, and in particular, on quantitative estimates of cancer risk. Industry and government came to agree that food safety decisions must be based on "better science," and that precise risk estimates offered a sounder basis for decisions than "simplistic" precautionary decision rules. After more than two decades of applying this approach, however, disillusionment has set in among many participants, and the limitations of risk assessment are a large part of the reason for the current growth of interest in precautionary approaches.

BST. A third, recent case in this category is the use of recombinant bovine somatotropin, or BST, a genetically engineered hormone used to increase the milk output of dairy cows. The U.S. FDA approved BST use in the early 1990s, after what FDA and makers of the drug characterized as a thorough risk assessment that proved its safety.[29] The FAO/WHO Joint Expert Committee on Food Additives has reviewed BST issues twice, in each case with heavy participation by FDA scientists, and has agreed with the FDA position.[30] But scientists from consumer NGOs and some expert bodies in other countries have cited risk questions that were inadequately answered in the U.S. and JECFA reviews.[31] While most critics do not assert that the evidence shows BST use is harmful to public health, they do contend that the data haven't provided "reasonable certainty of no harm." In addition, in the absence of evidence that BST use directly benefits consumers, many feel that a more precautionary stance toward unanswered risk questions is justified.[32]

BST use is controversial in the U.S., and is prohibited in Canada (because of effects on cattle) and in European Union. A number of other countries permit BST use, relying on the U.S. assessment or the JECFA reviews. Although consumer groups have asked the FDA to require labeling of milk and dairy products made with milk from cows treated with BST, the FDA has rejected that request, and has discouraged state laws and private-sector initiatives to provide such labeling. Thus, U.S. decisions on BST use reflect a less precautionary approach than other governments have taken to the same questions.

To summarize Type 3, cases in this category generally illustrate the difficulty of using either simple precautionary rules or risk assessment to make many food safety decisions. In each case examined here, scientific debate had not reached a consensus when decisions had to be made; substantial gaps, uncertainties and disputes remained. In some cases, government took precautionary action despite lack of convincing evidence of significant risk to human health. In other cases, risk assessments were used to justify permitting the continued exposure of the public to potential harm, although the soundness of the risk assessments was often vigorously challenged.

In most of these cases, broad public support for the definition of "acceptable risk" used (explicitly or implicitly) by decision-makers was lacking. In fact, when safer alternatives exist or when it is debatable whether use of a substance is necessary, many people find even a risk that risk assessment shows to be "negligible" unacceptable. Cases of this type reveal both limitations of the risk assessment approach and the need for more flexible and appropriate precautionary approaches than "banning at the drop of a rat."

Type 4. *Cases involving substances on which a great deal of toxicity data exist and "safe" exposure levels have been defined using risk assessments, but for which recent research suggests plausible new risks that cannot be effectively assessed with current data or methods, and the adequacy of established safety limits is in serious doubt.*

The primary examples in this category are pesticide residues in foods, and certain other environmental contaminants such as the polychlorinated biphenyls (PCBs) and dioxins. Most of these chemicals have been tested for several kinds of toxic effects, and maximum

limits in foods were set for many of them, often long ago, based on what seemed at the time to be sufficient data. But in the last several years, new perspectives on risks have gained support in the expert community, and the basis for presuming that current limits for these residues are adequately safe has been called into question, on several grounds:

Vulnerability of children. Infants' and children's organs and systems are growing and developing rapidly, which tends to make them more vulnerable to certain toxic effects than people at other stages of life. Children's small body size and comparatively high caloric intake also mean they are exposed to higher doses of toxic substances in foods, on a body-weight basis. A 1993 report by the U.S. National Research Council[33] concluded that current risk assessment methods and standard-setting approaches did not adequately protect children from potential adverse effects of pesticides in foods. That report also suggested that an extra "safety factor" be incorporated into standards, to provide better assurance of safety for children.

Endocrine effects and developmental toxicity. Evidence of effects of pollution on wildlife species suggests that some food chain contaminants (PCBs, dioxins and many pesticides) have had hormone-like effects, often at much lower levels of exposure than those typically associated with other effects.[34] Hormones act as signals that guide normal development, phyisological responses and homeostasis in animals. If a hormonal signal occurs at the wrong time or fails to occur at the right time, it could affect the development or function of many systems—not just the endocrine system, but the nervous and immune systems, among others, as well. Enough is known now to believe that this is a plausible hypothesis and that, if true, hormonally active food contaminants could pose risks of a wide range of subtle adverse developmental effects. But toxicologists have just begun to search for useful bioassays for risks of this type, and for credible models to estimate their magnitude and likelihood. At this point, not even good qualitative risk assessments for endocrine effects are feasible for most substances.[35]

Additive effects of multiple residues with a common mechanism of toxicity. Many of the most widely used pesticides belong to chemical families, the organophosphates and the

carbamates, that share common mechanisms of toxicity (they all inhibit an enzyme that is critical in the transmission of nerve signals.) Because of these common mechanisms, it is likely that multiple residues from the same families could have additive or more-than-additive effects.[36] However, while risk assessors have been aware of the occurrence of multiple residues with the same toxic mechanisms for decades, there are as yet no widely accepted, validated models for estimating their combined effects. Research is under way, and some models have been proposed, but it may be years before a consensus approach is found.[37]

Some examples can illustrate the difficulty of making safety decisions under conditions of such major, novel and uncertain scientific questions of risk. For pesticide residues, the Food Quality Protection Act, described earlier in this paper, instructs the U.S. EPA to use an additional 10-fold safety factor when setting exposure limits, unless sufficient reliable scientific data indicate that limits based on a smaller safety margin provide "reasonable certainty of no harm." The act specifically identifies infants and children as sub-groups whose safety must be assured, and instructs the EPA to consider the combined effects of chemicals with a common toxic mechanism in defining "safe" exposures. But, more than three years after the FQPA became law, EPA has not finalized its policies on how it will make these decisions, and has chosen not to apply an extra "safety" factor even in cases with major data gaps or clear evidence of developmental toxicity.[38] In short, even when the law requires precautionary action in the face of lack of scientific certainty, the EPA has found it very difficult to implement that mandate in practice.

A second example in this category is the recent debate over the safety of polycarbonate baby bottles. Tests done by the FDA and by Consumers Union have shown that bottles can leach bisphenol-A, the monomer that the plastic is made from, into the fluid inside the bottle when heated, at levels of around one part per billion.[39] Animal experiments have shown estrogen-like effects of bisphenol-A at doses within a factor of 10 of what a human infant could get from drinking formula containing 1 ppb.[40] The meaning of the animal data is controversial; the plastics industry insists that the bottles are safe, while CONSUMER REPORTS has advised parents to choose non-polycarbonate baby bottles as a precaution.[41]

The FDA has not yet used the risk of hormonal effects in infants as a basis for standards for any food contaminants, and FDA has previously concluded that poly-carbonate plastic is a safe food contact substance. FDA officials have said that too little is known about potential risks of endocrine disruption to conclude that bisphenol-A in infant formula poses a significant risk to human health, and that the existing evidence is not strong enough to remove these baby bottles from the market.[42] As a practical matter, then, the burden of proof has been shifted to the public; unless clearer evidence emerges showing that bisphenol-A exposure harms infants' health, the FDA seems unwilling to challenge the safety of a widely used plastic with many practical advantages.

To sum up Type 4 cases, several scientifically sound hypotheses about plausible adverse effects of low-level chemical exposure cannot be addressed effectively with current risk assessment methods. Because the questions are scientifically credible and the answers seem important, many qualified experts now assert that existing safety standards can no longer be presumed adequate to protect children against important known risks. As the two cases show, however, regulatory agencies to date have been reluctant to rely on this emerging science. Despite the clearly precautionary language of both the Food, Drug and Cosmetic Act and the Food Quality Protection Act, both FDA and EPA have declined to restrict economically important activities when new science suggests they can no longer meet the "reasonably certainty of no harm" test. Scientific uncertainty, and the inability of risk assessment to account for potentially important but relatively poorly understood risks, have been used to justify not precautionary action, but regulatory inaction.

The food safety community is thus faced with a formidable task. Continued reliance on risk assessment suggests that massive amounts of data and new risk assessment methods are needed, an effort that will take decades. It seems unthinkable that no action would be taken to better protect public health while research seeks improved ways to assess these risks. Precautionary measures seem essential. But there is as yet no consensus on what precautionary approaches are most appropriate in each case.

Type 5. *Emerging problems where the nature of the hazard is not yet fully understood, quantitative risk assessments are generally not feasible, and even qualitative assessments have a wide margin of error due to lack of basic scientific knowledge.*

Examples in this category include the Transmissible Spongiform Encephalopathies (or TSEs), including "mad cow disease" (BSE), and potential unintended effects of gene transfers in genetically modified crops.

BSE. The epidemic of BSE among British cattle and its association with several dozen cases (so far) of the similar disease, Creutzfeldt-Jacob Disease (CJD) in humans, was the public's first experience with this fascinating new category of chronic, degenerative and always-fatal brain diseases.[43] It is currently believed that the disease was spread through cattle in the U.K. by the practice of rendering the remains of slaughtered cattle into feed additives, and feeding them back to cattle and other food animals.

That practice has been banned, but not before unknown numbers of Britons and other beef-eaters were exposed to meat from cattle that may have had an early, symptom-free stage of BSE. Too little is understood now about the nature of the causative agent (an abnormal brain protein), how the disease is transmitted, or what factors affect its course once a person is exposed. Thus, it is impossible to predict the final human toll from BSE. Nonetheless, a massive effort has been mounted to stop the spread of BSE and to keep potentially infected materials out of the human food chain.

A similar disease (scrapie) has been recognized in sheep for nearly a century, but was never thought to pose a risk to humans. Other TSEs have been documented in wild deer and elk and in ranch-raised mink, all in the U.S. A number of studies suggest that beef is not the only food associated with CJD risk. Several studies looking at dietary risk factors for patients diagnosed with CJD have found eating pork products and animal brains to be associated with increased risk.[44] Four cases of CJD in young men who ate venison and hunted deer have been identified, and the Centers for Disease Control is on the alert for more cases. Two studies have documented CJD cases in people who hunted squirrel and ate their brains.[45] In short, the available evidence suggests that TSEs can occur in many

species, and humans may be exposed not only by eating beef but also by eating meat (and other tissues, such as brains) of other animals as well.

Some evidence also suggests that a native bovine TSE might have infected cows used as mink food.[46] But BSE has not been officially confirmed to occur here in the U.S., and government policy aims to keep it out if at all possible. The FDA has banned feeding of rendered mammal remains to ruminant food animals, and as noted earlier in this paper, the USDA has condemned two flocks of sheep and a herd of ranched elk, to be sure that they don't spread a TSE to cattle. The USDA has tested the brains of several thousand slaughtered cattle, monitoring to detect BSE if it does appear here. U.S. BSE policy is precautionary, though some consumer organizations have suggested to could be even more so—monitoring could be more extensive, the feeding of rendered remains to any food animals could be prohibited, and the sale of brains for human consumption could be banned, for instance. But overall, BSE is a classic case for invoking the precautionary principle, and the U.S. response has been decidedly precautionary.

Genetically engineered foods. In this case, opinions are deeply divided. On one hand, most scientists who have developed genetically engineered crops believe their methods for transferring genes are more precise and predictable than traditional plant breeding, and assert that the likelihood of unexpected, potentially harmful effects is very small. They also assert that any adverse changes in foods caused by gene transfers would be detected by testing before the foods were marketed.[47] The FDA has generally agreed, and has ruled that most transgenic crops are "substantially equivalent" to their non- engineered counterparts, and don't require pre-market safety approval. Although this policy is currently under review, it reflects a scientific belief that genetic engineering of crops raises no major novel food safety issues.[48]

On the other side of the question, a substantial minority of qualified scientists challenges the view that genetic engineering is like traditional crop breeding. Genetic engineering methods make possible transfers of genes into crops from organisms that could never be crossed by other means. "Promoter" genes are often inserted as well, to "turn on" the

transferred genes, and they may affect other genes in the host organism, with unknown or unpredictable effects. Overall, the critics say, the consequences of some gene transfer methods are much less predictable than those of traditional breeding methods.[49]

One area of particular concern is the possibility that transferred genes might code for new proteins in the engineered plant, some of which might be allergens. It is generally agreed that current test methods for screening novel foods for allergens, and especially unknown allergens, are not adequate.[50] Many observers believe that genetically engineered foods are being pushed to market before satisfactory methods have been developed to test them for theoretically possible changes that could have health and environmental implications. While there is not enough experience yet to say exactly how large or small the problem may be, and it may in fact turn out that most genetically engineered foods are safe, many experts are nonetheless sure that *some* unexpected, unwanted effects will occur.

The situation with genetically engineered crops is similar to the situation with respect to BSE in the late 1980s. At that point, the majority of experts believed that the disease in cattle posed no threat to human health. A minority disagreed, argued that far too little was known about BSE to be confident it posed no substantial risk, and urged a stronger precautionary policy. History proved the minority correct. Awareness of the BSE case undoubtedly is a factor in the call by many scientists, some governments and consumer NGOs for strongly precautionary postures toward genetically engineered foods. With a technology that has radically changed major sectors of agriculture in just a few years, it is easy to understand why many stakeholders believe policy should be more precautionary than the approach the U.S. has taken to date.

From Practice Back to Principles

Based on the cases examined here, what principles can be developed that describe where and how precautionary decisions are appropriately made in food safety risk analysis? As an initial step toward articulating such guidelines (and certainly not the final word on this subject), I offer ten proposed "principles:"

1. Precaution is not an alternative to science, or something used to counter science; it is itself rooted in and inseparable from rigorous science. A thorough assessment of what is known, what is not known, and what science cannot currently know, should support all food safety decisions. Typically, this requires more, rather than less, scientific rigor, and a wide range of scientific disciplines and expert perspectives, in assessing risks.

2. Precaution is not used only when there are inadequate scientific data. Many cases described here involved both extensive scientific knowledge *and* precautionary decisions. The two can co-exist happily. The idea that large scientific uncertainties are an essential prerequisite for taking precautionary action is mistaken, and can foster misunderstanding of some of the appropriate ways precaution is used. Assignment of the burden of proof typically has more effect on the use of precaution than uncertainty, *per se*.

3. Precautionary decisions can say "yes" as well as "no." In some cases examined here, precaution-based decisions permitted activities, when there was ample scientific evidence that they were safe. Precaution can also be a basis for banning risky activities because of insufficient evidence of safety, or for many lesser measures designed to prevent harm.

4. Precaution is an element in all kinds of decisions and choices, at all stages of a risk analysis. Precautionary action is not a discrete, final step at the end of the process (i.e., a decision by risk managers to invoke the "Precautionary Principle"), but is a pervasive component of risk assessment, risk management, and risk communication. It is applied in many different ways under different circumstances.

5. While precaution is a pervasive element of Risk Analysis, in actual practice some decisions are far more precautionary than others. Using precaution is generally a matter of degree. Even "precautionary" statutes have been unevenly applied in different cases.

6. There are many different kinds of uncertainty, and as many different precautionary responses. Each different type of food safety problem has different kinds and degrees of uncertainty, and different kinds and degrees of precautionary action are appropriate in

each case. Principles for the proper application of precaution must therefore be based on analysis of a broad array of different food safety problems.

7. Precautionary decisions are not just for governments to make. Although the focus in Codex is naturally on government decisions, cases examined here included examples of precautionary actions by industries, and by consumers exercising choices in the market. In the absence of preventive government actions, industry can both offer safer products and provide label information to help consumers make their own precautionary decisions.

8. Precautionary actions should not always be treated as "provisional." Sometimes a precautionary action is taken while research is carried out to collect better data on which to base a more precise decision. But there are cases in which research cannot reasonably be expected to answer critical questions, or where society is better off if it simply adopts a safer alternative, rather than wasting resources trying to get better risk estimates for a less safe activity. Tying research requirements to all precautionary actions is bad policy.

9. Assessment of alternatives is a valid and useful precautionary approach. The risk management approach that asks, "What is a safe level of exposure to X?" often finds decisions hampered by the limitations of risk assessment. An approach that asks, "What are alternative ways to fulfill the technical or economic need that X meets, and which of them poses the lowest risks?" is inherently more precautionary, although the questions may be more complicated to answer.

10. Precautionary actions need to be used more consistently and transparently in food safety decisions. Virtually all of the cases examined involved major scientific questions that risk assessments could not answer. Precautionary action was taken in some cases, but not in many others. More consistent application of precaution is probably needed and achievable. Well understood "rules" for using precaution can both help risk managers make better, more consistent decisions and make it easier for consumers, trading partners and others to see what decisions are based on, enhancing the credibility of decisions.

Where To Next?

I offer the following recommendations, which could support progress toward better understanding of the appropriate uses of precaution in food safety decisions:

At the national level: U.S. food safety agencies need to pursue an analysis similar to the one I have attempted here, examining an array of food safety problems, and sorting out the precautionary elements in decisions that were made. The discussion probably needs to be expanded to include other agencies with an interest in precautionary approaches, as applied in environmental protection policy, for example, or as they may affect trade. The process of developing principles for using precaution in food safety decisions should also include extensive consultations with the public. Consumers, industry and other interested stakeholders should be invited to participate in the discussion.

Once the U.S. has developed its "principles," it should apply them consistently to all of its food safety decisions. When it has defined its "vocabulary" for its use of precaution, the U.S. will also be in a better position to shape and lead the discussion of this subject in international arenas, such as the Codex Alimentarius system and the WTO.

Some attention might also be paid at the national level to research needs. It certainly is worth re-emphasizing the need for improved testing methods and more sophisticated models that can assess multi-factorial risk scenarios that more closely approximate "real life" than the methods and models relied on most often today. However, optimism that research can improve our tools must be tempered with realism about the likely pace of progress. These needs have been known for at least a quarter-century, and the problems have not been solved yet. In the absence of powerful new legislation forcing answers to such questions, we can expect progress to be slow.

An equally urgent need is for the research community to develop some frank assessments for risk managers of questions that science cannot now answer, and cannot reasonably be expected to be able to answer soon. Much more than they need a list of research needs, decision makers need a candid appraisal of the limitations of present scientific tools and a list of questions that risk assessment cannot currently resolve.

Another issue to be addressed at the national level is the scope of food safety laws. The decision-making frameworks established in most current laws envision government as a gatekeeper, permitting or denying permission for potentially risky foods, food ingredients and food-production methods to enter the market. This model lends itself to reductionist, one-substance-at-a-time, risk-based approaches. It is not government's job, currently, to look for safer alternatives to risky activities, or to take a broad approach to problems, to ask how to achieve technical objectives with the least risk to health and the environment. Questions of this nature are left to the market to answer. Unfortunately, the market often tends to appraise one activity at a time, and to discount effects that are hard to measure in economic terms; it is not very efficient at anticipating and forestalling risks. We not only need much better scientific methods and models in order to better understand the risks associated with our foods; we need better social models and instruments, to make more complicated choices, based on precaution as well as on risk.

At the international level: The discussion of the use of precaution, now under way in the Codex system, will continue, and Codex needs to analyze a large array of food safety problems and decisions, to identify precautionary elements applied in different countries and different cases. From that analysis, Codex should try to develop consensus principles about the legitimate uses of precaution, to guide both its own decisions and those made by national governments. While it may be very difficult to achieve consensus on how to use precaution appropriately, given the diversity of legislation, cultures and food safety problems in the 165 Codex member nations, this effort is essential. Sound international principles for the use of precaution can help ensure better and more harmonized decisions by Codex members, can make the basis for decisions more transparent to consumers, and may help avoid unwarranted trade challenges over safety decisions.

The member governments of the WTO also should also examine the issue of precaution in the context of the SPS Agreement, when the next review round occurs. That treaty now permits precautionary decisions, but considers them "provisional" and implicitly requires research to narrow uncertainties as evidence that the action is not a disguised trade barrier.

Building on the discussion in Codex, WTO members may wish to revise the way precautionary actions are treated in trade agreements.

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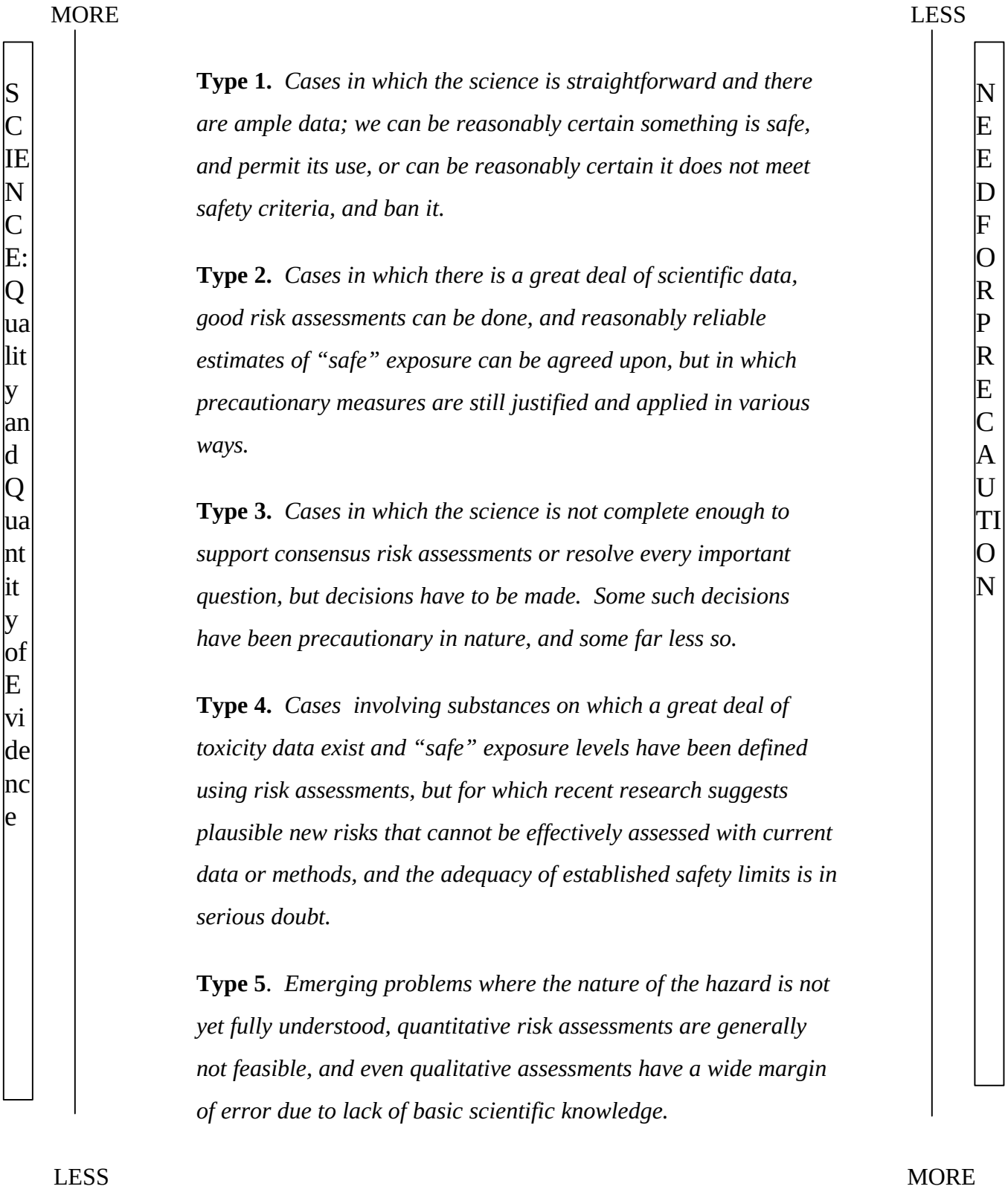
FIGURE 1

FIGURE 2

FIGURE 3. The Continuum of Food Safety Decisions



Type 1. *Cases in which the science is straightforward and there are ample data; we can be reasonably certain something is safe, and permit its use, or can be reasonably certain it does not meet safety criteria, and ban it.*

Type 2. *Cases in which there is a great deal of scientific data, good risk assessments can be done, and reasonably reliable estimates of "safe" exposure can be agreed upon, but in which precautionary measures are still justified and applied in various ways.*

Type 3. *Cases in which the science is not complete enough to support consensus risk assessments or resolve every important question, but decisions have to be made. Some such decisions have been precautionary in nature, and some far less so.*

Type 4. *Cases involving substances on which a great deal of toxicity data exist and "safe" exposure levels have been defined using risk assessments, but for which recent research suggests plausible new risks that cannot be effectively assessed with current data or methods, and the adequacy of established safety limits is in serious doubt.*

Type 5. *Emerging problems where the nature of the hazard is not yet fully understood, quantitative risk assessments are generally not feasible, and even qualitative assessments have a wide margin of error due to lack of basic scientific knowledge.*