2004 Presidential Address: The Sheep, the Ostrich, the Ant, Diabetes, and the Tragedy of the Common

When I first began considering what I would like to speak about today, I reviewed the last five presidential lectures. After considering these, it didn't seem like there was much left to cover! There was, however, the irresistible urge to have, at least, a catchy title, hence "The Sheep, the Ostrich, the Ant, Diabetes, and the Tragedy of the Common." What links these things together?

In 1968, Garrett Hardin published a thought-provoking article in the journal *Science* describing what he called, the "tragedy of the Commons" (1). Hardin was a population biologist concerned about the issue of population growth both in the U.S. and abroad. Briefly stated, the article suggested that the problem of population growth could be likened to the dilemma that arises when a community maintains a common resource. The example that Hardin gave was that of a common grazing area.

It was a frequent practice in the early years of this country, and in many areas of the world still, for villages and towns to create and maintain a common grazing area. This was land that had been cleared by the community where sheep, cattle, or other animals could graze in a shared field or "Common" that was owned, not by any individual, but by the entire community. If we visit Boston today we can still see its Common—no longer a grazing field, but still a community resource.

Hardin pointed out that, in the setting of a communally shared grazing field, there is a near-irresistible temptation for each member of the community to add additional sheep or cattle to graze the common ground. This temptation can be illustrated mathematically. If there are n sheep grazing on the common meadow, each member of the community can consider the benefit and deficit of adding one additional sheep. For the community member adding another animal the benefit equals 1. The benefits to the individual are clear: he or she will have one more animal as a source of wool, milk, or meat for his family. What about the deficits or costs? These are less clear.

However, with some thought, the farmer realizes that the ability of the common grazing ground to support a flock of sheep is not without limit. Vegetation, water, or other resources may be exhausted. Upon further reflection, he also realizes that the burden of overpopulation is shared among *all* farmers ($1/[n + 1]$). So, the arithmetic for the individual shepherd is compelling.

While the benefits to the shepherd and his family are substantial, the detrimental effects are shared among a larger community. As a result, there is the irresistible urge to add yet another sheep. This logic is not lost on other members of the community, and the result is that more and more sheep are added until, eventually, the Common is so overcrowded that it cannot sustain the sheep population. The analogy to the human population is clear, hence the logic of Hardin's choice of this paradigm.

He likened this to a true Shakespearean tragedy, where with a given set of circumstances, the players move inexorably to an inevitable fate. To quote: "Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit—in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own interest, in a society that believes in the freedom of the Commons."

Can this tragedy be delayed or avoided altogether? Hardin pointed out that a typical response to this quandary is to search for technical solutions. For example, we can provide wells to bring more water to the surface, we can seed and fertilize the soil to provide additional vegetation, and we can even import food from elsewhere (creating the modern day feed lot). While these measures may help to sustain a greater sheep population, the arithmetic and the outcome remain unchanged. Hardin used this analogy to illustrate the difficulties of dealing with population expansion. He went on to suggest that there may not be a technical or technological solution. This was a bold suggestion for a biological scientist.

In science, it is axiomatic that problems have technical solutions. Solutions simply require diligent search, careful thought, and the right tools. With these, any problem can be solved. In effect, Hardin proposed that in a complex world we can encounter biologic problems for which there are no technical solutions.

Following Hardin's exposition, there was a flurry of academic discussion suggesting that the problem of the Commons is actually just one example of a wider class of environmental problems in which resources are not limitless, such as potable water, fossil fuels, and wildlife habitats. These were termed "common pool resource" (CPR) problems.

But what does this have to do with diabetes? I suggest that our 21st century environment is a CPR whose tragedy is the growing prevalence of diabetes and obesity and that, in turn, these two diseases are precipitating a crisis in another CPR—our health care financing system. First, imagine that the Common is the shared human environment in the developed world. This is an environment of wonderful creativity, energy, and enterprise. We are the beneficiaries of a large number of creative and useful accoutrements of our "common living environment." Some examples include the advances in agriculture and animal husbandry that have provided us with an abundant, inexpensive, safe, and readily available food supply.

In the developed world, starvation, which had plagued mankind through the millennia, has nearly vanished. Certainly this is a positive addition to our total living environment. To this same environment we can add the advances in transportation and locomotion. We can

travel across continents and oceans in a matter of hours, we have expansive networks of well-maintained roads that connect our cities and towns, and we have abundant automobiles to populate these roads. Certainly, again, these are positive additions to our living environment.

The automobile is only one of the wonderful machines that have been developed. We have manufactured a vast array of labor-saving products that reduce the physical work of farming, homemaking, manufacturing, and other occupations. Furthermore, with ever greater use of robotic devices, there is less need for human labor to make labor-saving devices. Additionally, we have developed new technologies to fuel our machines, whether from the sun, wind, fossil fuels, or even nuclear power. Finally, in our information age, we have shortened the time between the development of new devices and their broad availability. We don't even need to leave home to "go shopping" anymore.

Each of these advances is clearly good. Mathematically, these have a benefit value of 1, each adding to the quality of our lives. However, is there a downside that must be considered with any of these modern advances? And, if so, can we quantify it? Well, if there is a downside, it is difficult to quantify and generally perceived to be negligible. Thus, our society continues to add new tools, devices, gizmos, nutrients, and products to our environment. I suggest that we can consider this "environment" as a CPR.

However, we need now turn to the individual who lives in this aggregate environment and address whether there is only an "upside" to the culture of consumption. I think that this audience is only too aware of the downside created by an abundant food supply and our sedentary lifestyle. The increasing prevalence of obesity in the U.S. over the past decade is well illustrated by the BRFSS (Behavioral Risk Factor Surveillance System) survey data (2). I'm sure you've all seen the data that start at 1991, when only a handful of states had obesity rates of so much as 19% and the rest were 14% and under. The data for 2002, however, show that most states have obesity rates of over 20%, with some over 25%. There is a remarkable parallel in the increasing prevalence of diabetes, and comparable data exist for heart disease, kidney disease, eye disease, and other complications of diabetes and obesity.

We also appreciate that this is not a U.S. problem, or merely a North American problem, but a worldwide problem because diabetes is projected to increase by 72% by the year 2025. This estimate promises an expanding human tragedy, the tragedy of the CPR, that arises from our developed environment. Hopefully, this is an avoidable human tragedy.

Beyond this human element is a less personal, but closely allied, economic problem. Health care expenditures in the U.S. are yet another CPR. Put simply, it is in the interest of every individual to obtain the highest quality and most comprehensive health care services that are available. With great creativity and energy, we have advanced the art and science of medicine substantially in the past decade. Examples include diagnostic technology like magnetic resonance imaging and computed tomography angiography and therapeutic technology such as biologicals, classical pharmaceuticals, and new interventional procedures. With this, we continue to see annual increases in the costs of health care for all individuals. These costs are driven by both the skyrocketing price of managing chronic illnesses like diabetes and obesity and the rising prevalence of these disorders in the population; they presage an economic and health care crisis to come.

It is estimated that the costs of caring for people with diabetes and obesity will, as the population ages, be a dominant factor in bankrupting the Medicare trust fund by the year 2019. Our health and economic system simply cannot sustain these problems at their current rate of growth. And this problem is not unique to the U.S. As recently as last week, an expert panel predicted that the costs of obesity alone would collapse the British national health system.

So, we have two CPR problems. One is that our personal health is being adversely affected by the changes in our environment. The other is our ability to deal with the costs of this health issue. What has been done and what can be done about these problems? To help with this effort we need another animal friend: the ostrich.

Why the ostrich? Well, there are several interesting parallels between the ostrich and humans. Both are bipeds and walk upright throughout life. The ostrich stands 5–8 ft tall, weighs 250–350 lb, and lives up to 50 years.

Unlike humans, it has a very small brain approximately the size of its eyeball. Yet, despite its tiny brain, despite the fact that it cannot fly, and despite the fact that it lives its life walking about the African grassland looking like a large hors d'oeuvre to the carnivores around, it is among the oldest species of birds, having originated 70–90 million years ago. Compared to its human counterparts, at first glance it looks like an extreme example of central obesity. However, this is not why I have chosen the ostrich to illustrate a point.

I could have chosen it because it is the bird that many patients might be referring to when they describe how they "eat like a bird." This was also not the reason. Rather, I chose it because of its mythical ascribed behavior of putting its head in the sand when faced with a threat. This is not, in fact, how the ostrich reacts to a threat. In reality, it simply fluffs its feathers to look even larger, and if the aggressor is not discouraged, it simply runs away.

As we face the two CPR problems that I have outlined above, it is fair to ask whether we are reacting by putting our collective heads in the sand. As scientists and clinicians, we have sought and continue to seek a technological solution to the problem of overconsumption. Jeff Flier addressed this in part in a recent article in the journal *Cell* titled "Obesity Wars: Molecular Progress Confronts an Expanding Epidemic" (3). Dr. Flier, after detailing much of the wonderful progress that has been made in recent years in understanding genetic models of obesity in mice and humans, noted that "Scientific progress in elucidating the molecular physiology of energy balance and obesity has so far failed to mitigate the prevalence of this condition . . . This tension between expectations and reality has stimulated an increasingly vigorous public policy debate. Is it rational to pursue development of pharmaceutical antidotes to the existing environment or should we devote all efforts to changing the toxic environment?"

In Hardin's original formulation of the common resource problem, he expressed concern that many CPR problems lack technical solutions. The optimist in every scientist says that we will develop a solution. We will unravel the pathways of appetite and satiety regulation, energy

consumption and expenditure, and introduce therapies that will stem the rising tide of obesity and its offspring, type 2 diabetes. I hope and even trust that this will occur.

However, if we consider Hardin's caution, we must conclude that we cannot solely pursue a scientific solution.

It may elude us, as it has so far. Nor can we emulate the mythical behavior of the ostrich and put our heads in the sand. How then do we approach the problems of our unhealthful environment and our ongoing health care funding crises? In the original formulation of the tragedy of the Common, Hardin suggested several sociologic solutions that can be divided into three broad categories: *1*) education and information, *2*) inciting and cooperation, and *3*) regulation and legislation.

The first potential solution is simply to educate the affected population. The assumption underlying this is that, once individuals of goodwill understand the problem, they will make the correct choices. I would point out that there is an element of coercion within this. It is the coercion of guilt or conscience. In considering this as an option for dealing with the world population problem, Hardin was pessimistic. He felt that the combination of information and guilt would not overcome the perceived benefits of reproductive freedom. Certainly, we all recognize that education and information are vital first steps. But, do they get the job done?

Perhaps a little vignette here from the National Cholesterol Education Program is illustrative. As you are aware, this is a program that has been ongoing for almost 20 years managed by the Heart Institute of the National Institute Health. It is an extremely thoughtful, well-managed program. However, in a recent poll of randomly selected U.S. women quizzed on their knowledge of cholesterol, fewer than 25% knew what LDL cholesterol and HDL cholesterol were. Although it was not tested, I am confident that men would fare no better.

We clearly have much to do with regard to educating and informing the public regarding the behaviors that predispose to obesity and type 2 diabetes. But much experience suggests that education and information alone will not win the day.

What about incentives and cooperative behavior? In our description of the Common, it is clear that a major contributing factor to its collapse is that the incentives all lead to the exploitation of a common resource. This is demonstrably the case with our 21st century environment and the problems of diabetes and obesity. How can this be changed? I will come back to this but, first, a brief anecdote.

I recently had an opportunity to participate in the Department of Health and Human Services second annual "Steps to a Healthier U.S." symposium. One of the presenters, Lieutenant Governor Carney from Delaware, spoke about a statewide workplace- and school-based exercise program that they initiated to improve health of the citizens of Delaware. Incentives were provided in the form of gold or silver medals for participants depending on the level of participation. The Lieutenant Governor visited several sites in the state during an evaluation phase of the program.

At one workplace, he was informed that nearly 40% of individuals had participated in the program and some half of these appeared to be continuing with their exercise regimen after the program had ended. He was discouraged by what he perceived as a low level of participation, but was informed by staff that this was extraordinarily good for this type of program.

He subsequently visited a school and, while talking with one of the teachers, asked what the level of participation was among students. He was informed that it was over 95%. Very impressed, he asked for the reason for this success. The teacher promptly responded "That's easy, we made them do it."

Clearly, regulation or legislation can be an effective form of motivation. But is this an option in a free society? Professor Hardin, in considering the world population problem, felt that regulation and legislation were likely the only effective tools because the incentives to act were so strong and for the individual's benefit. Indeed, in some cases, the urgent nature of the problem and the urgent need for intervention cause there to be few choices other than legislative interventions.

However, given more time and opportunities for planning and creativity, I suggest that motivation, incentives, and cooperation will provide a longer-term, more socially acceptable and desirable outcome. To illustrate this, I would like to use yet another animal model—in this case, the ant.

We are all familiar with ants and their ability to build communities and to work together in a seemingly cooperative manner. They are known for their industry and their problem-solving ability. These remarkable little creatures are able to accomplish feats we would consider to be impossible, such as the giant anthills (frequently 10–15 ft tall) that can be found at the edge of the Australian desert.

How do these little insects accomplish such seemingly prodigious feats? We're only coming to learn some of their tricks. But studying them has been informative in very surprising ways and has helped us solve extraordinarily difficult problems facing the human species. To illustrate, at a simple level, it has long been observed that if you watch a group of ants and put some food nearby, they quickly find the shortest pathway to the food and bring pieces back to the ant hill. Other ants coming out from the ant hill don't have to search for the food but already know the shortest path.

Only recently, it has been found that although the ants can't communicate geography to each other, they leave a "trail." That trail is a chemical, a pheromone that is deposited along the path when they initially find the food. Given several potential paths to follow, the shortest path will, with the passage of several additional ants, have the highest concentration of pheromone and therefore attract the next group of ants. This process reinforces itself until every new ant simply exits the ant hill and goes straight to the food, never having communicated directly with another ant or explored other paths.

Observing how the ant solves the problem of finding food, clever computer scientists have adapted this to complex problems, e.g., the traveling salesman problem. This is not the traveling salesman problem faced by the farmer or his daughter that may immediately come to mind. Rather, this is the problem of the salesman planning the route for his sales calls wanting to reach each client with the shortest distance traveled, wasting as little time as possible on travel to maximize time with the client. If he only wants to visit one, two, or three clients, we can each solve this with pencil, paper, and a calculator. It becomes more complex if we want to visit, for example, all the cities that have major league baseball teams while traveling the shortest possible distance.

This requires a computer; however,

as the problem becomes more complex, like attempting to route telephone calls through the least busy nodes in the MCI system, even our computers are taxed to their limit. By designing "mechanical ants" who leave artificial "pheromones" indicating the path they have taken, the time for travel, and snags encountered along the way, and by setting loose "swarms" of these ants, computer scientists have developed solutions to the complex network problems of telephone, Internet, and automobile traffic (4).

I am not suggesting that the ant, either native or mechanical, offers the solution to the dual CPRs we face in our diabetes/obesity-producing environment or our health care–financing crises. I use them as examples of how, in nature, seemingly simple creatures solve enormously complex problems.

The hallmarks of the ant are its industry, cooperation, and the clever ways they have evolved to solve their everyday problems of food, shelter, and propagation of the species. We have seen that society in the 21st century increasingly threatens our health precisely because of our success in mastering our environment. There is a seemingly inexorable movement to improve convenience and accessibility and to ease the burden of work in life, which paradoxically leads us to the other, less anticipated, but adverse outcomes of obesity and diabetes. This is the tragedy of our Common.

The tragedy is individual. It limits both the quality and quantity of life. The tragedy is communal as it will bankrupt our health care system. The tragedy is also avoidable. Perhaps technology holds the key. But through societal changes, it is certainly possible.

What is needed for this to occur? First, there is attention to this multidimensional problem. We cannot emulate the mythical ostrich behavior by putting our head in the sand and ignoring the problem. Education is a start, but not a solution. I predict that regulation through legislation on a broad scale will be unacceptable and will not succeed alone. However, used cautiously, and in selected arenas (particularly when children are involved), it will be useful.

In closing, we need the creativity and the willfulness of the ant. We need to act as a community to solve problems that appear almost too complex by providing incentives and motivation. We need initiatives such as reducing insurance rates for sustaining healthful habits like smoking cessation, weight loss, exercise, and routine health exams. Or initiatives such as "health days" off from work for similar changes in behavior. We can use technology if it is available, but we cannot rely on technology alone for a solution.

Providing incentives for healthful behaviors to achieve communally desired outcomes appears to hold hope and promise, but requires creativity, courage, and the ant's determination. So we must persevere; we must take our collective heads out of the sand if we hope to stem this rising tide of diabetes and obesity in our 21st century common resource pool.

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