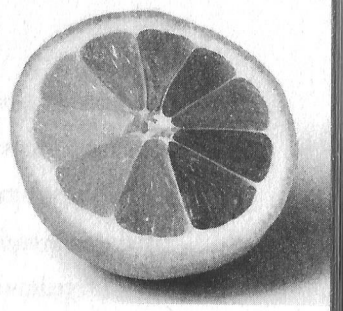
adopted by farmers is a bit frightening because the public is so unaware. Fewer than 2 percent of Americans work on a farm. Thus many find it difficult to understand why farmers adopt certain practices or technologies or what problems they may be solving when they do. Getting their perspectives can help shed some light. Moreover, as I will discuss, food and agriculture innovation doesn't come only from Monsanto, Cargill, and McDonald's. It comes from students, nonprofit scientists, university professors, and struggling entrepreneurs. Fostering an environment that is hostile to innovation and growth in food and agriculture not only thwarts the plans of Big Food but also makes it harder for scientists to get their innovations to market.

If I accomplish nothing else with this book, I hope a few young people might see a new way to effect food change. Yes, take classes in food journalism and environmental sustainability. But don't forget mathematics, biology, geography, engineering, and genetics. Ironically, the greatest outcomes from study of the natural sciences may well be all the unnatural things we learned to create: planes, cars, iPhones, air conditioning, and vaccines. We may romanticize the past, but most of us would not wish to be born in 1800. Changes in automotive, medical, computing, communications, *and* agricultural technology deserve the credit. Life—particularly in the realm of eating—*is* substantially better today than it was in our great grandparents' time. And, if history is our guide, it will become better still. Let me tell you how.



2

The Price of Happy Hens

When I was in college, one of my food science professors would often tell us that eggs were a near-perfect food. They are a complete source of protein, containing all the essential amino acids that our body can't make on its own. Fear of cholesterol caused a significant reduction in per-capita egg consumption throughout the 1960s, 1970s, and 1980s, but the latest report from the Dietary Guidelines Advisory Committee (the group responsible for creating the food pyramid and MyPlate) suggests those fears were unfounded and now says that "cholesterol is not a nutrient of concern."[1]

Not only are eggs nutritious, but it's hard to imagine how we could make some foods without them. Obviously, dishes like omelets and deviled eggs would have to go, but eggs are also the crucial ingredient in mayonnaise and salad dressing: they bind the water and vinegar to the oil. Hollandaise and bearnaise sauces,

spaghetti carbonara, quiche, cake, and pie all rely on eggs as a key ingredient.

New companies like Hampton Creek, the maker of Just Mayo, are trying to replace the egg with a specially engineered mix of yellow pea proteins.[2] It's too early to tell how successful Just Mayo might be, but previous efforts to sell egg substitutes haven't gained much traction. For now it appears our eggs will come from chickens. A lot of chickens. In 2014 the United States was home to more than 300 million hens, who laid 86.9 billion eggs for our dinner table.[3] Add it all up and the average American ate about 260 eggs last year—an amount roughly equal to what a single chicken lays in a year.[4]

We tend to have romantic views about the lives of the chickens laying all these eggs. That is, if we think about it at all. Most consumers have little idea of how eggs are produced, and the public tends to have an idealized view of agricultural production. For example, a colleague and I asked several hundred consumers what percentages of eggs in the United States are laid in cage versus cage-free systems. On average the respondents thought only 37 percent of eggs come from cage systems. The reality is that more than 90 percent do.[5] Moreover, after we gave consumers unbiased information about different types of animal housing conditions on U.S. farms, more than 70 percent of consumers reported having greater concerns about the well-being of farm animals.

It seems the more people learn about the living conditions of farm animals—particularly egg-laying hens—the more concerned they become. Sometimes these concerns translate into political action.

In November 2008 Californians went to the polls to vote for a new president. Sixty-three percent of those voters also chose to give egg-laying chickens in the state a new home. As in the rest of the country, hens in California lived in so-called battery cages so small that the hens cannot completely stretch their wings. Hens living in these housing systems typically have about sixty-seven square inches of space—which is 28 percent less space than a typical 8.5-by-11-inch sheet of paper.

I suspect most people would applaud the mandated space increase as self-evidently positive. As it turns out, the story is more complex.

One problem is that Californians used the political process to ban a practice that they routinely embrace in the marketplace. Even before the vote, virtually every major grocery store sold cage-free and organic eggs. Yet fewer than 10 percent of Californians were willing or able to pay the extra cost for eggs produced that way (cage-free and organic eggs were 20 to 80 percent more expensive than eggs produced by caged hens in California).[6] The result was that voters told California egg farmers to adopt a more expensive production system without sufficient compensation from consumers to cover the costs.

This vote-buy paradox is no academic quandary for Tom Silva, vice present at JS West, a 106-year-old company owned by a family and its employees and based in Modesto, California.[7] Silva is responsible for the production and well-being of about 1.5 million hens housed at farms owned by the company.[8] Silva could choose to simply give hens more space, but to do so would entail higher costs. Higher costs would curtail egg consumption,

particularly among lower-income consumers. Did I mention the nutritional value of eggs?

In fact, the new California law forces Silva and all other egg farmers in the state to incur higher costs if they want to stay in business, even though they are unlikely to reap any additional money from the market. Silva and other egg producers in California soon realized that the new law would put them at a cost disadvantage in relation to egg producers in Arizona, Idaho, and Iowa.

When the voters approved the proposition, nothing prevented California grocery stores from simply importing the less expensive battery-cage eggs from other states that had no such law.

Not surprisingly, California egg farmers barred from producing battery-cage eggs soon convinced the state legislature to outlaw grocery stores from selling these sorts of eggs as well. Whether the sales ban can withstand legal challenges that argue it violates the Commerce Clause of the Constitution remains to be seen. What is clear is that California farmers are struggling to figure out exactly how to house their chickens. And because California is such a large state (and imports a large number of eggs from other states), the laws there are affecting egg farmers throughout the country. In fact, the state legislatures of Oregon and Washington subsequently passed their own laws regarding hen housing.

The answer to the conundrum might seem simple. Why not simply adopt the cage-free production systems that provide high-end eggs to places like Whole Foods? When we see cage-free eggs in the store, with their fancier packaging, brown shell, and

invariably higher price tag, it's easy to imagine hens frolicking in a scene from a children's storybook. Old MacDonald had a farm, and it was a cage-free farm. But we don't live in a storybook world.

Typical cage-free systems (often called barn or aviary systems) provide hens with much more space than do the cage systems. The barns allow the birds to exhibit natural behaviors like scratching and dust bathing, and they provide nesting areas for laying eggs. But they are far from the paradise many people envision. As Silva put it, "Cage-free isn't what most people think it is."

The barns or aviaries are often chaotic, dusty, and smelly. Mortality rates for cage-free hens can be twice as high as those for hens in cages. So even though the hens have more amenities and freedom than in the battery-cage system, they die at a much higher rate. Some of that is a result of more fighting (the phrase "pecking order" is not some abstraction but a reality in hen houses). Higher death rates are also partially attributable to the different breeds of chickens typically used in cage-free systems, Rhode Island Reds, which lay brown eggs, whereas White Leghorns, which lay white eggs, are typically used in cage systems. But the higher mortality in the cage-free systems can also be partially attributed to conditions that are less sanitary. Air quality is particularly bad, as are particulate matter emissions. This is bad news for the birds, and many employees also don't like it. I've talked to large-scale egg farmers who have both cage and cage-free systems, and most prefer the cage. In addition, cage-free systems have higher carbon footprints and produce eggs that are 30 to 40 percent more expensive than eggs from cage systems.[9]

If all that's a bit depressing, maybe all of us should stop by Williams-Sonoma the next time we're at the mall. Last time I checked the catalog, you could get a backyard cage big enough for about six hens that will run you $300 to $1,500.[10] No doubt backyard chickens have become fashionable. My neighbors have some. Their eggs are tasty, and the hens are fun to watch. The girls look like they're enjoying themselves as they roam around the yard. Except when the temperature drops below freezing. Or when the mercury tops out at more than 100 degrees for months on end. Or when the hawks, coyotes, foxes, or neighborhood dogs come prowling.

There's a reason farmers started bringing their hens indoors decades ago. It wasn't because they were evil "factory farmers" but because they could provide a safer and more stable environment for the hens. It also allowed the farmers to more closely monitor the hens' diets. Eating bugs and grass and dirt is all fine and well—and these varied feedstuffs can produce tastier eggs—but such diets can also convey parasites and disease. One of the big concerns is the spread of avian influenza (or bird flu) through backyard chickens.[11] In 2015 millions of turkeys and chickens died or were euthanized because their flocks were infected with avian influenza thought to have been spread by wild birds.[12] I'm not necessarily trying to dissuade backyard chicken owners, but land, space, time, knowledge, and income constraints mean most Americans aren't going to have backyard hen houses. Trying to imagine how each and every American could get their annual consumption of 260 affordable eggs from backyard hens boggles the mind, and the very notion stretches credulity.

Is there a middle ground? An innovative solution?

Silva thinks so. He helped JS West become the first egg producer in the United States to adopt a new kind of housing system—an enriched, or colony, cage system (sometimes also referred to as a furnished or modified cage). Silva realized the new California laws would dictate change, but simply adopting the cage-free aviaries didn't seem like the right approach for many of the reasons I've discussed. Silva and JS West looked east toward Europe. More than a decade before Californians decided to outlaw battery cages, several European countries had done the same. Aware of the pushback against the battery cage system, animal welfare researchers in Europe had been working for years on alternatives that could combine the advantages of the cage system with the advantages of the cage-free systems while avoiding some of the worst drawbacks of each.[13] Jon Bareham, a British animal welfare researcher, proposed a "get-away cage" in the late 1970s.[14] The idea was to make a cage that had perches and nests on different levels where hens could get away from attacks by bullying birds and nest in a secluded place. His ideas were further explored and studied by Dutch and German scientists.[15] The development of enriched cages that included furnishings like perches, scratching areas, and nesting areas ultimately was brought about by Mike Appleby and others at the Poultry Research Centre in Edinburgh, Scotland.[16]

Silva traveled to Europe to take a look at the enriched cage system. They are conspicuously bigger and more spacious than battery cages: the enriched cages provide 73 percent more space per hen. Although the set-up differs from farm to farm, a typical

enriched cage provides about 15 percent more space than a king-sized mattress.[17] The much larger cage is home to sixty hens—providing about 116 square inches per hen instead of 67.

In a typical battery-cage system, hens lay their eggs on a slanted wire floor (the eggs roll to the edge of the cage, where they fall onto a conveyer belt). It is the same wire floor on which the hens routinely stand. In contrast, hens in enriched cages may be on perches mounted over a wire floor or in a staging area with a mat for scratching, or they may be in a secure nesting area when they lay their eggs. The hens must like the nests because 95 percent of the time they enter the nesting area to lay their eggs, which gently roll onto a conveyer belt before being whisked away into an adjacent sorting and washing room.[18]

Unlike the barren environment in the battery cages, the enriched colony cages have the mat area that allows the hens to exercise their natural urge to scratch. Also available are perches that allow the hens to get up off the wire floor. In addition to the nests, the perches are a popular sleeping area for the hens. Running underneath the colony cage is a conveyor belt that removes the manure and keeps it away from the birds.

The enriched colony cages aren't perfect, and some animal advocacy groups think they don't go far enough. But they're an innovative compromise. Indeed, two groups that are often foes—the Humane Society of the United States (HSUS) and the United Egg Producers—worked together for a time to try to make the enriched cage system a national standard.[19]

Silva is proud of the new barns he helped build at JS West, and the company plans to build more. The company is so proud,

in fact, that its website has videos of the operation and streaming web cameras in its barns so that customers can check in at any time to see how hens are being treated.[20] In an era when consumers demand greater transparency, JS West—through the power of the Internet—has provided it. This is more transparency than you'd get from a vendor at a farmers' market. But transparency isn't always appreciated. Silva says he sometimes receives angry or negative comments about the live camera feed (some of it likely from coordinated efforts by activist groups). Some of the outrage reflects our agrarian idealism, while other protesters are simply letting the perfect be the enemy of the good.

None of that is to say we can't do better. The challenge is that the choice between free-range, cage-free, and battery-cage housing entails tough trade-offs between egg affordability, worker health, hen mortality, and hens' freedom of movement. The way around these trade-offs is innovation. The enriched colony cages give the hens more room and amenities without the spike in mortality and dust that tends to come with the cage-free systems—all at a cost only somewhat higher than what we expect to pay for eggs.

More innovation is possible. For example, one of the downsides of the enriched colony cage system is that hens don't have access to the outdoors. My research suggests that we humans tend to think outdoor access is an important component of animal welfare.[21] Yet we're probably suffering a bit from anthropomorphism. It's not that hens wouldn't like to go outside from time to time, only that outdoor access ranks relatively low among the factors that influence hen welfare. One scientific study, for

example, ranked twenty-five different issues that could affect hen well-being, and outdoor access, or the ability to range free, ranked only nineteenth. Having nests is three times more important than access to the outdoors with ample shelter, and having a dust-bathing area is twice as important in boosting hen welfare.[22] Thus, if we want to provide hens with outdoor access, we need to do it in a way that actually improves hen welfare in an affordable and responsible manner.

One group of Dutch researchers has been working to create just such a system—the Roundel (the eggs are sold in a circular, biodegradable carton under the name Rondeel).[23] The name comes from the shape of the circular barn devised by researchers at Wageningen University, one of the top agricultural universities in the world. The circular barn is divided into different slices like a pie, with each slice offering a different amenity for the hen. One slice is for nesting, another for perching, and another for indoor foraging and dust bathing. The center of the pie houses the egg collection, cleaning, and storage operation. One slice of the pie is reserved for trucks bringing in feed and taking away eggs. Surrounding the circular barn (minus the slice reserved for transportation) are fenced-off areas that provide outdoor access and that can be open or closed depending on weather conditions or threats of avian influenza.

The Roundel is the Ritz Carlton of hen living. Hens have virtually all the freedoms and amenities they'd want from the wild but with ample feed and without any of the dangers from predators or hardships from adverse weather. The Roundel also comes with a luxury hotel price. When I checked the prices of eggs in a

large Amsterdam supermarket, a round-pack of seven eggs from Rondeel cost $2.23, or about $0.31 per egg. There were much less expensive eggs for sale at the store, such as the plain carton of white eggs selling for $0.14 per egg, but there were also a couple more expensive organic (or "bio," as the Europeans call it) egg cartons with a sticker price of more than $0.34 per egg.[24] There isn't yet much research on the environmental and animal welfare impacts of the Roundel system, and it remains unclear whether further innovation can bring the costs down to a more affordable level. Yet these sorts of science-led innovations have the potential to improve the lives not only of the hens but of us as well.

* * *

There also are some exciting innovations in hog and dairy cattle housing. However, new housing systems or more transparency are unlikely to address all the concerns about animal welfare. Even though many people appreciate the changes being made at places like JS West, Silva lacks a way to recoup his company's investment in the improvements in hen well-being because many people aren't willing to pay a sufficient amount to offset the extra costs. After three years of trying to separately brand and market eggs produced in the enriched cage system, JS West gave up. Silva said the least expensive eggs sell the best, and it was tough to justify the added marketing costs, especially if, after the change in law in California, the enriched-cage eggs become the lowest-common denominator commodity egg.

The current market environment poses an altogether different challenge for animal advocates. Some of the people most

passionate about farm animal living conditions don't eat meat or eggs. A vegan who is troubled by farm production practices can't switch from cage to cage-free eggs. Nor can they eat less meat. They aren't buying any to begin with. How can the vegetarian, vegan, or infrequent carnivore encourage the changes they want in the food system? It is not surprising that these folks turn to protest, activism, the courts, and the ballot box in an effort to improve farm animal welfare.

Usually when we want something, we search the Internet or head to the supermarket to find someone willing to sell it to us. We may not always make a purchase if the price is high, but we know we can generally turn to the marketplace to find the things we want. The profit incentives embedded in the market economy prompt entrepreneurs to find, create, and manufacture the things we want to buy.

The crux of the problem is that it is not possible to directly buy animal welfare. You can buy cage-free eggs, but—at least at present—you can't directly buy happier hens. What we need, then, is a market that allows us to directly buy the thing we want, improved animal well-being, whether we want eggs or milk or bacon—or not.

If all this seems a bit far-fetched, perhaps it might be useful to consider an analogous market: the market for pollution. When coal plants make electricity, they also produce pollution, an output not traded in the market. Back in the 1960s a few economists proposed "pollution trading" as a more effective way to deal with environmental problems than command-and-control policies that dictate which technology can be used or how much

pollution can be emitted. Many of these ideas came to fruition with the passage of the 1990 Clean Air Act, which established the first large-scale tradable emissions permits to curb the sulfur emissions responsible for acid rain. The program set a cap on the emissions that a power company could emit, but the policy allowed those companies wishing to generate more pollution than the cap to buy "allowances" from those companies that produced less pollution. In so doing, the policy provides a financial incentive for power companies to adopt the lowest-cost methods of curbing pollution. The more energy efficient the company becomes, the fewer allowances it has to buy. If the power plants become efficient enough to fall under the cap, the company could even profit by selling allowances.

The emissions-trading markets have been heralded as a great success. For example, a group of MIT economists write,

> Not only did [the market trading program] more than achieve the [sulfur] emissions goal . . . it did so on time, without extensive litigation, and at a cost lower than had been projected. . . . We have learned that large-scale tradable permit programs can work roughly as the textbooks describe; that is, they can both guarantee emissions reductions and allow profit-seeking emitters to reduce total compliance costs.[25]

Similarly, the Harvard economist Robert Stavins has declared, "Market-based instruments for environmental protection—and, in particular, tradable permit systems—now enjoy proven successes in reducing pollution at low cost."[26]

It is possible to imagine a similar approach to animal welfare—a mandated minimal level of animal well-being (farms that have lower levels of animal welfare must buy allowances from other farms that provide higher levels of animal welfare), but purely voluntary schemes are also possible. One example is the active voluntary markets for carbon emissions aimed at curbing climate change.

At present no federal regulations force U.S. firms to limit carbon emissions and yet markets like the now-defunct Chicago Climate Exchange and the still-active European Climate Exchange allowed companies and municipalities to offset their carbon emissions by buying credits produced by farmers and forest owners willing to make changes to store and sequester carbon.

Some cities and municipalities participated in the exchanges in response to voter pressure to reduce carbon emissions. Many companies did the same as a part of green and sustainability initiatives promoted by shareholders and as a part of public relations campaigns. And many individuals purchased carbon offsets to salve their own conscience. Although these exchanges were voluntary, the world market for carbon trading involved more than $60 billion in trades in 2006.[27]

Today, if you want to counter the carbon impacts you create from flying, you too can buy carbon offsets. Offsetting the carbon impacts of one 6,000-mile flight will cost you a little more than $11 at carbonfund.org. The annual carbon impacts of eating beef can be offset for less than $10.[28] The organization uses the money to fund projects like planting trees that sequester carbon.

What does pollution trading have to do with animal welfare? Just as firms create carbon when making cars or electricity, farmers create animal welfare (both good and bad) when they make eggs and milk and bacon. If we can measure the level of animal welfare a farm provides, the farmer can receive a certain amount of credits—or animal well-being units (AWBUs), as I called them in a paper for the journal *Agriculture and Human Values,* where I introduced the topic.[29]

Once a farmer earns credits, the farmer can sell the credits to anyone wishing to improve animal welfare. In such a system people passionate about animal well-being have a direct and tangible means to get what they want. Such a system would achieve an overall level of animal well-being that balances the costs of providing higher levels of care with people's demand for it. The price of AWBUs would be determined by the interaction of buyers and sellers, and it would no doubt fluctuate over time in response to changes in demand for animal welfare and in response to changes in the costs of providing it.

Creating AWBUs may seem fine in theory, but is it possible to actually quantify animal well-being so that it could be tradable? Difficulties are involved in such a calculation, but they are not insurmountable, no more so than, for example, measuring the carbon impacts of different types of food production. A variety of approaches are available to determine the overall well-being of animals in housing conditions. These approaches range from expert opinion to simple checklists to formal models that rank various measures on the farm, with more weight given to those measures that scientific studies deem more important to animal

well-being. Numerous animal welfare auditing and certification programs are already in use, which suggests that companies and third-party certifiers are already quantifying the concept of animal welfare. It is true that people may differ in their subjective beliefs about the effect of certain factors on animal well-being (for example, how important is providing hens with nests versus scratching space?), but this need not hinder the creation of a market for animal well-being any more than trading in the market for computers, cars, and food depends on subjective beliefs about the merits of brand names, *Consumer Reports* ratings, the recommendations of friends on Facebook, and so on. If potential traders don't like the way animal welfare is calculated in a particular market, they don't have to buy AWBUs, but this need not prohibit individuals or organizations from creating a market around a particular concept of farm animal welfare.

I prefer the use of mathematical models that look at specific, individual issues on a farm—the amount of space, air quality levels, animal health, and so on—and aggregate them to create an overall score related to the well-being of that farm's animals.[30] For example, at the high end, farms where animals have ample space, food, and access to amenities and are free from stress and disease might get a score of one hundred, whereas farms with high mortality and high injury rates, and where animals are housed in cramped and austere conditions, might get a score of zero. Farms with intermediate conditions would receive intermediate scores. These scores could be used, along with the number of animals on the farm, to assign a certain number of AWBUs to the farmer.

Once in possession of the AWBUs, the farmer can bring them to market and offer to sell them to any willing buyer.

The potential buyers of AWBUs are numerous and diverse. People donate billions of dollars to charities each year, and it is plausible that donors might use some of this money, either directly or through the charities to which they donate, to purchase AWBUs. Take, for example, the Humane Society of the United States. The HSUS has more than 2.2 million Facebook fans and reported donations in excess of $186 million in 2014.[31] Some of this money was spent in legislative battles and in other public relations campaigns that, at best, have an uncertain and indirect effect on animal well-being. Supporters of the 2008 California ballot measure that outlawed the smallest battery cages spent $5.2 million to convince voters to approve it.[32] Some of the HSUS's $186 million budget, or the $5.2 million spent by supporters of the California iniative, could have been spent on AWBUs, which would have had a certain and direct effect on animal well-being.

The HSUS is only one of many animal advocacy organizations that spend millions each year attempting to improve the well-being of farm animals. However, these organizations are not the only potential buyers of AWBUs. Companies like McDonald's and Walmart, for example, might want to make public statements about their commitments to animal well-being by buying AWBUs at a volume proportionate to their use of animal products. And, of course, any individual might buy AWBUs if she wishes to "offset" the impacts of egg purchases. Even if a

consumer doesn't buy eggs, she may want to buy AWBUs to improve hen well-being.

Farm organizations have little reason to fight the creation of a voluntary market for AWBUs. The ability to profit is all the incentive a farmer would need to participate. For example, many farmers have completed costly processes to qualify for certification programs, adopted organic practices, or have stopped using growth promoters in animal production for no other reason than that some consumers are willing to pay for these sorts of foods. If creating more AWBUs yields more profit, you can bet some progressive farmers will sign up.

I've presented these ideas to both animal production groups and members of animal advocacy organizations. By and large, farmers and ranchers have liked the idea, especially if it's voluntary. After all, if they don't like the program, they don't have to participate. I've received more pushback from the philosophers and ethicists who advocate for sweeping changes in the way we treat animals. They say things like, "Well-being is infinitely valuable because all animals deserve humane treatment" or "We need to recognize that there are some things that money can't buy and other things that money can buy but shouldn't." But some of this reflects an all-or-nothing mentality. We are unlikely to reach utopia in the near future, but we can make incremental improvements in animal well-being.

The reality is that the vast majority of Americans eat meat, dairy, and eggs. Current levels of animal welfare are already determined by a market. The meat market. Thus the question isn't whether markets should dictate farm animal well-being but

rather what kind of market will dictate farm animal well-being. If we don't like how our current meat, egg, and dairy markets have incentivized certain production practices that reduce animal welfare, we can harness that same power to create new, innovative markets that do just the opposite.