

THE  
OMNIVORE'S  
DILEMMA

A NATURAL HISTORY  
OF FOUR MEALS

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ONE

## THE PLANT

*Corn's Conquest*

### 1. A NATURALIST IN THE SUPERMARKET

Air-conditioned, odorless, illuminated by buzzing fluorescent tubes, the American supermarket doesn't present itself as having very much to do with Nature. And yet what is this place if not a landscape (man-made, it's true) teeming with plants and animals?

I'm not just talking about the produce section or the meat counter, either—the supermarket's flora and fauna. Ecologically speaking, these are this landscape's most legible zones, the places where it doesn't take a field guide to identify the resident species. Over there's your eggplant, onion, potato, and leek; here your apple, banana, and orange. Spritzed with morning dew every few minutes, Produce is the only corner of the supermarket where we're apt to think "Ah, yes, the bounty of Nature!" Which probably explains why such a garden of fruits and vegetables (sometimes flowers, too) is what usually greets the shopper coming through the automatic doors.

Keep rolling, back to the mirrored rear wall behind which the butch-

ers toil, and you encounter a set of species only slightly harder to identify—there's chicken and turkey, lamb and cow and pig. Though in Meat the creaturely character of the species on display does seem to be fading, as the cows and pigs increasingly come subdivided into boneless and bloodless geometrical cuts. In recent years some of this supermarket euphemism has seeped into Produce, where you'll now find formerly soil-encrusted potatoes cubed pristine white, and "baby" carrots machine-lathed into neatly tapered torpedoes. But in general here in flora and fauna you don't need to be a naturalist, much less a food scientist, to know what species you're tossing into your cart.

Venture farther, though, and you come to regions of the supermarket where the very notion of species seems increasingly obscure: the canyons of breakfast cereals and condiments; the freezer cases stacked with "home meal replacements" and bagged platonic peas; the broad expanses of soft drinks and towering cliffs of snacks; the unclassifiable Pop-Tarts and Lunchables; the frankly synthetic coffee whiteners and the Linnaeus-defying Twinkie. Plants? Animals?! Though it might not always seem that way, even the deathless Twinkie is constructed out of . . . well, precisely what I don't know offhand, but ultimately some sort of formerly living creature, i.e., a species. We haven't yet begun to synthesize our foods from petroleum, at least not directly.

If you do manage to regard the supermarket through the eyes of a naturalist, your first impression is apt to be of its astounding biodiversity. Look how many different plants and animals (and fungi) are represented on this single acre of land! What forest or prairie could hope to match it? There must be a hundred different species in the produce section alone, a handful more in the meat counter. And this diversity appears only to be increasing: When I was a kid, you never saw radicchio in the produce section, or a half dozen different kinds of mushrooms, or kiwis and passion fruit and durians and mangoes. Indeed, in the last few years a whole catalog of exotic species from the tropics has colonized, and considerably enlivened, the produce department. Over in fauna, on a good day you're apt to find—beyond beef—ostrich and quail and even bison, while in Fish you can catch not just salmon and

shrimp but catfish and tilapia, too. Naturalists regard biodiversity as a measure of a landscape's health, and the modern supermarket's devotion to variety and choice would seem to reflect, perhaps even promote, precisely that sort of ecological vigor.

Except for the salt and a handful of synthetic food additives, every edible item in the supermarket is a link in a food chain that begins with a particular plant growing in a specific patch of soil (or, more seldom, stretch of sea) somewhere on earth. Sometimes, as in the produce section, that chain is fairly short and easy to follow: As the netted bag says, this potato was grown in Idaho, that onion came from a farm in Texas. Move over to Meat, though, and the chain grows longer and less comprehensible: The label doesn't mention that that rib-eye steak came from a steer born in South Dakota and fattened in a Kansas feedlot on grain grown in Iowa. Once you get into the processed foods you have to be a fairly determined ecological detective to follow the intricate and increasingly obscure lines of connection linking the Twinkie, or the nondairy creamer, to a plant growing in the earth some place, but it can be done.

So what exactly would an ecological detective set loose in an American supermarket discover, were he to trace the items in his shopping cart all the way back to the soil? The notion began to occupy me a few years ago, after I realized that the straightforward question "What should I eat?" could no longer be answered without first addressing two other even more straightforward questions: "What am I eating? And where in the world did it come from?" Not very long ago an eater didn't need a journalist to answer these questions. The fact that today one so often does suggests a pretty good start on a working definition of industrial food: Any food whose provenance is so complex or obscure that it requires expert help to ascertain.

When I started trying to follow the industrial food chain—the one that now feeds most of us most of the time and typically culminates either in a supermarket or fast-food meal—I expected that my investigations would lead me to a wide variety of places. And though my journeys did take me to a great many states, and covered a great many

niles, at the very end of these food chains (which is to say, at the very beginning). I invariably found myself in almost exactly the same place: a farm field in the American Corn Belt. The great edifice of variety and choice that is an American supermarket turns out to rest on a remarkably narrow biological foundation comprised of a tiny group of plants that is dominated by a single species: *Zea mays*, the giant tropical grass most Americans know as corn.

Corn is what feeds the steer that becomes the steak. Corn feeds the chicken and the pig, the turkey and the lamb, the catfish and the tilapia and, increasingly, even the salmon, a carnivore by nature that the fish farmers are reengineering to tolerate corn. The eggs are made of corn. The milk and cheese and yogurt, which once came from dairy cows that grazed on grass, now typically come from Holsteins that spend their working lives indoors tethered to machines, eating corn.

Head over to the processed foods and you find ever more intricate manifestations of corn. A chicken nugget, for example, piles corn upon corn: what chicken it contains consists of corn, of course, but so do most of a nugget's other constituents, including the modified corn starch that glues the thing together, the corn flour in the batter that coats it, and the corn oil in which it gets fried. Much less obviously, the leavenings and lecithin, the mono-, di-, and triglycerides, the attractive golden coloring, and even the citric acid that keeps the nugget "fresh" can all be derived from corn.

To wash down your chicken nuggets with virtually any soft drink in the supermarket is to have some corn with your corn. Since the 1980s virtually all the sodas and most of the fruit drinks sold in the supermarket have been sweetened with high-fructose corn syrup (HFCS)—after water, corn sweetener is their principal ingredient. Grab a beer for your beverage instead and you'd still be drinking corn, in the form of alcohol fermented from glucose refined from corn. Read the ingredients on the label of any processed food and, provided you know the chemical names it travels under, corn is what you will find. For modified or unmodified starch, for glucose syrup and maltodextrin, for crystalline fructose and ascorbic acid, for lecithin and dextrose, lactic acid and ly-

sine, for maltose and HFCS, for MSG and polyols, for the caramel color and xanthan gum, read: corn. Corn is in the coffee whitener and Cheez Whiz, the frozen yogurt and TV dinner, the canned fruit and ketchup and candies, the soups and snacks and cake mixes, the frosting and gravy and frozen waffles, the syrups and hot sauces, the mayonnaise and mustard, the hot dogs and the bologna, the margarine and shortening, the salad dressings and the relishes and even the vitamins. (Yes, it's in the Twinkie, too.) There are some forty-five thousand items in the average American supermarket and more than a quarter of them now contain corn. This goes for the nonfood items as well: Everything from the toothpaste and cosmetics to the disposable diapers, trash bags, cleansers, charcoal briquettes, matches, and batteries, right down to the shine on the cover of the magazine that catches your eye by the checkout: corn. Even in Produce on a day when there's ostensibly no corn for sale you'll nevertheless find plenty of corn: in the vegetable wax that gives the cucumbers their sheen, in the pesticide responsible for the produce's perfection, even in the coating on the cardboard it was shipped in. Indeed, the supermarket itself—the wallboard and joint compound, the linoleum and fiberglass and adhesives out of which the building itself has been built—is in no small measure a manifestation of corn.

And us?

## 2. CORN WALKING

Descendants of the Maya living in Mexico still sometimes refer to themselves as "the corn people." The phrase is not intended as metaphor. Rather, it's meant to acknowledge their abiding dependence on this miraculous grass, the staple of their diet for almost nine thousand years. Forty percent of the calories a Mexican eats in a day comes directly from corn, most of it in the form of tortillas. So when a Mexican says "I am maize" or "corn walking," it is simply a statement of fact. The very substance of the Mexican's body is to a considerable extent a manifestation of this plant.

For an American like me, growing up linked to a very different food chain, yet one that is also rooted in a field of corn, not to think of himself as a corn person suggests either a failure of imagination or a triumph of capitalism. Or perhaps a little of both. It does take some imagination to recognize the ear of corn in the Coke bottle or the Big Mac. At the same time, the food industry has done a good job of persuading us that the forty-five thousand different items or SKUs (stock keeping units) in the supermarket—seventeen thousand new ones every year—represent genuine variety rather than so many clever rearrangements of molecules extracted from the same plant.

You are what you eat, it's often said, and if this is true, then what we mostly are is corn—or, more precisely, processed corn. This proposition is susceptible to scientific proof: The same scientists who glean the composition of ancient diets from mummified human remains can do the same for you or me, using a snip of hair or fingernail. The science works by identifying stable isotopes of carbon in human tissue that bear the signatures, in effect, of the different types of plants that originally took them from the air and introduced them into the food chain. The intricacies of this process are worth following, since they go some distance toward explaining how corn could have conquered our diet and, in turn, more of the earth's surface than virtually any other domesticated species, our own included.

Carbon is the most common element in our bodies—indeed, in all living things on earth. We earthlings are, as they say, a carbon life form. (As one scientist put it, carbon supplies life's quantity, since it is the main structural element in living matter, while much scarcer nitrogen supplies its quality—but more on that later.) Originally, the atoms of carbon from which we're made were floating in the air, part of a carbon dioxide molecule. The only way to recruit these carbon atoms for the molecules necessary to support life—the carbohydrates, amino acids, proteins, and lipids—is by means of photosynthesis. Using sunlight as a catalyst the green cells of plants combine carbon atoms taken from the air with water and elements drawn from the soil to form the

simple organic compounds that stand at the base of every food chain. It is more than a figure of speech to say that plants create life out of thin air.

But corn goes about this procedure a little differently than most other plants, a difference that not only renders the plant more efficient than most, but happens also to preserve the identity of the carbon atoms it recruits, even after they've been transformed into things like Gatorade and Ring Dings and hamburgers, not to mention the human bodies nourished on those things. Where most plants during photosynthesis create compounds that have three carbon atoms, corn (along with a small handful of other species) make compounds that have four: hence "C-4," the botanical nickname for this gifted group of plants, which wasn't identified until the 1970s.

The C-4 trick represents an important economy for a plant, giving it an advantage, especially in areas where water is scarce and temperatures high. In order to gather carbon atoms from the air, a plant has to open its stomata, the microscopic orifices in the leaves through which plants both take in and exhaust gases. Every time a stoma opens to admit carbon dioxide precious molecules of water escape. It's as though every time you opened your mouth to eat you lost a quantity of blood. Ideally, you would open your mouth as seldom as possible, ingesting as much food as you could with every bite. This is essentially what a C-4 plant does. By recruiting extra atoms of carbon during each instance of photosynthesis, the corn plant is able to limit its loss of water and "fix"—that is, take from the atmosphere and link in a useful molecule—significantly more carbon than other plants.

At its most basic, the story of life on earth is the competition among species to capture and store as much energy as possible—either directly from the sun, in the case of plants, or, in the case of animals, by eating plants and plant eaters. The energy is stored in the form of carbon molecules and measured in calories. The calories we eat, whether in an ear of corn or a steak, represent packets of energy once captured by a plant. The C-4 trick helps explain the corn plant's success in this competition:

Few plants can manufacture quite as much organic matter (and calories) from the same quantities of sunlight and water and basic elements as corn. (Ninety-seven percent of what a corn plant is comes from the air, three percent from the ground.)

The trick doesn't yet, however, explain how a scientist could tell that a given carbon atom in a human bone owes its presence there to a photosynthetic event that occurred in the leaf of one kind of plant and not another—in corn, say, instead of lettuce or wheat. The scientist can do this because all carbon is not created equal. Some carbon atoms, called isotopes, have more than the usual complement of six protons and six neutrons, giving them a slightly different atomic weight. C-13, for example, has six protons and seven neutrons. (Hence "C-13.") For whatever reason, when a C-4 plant goes scavenging for its four-packs of carbon, it takes in more carbon 13 than ordinary—C-3—plants, which exhibit a marked preference for the more common carbon 12. Greedy for carbon, C-4 plants can't afford to discriminate among isotopes, and so end up with relatively more carbon 13. The higher the ratio of carbon 13 to carbon 12 in a person's flesh, the more corn has been in his diet—or in the diet of the animals he or she ate. (As far as we're concerned, it makes little difference whether we consume relatively more or less carbon 13.)

One would expect to find a comparatively high proportion of carbon 13 in the flesh of people whose staple food of choice is corn—Mexicans, most famously. Americans eat much more wheat than corn—114 pounds of wheat flour per person per year, compared to 11 pounds of corn flour. The Europeans who colonized America regarded themselves as wheat people, in contrast to the native corn people they encountered; wheat in the West has always been considered the most refined, or civilized, grain. If asked to choose, most of us would probably still consider ourselves wheat people (except perhaps the proud corn-fed Midwesterners, and they don't know the half of it), though by now the whole idea of identifying with a plant at all strikes us as a little old-fashioned. Beef people sounds more like it, though nowadays chicken people, which sounds not nearly so good, is probably closer to

the truth of the matter. But carbon 13 doesn't lie, and researchers who have compared the isotopes in the flesh or hair of North Americans to those in the same tissues of Mexicans report that it is now we in the North who are the true people of corn. "When you look at the isotope ratios," Todd Dawson, a Berkeley biologist who's done this sort of research, told me, "we North Americans look like corn chips with legs." Compared to us, Mexicans today consume a far more varied carbon diet: the animals they eat still eat grass (until recently, Mexicans regarded feeding corn to livestock as a sacrilege); much of their protein comes from legumes; and they still sweeten their beverages with cane sugar.

So that's us: processed corn, walking.

### 3. THE RISE OF ZEA MAYS

How this peculiar grass, native to Central America and unknown to the Old World before 1492, came to colonize so much of our land and bodies is one of the plant world's greatest success stories. I say the plant world's success story because it is no longer clear that corn's triumph is such a boon to the rest of the world, and because we should give credit where credit is due. Corn is the hero of its own story, and though we humans played a crucial supporting role in its rise to world domination, it would be wrong to suggest we have been calling the shots, or acting always in our own best interests. Indeed, there is every reason to believe that corn has succeeded in domesticating us.

To some extent this holds true for all of the plants and animals that take part in the grand coevolutionary bargain with humans we call agriculture. Though we insist on speaking of the "invention" of agriculture as if it were our idea, like double-entry bookkeeping or the light-bulb, in fact it makes just as much sense to regard agriculture as a brilliant (if unconscious) evolutionary strategy on the part of the plants and animals involved to get us to advance their interests. By evolving certain traits we happen to regard as desirable, these species got themselves noticed by the one mammal in a position not only to spread their

genes around the world, but to remake vast swathes of that world in the image of the plants' preferred habitat. No other group of species gained more from their association with humans than the edible grasses, and no grass has reaped more from agriculture than *Zea mays*, today the world's most important cereal crop.

Corn's success might seem fated in retrospect, but it was not something anyone would have predicted on that day in May 1493 when Columbus first described the botanical oddity he had encountered in the New World to Isabella's court. He told of a towering grass with an ear as thick as a man's arm, to which grains were "affixed by nature in a wondrous manner and in form and size like garden peas, white when young." Wondrous, perhaps, yet this was, after all, the staple food of a people that would shortly be vanquished and all but exterminated.

By all rights, maize should have shared the fate of that other native species, the bison, which was despised and targeted for elimination precisely because it was "the Indians' commissary," in the words of General Philip Sheridan, commander of the armies of the West. Exterminate the species, Sheridan advised, and "[t]hen your prairies can be covered with speckled cattle and the festive cowboy." In outline Sheridan's plan was the plan for the whole continent: The white man brought his own "associate species" with him to the New World—cattle and apples, pigs and wheat, not to mention his accustomed weeds and microbes—and wherever possible helped them to displace the native plants and animals allied with the Indian. More even than the rifle, it was this biotic army that did the most to defeat the Indians.

But corn enjoyed certain botanical advantages that would allow it to thrive even as the Native Americans with whom it had coevolved were being eliminated. Indeed, maize, the one plant without which the American colonists probably would never have survived, let alone prospered, wound up abetting the destruction of the very people who had helped develop it. In the plant world at least, opportunism trumps gratitude. Yet in time, the plant of the vanquished would conquer even the conquerors.

Squanto taught the Pilgrims how to plant maize in the spring of

1621, and the colonists immediately recognized its value: No other plant could produce quite as much food quite as fast on a given patch of New World ground as this Indian corn. (Originally "corn" was a generic English word for any kind of grain, even a grain of salt—hence "corned beef"; it didn't take long for *Zea mays* to appropriate the word for itself, at least in America.) The fact that the plant was so well adapted to the climate and soils of North America gave it an edge over European grains, even if it did make a disappointingly earthbound bread. Centuries before the Pilgrims arrived the plant had already spread north from central Mexico, where it is thought to have originated, all the way to New England, where Indians were probably cultivating it by 1000. Along the way, the plant—whose prodigious genetic variability allows it to adapt rapidly to new conditions—made itself at home in virtually every microclimate in North America: hot or cold, dry or wet, sandy soil or heavy, short day or long, corn, with the help of its Native American allies, evolved whatever traits it needed to survive and flourish.

Lacking any such local experience, wheat struggled to adapt to the continent's harsh climate, and yields were often so poor that the settlements that stood by the old world staple often perished. Planted, a single corn seed yielded more than 150 fat kernels, often as many as 300, while the return on a seed of wheat, when all went well, was something less than 50:1. (At a time when land was abundant and labor scarce, agricultural yields were calculated on a per-seed-sown basis.)

Corn won over the wheat people because of its versatility, prized especially in new settlements far from civilization. This one plant supplied settlers with a ready-to-eat vegetable and a storable grain, a source of fiber and animal feed, a heating fuel and an intoxicant. Corn could be eaten fresh off the cob ("green") within months after planting, or dried on the stalk in fall, stored indefinitely, and ground into flour as needed. Mashed and fermented, corn could be brewed into beer or distilled into whiskey; for a time it was the only source of alcohol on the frontier. (Whiskey and pork were both regarded as "concentrated corn," the latter a concentrate of its protein, the former of its calories; both had the virtue of reducing corn's bulk and raising its price.) No part of the big

grass went to waste: The husks could be woven into rugs and twine; the leaves and stalks made good silage for livestock; the shelled cobs were burned for heat and stacked by the privy as a rough substitute for toilet paper. (Hence the American slang term “corn hole.”)

“Corn was the means that permitted successive waves of pioneers to settle new territories,” writes Arturo Warnan, a Mexican historian. “Once the settlers had fully grasped the secrets and potential of corn, they no longer needed the Native Americans.” Squanto had handed the white man precisely the tool he needed to dispossess the Indian. Without the “fruitfulness” of Indian corn, the nineteenth-century English writer William Cobbett declared, the colonists would never have been able to build “a powerful nation.” Maize, he wrote, was “the greatest blessing God ever gave to man.”

Valuable as corn is as a means of subsistence, the kernel's qualities make it an excellent means of accumulation as well. After the crop has supplied its farmer's needs, he can go to market with any surplus, dried corn being the perfect commodity: easy to transport and virtually indestructible. Corn's dual identity, as food and commodity, has allowed many of the peasant communities that have embraced it to make the leap from a subsistence to a market economy. The dual identity also made corn indispensable to the slave trade: Corn was both the currency traders used to pay for slaves in Africa and the food upon which slaves subsisted during their passage to America. Corn is the protocapitalist plant.

#### 4. MARRIED TO MAN

But while both the new and the native Americans were substantially dependent on corn, the plant's dependence on the Americans had become total. Had maize failed to find favor among the conquerors it risked extinction, because without humans to plant it every spring, corn would disappear from the earth in a matter of a few years. The novel cob-and-husk arrangement that makes corn such a convenient grain for us renders the plant utterly dependent for its survival on an animal in

possession of the opposable thumb needed to remove the husk, separate the seeds, and plant them.

Plant a whole corncob and watch what happens: If any of the kernels manage to germinate, and then work their way free of the smothering husk, they will invariably crowd themselves to death before their second set of leaves has emerged. More than most domesticated plants (a few of whose offspring will usually find a way to grow unassisted), corn completely threw its lot in with humanity when it evolved its peculiar husked ear. Several human societies have seen fit to worship corn, but perhaps it should be the other way around: For corn, we humans are the contingent beings. So far, this reckless-seeming act of evolutionary faith in us has been richly rewarded.

It is tempting to think of maize as a human artifact, since the plant is so closely linked to us and so strikingly different from any wild species. There are in fact no wild maize plants, and teosinte, the weedy grass from which corn is believed to have descended (the word is Nahuatl for “mother of corn”), has no ear, bears its handful of tiny naked seeds on a terminal rachis like most other grasses, and generally looks nothing whatsoever like maize. The current thinking among botanists is that several thousand years ago teosinte underwent an abrupt series of mutations that turned it into corn; geneticists calculate that changes on as few as four chromosomes could account for the main traits that distinguish teosinte from maize. Taken together, these mutations amounted to (in the words of botanist Hugh Illis) a “catastrophic sexual transmutation”: the transfer of the plant's female organs from the top of the grass to a monstrous sheathed ear in the middle of the stalk. The male organs stayed put, remaining in the tassel.

It is, for a grass, a bizarre arrangement with crucial implications: The ear's central location halfway down the stalk allows it to capture far more nutrients than it would up top, so suddenly producing hundreds of gigantic seeds becomes metabolically feasible. Yet because those seeds are now trapped in a tough husk, the plant has lost its ability to reproduce itself—hence the catastrophe in teosinte's sex change. A mutation this freakish and maladaptive would have swiftly brought the plant to an evo-



lutionary dead end had one of these freaks not happened to catch the eye of a human somewhere in Central America who, looking for something to eat, peeled open the husk to free the seeds. What would have been an unheralded botanical catastrophe in a world without humans became an incalculable evolutionary boon. If you look hard enough, you can still find teosinte growing in certain Central American highlands; you can find maize, its mutant offspring, anywhere you find people.

## 5. CORN SEX

Maize is self-fertilized and wind-pollinated, botanical terms that don't begin to describe the beauty and wonder of corn sex. The tassel at the top of the plant houses the male organs, hundreds of pendant anthers that over the course of a few summer days release a superabundance of powdery yellow pollen: 14 million to 18 million grains per plant, 20,000 for every potential kernel. ("Better safe than sorry" or "more is more," being nature's general rule for male genes.) A meter or so below await the female organs, hundreds of minuscule flowers arranged in tidy rows along a tiny, sheathed cob that juts upward from the stalk at the crotch of a leaf midway between tassel and earth. That the male anthers resemble flowers and the female cob a phallus is not the only oddity in the sex life of corn.

Each of the four hundred to eight hundred flowers on a cob has the potential to develop into a kernel—but only if a grain of pollen can find its way to its ovary; a task complicated by the distance the pollen has to travel and the intervening husk in which the cob is tightly wrapped. To surmount this last problem, each flower sends out through the tip of the husk a single, sticky strand of silk (technically its "style") to snag its own grain of pollen. The silks emerge from the husk on the very day the tassel is set to shower its yellow dust.

What happens next is very strange. After a grain of pollen has fallen through the air and alighted on the moistened tip of silk, its nucleus divides in two, creating a pair of twins, each with the same set of genes

but a completely different role to perform in the creation of the kernel. The first twin's job is to tunnel a microscopic tube down through the center of the silk thread. That accomplished, its clone slides down through the tunnel, past the husk, and into the waiting flower, a journey of between six and eight inches that takes several hours to complete. Upon arrival in the flower the second twin fuses with the egg to form the embryo—the germ of the future kernel. Then the first twin follows, entering the now fertilized flower, where it sets about forming the endosperm—the big, starchy part of the kernel. Every kernel of corn is the product of this intricate ménage à trois; the tiny, stunted kernels you often see at the narrow end of a cob are flowers whose silk no pollen grain ever penetrated. Within a day of conception, the now superfluous silk dries up, eventually turning reddish brown; fifty or so days later, the kernels are mature.\*

The mechanics of corn sex, and in particular the great distance over open space corn pollen must travel to complete its mission, go a long way toward accounting for the success of maize's alliance with humankind. It's a simple matter for a human to get between a corn plant's pollen and its flower, and only a short step from there to deliberately crossing one corn plant with another with an eye to encouraging specific traits in the offspring. Long before scientists understood hybridization, Native Americans had discovered that by taking the pollen from the tassel of one corn plant and dusting it on the silks of another, they could create new plants that combined the traits of both parents. American Indians were the world's first plant breeders, developing literally thousands of distinct cultivars for every conceivable environment and use.

Looked at another way, corn was the first plant to involve humans so intimately in its sex life. For a species whose survival depends on how well it can gratify the ever shifting desires of its only sponsor, this has proved to be an excellent evolutionary strategy. More even than other domesticated species, many of which can withstand a period of human

\*My account of the sex life of corn is drawn from Betty Fussell's *The Story of Corn* (1992) and Frederick Sargent's *Corn Plants* (1901).

neglect, it pays for corn to be obliging—and to be so quick about it. The usual way a domesticated species figures out what traits its human ally will reward is through the slow and wasteful process of Darwinian trial and error. Hybridization represents a far swifter and more efficient means of communication, or feedback loop, between plant and human; by allowing humans to arrange its marriages, corn can discover in a single generation precisely what qualities it needs to prosper.

It is by being so obliging that corn has won itself as much human attention and habitat as it has: The plant's unusual sexual arrangements, so amenable to human intervention, has allowed it to adapt to the very different worlds of Native Americans (and to their very different worlds, from southern Mexico to New England), of colonists and settlers and slaves, and of all the other corn-eating societies that have come and gone since the first human chanced upon that first teosinte freak.

But of all the human environments to which corn has successfully adapted since then, the adaptation to our own—the world of industrial consumer capitalism; the world, that is, of the supermarket and fast-food franchise—surely represents the plant's most extraordinary evolutionary achievement to date. For to prosper in the industrial food chain to the extent it has, corn had to acquire several improbable new tricks. It had to adapt itself not just to humans but to their machines, which it did by learning to grow as upright, stiff-stalked, and uniform as soldiers. It had to multiply its yield by an order of magnitude, which it did by learning to grow shoulder to shoulder with other corn plants, as many as thirty thousand to the acre. It had to develop an appetite for fossil fuel (in the form of petrochemical fertilizer) and a tolerance for various synthetic chemicals. But even before it could master these tricks and make a place for itself in the bright sunshine of capitalism, corn first had to turn itself into something never before seen in the plant world: a form of intellectual property.

The free corn sex I've described allowed people to do virtually anything they wanted with the genetics of corn except own them—a big problem for a would-be capitalist plant. If I crossed two corn plants to create a variety with an especially desirable trait, I could sell you my

special seeds, but only once, since the corn you grew from my special seeds would produce lots more special seeds, for free and forever, putting me out business in short order. It's difficult to control the means of production when the product you're selling can reproduce itself endlessly. This is one of the ways in which the imperatives of biology are difficult to mesh with the imperatives of business.

Difficult, but not impossible. Early in the twentieth century American corn breeders figured out how to bring corn reproduction under firm control, and to protect the seed from copiers. The breeders discovered that when they crossed two corn plants that had come from inbred lines—from ancestors that had themselves been exclusively self-pollinated for several generations—the hybrid offspring displayed some highly unusual characteristics. First, all the seeds in that first generation (F-1, in the plant breeder's vocabulary) produced genetically identical plants—a trait that, among other things, facilitates mechanization. Second, those plants exhibited heterosis, or hybrid vigor—better yields than either of their parents. But most important of all, they found that the seeds produced by these seeds did not “come true”—the plants in the second (F-2) generation bore little resemblance to the plants in the first. Specifically, their yields plummeted by as much as a third, making their seeds virtually worthless.

Hybrid corn now offered its breeders what no other plant at that time could: the biological equivalent of a patent. Farmers now had to buy new seeds every spring; instead of depending upon their plants to reproduce themselves, they now depended on a corporation. The corporation, assured for the first time of a return on its investment in breeding, showered corn with attention—R&D, promotion, advertising—and the plant responded, multiplying its fruitfulness year after year. With the advent of the F-1 hybrid, a technology with the power to remake nature in the image of capitalism, *Zea mays* entered the industrial age and, in time, it brought the whole American food chain with it.

## TWO

# THE FARM

### I. ONE FARMER, 129 EATERS

To take the wheel of a clattering 1975 International Harvester tractor, pulling a spidery eight-row planter through an Iowa cornfield during the first week of May, is like trying to steer a boat through a softly rolling sea of dark chocolate. The hard part is keeping the thing on a straight line, that and hearing the shouted instructions of the farmer sitting next to you when you both have wads of Kleenex jammed into your ears to muffle the diesel roar. Driving a boat, you try to follow the compass heading or aim for a landmark on shore; planting corn, you try to follow the groove in the soil laid down on the previous pass by a rolling disk at the end of a steel arm attached to the planter behind us. Deviate from the line and your corn rows will wobble, overlapping or drifting away from one another. Either way, it'll earn you a measure of neighborly derision and hurt your yield. And yield, measured in bushels per acre, is the measure of all things here in corn country.

The tractor I was driving belonged to George Naylor, who bought it new back in the midseventies, when, as a twenty-seven-year-old, he returned to Greene County, Iowa, to farm his family's 470 acres. Naylor is a big man with a moon face and a scraggly gray beard. On the phone his gravelly voice and incontrovertible pronouncements ("That is just the biggest bunch of bullshit! Only the *New York Times* would be dumb enough to believe the Farm Bureau still speaks for American farmers!") led me to expect someone considerably more ornery than the shy fellow who climbed down from his tractor cab to greet me in the middle of a field in the middle of a slate-gray day threatening rain. Naylor had on the farmer's standard-issue baseball cap, a yellow chamois shirt, and overalls—the striped blue kind favored by railroad workers, about as un-intimidating an article of clothing as has ever been donned by a man. My first impression was more shambling Gentle Ben than fiery prairie populist, but I would discover that Naylor can be either fellow, the mere mention of "Cargill" or "Earl Butz" supplying the transformational trigger.

This part of Iowa has some of the richest soil in the world, a layer of cakey alluvial loam nearly two feet thick. The initial deposit was made by the retreat of the Wisconsin glacier ten thousand years ago, and then compounded at the rate of another inch or two every decade by prairie grasses—big bluestem, foxtail, needlegrass, and switchgrass. Tall-grass prairie is what this land was until the middle of the nineteenth century, when the sod was first broken by the settler's plow. George's grandfather moved his family to Iowa from Derbyshire, England, in the 1880s, a coal miner hoping to improve his lot in life. The sight of such soil, pushing up and then curling back down behind the blade of his plow like a thick black wake behind a ship, must have stoked his confidence, and justifiably so: It's gorgeous stuff, black gold as deep as you can dig, as far as you can see. What you can't see is all the soil that's no longer here, having been blown or washed away since the sod was broken; the two-foot crust of topsoil here probably started out closer to four.

The story of the Naylor farm since 1919, when George's grandfathers bought it, closely tracks the twentieth-century story of American agriculture, its achievements as well as its disasters. It begins with a farmer supporting a family on a dozen different species of plants and animals. There would have been a fair amount of corn then too, but also fruits and other vegetables, as well as oats, hay, and alfalfa to feed the pigs, cattle, chickens, and horses—horses being the tractors of that time. One of every four Americans lived on a farm when Naylor's grandfather arrived here in Churdan; his land and labor supplied enough food to feed his family and twelve other Americans besides. Less than a century after, fewer than 2 million Americans still farm—and they grow enough to feed the rest of us. What that means is that Naylor's grandson, raising nothing but corn and soybeans on a fairly typical Iowa farm, is so astoundingly productive that he is, in effect, feeding some 129 Americans. Measured in terms of output per worker, American farmers like Naylor are the most productive humans who have ever lived.

Yet George Naylor is all but going broke—and he's doing better than many of his neighbors. (Partly because he's still driving that 1975 tractor.) For though this farm might feed 129, it can no longer support the four who live on it: The Naylor farm survives by the grace of Peggy Naylor's paycheck (she works for a social services agency in Jefferson) and an annual subsidy payment from Washington, D.C. Nor can the Naylor farm literally feed the Naylor family, as it did in grandfather Naylor's day. George's crops are basically inedible—they're commodities that must be processed or fed to livestock before they can feed people. Water, water, everywhere and not a drop to drink: Like most of Iowa, which now imports 80 percent of its food, George's farm (apart from his garden, his laying hens, and his fruit trees) is basically a food desert.

The 129 people who depend on George Naylor for their sustenance are all strangers, living at the far end of a food chain so long, intricate, and obscure that neither producer nor consumer has any reason to know the first thing about the other. Ask one of those eaters where their steak

or soda comes from and she'll tell you "the supermarket." Ask George Naylor whom he's growing all that corn for and he'll tell you "the military-industrial complex." Both are partly right.

I came to George Naylor's farm as an unelected representative of the Group of 129, curious to learn who, and what, I'd find at the far end of the food chain that keeps me alive. There's no way of knowing whether George Naylor is *literally* growing the corn that feeds the steer that becomes my steak, or that sweetened my son's soft drink, or supplied the dozen or so corn-derived ingredients from which his chicken nugget is constructed. But given the complexly ramifying fate of a bushel of commodity corn, the countless forking paths followed by its ninety thousand kernels as they're dispersed across the nation's sprawling food system, the odds are good that at least one of the kernels grown on the Naylor farm has, like the proverbial atom from Caesar's dying breath, made its way to me. And if not me, then certainly you. This Iowa cornfield (and all the others just like it) is the place most of our food comes from.

## 2. PLANTING THE CITY OF CORN

The day I showed up was supposed to be the only dry one all week, so George and I spent most of it in the cab of his tractor, trying to get acquainted and get his last 160 acres of corn planted at the same time; a week or two later he'd start in on the soybeans. The two crops take turns in these fields year after year, in what has been the classic Corn Belt rotation since the 1970s. (Since that time soybeans have become the second leg supporting the industrial food system: It too is fed to livestock and now finds its way into two-thirds of all processed foods.) For most of the afternoon I sat on a rough cushion George had fashioned for me from crumpled seed bags, but after a while he let me take the wheel.

Back and forth and back again, a half a mile in each direction, planting corn feels less like planting, or even driving, than stitching an interminable cloak, or covering a page with the same sentence over and over

again. The monotony, compounded by the roar of a diesel engine well past its prime, is hypnotic after a while. Every pass across this field, which is almost but not quite dead flat, represents another acre of corn planted, another thirty thousand seeds tucked into one of the eight furrows being simultaneously etched into the soil by pairs of stainless steel disks; a trailing roller then closes the furrows over the seed.

The seed we were planting was Pioneer Hi-Bred's 34H31, a strain that the catalog described as "an adaptable hybrid with solid agronomics and yield potential." The lack of hype, notable for a seed catalog, probably reflects the fact that 34H31 does not contain the "YieldGard gene," the Monsanto-developed line of genetically engineered corn that Pioneer is currently pushing: The genetically modified 34B98, on the same page, promises "outstanding yield potential." Despite the promises, Naylor, unlike many of his neighbors, doesn't plant GMOs (genetically modified organisms). He has a gut distrust of the technology ("They're messing with three billion years of evolution") and doesn't think it's worth the extra twenty-five dollars a bag (in technology fees) they cost. "Sure, you might get a yield bump, but whatever you make on the extra corn goes right back to cover the premium for the seed. I fail to see why I should be lauding money for Monsanto." As Naylor sees it, GMO seed is just the latest chapter in an old story: Farmers eager to increase their yields adopt the latest innovation, only to find that it's the companies selling the innovations who reap the most from the gain in the farmer's productivity.

Even without the addition of transgenes for traits like insect resistance, the standard F-1 hybrids Naylor plants are technological marvels, capable of coaxing 180 bushels of corn from an acre of Iowa soil. One bushel holds 56 pounds of kernels, so that's slightly more than ten thousand pounds of food per acre; the field George and I planted that day would produce 1.8 million pounds of corn. Not bad for a day's work sitting down, I thought to myself that afternoon, though of course there'd be several more days of work between now and the harvest in October.

One way to tell the story of this farm is by following the steady upward arc in the yield of corn. Naylor has no idea how many bushels of corn per acre his grandfather could produce, but the average back in

1920 was about twenty bushels per acre—roughly the same yields historically realized by Native Americans. Corn then was planted in widely spaced bunches in a checkerboard pattern so farmers could easily cultivate between the stands in either direction. Hybrid seed came on the market in the late the 1930s, when his father was farming. "You heard stories," George shouted over the din of the tractor. "How they talked him into raising an acre or two of the new hybrid, and by god when the old corn fell over, the hybrid stood straight up. Doubled Dad's yields, till he was getting seventy to eighty an acre in the fifties." George has doubled that yet again, some years getting as much as two hundred bushels of corn per acre. The only other domesticated species ever to have multiplied its productivity by such a factor is the Holstein cow.

"High yield" is a fairly abstract concept, and I wondered what it meant at the level of the plant: more cobs per stalk? more kernels per cob? Neither of the above, Naylor explained. The higher yield of modern hybrids stems mainly from the fact that they can be planted so close together, thirty thousand to the acre instead of eight thousand in his father's day. Planting the old open-pollinated (nonhybrid) varieties so densely would result in stalks grown spindly as they jostle each other for sunlight; eventually the plants topple in the wind. Hybrids have been bred for thicker stalks and stronger root systems, the better to stand upright in a crowd and withstand mechanical harvesting. Basically, modern hybrids can tolerate the corn equivalent of city life, growing amid the multitudes without succumbing to urban stress.

You would think that competition among individuals would threaten the tranquility of such a crowded metropolis, yet the modern field of corn forms a most orderly mob. This is because every plant in it, being an F-1 hybrid, is genetically identical to every other. Since no individual plant has inherited any competitive edge over any other, precious resources like sunlight, water, and soil nutrients are shared equitably. There are no alpha corn plants to hog the light or fertilizer. The true socialist utopia turns out to be a field of F-1 hybrid plants.

Iowa begins to look a little different when you think of its sprawling fields as cities of corn, the land, in its own way, settled as densely as

Manhattan for the very same purpose: to maximize real estate values. There may be little pavement out here, but this is no middle landscape. Though by any reasonable definition Iowa is a rural state, it is more thoroughly developed than many cities: A mere 2 percent of the state's land remains what it used to be (tall-grass prairie), every square foot of the rest having been completely remade by man. The only thing missing from this man-made landscape is . . . man.

### 3. VANISHING SPECIES

A case can be made that the corn plant's population explosion in places like Iowa is responsible for pushing out not only other plants but the animals and then finally the people, too. When Naylor's grandfather arrived in America the population of Greene County was near its peak: 16,467 people. In the most recent census it had fallen to 10,366. There are many reasons for the depopulation of the American Farm Belt, but the triumph of corn deserves a large share of the blame—or the credit, depending on your point of view.

When George Naylor's grandfather was farming, the typical Iowa farm was home to whole families of different plant and animal species, corn being only the fourth most common. Horses were the first, because every farm needed working animals (there were only 225 tractors in all of America in 1920), followed by cattle, chickens, and then corn. After corn came hogs, apples, hay, oats, potatoes, and cherries; many Iowa farms also grew wheat, plums, grapes, and pears. This diversity allowed the farm not only to substantially feed itself—and by that I don't mean feed only the farmers, but also the soil and the livestock—but to withstand a collapse in the market for any one of those crops. It also produced a completely different landscape than the Iowa of today.

"You had fences everywhere," George recalled, "and of course pastures. Everyone had livestock, so large parts of the farm would be green most of the year. The ground never used to be this bare this long." For much of the year, from the October harvest to the emergence of the

corn in mid-May, Greene County is black now, a great tarmac only slightly more hospitable to wildlife than asphalt. Even in May the only green you see are the moats of lawn surrounding the houses, the narrow strips of grass dividing one farm from another, and the roadside ditches. The fences were pulled up when the animals left, beginning in the fifties and sixties, or when they moved indoors, as Iowa's hogs have more recently done; hogs now spend their lives in aluminum sheds perched atop manure pits. Greene County in the spring has become a monotonous landscape, vast plowed fields relieved only by a dwindling number of farmsteads, increasingly lonesome islands of white wood and green grass marooned in a sea of black. Without the fences and hedgerows to slow it down, Naylor says, the winds blow more fiercely in Iowa today than they once did.

Corn isn't solely responsible for remaking this landscape: It was the tractor, after all, that put the horses out of work, and with the horses went the fields of oats and some of the pasture. But corn was the crop that put cash in the farmer's pocket, so as corn yields began to soar at midcentury, the temptation was to give the miracle crop more and more land. Of course, every other farmer in America was thinking the same way (having been encouraged to do so by government policies), with the inevitable result that the price of corn declined. One might think falling corn prices would lead farmers to plant less of it, but the economics and psychology of agriculture are such that exactly the opposite happened.

Beginning in the fifties and sixties, the flood tide of cheap corn made it profitable to fatten cattle on feedlots instead of on grass, and to raise chickens in giant factories rather than in farmyards. Iowa livestock farmers couldn't compete with the factory-farmed animals their own cheap corn had helped spawn, so the chickens and cattle disappeared from the farm, and with them the pastures and hay fields and fences. In their place the farmers planted more of the one crop they could grow more of than anything else: corn. And whenever the price of corn slipped they planted a little more of it, to cover expenses and stay even. By the 1980s the diversified family farm was history in Iowa, and corn was king.

(Planting corn on the same ground year after year brought down the predictable plagues of insects and disease, so beginning in the 1970s Iowa farmers started alternating corn with soybeans, a legume. Recently, though, bean prices having fallen and bean diseases having risen, some farmers are going back to a risky rotation of “corn on corn.”)

With the help of its human and botanical allies (i.e., farm policy and soybeans), corn had pushed the animals and their feed crops off the land, and steadily expanded into their paddocks and pastures and fields. Now it proceeded to push out the people. For the radically simplified farm of corn and soybeans doesn't require nearly as much human labor as the old diversified farm, especially when the farmer can call on sixteen-row planters and chemical weed killers. One man can handle a lot more acreage by himself when it's planted in monoculture, and without animals to care for he can take the weekend off, and even think about spending the winter in Florida.

“Growing corn is just riding tractors and spraying,” Naylor told me; the number of riding and spraying days it takes to raise five hundred acres of industrial corn can probably be counted in weeks. So the farms got bigger, and eventually the people, whom the steadily falling price of corn could no longer support anyway, went elsewhere, ceding the field to the monstrous grass.

Today Churdan is virtually a ghost town, much of its main street shuttered. The barbershop, a food market, and the local movie theater have all closed in recent years; there's a café and one sparsely stocked little market somehow still hanging on, but most people drive the ten miles to Jefferson to buy their groceries or pick up milk and eggs when they're getting gas at the Kumm & Go. The middle school can no longer field a baseball team or put together a band, it has so few students left, and it takes four local high schools to field a single football team: the Jefferson-Scranton-Paton-Churdan Rams. Just about the only going concern left standing in Churdan is the grain elevator, rising at the far end of town like a windowless concrete skyscraper. It endures because, people or no people, the corn keeps coming, more of it every year.

#### 4. THERE GOES THE SUN

I've oversimplified the story a bit; corn's rapid rise is not quite as self-propelled as I've made it sound. As in so many other “self-made” American successes, the closer you look the more you find the federal government lending a hand—a patent, a monopoly, a tax-break—to our hero at a critical juncture. In the case of corn, the botanical hero I've depicted as plucky and ambitious was in fact subsidized in crucial ways, both economically and biologically. There's a good reason I met farmers in Iowa who don't respect corn, who will tell you in disgust that the plant has become “a welfare queen.”

The great turning point in the modern history of corn, which in turn marks a key turning point in the industrialization of our food, can be dated with some precision to the day in 1947 when the huge munitions plant at Muscle Shoals, Alabama, switched over to making chemical fertilizer. After the war the government had found itself with a tremendous surplus of ammonium nitrate, the principal ingredient in the making of explosives. Ammonium nitrate also happens to be an excellent source of nitrogen for plants. Serious thought was given to spraying America's forests with the surplus chemical, to help out the timber industry. But agronomists in the Department of Agriculture had a better idea: Spread the ammonium nitrate on farmland as fertilizer. The chemical fertilizer industry (along with that of pesticides, which are based on poison gases developed for the war) is the product of the government's effort to convert its war machine to peacetime purposes. As the Indian farmer activist Vandana Shiva says in her speeches, “We're still eating the leftovers of World War II.”

Hybrid corn turned out to be the greatest beneficiary of this conversion. Hybrid corn is the greediest of plants, consuming more fertilizer than any other crop. For though the new hybrids had the genes to survive in reeming cities of corn, the richest acre of Iowa soil could never have fed thirty thousand hungry corn plants without promptly bankrupting its fertility. To keep their land from getting “corn sick” farmers

in Naylor's father's day would carefully rotate their crops with legumes (which add nitrogen to the soil), never growing corn more than twice in the same field every five years; they would also recycle nutrients by spreading their cornfields with manure from their livestock. Before synthetic fertilizers the amount of nitrogen in the soil strictly limited the amount of corn an acre of land could support. Though hybrids were introduced in the thirties, it wasn't until they made the acquaintance of chemical fertilizers in the 1950s that corn yields exploded.

The discovery of synthetic nitrogen changed everything—not just for the corn plant and the farm, not just for the food system, but also for the way life on earth is conducted. All life depends on nitrogen; it is the building block from which nature assembles amino acids, proteins, and nucleic acid; the genetic information that orders and perpetuates life is written in nitrogen ink. (This is why scientists speak of nitrogen as supplying life's quality, while carbon provides the quantity.) But the supply of usable nitrogen on earth is limited. Although earth's atmosphere is about 80 percent nitrogen, all those atoms are tightly paired, nonreactive, and therefore useless; the nineteenth-century chemist Justus von Liebig spoke of atmospheric nitrogen's "indifference to all other substances." To be of any value to plants and animals, these self-involved nitrogen atoms must be split and then joined to atoms of hydrogen. Chemists call this process of taking atoms from the atmosphere and combining them into molecules useful to living things "fixing" that element. Until a German Jewish chemist named Fritz Haber figured out how to turn this trick in 1909, all the usable nitrogen on earth had at one time been fixed by soil bacteria living on the roots of leguminous plants (such as peas or alfalfa or locust trees) or, less commonly, by the shock of electrical lightning, which can break nitrogen bonds in the air, releasing a light rain of fertility.

Vaclav Smil, a geographer who has written a fascinating book about Fritz Haber called *Enriching the Earth*, pointed out that "there is no way to grow crops and human bodies without nitrogen." Before Fritz Haber's invention the sheer amount of life earth could support—the size of crops and therefore the number of human bodies—was limited by the

amount of nitrogen that bacteria and lightning could fix. By 1900, European scientists recognized that unless a way was found to augment this naturally occurring nitrogen, the growth of the human population would soon grind to a very painful halt. The same recognition by Chinese scientists a few decades later is probably what compelled China's opening to the West: After Nixon's 1972 trip the first major order the Chinese government placed was for thirteen massive fertilizer factories. Without them, China would probably have starved.

This is why it may not be hyperbole to claim, as Smil does, that the Haber-Bosch process (Carl Bosch gets the credit for commercializing Haber's idea) for fixing nitrogen is the most important invention of the twentieth century. He estimates that two of every five humans on earth today would not be alive if not for Fritz Haber's invention. We can easily imagine a world without computers or electricity, Smil points out, but without synthetic fertilizer billions of people would never have been born. Though, as these numbers suggest, humans may have struck something of a Faustian bargain with nature when Fritz Haber gave us the power to fix nitrogen.

Fritz Haber? No, I'd never heard of him either, even though he was awarded the Nobel Prize in 1920 for "improving the standards of agriculture and the well-being of mankind." But the reason for his obscurity has less to do with the importance of his work than the ugly twist of his biography, which recalls the dubious links between modern warfare and industrial agriculture. During World War I, Haber threw himself into the German war effort, and his chemistry kept alive Germany's hopes for victory. After Britain choked off Germany's supply of nitrates from Chilean mines, an essential ingredient in the manufacture of explosives, Haber's technology allowed Germany to continue making bombs from synthetic nitrate. Later, as the war became mired in the trenches of France, Haber put his genius for chemistry to work developing poison gases—ammonia, then chlorine. (He subsequently developed Zyklon B, the gas used in Hitler's concentration camps.) On April 22, 1915, Smil writes, Haber was "on the front lines directing the first gas attack in military history." His "triumphant" return to Berlin



was ruined a few days later when his wife, a fellow chemist sickened by her husband's contribution to the war effort, used Haber's army pistol to kill herself. Though Haber later converted to Christianity, his Jewish background forced him to flee Nazi Germany in the thirties; he died, broken, in a Basel hotel room in 1934. Perhaps because the history of science gets written by the victors, Fritz Haber's story has been all but written out of the twentieth century. Not even a plaque marks the site of his great discovery at the University of Karlsruhe.

Haber's story embodies the paradoxes of science: the double edge to our manipulations of nature, the good and evil that can flow not only from the same man but the same knowledge. Haber brought a vital new source of fertility and an awful new weapon into the world; as his biographer wrote, "[I]t's the same science and the same man doing both." Yet this dualism dividing the benefactor of agriculture from the chemical weapons maker is far too pat, for even Haber's benefaction has proven decidedly to be a mixed blessing.

When humankind acquired the power to fix nitrogen, the basis of soil fertility shifted from a total reliance on the energy of the sun to a new reliance on fossil fuel. For the Haber-Bosch process works by combining nitrogen and hydrogen gases under immense heat and pressure in the presence of a catalyst. The heat and pressure are supplied by prodigious amounts of electricity, and the hydrogen is supplied by oil, coal, or, most commonly today, natural gas—fossil fuels. True, these fossil fuels were at one time billions of years ago created by the sun, but they are not renewable in the same way that the fertility created by a legume nourished by sunlight is. (That nitrogen is actually fixed by a bacteria living on the roots of the legume, which trades a tiny drip of sugar for the nitrogen the plant needs.)

On the day in the 1950s that George Naylor's father spread his first load of ammonium nitrate fertilizer, the ecology of his farm underwent a quiet revolution. What had been a local, sun-driven cycle of fertility, in which the legumes fed the corn which fed the livestock which in turn (with their manure) fed the corn, was now broken. Now he could

plant corn every year and on as much of his acreage as he chose, since he had no need for the legumes or the animal manure. He could buy fertility in a bag, fertility that had originally been produced a billion years ago halfway around the world.

Liberated from the old biological constraints, the farm could now be managed on industrial principles, as a factory transforming inputs of raw material—chemical fertilizer—into outputs of corn. Since the farm no longer needs to generate and conserve its own fertility by maintaining a diversity of species, synthetic fertilizer opens the way to monoculture, allowing the farmer to bring the factory's economies of scale and mechanical efficiency to nature. If, as has sometimes been said, the discovery of agriculture represented the first fall of man from the state of nature, then the discovery of synthetic fertility is surely a second precipitous fall. Fixing nitrogen allowed the food chain to turn from the logic of biology and embrace the logic of industry. Instead of eating exclusively from the sun, humanity now began to sip petroleum.

Corn adapted brilliantly to the new industrial regime, consuming prodigious quantities of fossil fuel energy and turning out ever more prodigious quantities of food energy. More than half of all the synthetic nitrogen made today is applied to corn, whose hybrid strains can make better use of it than any other plant. Growing corn, which from a biological perspective had always been a process of capturing sunlight to turn it into food, has in no small measure become a process of converting fossil fuels into food. This shift explains the color of the land: The reason Greene County is no longer green for half the year is because the farmer who can buy synthetic fertility no longer needs cover crops to capture a whole year's worth of sunlight; he has plugged himself into a new source of energy. When you add together the natural gas in the fertilizer to the fossil fuels it takes to make the pesticides, drive the tractors, and harvest, dry, and transport the corn, you find that every bushel of industrial corn requires the equivalent of between a quarter and a third of a gallon of oil to grow it—or around fifty gallons of oil per acre of corn. (Some estimates are much higher.) Put another way, it takes

more than a calorie of fossil fuel energy to produce a calorie of food; before the advent of chemical fertilizer the Naylor farm produced more than two calories of food energy for every calorie of energy invested.

From the standpoint of industrial efficiency, it's too bad we can't simply drink the petroleum directly, because there's a lot less energy in a bushel of corn (measured in calories) than there is in the half gallon or so of oil required to produce it. Ecologically this is a fabulously expensive way to produce food—but "ecologically" is no longer the operative standard. As long as fossil fuel energy is so cheap and available, it makes good economic sense to produce corn this way. The old way of growing corn—using fertility drawn from the sun—may have been the biological equivalent of a free lunch, but the service was much slower and the portions were much skimpier. In the factory time is money, and yield is everything.

One problem with factories, as compared to biological systems, is that they tend to pollute. Hungry for fossil fuel as hybrid corn is, farmers still feed it far more than it can possibly eat, wasting most of the fertilizer they buy. Maybe it's applied at the wrong time of year; maybe it runs off the fields in the rain; maybe the farmer puts down extra just to play it safe. "They say you only need a hundred pounds per acre. I don't know. I'm putting on up to two hundred. You don't want to err on the side of too little," Naylor explained to me, a bit sheepishly. "It's a form of yield insurance."

But what happens to the one hundred pounds of synthetic nitrogen that Naylor's corn plants don't take up? Some of it evaporates into the air, where it acidifies the rain and contributes to global warming. (Ammonium nitrate is transformed into nitrous oxide, an important greenhouse gas.) Some seeps down to the water table. When I went to pour myself a glass of water in the Naylor's kitchen, Peggy made sure I drew it from a special faucet connected to a reverse-osmosis filtration system in the basement. As for the rest of the excess nitrogen, the spring rains wash it off Naylor's fields, carrying it into drainage ditches that eventually spill into the Raccoon River. From there it flows into the Des Moines River, down to the city of Des Moines—which drinks from the

Des Moines River. In spring, when nitrogen runoff is at its heaviest, the city issues "blue baby alerts," warning parents it's unsafe to give children water from the tap. The nitrates in the water bind to hemoglobin, compromising the blood's ability to carry oxygen to the brain. So I guess I was wrong to suggest we don't sip fossil fuels directly; sometimes we do.

It has been less than a century since Fritz Haber's invention, yet already it has changed earth's ecology. More than half of the world's supply of usable nitrogen is now man-made. (Unless you grew up on organic food, most of the kilo or so of nitrogen in your body was fixed by the Haber-Bosch process.) "We have perturbed the global nitrogen cycle," Smil wrote, "more than any other, even carbon." The effects may be harder to predict than the effects of the global warming caused by our disturbance of the carbon cycle, but they may be no less momentous. The flood of synthetic nitrogen has fertilized not just the farm fields but the forests and the oceans too, to the benefit of some species (corn and algae being two of the biggest beneficiaries), and to the detriment of countless others. The ultimate fate of the nitrates that George Naylor spreads on his cornfield in Iowa is to flow down the Mississippi into the Gulf of Mexico, where their deadly fertility poisons the marine ecosystem. The nitrogen tide stimulates the wild growth of algae, and the algae smother the fish, creating a "hypoxic," or dead, zone as big as the state of New Jersey—and still growing. By fertilizing the world, we alter the planet's composition of species and shrink its biodiversity.

## 5. A PLAGUE OF CHEAP CORN

The day after George Naylor and I finished planting his corn, the rains came, so we spent most of it around his kitchen table, drinking coffee and talking about what farmers always talk about: lousy commodity prices; benighted farm policies; making ends meet in a dysfunctional farm economy. Naylor came back to the farm at what would turn out to be the good old days in American agriculture: Corn prices were at an

all-time high, and it looked as though it might actually be possible to make a living growing it. But by the time Naylor was ready to take his first crop to the elevator, the price of a bushel of corn had dropped from three dollars to two dollars, the result of a bumper crop. So he held his corn off the market, storing it in the hope that the price would rebound. But the price kept falling all through that winter and into the following spring and, if you factor in inflation, it has pretty much been falling ever since. These days the price of a bushel of corn is about a dollar beneath the true cost of growing it, a boon for everyone but the corn farmer. What I was hoping George Naylor could help me understand is, if there's so much corn being grown in America today that the market won't pay the cost of producing it, then why would any farmer in his right mind plant another acre of it?

The answer is complicated, as I would learn, but it has something to do with the perverse economics of agriculture, which would seem to defy the classical laws of supply and demand; a little to do with the psychology of farmers; and everything to do with farm policies, which underwent a revolution right around the time George Naylor was buying his first tractor. Government farm programs once designed to limit production and support prices (and therefore farmers) were quietly rejiggered to increase production and drive down prices. Put another way, instead of supporting farmers, during the Nixon administration the government began supporting corn at the expense of farmers. Corn, already the recipient of a biological subsidy in the form of synthetic nitrogen, would now receive an economic subsidy too, insuring its final triumph over the land and the food system.

NAYLOR'S PERSPECTIVE on farm policy was shaped by a story his dad used to tell him. It takes place during the winter of 1933, in the depths of the farm depression. "That's when my father hauled corn to town and found out that the price of corn had been ten cents a bushel the day before, but on that day the elevator wasn't even buying." The price of corn had fallen to zero. "Tears always came to his eyes when he re-

counted the neighbors losing their farms in the nineteen twenties and thirties," Naylor told me. America's farm policy was forged during the Depression not, as many people seem to think, to encourage farmers to produce more food for a hungry nation, but to rescue farmers from the disastrous effects of growing too much food—far more than Americans could afford to buy.

For as long as people have been farming, fat years have posed almost as stiff a challenge as lean, since crop surpluses collapse prices and bankrupt farmers who will be needed again when the inevitable lean years return. When it comes to food, nature can make a mockery of the classical economics of supply and demand—nature in the form of good or bad weather, of course, but also the nature of the human body, which can consume only so much food no matter how plentiful the supply. So, going back to the Old Testament, communities have devised various strategies to even out the destructive swings of agricultural production. The Bible's recommended farm policy was to establish a grain reserve. Not only did this insure that when drought or pestilence ruined a harvest there'd still be food to eat, but it kept farmers whole by taking food off the market when the harvest was bountiful.

This is more or less what New Deal farm programs attempted to do. For storable commodities such as corn, the government established a target price based on the cost of production, and whenever the market price dropped below that target, the farmer was given a choice. Instead of dumping corn onto a weak market (thereby weakening it further), the farmer could take out a loan from the government—using his crop as collateral—that allowed him to store his grain until prices recovered. At that point, he sold the corn and paid back the loan; if corn prices stayed low, he could elect to keep the money he'd borrowed and, in repayment, give the government his corn, which would then go into something that came to be called, rather quaintly, the "Ever-Normal Granary." Other New Deal programs, such as those administered by the Soil Conservation Service, sought to avert overproduction (and soil erosion) by encouraging farmers to idle their most environmentally sensitive land.

The system, which remained in place more or less until shortly before George Naylor came back to the farm in the 1970s, did a fairly good job of keeping corn prices from collapsing in the face of the twentieth century's rapid gains in yield. Surpluses were held off the market by the offer of these "nonrecourse loans," which cost the government relatively little, since most of the loans were eventually repaid. And when prices climbed, as a result of bad weather, say, the government sold corn from its granary, which helped both to pay for the farm programs and smooth out the inevitable swings in price.

I say this system remained in place "more or less" until the 1970s because, beginning in the 1950s, a campaign to dismantle the New Deal farm programs took root, and with every new farm bill since then another strut was removed from the structure of support. Almost from the start, the policy of supporting prices and limiting production had collected powerful enemies: exponents of *laissez-faire* economics, who didn't see why farming should be treated differently than any other economic sector; food processors and grain exporters, who profited from overproduction and low crop prices; and a coalition of political and business leaders who for various reasons thought America had far too many farmers for her (or at least their) own good.

America's farmers had long been making political trouble for Wall Street and Washington; in the words of historian Walter Karp, "since the Civil War at least, the most unruly, the most independent, the most republican of American citizens have been the small farmers." Beginning with the populist revolt of the 1890s, farmers had made common cause with the labor movement, working together to check the power of corporations. Rising agricultural productivity handed a golden opportunity to the farmers' traditional adversaries. Since a smaller number of farmers could now feed America, the moment had come to "rationalize" agriculture by letting the market force prices down and farmers off the land. So Wall Street and Washington sought changes in farm policies that would loose "a plague of cheap corn" (in the words of George Naylor, a man very much in the old rural-populist mold) on the nation, the effects of which are all around us—indeed, in us.

## 6. THE SAGE OF PURDUE

Earl "Rusty" Butz, Richard Nixon's second secretary of agriculture, probably did more than any other single individual to orchestrate George Naylor's plague of cheap corn. In every newspaper article about him, and there were scores, the name of Earl Butz, a blustering, highly quotable agricultural economist from Purdue University, is invariably accompanied by the epithet "colorful." Butz's plainspoken manner and barnyard humor persuaded many people he must be a friend to the farmer, but his presence on the board of Ralston Purina probably offered a more reliable guide to his sympathies. Though chiefly remembered outside agriculture for the racist joke that cost him his job during the 1976 election, Butz revolutionized American agriculture, helping to shift the food chain onto a foundation of cheap corn.

Butz took over the Department of Agriculture during the last period in American history that food prices climbed high enough to generate real political heat; his legacy would be to make sure that never happened again. In the fall of 1972 Russia, having suffered a series of disastrous harvests, purchased 30 million tons of American grain. Butz had helped arrange the sale, in the hopes of giving a boost to crop prices in order to bring restive farmers tempted to vote for George McGovern into the Republican fold. The plan worked all too well: The unexpected surge in demand, coinciding with a spell of bad weather in the Farm Belt, drove grain prices to historic heights. These were the corn prices that persuaded George Naylor he could make a go of it on his family's farm.

The 1972 Russian grain sale and the resulting spike in farm income that fall helped Nixon nail down the farm vote for his reelection, but by the following year those prices had reverberated through the food chain, all the way to the supermarket. By 1973 the inflation rate for groceries reached an all-time high, and housewives were organizing protests at supermarkets. Farmers were killing chicks because they couldn't afford to buy feed, and the price of beef was slipping beyond the reach of middle-class consumers. Some foods became scarce; horse

meat began showing up in certain markets. "Why a Food Scare in a Land of Plenty?" was a headline in *U.S. News and World Report* that summer. Nixon had a consumer revolt on his hands, and he dispatched Earl Butz to quell it. The Sage of Purdue set to work reengineering the American food system, driving down prices and vastly increasing the output of American farmers. What had long been the dream of agribusiness (cheaper raw materials) and the political establishment (fewer restless farmers) now became official government policy.

Butz made no secret of his agenda: He exhorted farmers to plant their fields "fencerow to fencerow" and advised them to "get big or get out." Bigger farms were more productive, he believed, so he pushed farmers to consolidate ("adapt or die" was another of his credos) and to regard themselves not as farmers but as "agribusinessmen." Somewhat less noisily, Butz set to work dismantling the New Deal farm regime of price supports, a job made easier by the fact that prices at the time were so high. He abolished the Ever-Normal Granary and, with the 1973 farm bill, began replacing the New Deal system of supporting prices through loans, government grain purchases, and land idling with a new system of direct payments to farmers.

The change from loans to direct payments hardly seems momentous—either way, the government pledged to make sure the farmer receives some target price for a bushel of corn when prices are weak. But in fact paying farmers directly for the shortfall in the price of corn was revolutionary, as its proponents surely must have understood. They had removed the floor under the price of grain. Instead of keeping corn out of a falling market, as the old loan programs and federal granary had done, the new subsidies encouraged farmers to sell their corn at any price, since the government would make up the difference. Or, as it turned out, make up some of the difference, since just about every farm bill since has lowered the target price in order, it was claimed, to make American grain more competitive in world markets. (Beginning in the 1980s, big buyers of grain like Cargill and Archer Daniels Midland (ADM) took a hand in shaping the farm bills, which predictably came to reflect their interests more closely than those of

farmers.) Instead of supporting farmers, the government was now subsidizing every bushel of corn a farmer could grow—and American farmers pushed to go flat out could grow a hell of a lot of corn.

## 7. THE NAYLOR CURVE

It's not at all clear that very many American farmers know exactly what hit them, even now. The rhetoric of competitiveness and free trade persuaded many of them that cheap corn would be their salvation, and several putative farmers' organizations have bought into the virtues of cheap corn. But since the heyday of corn prices in the early seventies, farm income has steadily declined along with corn prices, forcing millions of farmers deeper into debt and thousands of them into bankruptcy every week. Exports, as a percentage of the American corn harvest, have barely budged from around 20 percent, even as prices have fallen. Iowa State University estimates that it costs roughly \$2.50 to grow a bushel of Iowa corn; in October 2005 Iowa grain elevators were paying \$1.45, so the typical Iowa farmer is selling corn for a dollar less than it costs him to grow it. Yet the corn keeps coming, more of it every year.

*How can this possibly be?*

George Naylor has studied this question, and he has come up with a convincing answer. He's often asked to speak at meetings on the farm crisis, and to testify at hearings about farm policy, where he often presents a graph he's drawn to explain the mystery. He calls it the Naylor Curve. ("Remember the Laffer curve? Well, this one looks a little like that one, only it's true.") Basically it purports to show why falling farm prices force farmers to increase production in defiance of all rational economic behavior.

"Farmers facing lower prices have only one option if they want to be able to maintain their standard of living, pay their bills, and service their debt, and that is to produce more." A farm family needs a certain amount of cash flow every year to support itself, and if the price of corn

falls, the only way to stay even is to sell more corn. Naylor says that farmers desperate to boost yield end up degrading their land, plowing and planting marginal land, applying more nitrogen—anything to squeeze a few more bushels from the soil. Yet the more bushels each farmer produces, the lower prices go, giving another turn to the perverse spiral of overproduction. Even so, corn farmers persist in measuring their success in bushels per acre, a measurement that improves even as they go broke.

"The free market has never worked in agriculture and it never will. The economics of a family farm are very different than a firm's: When prices fall, the firm can lay off people, idle factories, and make fewer widgets. Eventually the market finds a new balance between supply and demand. But the demand for food isn't elastic; people don't eat more just because food is cheap. And laying off farmers doesn't help to reduce supply. You can fire me, but you can't fire my land, because some other farmer who needs more cash flow or thinks he's more efficient than I am will come in and farm it. Even if I go out of business this land will keep producing corn."

But why corn and not something else? "We're on the bottom rung of the industrial food chain here, using this land to produce energy and protein, mostly to feed animals. Corn is the most efficient way to produce energy; soybeans the most efficient way to produce protein." The notion of switching to some other crop Naylor gruffly dismisses. "What am I going to grow here, broccoli? Lettuce? We've got a long-term investment in growing corn and soybeans; the elevator is the only buyer in town, and the elevator only pays me for corn and soybeans. The market is telling me to grow corn and soybeans, period." As is the government, which calculates his various subsidy payments based on his yield of corn.

So the plague of cheap corn goes on, impoverishing farmers (both here and in the countries to which we export it), degrading the land, polluting the water, and bleeding the federal treasury, which now spends up to \$5 billion a year subsidizing cheap corn. But though those subsidy checks go to the farmer (and represents nearly half of net farm

income today), what the Treasury is really subsidizing are the buyers of all that cheap corn. "Agriculture's always going to be organized by the government; the question is, organized for whose benefit? Now it's for Cargill and Coca-Cola. It's certainly not for the farmer."

Early that afternoon, after George and I had been talking agricultural policy for longer than I ever thought possible, the phone rang; his neighbor, Billy, needed a hand with a balky corn planter. On the drive over Naylor told me a little about Billy. "He's got all the latest toys: the twelve-row planter, Roundup Ready seed, the new John Deere combine." George rolled his eyes. "Billy's in debt up to his eyeballs." George believes he's managed to survive on the farm by steering clear of debt, nursing along his antique combine and tractor, and avoiding the trap of expansion.

A blockish fellow in his fifties, with a seed cap perched over a gray-ing crew cut, Billy seemed cheerful enough, especially considering he'd just blown his morning fiddling with a broken tractor cable. While he and George were working on it I checked out the shed full of state-of-the-art farm equipment and asked him what he thought about the Bt corn he was planting—corn genetically engineered to produce its own pesticide. Billy thought the seed was the greatest. "I'm getting 220 bushels an acre on that seed," he boasted. "How's that compare, George?"

George owned he was getting something just south of two hundred, but he was too polite to say what he knew, which was that he was almost certainly clearing more money per acre growing less corn more cheaply. But in Iowa, bragging rights go to the man with the biggest yield, even if it's bankrupting him.

In a shed across the way I noticed the shiny chrome prow of a tractor trailer poking out and asked Billy about it. He explained he'd had to take on long-distance hauling work to keep the farm afloat. "Have to drive the big rig to pay for all my farm toys," he chuckled.

George tossed me a look, as if to say, kind of pathetic, isn't it? Poignant seemed more like it, to think what this farmer had to do to hold on to his farm. I was reminded of Thoreau's line: "Men have be-

come the tools of their tools." And I wondered if Billy gave much thought, in those late-night hours rolling up the miles on Interstate 80, to how he got to this point, and about who he was really working for now. The bank? John Deere? Monsanto? Pioneer? Cargill? Two hundred and twenty bushels of corn is an astounding accomplishment, yet it didn't do Billy nearly as much good as it did those companies.

And then of course there's the corn itself, which if corn could form an opinion would surely marvel at the absurdity of it all—and at its great good fortune. For corn has been exempted from the usual rules of nature and economics, both of which have rough mechanisms to check any such wild, uncontrolled proliferation. In nature, the population of a species explodes until it exhausts its supply of food; then it crashes. In the market, an oversupply of a commodity depresses prices until the surplus is either consumed or it no longer makes sense to produce any more of it. In corn's case, humans have labored mightily to free it from either constraint, even if that means going broke growing it, and consuming it just as fast as we possibly can.

### THREE

## THE ELEVATOR

On the spring afternoon I visited the grain elevator in Jefferson, Iowa, where George Naylor hauls his corn each October, the sky was a soft gray, drizzling lightly. Grain elevators, the only significant verticals for miles around this part of Iowa, resemble tight clusters of windowless concrete office towers, but this day the cement sky had robbed them of contrast, rendering the great cylinders nearly invisible. What stood out as my car rumbled across the railroad tracks and passed the green and white "Iowa Farmers Cooperative" sign was a bright yellow pyramid the size of a circus tent pitched near the base of the elevator: an immense pile of corn left out in the rain.

The previous year's had been a bumper crop in this part of the Midwest; the pile represents what's left of the millions of bushels of corn that overflowed the elevators last October. Even now, seven months later, there was still a surfeit of corn, and I watched a machine that looked like a portable escalator pour several tons of it over the lip of a railroad car. As I circumnavigated the great pile, I started to see the golden kernels everywhere, ground into the mud by tires and boots,

floating in the puddles of rainwater, pancaked on the steel rails. Most of this grain is destined for factory farms and processing plants, so no one worries much about keeping it particularly clean. Even so, it was hard not to register something deeply amiss in the sight of so much food lying around on the wet ground.

In Ames the following afternoon I met a Mexican American agronomist named Ricardo Salvador, a professor at Iowa State University, who told me he'd had a similar reaction the first time he'd seen kernels littering Iowa roads in October; farmers haul their corn to town in big open wagons that fishail across the county highways, scattering a light rain of yellow kernels as they go. "To be honest, I felt a revulsion. In Mexico, even today, you do not let corn lay on the ground; it is considered almost sacrilegious." He sent me to a passage from a sixteenth-century writer, Friar Sahagún, who had chronicled the Aztecs' reverence for maize:

If they saw dry grains of maize scattered on the ground, they quickly gathered them up, saying "Our Sustenance suffereth, it lieth weeping. If we should not gather it up, it would accuse us before our Lord. It would say; 'O, Our Lord, this vassal picked me not up when I lay scattered upon the ground. Punish him!' Or perhaps we should starve."

The agronomist's reaction, like mine, owes something to our confusion of corn-the-food with corn-the-commodity, which turn out to be two subtly but crucially different things. What George Naylor grows, and what the pile by the elevator consists of, is "number 2 field corn," an internationally recognized commodity grown everywhere (and nowhere in particular), fungible, traded in and speculated upon and accepted as a form of capital all over the world. And while number 2 field corn certainly looks like the corn you would eat, and is directly descended from the maize Friar Sahagún's Aztecs worshipped as the source of life, it is less a food than an industrial raw material—and an abstraction. The kernels are hard to eat, but if you soak them in water

for several hours you'll find they taste less like corn than lightly corn-flavored starch.

Actually there are many different kinds of corn heaped together in this pile: George Naylor's Pioneer Hi-Bred 34H31 mixed in with his neighbor Billy's genetically modified 33P67; corn grown with atrazine mixed with corn grown with metolachlor. Number 2 corn is a lowest common denominator; all the designation tells you is that the moisture content of this corn is no more than 14 percent, and that fewer than 5 percent of the kernels exhibit insect damage. Other than that, this is the corn without qualities; quantity is really the only thing that counts. Such corn is not something to feel reverent or even sentimental about, and nobody in Iowa, save the slightly embarrassed agronomist, does.

Commodity corn, which is as much an economic abstraction as it is a biological fact, was invented in Chicago in the 1850s.\* Before then corn was bought and sold in burlap sacks. More often than not the sacks bore the name of the farm where the corn had been grown. You could follow a sack from a farm in Iowa to the mill in Manhattan where it was ground into meal, or to the dairy in Brooklyn where it was fed to a cow. This made a difference. For most of history farmers have had to think about the buyers of their crops, to worry about making sure their corn found its way to the right place at the right time, before it spoiled or got waylaid or its price collapsed. Farmers had to worry, too, about the quality of their corn, since customers didn't pay before sampling what was in the sack. In America before the 1850s a farmer owned his sacks of corn up to the moment when a buyer took delivery, and so bore the risk for anything that went wrong between farm and table or trough. For better or worse that burlap sack linked a corn buyer anywhere in America with a particular farmer cultivating a particular patch of the earth.

With the coming of the railroads and the invention of the grain elevator (essentially a great vertical warehouse filled by conveyor belt and

\*I'm drawing on the excellent account of the invention of agricultural commodities in William Cronon's *Nature's Metropolis: Chicago and the Great West* (1991).



emptied by spigot) the sacks suddenly became a problem. Now it made sense to fill railroad cars and elevators by conveyor, to treat corn less as a certain number of discrete packages someone had to haul and more like an unbounded liquid that could be pumped, in effect, by machine. Mix it all together in a great golden river. The river of corn would flow from the farms to the Chicago market and then out from there to buyers anywhere in the world. But before buyers would accept this new nonspecific, trackless corn they would have to have some assurance of its quality.

The breakthrough came in 1856, when the Chicago Board of Trade instituted a grading system. Now any number 2 corn was guaranteed to be as good as any other number 2 corn. So there was no longer any reason for anyone to care where the corn came from or who grew it, as long as it met the board's standard. Since this standard was fairly minimal (specifying acceptable levels of insect damage, dirt and extraneous matter, and moisture) growers and breeders were now free to train their energies on producing bigger and bigger harvests. Before the commodity system farmers prided themselves on a panoply of qualities in their crop: big ears, plump kernels, straight rows, various colors; even the height of their corn plants became a point of pride. Now none of these distinctions mattered; "bushels per acre" became the only boast you heard. No one could foresee it at the time, but the Chicago Board of Trade's decision redirected the evolution of *Zea mays*. From that moment on the trajectory of the species' descent was guided by a single quality: yield. Which is to say, by the quality of sheer quantity.

The invention of commodity grain severed any link between the producer of a foodstuff and its ultimate consumer. A commodity is like a filter, stripping qualities and histories from the harvest of a particular farm and farmer. When George Naylor delivers his wagonload to the elevator in Jefferson, which at the height of the harvest runs twenty-four hours a day seven days a week, his corn is weighed and graded, his account is credited with that day's posted price per bushel, and Naylor's worries about his crop—his responsibility for it, indeed his whole relationship to it—are over for another year.

Within hours Naylor's corn joins the streams of corn coming off his neighbors' farms; later, that tributary flows from Jefferson County into the river of commodity corn flowing mostly east and south from Iowa into the tremendous maw of the American food system. (Today much of it flows farther south, into Mexico.) Watching a pile of corn stream over the lip of a hopper car painted with Cargill's blue-and-yellow logo, a car destined to join a train more than a mile long and holding 440,000 bushels of corn, I began to see what George Naylor was getting at when he'd told me whom it was he grew his corn for: "the military-industrial complex."

The immense pyramid of corn I stood before in Jefferson is of course only a tiny part of an infinitely more immense mountain of corn dispersed over thousands of grain elevators across the American Corn Belt every autumn. That mountain is the product of the astounding efficiency of American corn farmers, who—with their technology, machinery, chemicals, hybrid genetics, and sheer skill—can coax five tons of corn from an acre of Iowa soil. All this you can see with your own eyes, hanging around during the harvest. What is much harder to see is that all this corn is also the product of government policies, which have done more than anything else to raise that mountain and shrink the price of each bushel in it.

The Iowa Farmers Cooperative does not write the only check George Naylor will receive for his corn crop this fall. He gets a second check from the U.S. Department of Agriculture (USDA)—about twenty-eight cents a bushel no matter what the market price of corn is, and considerably more should the price of corn drop below a certain threshold. Let's say the price of a bushel falls to \$1.45, as it most recently did in October 2005. Since the official target price (called the "loan rate") in Greene County stands at \$1.87, the government would then send farmers another \$0.42 in "deficiency payments," for a total of \$0.70 for every bushel of corn they can grow. Taken together these federal payments account for nearly half the income of the average Iowa corn farmer, and represent roughly a quarter of the \$19 billion U.S. taxpayers spend each year on payments to farmers.

This is a system designed to keep production high and prices low. In fact, it's designed to drive prices ever lower, since handing farmers deficiency payments (as compared to the previous system of providing loans to support prices) encourages them to produce as much corn as they possibly can, and then to dump it all on the market no matter what the price—a practice that inevitably pushes prices even lower. And as prices decline, the only way a farmer like George Naylor can keep his income from declining is by producing still more corn. So the mountain grows, from 4 billion bushels in 1970 to 10 billion bushels today. Moving that mountain of cheap corn—finding the people and animals to consume it, the cars to burn it, the new products to absorb it, and the nations to import it—has become the principal task of the industrial food system, since the supply of corn vastly exceeds the demand.

Another way to look at this 10-billion-bushel pile of commodity corn—a naturalist's way of looking at it\*—is that industrial agriculture has introduced a vast new stock of biomass to the environment, creating what amounts to an imbalance—a kind of vacuum in reverse. Ecology teaches that whenever an excess of organic matter arises anywhere in nature, creatures large and small inevitably step forward to consume it, sometimes creating whole new food chains in the process. In this case the creatures feasting on the surplus biomass are both metaphorical and real: There are the agribusiness corporations, foreign markets, and whole new industries (such as ethanol), and then there are the food scientists, livestock, and human eaters, as well as the usual array of microorganisms (such as *E. coli* 0157:H7).

What's involved in absorbing all this excess biomass goes a long way toward explaining several seemingly unconnected phenomena, from the rise of factory farms and the industrialization of our food, to the epidemic of obesity and prevalence of food poisoning in America, to the fact that in the country where *Zea mays* was originally domesticated, *campesinos* descended from those domesticators are losing their

farms because imported corn, flooding in from the North, has become too cheap. Such is the protean, paradoxical nature of the corn in that pile, that getting rid of it could contribute to obesity and to hunger both.

My PLAN when I came to Iowa was to somehow follow George Naylor's corn on its circuitous path to our plates and into our bodies. I should have known that tracing any single bushel of commodity corn is as impossible as tracing a bucket of water after it's been poured into a river. Making matters still more difficult, the golden river of American commodity corn, wide though it is, passes through a tiny number of corporate hands. Though the companies won't say, it has been estimated that Cargill and ADM together probably buy somewhere near a third of all the corn grown in America.

These two companies now guide corn's path at every step of the way: They provide the pesticide and fertilizer to the farmers; operate most of America's grain elevators (Naylor's member-owned cooperative is an exception); broker and ship most of the exports; perform the wet and dry milling; feed the livestock and then slaughter the corn-fattened animals; ferment the ethanol; and manufacture the high-fructose corn syrup and the numberless other fractions derived from number 2 field corn. Oh, yes—and help write many of the rules that govern this whole game, for Cargill and ADM exert considerable influence over U.S. agricultural policies. More even than the farmers who receive the checks (and the political blame for cashing them), these companies are the true beneficiaries of the "farm" subsidies that keep the river of cheap corn flowing. Cargill is the biggest privately held corporation in the world.

Cargill and ADM together comprise the vanishingly narrow sluice gate through which the great corn river passes every year. That gate is also virtually invisible. Neither company sells products directly to consumers, so they have little to gain from cooperating with journalists—and seldom do. Both companies declined to let me follow the corn river

\* See Manning (2004).

as it passes through their elevators, pipes, vats, tankers, freighters, feedlots, mills, and laboratories on its complex and increasingly obscure path to our bodies. The reason this segment of our food chain is essentially off-limits, they explained, is “food security.”

Even so, it is possible to follow a bushel of George Naylor’s corn, provided you are willing to regard it as the commodity it is—that is, treat it not as a specific physical entity you can hold in your hands but as a generic, fungible quantity; no different from any other bushel of number 2 field corn boarding that Cargill train or any other. Since Naylor’s corn is mixed in with all the other corn grown this year, the destinations of the kernels in any one of his bushels will mirror, more or less precisely, the ultimate destinations of the crop as a whole—export, livestock, high-fructose corn syrup, etc.

So where do those ninety thousand generic kernels wind up? After they’ve been milled and fractionated, processed and exported and passed through the guts of cows and chickens and pigs, what sort of meal do they make? And—at the risk of employing a word that might sound extreme attached to something as wholesome and all-American as corn—what sort of havoc can those ninety thousand kernels wreak?

THE PLACE where most of those kernels wind up—about three of every five—is on the American factory farm, a place that could not exist without them. Here, hundreds of millions of food animals that once lived on family farms and ranches are gathered together in great commiseraries, where they consume as much of the mounting pile of surplus corn as they can digest, turning it into meat. Enlisting the cow in this undertaking has required particularly heroic efforts, since the cow is by nature not a corn eater. But Nature abhors a surplus, and the corn must be consumed.

Enter the corn-fed American steer.

## FOUR

# THE FEEDLOT

## *Making Meat*

(54,000 KERNELS)

### 1. CATTLE METROPOLIS

The landscape that corn has made in the American Middle West is unmistakable: It forms a second great American lawn, unfurling through the summer like an absurdly deep-pile carpet of green across the vast lands drained by the Mississippi River. Corn the plant has colonized some 125,000 square miles of the American continent, an area twice the size of New York State; even from outer space you can’t miss it. It takes a bit more looking, however, to see some of the other landscapes that corn the commodity has created, in obscure places like Garden City, Kansas. Here in the high plains of western Kansas is where America’s first feedlots were built, beginning in the early fifties.

You’ll be speeding down one of Finney County’s ramrod roads when the empty, dun-colored January prairie suddenly turns black and geometric, an urban grid of steel-fenced rectangles as far as the eye can see—which in Kansas is really far. I say “suddenly” but in fact the swiftly rising odor—an aroma whose Proustian echoes are decidedly

more bus station men's room than cows in the country—has been heralding the feedlot's approach for more than a mile. And then it's upon you: Poky Feeders, population, thirty-seven thousand. A sloping subdivision of cattle pens stretches to the horizon, each one home to a hundred or so animals standing dully or lying around in a grayish mud that, it eventually dawns on you, isn't mud at all. The pens line a network of unpaved roads that loop around vast waste lagoons on their way to the feedyard's thunderously beating heart and dominating landmark: a rhythmically chugging feed mill that rises, soaring and silvery in the early morning light, like an industrial cathedral in the midst of a teeming metropolis of meat. As it does twelve hours a day seven days a week, the mill is noisily converting America's river of corn into cattle feed.

I'd traveled to Poky early one January with the slightly improbable notion of visiting one particular resident, though as I nosed my rental car through the feedlot's rolling black sea of bovinity, I began to wonder if this was realistic. I was looking for a young black steer with three white blazes on his face that I'd met the previous fall on a ranch in Vale, South Dakota, five hundred miles due north of here. In fact, the steer I hoped to find belonged to me: I'd purchased him as an eight-month-old calf from the Blair Ranch for \$598. I was paying Poky Feeders \$1.60 a day for his room and board (all the corn he could eat) and meds.

My interest in this steer was not strictly financial, or even gustatory. No, my primary interest in this animal was educational. I wanted to learn how the industrial food chain transforms bushels of corn into streaks. How do you enlist so unlikely a creature—for the cow is an herbivore by nature—to help dispose of America's corn surplus? By far the biggest portion of a bushel of American commodity corn (about 60 percent of it, or some fifty-four thousand kernels) goes to feeding livestock, and much of that goes to feeding America's 100 million beef cattle—cows and bulls and steers that in times past spent most of their lives grazing on grasses out on the prairie.

America's food animals have undergone a revolution in lifestyle in the years since World War II. At the same time much of America's hu-

man population found itself leaving the city for the suburbs, our food animals found themselves traveling in the opposite direction, leaving widely dispersed farms in places like Iowa to live in densely populated new animal cities. These places are so different from farms and ranches that a new term was needed to denote them: CAFO—Confined Animal Feeding Operation. The new animal and human landscapes were both products of government policy. The postwar suburbs would never have been built if not for the interstate highway system, as well as the G.I. Bill and federally subsidized mortgages. The urbanization of America's animal population would never have taken place if not for the advent of cheap, federally subsidized corn.

Corn itself profited from the urbanization of livestock twice. As the animals left the farm, more of the farm was left for corn, which rapidly colonized the paddocks and pastures and even the bariyards that had once been the animals' territory. The animals left because the farmers simply couldn't compete with the CAFOs. It cost a farmer more to grow feed corn than it cost a CAFO to buy it, for the simple reason that commodity corn now was routinely sold for less than it cost to grow. Corn profited again as the factory farms expanded, absorbing increasing amounts of its surplus. Corn found its way into the diet of animals that never used to eat very much of it (like cattle) or any corn at all, like the farmed salmon now being bred to tolerate grain. All that excess biomass has to go somewhere.

The economic logic of gathering so many animals together to feed them cheap corn in CAFOs is hard to argue with; it has made meat, which used to be a special occasion in most American homes, so cheap and abundant that many of us now eat it three times a day. Not so compelling is the biological logic behind this cheap meat. Already in their short history CAFOs have produced more than their share of environmental and health problems: polluted water and air, toxic wastes, novel and deadly pathogens.

Raising animals on old-fashioned mixed farms such as the Naylor's used to make simple biological sense: You can feed them the waste products of your crops, and you can feed their waste products to your

crops. In fact, when animals live on farms the very idea of waste ceases to exist; what you have instead is a closed ecological loop—what in retrospect you might call a solution. One of the most striking things that animal feedlots do (to paraphrase Wendell Berry) is to take this elegant solution and neatly divide it into two new problems: a fertility problem on the farm (which must be remedied with chemical fertilizers) and a pollution problem on the feedlot (which seldom is remedied at all).

This biological absurdity, characteristic of all CAFOs, is compounded in the cattle feedyard by a second absurdity. Here animals exquisitely adapted by natural selection to live on grass must be adapted by us—at considerable cost to their health, to the health of the land, and ultimately to the health of their eaters—to live on corn, for no other reason than it offers the cheapest calories around and because the great pile must be consumed. This is why I decided to follow the trail of industrial corn through a single steer rather than, say, a chicken or a pig, which can get by just fine on a diet of grain: The short, unhappy life of a corn-fed feedlot steer represents the ultimate triumph of industrial thinking over the logic of evolution.

## 2. PASTORAL: VALE, SOUTH DAKOTA

The Blair Ranch occupies fifty-five hundred acres of rolling short-grass prairie a few miles outside Sturgis, South Dakota, and directly in the shadow of Bear Butte. The Bismarck-Deadwood trail crossed their land just to the north of the butte, which rises dramatically from the plains like a chubby ten-story exclamation mark. You can still make out ruts in the turf dug by stagecoaches and cattle drives the century before last. The turf itself in November, when I visited, forms a luxuriant pelt of grass oscillating yellow and gold in the constant wind and sprinkled with perambulating black dots: Angus cows and calves, grazing.

Ed and Rich Blair run what's called a "cow-calf" operation, the first stage in the production of a hamburger and the stage least changed by

the modern industrialization of meat. While the pork and chicken industries have consolidated the life cycle of those animals under a single roof, beef cattle still get born on hundreds of thousands of independently owned ranches scattered mainly across the West. Although a mere four giant meatpacking companies (Tyson subsidiary IBP, Cargill subsidiary Excel, Swift & Company, and National) now slaughter and market four of every five beef cattle born in this country, that concentration represents the narrow end of a funnel that starts out as wide as the Great Plains. These corporations have concluded that it takes so much land (and therefore capital) to produce a calf ready for the feedlot—ten acres per head at a minimum—that they're better off leaving the ranching (and the risk) to the ranchers.

Steer number 534 spent his first six months in these lush pastures alongside his mother, 9534. The number signifies she was the thirty-fourth cow born in 1995; since none of her male offspring stick around long enough to meet, they're all named 534. His father was a registered Angus by the name of Gar Precision 1680, a bull distinguished by the size and marbling of his offsprings' rib-eye steaks. Gar Precision's only contact with 9534 came by way of a fifteen-dollar mail-order straw of his semen.

Born on March 13, 2001, in the birthing shed across the road, 534 and his mother were turned out on pasture just as soon as the eighty-pound calf stood up and began nursing. Within a few weeks the calf began supplementing his mother's milk by nibbling on a salad bar of mostly native grasses: western wheatgrass, little bluestem, buffalo grass, green needlegrass.

Apart from the trauma of the Saturday in April when he was branded and castrated, one could imagine 534 looking back on those six months as the good old days. It might be foolish for us to presume to know what a cow experiences, yet we can say that a calf grazing on grass is at least doing what he has been supremely well suited by evolution to do. Oddly enough, though, eating grass is something that after October my steer will never have the opportunity to do again.

THE REVOLUTIONARY RELATIONSHIP between cows and grass is one of nature's underappreciated wonders; it also happens to be the key to understanding just about everything about modern meat. For the grasses, which have evolved to withstand the grazing of ruminants, the cow maintains and expands their habitat by preventing trees and shrubs from gaining a foothold and hogging the sunlight; the animal also spreads grass seed, plants it with his hooves, and then fertilizes it with his manure. In exchange for these services the grasses offer ruminants a plentiful and exclusive supply of lunch. For cows (like sheep, bison, and other ruminants) have evolved the special ability to convert grass—which single-stomached creatures like us can't digest—into high-quality protein. They can do this because they possess what is surely the most highly evolved digestive organ in nature: the rumen. About the size of a medicine ball, the organ is essentially a forty-five-gallon fermentation tank in which a resident population of bacteria dines on grass. Living their unseen lives at the far end of the food chain that culminates in a hamburger, these bacteria have, like the grasses, coevolved with the cow, whom they feed.

Truly this is an excellent system for all concerned: for the grasses, for the bacteria, for the animals, and for us, the animals' eaters. While it is true that overgrazing can do ecological harm to a grassland, in recent years ranchers have adopted rotational grazing patterns that more closely mimic the patterns of the bison, a ruminant that sustainably grazed these same grasses for thousands of years before the cow displaced it. In fact, a growing number of ecologists now believe the rangelands are healthier with cattle on them, provided they're moved frequently. Today the most serious environmental harm associated with the cattle industry takes place on the feedlot.

In fact, growing meat on grass makes superb ecological sense: It is a sustainable, solar-powered food chain that produces food by transforming sunlight into protein. Row crops could accomplish this trick too, but not around here. In places like western South Dakota the land

is far too arid, thin, and hilly to grow crops without large amounts of irrigation, chemicals, and erosion. "My cattle can take low-quality forage and convert it into a pretty desirable product," Rich Blair pointed out. "If you didn't have ruminant animals, all this"—he gestures to the high plains rolling out from his ranch in every direction—"would be the great American desert."

So then why is it that steer number 534 hasn't tasted a blade of prairie grass since October? Speed, in a word, or, in the industry's preferred term, "efficiency." Cows raised on grass simply take longer to reach slaughter weight than cows raised on a richer diet, and for half a century now the industry has devoted itself to shortening a beef animal's allotted span on earth. "In my grandfather's time, cows were four or five years old at slaughter," Rich explained. "In the fifties, when my father was ranching, it was two or three years old. Now we get there at fourteen to sixteen months." Fast food, indeed. What gets a steer from 80 to 1,100 pounds in fourteen months are tremendous quantities of corn, protein and fat supplements, and an arsenal of new drugs.

Weaning marks the fateful moment when the natural, evolutionary logic represented by a ruminant grazing on grass bumps up against the industrial logic that will propel the animal on the rest of its swift journey to a wholesale box of beef. This industrial logic is rational and even irresistible—after all, it has succeeded in making beef everyday fare for millions of people for whom it once represented a luxury. And yet the further you follow it, the more likely you are to begin wondering if that rational logic might not also be completely mad.

IN OCTOBER, two weeks before I made his acquaintance, steer number 534 was weaned from his mother. Weaning is perhaps the most traumatic time on a ranch for animals and ranchers alike; cows separated from their calves will mope and bellow for days, and the calves, stressed by the change in circumstance and diet, are prone to getting sick. Calves are weaned for a couple of reasons: to free their mothers to have more calves (9534 had already been inseminated again in June), and to

get the animals, now five or six hundred pounds, ready for life on the feedlot.

The animals are rounded up and herded into a “backgrounding” pen, where they’ll spend a couple of months before boarding the truck for Poky Feeders. Think of backgrounding as prep school for feedlot life: The animals are, for the first time in their lives, confined to a pen, “bunk broken”—taught to eat from a trough—and gradually accustomed to eating what is for them a new and unnatural diet. Here is where the rumen first encounters corn.

It was in the backgrounding pen that I first made the acquaintance of 534. Before coming to Vale I’d told the Blairs I wanted to follow one of their steers through the life cycle; Ed Blair, the older of the brothers, suggested only half in jest that I might as well go whole hog and buy the animal, if I really wanted to appreciate the challenges of ranching. This immediately struck me as a promising idea.

Ed and Rich told me what to look for: a broad straight back and thick shoulders—basically, a sturdy frame on which to hang a lot of meat. I was also looking for a memorable face in this black Angus sea, one that I could pick out of the crowd at the feedlot. Almost as soon as I began surveying the ninety or so animals in the pen, 534 moseyed up to the railing and made eye contact. He had a wide stout frame and was brockle-faced—he had three easy-to-spot white blazes. Here was my boy.

### 3. INDUSTRIAL: GARDEN CITY, KANSAS

Traveling from the ranch to the feedyard, as 534 and I both did (in separate vehicles) the first week of January, feels a lot like going from the country to the big city. A feedlot is very much a premodern city, however, reeking and filthy and stinking, with open sewers, unpaved roads, and choking air rendered visible by dust.

The urbanization of the world’s livestock being a fairly recent historical development, it makes a certain sense that cow towns like Poky

Feeders would recall human cities centuries ago, in the days before modern sanitation. As in fourteenth-century London, say, the workings of the metropolitan digestion remain vividly on display, the foodstuffs coming in, the streams of waste going out. The crowding into tight quarters of recent arrivals from all over, together with the lack of sanitation, has always been a recipe for disease. The only reason contemporary animal cities aren’t as plague-ridden or pestilential as their medieval human counterparts is a single historical anomaly: the modern antibiotic.

I spent the better part of a day at Poky Feeders, walking the streets, cattle watching, looking up my steer, and touring local landmarks like the towering feed mill. In any city it’s easy to lose track of nature—of the transactions between various species and the land on which everything ultimately depends. Back on the ranch the underlying ecological relationship could not have been more legible: It is a local food chain built upon grass and the ruminants that can digest grass, and it draws its energy from the sun. But what about here?

As the long shadow of the mill suggests, the feedlot is a city built upon America’s mountain of surplus corn—or rather, corn plus the various pharmaceuticals a ruminant must have if it is to tolerate corn. Yet, having started out from George Naylor’s farm, I understood that the corn on which this place runs is implicated in a whole other set of ecological relationships powered by a very different source of energy—the fossil fuel it takes to grow all that corn. So if the modern CAPO is a city built upon commodity corn, it is a city afloat on an invisible sea of petroleum. How this peculiar state of affairs came to seem sensible is a question I spent my day at Poky trying to answer.

IT WAS ONLY NATURAL that I start my tour at the feed mill, the feedlot’s thundering hub, where three meals a day for thirty-seven thousand animals are designed and mixed by computer. A million pounds of feed pass through the mill each day. Every hour of every day a tractor trailer pulls up to the loading dock to deliver another fifty tons of corn. The

driver opens a valve in the belly of the truck and a golden stream of grain—one thin rivulet of the great corn river coursing out of the Middle West—begins to flow, dropping down a chute into the bowels of the mill. Around to the other side of the building, tanker trucks back up to silo-shaped tanks into which they pump thousands of gallons of liquefied fat and protein supplements. In a shed attached to the mill sit vats of liquid vitamins and synthetic estrogen beside pallets stacked with fifty-pound sacks of antibiotics—Rumensin and Tylosin. Along with alfalfa hay and silage (for roughage), all these ingredients will be automatically blended and then piped into the parade of dump trucks that three times a day fan out from here to keep Poky's eight and a half miles of trough filled.

The feed mill's pulsing din is the sound of two giant steel rollers turning against one another twelve hours a day, crushing steamed corn kernels into warm and fragrant flakes. (Flaking the corn makes it easier for cattle to digest it.) This was the only feed ingredient I sampled, and it wasn't half bad: not as crisp as a Kellogg's flake, but with a cornier flavor. I passed on the other ingredients: the liquefied fat (which on today's menu is beef tallow, trucked in from one of the nearby slaughterhouses), and the protein supplement, a sticky brown goop consisting of molasses and urea. The urea is a form of synthetic nitrogen made from natural gas, similar to the fertilizer spread on George Naylor's fields.

Before being put on this highly concentrated diet, new arrivals to the feedyard are treated to a few days of fresh long-stemmed hay. (They don't eat on the long ride and can lose up to one hundred pounds, so their rumens need to be carefully restarted.) Over the next several weeks they'll gradually step up to a daily ration of thirty-two pounds of feed, three-quarters of which is corn—nearly a half bushel a day.

What got corn onto the menu at this and almost every other American feedlot is price, of course, but also USDA policy, which for decades has sought to help move the mountain of surplus corn by passing as much of it as possible through the digestive tracks of food animals, who can convert it into protein.

We've come to think of "corn-fed" as some kind of old-fashioned virtue, which it may well be when you're referring to Midwestern children, but feeding large quantities of corn to cows for the greater part of their lives is a practice neither particularly old or virtuous. Its chief advantage is that cows fed corn, a compact source of caloric energy, get fat quickly; their flesh also marbles well, giving it a taste and texture American consumers have come to like. Yet this corn-fed meat is demonstrably less healthy for us, since it contains more saturated fat and less omega-3 fatty acids than the meat of animals fed grass. A growing body of research suggests that many of the health problems associated with eating beef are really problems with corn-fed beef. (Modern-day hunter-gatherers who subsist on wild meat don't have our rates of heart disease.) In the same way ruminants are ill adapted to eating corn, humans in turn may be poorly adapted to eating ruminants that eat corn.

Yet the USDA's grading system has been designed to reward marbling (a more appealing term than "intramuscular fat," which is what it is) and thus the feeding of corn to cattle. Indeed, corn has become so deeply engrained in the whole system of producing beef in America that whenever I raised any questions about it among ranchers or feedlot operators or animal scientists, people look at me as if I'd just arrived from another planet. (Or perhaps from Argentina, where excellent steaks are produced on nothing but grass.)

The economic logic behind corn is unassailable, and on a factory farm there is no other kind. Calories are calories, and corn is the cheapest, most convenient source of calories on the market. Of course, it was the same industrial logic—protein is protein—that made feeding rendered cow parts back to cows seem like a sensible thing to do, until scientists figured out that this practice was spreading bovine spongiform encephalopathy (BSE), more commonly known as mad cow disease. Rendered bovine meat and bonemeal represented the cheapest, most convenient way of satisfying a cow's protein requirement (never mind these animals were herbivores by evolution) and so appeared on the daily menus of Poky and most other feedyards until the FDA banned the practice in 1997.



We now understand that while at a reductive, molecular level protein may indeed be protein, at an ecological or species level, this isn't quite true. As cannibal tribes have discovered, eating the flesh of one's own species carries special risks of infection. Kuru, a disease bearing a striking resemblance to BSE, spread among New Guinea tribesmen who ritually ate the brains of their dead kin. Some evolutionary biologists believe that evolution selected against cannibalism as a way to avoid such infections; animals' aversion to their own feces, and the carcasses of their species, may represent a similar strategy. Through natural selection animals have developed a set of hygiene rules, functioning much like taboos. One of the most troubling things about factory farms is how cavalierly they flout these evolutionary rules, forcing animals to overcome deeply engrained aversions. We make them trade their instincts for antibiotics.

Though the industrial logic that made feeding cattle to cattle seem like a good idea has been thrown into doubt by mad cow disease, I was surprised to learn it hadn't been discarded. The Food and Drug Administration (FDA) ban on feeding ruminant protein to ruminants makes an exception for blood products and fat; my steer will probably dine on beef tallow recycled from the very slaughterhouse he's heading to in June. ("Fat is fat," the feedlot manager shrugged, when I raised an eyebrow.) Though Poky doesn't do it, the rules still permit feedlots to feed nonruminant animal protein to ruminants. Feather meal and chicken litter (that is, bedding, feces, and discarded bits of feed) are accepted cattle feeds, as are chicken, fish, and pig meal. Some public health experts worry that since the bovine meat and bonemeal that cows used to eat is now being fed to chickens, pigs, and fish, infectious prions could find their way back into cattle when they're fed the protein of the animals that have been eating them.

Before mad cow disease remarkably few people in the cattle business, let alone the general public, comprehended the strange new semi-circular food chain that industrial agriculture had devised for the beef animal—and so, in turn, for the beef eater. When I mentioned to Rich

Blair how surprised I'd been to learn cattle were eating cattle, he said, "To tell you the truth, it was kind of a shock to me, too."

COMPARED TO ALL the other things we feed cattle these days, corn seems positively wholesome. And yet it too violates the biological or evolutionary logic of bovine digestion. During my day at Poky I spent a few hours with Dr. Mel Metzlin, the staff veterinarian, learning more than any beef eater really should know about the gastrointestinal life of the modern cow. Dr. Mel, as he's known at Poky, oversees a team of eight cowboys who spend their days riding the yard's dusty streets, spotting sick animals and bringing them into Poky's three "hospitals" for treatment. Most of the health problems that afflict feedlot cattle can be traced either directly or indirectly to their diet. "They're made to eat forage," Dr. Metzlin explained, "and we're making them eat grain."

"It's not that they can't adjust," he continues, "and now we're breeding cattle to do well in a feedyard." One way to look at the breeding work going on at ranches like the Blairs' is that the contemporary beef cow is being selected for the ability to eat large quantities of corn and efficiently convert it to protein without getting too sick. (These, after all, are precisely the genes prized in 534's father, Gar Precision 1680.) The species is evolving, in other words, to help absorb the excess biomass coming off America's cornfields. But the cow's not there quite yet, and a great many feedlot cattle—virtually all of them to one degree or another, according to several animal scientists I talked to—are simply sick.

Bloat is perhaps the most serious thing that can go wrong with a ruminant on corn. The fermentation in the rumen produces copious amounts of gas, which is normally expelled by belching during rumination. But when the diet contains too much starch and too little roughage, rumination all but stops, and a layer of foamy slime forms in the rumen that can trap the gas. The rumen inflates like a balloon until it presses against the animal's lungs. Unless action is taken promptly to

relieve the pressure (usually by forcing a hose down the animal's esophagus), the animal suffocates.

A concentrated diet of corn can also give a cow acidosis. Unlike our own highly acid stomachs, the normal pH of a rumen is neutral. Corn renders it acidic, causing a kind of bovine heartburn that in some cases can kill the animal, but usually just makes him sick. Acidotic animals go off their feed, pant and salivate excessively, paw and scratch their bellies, and eat dirt. The condition can lead to diarrhea, ulcers, bloat, rumenitis, liver disease, and a general weakening of the immune system that leaves the animal vulnerable to the full panoply of feedlot diseases—pneumonia, coccidiosis, enterotoxemia, feedlot polio. Much like modern humans, modern cattle are susceptible to a set of relatively new diseases of civilization—assuming, that is, we're willing to put the modern feedlot under the rubric of civilization.

Cattle rarely live on feedlot diets for more than 150 days, which might be about as much as their systems can tolerate. "I don't know how long you could feed them this ration before you'd see problems," Dr. Metz said; another vet told me the diet would eventually "blow out their livers" and kill them. Over time the acids eat away at the rumen wall, allowing bacteria to enter the animal's bloodstream. These microbes wind up in the liver, where they form abscesses and impair the liver's function. Between 15 percent and 30 percent of feedlot cows are found at slaughter to have abscessed livers; Dr. Mel told me that in some pens the figure runs as high as 70 percent.

What keeps a feedlot animal healthy—or healthy enough—are antibiotics. Ruminant buffers acidity in the rumen, helping to prevent bloat and acidosis, and Tylosin, a form of erythromycin, lowers the incidence of liver infection. Most of the antibiotics sold in America today end up in animal feed, a practice that, it is now generally acknowledged (except in agriculture), is leading directly to the evolution of new antibiotic-resistant superbugs. In the debate over the use of antibiotics in agriculture, a distinction is usually made between their clinical and nonclinical uses. Public health advocates don't object to treating sick animals with antibiotics; they just don't want to see the drugs lose their

effectiveness because factory farms are feeding them to healthy animals to promote growth. But the use of antibiotics in feedlot cattle confounds this distinction. Here the drugs are plainly being used to treat sick animals, yet the animals probably wouldn't be sick if not for the diet of grain we feed them.

I asked Dr. Mel what would happen if drugs like Rumensin and Tylosin were banned from cattle feed, as some public health experts advocate. "We'd have a high death rate [it's currently about 3 percent, matching the industry average] and poorer performing cattle. We just couldn't feed them as hard." The whole system would have to change—and slow down.

"Hell, if you gave them lots of grass and space, I wouldn't have a job."

MY FIRST IMPRESSION of pen 63, where my steer is spending his last five months, was, *Not a bad little piece of real estate, all considered.* The pen is far enough from the feed mill to be fairly quiet and it has a water view of what I thought was a pond or reservoir until I noticed the brown scum. The body of water is what is known, in the geography of CAFOs, as a manure lagoon. I asked the feedlot manager why they didn't just spray the liquefied manure on neighboring farms. The farmers don't want it, he explained. The nitrogen and phosphorus levels are so high that spraying the crops would kill them. He didn't say that feedlot wastes also contain heavy metals and hormone residues, persistent chemicals that end up in waterways downstream, where scientists have found fish and amphibians exhibiting abnormal sex characteristics. CAFOs like Poky transform what at the proper scale would be a precious source of fertility—cow manure—into toxic waste.

The pen 534 lives in is surprisingly spacious, about the size of a hockey rink, with a concrete feed bunk along the road, and a fresh water trough out back. I climbed over the railing and joined the ninety steers, which, en masse, retreated a few lumbering steps, and then stopped to see what I would do.

I had on the same carrot-colored sweater I'd worn to the ranch in South Dakota, hoping to elicit some glint of recognition from my steer. I couldn't find him at first; all the faces staring at me were either completely black or bore an unfamiliar pattern of white marks. And then I spotted him—the three white blazes—way off in the back. As I gingerly stepped toward him the quietly shuffling mass of black cowhide between us parted, and there stood 534 and I, staring dumbly at one another. Glimp of recognition? None, none whatsoever. I told myself not to take it personally; 534 and his pen mates have been bred for their marbling, after all, not their ability to form attachments.

I noticed that 534's eyes looked a little bloodshot. Dr. Metzlin had told me that some animals are irritated by feedlot dust. The problem is especially serious in the summer months, when the animals kick up clouds of the stuff and workers have to spray the pens with water to keep it down. I had to remind myself that this is not ordinary dirt dust, inasmuch as the dirt in a feedyard is not ordinary dirt; no, this is fecal dust. But apart from the air quality, how did feedlot life seem to be agreeing with 534? I don't know enough about the emotional life of a steer to say with confidence that 534 was miserable, bored, or indifferent, but I would not say he looked happy.

He's clearly eating well, though. My steer had put on a couple hundred pounds since we'd last met, and he looked it: thicker across the shoulder and round as a barrel through the middle. He carried himself more like a steer now than a calf, even though his first birthday was still two months away. Dr. Metzlin complimented me on his size and conformation. "That's a handsome-looking beef you got there." (Shucks.)

If I stared at my steer hard enough, I could imagine the white lines of the butcher's chart dissecting his black hide: rump roast, flank steak, standing rib, tenderloin, brisket. One way of looking at 534—the feedlot way, the industrial way—was as a most impressive machine for turning number 2 field corn into cuts of beef. Every day between now and his slaughter in six months, 534 will convert thirty-two pounds of feed into four pounds of gain—new muscle, fat, and bone. This at least is how 534 appears in the computer program I'd seen at the mill: the

ratio of feed to gain that determines his efficiency. (Compared to other food animals, cattle are terribly inefficient: The ratio of feed to flesh in chicken, the most efficient animal by this measure, is two pounds of corn to one of meat, which is why chicken costs less than beef.) Poky Feeders is indeed a factory, transforming—as fast as bovinely possible—cheap raw materials into a less cheap finished product, through the mechanism of bovine metabolism.

Yet metaphors of the factory and the machine obscure as much as they reveal about the creature standing before me. He has, of course, another, quite different identity—as an animal. I mean, connected as all animals must be to certain other animals and plants and microbes, as well as to the earth and the sun. He's a link in a food chain, a thread in a far-reaching web of ecological relationships. Looked at from this perspective, everything going on in this cattle pen appears quite different, and not nearly as far removed from our world as this manure-encrusted patch of ground here in Nowhere, Kansas, might suggest.

For one thing, the health of these animals is inextricably linked to our own by that web of relationships. The unnaturally rich diet of corn that undermines a steer's health fattens his flesh in a way that undermines the health of the humans who will eat it. The antibiotics these animals consume with their corn at this very moment are selecting, in their gut and wherever else in the environment they end up, for new strains of resistant bacteria that will someday infect us and withstand the drugs we depend on to treat that infection. We inhabit the same microbial ecosystem as the animals we eat, and whatever happens in it also happens to us.

Then there's the deep pile of manure on which I stand, in which 534 sleeps. We don't know much about the hormones in it—where they will end up, or what they might do once they get there—but we do know something about the bacteria, which can find their way from the manure on the ground to his hide and from there into our hamburgers. The speed at which these animals will be slaughtered and processed—four hundred an hour at the plant where 534 will go—means that sooner or later some of the manure caked on these hides

gets into the meat we eat. One of the bacteria that almost certainly resides in the manure I'm standing in is particularly lethal to humans. *Escherichia coli* 0157:H7 is a relatively new strain of the common intestinal bacteria (no one had seen it before 1980) that thrives in feedlot cattle, 40 percent of which carry it in their gut. Ingesting as few as ten of these microbes can cause a fatal infection; they produce a toxin that destroys human kidneys.

Most of the microbes that reside in the gut of a cow and find their way into our food get killed off by the strong acids in our stomachs, since they evolved to live in the neutral pH, environment of the rumen. But the rumen of a corn-fed feedlot steer is nearly as acidic as our own, and in this new, man-made environment new acid-resistant strains of *E. coli*, of which 0157:H7 is one, have evolved—yet another creature recruited by nature to absorb the excess biomass coming off the Farm Belt. The problem with these bugs is that they can shake off the acid bath in our stomachs—and then go on to kill us. By acidifying the rumen with corn we've broken down one of our food chain's most important barriers to infection. Yet another solution turned into a problem.

We've recently discovered that this process of acidification can be reversed, and that doing so can greatly diminish the threat from *E. coli* 0157:H7. Jim Russell, a USDA microbiologist on the faculty at Cornell, has found that switching a cow's diet from corn to grass or hay for a few days prior to slaughter reduces the population of *E. coli* 0157:H7 in the animal's gut by as much as 80 percent. But such a solution (*Grass?*) is considered wildly impractical by the cattle industry and (therefore) by the USDA. Their preferred solution for dealing with bacterial contamination is irradiation—essentially, to try to sterilize the manure getting into the meat.

So much comes back to corn, this cheap feed that turns out in so many ways to be not cheap at all. While I stood in pen 63 a dump truck pulled up alongside the feed bunk and released a golden stream of feed. The black mass of cowhide moved toward the trough for lunch. The \$1.60 a day I'm paying for three meals a day here is a bargain only by the narrowest of calculations. It doesn't take into account, for example,

the cost to the public health of antibiotic resistance or food poisoning by *E. coli* 0157:H7. It doesn't take into account the cost to taxpayers of the farm subsidies that keep Poky's raw materials cheap. And it certainly doesn't take into account all the many environmental costs incurred by cheap corn.

I stood alongside 534 as he lowered his big head into the stream of fresh grain. How absurd, I thought, the two of us standing hock-deep in manure in this godforsaken place, overlooking a manure lagoon in the middle of nowhere somewhere in Kansas. Godforsaken perhaps, and yet not apart, I realized, as I thought of the other places connected to this place by the river of commodity corn. Follow the corn from this bunk back to the fields where it grows and I'd find myself back in the middle of that 125,000-mile-square monoculture, under a steady rain of pesticide and fertilizer. Keep going, and I could follow the nitrogen runoff from that fertilizer all the way down the Mississippi into the Gulf of Mexico, adding its poison to an eight-thousand-square-mile zone so starved of oxygen nothing but algae can live in it. And then go farther still, follow the fertilizer (and the diesel fuel and the petrochemical pesticides) needed to grow the corn all the way to the oil fields of the Persian Gulf.

I don't have a sufficiently vivid imagination to look at my steer and see a barrel of oil, but petroleum is one of the most important ingredients in the production of modern meat, and the Persian Gulf is surely a link in the food chain that passes through this (or any) feedlot. Steer 534 started his life part of a food chain that derived all of its energy from the sun, which nourished the grasses that nourished him and his mother. When 534 moved from ranch to feedlot, from grass to corn, he joined an industrial food chain powered by fossil fuel—and therefore defended by the U.S. military, another never-counted cost of cheap food. (One-fifth of America's petroleum consumption goes to producing and transporting our food.) After I got home from Kansas, I asked an economist who specializes in agriculture and energy if it might be possible to calculate precisely how much petroleum it will take to grow my steer to slaughter weight. Assuming 534 continues to eat twenty-five pounds of

corn a day and reaches a weight of twelve hundred pounds, he will have consumed in his lifetime the equivalent of thirty-five gallons of oil—nearly a barrel.

So this is what commodity corn can do to a cow: industrialize the miracle of nature that is a ruminant, taking this sunlight- and prairie grass-powered organism and turning it into the last thing we need: another fossil fuel machine. This one, however, is able to suffer.

Standing there in the pen alongside my steer, I couldn't imagine ever wanting to eat the flesh of one of these protein machines. Hungry was the last thing I felt. Yet I'm sure that after enough time goes by, and the stink of this place is gone from my nostrils, I will eat feedlot beef again. Eating industrial meat takes an almost heroic act of not knowing or, now, forgetting. But I left Poky determined to follow this meat to a meal on a table somewhere, to see this food chain at least that far. I was curious to know what feedlot beef would taste like now, if I could taste the corn or even, since taste is as much a matter of what's in the head as it is about molecules dancing on the tongue, some hint of the petroleum. "You are what you eat" is a truism hard to argue with, and yet it is, as a visit to a feedlot suggests, incomplete, for you are what what you eat eats, too. And what we are, or have become, is not just meat but number 2 corn and oil.

## FIVE

# THE PROCESSING PLANT

## *Making Complex Foods*

(18,000 KERNELS)

### 1. TAKING THE KERNEL APART: THE MILL

One of the truly odd things about the 10 billion bushels of corn harvested each year is how little of it we eat. Sure, we grind some of it to make cornmeal, but most of the corn we eat as *corn*—whether on the cob, flaked, or baked into muffins or tortillas or chips—comes from varieties other than number 2: usually sweet corn or white corn. These uses represent a tiny fraction of the harvest—less than a bushel per person per year—which is probably why we don't think of ourselves as big corn eaters. And yet each of us is personally responsible for consuming a ton of the stuff every year.

Much of the rest of that per capita ton does enter our bodies, but not before it has been heavily processed, broken down into simple compounds either by animals like steer 534 or a processing plant, and then reassembled either as beef, chicken, or pork, or as soft drinks, breakfast cereals, or snacks. What doesn't pass through the gut of a food animal to become meat will pass through one of America's twenty-five

“wet mills” on its way to becoming one of the innumerable products food science has figured out how to tease from a kernel of corn. (These mills are called wet to distinguish them from the traditional mills where corn is simply ground into dry meal for things like tortillas.)

About a fifth of the corn river flowing out from the elevators at the Iowa Farmers Cooperative travels to a wet milling plant, usually by train. There it diverges into a great many slender branching tributaries, only to converge much later on a plate or in a cup. For what the wet mill does to a bushel of corn is to turn it into the building blocks from which companies like General Mills, McDonald’s, and Coca-Cola assemble our processed foods.

The first rough breakdown of all that corn begins with the subdivision of the kernel itself: Its yellow skin will be processed into various vitamins and nutritional supplements; the tiny germ (the dark part nearest the cob, which holds the embryo of the potential future corn plant) will be crushed for its oil; and the biggest part, the endosperm, will be plundered for its rich cache of complex carbohydrate.

This oversized packet of starch is corn’s most important contribution to the industrial food chain: an abundance of carbohydrate molecules in long chains that chemists have learned to break down and then rearrange into hundreds of different organic compounds—acids, sugars, starches, and alcohols. The names of many of these compounds will be familiar to anyone who’s studied the ingredient label on a package of processed food: citric and lactic acid; glucose, fructose, and maltodextrin; ethanol (for alcoholic beverages as well as cars) sorbitol, mannitol, and xanthan gum; modified and unmodified starches; as well as dextrans and cyclodextrins and MSG, to name only a few.

To watch the stream of corn coming off of George Naylor’s farm proceed to divide, subdivide, and ultimately branch off into a molecule of fructose destined to sweeten a soda is not as easy as following it to a feedlot into a cut of meat. For one thing, the two companies who wet mill most of America’s corn (Cargill and ADM) declined to let me watch them do it. For another, the process is largely invisible, since it takes place inside a series of sealed vats, pipes, fermentation tanks, and

filters. Even so, I would have liked to follow my bushel of corn through ADM’s plant in Decatur, Illinois (the unofficial capital of corn processing in America), or to Cargill’s mill in Iowa City (the likely destination of the train I saw being loaded at the elevator in Jefferson), but the industrial food chain goes underground, in effect, as it passes through these factories on its path to our plates.

The closest I got to following corn through a mill was at the Center for Crops Utilization Research at Iowa State University, in Ames, forty-five miles from the farmers cooperative elevator in Jefferson. After my visit to George Naylor’s farm, I spent a couple of days on the Ames campus, which really should be called the University of Corn. Corn is the hero of the most prominent sculptures and murals on campus, and the work of the institution is dedicated in large part to the genetics, culture, history, and uses of this plant, though the soybean, Iowa’s second crop, gets its share of attention too. The Center for Crops Utilization Research is charged with developing new uses for America’s corn and soybean surplus, and to this end operates a scaled-down wet milling operation, a Rube Goldberg contraption of stainless steel tubes, pipes, valves, vents, drying tables, centrifuges, filters, and tanks that Larry Johnson, the center’s director, was more than happy to show me.

To hear Johnson describe it, the wet milling process is essentially an industrial version of digestion: A food is broken down through a series of steps that includes the application of physical pressure, acids, and enzymes. The order of the steps is different in industrial digestion—the acids come before the mechanical chewing, for instance—but the results are much the same: A complex food is reduced to simple molecules, mostly sugars.

“First we separate the corn into its botanical parts—embryo, endosperm, fiber—and then into its chemical parts,” Johnson explained as we began our tour of the plant. When a shipment of corn arrives at the mill, it is steeped for thirty-six hours in a bath of water containing a small amount of sulphur dioxide. The acid bath swells the kernels and frees the starch from the proteins that surround it.

After the soak, the swollen kernels are ground in a mill. “By now the

germ is rubbery and it pops right off," Johnson explained. "We take the slurry to a hydroclone"—basically a centrifuge for liquids—"where the germ floats off. After it's dried, we squeeze it for corn oil." Corn oil can be used as a cooking or salad oil, or hydrogenated for use in margarine and other processed foods: Atoms of hydrogen are forced into the fat molecules to make them solid at room temperature. (Though originally designed as a healthy substitute for animal fats, medical researchers now think these trans fats are actually worse for our arteries than butter.)

Once the germ has been removed and the kernels crushed, what's left is a white mush of protein and starch called "mill starch." To draw off as much of the protein as possible, the mill starch undergoes a progressively finer series of grindings and filterings and centrifuges. The extracted protein, called gluten, is used in animal feed. At each step more fresh water is added—it takes about five gallons to process a bushel of corn, and prodigious amounts of energy. Wet milling is an energy-intensive way to make food; for every calorie of processed food it produces, another ten calories of fossil fuel energy are burned.

At this point the process has yielded a white slurry that's poured out onto a stainless steel table and dried to a fine, superwhite powder—cornstarch. Cornstarch comprised wet milling's sole product when the industry got its start in the 1840s. At first the laundry business was its biggest customer, but cooks and early food processors soon began adding cornstarch to as many recipes as they could: It offered the glamour of modernity, purity, and absolute whiteness. By 1866, corn refiners had learned how to use acids to break down cornstarch into glucose, and sweeteners quickly became—as they remain today—the industry's most important product. Corn syrup (which is mostly glucose or dextrose—the terms are interchangeable) became the first cheap domestic substitute for cane sugar.

I remember an elementary school science experiment in which we were instructed to chew—and chew and chew—a cracker until the slurry of starch turned suddenly sweet on our tongues. The teacher explained that the enzymes in our saliva had broken the long starch mol-

ecules into shorter molecules of glucose. Much the same process—it's called "enzyme hydrolysis"—revolutionized corn refining in the 1940s. As enzymes replaced acids, refiners were able to produce progressively sweeter sweeteners from corn. Yet none were quite as sweet as sugar (or, to be more precise, sucrose). That threshold wasn't crossed until the late 1960s, when Japanese chemists "broke the sweetness barrier," in the words of the Corn Refiners Association's official history of high-fructose corn sweetener. They discovered that an enzyme called glucose isomerase could transform glucose into the much sweeter sugar molecule called fructose. By the 1970s the process of refining corn into fructose had been perfected, and high-fructose corn syrup—which is a blend of 55 percent fructose and 45 percent glucose that tastes exactly as sweet as sucrose—came onto the market. Today it is the most valuable food product refined from corn, accounting for 530 million bushels every year. (A bushel of corn yields thirty-three pounds of fructose.)

But if the pipe marked "HFCS" leads to the fattest spigot at the far end of a corn refinery's bewildering tangle of pipes and valves, it is by no means the only spigot you'll find back there. There are dozens of other "output streams." At various points along its way through the mill some portion of the thick white slurry of starch is diverted to another purpose or, in the refiner's jargon, another "fraction." The starch itself is capable of being modified into spherical, crystalline, or highly branched molecules, each suitable for a different use: adhesives, coatings, sizings, and plastics for industry; stabilizers, thickeners, gels, and "viscosity-control agents" for food.

What remains in the slurry is "saccharified"—treated with enzymes that turn it into dextrose syrup. A portion of this dextrose is siphoned off for use as corn syrup; other fractions are recruited to become sugars like maltodextrin and maltose. The largest portion of the corn syrup stream is piped into a tank where it is exposed to glucose isomerase enzymes and then passed through ion exchange filters, emerging eventually as fructose. Now what's left of the dextrose stream is piped into a fermentation tank, where yeasts or amino acids go to work eating the sugars, in several hours yielding an alcoholic brew. This itself is frac-

tionated into various alcohols, ethanol chief among them, our gas tanks being the ultimate destination of a tenth of the corn crop. The fermented brew can also be refined into a dozen different organic and amino acids for use in food processing or the manufacture of plastic.

And then that's about it: There's no corn left, and not much of anything else either, except for some dirty water. (Though even some of this "steep water" is used to make animal feeds.) The primary difference between the industrial digestion of corn and an animal's is that in this case there is virtually no waste at the end of it.

Step back for a moment and behold this great, intricately piped stainless steel beast: This is the supremely adapted creature that has evolved to help eat the vast surplus biomass coming off America's farms, efficiently digesting the millions of bushels of corn fed to it each day by the trainload. Go around back of this beast and you'll see a hundred different spigots, large and small, filling tanker cars of other trains with HFCS, ethanol, syrups, starches, and food additives of every description. The question now is, who or what (besides our cars) is going to consume and digest all this freshly fractionated biomass—the sugars and starches, the alcohols and acids, the emulsifiers and stabilizers and viscosity-control agents? This is where we come in. It takes a certain kind of eater—an industrial eater—to consume these fractions of corn, and we are, or have evolved into, that supremely adapted creature: the eater of processed food.

## 2. PUTTING IT BACK TOGETHER AGAIN: PROCESSED FOODS

The dream of liberating food from nature is as old as eating. People began processing food to keep nature from taking it back: What is spoilage, after all, if not nature, operating through her proxy microorganisms, repossessing our hard-won lunch? So we learned to salt and dry and cure and pickle in the first age of food processing, and to can, freeze, and vacuum-pack in the second. These technologies were bless-

ings, freeing people from nature's cycles of abundance and scarcity, as well as from the tyranny of the calendar or locale. Now a New Englander could eat sweet corn, or something reminiscent of it, in January, and taste a pineapple for the first time in his life. As Massimo Montanari, an Italian food historian, points out, the fresh, local, and seasonal food we prize today was for most of human history "a form of slavery," since it left us utterly at the mercy of the local vicissitudes of nature.

Even after people had learned the rudiments of preserving food, however, the dream of liberating food from nature continued to flourish—indeed, to expand in ambition and confidence. In the third age of food processing, which begins with the end of World War II, merely preserving the fruits of nature was deemed too modest: The goal now was to improve on nature. The twentieth-century prestige of technology and convenience combined with advances in marketing to push aside butter to make shelf space for margarine, replace fruit juice with juice drinks and then entirely juice-free drinks like Tang, cheese with Cheez Whiz, and whipped cream with Cool Whip.

Corn, a species that had been a modest beneficiary of the first two ages of food processing (having taken well to the can and the freezer), really came into its own during the third. You would never know it without reading the ingredient label (a literary genre unknown until the third age), but corn is the key constituent of all four of these processed foods. Along with the soybean, its rotational partner in the field, corn has done more than any other species to help the food industry realize the dream of freeing food from nature's limitations and seducing the omnivore into eating more of a single plant than anyone would ever have thought possible.

In fact, you would be hard-pressed to find a late-model processed food that isn't made from corn or soybeans. In the typical formulation, corn supplies the carbohydrates (sugars and starches) and soy the protein; the fat can come from either plant. (Remember what George Naylor said about the real produce of his farm: not corn and soybeans but "energy and protein.") The longer the ingredient label on a food, the more fractions of corn and soybeans you will find in it. They supply the



essential building blocks, and from those two plants (plus a handful of synthetic additives) a food scientist can construct just about any processed food he or she can dream up.

A FEW YEARS AGO, in the days when "food security" meant something very different than it does today, I had the chance to visit one of the small handful of places where this kind of work is done. The Bell Institute, a leafy corporate campus on the outskirts of Minneapolis, is the research-and-development laboratory for General Mills, the sixth-largest food company in the world. Here nine hundred food scientists spend their days designing the future of food—its flavor, texture, and packaging.

Much of their work is highly secretive, but nowhere more so than in the cereals area. Deep in the heart of the heart of the Bell Institute, down in the bowels of the laboratory, you come to a warren of windowless rooms called, rather grandly, the Institute of Cereal Technology. I was permitted to pass through a high-security conference room furnished with a horseshoe-shaped table that had a pair of headphones at every seat. This was the institute's inner sanctum, the cereal situation room, where General Mills executives gather to hear briefings about new products.

The secrecy surrounding the successor to Cocoa Pebbles struck me as laughable, and I said so. But as an executive explained to me, "Recipes are not intellectual property; you can't patent a new cereal. All you can hope for is to have the market to yourself for a few months to establish your brand before a competitor knocks off the product. So we're very careful not to show our hand." For the same reason, the institute operates its own machine shop, where it designs and builds the machines that give breakfast cereals their shapes, making it that much harder for a competitor to knock off, say, a new marshmallow bit shaped to resemble a shooting star. In the interests of secrecy, the food scientists would not talk to me about current projects, only past failures, like the breakthrough cereal in the shapes of little bowling pins

and balls. "In focus group the kids loved it," the product's rueful inventor told me, "but the mothers didn't like the idea of kids bowling their breakfast across the table." Which is why bowling pin cereal never showed up in your supermarket.

In many ways breakfast cereal is the prototypical processed food: four cents worth of commodity corn (or some other equally cheap grain) transformed into four dollars worth of processed food. What an alchemy! Yet it is performed straightforwardly enough: by taking several of the output streams issuing from a wet mill (corn meal, corn starch, corn sweetener, as well as a handful of tinier chemical fractions) and then assembling them into an attractively novel form. Further value is added in the form of color and taste, then branding and packaging. Oh yes, and vitamins and minerals, which are added to give the product a sheen of healthfulness and to replace the nutrients that are lost whenever whole foods are processed. On the strength of this alchemy the cereals group generates higher profits for General Mills than any other division. Since the raw materials in processed foods are so abundant and cheap (ADM and Cargill will gladly sell them to all comers) protecting whatever is special about the value you add to them is imperative.

I think it was at General Mills that I first heard the term "food system." Since then, I've seen in the pages of *Food Technology*, the monthly bible of the food-processing industry, that this term seems to be taking over from plain old "food." Food system is glossier and more high-tech than food, I guess; it also escapes some of the negative connotations that got attached to "processed food" during the sixties. It's probably as good a term as any when you're describing, as that magazine routinely does, new edible materials constructed from "textured vegetable protein," or a nutraceutical breakfast cereal so fortified with green tea, grape seed extract, and antioxidants that it's not even called a cereal but a "healthy heart system."

Exactly what corn is doing in such food systems has less to do with nutrition or taste than with economics. For the dream of liberating food from nature, which began as a dream of the eaters (to make it less

perishable), is now primarily a dream of the feeders—of the corporations that sell us our food. No one was clamoring for synthetic cheese, or a cereal shaped like a bowling pin; processed food has become largely a supply-driven business—the business of figuring out clever ways to package and market the glut of commodities coming off the farm and out of the wet mills. Today the great advantages of processing food redound to the processors themselves. For them, nature is foremost a problem—not so much of perishable food (though that's always a concern when your market is global) as of perishable profits.

Like every other food chain, the industrial food chain is rooted at either end in a natural system: the farmer's field at one end, and the human organism at the other. From the capitalist's point of view, both of these systems are less than ideal.

The farm, being vulnerable to the vicissitudes of weather and pests, is prone to crises of over- and underproduction, both of which can hurt business. Rising raw material prices cut into profits, obviously enough. Yet the potential boon of falling raw material prices—which should allow you to sell a lot more of your product at a lower price—can't be realized in the case of food because of the special nature of your consumer, who can eat only so much food, no matter how cheap it gets. (Food industry executives used to call this the problem of the “fixed stomach”; economists speak of “inelastic demand.”) Nature has cursed the companies working the middle of the food chain with a recipe for falling rates of profits.

The growth of the American food industry will always bump up against this troublesome biological fact: Try as we might, each of us can eat only about fifteen hundred pounds of food a year. Unlike many other products—CDs, say, or shoes—there's a natural limit to how much food we can each consume without exploding. What this means for the food industry is that its natural rate of growth is somewhere around 1 percent per year—1 percent being the annual growth rate of the American population. The problem is that 1 percent will never satisfy Wall Street, which demands at the very least a 10 percent return on its capital.

This leaves companies like General Mills and McDonald's with two

options if they hope to grow faster than the population: figure out how to get people to spend more money for the same three-quarters of a ton of food, or entice them to actually eat more than that. The two strategies are not mutually exclusive, of course, and the food industry energetically pursues them both at the same time. Which is good news indeed for the hero of our story, for it happens that turning cheap corn into complex food systems is an excellent way to achieve both goals.

BUILDING PROCESSED FOOD out of a commodity like corn doesn't completely cushion you from the vicissitudes of nature, but it comes close. The more complex your food system, the more you can practice “substitutionism” without altering the taste or appearance of the product. So if the price of hydrogenated fat or lecithin derived from corn spikes one day, you simply switch to fat or lecithin from soy, and the consumer will never know the difference. (This is why ingredient labels says things like “Contains one or more of the following: corn, soybean, or sunflower oil.”) As a management consultant once advised his food industry clients, “The further a product's identity moves from a specific raw material—that is, the more processing steps involved—the less vulnerable is its processor” to the variability of nature.

In fact, there are lots of good reasons to complicate your product—or, as the industry prefers to say, to “add value” to it. Processing food can add months, even years, to its shelf life, allowing you to market globally. Complicating your product also allows you to capture more of the money a consumer spends on food. Of a dollar spent on a whole food such as eggs, \$0.40 finds its way back to the farmer. By comparison, George Naylor will see only \$0.04 of every dollar spent on corn sweeteners; ADM and Coca-Cola and General Mills capture most of the rest. (Every farmer I've ever met eventually gets around to telling the story about the food industry executive who declared, “There's money to be made in food, unless you're trying to grow it.”) When Tyson food scientists devised the chicken nugget in 1983, a cheap bulk commodity—chicken—overnight became a high-value-added product, and most of

the money Americans spend on chicken moved from the farmer's pocket to the processor's.

As Tyson understood, you want to be selling something more than a commodity, something more like a service: novelty, convenience, status, fortification, lately even medicine. The problem is, a value-added product made from a cheap commodity can itself become a commodity, so cheap and abundant are the raw materials. That lesson runs straight through the history of a company like General Mills, which started out in 1926 as a mill selling whole wheat flour: ground wheat. When that product became a cheap commodity, the company kept ahead of the competition by processing the grain a bit more, creating bleached and then "enriched" flour. Now they were adding value, selling not just wheat but an idea of purity and health, too. In time, however, even enriched white flour became a commodity, so General Mills took another step away from nature—from the farm and the plants in question—by inventing cake mixes and sweetened breakfast cereals. Now they were selling convenience, with a side of grain and corn sweetener, and today they're beginning to sell cereals that sound an awful lot like medicines. And so it goes, the rushing stream of ever cheaper agricultural commodities driving food companies to figure out new and ever more elaborate ways to add value and so induce us to buy more.

When I was in Minneapolis I spoke to a General Mills vice president who was launching a new line of organic TV dinners, a product that at first blush sounded like an oxymoron. The ingredient list went on forever, brimming with additives and obscure fractions of corn: maltodextrin, corn starch, xanthan gum. It seems that even organic food has succumbed to the economic logic of processing. The executive patiently explained that selling unprocessed or minimally processed whole foods will always be a fool's game, since the price of agricultural commodities tends to fall over time, whether they're organic or not. More food coming off the farm leads to either falling profits—or more processing.

The other problem with selling whole foods, he explained, is that it will always be hard to distinguish one company's corn or chickens or apples from any other company's. It makes much more sense to turn

the corn into a brand-name cereal, the chicken into a TV dinner, and the apples into a component in a nutritional food system.

This last is precisely what one company profiled in a recent issue of *Food Technology* has done. TreeTop has developed a "low-moisture, naturally sweetened apple piece infused with a red-wine extract." Just eighteen grams of these apple pieces have the same amount of cancer-fighting "flavonoid phenols as five glasses of wine and the dietary fiber equivalent of one whole apple." Remember the sixties dream of an entire meal served in a pill, like the Jetsons? We've apparently moved from the meal-in-a-pill to the pill-in-a-meal, which is to say, not very far at all. Either way, the message is: We need food scientists to feed us. Of course, it was fortified breakfast cereal that first showed the way, by supplying more vitamins and minerals than any mere grain could hope to. Nature, these products implied, was no match for food science.

The news of TreeTop's breakthrough came in a recent *Food Technology* trend story titled "Getting More Fruits and Vegetables into Food." I had thought fruits and vegetables were already foods, and so didn't need to be gotten into them, but I guess that just shows I'm stuck in the food past. Evidently we're moving into the fourth age of food processing, in which the processed food will be infinitely better (i.e., contain more of whatever science has determined to be the good stuff) than the whole foods on which they're based. The food industry has gazed upon nature and found it wanting—and has gotten to work improving it.

Back in the seventies, a New York food additive manufacturer called International Flavors & Fragrances used its annual report to defend itself against the rising threat of "natural foods" and explain why we were better off eating synthetics. Natural ingredients, the company pointed out rather scarily, are a "wild mixture of substances created by plants and animals for completely non-food purposes—their survival and reproduction." These dubious substances "came to be consumed by humans at their own risk."

Now, thanks to the ingenuity of modern food science, we had a choice. We could eat things designed by humans for the express purpose of being eaten by people—or eat "substances" designed by natu-

ral selection for its own purposes: to, say, snooker a bee or lift a wing or (eck!) make a baby. The meal of the future would be fabricated “in the laboratory out of a wide variety of materials,” as one food historian wrote in 1973, including not only algae and fungi but also petrochemicals. Protein would be extracted directly from petroleum and then “spun and woven into ‘animal’ muscle—long, wrist-thick tubes of ‘flet steak.’” (Come to think of it, agribusiness has long since mastered this trick of turning petroleum into steak, though it still needs corn and cattle to do it.)

All that’s really changed since the high-tech food future of the sixties is that the laboratory materials out of which these meals will be constructed are nominally natural—the relative prestige of nature and modern chemistry having traded places in the years since the rise of environmentalism. And besides, why go to the trouble and expense of manufacturing food from petroleum when there is such a flood of cheap carbon coming off the farm? So instead of creating foods whole cloth from completely synthetic materials, the industry is building them from fortified apple bits, red-wine extract, flavor fractions derived from oranges, isoflavones from soy, meat substitutes fashioned from mycoprotein, and resistant starches derived from corn. (“Natural raspberry flavor” doesn’t mean the flavor came from a raspberry; it may well have been derived from corn, just not from something synthetic.) But the underlying reductionist premise—that a food is nothing more than the sum of its nutrients—remains undisturbed. So we break down the plants and animals into their component parts and then reassemble them into high-value-added food systems. The omnivore’s predilection to eat a variety of species is tricked by this protean plant, and even the biological limit on his appetite is overcome.

Resistant starch, the last novelty on that list of ingredients, has the corn refiners particularly excited today. They’ve figured out how to tease a new starch from corn that is virtually indigestible. You would not think this is a particularly good thing for a food to be, unless of course your goal is to somehow get around the biological limit on how much each of us can eat in a year. Since the body can’t break down re-

sistant starch, it slips through the digestive track without ever turning into calories of glucose—a particular boon, we’re told, for diabetics. When fake sugars and fake fats are joined by fake starches, the food industry will at long last have overcome the dilemma of the fixed stomach: whole meals you can eat as often or as much of as you like, since this food will leave no trace. Meet the ultimate—the utterly elastic!—industrial eater.

## SIX

## THE CONSUMER

*A Republic of Fat*

In the early years of the nineteenth century, Americans began drinking more than they ever had before or since, embarking on a collective bender that confronted the young republic with its first major public health crisis—the obesity epidemic of its day. Corn whiskey, suddenly superabundant and cheap, became the drink of choice, and in 1820 the typical American was putting away half a pint of the stuff every day. That comes to more than five gallons of spirits a year for every man, woman, and child in America. The figure today is less than one.

As the historian W. J. Rorabaugh tells the story in *The Alcoholic Republic*, we drank the hard stuff at breakfast, lunch, and dinner, before work and after and very often during. Employers were expected to supply spirits over the course of the workday; in fact, the modern coffee break began as a late-morning whiskey break called “the elevenses.” (Just to pronounce it makes you sound tipsy.) Except for a brief respite Sunday morning in church, Americans simply did not gather—whether for a barn raising or quilting bee, corn husking or political rally—without passing the whiskey jug. Visitors from Europe—hardly models of sobri-

ety themselves—marveled at the free flow of American spirits. “Come on then, if you love toting,” the journalist William Cobbet wrote his fellow Englishmen in a dispatch from America. “For here you may drink yourself blind at the price of sixpence.”

The results of all this toting were entirely predictable: a rising tide of public drunkenness, violence, and family abandonment, and a spike in alcohol-related diseases. Several of the Founding Fathers—including George Washington, Thomas Jefferson, and John Adams—denounced the excesses of “the Alcoholic Republic,” inaugurating an American quarrel over drinking that would culminate a century later in Prohibition.

But the outcome of our national drinking binge is not nearly as relevant to our own situation as its underlying cause. Which, put simply, was this: American farmers were producing far too much corn. This was particularly true in the newly settled regions west of the Appalachians, where fertile, virgin soils yielded one bumper crop after another. A mountain of surplus corn piled up in the Ohio River Valley. Much as today, the astounding productivity of American farmers proved to be their own worst enemy, as well as a threat to public health. For when yields rise, the market is flooded with grain, and its price collapses. What happens next? The excess biomass works like a vacuum in reverse: Sooner or later, clever marketers will figure out a way to induce the human omnivore to consume the surfeit of cheap calories.

As it is today, the clever thing to do with all that cheap corn was to process it—specifically, to distill it into alcohol. The Appalachian range made it difficult and expensive to transport surplus corn from the lightly settled Ohio River Valley to the more populous markets of the East, so farmers turned their corn into whiskey—a more compact and portable, and less perishable, value-added commodity. Before long the price of whiskey plummeted to the point that people could afford to drink it by the pint. Which is precisely what they did.

The Alcoholic Republic has long since given way to the Republic of Fat; we’re eating today much the way we drank then, and for some of the same reasons. According to the surgeon general, obesity today is of-

cially an epidemic; it is arguably the most pressing public health problem we face, costing the health care system an estimated \$90 billion a year. Three of every five Americans are overweight; one of every five is obese. The disease formerly known as adult-onset diabetes has had to be renamed Type II diabetes since it now occurs so frequently in children. A recent study in the *Journal of the American Medical Association* predicts that a child born in 2000 has a one-in-three chance of developing diabetes. (An African American child's chances are two in five.) Because of diabetes and all the other health problems that accompany obesity, today's children may turn out to be the first generation of Americans whose life expectancy will actually be shorter than that of their parents. The problem is not limited to America: The United Nations reported that in 2000 the number of people suffering from overnutrition—a billion—had officially surpassed the number suffering from malnutrition—800 million.

You hear plenty of explanations for humanity's expanding waistline, all of them plausible. Changes in lifestyle (we're more sedentary; we eat out more). Affluence (more people can afford a high-fat Western diet). Poverty (healthier whole foods cost more). Technology (fewer of us use our bodies in our work; at home, the remote control keeps us pinned to the couch). Clever marketing (supersized portions; advertising to children). Changes in diet (more fats; more carbohydrates; more processed foods).

All these explanations are true, as far as they go. But it pays to go a little further, to search for the cause behind the causes. Which, very simply, is this: When food is abundant and cheap, people will eat more of it and get fat. Since 1977 an American's average daily intake of calories has jumped by more than 10 percent. Those two hundred calories have to go somewhere, and absent an increase in physical activity (which hasn't happened), they end up being stored away in fat cells in our bodies. But the important question is, Where, exactly, did all those extra calories come from in the first place? And the answer to that question takes us back to the source of almost all calories: the farm.

Most researchers trace America's rising rates of obesity to the 1970s.

This was, of course, the same decade that America embraced a cheap-food farm policy and began dismantling forty years of programs designed to prevent overproduction. Earl Butz, you'll recall, sought to drive up agricultural yields in order to drive down the price of the industrial food chain's raw materials, particularly corn and soybeans. It worked: The price of food is no longer a political issue. Since the Nixon administration, farmers in the United States have managed to produce 500 additional calories per person every day (up from 3,300, already substantially more than we need); each of us is, heroically, managing to put away 200 of those surplus calories at the end of their trip up the food chain. Presumably the other 300 are being dumped overseas, or turned (once again!) into ethyl alcohol: ethanol for our cars.

The parallels with the alcoholic republic of two hundred years ago are hard to miss. Before the changes in lifestyle, before the clever marketing, comes the mountain of cheap corn. Corn accounts for most of the surplus calories we're growing and most of the surplus calories we're eating. As then, the smart thing to do with all that surplus grain is to process it, transform the cheap commodity into a value-added consumer product—a denser and more durable package of calories. In the 1820s the processing options were basically two: You could turn your corn into pork or alcohol. Today there are hundreds of things a processor can do with corn: They can use it to make everything from chicken nuggets and Big Macs to emulsifiers and nutraceuticals. Yet since the human desire for sweetness surpasses even our desire for intoxication, the cleverest thing to do with a bushel of corn is to refine it into thirty-three pounds of high-fructose corn syrup.

That at least is what we're doing with about 530 million bushels of the annual corn harvest—turning it into 17.5 billion pounds of high-fructose corn syrup. Considering that the human animal did not taste this particular food until 1980, for HFCS to have become the leading source of sweetness in our diet stands as a notable achievement on the part of the corn-refining industry, not to mention this remarkable plant. (But then, plants have always known that one of the surest paths to evolutionary success is by gratifying the mammalian omnivore's in-

nate desire for sweetness.) Since 1985, an American's annual consumption of HFCS has gone from forty-five pounds to sixty-six pounds. You might think that this growth would have been offset by a decline in sugar consumption, since HFCS often replaces sugar, but that didn't happen: During the same period our consumption of refined sugar actually went up by five pounds. What this means is that we're eating and drinking all that high-fructose corn syrup on top of the sugars we were already consuming. In fact, since 1985 our consumption of all added sugars—came, beet, HFCS, glucose, honey, maple syrup, whatever—has climbed from 128 pounds to 158 pounds per person.

This is what makes high-fructose corn syrup such a clever thing to do with a bushel of corn: By inducing people to consume more calories than they otherwise might, it gets them to really chomp through the corn surplus. Corn sweetener is to the republic of fat what corn whiskey was to the alcoholic republic. Read the food labels in your kitchen and you'll find that HFCS has insinuated itself into every corner of the pantry: not just into our soft drinks and snack foods, where you would expect to find it, but into the ketchup and mustard, the breads and cereals, the relishes and crackers, the hot dogs and hams.

But it is in soft drinks that we consume most of our sixty-six pounds of high-fructose corn syrup, and to the red-letter dates in the natural history of *Zea mays*—right up there with teosinte's catastrophic sexual mutation, Columbus's introduction of maize to the court of Queen Isabella in 1493, and Henry Wallace's first F-1 hybrid seed in 1927—we must now add the year 1980. That was the year corn first became an ingredient in Coca-Cola. By 1984, Coca-Cola and Pepsi had switched over entirely from sugar to high-fructose corn syrup. Why? Because HFCS was a few cents cheaper than sugar (thanks in part to tariffs on imported sugarcane secured by the corn refiners) and consumers didn't seem to notice the substitution.

The soft drink makers' switch should have been a straightforward, zero-sum trade-off between corn and sugarcane (both, incidentally, C-4 grasses), but it wasn't: We soon began swilling a lot more soda and therefore corn sweetener. The reason isn't far to seek: Like corn whiskey

in the 1820s, the price of soft drinks plummeted. Note, however, that Coca-Cola and Pepsi did not simply cut the price of a bottle of cola. That would only have hurt profit margins, for how many people are going to buy a second soda just because it cost a few cents less? The companies had a much better idea: They would supersize their sodas. Since a soft drink's main raw material—corn sweetener—was now so cheap, why not get people to pay just a few pennies more for a substantially bigger bottle? Drop the price per ounce, but sell a lot more ounces. So began the transformation of the svelte eight-ounce Coke bottle into the chubby twenty-ouncer dispensed by most soda machines today.

But the soda makers don't deserve credit for the invention of supersizing. That distinction belongs to a man named David Wallerstein. Until his death in 1993, Wallerstein served on the board of directors at McDonald's, but in the fifties and sixties he worked for a chain of movie theaters in Texas, where he labored to expand sales of soda and popcorn—the high-mark-up items that theaters depend on for their profitability. As the story is told in John Love's official history of McDonald's, Wallerstein tried everything he could think of to goose up sales—two-for-one deals, marine specials—but found he simply could not induce customers to buy more than one soda and one bag of popcorn. He thought he knew why: Going for seconds makes people feel piggyish.

Wallerstein discovered that people would spring for more popcorn and soda—a lot more—as long as it came in a single gigantic serving. Thus was born the two-quart bucket of popcorn, the sixty-four-ounce Big Gulp, and, in time, the Big Mac and the jumbo fries, though Ray Kroc himself took some convincing. In 1968, Wallerstein went to work for McDonald's, but try as he might, he couldn't convince Kroc, the company's founder, of supersizing's magic powers.

"If people want more fries," Kroc told him, "they can buy two bags." Wallerstein patiently explained that McDonald's customers did want more but were reluctant to buy a second bag. "They don't want to look like gluttons."

Kroc remained skeptical, so Wallerstein went looking for proof. He began staking out McDonald's outlets in and around Chicago, observ-

ing how people ate. He saw customers noisily draining their sodas, and digging infinitesimal bits of salt and burnt spud out of their little bags of French fries. After Wallerstein presented his findings, Kroc relented, approved supersized portions, and the dramatic spike in sales confirmed the marketer's hunch. Deep cultural taboos against gluttony—one of the seven deadly sins, after all—had been holding us back. Wallerstein's dubious achievement was to devise the dietary equivalent of a papal dispensation: Super-size it! He had discovered the secret to expanding the (supposedly) fixed human stomach.

One might think that people would stop eating and drinking these gargantuan portions as soon as they felt full, but it turns out hunger doesn't work that way. Researchers have found that people (and animals) presented with large portions will eat up to 30 percent more than they would otherwise. Human appetite, it turns out, is surprisingly elastic, which makes excellent evolutionary sense: It behaved our hunter-gatherer ancestors to feast whenever the opportunity presented itself, allowing them to build up reserves of fat against future famine. Obesity researchers call this trait the "thrifty gene." And while the gene represents a useful adaptation in an environment of food scarcity and unpredictability, it's a disaster in an environment of fast-food abundance, when the opportunity to feast presents itself 24/7. Our bodies are storing reserves of fat against a famine that never comes.

But if evolution has left the modern omnivore vulnerable to the blandishments of supersizing, the particular nutrients he's most likely to encounter in those supersized portions—lots of added sugar and fat—make the problem that much worse. Like most other warm-blooded creatures, humans have inherited a preference for energy-dense foods, a preference reflected in the sweet tooth shared by most mammals. Natural selection predisposed us to the taste of sugar and fat (its texture as well as taste) because sugars and fats offer the most energy (which is what a calorie is) per bite. Yet in nature—in whole foods—we seldom encounter these nutrients in the concentrations we now find them in in processed foods: You won't find a fruit with any-

where near the amount of fructose in a soda, or a piece of animal flesh with quite as much fat as a chicken nugget.

You begin to see why processing foods is such a good strategy for getting people to eat more of them. The power of food science lies in its ability to break foods down into their nutrient parts and then reassemble them in specific ways that, in effect, push our evolutionary buttons, fooling the omnivore's inherited food selection system. Add fat or sugar to anything and it's going to taste better on the tongue of an animal that natural selection has wired to seek out energy-dense foods. Animal studies prove the point: Rats presented with solutions of pure sucrose or tubs of pure lard—goodies they seldom encounter in nature—will gorge themselves sick. Whatever nutritional wisdom the rats are born with breaks down when faced with sugars and fats in unnatural concentrations—nutrients ripped from their natural context, which is to say, from those things we call foods. Food systems can cheat by exaggerating their energy density, tricking a sensory apparatus that evolved to deal with markedly less dense whole foods.

It is the amped-up energy density of processed foods that gets omnivores like us into trouble. Type II diabetes typically occurs when the body's mechanism for managing glucose simply wears out from overuse. Just about everything we eat sooner or later winds up in the blood as molecules of glucose, but sugars and simple starches turn to glucose faster than anything else. Type II diabetes and obesity are exactly what you would expect to see in a mammal whose environment has overwhelmed its metabolism with energy-dense foods.

This begs the question of why the problem has gotten so much worse in recent years. It turns out the price of a calorie of sugar or fat has plummeted since the 1970s. One reason that obesity and diabetes become more prevalent the further down the socioeconomic scale you look is that the industrial food chain has made energy-dense foods the cheapest foods in the market, when measured in terms of cost per calorie. A recent study in the *American Journal of Clinical Nutrition* compared the "energy cost" of different foods in the supermarket. The researchers



found that a dollar could buy 1,200 calories of potato chips and cookies; spent on a whole food like carrots, the same dollar buys only 250 calories. On the beverage aisle, you can buy 875 calories of soda for a dollar, or 170 calories of fruit juice from concentrate. It makes good economic sense that people with limited money to spend on food would spend it on the cheapest calories they can find, especially when the cheapest calories—fats and sugars—are precisely the ones offering the biggest neurobiological rewards.

Corn is not the only source of cheap energy in the supermarket—much of the fat added to processed foods comes from soybeans—but it is by far the most important. As George Naylor said, growing corn is the most efficient way to get energy—calories—from an acre of Iowa farmland. That corn-made calorie can find its way into our bodies in the form of an animal fat, a sugar, or a starch, such is the protean nature of the carbon in that big kernel. But as productive and protean as the corn plant is, finally it is a set of human choices that have made these molecules quite as cheap as they have become: a quarter century of farm policies designed to encourage the overproduction of this crop and hardly any other. Very simply, we subsidize high-fructose corn syrup in this country, but not carrots. While the surgeon general is raising alarms over the epidemic of obesity, the president is signing farm bills designed to keep the river of cheap corn flowing, guaranteeing that the cheapest calories in the supermarket will continue to be the unhealthiest.

## SEVEN

# THE MEAL

### *Fast Food*

The meal at the end of the industrial food chain that begins in an Iowa cornfield is prepared by McDonald's and eaten in a moving car. Or at least this was the version of the industrial meal I chose to eat; it could easily have been another. The myriad streams of commodity corn, after being variously processed and turned into meat, converge in all sorts of different meals I might have eaten, at KFC or Pizza Hut or Applebee's, or prepared myself from ingredients bought at the supermarket. Industrial meals are all around us, after all; they make up the food chain from which most of us eat most of the time.

My eleven-year-old son, Isaac, was more than happy to join me at McDonald's; he doesn't get there often, so it's a treat. (For most American children today, it is no longer such a treat: One in three of them eat fast food every single day.) Judith, my wife, was less enthusiastic. She's careful about what she eats, and having a fast-food lunch meant giving up a "real meal," which seemed a shame. Isaac pointed out that she could order one of McDonald's new "premium salads" with the Paul Newman dressing. I read in the business pages that these salads are a big

hit, but even if they weren't, they'd probably stay on the menu strictly for their rhetorical usefulness. The marketers have a term for what a salad or veggie burger does for a fast-food chain: "denying the denier." These healthier menu items hand the child who wants to eat fast food a sharp tool with which to chip away at his parents' objections. "But Mom, you can get the salad . . ."

Which is exactly what Judith did: order the Cobb salad with Caesar dressing. At \$3.99, it was the most expensive item on the menu. I ordered a classic cheeseburger, large fries, and a large Coke. Large turns out to be a full 32 ounces (a quart of soda!) but, thanks to the magical economics of supersizing, it cost only 30 cents more than the 16-ounce "small." Isaac went with the new white-meat Chicken McNuggets, a double-thick vanilla shake, and a large order of fries, followed by a new dessert treat consisting of freeze-dried pellets of ice cream. That each of us ordered something different is a hallmark of the industrial food chain, which breaks the family down into its various demographics and markets separately to each one: Together we would be eating alone together, and therefore probably eating more. The total for the three of us came to fourteen dollars, and was packed up and ready to go in four minutes. Before I left the register I picked up a densely printed handout called "A Full Serving of Nutrition Facts: Choose the Best Meal for You."

We could have slipped into a booth, but it was such a nice day we decided to put the top down on the convertible and eat our lunch in the car, something the food and the car have both been engineered to accommodate. These days 19 percent of American meals are eaten in the car. The car has cup holders, front seat and rear, and, except for the salad, all the food (which we could have ordered, paid for, and picked up without opening the car door) can be readily eaten with one hand. Indeed, this is the genius of the chicken nugget: It liberated chicken from the fork and plate, making it as convenient, waste-free, and automobile-friendly as the precondimented hamburger. No doubt the food scientists at McDonald's corporate headquarters in Oak Brook, Illinois, are right now hard at work on the one-handed salad.

But though Judith's Cobb salad did present a challenge to front-seat

dining, eating it at fifty-five miles per hour seemed like the thing to do, since corn was the theme of this meal: The car was eating corn too, being fueled in part by ethanol. Even though the additive promises to diminish air quality in California, new federal mandates pushed by the corn processors require refineries in the state to help eat the corn surplus by diluting their gasoline with 10 percent ethanol.

I ate a lot of McDonald's as a kid. This was in the pre-Wallerstein era, when you still had to order a second little burger or sack of fries if you wanted more, and the chicken nugget had not yet been invented. (One memorable childhood McDonald's meal ended when our station wagon got rear-ended at a light, propelling my milk shake across the car in creamy white lariats.) I loved everything about fast food: the individual portions all wrapped up like presents (not having to share with my three sisters was a big part of the appeal; fast food was private property at its best); the familiar meaty perfume of the French fries filling the car; and the pleasingly sequenced bite into a burger—the soft, sweet roll, the crunchy pickle, the savory moistness of the meat.

Well-designed fast food has a fragrance and flavor all its own, a fragrance and flavor only nominally connected to hamburgers or French fries or for that matter to any particular food. Certainly the hamburgers and fries you make at home don't have it. And yet Chicken McNuggets do, even though they're ostensibly an entirely different food made from a different species. Whatever it is (surely the food scientists know), for countless millions of people living now, this generic fast-food flavor is one of the unerasable smells and tastes of childhood—which makes it a kind of comfort food. Like other comfort foods, it supplies (besides nostalgia) a jolt of carbohydrates and fat, which, some scientists now believe, relieve stress and bathe the brain in chemicals that make it feel good.

Isaac announced that his white-meat McNuggets were tasty, a definite improvement over the old recipe. McNuggets have come in for a lot of criticism recently, which might explain the reformulation. Ruling in 2003 in a lawsuit brought against McDonald's by a group of obese teenagers, a federal judge in New York had defamed the McNugget even

as he dismissed the suit. "Rather than being merely chicken fried in a pan," he wrote in his decision, McNuggets "are a McFranksteinian creation of various elements not utilized by the home cook." After cataloging the thirty-eight ingredients in a McNugget, Judge Sweet suggested that McDonald's marketing bordered on deceptive, since the dish is not what it purports to be—that is, a piece of chicken simply fried—and, contrary to what a consumer might reasonably expect, actually contains more fat and total calories than a cheeseburger. Since the lawsuit, McDonald's has reformulated the nugget with white meat, and begun handing out "A Full Serving of Nutrition Facts."\* According to the flyer, a serving of six nuggets now has precisely ten fewer calories than a cheeseburger. Chalk up another achievement for food science.

When I asked Isaac if the new nuggets tasted more like chicken than the old ones, he seemed baffled by the question. "No, they taste like what they are, which is nuggets," and then dropped on his dad a withering two-syllable "dub." In this consumer's mind at least, the link between a nugget and the chicken in it was never more than notional, and probably irrelevant. By now the nugget constitutes its own genre of food for American children, many of whom eat nuggets every day. For Isaac, the nugget is a distinct taste of childhood, quite apart from chicken, and no doubt a future vehicle of nostalgia—a madeleine in the making.

Isaac passed one up to the front for Judith and me to sample. It looked and smelled pretty good, with a nice crust and bright white interior reminiscent of chicken breast meat. In appearance and texture a nugget certainly alludes to fried chicken, yet all I could really taste was salt, that all-purpose fast-food flavor, and, okay, maybe a note of chicken bouillon informing the salt. Overall the nugget seemed more like an abstraction than a full-fledged food, an idea of chicken waiting to be fleshed out.

The ingredients listed in the flyer suggest a lot of thought goes into a nugget, that and a lot of corn. Of the thirty-eight ingredients it takes

to make a McNugget, I counted thirteen that can be derived from corn: the corn-fed chicken itself; modified cornstarch (to bind the pulverized chicken meat); mono-, tri-, and diglycerides (emulsifiers, which keep the fats and water from separating); dextrose; lecithin (another emulsifier); chicken broth (to restore some of the flavor that processing leaches out); yellow corn flour and more modified cornstarch (for the batter); cornstarch (a filler); vegetable shortening; partially hydrogenated corn oil; and citric acid as a preservative. A couple of other plants take part in the nugget: There's some wheat in the batter, and on any given day the hydrogenated oil could come from soybeans, canola, or cotton rather than corn, depending on market price and availability.

According to the handout, McNuggets also contain several completely synthetic ingredients, quiescible substances that ultimately come not from a corn or soybean field but from a petroleum refinery or chemical plant. These chemicals are what make modern processed foods possible, by keeping the organic materials in them from going bad or looking strange after months in the freezer or on the road. Listed first are the "leavening agents": sodium aluminum phosphate, monocalcium phosphate, sodium acid pyrophosphate, and calcium lactate. These are antioxidants added to keep the various animal and vegetable fats involved in a nugget from turning rancid. Then there are "anti-foaming agents" like dimethylpolysiloxene, added to the cooking oil to keep the starches from binding to air molecules, so as to produce foam during the fry. The problem is evidently grave enough to warrant adding a toxic chemical to the food: According to the *Handbook of Food Additives*, dimethylpolysiloxene is a suspected carcinogen and an established mutagen, tumorigen, and reproductive effector; it's also flammable. But perhaps the most alarming ingredient in a Chicken McNugget is tertiary butylhydroquinone, or TBHQ, an antioxidant derived from petroleum that is either sprayed directly on the nugget or the inside of the box it comes in to "help preserve freshness." According to *A Consumer's Dictionary of Food Additives*, TBHQ is a form of butane (i.e., lighter fluid) the FDA allows processors to use sparingly in our food: It can

\*In 2005 McDonald's announced it would begin printing nutrition information on its packaging.

comprise no more than 0.02 percent of the oil in a nugget. Which is probably just as well, considering that ingesting a single gram of TBHQ can cause “nausea, vomiting, ringing in the ears, delirium, a sense of suffocation, and collapse.” Ingesting five grams of TBHQ can kill.

With so many exotic molecules organized into a food of such complexity, you would almost expect a chicken nugget to do something more spectacular than taste okay to a child and fill him up inexpensively. What it has done, of course, is to sell an awful lot of chicken for companies like Tyson, which invented the nugget—at McDonald’s behest—in 1983. The nugget is the reason chicken has supplanted beef as the most popular meat in America.

Compared to Isaac’s nuggets, my cheeseburger is a fairly simple construct. According to “A Full Serving of Nutrition Facts,” the cheeseburger contains a mere six ingredients, all but one of them familiar: a 100 percent beef patty, a bun, two American cheese slices, ketchup, mustard, pickles, onions, and “grill seasoning,” whatever that is. It tasted pretty good, too, though on reflection what I mainly tasted were the condiments: Sampled by itself, the gray patty had hardly any flavor. And yet the whole package, especially on first bite, did manage to give off a fairly convincing burgerish aura. I suspect, however, that owes more to the olfactory brilliance of the “grill seasoning” than to the 100 percent beef patty.

In truth, my cheeseburger’s relationship to beef seemed nearly as metaphorical as the nugget’s relationship to a chicken. Eating it, I had to remind myself that there was an actual cow involved in this meal—most likely a burned-out old dairy cow (the source of most fast-food beef) but possibly bits and pieces of a steer like 534 as well. Part of the appeal of hamburgers and nuggets is that their boneless abstractions allow us to forget we’re eating animals. I’d been on the feedlot in Garden City only a few months earlier, yet this experience of cattle was so far removed from that one as to be taking place in a different dimension. No, I could not taste the feed corn or the petroleum or the antibiotics or the hormones—or the feedlot manure. Yet while “A Full Serving of Nutrition Facts” did not enumerate these facts, they too have gone into

the making of this hamburger, are part of its natural history. That perhaps is what the industrial food chain does best: obscure the histories of the foods it produces by processing them to such an extent that they appear as pure products of culture rather than nature—things made from plants and animals. Despite the blizzard of information contained in the helpful McDonald’s flyer—the thousands of words and numbers specifying ingredients and portion sizes, calories and nutrients—all this food remains perfectly opaque. Where does it come from? It comes from McDonald’s.

But that’s not so. It comes from refrigerated trucks and from warehouses, from slaughterhouses, from factory farms in towns like Garden City, Kansas, from ranches in Sturgis, South Dakota, from food science laboratories in Oak Brook, Illinois, from flavor companies on the New Jersey Turnpike, from petroleum refineries, from processing plants owned by ADM and Cargill, from grain elevators in towns like Jefferson, and, at the end of that long and tortuous trail, from a field of corn and soybeans farmed by George Naylor in Churdan, Iowa.

It would not be impossible to calculate exactly how much corn Judith, Isaac, and I consumed in our McDonald’s meal. I figure my 4-ounce burger, for instance, represents nearly 2 pounds of corn (based on a cow’s feed conversion rate of 7 pounds of corn for every 1 pound of gain, half of which is edible meat). The nuggets are a little harder to translate into corn, since there’s no telling how much actual chicken goes into a nugget; but if 6 nuggets contain a quarter pound of meat, that would have taken a chicken half a pound of feed corn to grow. A 32-ounce soda contains 86 grams of high-fructose corn syrup (as does a double-thick shake), which can be refined from a third of a pound of corn; so our 3 drinks used another 1 pound. Subtotal: six pounds of corn.

From here the calculations become trickier because, according to the ingredients list in the flyer, corn is everywhere in our meal, but in unspecified amounts. There’s more corn sweetener in my cheeseburger, of all places: The bun and the ketchup both contain HFCS. It’s in the salad dressing, too, and the sauces for the nuggets, not to mention Isaac’s dessert. (Of the sixty menu items listed in the handout, forty-

five contain HFCS.) Then there are all the other corn ingredients in the nugget: the binders and emulsifiers and fillers. In addition to corn sweeteners, Isaac's shake contains corn syrup solids, mono- and diglycerides, and milk from corn-fed animals. Judith's Cobb salad is also stuffed with corn, even though there's not a kernel in it: Paul Newman makes his dressing with HFCS, corn syrup, corn starch, dextrin, caramel color, and xanthan gum; the salad itself contains cheese and eggs from corn-fed animals. The salad's grilled chicken breast is injected with a "flavor solution" that contains maltodextrin, dextrose, and monosodium glutamate. Sure, there are a lot of leafy greens in Judith's salad too, but the overwhelming majority of the calories in it (and there are 500 of them, when you count the dressing) ultimately come from corn. And the French fries? You would think those are mostly potatoes. Yet since half of the 540 calories in a large order of fries come from the oil they're fried in, the ultimate source of these calories is not a potato farm but a field of corn or soybeans.

The calculation finally defeated me, but I took it far enough to estimate that, if you include the corn in the gas tank (a whole bushel right there, to make two and a half gallons of ethanol), the amount of corn that went into producing our movable fast-food feast would easily have overflowed the car's trunk, spilling a trail of golden kernels on the blacktop behind us.

Some time later I found another way to calculate just how much corn we had eaten that day: I asked Todd Dawson, a biologist at Berkeley, to run a McDonald's meal through his mass spectrometer and calculate how much of the carbon in it came originally from a corn plant. It is hard to believe that the identity of the atoms in a cheeseburger or a Coke is preserved from farm field to fast-food counter, but the atomic signature of those carbon isotopes is indestructible, and still legible to the mass spectrometer. Dawson and his colleague Stefania Mambelli prepared an analysis showing roughly how much of the carbon in the various McDonald's menu items came from corn, and plotted them on a graph. The sodas came out at the top, not surprising since they consist of little else than corn sweetener, but virtually everything else we

ate revealed a high proportion of corn, too. In order of diminishing corniness, this is how the laboratory measured our meal: soda (100 percent corn), milk shake (78 percent), salad dressing (65 percent), chicken nuggets (56 percent), cheeseburger (52 percent), and French fries (23 percent). What in the eyes of the omnivore looks like a meal of impressive variety turns out, when viewed through the eyes of the mass spectrometer, to be the meal of a far more specialized kind of eater. But then, this is what the industrial eater has become: corn's koala.

SO WHAT? Why should it matter that we have become a race of corn eaters such as the world has never seen? Is this necessarily a bad thing? The answer all depends on where you stand.

If where you stand is in agribusiness, processing cheap corn into forty-five different McDonald's items is an impressive accomplishment. It represents a solution to the agricultural contradictions of capitalism, the challenge of increasing food industry profits faster than America can increase its population. Supersized portions of cheap corn-fixed carbon solves the problem of the fixed stomach; we may not be expanding the number of eaters in America, but we've figured out how to expand each of their appetites, which is almost as good. Judith, Isaac, and I together consumed a total of 4,510 calories at our lunch—more than half as many as we each should probably consume in a day. We had certainly done our parts in chomping through the corn surplus. (We had also consumed a lot of petroleum, and not just because we were in a car. To grow and process those 4,510 food calories took at least ten times as many calories of fossil energy, the equivalent of 1.3 gallons of oil.)

If where you stand is on one of the lower rungs of America's economic ladder, our cornified food chain offers real advantages: not cheap food exactly (for the consumer ultimately pays the added cost of processing), but cheap calories in a variety of attractive forms. In the long run, however, the eater pays a high price for these cheap calories: obesity, type II diabetes, heart disease.

If where you stand is at the lower end of the world's economic ladder,

however, America's corn-fed food chain looks like an unalloyed disaster. I mentioned earlier that all life on earth can be viewed as a competition for the energy captured by plants and stored in carbohydrates, energy we measure in calories. There is a limit to how many of those calories the world's arable land can produce each year, and an industrial meal of meat and processed food consumes—and wastes—an unreasonable amount of that energy: To eat corn directly (as Mexicans and many Africans do) is to consume all the energy in that corn, but when you feed that corn to a steer or a chicken, 90 percent of its energy is lost—to bones or feathers or fur, to living and metabolizing as a steer or chicken. This is why vegetarians advocate eating “low on the food chain”; every step up the chain reduces the amount of food energy by a factor of ten, which is why in any ecosystem there are only a fraction as many predators as there are prey. But processing food also burns energy: What this means is that the amount of food energy lost in the making of something like a Chicken McNugget could feed a great many more children than just mine, and that behind the 4,510 calories the three of us had for lunch stand tens of thousand of corn calories that could have fed a great many hungry people.

And how does this corn-fed food chain look if where you stand is in the middle of a field of corn? Well, it depends on whether you are the corn farmer or the plant. For the corn farmer, you might think the cornification of our food system would have redounded to his benefit, but it has not. Corn's triumph is the direct result of its overproduction, and that has been a disaster for the people who grow it. Growing corn and nothing but corn has also exacted a toll on the farmer's soil, the quality of the local water and the overall health of his community, the biodiversity of his landscape, and the health of all the creatures living on or downstream from it. And not only those creatures, for cheap corn has also changed, and much for the worse, the lives of several billion food animals, animals that would not be living on factory farms if not for the ocean of corn on which these animal cities float.

But return to that Iowa farm field for a moment and look at the matter—at us—from the standpoint of the corn plant itself. Corn, corn,

corn as far as the eye can see, ten-foot stalks soldiering in perfect thirty-inch rows to the far horizon, an 80-million-acre corn lawn rolling across the continent. It's a good thing this plant can't form an impression of us, for how risible that impression would be: The farmers going broke cultivating it; the countless other species routed or emiserated by it; the humans eating and drinking it as fast as they can, some of them—like me and my family—in automobiles engineered to drink it, too. Of all the species that have figured out how to thrive in a world dominated by *Homo sapiens*, surely no other has succeeded more spectacularly—has colonized more acres and bodies—than *Zea mays*, the grass that domesticated its domesticator. You have to wonder why we Americans don't worship this plant as fervently as the Aztecs; like they once did, we make extraordinary sacrifices to it.

These, at least, were my somewhat fevered speculations, as we sped down the highway putting away our fast-food lunch. What is it about fast food? Not only is it served in a flash, but more often than not it's eaten that way too: We finished our meal in under ten minutes. Since we were in the convertible and the sun was shining, I can't blame the McDonald's ambiance. Perhaps the reason you eat this food quickly is because it doesn't bear savoring. The more you concentrate on how it tastes, the less like anything it tastes. I said before that McDonald's serves a kind of comfort food, but after a few bites I'm more inclined to think they're selling something more schematic than that—something more like a signifier of comfort food. So you eat more and eat more quickly, hoping somehow to catch up to the original idea of a cheeseburger or French fry as it retreats over the horizon. And so it goes, bite after bite, until you feel not satisfied exactly, but simply, regrettably, full.