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 carbohydrates.

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 dextins 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 Farnhamville), 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 Farnhamville. 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 centrifuging. 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 powdery 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 mole-

ules 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 sixteenth-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 ruseful 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
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 nutraceutical 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 (eek!) 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 'fleat' 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-