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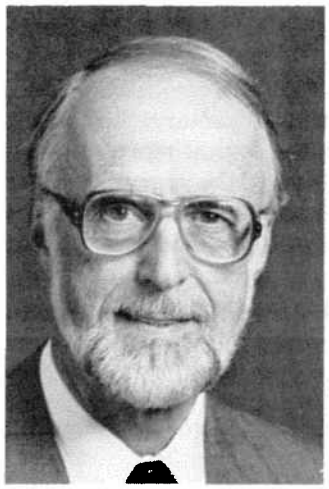

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Early Years - the 1930s

In 1930 I asked my uncle why the picture on the front page of the Chicago Tribune showed a baby in a diaper chasing a bad old man with a scythe on his shoulder. My uncle said that the old man was 1929, the year just ended. 1929 had been a bad year because people lost their money, and we hoped that the baby new year, 1930, would be a good year, when people could get their money back.

Of course they didn't, not in 1930, nor for the next 10 years. During that time the farm economy—which had led the way to the Great Depression—deteriorated to the point that corn was used as fuel since it was virtually worthless as grain. My father was forced from his farm like many of his contemporaries. Fortunately, we were able to resettle on a small farm owned by my grandmother. Her 90-acre farm was vacant because the previous renter had gone completely bankrupt and chose to move to town, where he hoped to find work or at least become eligible for "relief," as we called it.

That is my earliest memory of the flight from the farm.

My parents raised four boys in the 1930s on my grandmother's 90 acres—they did it virtually without cash, my mother recently reminded me. We milked a few cows and sold milk and butter. My mother raised chickens and sold dressed chickens and eggs. Pigs, the vegetable

garden, and an occasional worn-out dairy cow provided additional food for the family. Our farm expenses were few. We had a tractor that required fuel and occasional repairs; we of course didn't replace it. We occasionally had to buy a new horse, when the old ones got lame or died. We saved part of our corn, oats, clover harvest for seed and so had no seed expense. We rarely paid for extra farm labor; men—heads of families—worked out their milk, butter, and egg debts to us by doing odd jobs for us, for they had no cash either. My mother told me of an interesting dichotomy—the poorest families settled their debts to us in this way; the wealthier ones simply didn't pay!

For a few years, after our move, we milked a herd of some 25 dairy cows. We strained, cooled, and bottled the milk, and delivered it daily from door to door, unpasteurized, but very fresh. This kind of farming was highly labor intensive—my parents worked together until late every night, washing, filling, and capping hundreds of bottles of milk for delivery the next morning. Then our cows, one after another, began to abort. The veterinarian told us they had Bang's disease, not uncommon in dairy herds in those days. We decided to sell all animals that tested positive for the disease, and eventually were left with only five or six milking cows and a much reduced gross income. I learned, years later, that Bang's disease, also called undulant fever or brucellosis, can be transmitted to people who drink unpasteurized milk from infected cows.

Our farm was worn out when we got it and grew mostly quack grass and Canada thistles. We used to "blind-tend" the corn, meaning the first cultivation was made before the corn emerged, in ground already greener than a lawn with a solid stand of quack grass. I wonder, now, why the quack grass had such a healthy green color. Did—or does—it have some way of collaborating with nitrogen-fixing bacteria? My three brothers and I were the thistle brigade—we lost the war, every summer. Four hoes in the hands of bored small boys were not very effective.

Fertilizer was provided by the manure pile outside the horse and cattle barn. My mother told me that when she was a girl, on the same farm, her sisters were stricken with typhoid because they drank from the well in the barnyard, intended to water only the livestock. The household well was up the slope, a "safe" 100 feet from the barnyard. (Incidentally, our privy was also a "safe" 100 feet from the household well.)

Manure was hauled each spring, and covered not more than 10 percent of the fields. We depended on a corn-oats-clover rotation for maintenance of fertility. But of course, needs for limestone, phosphate, and potash simply weren't met. We had no cash for such amendments.

Corn yielded 30 bushels per acre; 50 in a good year. Yields of oats and hay were proportionate. I suppose we were doing our part to help U.S. agriculture, by maintaining our yields at a low level. Grains were in surplus and high yields, nationally, weren't needed. Farmers were paid to take land out of production, a recently inaugurated temporary measure, intended to get supply and demand back in balance.

In 1934 the rains never came. My father didn't pick one ear of corn. He borrowed money—or more likely got credit—from the lumberyard and put up a make shift silo to preserve the corn fodder for winter feed for our cattle. He got almost no hay that year, either. I herded the cows along grassy roadsides and the railroad right of way; our pastures were brown and bare.

In 1936 the rains failed again, suddenly in July, accompanied by a terrible heat wave. We got no corn grain again, except on five acres planted to some expensive seed, something new called "hybrid" corn, sold by the Jung Seed Company in Wisconsin. Neighbors came from miles around to see our hybrid corn.

My father never again saved his own corn for seed. Except he did, just once, replant a few acres of F2 seed from his favorite hybrid. It "ran out," yielding some 25 percent less than the original hybrid, just as the salesman had said it would. Dad grinned and said "I just thought I'd check it out." After 1936 our corn yields were always better than before, up 25 percent or

more, averaging 40 bushels per acre, with yields as high as 75 bushels in good years on good ground. Cash seemed a little more plentiful in our family in the late 30s, even though prices for grain and livestock remained low. Grain surpluses were still blamed for the low grain prices and farmers were still paid to take land out of production. But I never heard anyone disparage the use of higher yielding hybrid corn, now grown by all our neighbors.

In 1939 my father took his first trip to another state. He went to Iowa, and returned full of stories about how Iowa farming differed from that in Illinois. The United States was a very big country in those days.

In 1940 I won a gold medal in a Future Farmers of America speech contest, speaking on the topic "Soil Erosion, a National Disgrace." I told the audience that U.S. farms lost four tons of topsoil for every ton of crop production, and blamed the problem on row-crop farming and sod-busting. I recommended that farmers put erodable land back into pasture and hay crops or, at the least, farm it on the contour. "If farmers don't soon wake up, they will have no land left...."

One day I came home from high school and told my father that my vocational agriculture teacher had said we could increase the production of milk from our dairy cows by 50 percent, simply by adding soybean meal or cottonseed meal to their ration, along with grain, ground for quick digestion. We tried it, and did indeed get a significant increase in production. Unfortunately in those days the price of oil meal, a high protein feed supplement, was very high, we still didn't have much cash, and at that particular time we were paying off an emergency medical bill. So we took only partial advantage of this technological breakthrough. Others, with more cash, made full use of the information and got substantial increases in production and income, until general adoption of the revolutionary new practice raised all production and lowered milk prices.

The Post-War Years

World War II solved the problem of overproduction, temporarily; it brought higher prices for our farm products, and took two of the sons to the army. When we returned to the farm in the mid-forties, we found some changes. My father was growing a new crop, soybeans, as a cash crop. He bought a new (to him) second-hand tractor, with a self-lifting two-row corn cultivator, rubber tires, and a road gear. The team of horses was no longer indispensable; Dad kept them and used them for odd jobs but when they were too old to work any longer he did not replace them. He was now tied to the farm machinery industry, with no recourse. He also was now a cash grain farmer, at least in regard to his soybean crop.

My parents then remodeled part of the horse barn and kept a large (for them) flock of hybrid layers. The word "hybrid" still had some magic and indeed the hybrid hens were remarkably productive. But to keep them productive, my parents bought special feed supplements, soybean meal, and minerals, to mix with farm-grown corn and oats. And the chicks, to be raised into layers, were very expensive, also. Nevertheless, my parents' real profit on these layers greatly exceeded that from my mother's old corn-fed flock of the 1930s; the hybrid layers were a major source of income. Mother and father never turned back. They now were tied to the animal feed industry, and also to the animal genetic supply industry.

Increased farm profits plus the GI Bill of Rights for two of us would have allowed all four sons to attend college. Three of us did so; one elected to stay home and farm. We three studied agriculture at the state university, and intended to return to farming. I discovered genetics and went on to graduate school and eventually to a job as a geneticist for a seed corn company. My brothers returned from college and took up farming, although not on the home farm, which was too small.

So for a time, three of four sons were farming. Then one of the farmer sons, unable to find a farm large enough for a good living, went back to graduate school, and eventually to a position in agricultural economics at a midwestern land-grant university. Then another son left farming, for a job with a seed

company in a neighboring state. This left only one of four sons still in farming. But the other three were still in agriculture. We sorted out as follows: 25 percent were actively farming, 25 percent were employed in the public sector, and 50 percent were employed by the private sector of agricultural support services.

My father and one of the brothers bought a small combine in the 1950s. This signaled the end of an institution, the neighborhood cooperative threshing ring, when a dozen or more farmers collaborated to complete the small grain harvest. It also signaled the end of my mother's responsibility to provide "threshers' dinners," a back-breaking chore in the heat of summer. Our farm was increasingly independent of the neighbor's activities, required increasingly less outside labor of any kind, and also was increasingly dependent on the farm machinery industry.

More Changes

I left college, and moved to another state. My contacts with home and our farm were less frequent; my recollections are like a series of snapshots. The farm seemed to shrink in size as machinery grew larger. My parents' financial and home-comfort aspirations also enlarged. The house was wired for electricity; an electric refrigerator replaced the ice box, a deep-freezer replaced mason jars and hot pack for vegetable preservation; and one day I brought my bride-to-be for a first visit just in time to help inaugurate a newly installed system of household running water, complete with indoor bathroom.

My farming brother was now operating, as a tenant, another much larger farm, in the same community. In actuality, he worked what had been two farms, separated from each other by one or two miles. He also rented the home place from our parents, after my father retired from farming. The 10-mile round trip, unthinkable in the 1930s with horses or steel wheeled tractors, was no problem. My brother began, routinely, to apply practices learned in college: commercial fertilizer covered all his acres, including the old home place. Herbicides were applied: 2-4D at first, then more sophisticated ones. Insecticides were used, but more sparingly than in the hands of some of the neighbors; his crop rotations reduced the need for chemical aids to control corn rootworm. Results were as predicted; yields and profits went up. Input costs, of course, were increased also, but added profits were three to five times as great as added expenditures.

He fed cattle for several years, 40 or 50 at a time. Then he dropped the practice; there was no profit, even though (so he heard) very large cattle feeding operations, factory-like, seemed to be successful out towards Denver and Amarillo. He understood that out there the cattle were fed on milo grain, unheard of in Illinois. The milo was grown in Texas and thereabouts, as high yielding hybrids, watered with a new kind of mechanized irrigaton system, called "center pivot."

He began to specialize in hogs; he set up a confinement (year-round farrowing system) using specially bred boars from a breeding company. He fed his own corn, but in addition he bought special pig-starter feed blends laced with antibiotics, anti-worm chemicals and mineral and amino acid supplements. His oldest son, wanting to farm but finding no land, took over the pig operation. Father and son were now associates.

My brother got a new line of machinery—an extra tractor for odd jobs since the main one was too large for such, a combine as well as a corn picker, various kinds of feed mills, mixers, weed sprayers, fertilizer application attachments, and new and exotic (to me) kinds of tillage and ground preparation tools. He annually bought new higher yielding varieties of soybean seed from various seed companies. He could have saved his own seed of these varieties after the first purchase, but he said the increased purity, better germination, and increased quality and convenience made the extra expense worthwhile. He, of course, bought hybrid corn seed every year. The seed companies regularly brought out new, better performing hybrids. They vied for his business. He had to decide which ones were the best for him.

Corn yields on the old home place continued

to increase: 75 bushels per acre in the 1960s; 90 and 100 in the 1970s; 130, 150, and up to 170 bushels per acre in the 1980s. Soybean yields increased proportionately. But oats and clover hay showed no such increase. They were no longer grown. Nor was livestock of any sort furnishing manure for fertilizer any longer. Since my father's retirement the 90 acres were farmed strictly on a cash grain basis. The old farm was now a minor addition—just an extra field, almost—to the hundreds of acres my farmer brother operated in association with his son.

One summer, walking the fields on the old home place, I made a discovery. The quack grass and Canada thistle were gone. I hadn't noticed their demise. My brother told me that atrazine in extra heavy doses, plus 2-4D and clean cultivation with modern tractor cultivator sweeps, made the job easy, and cost very little, compared to the added income from extra yields. I had recently heard of some studies in Nebraska that found atrazine build-up in groundwater, in the irrigated Platte Valley, and wondered what might be happening on the old home place. Of course, the only public concern was that the atrazine-laced water in Nebraska might be pumped for irrigation and applied on susceptible crops. That would be no problem on my brother's rain-fed acres in Illinois.

Present Day Farming, and Farmers

I have now reached the present time, in this retrospective tale of 60 years of change in midwestern farming. The story I have told, while personal and isolated, is perhaps typical and representative of growth and change in much of U.S. agriculture. It illustrates the gradual and increasing dependence of farming on the agricultural supply industries. It illustrates the increasing size and sophistication of the family farm—still a family farm—and its increasing integration with industrial America. It illustrates the increasingly important role of chemicals in American farming. And it illustrates the emergence of the American farm family from primitive living standards to conditions equal to those of dwellers in city and town.

My brothers and I spent a day together recently, on the occasion of a family wedding. We recalled, together, our family's excitement over our father's first out-of-state visit, made at the age of 42. We remarked on our insularity in other ways as well, in those days. Farming in the 1930s was comparatively isolated and independent in regard to most of its supplies and infrastructure, not so independent and self-reliant as in frontier days, of course, but very self-sufficient compared to present times. We brothers traded illustrative examples from our own lives of how today's agriculture is interlaced, nationally and internationally, with agricultural, business, and academic activities.

My farmer brother regularly vacationed by traveling to other farming regions in the U.S. and Canada. He was just back from a swing through Manitoba and was impressed with the hundreds of thousands of acres of oil seed rape—Canola—in full bloom, transforming the prairies into oceans of yellow. He wondered about their eventual impact on the price of soybean oil—and on the price of his own bean crop.

My economist brother, in a few days, was to lead a group of young farmers—chosen as potential agricultural leaders in his state—on a tour of European farms, agribusinesses, and governmental bureaus. The tour was intended to acquaint them with people and institutions of a foreign economy that was likely to be strongly interacting with theirs, as they reached their maturity of action and decision-making.

My seed company brother routinely supervised his company's integrated seed production and conditioning activities in half a dozen states, in the midwest in the summer, Florida in the winter, and in various points in between during other seasons.

My own work, scientific and administrative, was to take me to three continents in the next month to participate in international scientific conferences and to inspect some of the overseas plant breeding programs operated by my company.

We wished our father could have been with

us to enjoy, vicariously, the geographically broadened expanse of agriculture's activities.

We shared news of the agricultural depression, as it affected us in our jobs, as well as how it looked from our various vantage points—four states, four societal points of view.

My farmer brother, fortunately, had not bought land nor incurred excessive debt for other farm needs during the heady '70s and so was relatively unharmed by the precipitous fall in land values and drastic tightening of agricultural credit. But nevertheless, reduced crop and livestock prices were forcing him to tighten his belt in many ways; he was now replanting soybeans from his bin, squeezing back on fertilizer application amounts, and above all, not buying machinery.

My economist brother, whose specialty was in extension, had a clear view of the farm economy from the farmer's point of view, and had indeed pointed out the ominous trends to me some years earlier. He disputed media stories of revolutionary change in U.S. farming, stories that forecast replacement of the family farm by vast, impersonal corporate farms. Rather, he said, farms were splitting into two kinds of family farms (in the midwest, at least): small acreages, operated on weekends by factory workers and such, and large family farms, larger than before, but still run by one family or, at the most, by two or three families—somewhat like our farmer brother and his son but on a larger scale. He told us that a graph of increasing farm size would show that there has been steady growth in acres per farm ever since the land was homesteaded; the trend line would show a small bump upward in the '80s, but long range the bump would hardly be noticed.

We two seed company brothers were interested in his "two-farmer" analysis, for we translated the two kinds of farmers into two kinds of customers for farm seeds.

The weekend-farmers, the first kind, would have little time for updating themselves in farming technologies and little need to be really profitable in farming—their town job paid the bills. These people would need special help in choosing proper seeds, as well as in keeping up-to-date in other farming technologies. Or maybe one could just depend on impressing them with flashy advertising.

The second kind, the full-time professional farmer, was very different. These farmers had survived the agricultural depression, so far, because they were canny, smart, and tough. They drove hard bargains but they also knew how to determine true economic value, from their point of view. They insisted on trying things out for themselves, before purchase; but at the same time they demanded a full and trustworthy description of each of the products they wanted to buy. They put us on our mettle.

We speculated a bit—we four brothers—on what kinds of advances in agricultural technology had taken place since we were together on the old home place. It was clear to all of us that public and private contributions were both important. We knew of the USDA's and ag colleges' basic scientific work in genetics, soil science, agronomy, veterinary science, and animal nutrition; we knew how their work supported those facets of agriculture that, collectively, gave us our livelihood. We knew of the contributions to agriculture made by the machinery manufacturers, fertilizer companies, pesticide manufacturers, and seed companies. We knew that private and public sectors, from the start, have worked closely together, to the point that U.S. technology transfer, from the laboratory bench and the research test plot to the farm, is the model for the world.

None of us recalled it, on that August day, but we might well have quoted, with appreciation, from the words of Jonathan B. Turner, father of the 1862 Morrill Act that laid the foundation for the land grant universities. (Turner's words, written 150 years ago, are still inscribed in terra cotta relief on the front of the original agriculture building at the University of Illinois, and were read by each of us during our times on the campus.) The quotation reads as follows: "Industrial education prepares the way for a millennium of labor." In my college days I interpreted these words to say that the fruits of honest labor are best realized through

sound technical training and its application to production agriculture. Turner's statement is paired with another quotation on the same building, words written 100 years ago by an early University of Illinois president, Andrew Draper: "The wealth of Illinois is in her soil and her strength lies in its intelligent development." This sentence clearly admonished us to extract profits from Illinois' rich soil.

The day in August ended, too soon, and we four brothers went our separate ways. If time had allowed, we could have profitably continued our conversation on applications of technology to agriculture, dealing especially with its responsible application in today's world.

Which brings me to a main part of this essay: consideration of the potential for ecologically damaging effects of modern technology, and of private industry's share of responsibility for such effects. The litany of problems is long: in crop culture, we know of soil erosion brought on by excessive row cropping, the effects of which can be masked, short term, by use of commercial nitrogen fertilizer.... In animal culture, we have gone through the stilbestrol drama, abandoning use of this carcinogenic hormone in cattle.... Some of us fear the future even more than the present.

Recapitulation—Sixty years of Change

Had we done so, I could have pointed out (perhaps in mind-numbing detail) the real gains in productive ability of U.S. farms during the past 60 years. Per acre yields of corn, for example, were essentially unchanged through the years from 1900 to 1930. Farm technology for growing corn was stagnant. But in 1930 corn yields started rising, trending up at a steady annual rate of 0.9 bushels per acre until the mid 1950s when the trend line inflected upward even more sharply; annual yield gains since 1955 have averaged 2.3 bushels per acre. Wheat yields showed a nearly identical pattern of change, with upward inflections also at about 1930 and 1955, but with smaller average annual gains: 0.2 bushels per acre from 1930 to 1955, and 0.4 bushels per acre from 1955 to the present time. Since 1930, corn yields have increased on average at a rate of 3 percent per year; increases in wheat yields have averaged 1.5 percent per year.

The upsurge in per acre yields in the 1930s coincided with the first introductions of scientifically bred varieties of wheat and hybrid corn. The principles of genetics were being put to practical use by agricultural scientists in the USDA and the land grant universities, the culmination of 50 years of gradually increasing competence in plant breeding and the sciences that undergirded it. But the 1930s upsurge in yields also coincided with an influx of new yield-promoting and labor-saving inputs from machinery manufacturing firms: corn pickers, row-crop tractors, and grain combines. And better ideas about crop rotation and other beneficial agronomic practices also were being adopted, increasingly, by farmers who were beginning to believe the advice given them by the university folks.

The 1950s upswing in yields of corn and wheat is due in important measure to increased use of synthetic nitrogen fertilizer. Indeed, the graph of change over time for U.S. consumption of commerical nitrogen fertilizer shows the same upward inflection in 1955 as that for

yields of wheat and corn. And significantly, the graph for soybean yields shows no such change in 1955. Soybeans, a legume, are not benefitted by and receive no applications of commerical nitrogen fertilizer.

But nitrogen fertilizer cannot take all the credit—or blame—for higher grain yields. Experimental and empirical data indicate that numberous additional inputs also were important. In Minnesota, for example, nitrogen fertilizer is credited with about 20 percent of the per acre yield gains in corn since 1930; herbicides accounted for 23 percent, and genetic improvements in corn hybrids (additional to the initial large improvement given by the switch from open pollinated varieties to hybrids) gave another 43 percent. And of course, planting and harvesting machinery was greatly improved in precision and speed of operation, making for greater savings in harvested grain, better stand establishment, and above all, more timely operations, which often made the difference between good yields and comparative failures.

Thus, the private sector: machinery manufacturers, fertilizer companies, pesticide manufacturers, and private seed firms (many of which sell the products of their own breeding), all contributed heavily—in fact gave most of the inputs—to the increasing corn yields in Minnesota. Similar analyses could be shown for other crops in other states.

Problems in Paradise

But the Minnesota analysis shows something more. The sum of all potential yield enhancements comes to more than 100 percent. This is because certain negative effects also were contributed by some of the new technologies. For example, the switch to high levels of application of commercial nitrogen fertilizer allowed planting of continuous corn; clover or alfalfa were no longer needed as sources of nitrogen. But planting continuous corn fostered soil erosion and corn rootworm infestations, both of which caused yield loss. Thus, although the net change in yield per acre was positive, some real and potentially dangerous negative effects were also brought about by the new technologies.

Which brings me to a main part of this essay: consideration of the potential for ecologically damaging effects of modern technology, and of private industry's share of responsibility for such effects.

The litany of problems is long: in crop culture, we know of soil erosion brought on by excessive row cropping, the effects of which can be masked, short term, by use of commercial nitrogen fertilizer. We know of accumulations of nitrate in groundwater—and thus in farm and municipal well water—brought about by excessive use of fertilizer nitrogen. We know of accumulations of insecticides and herbicides in groundwater, accumulations that sometimes are not detected until 20 years after initial use. We hear accusations of corporate genetic miserliness; of companies that use patent protection to hoard up valuable plant varieties and genes in corporate treasuries.

In animal culture, we have gone through the stilbestrol drama, abandoning use of this carcinogenic hormone in cattle; we are still debating use of antibiotics in animal feeds, fearing that they may select drug-resistant microorganisms dangerous to humans. We are just now learning about respiratory problems affecting workers in swine confinement facilities.

Some among us fear the future even more than the present: the products of biotechnology, applied to agriculture, are said to be capable of changing climate for the worse, upsetting the balance of nature, changing beneficial plants into ineradicable weeds, capable of destroying the social fabric of rural America.

Private industry is involved in all of these matters. Corporations make and sell pesticides; corporations make and sell nitrogen fertilizers; corporations make and sell hormones and antibiotics; corporations, above all, are supporting research in biotechnology and aim to add to their wealth by selling new products created via biotechnology.

We can argue with vigor about whether the problems I have listed are as dangerous as they

are reputed to be. I haven't time in this essay to discuss them individually. I think that in many instances the imputed dangers are exaggerated beyond reason or fact; but on the other hand, some problems may give even more trouble than is yet appreciated. But, I know they are all perceived as serious problems and they will be treated as such. And I know industry is connected with many of them.

I know also that some thoughtful people believe these problems are an ineluctable consequence of industry's having meddled in agriculture, "[aiming] to 'hot-wire' the American landscape with commerical fertilizers, pesticides, and expensive industrial equipment," as Wes Jackson puts it. "The industrial fundamentalist isn't satisfied just to square the circle [to practice ecologically sound agriculture], as agriculture has done for centuries, but sees agriculture more as a straight line of industrial mass production hitched to, and more or less parallel with, the extractive economy." It is said that production agriculture—simple-minded, ever-increasing output of agricultural products—is the sole goal of industry, and that industry has selfishly led agriculture—farmers—down this path to destruction.

I think Jackson is right in saying that industry is directly on the straight line of agricultural production as an extractive economy. But industry is there, not because of conspiracy, nor in willful disregard of agriculture's wish to practice ecologically sound farming. Rather, industry is on the straight line with extractive production agriculture, because that is what the nation's farmers and indeed all of America have demanded. To increase agricultural production—either by an increase in acres as when the frontier was settled, or by increasing yields per acre when the frontier was gone—has always been our farmers' and our national goal.

That is what was happening in the 1930s when America's farmers—of their own volition—were scouring off the topsoil by plowing up and down the hills. That is what was happening in the 1960s when the nation's farmers used up fertilizer inventory as fast as manufacturers replaced it. That is what happened in the 1970s when the nation's farmers bought and applied herbicides and insecticides in massive amounts in efforts to raise the production and profitability of their individual farms. The nation's farmers were the force that brought on the agricultural support industry. They called, it responded. (Granted, businesses cultivated "their" markets once they were discovered, and still treasure them. But without the primal pull of the American urge to produce, businesses could not have moved in with products that maximize production.)

And the American public has enthusiastically supported production agriculture—non-ecological, extractive agriculture. In the short term it has been good for Americans; they have been well-fed for proportionately less personal expense than any other nation in any age.

So the farmer, the agricultural support industries, and the public have all been in it together; or, more nicely put, they have all cooperated to raise productivity of American agriculture, jointly making a system that is seen as direct, efficient, and technically sound. And it was done for one of the best reasons in the world—to feed the hungry.

In fifty years, thousands of new principles, products, chemicals, and machines, and combinations of them, have been introduced to farming with the intention of raising productivity and making the U.S.—and the world—a better fed and therefore a healthier place. And by and large we have succeeded. Typhoid, undulant fever, and quack grass are gone. Incomes and amenities for farm families are increasingly higher, and no one anywhere would knowingly go back to the life we led in the 1930s, happy as it might seem in retrospect.

But we were not omniscient. We didn't foresee the potential carcinogenicity of some of our new chemicals (nor did those physicians who administered stilbestrol to pregnant women and doomed their daughters to cancer, thirty years later). We didn't think of farming as being ecologically united with the rest of nature, and so we unwittingly brought on epidemic disease and insect problems. (But until the epidemics came, few biologists knew or said that such could happen; "prediction" followed

fact.) We didn't foresee that the widespread adoption of insecticides and herbicides would put an unbearably heavy chemical load on our land and in its groundwater. We didn't appreciate how enormously popular individual new crop varieties were going to be, with consequent reduction of on-farm genetic diversity.

Our problems are due in part, therefore, to our success in creating a highly popular and super-efficient production agriculture, one in which farmers, industry, and universities are all in a straight line, working together.

How To Correct the Problems?

Now, who is to correct the problems? At this point, I differ strongly with those who point to the agricultural support industry and say, "You made this mess, now you must straighten it out."

I don't mean to say that industry should not cease production of products deemed dangerous by society, or that it has no responsibility for testing the safety of its new products. Industry must learn from past mistakes.

But I do believe that the general direction, the real goals of applied biology, of agricultural science and technology, and the consequent forms of rural societal organization have been set by society in general, by all of us. Society ultimately is responsible for agricultural technology as we see it today; society has called the tune, even though this fact may not be apparent to everyone.

Industry as a part of society is also responsible for today's agricultural technology, but one should not and can not expect industry to have full responsibility (it can neither take full credit nor bear full blame), for industry has not really led the way, it has not really called the tune, even though it may seem so.

I can give an example, of how one "leads" by actually following the trend: Mohandas K. Ghandi once interrupted a street-side conversation with reporters as he said, "I must hurry to get at the head of that passing procession, so I can find out where they are going, and lead them." This is how successful businesses "create" new markets. They find them before anyone else, often when they are still an unexpressed need or desire, determine the direction they are going, and take the lead in developing their potential. They develop the market; they don't control the forces that created its potential.

But agribusiness cannot develop just any agricultural market, nor will its goals or products always fulfill all of society's goals and needs.

By definition, agribusiness—any business—is engaged in a limited set of production technologies, making products that can be produced efficiently, have a ready market, and can be sold at a profit. To produce and disseminate such products, private enterprise is probably the best way yet invented to get the job done. The spur of competition for profits combined with a discerning customer clientele gives desired results, efficiently.

But many kinds of needed agricultural inputs—finite products as well as agricultural systems—fall outside the competency of the agribusiness sphere. Some kinds of seeds, for example, sell for so low a price or have such a limited market that no private firm can afford to invest in research to improve them. If the public wants such seeds to be improved it must finance, with public monies, the research for their improvement. Agribusinesses must not be expected to perform not-for-profit activities on a large scale, since profits are their sole means of support, and their first goal.

Additionally, we must recognize that to plan and operate ecologically sound agricultural systems requires, by definition, a degree of holism that is precisely the opposite of the way that businesses—and farmers—sort out and concentrate on finite pieces of a market. Financially successful businesses and financially successful farmers will tend to ignore broader, long range societal concerns in favor of their own efficiency and profitability in the short term. Even though they can be and usually are public-spirited and well-intentioned, they are organized for profit, not for altruism.

But this need not mean that profitable industry and profitable farming are inherently antagonistic to ecologically sound agriculture.

Enlightened self-interest will inspire those that want to be in farming or business for many years to follow ecologically sound practices. Farmers and agribusinesses are not bound to be adversaries of those interested in the ecological health of our country. Long range, all three groups have the same goals. Therefore they—and we—are challenged to find ways of co-opting industry, farmers, and the environmentally caring public—all of us—into collaboration. We need to find ways to coordinate our efforts to produce, as partners, an ecologically sounder agriculture than any class of us could accomplish on our own.

Respectful Partners

Note, I recommend a partnership, not a war. For the ecologically-minded to treat profit-oriented industry as an enemy or at best as ecologically feeble-minded is a kind of hubris that will reduce or even eliminate any chance of success in achieving environmental goals. For industry to regard all ecologically-minded individuals and organizations as enemies or poorly informed dreamers is also a kind of hubris that will foil industry's efforts to achieve its financial goals. Both groups can take to heart a statement, here paraphrased, of the head of a public relations firm: "Corporations [and environmentalists] are awed by their own accomplishments. But their target audiences [also] have concerns, needs, worries, and interests. Corporate advertising [and action, and environmentalists' advertising and action] should begin with those."

Best results, long-term, will come when an informed public, agricultural industry, and also our public agricultural institutions work as equally responsible partners towards achievement of clearly enunciated, ecologically sound goals. This will require education of the best kind, in which equals speak truth to respected equals. It will require achievable economic inducements, societally and legislatively administered. It will require spirited debate, but not hyperbole. Agreement will not always be easy, nor will the job ever be completely done. But we must get on with it.

My ideas on this subject are not original. Aldo Leopold said in 1939, "Let us admit at the outset that harmony between man and land, like harmony between neighbors, is an ideal—and one we shall never attain.... But any man who respects himself and his land can try to."

My goal is that we will respect our land and ourselves, ourselves as farmers and city dwellers, agribusinesses, and public institutions, and that with such mutual respect we will continually try to achieve harmony between man (and woman) and the land.

Agricultural Industry in the Future

Future directions of agricultural technology, and the part industry will play, are of course not predictable with a high degree of certainty. But one can be sure that simply because of an explosively expanding knowledge base, and because transportation and communication technology are bringing all parts of the world closer and closer together, agricultural technology will be increasingly sophisticated, changing, and international.

Agricultural support industries will be even more international than at present; large transnationals will tend to engage in a full line of products: fertilizers, seeds, pesticides, and growth regulators. Their products will be sold wherever in the world a market for them can be developed. Indigenous, often small, local industries will continue to be important, however. Change always gives room for upstart entrepreneurial firms; local needs always encourage survival of local firms to fill niche needs.

We hear much about biotechnology and/or genetic engineering as related to agriculture. I can summarize my beliefs on this subject as follows: biotechnology is based on the science of molecular biology. This science, molecular biology, is new, vibrant, and is advancing fundamental knowledge of biological organisms at breakneck speed. It therefore eventually will provide indispensable tools for plant and animal breeding.

In crop breeding (my specialty)

biotechnology based on the science of molecular biology will be especially useful, at first, for improving disease and insect resistance of plant varieties. Next, in time, it will help breeders to improve quality traits such as nutritive values of food and feed grains; at about the same time it also will help breeders develop new uses for old crops, for example, corn starches with new properties for industrial uses. Eventually molecular biology and accompanying new technologies will help breeders develop varieties with greater stability in adverse environments such as heat, drought, or salinity. All of these changes will allow farmers to get higher and more stable yields, or new kinds of products, with little or no increase in inputs.

These changes, however, will not be qualitatively different in their end results from those that can be achieved by today's standard plant breeding techniques (even though some improvements will be spectacularly large). But advantages from use of biotechnology will nevertheless be great, for breeders will be able to move ahead with greater knowledge of what they are doing, they will be able to work with a greater range of useful genes (available from previously inaccessible species) and they thus will be able to get desired results with greater speed and precision.

As usual, society will have the responsiblity of pulling those using the knowledge of molecular biology toward socially desirable goals. Molecular biology, genetic engineering (a popular term for planned transfer of genes via recombinant DNA techniques) and the whole gamut of technologies known collectively as biotechnology are nothing more than tools that can be used as desired. Biotechnology can be used to raise yields without concern to cost of inputs or it can be used to reduce cost of inputs. It can be used to reduce dependency on environmentally undesirable chemicals or it can be used to promote chemical dependency. Society can choose, via the products it demands and the goals it sets. But society will need to learn how best to encourage wise use of biotechnology, how to avoid mindless meddling, how to lead by precept and example.

As industry plays its role in technology transfer, it will be the prime user of biotechnology. Industry is strongly attracted to biotechnology because it opens up new product possibilities and thus new profit possibilities. But industry also is frightened by and worried about biotechnology because it upsets the status quo; those firms that don't adapt will fail.

Agriculture will not see anything particularly advantageous or disadvantageous in biotechnology. New technologies have come into agriculture continually, ever since agriculture's invention; they have come into agriculture at an especially high rate during the past 50 or 60 years. Biotechnology will be just one more important new technology in agriculture, and will bring changes in its wake, as have all new technologies.

The early adopters of new farming technology have always benfitted—reaped a kind of bonus—from using the new technology. They make profits from the extra yield of greater efficiency of production before the mass of farmers join in and thereby, in competition with each other, pull profits back to the original level. All farmers must then adopt the new technology to survive. (My farming brother may not be much better off, comparatively speaking, than was our father in the 1950s, but he could not survive in farming today with 1950s technology.) And a certain percentage of farmers, as always, either through misfortune or through failure to adjust to the times, are late- or non-adapters, and usually are forced out of farming, like our predecessor on the old home place. This cyclic pattern, a very serious kind of musical chairs game, will be repeated as changes due to biotechnology are gradually incorporated into today's farming.

I recently discovered an interesting example of the consequence of technological change, documented by the historian Fernand Braudel. The real price of wheat in France has dropped continually for 200 years, ever since the beginning of the nineteenth century. But French farmers as a class have survived because their production costs per hundredweight also have decreased continually during the past 200

years. Who knows how many French farmers have profited by being the first to adopt specific new efficiencies in wheat production? And how many French farmers have been forced into poverty, or worse, by being the last to adopt, or by being unable to adopt through no fault of their own?

Concluding Remarks

This essay has dealt with private industry's role in a responsible agricultural technology. Agricultural technology, for the past 50 years or more, has grown and evolved as a seamless whole, developed, transmitted, and received by public institutions, private businesses, and farmers. It has developed as an expression of the common will of the entire American public. During all of this time the trend has been towards increasing size and sophistication of the farming operation, increasing dependence on fossil fuels as a source of power, increasing reliance on synthetic chemicals as sources of fertilizers and pesticides, and increasing integration, usually indirect, with those parts of industrial America that support the nation's agricultural enterprise. Additionally, American agriculture has become increasingly integrated with the world economy, treating the world outside the United States both as a market for its products and also as a source of materials, finished and unfinished, to support the U.S. agricultural system. Thus, in all respects, American agriculture has developed like all other parts of the American economy, like American society in general.

In the past few years a growing knowledge of the capacity of many agricultural chemicals to introduce undesirable and harmful chemicals into the environment, from whence they can also damage human health, has aroused concern that the trend towards use of synthetic chemicals has gone too far and should be slowed down, stopped, or reversed. Likewise, general realization of the size, complexity, and economic integration of the agricultural enterprise in America has aroused feelings that individual control has eroded to the point that the 200-year-old trend towards increase in size and complexity of farming operations should be slowed, stopped, or reversed.

Intertwined with concerns about chemicals in farming and the integration of farming with industry and the world economy is the belief that businesses, particularly agricultural support industries, may be a root cuase of the undesired trends, and that simply to control or repress them would allow agriculture to find its proper and happier role. I disagree with this simplistic view: society as a whole determines the directions its science, economy, and agriculture will take; agribusinessess (and farmers) will work in those areas indicated to them as useful by society. That is, the nature of agriculture and agribusiness is dictated by the nature of the public's real demand for goods and services, for protecting health, and for securing social justice.

Nevertheless, industry (and agribusiness in particular) as a responsible part of society can and should take an active partnership in helping to define new and ecologically sounder societal goals, and in developing the kinds of needed technological supports it uniquely can provide for assistance in reaching those goals. But the public must realize that industry can serve agriculture only with products or systems that can be made and sold for a profit. There are practical limitations to what agribusiness can do on its own.

Finally, change in agricultural technology is continuous, inevitable, and always forward in the sense that it never recapitulates the past (nor can it do so). Agricultural technology necessarily is increasingly complex because our people-burgeoning world, with logarithmic increases in knowledge and its applications, is increasingly complex. The powerful tools available to today's agricultural technology are suited for dealing with this complex world; they can be used to ameliorate living conditions, promote social justice, and increase standards of health and well-being, even more than has been done in the recent past, and within ecologically acceptable bounds. If its goals are intelligent, reasonable, and responsible, private industry can be an indispensable part of modern agricultural technology.