Sept. 5, 1962

The United States Department of Agriculture - The First and Second 100 Years 1/

The Act of May 15, 1862, establishing the United States Department of Agriculture, is sometimes referred to as the organic act. This is because it provides that:

"There shall be at the seat of government a Department of Agriculture, the general design and duties of which shall be to acquire and to diffuse among the people of the United States useful information on subjects connected with agriculture, in the most general and comprehensive sense of that word. . ."

Under this and subsequent legislation, the Department today provides a broad range of services under the authority of statutes enacted by the Congress in response to the expressed needs of farmers.

The productive capacity of our land and water resources, of our forests and their associated range, wildlife, water yield and recreational capabilities are assured by farmers and other citizens cooperating in local, State, and National programs of USDA. A variety of services thus help to protect and enhance our heritage of renewable natural resources. Among them are research, regulatory programs, market standards and services, technical and credit assistance, legislatively authorized supply management programs, crop estimates and others. They help 4 million farmers and millions more of nonfarm people in rural and urban areas assemble, process, store, package, and distribute farm and forest products. The principal beneficiary of all USDA services is the American citizen and consumer, everyone of us, whether we live in town or country.

The first hundred years of the USDA Land-Grant College System have been concomitant with an increase of about five times in output of farm products, an increase of about 2.5 times in all inputs into farming, thus a doubling in efficiency. While this is true of all inputs, it is also true that manhour output in farming doubled during the fifties alone.

Research and experience are the source of information with which technology and service are built. I will talk chiefly of research today.

What has been the role of research during the past hundred years? What will be its role during the second hundred? Where are we now? Where are we going? Why? It is conventional to deny any ability to predict; rather, we modestly note such trends as are recent and current and comment on the future if these trends continue. We project. We do so without confidence limits. Surely some linear programmer, some cyberneticist, some systems engineer, some opsearcher, some expert in games theory will solve this riddle of how we may determine the confidence limits of projections and thus make predictions of them.

1/ Talk by T. C. Byerly, Administrator, Cooperative State Experiment Station Service, U. S. Department of Agriculture, at the Land-Grant College — U. S. Department of Agriculture Centennial Celebration at the Agricultural and Mechanical College of Texas, College Station, Texas, September 5, 1962.

We do have a few ground rules applicable to estimates of present trends and future projections; equally applicable to research planning or every day living. Indeed, they are so simple that they could be classed as simple horse sense. The first of these is the law of parsimony. It may be stated as: You should adhere to the simplest explanation with which observed facts are compatible. A corollary of the law of parsimony is that in developing a hypothesis we should use the fewest and most reasonable assumptions.

Research has provided the hybrid breeding method; crop plant stocks genetically resistant to important diseases and insects; nutritional information which has been applied in pigs and poultry production to increase efficiency of feed use by those species. Research has produced chemical fertilizers, insecticides, herbicides, parasiticides, dessicants, and defoliants; research has adapted machines to farm use, displacing the horse. Research has provided information on the interdependent relationships of soil, water, fertilizer, season, crop plant, crop pests and agronomic skill in increasing (or decreasing) crop yield. Research assures our capacity to produce the food and fiber we need. Research can assure capacity to meet the needs of the coming generations. This latter statement is an hypothesis; it is simple, it accords with current and past experience. On what assumptions does it rest?

The assumptions are: Land enough; water enough; technology enough; enough for what? To meet the needs of future populations? Population of the United States of America has never taken longer that 50 years to double — This longest period was 1900 to 1950. Present reasonable population projection is that we'll have a third more people in 1980 than there are now, and maybe twice as many in 2000. Of water, the United States gets an average of about 30 inches of rainfall a year. We have little present prospects of increasing it. Its distribution annually, geographically, and seasonally will continue to vary. Of land, we have plenty for the present and next generation. We have a total of 636 million acres of land in land capability classes I to III, which may be used regularly for crop production. We harvested crops from less than half those acres last year. About one of each 6 crop land acres we use produces crops that are exported. We have land and water enough to meet our present and prospective needs for food, for fiber, for forest products, for wildlife, for recreation, and for open space. We have enough if we apply present knowledge gained through research and if we continue to gain new research knowledge and to apply it.

I have participated in about a third of the first hundred years. During the years since I entered the Department in 1929, the horse has all but disappeared as a source of farm power; broiler production has grown from zero to a billion and a half chickens per year; beef cow population has doubled; soybean acreage has increased from almost nothing to 27 million acres; hybrid corn has doubled per acre yields.

We must move into the future from our present position and our present resources. Where are we, what have we to work with, and what do we need?

In the allocation of limited resources, we must consider: (1) the relative importance of problems requiring solution; (2) the relative urgency of their solution; (3) the relative probability of solution; and (4) our resources for solving them.

Major research problems facing us include more efficient use of sunlight, water, CO_2, and mineral nutrients in the photosynthetic process. Presently we use perhaps one percent of the sunlight that falls on growing plants. Use of more efficient plants, more effective cultural practices, optimal application of water and fertilizer could multiply photosynthetic efficiency by 5 times. Certainly, prevention of evaporation from soil surface and water surface can save a lot of water. Present chemicals available for this purpose are approaching cost figures that will make them practical for use on vegetable and other high value crops. Of very great interest are the recently announced results at the New Haven, Connecticut, Experiment Station on the use of a chemical which closes the stomata, thus reducing transpiration loss. There is correlation between rate of transpiration and photosynthesis. To what extent this is obligate remains to be determined. Certainly, transpiration keeps the leaf surface at a tolerable temperature. I have put this problem first; from the biological standpoint, it should be first. Yield per unit of surface area, of land and of sea, will limit the population this country and this planet can feed.

We have land enough and water enough for the next generation at least. We need research on laws and other institutions which may facilitate their effective use. We need research in economics, social science, biological science, and engineering science on multiple use of land and water, of recreational use, of use for forest, wildlife, and open space and of the interaction of these uses and agricultural use. Cows, sheep, and goats may compete with deer on the range; reciprocally for hay.

During the past 20 years, use of chemicals as pesticides, as fertilizers, as feed additives has contributed greatly to increase in crop production and decrease in animal and human disease. Insect-borne diseases such as malaria and tick fever have been greatly reduced. But bees, and sometimes birds and fish, have been damaged by use of chemicals to control pests. Selective use of chemicals is essential to agriculture, to industry, and to daily living. We have a great deal of research to do on metabolism of the many chemicals in our environment. It is commonplace that insects "develop" resistance to insecticides. Presumably, such resistance is genetic resistance through selective survival of exposed genetically resistant stocks. The physiological nature of resistance to certain insecticides was found by Plapp and his associates in the Entomology Research Division working at Corvallis to be associated with grossly different amounts of an enzyme, aliesterase, in susceptible and resistant stocks. Based on this information, use of an appropriate synergist made the insecticide effective against the "resistant" insect stock. Work of this sort will increase our understanding and may save a lot of time and expense involved in screening new insecticides.

Feeding hormones to feedlot cattle has become general practice. We are still ill informed as to the chain of events by which the increased rate of gain generally obtained by hormone administration is accomplished.

Use of hormones to synchronize estrus and ovulation seems close to accomplishment on a practical basis. But such control has seemed imminent for 15 years. Certainly a lot of research is going on in this field, including research at at least 18 State experiment stations. Success in this research will make possible rapid increase in the use of semen from superior sires by artificial insemination, especially on range herds of beef cows.

Chemicals in agriculture and chemicals from agriculture will surely change. Nonfood fats have traditionally gone to the soap maker; as soaps have been displaced by detergents, fats have gone into feeds. Now, some new fat-based detergents are making a bid for a market. These fat-based detergents are decomposed by bacteria in the usual sewage disposal systems while many other detergents pass through the sewage system unchanged.

Problems of chemicals in the environment stem chiefly from incomplete knowledge. We find a beneficial use for a chemical and often exploit it without full knowledge of costs.

I wish to emphasize at this point that I do not advocate delaying all action until research information is complete. I do wish to emphasize the urgency of basic research. Basic research consists of the identification and quantification of parameters, both constants and variables, and of their actions and interactions throughout their effective range. In addition to the simple important pragmatic affirmative answers we need to know answers to the questions how and why it will work and it will pay. Tomorrow's biologist will need knowledge and skill in molecular biology and behavioral science as well as in chemistry, physics, and husbandry. Complex biological problems abound. Among them diseases, parasites, weed and competitor, for example phreatophyte problems. The relation between host, be it plant or animal, and parasite — be it an ectoparasite louse or tick, an endoparasitic worm or coccidian, a parasite fungus, bacterium, pplo rickettsia or virus--is one of the presently most productive areas for research. Flor and his colleagues at North Dakota established the fact that there is a common chemical component in susceptible flax and virulent rust. Animal cells have been demonstrated to contain latent viruses by inducing virus production by an unrelated virus. Embryos tolerate viruses, which infect them and may produce carrier adults. Parasites of all sorts are more or less host-specific. Why? Predators are, too. Phytophagous insects like the boll weevil are highly specific. Can we induce mutations, or find them, that would make the boll weevil prefer Johnson grass? Why not?

Cold hardiness is something we strive for in citrus, in winter cereals, in alfalfa and other perennials. Obviously, there is wide genetic variability in cold hardiness and wide physiological variability, too. Will our present knowledge and current studies of factors affecting cold hardiness-dormancy, new growth--help? Research workers in Alaska are studying an alfalfa derived from crosses between a Siberian alfalfa and Vernal. What is cold hardiness?

In problems for the future, I should like to use the black lands as illustrative, and more than illustrative, as an example of a major problem which must be attacked by interdisciplinary approach, by cooperation between USDA and Texas research agencies, by dissemination of information, by extension, by application by farmers and by their cooperation with Soil Conservation Districts, Rural Area Development, Farmers Home Administration, Rural Electrification Administration, and every available program.

The black lands average cotton yield is less than half that of irrigated high plains, often less than dryland high plains. Root rot gets it, not always, but too often. Rotation, use of Hubam sweet clover, careful cultural practices sometimes result in fair cotton yields. Maybe the answer for the black lands is principally in beef production. How much land will it take to support a hundred cows the year round? Will pasture be most economical? Or harvested forage? Or mostly grain? Can cow-calf operations in the black lands be made profitable? Certainly, the soil scientist, the geneticist, the animal husbandman, the plant pathologist, the agrostologist, the parasitologist, the land use economist, the linear program expert, the sociologist, the credit expert, and others must work with the cotton breeder and the phytopathologist to solve the black lands problem.

Not only will the future require cooperation among scientists in different disciplines, and with social scientists as well as with physical and natural scientists, it will also require estimates of net effects of interaction. To produce cotton requires viable seed of suitable genetic capacity, water, soil, mineral nutrients, CO_2, equable temperature, pest protection, sunlight, and time. It also requires a decision — to grow cotton.

In planning for the future we must be guided by carefully determined cost-benefit ratios. These cost-benefit ratios must be determined by basic research. They must include every appropriate parameter; they must include estimates of interaction among parameters. Qualitative factors, those dependent for estimation on sensory, esthetic, intuitional measures, may all be quantified. If you can observe that for any factor there is variation in intensity, in urgency in any quality, it can be assigned a number indicating degree. Every quality criterion, just as every quantity criterion, be it the beauty of a landscape or the minimum lethal dose of a pesticide formulation, can be used in determining costs and benefits of preserving, enhancing, or altering that landscape.

Tomorrow's news? A couple of current items from Land-Grant Colleges intrigue me for several reasons. First, reported from Oregon State University, by scientists Anderson, Cain and their colleagues, a new microbe, Micrococcus radio durans, highly resistant to irradiation. From that microbe, a chemical isolated which, when injected into mice, seems to protect about half of them from irreversible fatal destruction of blood-forming tissues. This research is supported by a National Institutes of Health grant.

Second, it is reported that Cochran of Utah State University has made a virus from inert chemicals outside a living cell. This research was supported by both Atomic Energy Commission and National Institutes of Health.

The United States Department of Agriculture exists to serve all the people of the United States. It has served them well during its first hundred years. It has indeed acquired information and diffused it among the people of the United States. Applications of technology based on that information has made us beneficiaries of abundant, varied, nutritious food at a continually decreasing proportion of our expendable income.

During the next hundred years the United States Department of Agriculture will continue to help farmers provide food and fiber economically and in abundance. It will do likewise with forest products. It will cooperate with the States and local institutions, with farmers and others in protecting and enhancing the quality and availability of farm and forest products.

In addition it will help find new ways and improve old ones for all people, especially farmers and those who live in the rural countryside, to enjoy its beauty, its open spaciousness, its challenge and opportunity for physical exercise and relaxation. USDA will cooperate in the conservation and improvement of our soil, of the beneficial use of our waters for agriculture, recreation, industry and domestic use. It will help the entire community assure a favorable cost-benefit ratio for farming and for agriculture as a whole.

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U. S. Department of Agriculture
Cooperative State Experiment Station Service

PESTICIDES: BLESSING OR BLIGHT*/

T. C. Byerly, Administrator, Cooperative State Experiment Station Service, U. S. Department of Agriculture, Washington, D. C.

The title assigned to this talk, and the material I have assembled to present to you, remind me of an incident which a friend of mine described. Some 15 years ago he was working in a defense laboratory engaged in the development and testing of new explosives. The laboratory was provided with a testing pavilion with thick walls of reinforced concrete and appropriately protected viewing points. One day a new explosive was placed in the pavilion for testing. The scientists who developed it waited eagerly at the viewing points. The count down began: 10 - 9 - 8 - 7 - 6 - 5 - 4 - 3 - 2 - 1 - phtt!

Use of chemicals in agriculture for control of several thousand insects, parasites, diseases of crop and range plants, forest trees and ornamentals, of man and animals, and of weeds and for defoliation or desiccation of foliage as a harvest aid in a few crops, such as cotton and potatoes, has increased rapidly during the past few years as new, more effective, and more selective chemicals have become available. Pest control programs are based on the assumption that benefits will exceed costs.

The amount of damage caused to agriculture is in process of review. In 1954, such costs of crop, livestock and product loss and of damage to quality, and cost of control measures were estimated to amount to more than $11 billion at their current prices. Damage by insects to forests is estimated to be several times the cost of forest fires, amounting to more than 7 billion board feet annually. Many millions of dollars are expended annually in control of household insects and in mosquito control for prevention of illness and protection of recreational values. Florida and California alone spend a combined total of over $10 million annually for this purpose.

According to Cushing1/, more than one million U. S. Army personnel were admitted to hospitals and quarters at home and overseas for specific insect-borne diseases. Principal diseases in numbers of cases were diarrhea and dysentery (523,000), dengue (84,000), and malaria (460,000). Other insect-borne diseases included filariasis, sand-fly fever, scabies, and typhus.

Life expectancy in many emerging countries of the world has increased dramatically since effective insecticides have come into general use. A recent report by Hall2/ indicates that insecticides are applied to about 84 million of our approximately 2 billion acres in the United States annually, or less than 5 percent. The amount treated includes about 1.8 million acres of forest land, about 1.6 million acres of range land, about 2.5 million acres of swamp, wild land and miscellaneous other land, about 15 million acres of urban and other built up areas, and about 68.6 million acres of cropland.

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*/ Talk given at a meeting of the Society of Hygiene at the School of Hygiene and Public Health, The Johns Hopkins University, Baltimore, Maryland, November 20, 1962.

The Hall report indicates that about 1.7 million pounds, or slightly less than one pound per acre, of insecticidal chemicals are used on forests. About 200 thousand pounds of insecticidal chemicals are used annually on range lands to control grasshoppers and Mormon crickets. About 2.5 million pounds of insecticidal chemicals are used annually to open salt and fresh water swampland by mosquito control districts. In the urban areas where most of our people live, about 56 million pounds of insecticidal chemicals are used. This amount includes about 2.7 million pounds used by the military services to protect the health and comfort of military personnel, and to protect equipment, clothing and housing. About 18.1 million pounds are used in packing plants, restaurants, warehouses, elevators, flour and feed mills, and other commercial establishments. About 45 million pounds are used by householders on their private premises, and by public authorities on park and street plantings and for public health use.

The pattern of crop use given by Hall indicates about 90 million pounds used on about 16 million acres of cotton, more than 5.5 pounds per acre. About 6.2 million pounds are used on about 2 million acres of vegetable crops, or about 3 pounds per acre. About 16 million pounds are applied on about 2.3 million acres of fruit and nut crops. About 2 million pounds are applied to livestock and poultry, about 8 million pounds to barns, sheds and storage buildings, about 35 million pounds to cereal grain fields, and about 19 million pounds to hay and other crops.

Strickler and Hinson[3/] report that farmers treated about 92 million acres for control of insects, diseases, weeds and brush in 1958. In addition, about 3.7 million acres were sprayed or dusted for defoliation. Ground equipment was used for application on 78 percent of the treated acreage and aircraft for 22 percent. About 37 million acres of cropland were treated for insect control in 1958. This estimate may be compared to Hall's current estimate of about 69 million acres. The Strickler and Hinson report indicated that corn treated in 1952 amounted to only about 400 thousand acres, but had increased to 4.5 million in 1958. Hall's estimate of 35 million acres for all cereal grains shows how rapidly insecticides have come into use for cereals. The 30 million acre difference between the 1958 and current estimate for use on cereals accounts for most of the difference in total cropland acreage treated. Geographically, the 5 States of most extensive use--Texas, California, Mississippi, Arkansas, and Florida--accounted for more than 40 percent of the cropland treated in 1958.

In keeping with Dr. Stine's letter, I am confining my comments chiefly to chemicals sprayed or dusted or applied to livestock for arthropod control. There is, of course, very extensive use of parasiticides. Coccidiostats are largely used as medicaments in feeds. Sanitizers and fumigants are widely used. Detergents present a widespread and important problem. Prophylactic, therapeutic, and growth promotant use of antibiotics and chemicals is general in production of pigs and poultry, and antibiotics are widely used in treatment of mastitis. Hormones are generally used by implantation or as feed additives for feedlot cattle.

Let's consider briefly the pesticide chemicals used in agriculture. Shepard et al.[4/] (1962) state that the quantity of synthetic organic pesticides produced in 1961 was about 698 million pounds, with a value of about $359 million. Exports during 1961 were valued at about $107 million, of which DDT accounted for about $24 million. Production of chlorinated hydrocarbon pesticides (aldrin, chlordane, dieldrin, endrin, heptachlor, toxaphene, DDT, BHC) amounted to about 300 million pounds. Production of the organophosphorus insecticides, parathion and methylparathion, amounted to about

27 million pounds. We imported over $5 million worth of pyrethrins, largely from British East Africa, and about $380 thousand worth of rotenone, chiefly from Peru.

We still use lead arsenate and calcium arsenate. About 10 million pounds of the former and 5 million of the latter per year.

The approximate retail value of all pesticides produced in the United States annually is about $1 billion. During fiscal 1962, 5104 new formulations were registered. On June 30, 1962, the total active registrations were 54,316 formulations, comprising 494 active ingredients, of which 375 are registered for use on food crops. Thirty-four new active ingredients were registered in 1962, of which 28 were accepted for use on food crops.

Our information on the metabolism of pesticide chemicals in plants, animals, and soils is far from complete. A new USDA laboratory for the study of metabolism of such chemicals is now under construction at North Dakota State College at Fargo. We do have quite a lot of fragmentary information gained at Beltsville, at the USDA laboratories at Kerrville, Texas, and at Corvallis, Oregon. Westlake and San Antonio (1960)[5] summarized our then existing information. They note that DDT may be slowly metabolized in mammals to DDA and excreted, while in insects DDE is the only metabolite found in quantity. Both heptachlor and aldrin undergo epoxidation in the animal body.

The organophosphorus insecticides are generally anticholinesterases in varying degree. They are readily metabolized in plants and animals. Some of them, for example, Schradan, are relatively nontoxic until metabolized in plants.

The carbamates, of which Sevin is a widely used example, are metabolized to 1-naphthol.

In soils at Beltsville, chlorinated hydrocarbon insecticides applied to soil in 1952 were present from about 25 percent of original application (BHC) to about 75 percent (aldrin and DDT).

DDT and other chlorinated hydrocarbons are fat soluble and stored to greater or lesser degree.

Fleck and Haller (1944)[6] studied the dehydrochlorination and found that iron and aluminum salts could serve as catalysts producing DDE.

Mattson et al. (1953)[7] found both DDT and DDE in all but two of about 50 samples of human fat.

Davidow and Radomski[8] (1953) found heptachlor epoxide as a metabolite of heptachlor in animals, and Baum et al. (1956)[9] showed the conversion of aldrin to dieldrin, its epoxide, in animals and showed the storage of dieldrin in the fat.

Organophosphate insecticides are generally inhibitors of cholinesterase, though they vary widely in the degree of inhibition. These include parathion, which is quite toxic; ronnel, much less so; and malathion, which has very low acute toxicity. These compounds are stored by plants and animals only for short periods.

Sevin, 1-naphthol methyl carbamate, is a broad-spectrum insecticide, quite useful, hydrolyzed to 1-naphthol by both plants and animals. It is very effective in killing bees.

Biological control

More than 500 species imported into the United States - about 31 successful.

300 into Hawaii - 80 est., 19 successful

Control of cottony cushion scale

Cornstock mealy bug

Some control

Gypsy moth
Jap beetle
European corn borer
Alfalfa weevil
Spotted alfalfa aphid
Citrus mealy bug
Sugarcane borer
Asparagus beetle
Elm leaf beetle

Paris lab.

Spruce bud worm

B. thuringiensis - Alfalfa caterpillar
European spruce sawfly
Tobacco hornworm
Cabbage looper

USDA has accepted registrations

Insect virus diseases used effectively against alfalfa caterpillar European pine sawfly

Woodpeckers effective against Engelmann spruce beetle in isolated infestations.

38 insect-resistant crop varieties grown in U. S. in 1958

17 wheat - Hessian fly
3 alfalfa - spotted alfalfa aphid
- corn - corn earworm and corn borer

Male sterilization

radiation - cobalt - screwworm
Chemosterilants

Bait spray - protein hydrolosate - malathion for Med. fly.

Gyplure Jacobson
Cockroach attractant?

Use of insecticides has enabled us to eradicate piroplasmosis, which used to scourge our cattle from Texas to the Potomac, and to eradicate it again on the several occasions on which it has been reintroduced. Arsenic dips have been used in times past to rid infested cattle of the tick vector--the first arthropod vector to be demonstrated.

There are several arthropod-borne human diseases, unusual in the United States, though up to very recent times endemic and frequently epidemic in many countries of the world. Yellow fever, malaria, mosquito-borne, have yielded to control programs in most of the world. Encephalitis, also mosquito-borne from our lovely singing and other feathered friends to the people who feed the birds but are careless in permitting mosquitoes to breed on their premises, is said to be our most frequent insect-borne disease in continental United States.

In many countries of the world, control of malaria and other arthropod-borne diseases by use of DDT and other chemical insecticides has been a major factor in decreasing death rate among infants and children. Unfortunately, removing or reducing these health hazards doesn't increase the local food supply, also limited by insect pests. In Southeast Asia, for example, per acre rice yields are generally about a third as large as those in Japan and the United States. Insects are not the sole reason. They are one of the reasons. The problem is neat and only moderately complex from the biological standpoint--or perhaps I have understated its biological complexity. If we construe human behavior as subject to biological definition and modification, then the first and most difficult part of this biological complex is the people's preference for their indica rice, which is nonglutinous, but notoriously weakstrawed. The high yielding Japanese types are stiff-strawed, high yielding, but glutinous. The weak-strawed indica sorts are also subject to a disease called blast, and when this disease is present there is little yield response to nitrogen fertilizer. There are a half dozen new breeding stocks of rice in Indonesia and Thailand that are efficiently stiff-strawed to stand erect and give a major yield response under heavy fertilization. Some of these are genetically resistant to blast. Such rice when fertilized and when protected by insecticide can produce double the yields of the generally grown varieties.

I had an interesting experience in this connection at a farmers' meeting near Madras. They asked me how to improve their yields and I emphasized the problem of weak straw. They protested, to them very sensibly, that their work cattle must subsist on rice straw and their soft-strawed rice was much better for this purpose than stiff-strawed varieties. Would I have their poor oxen chew upon pipes? But they were using insecticides on their rice and the simplest shirtless laborer knew what insecticide to use and when to use it.

Fire Ant Program

Initial use 2 pounds heptachlor per acre - subsequent official use after 18 months at 1.25 cut to split application of 0.250 (0.50 total). Residual, once over, and effective.

Some local kills of birds due to accident or unexpected rain making contaminated puddles.

Now replaced by nurex bait analogue of kepone - chlorinated hydrocarbon.

One-seventh ounce toxicant per acre on corncob grits with soybean oil attractant.

Generally but not always effective - fish and wildlife well pleased no kills.

Areas sprayed for control of spruce budworm have been carefully studied relative to effect on woodpeckers which are depended on for control of residual pockets of budworm infestation. Woodpeckers do not feed on sprayed budworms but seek the ones missed by the spray.

There are a few fish killed in streams in sprayed areas. A few outbreaks of red spider mites have followed budworm spraying due to death of mite predators.

Pesticide Registration

Each pesticide considered for registration by the Pesticides Regulation Division of the U. S. Department of Agriculture must have an acute LD_{50} for rats and results of skin absorption and inhalation tests.

Added tests are specified as results of screening experiments disclose need. In some cases, subacute or long continued skin absorption or inhalation tests required. Tests on human subjects essential for repellents to be applied to skin. Aerosols for household use must have records of eye and nose reaction.

Seek PHS guidance on allergies.

On June 30, 1862, the total active original registrations of all pesticides amounted to 54,316. These comprise 494 active ingredients, of which 34 were new in 1962.

When an application is filed with the U. S. Department of Agriculture for the registration of an insecticide under the Federal Insecticide, Fungicide, Rodenticide Act, there may also be filed with the Food and Drug Administration a petition for a tolerance or an exemption. The petition must be supported by a statement of the identity and composition of the insecticide, methods for analysis, information on use and resultant residues, and information on toxicity.

In appraising petitions, first concern is to determine if the proposed tolerance is indeed a safe one; second consideration is given to whether the proposed tolerance is needed for the effective use of the insecticide. Tolerances are set no higher than necessary, even though higher tolerances might be safe. Adequate methods are absolutely necessary for determining residues in the materials on which the insecticide is to be applied so that enforcement of tolerances may be effective.

Forty-seven States have pesticide laws--all but Delaware, Idaho, and Ohio. Ohio has a livestock remedy statute which covers all pesticides used on animals. In general, the States accept only pesticide labels registered by the U. S. Department of Agriculture.

U. S. Department of Agriculture
Cooperative State Experiment Station Service

EXPERIMENT STATION GOALS AND THEIR ATTAINMENT

State Agricultural Experiment Stations exist to serve the people - all of them; all of us who eat food, wear clothes, and live in houses. Research work conducted in these experiment stations is designed to provide the information needed by farmers and by those off the farm who depend directly or indirectly on farm products. It assures the economic production, assembly and distribution of the essential goods and enjoyments provided by good farms and good rural communities. Experiment station research contributes to our store of knowledge and especially in the biological sciences has contributed knowledge that is essential in the control of human disease as well as animal disease. Experiment station research provides challenging opportunities for achievement and service to young people with curiosity, imagination, intelligence and perseverance.

We in the United States are particularly fortunate in the resources with which we are endowed -- land and water -- and people. In the world as a whole each person has about 1 acre of cropland; we have about 2.5. When needed, we have available for use more than 600 million acres of cropland in capability classes I to III, suitable for crop use with moderate care. We harvested crops last year from only about half that many acres.

Address by T. C. Byerly, Administrator, Cooperative State Experiment Station Service, U. S. Department of Agriculture, given on RESEARCH DAY, initiating the 75th Anniversary of the Agricultural Experiment Station, Utah State University, Logan, Utah, February 9, 1963.

The United States has demonstrated its capacity to supply the food, fiber and forest needs of its present population and to share a surplus with less fortunate nations of the world. Our capacity to meet the needs of future populations depends on conservative use of our land and water resources within their capability. We have the most abundant, wholesome and economical food supply any nation has ever enjoyed.

Our abundance and efficiency have resulted in large part from the application of science and technology growing out of research in the State agricultural experiment stations and the laboratories and field trials of the U. S. Department of Agriculture, often in cooperation. We are complacent. But we ought not to be. Research achievements of the past will not be sufficient to supply information needed to solve the problems of the future. New diseases and pests will attack our crops and livestock. Competition for land and water for dwelling, recreational, urban and industrial use will increase. Further research can increase our capacity to produce to meet future problems forseen and unforseen. Research is an important factor in determining our capacity to produce. Research provides information which becomes an important resource useful in farming. Research should provide information enabling us to make wiser decisions on resources to be used in farming so that our people may continue to be well fed, clothed, and housed and that both farmers and those who serve farmers may be assured a balanced economy. Scientific research and the primary information it yields should also be a major guide to community development.

We have 53 State agricultural experiment stations in the 50 States and Puerto Rico. They use about 5300 professional man years in research. They conduct research on problems of our major crops and livestock species, on genetics, physiology, pathology, molecular biology, ecology. They conduct research on soil, on water, on forestry, on recreation, on housing, on family and community development, on ornamentals, on wildlife. They conduct research on food and fiber and forest products and human nutrition. They conduct research in chemistry, physics, mathematics, biometrics, and engineering of many sorts. They conduct interdisciplinary research. About 35 percent of their research is basic research - essential to the quick and effective solution of tomorrow's problems. Many graduate students are employed in experiment station research, assuring a supply of competently trained young people to solve tomorrow's problems.

Expenditures for experiment station research are on a modest scale - amounting to less than $200 million annually at all stations from all sources. Federal appropriations for Grant funds under the Hatch Act, an essential component of State experiment station support, amount to about $40 million. This is about 0.3 percent of the total amount proposed in the budget now before the Congress for all research and development. Most of the funds provided annually are of course, for defense-related and health-related research and development, and certainly are not in excess of need.

Dr. Thorne asked me to discuss past accomplishments of agricultural experiment stations, the responsibilities of stations in research, patterns of successful research programs and the challenges and rewards in research for the participants.

Relevant to patterns of successful research programs through the coordinated use of research funds from several sources, a major problem for every experiment station director is contained in the following quotation from Dean E. J. Nesius' Morrill Centennial Lecture, "Charting our course over the next decade," presented December 4, 1962, at West Virginia University:

> "The existence of the Hatch Act as a stable and continuing source of funds provides an unusual opportunity for the researcher to select his core project and, in due time, build a satellite system of complementary and supplementary sub-projects. In this sense, the complex we call a research program is made up of small, semi-autonomous systems centered about key individuals in the research organization."

Section 2 of the Act of 1955 Consolidating the Hatch Act and Laws Supplementary Thereto, says in part, "It shall be the object and duty of the State agricultural experiment stations through the expenditure of the appropriations hereinafter authorized to conduct original and other researches, investigations, and experiments bearing directly on and contributing to the establishment and maintenance of a permanent and effective agricultural industry of the United States, including researches basic to the problems of agriculture in its broadest aspects, and such investigations as have for their purpose the development and improvement of the rural home and rural life and the maximum contribution by agriculture to the welfare of the consumer, as may be deemed advisable, having due regard to the varying conditions and needs of the respective states."

The research of the experiment stations began with basic and applied research on soils and fertilizers, on energy requirements of man and of his livestock, on new crops and better seed, on the diseases and pests which afflict us, our crops and our livestock, and on the ways in which the family farm could be made more productive of economic and non-economic goods for the farm family, the rural community, the State, the Nation, and for the world. Yes, for the world. The pioneers came from many nations. They brought their crops, their skills, their traditions to the new lands of America - there to build new communities based on a new agriculture. Our joint success has amazed us and the world. It has confused us, made us question what our objectives and our pathways during the second hundred years may and ought to be.

In part, the framework is fixed by the resources available to us. In part, we may fix it further by our assumptions, by our mores, our regulations, and laws. But, finally, we are free to modify that pattern through research, education, and action, or indeed, through caprice or through inaction and vacillation. We ought to and must further strengthen our established effective institutions, modify them to suit the needs of the future, and proceed with all deliberate speed to meet the problems of the future. Among our fully tested and effective institutions are the State agricultural experiment stations, fostered by the support provided under the Hatch Act and by the more-than-matching support provided by the respective States.

Dr. Thorne asked me to speak a bit of the achievements we have made and of the problems we must solve. In aggregate our achievements are evidenced by the fact that the people of the United States enjoy an abundant, varied, nutritious, safe, and wholesome supply of food and fibers and forest products. They enjoy this bounty at less cost than any other industrial nation. Our food, for example, costs us only about

19 percent of our expendable income. Our fathers paid about 25 percent of their income for food. People in other countries now pay from 25 to 75 percent of their income for their food. We have increased our inputs into farming in the United States by about 2.5 times during the past century. We have increased our farm outputs by 5 times; thus, our efficiency has doubled. Much of that increased efficiency has occurred during the past few years. It has resulted in large part from the application of technology based on information gained through research - much of it done in State agricultural experiment stations, and much of it done at the Utah State Agricultural Experiment Station.

Let us shift now from the general to the particular. Among the great achievements in which State agricultural experiment station research workers have played, are playing, and will continue to play a major role is the identification and quantification of energy sources, pathways, and use in plant and animal metabolism. Atwater, first Director of the Office of Experiment Stations, played a major role in determining energy use of man. Armsby, Forbes, and their colleagues at the Pennsylvania station have played a continuing and productive role in studies of the energy metabolism of cattle, as have Ritzman, Colavos and others at the New Hampshire station, as has Mitchell at Illinois, Brody at Missouri, Kleiber in California, and others. Energy is the prime purpose of food; energy enables us to live, to work. Excess energy enables us to play or to get fat. Our livestock are dependent every day on food or stored energy. Our range livestock keep warm at 20 below on a belly full of dry, leached range forage because it has a high heat increment which keeps them warm. Fraps at Texas laid the foundation for our knowledge of productive energy, an idea exploited by H. M. Scott and his colleagues at Storrs, and put to work through sophisticated formulation of high energy feeds by feed manufacturers for efficient production of broilers and turkeys.

Energy remains among our most important problems because we need enough of it for ourselves and tend to ingest too large quantities of it in food sources. It is most important for the future of our livestock industry in many ways. Can we in terms of human energy, continue to increase our cattle by utilizing grass as the source of about 60 percent of their energy, as we do now? Or will it be cheaper to depend much more largely on energy from feed grains brought to them in the dry lot? For land which has no other profitable alternate use, grass is not only a fine soil conserving crop, but also certainly will continue to be a major source of livestock feed. But are we likely to expand grass supplies very much? We can. There are often quoted yields of up to a ton of beef per acre from Everglades improved pastures of St. Augustine grass, but general production from grass is quite deficient.

We have about 840 million acres of pasture and range of all sorts, including about 69 million acres of cropland pasture. From this we realize through harvest by livestock the feed equivalent of something more than 4 billion bushels of corn a year -- a little more than that from our actual corn harvest.

Grass and other forage is very important in Utah. Most of the land surface of the State provides grazing, browse, or harvested forage to meet a major portion of the feed requirements of livestock and game. Irrigated pastures and meadows are often highly productive, frequently producing a hundred times as much forage as do many of the less productive acres of range land.

A North Dakota horticulturist, Hansen, is generally credited with the introduction about 1898 from Russian Turkestan of crested wheat grass. This is the most widely used grass for range reseeding in the northern plains and intermountain region. It is a cool weather grass and while highly productive, provides grazing for only part of the year. Hansen also introduced apple, plum and cherry stocks still in our world collections, still useful to geneticists and breeders working with these species. Hansen's explorations were jointly supported by North Dakota and USDA.

Appropriate to the relatively great importance of range and pasture in Utah, the achievements of research workers in the Utah Agricultural Experiment Station have been substantial. Stoddard's achievement as a teacher and the value of his text on range management are widely appreciated. Cook and Harris earned a Hoblitzelle Award for their outstanding contribution through field and laboratory studies of the nutrient contributions of range grass and browse species to range livestock and the feed supplements needed to make them adequate. Highly productive research on poisonous plants continues here. Wayne Binns, stationed here by the USDA, has contributed much to our understanding of the relationship of forage to the etiology of monkey face and other nutritionally related reproduction anomalies in range sheep and cattle.

We need more research related to range forage production and use. We have almost no genetic research on browse species. Some of them such as winterfat and bitterbrush are both palatable and nutritious. While we have other useful wheat grasses and other useful grasses for reseeding, we urgently need warm weather grasses, good seed producers, big seeded and sure to produce a stand. Industrial research on soil coatings to conserve moisture may help but products now available seem too costly to justify use in range seeding.

There are many studies demonstrating the feasibility of increasing per acre range forage production. Few of them demonstrate that cost can be recovered in less than 5-10 years. We need more and more sophisticated economic studies to determine how and under what circumstances range improvement will pay.

One of the great achievements of the past, presently a highly productive field of research in which basic research achievements of great importance seem imminent, is that of wheat rust. Merited honor has been bestowed on E. C. Stakman, now emeritus of the Minnesota Experiment Station, for his innovations and achievements in this area. Stakman was an agent of the U. S. Department of Agriculture as well as a staff member of the Minnesota station. Stakman laid the foundation of our present knowledge of the epidemiology of wheat rust. He postulated and proved its over-wintering in the South, its travel on the wind to inoculate and destroy the wheat fields of the North. He did much of the work on identification of rust races, and with his geneticist colleague, Hayes, developed resistant wheats.

But the fact of resistance is not enough. Rusts change and new races virulent for the new wheats appear and flourish, so that geneticists and pathologists are barely able, sometimes, as in the case of race 15B which nearly wiped out Durum wheat a few years ago, to replace susceptible wheats with resistant ones. That the future may finally see the victory of science over rust seems likely when the nature of resistance is fully learned.

H. H. Flor, a USDA employee stationed at the North Dakota station, working with colleagues on the staff of that station, has made a great stride toward understanding host-parasite relationships in studies of flax rust. They demonstrated a common chemical component in susceptible flax and virulent rust-genetic compatibility. Should this phenomenon prove general in rust-host relationships, the chemist may find means of systemic protection, or the geneticist may achieve complete resistance against all rusts.

The recent announcement from the Nebraska station that Schmidt and Maan of that station, working with Johnson, a USDA agronomist located at the Nebraska station, have found an effective fertility restorer gene in their wheat breeding material, makes advent of hybrid wheat imminent. This work follows the first essential step toward hybrid wheat, the discovery of cytoplasmic male sterility by Wilson then on the staff of the Kansas Agricultural Experiment Station working at the Ft. Hays substation, and Ross, a USDA geneticist stationed there. Since wheat is generally self fertile, male sterility is an essential tool to hybridization and the restorer gene is equally necessary so that the hybrid wheat flowers will form grain.

It remains to be demonstrated that the hybrid method will be superior to present methods of forming breeding stocks resistant to disease, to cold drouth, insects and with quality and yield characteristics necessary for economic production. Experience with hybrid corn, sorghum, chickens and other crop and livestock species warrants confidence that hybrid wheats will be valuable.

The Wisconsin station has been the source of several major research achievements. Notable among them is the demonstration by E. V. McCollum and his associates of the existence and the physiological role of vitamins A and D. McCollum and Davis in 1913 discovered an ether-soluble factor in butterfat and egg yolk necessary for the growth of rats. This discovery was confirmed by Osborne and Mendel at the Connecticut station during the same year. There is an anecdote associated with this discovery which has always interested me. My old friend Jimmie Halpin, who was in charge of poultry research at Wisconsin for many years, is said to have told Dr. McCollum that yellow corn is better feed than white corn. Its higher content of carotene does, in fact, make it better feed in diets low in vitamin A or carotene, its precursor. Obviously, the discovery of vitamin A and the demonstration of its importance in human and animal nutrition are not the end of the story.

Within the past ten years, Brazzell, working first with Newsome at the Louisiana station, established the fact and importance of diapause in the life history of the cotton boll weevil. They found that toward the end of the season weevils store fat, hide themselves in trash, and spend the winter in a dormant condition--diapause. Without diapause, few or no boll weevils survive the winter. Brazzell has worked for the past several years at Presidio, where, in cooperation with plant pest control workers, he has applied his knowledge of the importance of diapause by destroying with successive applications of methylparathion the boll weevils at the end of the growing season, to prevent the development of an overwintering diapause population. Thus far, this program seems to have checked the westward advance of the boll weevil. On January 1, Dr. Brazzell became head of Entomology at Mississippi State, where he will work in cooperation with the staff of the new USDA boll weevil laboratory.

Many of the major research achievements of the past were made by individual scientists, or small groups working in a narrow scientific area, often studying a single variable. Much of the research now needed will require teams of scientists trained in various scientific disciplines. These research teams will be able to study the effects of several variables or of several relevant processes simultaneously. It is well recognized for example that maximizing the efficient use of water for crop production includes selection of appropriate crop of suitable genetic capacity, of scheduling the time and amount of irrigation water applied in accordance with the water needs of the plant, of applying appropriate amounts of all needed fertilizer nutrients, of using soil of high production potential, or amending it appropriately to make it productive. In this instance efficiency and yield are likely to be closely related. But this may not always be true. Economic studies of combinations of imputs which will produce higher economic returns from irrigation water are essential.

It is obvious that water for irrigation use must compete with alternate uses as population, industry and recreational demands for water increase. It seems reasonable to assume that irrigation agriculture in Utah can compete for the necessary water if it is used efficiently.

Utah scientists have for many years contributed substantially to our knowledge of water transport, application and efficient use in crop production. Lauritzern's recent work on water harvest and on canal liners has contributed importantly. Wayne D. Criddle, Utah State Engineer, and Harry F. Blaney, ARS, working in this State, recently published an important technical bulletin, No. 1275, "Determining Consumptive Use and Irrigation Requirements." From results of experimental studies in the United States and several foreign countries, Blaney and Criddle developed an empirical formula showing the relationship between temperature, length of growing season, monthly percentage of animal daytime hours and consumptive use of water. From this relationship, consumptive use of water by crops and natural vegetation can readily be estimated for any area where the basic climatological data are available.

The Water Resources Report prepared for the Committee on Natural Resources of the National Academy of Sciences, National Research Council stressed five areas of research which should be accelerated to provide information for use in wise public decisions on the development and use of water resources. The first of these areas is the development of a multidisciplinary water research program with a sound institutional base and the training and recruitment of scientists who are ready and able to study the nation's multidisciplinary water - resources problems in a unified manner. Agriculture's responsibility in the development of such a program is large.

The second area is research relevant to ground water supplies. Improved means of ground water exploration, better means of tracing ground water movement, better methods for forecasting capacity of aquifers and recharge areas, and ways of safe use of treated waste water for recharge are needed.

Third, research is needed on systems for the development of water resources. Systems analysis and other methods of simultaneous evaluation of alternate uses, operating procedures, and structures for developing and managing specific water resources should be undertaken. Such studies should include costs and benefits analyses and sophisticated projections of regional and national water needs such as evaluation of technological interrelationships.

The fourth major area of research needs is that of evaporation suppression and transpiration control. It is not news to you that evaporation from reservoirs and transpiration from phreatophytes in the 17 Western States is more than twice the amount of water withdrawn for public supplies in the entire United States.

The fifth research area recommended for increased attention is that of methods of water purification and forecasting pollution damage. Plant nutrients, detergents and other persistent organic chemicals pose difficult separation problems.

These recommendations have been transmitted to the Office of Science and Technology where, together with a parallel inter-agency study, they will be considered in connection with legislative and budgetary processes.

Our agricultural research stations face changes in program, facilities, and personnel to effectively meet future research needs because of the limited funds likely to be available and the competition for support and personnel from other new and exciting research areas such as space science. We must concentrate our resources on challenging problems that will enable us to recruit and retain research workers of unexcelled capacity and productivity. Every State experiment station has sufficient resources to develop and maintain outstanding competence in one or several research areas. Few have resources to become outstanding in all relevant research areas.

On the experiment station directors and their research associates rests principal responsibility for determining the most critical problem-solving needs within a State--and for developing scientific competence and skills in those areas that will do the State most good. That directors will rise to such responsibility is demonstrated by the leadership given here in Utah during your station's 75-year history. We may be confident that they will continue to do so. Personally I trust that they will.

U. S. Department of Agriculture
Cooperative State Experiment Station Service

PROGRAMS OF SERVICE TO STATE AND NATION - U. S. DEPARTMENT OF AGRICULTURE AND THE LAND-GRANT COLLEGES

We begin the second hundred years of Federal-State cooperation in agricultural education, and the seventy-sixth year of formal Federal-State cooperation in agricultural research, with abundant food, fiber and forest products.

Research has provided much of the information that has made possible the improvements in technology which have, diligently and ingeniously applied by farmers, produced that abundance. Weather, too, has been a major factor in our current abundance. Research has not yet provided means for controlling the weather. Nor has research fulfilled its potential role in the development and evaluation of methods of economic adjustment which may enable farmers to retain for themselves a fair share of the benefits which improved farming efficiency has brought to all of us as consumers.

Those benefits for all of us who eat, wear clothes, and live in houses are very large. Ten years ago, we spent almost 24 percent of our disposable income for food. Last year we spent less than 20 percent--a clear saving on our food bill of $15 billion--more than twice the current budget of the U. S. Department of Agriculture for all purposes.

However, we have no reason to be complacent. While we have bred wheats resistant to certain strains of rust, rusts change, too, and without research new strains of rust pathogenic to our current wheat strains would overwhelm them. Kansas and USDA researchers working at the Hays Station deserve a great deal of credit for their genetic work, which has

Address by Administrator T. C. Byerly, Cooperative State Experiment Station Service, U. S. Department of Agriculture, given before the Joint USDA--Land-Grant Centennial Banquet, Kansas State University, Manhattan, Kansas, January 15, 1963.

laid much of the foundation for the development of hybrid wheat. New hybrid sorghums have been a major factor in bringing about increased yields of this grain. Diseases will attack these hybrids. Research has provided means of protection of our livestock against many diseases. Soon after the passage of the Hatch Act, scientists in the U. S. Department of Agriculture proved that piroplasmosis, later called tick fever, was transmitted by ticks--the first demonstration of an arthropod-borne disease. Control of the tick has banished tick fever from Kansas cattle herds. Not gone, but reduced to a very low incidence, are bovine tuberculosis and brucellosis; a national program of hog cholera elimination is getting underway; pullorum disease of poultry has become unusual. But the list of diseases is long; for many we lack adequate means of identification or control.

Our research establishments, their facilities, personnel, and support funds are essential to assure us the capacity to meet the problems of agriculture as they arise. Let us review briefly how we have achieved our current research competence and some of the problems we must solve to maintain and increase its effectiveness.

As background, let us recall a bit of general United States history. For this purpose, I shall use some quotes from inaugural addresses of some of our presidents and from other sources. These addresses constitute a fine series of declarations of intent, statements of noble purpose, and comment on their current problems.

My favorite is from the first inaugural address of Thomas Jefferson: "All, too, will bear in mind this sacred principle that though the will of the majority is in all cases to prevail, that will to be rightful

must be reasonable; that the minority possesses their equal rights, which equal law must protect, and to violate would be oppression."

The next one is from the inaugural address of James Buchanan, who commented with respect to the Nebraska-Kansas Act: "The whole Territorial question being thus settled upon the principle of popular sovereignty--a principle as ancient as free government itself--everything of a practical nature has been decided." In fact, only the method of decision making had been decided, and that not for long.

President Lincoln's first inaugural contains a statement consistent with Buchanan's and with the first Morrill Act, approved on July 2, 1862: "That the maintenance inviolate of the rights of the States, and especially the right of each State to order and control its own domestic institutions according to its own judgment exclusively, is essential to that balance of power on which the perfection and endurance of our political fabric depend..." Compare with this the language from Section 4 of the first Morrill Act, "to the endowment, support and maintenance of at least one college where the leading object shall be, without excluding other scientific and classical studies and including military tactics, to teach such branches of learning as are related to agriculture and the mechanic arts, in such manner as the legislatures of the States may respectively prescribe, in order to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life."

Section 2 of the Hatch Act of 1887, establishing the agricultural experiment stations, contains similar language: "That it shall be the object and duty of said experiment stations to conduct original researches or verify experiments on...and such other researches or experiments bearing

directly on the agricultural industry of the United States as may in each case be deemed advisable, having due regard to the varying conditions and needs of the respective States or Territories."

Benjamin Harrison was the first president inaugurated after passage of the Hatch Act of 1887. The year was also the centenary year of the Constitution of the United States. Harrison was elected to the 26th presidential term. In his inaugural address he noted the increase in territory, population and wealth during the first century, then said: "But our growth has not been limited to territory, population and aggregate wealth, marvelous as it has been in each of those directions. The masses of our people are better fed, clothed and housed than their fathers were. The facilities for popular education have been vastly enlarged and more generally diffused."

This, then, is the background. The States have accepted and discharged their responsibility for providing institutions for education and research related to agriculture. The Federal Government has provided some of the funds used for these purposes. Working together, a great deal has been accomplished for all of us, for all the world and especially for each of the respective States by their land-grant colleges and agricultural experiment stations.

As we enter the hundred and first year of this cooperative program, may we remember President Kennedy's notable words in his inaugural address, "And so, my fellow Americans, ask not what your country can do for you; ask what you can do for your country."

The Kansas Station has been fortunate in strength of its directors--strength built on character, modesty, scholarship, determination, perseverance. These qualities are vital for the efficient operation of the research program developed in accordance with Hatch Act principles.

Let us recall for a moment the five most recent Directors of the Kansas Agricultural Experiment Station. Some of you have known all of them, their strength and their achievements.

F. D. Farrell was Director from 1918 to 1925. His area of research experience included cereal investigations and irrigation.

L. E. Call was Director from 1925 to 1946. He, too, was an agronomist. Director Call was succeeded by R. I. Throckmorton, also an agronomist, who served as Director from 1946 to 1952.

In 1952 A. D. Weber, animal husbandman--Vice President Weber now, but affectionately Dad Weber to the many stockmen and animal husbandmen who know and admire him--became Director.

In 1956 Glenn Beck, your present Dean, became Director, to be succeeded in June 1962 by Peairs Wilson, your present Director.

These Kansas Directors have been wisely selected, and the fine record of achievement of the Kansas Station under their leadership is well known to all of you.

The Director's responsibility under the Hatch Act is explicit, as is his existence. Section 5 states in part: "Sums available for allotment to the States under terms of this act,...shall be paid to each Agricultural Experiment Station... Each such station...shall have a chief administrative officer known as a director..."

USDA Miscellaneous Publication 515, revised 1959, states on page 2: "It is the Director's responsibility to determine, on behalf of his agricultural college or governing board, and in cooperation with the Department of Agriculture, what researches bearing directly on the agricultural industry of the United States are advisable. For this the Director has sole authority within the State."

Responsible exercise of this authority is a major factor in the productivity of our State experiment stations. In determining to what researches the limited resources of his station are to be allocated a director has to consider quality as well as appropriateness. Prediction of quality of research yet to be done is highly uncertain. An appropriate hypothesis for solution of a problem, the established competence of the investigator, the availability of adequate materials and support personnel--all are important.

One more ingredient--the initiative of the individual research worker--often contributes to quality. Research workers of established capacity and productivity expect and should have a great deal of freedom in the selection and development of their research. But the price of freedom is responsibility. The responsible research worker recognizes and respects the obligation of the Director for the management of the research program of the station through allocation of resources and through coordination and evaluation of research. In our democratic society, all of us are peers. For convenience, we assign leadership in specific areas of activity. The leadership role of the experiment station director is an essential role.

On the Archives Building in Washington, D. C. are engraved the words, "What is past is prologue." No matter how productive our past, we can do nothing to change it; neither to augment nor to diminish. Let us examine, then, our current position, our capacity and our obligation to meet the foreseeable and unforeseeable problems of the second century.

In our 53 state agricultural experiment stations there are about 10,000 people engaged full time or part time in research. Deducting time

spent in teaching and extension, these people provide over 5200 professional man-years of time applied to research, of which about 104 were applied at the Kansas Station. In fiscal 1962, the agricultural experiment stations expended about $34.7 million of Federal-grant funds, administered by the Cooperative State Experiment Station Service, about $126 million of non-Federal funds, and $15.5 million from Federal agencies other than USDA. Departmental research agencies had about 2300 research employees on land-grant college campuses and State-owned field stations, of which about 34 were located at Kansas State University. These agencies spent about $20 million in support of research, largely cooperative, at these locations. The sum of personnel and funds for research at the 53 State experiment stations, with their substations, for 1962 is thus about $196 million and 7500 professional man-years.

For fiscal year 1961, the 50 States and Puerto Rico provided over $87 million of State-appropriated funds for agricultural research. Kansas was 19th among the States in this respect, with about $1.8 million. For fiscal 1962, the Kansas Experiment Station expended about $678 thousand in Federal-grant funds and $2.727 million of non-Federal monies, a total of $3.405 millions. In this respect Kansas ranked 18th among the 50 States. In the calendar year 1960 only five States--Iowa, Illinois, Minnesota, Texas, and California--exceeded Kansas in realized gross income from farming, although in some other years Missouri, Indiana, Wisconsin, and Nebraska have, too.

Federal research funds expended at the 68 Land-Grant institutions other than Hatch and Agricultural Marketing Act funds amounted to about $348 million in fiscal 1960. Of this total about $252.5 million, or over

72 percent, went to two Land-Grant institutions, the University of California and Massachusetts Institute of Technology. Contrast this with Federal grants under Hatch and Agricultural Marketing Acts. The Texas and North Carolina stations topped the list. Each received about 3.75 percent of the total. Of the grand total to experiment stations from Hatch, Agricultural Marketing Act, and non-Federal funds, California, the largest, had about 10 percent.

The use of project grant funds from several granting agencies has caused problems of coordination and orientation within some recipient institutions. Some institutions encourage their research workers to present proposals to granting agencies and, certainly, granting agencies invite proposals in their area of interest. It is intended that project grant support be awarded to the best proposals from the best qualified research workers. In the experiment stations, will this mean that Hatch, Agricultural Marketing Act, and non-Federal funds will be used principally by those research workers unable to obtain project grant support from other sources?

Will the successful applications for project grant support be oriented toward agriculture or to the area of interest of the granting agency? Experience indicates that project grants can and do provide increased support for basic research. Such support is needed. It can be highly beneficial to the total research program of the experiment stations. Experiment station directors and their management colleagues should make sure that project grants strengthen and to not serve to destroy their station program.

Project grant funds are admirably suited to the support of research by graduate students. Hatch and Agricultural Marketing Act funds support the research of about 1800 graduate students now. It has been said that there exist in some universities--surely not Land-Grant Universities--so many graduate students that their professors don't even know the names and faces of many, nor the research in which they are engaged. The association of professor and graduate student in research is an essential feature in training research personnel and a major source of innovation and new ideas growing out of research. We may logically ask, "If good research can be done by graduate students without counsel of the professor, why pay the professor's salary?"

There has been some complaint, too, that project grant funds do not carry sufficient latitude for payment of indirect costs. In my opinion, our State agricultural experiment stations should be proud that the States have for years provided facilities and indirect costs, as well as fully matching direct costs, of research on which Hatch and Agricultural Marketing Act grant funds are used.

The program of education built on the Morrill Act, its collateral program of research built on the Hatch Act, assure us of centers of excellence in research and education in every State. They are centers that have shown a high degree of responsibility. This built-in autonomy provided in the authorizing acts enables them to reflect and to evaluate local variations in problems, needs and capacities of local communities, farms and landscapes. Surely this fine resource will continue to serve our future needs as it has our past ones. Our responsibility is to use the experiment stations most effectively and to encourage their growth in quality of product.

The smallest of our State experiment stations has currently available annual operating funds of over $500 thousand. This amount is enough to provide adequate salaries and support funds for about 20 professional research workers, their scientific, labor and clerical assistance, and the materials, supplies and services which they need to carry on quality research. Twenty men could be in 20 different areas of agricultural research, or they could be working together in a single area. In my opinion, neither of these distributions is most appropriate. Within the funds and personnel available, each experiment station director and his colleagues must build a research program which takes into account the major commodity interests of their State and the major research competence of their staff. They must also provide means for research problem solving in all areas.

It is my opinion that each of our experiment stations should plan its future programs with effective concentration of its resources in commodity areas of principal importance in the State. Second, it should support productive individual research workers and teams of research workers in their own areas of research interest. Every man on the Station staff must be available through direct participation, or through consultation, for solution of acute local problems that inevitably come to the station.

No station can undertake research on every problem brought to it. Selection among those problems need to be based on urgency of the problem, on availability of funds, on facilities and personnel required for solving the problem, and on the probability of finding its solution within a reasonable time.

Among the important questions which we must face are:

First, at what level will the States support agricultural research?

Second, at what level will the Federal Government support agricultural research at State experiment stations through:

(a) Hatch Act and Agricultural Marketing Act funds;

(b) Cooperative research, including contracts;

(c) Project grant funds through USDA;

(d) Project grant funds administered by other Federal agencies.

Third, how will research in the State experiment stations be coordinated with that in other colleges and departments of the Land-Grant institutions of which most of them are a part?

Kansas farmers had cash receipts of about $1,218 million in 1960, about equally divided between receipts from livestock and products and from crops. Receipts from sales of cattle and calves amounted to 36.3 percent of total receipts, and sales of wheat to 36.2 percent.

Assume that $609 million received from crops and livestock bore charges for deterioration of equipment and facilities, taxes, interest on farm mortgages, and rent to nonfarm landlords of about $166 million each. Livestock bore charges for feed, livestock purchased, hired labor, and miscellaneous other costs of not less than $360 million so that livestock cash receipts represented about $87 million value added. Crops bore charges for seed, fertilizer, machinery repair and operation, labor and miscellaneous other production costs amounting to about $265 million, leaving realized value added by crops of about $177 million, so that net cash income from sales of farm products was about $265 million. Kansas net farm income for 1960 was about $440 million. This amount included

about $29 million Government payments, $27 million in value of farm products consumed at home, and gross rental value of farm buildings of about $57 million, and an increase in inventory worth about $62 million.

What guide lines can we deduce from these figures for allocation of limited research resources? I've cited them to remind you that while cattle and wheat are the principal sources of cash receipts from farming, necessary inputs require research attention, too. The $332 million cost for taxes, mortgage interest, rent to nonfarm landlords, and depreciation suggest need for economic research, not only for the benefit of the farmers who directly bear these costs, but for the individuals, institutions, and communities which benefit from them, too. The $57 million gross rental of farm buildings, the farm repair and operations costs of $157 million suggest need for research in engineering. So, for production research, even though it be focussed on beef cattle and wheat, competence in many related areas is needed, as well as research in plant and animal genetics, physiology, pathology, and ecology--yes, and animal husbandry, entomology, agronomy and soils, too. Kansas has an experiment station staff providing more than 100 professional man-years. This is a substantial staff, but it must be selectively used to achieve maximum efficiency.

In proportion to the very large proportion of the food dollar represented by marketing, processing, storage, packaging, and other costs of assembly and distribution, State agricultural experiment stations have generally lagged in the amount of research attention given to marketing, utilization, and consumer use research. Not more than 20 percent of professional research time at the State experiment station is devoted to research in these areas. Kansas is above the average of the State

experiment stations with 25 percent of its research effort directed toward such problems. Farm value of domestic farm food used by civilians in 1962 was only about a third of civilian expenditures for these foods.

One of our major problems in beef production is efficiency of feed conversion; a second is efficiency of reproduction; a third is carcass quality.

In terms of corn equivalent feed units, the average cost of producing a hundredweight of live cattle and calves in the United States was a thousand pounds 50 years ago, and is a thousand pounds today. On a comparable basis, broilers cost less than 3 pounds feed units per pound liveweight, and hogs about 5.5. This problem of feed efficiency is related to decisions Kansas beef producers must make between cow-calf operations and grass or feedlot growing and fattening operations. Each cow-calf unit requires a couple of tons of feed units for the cow and her calf to weaning. With a generous allowance of 400 pounds of calf weaned per cow, it is obvious that the calf costs 10 pounds of feed units per pound liveweight. Feeder cattle, especially thin ones, will add weight much more efficiently, but as they fatten, efficiency decreases.

The problem can be licked; outturn of 1000-pound finished cattle at a net feed unit cost of 7 pounds of feed units per pound liveweight is quite possible. But research must produce better feeding and management systems; ways of obtaining uniformly higher percentage calf crops and cattle bred to gain rapidly on grass and in the feedlot with fleshing acceptable to the market buyer.

Meat animal production hasn't improved in labor efficiency nearly so fast as crop production. Output per man-hour has increased about 60 percent in the past 50 years, which may be compared to an increase of about 800 percent in man-hour output in wheat production during the same period. Mechanized and automated feedlots are providing increased efficiency for large-scale operators. Paradoxically, the ancient and simple way of letting the beast find its own fodder, although efficient under extensive range conditions, apparently becomes inefficient under intensive conditions.

We've considered only commodities sold from the farm. We have not considered, for example, the value of grain sorghum, alfalfa, and range and pasture forage consumed by beef cattle, except by assignment of a share of capital and labor costs to livestock.

Kansas had about 4.2 million roughage-consuming animal units in 1951 and in 1960. She is fourth in number of cattle and calves.

Although cash receipts from grain sorghum in 1960 were only $76 million, value of production of sorghum, grain and forage, including that fed on farms, was about $140 million. Similarly, corn, which produced cash receipts of about $32 million, had a production value of at least $87 million, including grain and forage fed on farms where it was produced. Hay produced cash receipts of only $12 million, and had a production value of about $72 million. Pasture and range for the 4.2 million roughage-consuming animal units of livestock had a production value of about $45 million. These are some of the tangibles a director faces in considering allocation of his research resources. What value shall he place on communities? On recreation? On the woods, and streams, and lakes? On the fish and wildlife for which they provide habitat?

How shall he allocate resources to basic research? Basic research must grow to assure our capacity for problem solving. In my opinion, it should eventually use about 50 percent of our available research resources. Most basic research is problem oriented. It provides not only information essential to problem solving, but often leads to the discovery, definition, and solution of hitherto unknown but nonetheless important problems.

Let us consider briefly the other partner in Federal-State cooperation in agriculture--the U. S. Department of Agriculture. The Act of May 15, 1862, establishing the U. S. Department of Agriculture, is sometimes referred to as the Organic Act. It provides that: "There shall be at the seat of Government a Department of Agriculture, the general design and duties of which shall be to acquire and diffuse among the people of the United States useful information on subjects connected with agriculture, in the most general and comprehensive sense of that word..."

The Department has a proud record of achievement in research and a fine and productive program of research. In addition to the funds provided for grants to the States for research under authority of the Hatch Act, as amended in 1955, and the Agricultural Marketing Act, Section 204(b), the Department's appropriation for 1963 contains about $132 million for research on production and utilization of farm products, on human nutrition and consumer use, on forestry research, marketing research, and economic research. The Department expends about $20 million of its research funds at land-grant college campuses and State field stations, principally in cooperation with the respective State agricultural experiment stations. It has about 2300 research employees at these locations.

A recent report to the President, Senate Document 94, 87th Congress, 2d Session, on government contracting for research and development, contains several significant statements, among which are the following:

"It (the Government) should never lose a strong internal competence in research and development..." (p. 21)

"Direct Federal operations such as the governmental laboratory enjoy a close and continuing relationship to the agency they serve, which permits maximum responsiveness to the needs of that agency and a maximum sense of sharing the mission of the agency."

Research in USDA and in the State experiment stations, often in cooperation, are needed to meet the many and varied problems of the future.

The Food for Peace program became a major arm of agriculture's international relations in 1961. Our ability to produce more than the people of the United States can use has proved to be a blessing to more than 100 less fortunate countries that receive food and fiber from us under the Food for Peace program. During 1961, for example, about 45 billion pounds of agricultural commodities went overseas under this program.

Research exists in the Department to support the mission of that Department. I have quoted the Act of May 15, 1862, which established the Department. Research and dissemination of information are a part of the Department's basic mission, as well as essential tools in the development of methods and procedures for carrying out missions established by many acts subsequent to the Act of May 15, 1862. The Department is responsible, for example, for protecting our forests, crops and livestock against exotic diseases, insects, and other pests. It is responsible for development of foreign markets for farm and forest products. In cooperation with the

people, generally through cooperation with State or local agencies, this Department helps in the conservation of our national forests and grasslands; of our soil and water. It helps to identify and to protect quality and wholesomeness of food products; to identify other farm products with respect to quality; to assist in the stabilization of farm prices and returns, regulation of market and trade in farm products and facilities. The Department assists individuals and communities through information, advice, credit, cost-sharing and technical assistance in authorized farm and other rural development projects and programs.

The Morrill Act and the Hatch Act have provided a basis for the establishment and development of centers of excellence in research and education in every State. This may be contrasted with the concentration of project grant funds provided under other legislation and through other Federal agencies at a few locations.

The Director of each State experiment station can and, in my opinion should, selectively build excellence in his station so that it would be acknowledged as fully equal in excellence in those selected areas to any other research institution anywhere. The Director can concentrate Hatch funds in appropriate commodity areas. He can concentrate Hatch and Regional Research Funds in support of the research of research workers of outstanding capacity and competence. He can further strengthen research in these selected areas through cooperation with U. S. Department of Agriculture research divisions, and through project grant funds from other sources. He should, in my opinion, where choice is required, seek to add to strength rather than to bolster weakness. Every State experiment station has sufficient resources to build such strength in at least one area. Kansas has the resources to further develop research strength in several areas.

THE CHALLENGE TO THE SCHOLARS OF AGRICULTURE TODAY

Address by T. C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, to the Biennial Conclave of Alpha Zeta, Southern Illinois University, Carbondale, Illinois, September 8, 1964

There is no more succinct statement of the challenge to the scholars of agriculture today than the admonition in Genesis 3:19, "In the sweat of thy face shalt thou eat bread..." For though the proportion of people employed in farming has diminished dramatically as energy inputs have shifted from horses and man to machines and petroleum products, the work required of the scholars--the eggheads--in agriculture has increased. Your future in agriculture is surely one of work--hard work, challenging work, rewarding work.

Before we consider further the challenge of work for scholars in agriculture, let's define agriculture. It is surely more than farming as we know it today, though farming will always be its basic component. We might describe agriculture in terms of products--food, fiber, forest products and fun. Yes, fun, too, for the pleasures of rural living are increasingly sought by all people for their recreation. Farm people are increasingly conscious that the open space, the trees, birds, wildlife, streams and lakes interspersed with their cultivated fields are a valuable resource from which they can gain both pleasure and profit.

Alternately, we can define agriculture in terms of conservation, commodities, communities, and consumers. This framework permits a quantitative description of agriculture, or if you prefer, agriculture and forestry. Our first definition concerned itself with products of the land; in a broad sense, with commodities. In order to enjoy those commodities, we must conserve and improve the productive capacity of the land, water, air, and human resources necessary to their production. We may assign a rough dollar value to the land and buildings on farms, more than $140 billion, and our forests $25 billion or more, but dollars provide only the crudest measure of these essential resources. Land without water grows neither crops nor grass nor trees. Air, which we have been wont to take for granted, is equally essential for the moisture it bears, the oxygen and carbon dioxide it contains, and the sun's energy which it transmits. Of these resources, and of people, more later. About 54 million of us live in towns of 2500 or less, in the country, or on farms.

The net cash receipts from farm commodities at the farm gate amount to about $33 billion, and forest products at point of first delivery about $3 billion.

Our rural communities depend principally on the supplies and services they provide to farms and to one another, and on the assembly, storage, processing, manufacture, transportation, and distribution of farm and forest products--marketing in the broad sense. Domestically consumed food has an annual marketing charge of $45 billion; fiber, leather, tobacco, and other nonfood farm products domestically consumed $36 billion; and forest products about $11 billion. Exports amount to

about $6 billion. The total value of farm and forest products measured at the point of use, and excluding excise taxes, amounts to at least $128 billion.

While I have implied that agriculture and forestry involve the 54 million of us who live in rural America, in fact all the people of the United States and many who use our exports in other countries are dependent in part on our agriculture. For example, about 10 years ago, we in the United States spent about 23 percent of our expendable income for food; now we spend less than 19 percent. That 4 percent difference amounts, currently, to about $17 billion that we have available for other things than food.

I haven't really defined agriculture. You can make your own definition. I think I have reminded you that it extends far beyond the farm gate. As our country grows in population, perhaps to 245 million by 1980, the rural, especially the farm population, is likely to increase but little. Most of the increase in population will take place in the cities. Part of the increase in city population will result from continued migration from the country, where the birth rate far exceeds the death rate, but most of it will result from increase in the city home.

This discussion of agriculture, its nature, its importance to everyone in the United States, and the importance of United States agriculture to the world, provides background rather than evidence for the assertion that the lot of you, the coming eggheads in agriculture, have the challenge of work before you.

You are again reminded that while horses and men devoted to farming have been replaced in large part by machines and petroleum products, those men and women on the farm and those serving agriculture, and those dependent on agricultural and forest product processing and marketing must have ever-increasing skill. The efficiency of farm production has doubled in the last hundred years. Total inputs into farming have increased during this period by about 2-1/2 times, outputs by 5 times. This increase in efficiency has resulted in large part from the development of new technology and the adoption of that technology by our farmers.

Our colleges, our agricultural experiment stations, our extension services, our agricultural industries, the U. S. Department of Agriculture in its many services--or rather, the people who are the substance of these institutions--have provided much of the information on which technological improvements have been based. The farmers themselves have, through invention, innovation, and application, been the principal contributors.

Contributions to the necessary information for technological improvement come from basic science as well. Dr. Madsen has noted that Donald Danforth honored here tonight, is a Princeton graduate. George Shull, while a Princeton professor, made a major contribution to genetic theory on which the systematic improvement of hybrid corn is based.

Conversion of atmospheric nitrogen to forms useful as fertilizer, superphosphate, improvements in engineering, knowledge of role of trace minerals such as zinc in plant nutrition, and of manganese and selenium in animal nutrition, have helped increase economic use of feeds and fertilizers and increased efficiency.

The development and use of pesticides--chemicals for the control of insects, of weeds, of fungi, of animal parasites--have not only increased efficiency of production, but equally protect products and product quality and the health of our livestock and ourselves.

Yields per acre and per animal breeding unit have so increased during the past 30 years that we now provide food, fiber, and forest products for 50 percent more people in the United States, and for many abroad, from the same number of acres we had 30 years ago, and we have acres not now needed for production of farm and forest products to use for other purposes--for wilderness, for watersheds, for wildlife, for recreation, for open space, for rural living.

The spectacular growth crops of the past 30 years have been beef, soybeans, and broilers. Beef production has about doubled, soybeans increased more than 40-fold, and broilers have increased by more than 50 times during that period.

Research and action have eliminated ticks and tick fever, controlled screwworms, greatly reduced tuberculosis and brucellosis, bred faster gaining cattle, guided feeding improvement in beef cattle. Research and action have developed soybeans suited to the Delta and Dakota and points between. Research and action have controlled pullorum disease and coccidiosis, have doubled feed efficiency and growth rate in broilers.

What will be the growth crops of the next 30 years? Part of the answer is up to you. The notable advances we have made will not be enough for the future. We have problems to solve; tougher problems than those we have solved. Problems that you with your better training, with your youth, can and must solve. But you'll have to work to solve them.

Some of you will do research; some of you will teach, in colleges, schools or extension service; some of you will enter industry or farming. Wherever you serve you will have problems; you will have work to do.

Let's consider some of the problems and what it will take to solve them. Problems are solved through research, through discovery, through experience. Research, the orderly assembly of relevant information, the development of reasonable hypotheses containing minimal assumptions, the testing of these hypotheses with appropriate and adequate tests, is a sure road to problem solving. Research may be either basic or applied. Basic research in agricultural science must be conducted to provide new knowledge essential for the solution of problems. Applied research uses existing information for the solution of problems. Applied research has immediate practical objectives

such as, Will it work? Will it pay? Basic research must go beyond practical limits in order to determine what those practical limits are. Basic research must determine all effects of a course of action.

It was not enough to know that DDT would kill lice and mosquitoes. It is now obvious that we must find out how this and other pesticide chemicals work in order to understand, and eliminate, the development of resistance in pests, accumulation of residues in our environment, adverse effects on wildlife. My definition of basic research is that it consists of the identification and quantification of parameters, both constants and variables, and of their action and interaction throughout their effective range.

There are scholars who accuse science of narrowness in that it can deal only with quantities; that the values of art and literature and music, of politics and religion, are beyond its purview. There are scientists who believe that the scientific method has universal applicability. This problem, too, you will have to face, though it seems doubtful that you will reach a single conclusion.

Of the problems, some are now obvious; others will emerge. Our land--cropland, forest, grassland--faces increasing pressure for uses other than farm and forestry. Citrus groves in southern California give place to suburbs, new citrus land has to be developed. Our forests and grasslands provide wildlife habitat and are principal sources of water for our cities. Multiple use is an established principle. Research is needed to determine the best pattern of use.

Competition for water is already keen in many areas. Industrial users, household users, recreation users can afford to pay more for water than irrigation users in many places. Plants and the soil in which they grow return enormous quantities of moisture to the atmosphere. Part of this water loss through evapotranspiration is essential to keep the leaves cool enough to stay alive in hot weather. Research at the Connecticut Agricultural Experiment Station has identified a chemical which can be used to reduce evapotranspiration from leaves. With this and other tools, scientists will determine the relationship between evapotranspiration and plant growth and perhaps find ways to use water more efficiently. Research has already found ways to desalinize water, but at costs now too high for irrigation use. Perhaps nuclear power may some day be cheap enough to make desalinization of water for irrigation use economical. In the meantime, research is helping in the use of water of impaired quality and to reduce quality impairment through use. Water now and increasingly in the future must be used many times. Chemicals from industrial wastes, from pesticides, sewage residues, sediment, all impair water quality.

Our air, too, requires increasing research. Smog irritates us and adversely affects our plants. Research must find ways of averting or reducing it. Carbon dioxide is essential to plant growth, as is sun's energy. We are just beginning to understand use of carbon dioxide in increasing plant growth, now only practical in greenhouses. Some day in fields, too?

Our present programs of research in cloud physics, in telecommunications, in missiles and satellites, in aviation, but especially in meteorology, are helping us to better weather prediction. Of all industries, agriculture is most heavily affected by adverse weather. Forest fires, hail, drought, flood, weather delays in planting and harvest, wind, dust, and cold all take their toll. Weather modification is a continuing challenge. Perhaps within your lifetime, perhaps through your efforts, we'll find out how to do it.

The great success of the recent past in developing and applying technology to the production, marketing, and use of commodities from farm and forest gives assurance that we can achieve even more in the future.

Some of you will find your challenge in genetics and its application in breeding, some in nutrition and physiology, others in ecology and behavioral science, still others in chemistry, engineering, and chemurgy; some of you in economics and other social sciences. Geneticists, molecular biologists, biophysicists, and biochemists have identified the genetic materials and determined their structure. They have found out how genetic information is coded and generally how it is transmitted from generation to generation of cells or of multicellular organisms. They have found out how to induce genetic change by ionizing radiation, by chemical mutagens, or by genetic transfer. Tomorrow they may find ways of directing genetic change. It may be possible to form at will plants and animals with new and more desirable traits--resistance to pests and disease, improved quality, drought resistance, cold hardiness, for example.

Animal nutritionists face a very great challenge in improving the feed efficiency of ruminants. While our sheep and cattle do convert vast quantities of grass and other roughage into meat and wool, we have made little improvement in the efficiency of the process. As we learn more about the microbiology of the rumen flora, perhaps it can be modified to increase digestibility of fiber and the net energy of roughage feeds. We need to do this, for the realized harvest from our billion acres of grazing, while about equal to the corn crop in the aggregate, is produced from about 60 times the corn acreage. Alternately, nutritionists are learning to use high concentrate feeds effectively for ruminants. Physiologists will learn, indeed are learning, how to regulate flowering of plants, growth habit and fruiting by the use of light, dark, and chemicals. Animal physiologists will learn how to get a hundred percent calf crop or lamb crop. While the present generation of physiologists has made very great advances in knowledge of the physiology of reproduction of mammalian livestock species and of poultry, there are more and harder problems to solve than have yet been solved.

Ecology is coming into its own. The balance of nature is an unstable balance. Insect predators and parasites may be used effectively to control or eradicate some of these pests. We are just beginning to learn about the complex ecology of soil organisms, and their interactions. We know how disastrous soil pathogens can be and often are; disaster courted, it seems to me, by our increasing practice of monoculture.

In marketing research we've made great strides in convenience; instant prepared foods are myriad and economical. Cotton and wool quality have been enhanced by chemical modification so that wash and wear is a reality. But quality research lags. We separate out different sizes, colors, shapes of fruits and vegetables. We've learned how to preserve edibility--but quality? It still provides a challenge, and a still greater challenge as our fruits and vegetables are adapted to mechanical harvesting and handling; these processes, too, provide challenge.

But the greatest challenge of all is the human challenge. About half our farm families, 1.6 million of them, have incomes of less than $3,000. Many of our rural communities have schools, health and sanitary services, recreational facilities and other wanted services which are less than adequate. While improvement in production and marketing efficiency proceeds at a rapid, even a spectacular pace, social and economic progress for many rural people is slow or static.

Many children in rural communities should be prepared for jobs in the cities to which they will migrate. Those who wish to remain on farms and in rural communities require much more skill and training to succeed there than did the present generation. To some of you these people problems will provide the greatest challenge. It will not be enough to identify the gifted and help them to find opportunity, though this is very important. All who can learn, and almost everyone can, should have opportunity to learn. If they lack desire to learn, ways must be found to inform them that through learning, and only through learning, can they achieve greater returns to themselves. If they do not learn, they will find it increasingly hard to find work opportunities. If they cannot find work through which to support themselves, you eggheads will have to support them. For we are kind people; even the undeserving poor, and certainly their children, must be kept healthy and well-fed.

Finally, the world at large provides a challenge. There is just now being started an International Biological Program, sponsored by the International Council of Scientific Unions. The IBP has as its objective the determination of the productive capacity, present and potential, of the world's natural and managed plant and animal communities, both terrestrial and aquatic. Man is an important part of these biological communities. He may destroy or enhance their productivity. Research on human adaptability to the many environments of the world will be a major portion of the IBP. The productive capacity of the biological communities of the world will finally determine how many people and at what degree of well-being this world can support. Is this not a challenge? Do you agree that there is work for you to do? Work that will call for the very best effort of which you are capable?

WHAT IS EXCELLENCE IN RESEARCH MANAGEMENT? 1/

We are here tonight to honor Ordway Starnes--scholar, gentleman, administrator. He has earned our respect. We value his friendship. We know he will be effective in his new and challenging assignment. We will miss him while he is away and welcome his return.

Ordway has served as Director of the New Jersey Agricultural Experiment Station during a difficult transitional period in the history of agricultural research. This Station has a distinguished record of research productivity, creativity and leadership. Soil microbiology provided Selman Waksman, René Dubos and their colleagues material and insight which led to effective, lifesaving antibiotics. My old friend Red Beaudette produced effective immunization methods for laryngo-tracheitis and other diseases of poultry. Bill Martin had few peers as an administrator. These are but a few of the great men who have worked at this Station. The present staff contains men of equal capacity.

I have described the present and recent past as a period of transition--a difficult period--in the history of agricultural research. Change in program, change in methods, change in objectives is a normal and healthy state for research. Research produces information. Application of that information produces change. Change produces new problems. And the Agricultural Experiment Station must adjust to meet changing needs.

1/ Summary of remarks by T. C. Byerly, Administrator, given on ~~July~~ June 10, 1965 at Rutgers University, New Brunswick, New Jersey following a dinner honoring Director Ordway Starnes of the New Jersey Agricultural Experiment Station.

But the scientific method does not change. It is still necessary to state a question in answerable form; to assemble the relevant existing information; to develop a reasonable hypothesis containing minimal recognized assumptions; to test that hypothesis by appropriate experiments and observations, sufficient in time and space.

Agricultural research here and in other institutions has yielded much of the information which has served as the basis for the technology which has increased phenomenally production efficiency on the farm. Grain yields per acre have doubled during the past 30 years. Milk production per cow and eggs per hen have increased steadily year after year. We have achieved a steady supply of foods and other products of the land at economical costs to the consumer. Research has contributed to protection of food quality and convenience of form in which it may be bought. Research in food technology here has been notably productive.

Nor has the need expired for continued research to improve production efficiency and lower the costs of production and marketing. Competition is an ever present spur to research, an incentive to efficiency encouraging the efficient agriculturist to prosper. Thus abundance is provided for all consumers.

In addition to these successful and proven areas of research, we must accelerate our research to meet urgent problems in resource use and development, in the protection of our crops and livestock and our dwelling places and recreational areas against pests and pollution.

Here in the Garden State your Green Acres program is making rural New Jersey a better place to live as well as one in which to make a living. The Green Acres and similar programs, including our national one of enhancing Natural Beauty, require research to mobilize efficient and effective action.

It is obvious to all of you, sometimes painfully so, that the land, water and air resources of New Jersey are limited. The air is not a limitless reservoir for the dilution of the products of partial combustion of fossil fuels and wastes. Research at this Station has identified the various effects of air pollutants on different plants.

Water is needed for crops, livestock, lawns, woods, wildlife, recreation, industry and household use including waste disposal. Research is needed in order to achieve maximum beneficial use of the limited water supplies, acceptable methods of reuse, reduction of pollution.

Research to develop more effective methods of protection against pests without persistent residues has been given substantial additional financial support during the current year. Ordway Starnes has been a leader in the identification and evaluation of research needs and in research planning, regionally and nationally as well as in New Jersey, on pest control problems.

Insects despoil our shade trees, our woods, our crops. Some of them carry disease from plant to plant, from animal to animal, from animal to man. Insects frequently develop resistance to once effective pesticides. Residues of some of them persist in the environment. Effective biological control methods are yet to be developed for many of them. We must accelerate research to develop more specific, less persistent pesticides and research to develop more and better biological control methods. Ordway's training and talents in Entomology have provided a basis for his outstanding leadership in and counselling of research groups, locally, regionally and nationally. His leadership has led the way toward launching research aimed at many of todays insect problems.

A start had been made on determining the need for cooperative action in obtaining registrations and tolerances for pesticides to be used on minor crops. He pushed this effort and conducted a survey of the State stations and determined that authorizations for use of over 400 pesticides on minor crops were needed. Armed with this information he proposed IR-4, Evaluation of Current Data and Needed Research to Determine Tolerance Limits of Chemicals for Minor Uses on Agricultural Products. This project was approved as an interregional project and the project leader is located at the New Jersey station. Under it we're making progress.

He contacted the Pesticides Regulation Division of the Agricultural Research Service in USDA and the Food and Drug Administration in HEW seeking closer cooperation between them and the regional research committees on pesticide residues. After several conferences with officials of the two agencies, an invitation was extended to them to send representatives to the annual technical committee meetings of the four regional experiment station projects on pesticide residues, also the interregional one, IR-4. Representatives of the Pesticide Regulation Division attended.

Ordway has done outstanding work as administrative advisor of NE-36, Pesticide Residues in or on Raw Agricultural Commodities, as chairman of administrative advisors of IR-4, and as chairman of the Committee on Chemical Residues of the Experiment Station Committee on Organization and Policy.

Under his leadership, the New Jersey station sponsored a meeting of State Experiment Station and U. S. Department of the Interior personnel with State wildlife and conservation research workers interested in controlling bird depredations. As a result of that meeting, the regional project NE-49, The Control of Bird Depredation, was developed. It represents an exemplary cooperative effort of the Department of the Interior, State Agricultural Experiment Stations, and State departments of wildlife and conservation in seeking solution of the bird depredation. Outside the Northeastern region, the Ohio station participates in NE-49, and stations with bird depredation problems in other regions are also interested in this cooperative effort.

Agricultural research must be integrated with research in other areas. This process is going on in the New Jersey Agricultural Experiment Station and, in my opinion, most effectively. Agricultural research has only one unique characteristic. It is oriented to the problems of agriculture. The principles of biology, chemistry, physics, economics, sociology, mathematics are the same for all. The application of these principles to solve the problems of agriculture is special.

But the problems of agriculture cannot be settled without taking into account side effects and problems in other areas. Multiple use land, water, air and green open space must take into account the benefits of natural beauty, wildlife, recreation, and country living, as well as efficient production, processing and distribution of the commodities produced from the land. Agricultural research must have a role in the basic research necessary to provide information needed to solve agricultural problems. Competence in basic research will enhance competence in applied research. Competence effectively applied begets excellence.

What is excellence?

Each of you will have your own definition. Webster says: State of possessing good qualities in an eminent degree. I like that definition. There is room for all of us within it--room for many institutions--not just a few. If--if we, individually and institutionally, identify our "good qualities," our people and areas of greatest competence, and proceed to find opportunity for their most effective use, that's excellence in research management.

Men who tower above the rest of us will emerge and be recognized. I have named four among the many who did so at this station. Such men are unusual. Their achievements are in part the achievements of the institution of which they are a part.

Waksman's account of the discovery of streptomycin illustrates my point. In the publication, "Streptomycin 1944-64," is Waksman's inspiring paper, "Out of the Earth Shall Come Thy Salvation." Surely most of you have read it. In it, Waksman stated:

"On August 20, 1943, the poultry pathologist of the New Jersey Experiment Station (the late Dr. Fred Beaudette) swabbed the contents of a chicken's throat on an agar plate and observed certain colonies of actinomycetes developing on the plate. He asked one of my students (D. Jones), at that time visiting his laboratory, to take the plate to me for further examination.

"On August 23, 1943, I turned over the plate to another of my graduate students (A. Schatz) with instructions to transfer the colonies to sterile agar media, and to test them for their ability to inhibit the growth of various bacteria on the agar plate. Three Streptomyces cultures were thus isolated. They were designated as D-1, D-2, and D-3, D being the initial of the assistant (Doris) who brought over the plate. When these cultures were examined, they were found to possess considerable activity against various bacteria. They appeared to be identical with the culture of Actinomyces griseus (now known as Streptomyces griseus) that had been isolated in 1915 in our laboratory.

"I proceeded to study, with the help of several other graduate students and assistants (E. Bugie, C. Reilly), the formation, isolation and nature of the new antibiotic, and decided to name it streptomycin. Its limited toxicity and its marked activity in experimental animals were soon established in the Department of Animal Husbandry at our institution."

Each of these people played a role. Each contributed to excellence.

Research management--and I use the word "management" deliberately--is continually challenged and opinions as to its role in contributing to excellence vary widely. In my opinion, management is an essential factor in achieving and maintaining excellence in every research institution.

I believe that research management must share with the research scientists, or should I say the other research scientists, of the institution, responsibility for planning, initiating, terminating, modifying, coordinating and directing research. If the good qualities of each staff member are to be used most effectively so that each and everyone has opportunity to achieve excellence, then management must share responsibility with him to make sure that he or she is engaged in important, challenging research for which his competence is suited; and management must form judgments as to the relative productivity, relevance and quality of each research undertaking as it progresses. Under Dr. Starnes' direction several changes in station organization have been made. We feel these changes have helped to solidify the objectives of this research institution and provide for greater productivity.

In general, there appears to be a positive relationship between productivity and quality. Obviously, counting number of scientific publications, or citations, is a crude and insufficient measure either of productivity or quality. These measures should be used only in context with other measures such as the judgment of peers and the judgment of seniors. But despite the opprobrious connotations of the cliché, "Publish or perish," there is a measure of justice in the dictum. Some scientists delay publication until they are sure; more of them publish the first hint of discovery. Many, unfortunately or fortunately, publish infrequently because they have nothing of importance to say.

What can management do about the unproductive? I can make no generalization. Case by case, some need encouragement, some admonition, some training opportunity, some are hopeless. But the manager is responsible for the effective use of funds, principally, public funds. The man who pays the piper may not call the time but he has a right to expect a good return on the investment in research. And in the long run, the evaluation of the effectiveness of research management must rest on the productivity of good quality information relevant to important problems by the research institution.

Traditionally, research managers have been, and generally now are, themselves research scientists. Generally, research scientists accept more readily the judgments of another scientist than of a nonscientist with respect to their own research. But, if the scientist-manager is worth his salt as a scientist, it is fair to ask whether his role as manager provides him the best opportunity for achieving excellence. For achievement in research is no guarantee of skill in management. Principles of management are in process of establishment. One day the scientist who will become research manager may be required to acquire those skills as a formal requisite to his position. Or, persons skilled and trained in research management, nonscientists themselves may supersede scientist managers.

But here and now, we have scientist-research managers. Fortunately, some of them are excellent. In my opinion Ordway Starnes is, and I'm proud to know him and to have the privilege of working with him.

AGRICULTURAL RESEARCH FOR THE FUTURE

We have come here today to participate in the dedication of a fine new laboratory provided almost entirely by the people of the State of Washington to house the State and Federal folks who work here. Prosser is one of the finest examples of effective Federal-State-Industry cooperation I know about. Cooperation can only be effective when each and every cooperator is working and working compatibly with all the other workers at the location. One man, Singleton, personifies this station for me. He is a part of it--and has been so long and so thoroughly a part --that Prosser must be a part of him.

Research at Prosser is varied; while varied, it is responsive to the needs of this great and growing agricultural area. Research can grow more comfortably with this new laboratory. But let us not forget that research is done by people; that the laboratory only provides a place for them to work.

Agricultural research for the future is needed to: (1) conserve and increase the productive capacity of land, water, and air resources; (2) to lower cost of production and to protect and improve quality of farm and forest products; (3) to improve existing markets, find new markets and new uses for farm and forest products; and (4) to make rural America both a better place to make a living and a better place to live.

CONSERVATION RESEARCH

Air Conservation

The agricultural industry is more subject to weather than any other; more importantly, in dollar terms, even than the aviation industry. At Pullman, weather records have been and are carefully analyzed to provide a basis for design criteria for irrigation systems.

Areas dependent on rainfall for crop production are subject to drought, flood, and weather damage. Crops are subject to frost, livestock to seasonal and weather variations. Research is defining ways in which environment may be ameliorated--through use of high shade for feedlot cattle in the Imperial Valley of California, for example.

A growing program of weather research led by the Weather Bureau with help in essential data collection from the Bureau of Standards, NASA, Air Force, Navy, and other agencies--rapid communication and automatic data computation is giving us better weather prediction. Basic research supported by NSF and other agencies is yielding information which may make direct research on weather modification productive. When that time comes, agricultural research should expand its present modest research program in agroclimatology and biometeorology very substantially.

I spoke of frost; air pollution damages horticultural crops in many areas as well as producing discomfort and illness in man. Some day, we may indeed be able to do something about the weather as well as talk about it.

Talk by T. C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, at dedication program of H. Rodgers Hamilton Laboratory at Irrigation Experiment Station, Prosser, Washington, August 18, 1964.

Water Conservation Research

The recent enactment of the Water Resources Research Act, patterned after the Hatch Experiment Station Act, is gratifying evidence of public understanding of the importance of additional research in each of the States on this scarce and essential resource. At the same time, the probable availability of funds for water resources research under this new legislation will not reduce, but rather enhance, the necessity for increased research support for agriculturally oriented water research. The history of the new law makes it crystal clear that funds to be appropriated under its authority are not intended to duplicate, nor to supplement, nor to replace funds needed for water research related to agriculture.

Agriculturally related water research must be continued and should be expanded in the SAES. Agriculture is the largest user of water; is dependent on water for its very existence. Since water is a scarce resource, pressures for a larger share of water for nonagricultural use will increase. The water required for an acre of irrigated alfalfa could alternately supply the household needs of the seven families whose homes could occupy the same acre. And the home owners could easily afford to pay more for the water than could the irrigation farmer. Industrial water users can pay more than the farmer; and while most industrial use is consumptive use only to a small extent, quality impairment through industrial use is often substantial. In many locations, recreational use of water may yield a higher return economically than agricultural use.

These comments lead to the identification of one urgent need for added water resource research, that is research on the costs and benefits of alternate uses of water, on multiple use and on the laws, customs, and other institutional factors affecting water allocation to the various alternate uses. Agriculture has a major concern in such research; not the sole concern, and socioeconomic research on water research related to agriculture should be coordinated through the university-wide water resource research centers provided for in the Water Resources Research Act, with water research oriented to nonagricultural objectives.

Since water is a scarce resource, reuse is imperative. I mentioned water quality impairment by industry--effluent from pulp factories, cannery wastes, milk processing plants. There are many others--such as the temperature rise consequent to the use of water for cooling. Agricultural use impairs water quality, too. In bulk, sediment in runoff water is the biggest problem. USDA maintains a sedimentation laboratory at Oxford, Mississippi, where runoff from the loessial soils of that area makes the entrainment, transport, and deposit of sediment a major problem. Sedimentation research is needed here in Washington, too. Black fallow--the Palouse hills contribute sediment, the result of water erosion.

Another factor in water impairment through agricultural use is the accumulation of salts, of nitrogen from fertilizer and of pesticide chemicals used on crop land. As water percolates through soil it dissolves salts and takes them through the drainage system, ultimately to downstream users. We need more research to find ways to reduce salt accumulation as well as research on best ways to use water of high salt content. We need research to find ways of reducing or eliminating water contamination by pesticide chemicals. That such contamination exists is clear from the information adduced during the investigation of the

recent Mississippi river fish kills. Exquisitely sensitive chemical methods established the fact that the water in the lower Mississippi may contain as much as 0.2 ppb of endrin. While this pesticide is widely used in the area to control cotton and sugar insects, it has not been established that such use is directly responsible for the endrin in the Mississippi river. Nor has it been established that endrin at the levels found is of the slightest significance to human health. But the endrin is there; traces of other pesticide chemicals may be present in other streams and in lakes in areas where use of such chemicals is extensive. Research is needed to prevent or to eliminate their presence in our waters.

The biggest use of water is through evapotranspiration from field and leaf surfaces. Plants vary widely in their rate of water use in this way. Some loss of water from leaf surface is essential to keep the leaf cool during hot weather. Research at The Connecticut Agricultural Experiment Station at New Haven has identified chemicals which may be used to restrict loss from evapotranspiration; whether such restriction will have practical field application remains to be seen. Certainly more basic research on evapotranspiration is urgently needed.

I have barely touched a few of the areas of importance to agriculture of water research. You all know of the importance of water loss through seepage from ditches and reservoir surfaces. Research on time and amount of water application to growing crops is currently very productive. So, too, are studies of the interaction of water, crops, and fertilizer to obtain maximum return from water used.

Land Conservation Research

Sixty percent of the land in contenental United States is in farms. Much of the public land is grazed. We have a highly effective Federal-State-Local system of soil conservation and very effective research supporting it. Yet vexing and increasingly urgent problems remain. Some of those in the socioeconomic field seem particularly important. Some of them cannot be solved through research, but they can be understood through research. Research can, but has not yet, disclosed the factors leading to decisions to convert a bearing orchard to a suburban development. We in the United States have a limited acreage suited naturally to the culture of horticultural crops. In many areas--in California, in Florida, in New York, for example--suburbs encroach upon them. In Florida, land is undergoing physical amendment to make it suitable for citrus. If the present course continues, we need more research on soil building. We need it anyway. We need it to build the capacity of our soils, all of them, for generations to come.

The price of land has increased steadily for more than 20 years. It is not clear that the increase depends proportionally on increase in economic return. It is clear that every gain made through the application of technology in lowering the cost of crop production tends to be capitalized in land prices. While this may benefit the owners of land, it increases the difficulties for young people desiring to become farmers. It also accelerates the restriction of crop and livestock production to fewer acres.

We in the United States, thanks to the development of technology through research and its application by farmers, have enough land for farming and for other purposes, too. We may still have 50 million cropland acres excess to production needs in 1980. To what use shall we put it?

Commodity Research

Let us leave now the scarcely touched consideration of needed research related to land and move to a corollary area, grass. If we have 50 million excess acres, let's seed it down. Grass will check erosion, rest the land, maintain its productive capacity. Do we need more grass? Are we using what we have now?

Cattle and calves we have a plenty; they are the biggest item in farm cash receipts--about $8 billion. Eliminating interfarm sales, value of production is about $6.5 billion, still by far the biggest farm income item. Where does our beef come from? Grass?

Perhaps we are producing more beef than we used to from grass. After all, we've eliminated most of the horse pasture and range and sheep production has decreased. Too, there has been some increase in improved pastures in the Southeast and in the irrigated areas of the West. But most of our doubling of beef production in the past 25 years has been produced in the feed lot. And increasingly, feed lots are using grain and other concentrates, not forage.

Why? First of all, our eager and able researchers have proved that we can feed high concentrate rations even to dairy cows. As feed lots grow larger, the economy gained through ready automation of concentrate feeding offsets the initial lower cost of forage. Materials handling is one research area of importance to grass.

Perhaps of more importance to grass utilization is that, except for brief periods, grass and harvested forages contain a lot of bulk that cattle can use only to keep them warm. This function is essential to the survival of a range cow in a blizzard, but is of little importance to a steer in a feed lot or a dairy cow in a barn. Research may find ways to increase the digestibility of forage and, of equal importance, may find ways of using the digestible energy of forage with efficiency equal to the use of energy from grain. It is not certain that research can produce this happy result but some very good people are hard at work on the basic research on rumen physiology and microbiology essential to its solution, and more research is needed.

Research here in Washington has demonstrated that you can get more than 500 pounds of beef per acre from well managed irrigated pastures. Such research is very important, but what does the feeder steer cost to produce? And what do you feed in the feed lot to finish such steers? Feed disappearance data for the United States do not indicate that we have improved the efficiency of feed conversion in producing cattle and calves at all. This is in sharp contrast to the improvement of feed efficiency in producing broilers and turkeys resulting from the application of nutrition, feeding, and disease control research.

For efficiency cannot be had with sick animals. Sick flocks and herds have excessive death loss and low feed efficiency. Calf diarrhea presents research problems urgently requiring attention here in the Northwest.

Health may inhibit the concentration of breeding herds in dry lot. If the lot is truly desert dry, there may be no more problems with parasites and disease than on range--but are lots likely to be dry in the winter time?

The cost of grass, and harvested forage, including the cost of getting it to the cow or, conversely, the cow to the grass, may determine the place of grass in future beef production. In many places the 8 pounds of concentrate a day required to keep a cow is cheaper than the alternate 20 pounds of hay or its grazing equivalent. Research in Texas, in North Carolina, and other locations indicates that all-concentrate feeding is feasible and may become the economic choice in some areas. More research is needed. Much more research is needed on breeding grass, on seeding grass, on harvesting and handling grass, on feeding grass.

It is highly probable that research can find ways of lowering the cost of beef production. It is also likely that lowering cost of production may be compensated by increase in volume of production and decrease in market price of beef. Certainly this has been the story with broilers. Can research find ways in which the producer can participate more fully in the benefits from research?

In terms of acreage, alfalfa and soybeans have been the growth crops in recent years. Since 1950, soybean acreage has increased by 20 million and alfalfa by 8. Beef and broilers have increased by 80 percent and 200 percent, respectively, during the same period. What will the growth crops be during the next few years? The acreage of 22 fruits and planted nuts decreased from about 3.3 million acres in 1950 to about 2.9 million in 1963. Tonnage of 20 major fruits produced was about 16.4 million in 1950 and 16.6 in 1963. Yet our consumer population grew more than 35 million during that period.

What research do we need to increase demand for fruits? Certainly the development of frozen orange juice has helped to hold a market. Certainly the research here in Washington on control of insects and diseases has been, and is, essential to maintain efficient production of quality fruit.

But can we do better? What basic research is going on with fruits?

Basic research in genetics has made startling advances during the past few years. DNA and RNA have been added to our vocabulary. Mutagens, chemical, physical, and viral have been identified. I was impressed by the brief summary in "1964 Research Progress" by R. A. Nilan that "Recent experiments show clearly that the four factors--oxygen, water content, temperature and radiant energy--are interdependent in governing radiation effects in seeds. The action of each can be analyzed only in terms of the actual conditions of the others." To me this statement truly describes a piece of basic research. It fits my definition. I don't like the vague definition generally used that research is basic when its objective is purely an addition to human knowledge. Isn't that the objective of all research? My definition is: "Basic research consists of the identification and quantification of parameters, both constants and variables, and of their action and interaction throughout their effective range." It won't cover non-parametric research.

Nilan's statement doesn't include all the factors involved in radiation induced mutation. SCIENCE for August 14 contains an article by Osborne and Lunden of the Agricultural Research Laboratory at Oak Ridge, Tennessee, which pretty clearly shows that seed radiosensitivity is a function of nuclear size, too. Why shouldn't basic research in genetics be done with apples? Are our present ones perfect?

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Genetics has become heavily loaded with biochemistry of enzyme systems and productively so. Immunity or compatibility are also burgeoning fields. We've learned by cut and try methods that some rootstocks are compatible with some scions, others not or only incompletely so; why?

The chick embryo is widely used for the propagation of viruses for preparation of vaccines because it develops no immunity to them. A recent report by Melnick, Holm, and Struckmeyer in SCIENCE for August 7 showed that young fertilized strawberry ovules, transplanted into a developing pepper fruit developed mature seed. What is compatibility? What is insect resistance to pesticide chemical? What possibility is there for developing apples that codling moths won't or can't infest?

We have no immediate prospect of doing without pesticide chemicals. We do urgently need to know how they work, how they affect host as well as pest, how they affect nontarget organisms. Dunlap's work here in Washington showing that phenothiazine is a metabolic inhibitor for nematode parasites is a step toward better understanding of other widely used chemicals. So, too, is the Washington research on the phytotoxicity of mercurial fungicides for various bulbs and the studies on strain differences in chickens in mercury retention following dosage with mercury compounds.

We urgently need more research to find methods of pest control which will result in no residues in our food supply. Such research should include patterns of use which will minimize residues; chemicals which will leave no residue of the chemical or its degradation products; research on cultural control methods research on attractants, repellents, baits. We need research on parasites and predators of arthropod pests; research on their viral, mycotic, and bacterial diseases. A word of caution seems necessary with respect to insect diseases; these organisms to be useful must be pathogenic for the arthropod pest. There is no evidence that they may be pathogenic for man and other warm blooded animals. But absence of evidence is not enough. Research must test each one of them for possible pathogenicity for the usual test animals. We must not rest on an assumption of innocuity for man and animals of these organisms which are pathogenic for insects.

We need more research on chemosterilization of insect pests and on radiation sterilization which has been applied successfully in elimination of the screw-worm fly in Southeastern U. S.

We need economic research on the costs and benefits of pesticide use and of various patterns of use. Application on a fixed schedule may be no more effective than application according to need. A fixed schedule application will surely be more likely to result in residues than any lesser number of applications.

On the other hand, the success of the screwworm fly depended on the release of an overwhelming number of sterile males in proportion to the native fertile males. Is it possible to develop a method, chemical or not, to eradicate the codling moth--or the whitefly, carrier of curly top virus? If heavy application of pesticide could eradicate these pests, it would cost less than the perennial application of pesticides; impossible?

Communities and Consumer Research

About 54 million of us live in the country or in towns and villages with fewer than 2500 inhabitants. These people make their living largely from farming, from the assembly, processing, manufacture and distribution of farm and forest products or from supplying the goods and services used in farming and the marketing and use of farm and forest products. Agricultural research is responsible for developing ways to make rural America a better place to live, both for its inhabitants and to attract folks who come there for recreation, and a place to make a better living.

Research needs in this area are emphasized by passage of the Economic Opportunity Act for a disproportionate number of the poor people of the United States as measured by dollar income. More than one million farm families and almost two million rural nonfarm families have an annual income of less than $2,000.

About a year ago, I asked Mary Beth Minden of our CSRS staff and M. E. John, a social scientist at Penn State and a member of the Committee of Scientists Advisory to the Secretary of Agriculture, to assemble a working group of specialists to evaluate research status and needs in the area of community family and consumer research. Miss Minden and John have submitted an excellent draft report which will be released after appropriate review.

Among the conclusions in the report are the following: "Few fields of research are as full of promise as the complex areas of community, family, and consumer studies. Understanding the individual and his family is of prime importance if human well-being is to be advanced. Accelerated social and technological change is forcing us to be more keenly aware of human needs. Today man must be more than a reactor to change, he must be in a position to influence change. Research is an important tool in this effort."

Research concerning the nature and functioning of rural communities is not new, but only recently has much attention been given to the community decision making process and its relationship to realized community improvement. Although interest in community action is now high and some research has been undertaken, greater insight is required before the full impact of a research contribution is realized.

The current program of research in the State Agricultural Experiment Stations includes 541 Federal-grant projects--about 9 percent of the total of such projects. These include projects in health and nutrition; improved family living; improvement of rural living conditions and family and community services; employment opportunities and communication with rural people so that they may understand and apply new technology as it is developed. The Washington study of the human resources of Stevens County is an important contribution.

We need more research in this area. For example, most of our marketing research is designed to help sell farm and forest products. The buyer is of equal importance, essential to each sale. We have too little research in what the buyer wants and needs.

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Research Support

Research costs money; money to pay salaries for highly trained research people and their assistants; money to pay for training and retraining; money to pay for facilities, supplies, and materials; money to pay for publication and dissemination of research results.

In the United States, we are spending more than $700 million a year for agricultural research. About $400 million support research related to conservation of land, water, and air resources and to the production and protection of farm and forest products. This is about one percent of the value of sales of farm and forest products measured at the farm gate or, for forest products, at point of first delivery.

We are spending about $300 million for research related to marketing and utilization of farm and forest products and for other community family and consumer research. The total bill for marketing and processing and distributing farm and forest products and for the goods and services supplied to farmers is over $100 billion. Research expenditure is about 0.3 percent of this amount.

Industry as a whole spends more than 4 percent of value of sales for research. Expenditures for agricultural research are relatively low.

Estimates of costs and benefits of research are themselves currently subject to research in many places. Lowell Rasmussen has shown a sophisticated approach to the problem, an approach that sets a good example. My opinion is that agricultural research is a good investment and we need more of it.

Summary:

Agricultural research past has given us the most abundant, varied and wholesome food supply ever enjoyed by any Nation.

Research for the future must find more effective ways of protecting our soil, our water, our air, and our forests. Research must find ways for our farmers to participate more fully in the benefits resulting from agricultural research, benefits enjoyed by every consumer and every community in the U. S. and in many countries abroad, not only through the resulting availability of food, fiber, and forest products but, too, through the millions of jobs created for the assembly, processing, storage, manufacture, and marketing of these products.

Research of the future must help rural families and make rural communities better places to live as well as to earn a living.

The productive problem-solving research of past and present will continue. In order to be effective it must be buttressed by more basic research. Basic research in biology, chemistry, physics, mathematics, economics, behavior, and a myriad number of other sciences must provide the knowledge and competence to solve problems of agriculture as they arise--or better yet to provide information which may prevent problems.

Research is done by people; competent people trained in science and technology. The association of research and teaching in our land-grant universities and

Research Support

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In the United States, [illegible] About [illegible] million [illegible]

We are spending about [illegible]

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Problems

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agricultural experiment stations produces both research and researchers. It is natural and appropriate that groups of research workers such as these at Prosser will work on problems important in the areas where they are stationed and on basic research necessary to the solution of those problems.

Research of the future will find answers as to why procedures work as well as to demonstrate that they do work. Present concern over the contamination of water and air and soils with the residues of our factories, our homes, our feedlots, our automobiles is acute and growing. We need to know how to control pests without damage to birds and bees.

We must develop plants and animals able to thrive in the presence of pests; we must develop more selective pesticides and use them more selectively. We need new and varied crop plants and animals. Geneticists will find ways of producing them. We need more efficient methods for using water for irrigation.

It is not enough to protect our people, our communities, our resources; research must find ways of improving their productive capacity.

Research costs money; rather say it is a very good investment. Research expenditures for conservation of soil, water, forests, and air and that to improve the efficiency of plant and animal production and to improve and protect plant and animal product quality costs only about one percent of the amount of the sales of such products. Research on processing, marketing, and utilization of these products and research to serve consumers and communities generally costs less than one-half percent of the marketing bill on these products after they leave farm and forest. Federal and State funds pay about half the cost of agricultural research, industry the other half.

No industry other than agriculture obtains as much in research information per dollar spent.

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CHEMURGY IN THE STATE AGRICULTURAL EXPERIMENT STATIONS

President Corey's invitation to speak on "Chemurgy in the State Agricultural Experiment Stations" caused me to ponder before accepting. I am a biologist. Several of my colleagues in the Cooperative State Research Service are professionally competent in the area. But, the invitation stimulated me to closer examination of the status of chemurgic research and of the needs and opportunities for further research. Drs. Garner, Boyd, Rayman, and Joranson of CSRS staff have helped me a great deal in assembling the material. The opinions are my own.

Our categorization of research areas includes a major area which we call utilization research. It includes food and feed chemistry and technology, as well as chemurgy defined as the application of chemistry and related sciences to the finding of new nonfood uses for farm crops, profitable uses for agricultural residues, and the development of new farm crops.

These objectives are intimately entwined and interdependent on research to upgrade products for food and feed use, and with basic research on chemical composition and enzymic processes, including fermentation products. Chemurgy is equally applicable to forest product utilization.

In Table 1, data are summarized for profrssional man-years and dollars derived from Federal funds appropriated under the Hatch Act and under the McIntire-Stennis Act. The forest product research includes research at several State institutions designated as eligible for research support under the latter act which are not State agricultural experiment stations--Syracuse, for example. The segregation into food and feed "chemurgy" on the one hand, and "other" research support is a very rough approximation.

Talk by Dr. T. C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, Washington, D. C., at the annual meeting of the Chemurgic Council, Columbus, Ohio, September 23, 1965.

Table 1. Utilization research in the State agricultural experiment stations supported by Cooperative State Research Service grant and non-Federal funds

Commodity	Food and feed		Other	
	Man-years	1,000 dollars	Man-years	1,000 dollars
Forage	23	600	--	--
Cereals	17	450	20	500
Cotton	--	--	14	375
Wool and mohair	--	--	3	80
Fruits and vegetables	150	4000	4	100
Oilseeds	13	350	7	200
Dairy products	77	2070	10	300
Animal fats and oils	--	--	3	80
Meat and poultry products	87	2350	5	135
Tobacco	--	--	10	250
New crops	4	100	4	100
Sugar crops	5	135	2	50
Pharmacology	11	275	5	150
Forest products	--	--	34	885
Total	387	10,330	121	3,205

About a third of this research is basic chemistry and zymology, essential to the effective utilization of these commodities, whether for food, feed, or other use. Not included is a substantial amount of genetic and agronomic research relevant to development and evaluation of crops and products. I shall discuss specific examples of interdependent research with respect to soybean meal, cottonseed meal, and waste disposal a little later.

In addition to the research summarized in Table 1, the State agricultural experiment stations perform two other very important functions relevant to chemurgy. They, or the universities of which they are a part, serve as contractors for the utilization research divisions of the U. S. Department of Agriculture. They provide principal opportunities for many graduate students to learn to do research in chemurgy through employment to do such research under supervision, the traditional and still current method of research training. About 200 graduate students are employed in chemurgic research--research training in the State agricultural experiment stations and authorized forestry schools.

Contracts for utilization research totalling more than $6 million are current in 33 States. Since most of these contracts cover a 3- to 5-year period, the annual expenditure amounts to about $2 million.

Table 2 shows the distribution of these contracts by commodity and purpose.

Table 2. Utilization contracts at the State agricultural experiment stations

Commodity	Food and feed	Other
	1,000 dollars	1,000 dollars
Forage	397	--
Cereals	440	1,193
Cotton	--	360
Wool and mohair	--	108
Fruits and vegetables	445	--
Oilseeds	405	315
Dairy products	615	60
Animal fats and oils	--	359
Meat and poultry products	805	--
Tobacco	--	572
New crops	--	--
Sugar crops	--	134
Naval stores	--	165
Total	3,107	3,266

I shall discuss food and feed technology only incidentally to chemurgy relevant to other uses and as a part of the discussion of the three selected examples: soybean, cottonseed, and agricultural waste. Chemurgic research for the several commodity groups is organized under several regional and many State research projects.

Cereals.

State stations conduct a continuing program of research on the fundamental chemistry of cereal starches and their utilization. One North Central regional project is directed to modification of starch for industrial uses. Participating States are seeking to determine the fundamental reactions in the nonenzymatic dextrinization of starch; to investigate chemical polymerization of D-glucose derivatives for the production of new types of synthetic polymers; to determine the mode of action of oxidants on starch; to modify the basic structure of the D-glucose units in starch; to discover enzymatic reactions which can modify starch and the effect of structural characteristics of starch on the action of enzymes; and to develop methods by which nitrogen can be chemically attached to starch.

Research is under way on the fundamental structure of complex carbohydrates and the mechanism of their formation and breakdown. Enzyme systems from plants and microorganisms are being examined to determine their effect and role in structural changes, biosynthesis and deposition of starch. Systems of pure carbohydrates capable of attacking the whole spectrum of polysaccharide structure are being sought and their nature, mechanism, and specific actions are being determined.

Production of new types of hydrophilic polymers offers additional research challenges. Introduction of mercapto and amino groups as well as anhydro bridges in place of hydroxyl substituents is leading to additional families of modified polysaccharides. The resulting polymers are being characterized physically and biochemically.

Advances in carbohydrate chemistry continue to yield new and improved synthetic methods for preparing derivatives of both mono- and complex polysaccharides such as sulfated polysaccharides, heterocyclic sulfur sugars, new preparations of gentiobiose, more convenient introduction of isopropylidene groups, and novel syntheses of phosphorylated sugar acids. Studies of the reactivity and microstructure of starch granules illustrate still another facet to the starch utilization program of the stations.

In support of the program designed to develop high-amylose corn for industrial uses, Indiana, Missouri, and Nebraska stations are continuing development of lines high in amylose content. Samples are analyzed, often on an individual plant basis, to determine amylose content. Work is continuing on the development of techniques or processes for separating amylose from other kernel constituents, on studies of enzyme systems, and possible industrial applications.

The Montana station is studying conversion of barley into feed yeast protein. Barley carbohydrates are converted enzymatically into fermentable sugars which, in turn, serve as an energy source for the yeast. Current work involves establishing reliable yield and cost data for analysis of the process. In fermentation studies at other stations, work is directed toward biosynthesis of lysine and of polysaccharides, for example. Still other research involves fundamental studies of the organisms, the fermentative process and methods for separating desired products from fermentation liquors.

The newer types of malting barley are studied to determine adaptability for malting. Basic composition, including enzyme content, is determined and these properties are related to potential for commercial malting.

Cotton.

There are two projects on the influence of mechanical harvesting on fiber quality and moisture content of seed cotton at the time of harvest. The extent of mechanically harvested foreign matter and its composition are of importance for both machine design and gin operation. High-speed motion pictures of harvesting action have served as a research aid in studying spindle action and elimination of foreign matter pickup. It has been demonstrated that moisture vapor transport from trash to very dry field cotton results in a desirable water-tempering effect leading to improved ginning material which retains good staple length and, hence, fibers with better spinning potential. Evaluation of chemical agents as preharvest defoliants, weedicides, cotton preservatives, and for fungicidal-moistening action on harvested spindles continues. In a study directed toward the development of new principles and techniques for ginning cotton, the use of electrostatic fields to remove and recover fly lint from gin exhausts is under investigation.

A program of research to develop improved instruments for measuring fiber characteristics such as length, fineness, maturity, tenacity, elongation, crimp, and compressibility is continuing. It is directed to provide convenient devices of precision for measuring physical properties of small samples.

Three regional studies are directed to determining (1) the mechanism of fabric stress absorption and performance; (2) the relation of fiber properties to end-product performance (cotton sheets); and (3) properties of drapery and upholstery textiles and their importance to consumer satisfaction.

Other workers are conducting similar use tests of cotton garments and evaluating physical and chemical properties of fibers and fabric finishes.

Wool and Mohair.

Work at three western State stations is determining physical and chemical characteristics of grease wool and mohair. These characteristics include combing performance, scouring losses, content of foreign matter, moisture, and wool grease as well as fiber information on variability of fineness, staple length, crimp, strength and elongation.

Additional studies are being pursued on the merits of different types of packaging materials for raw wool and the feasibility of baling graded fleeces. Since wool fabrics, largely used for outer garments, are subjected to weather elements (sun, dust, and rain), a study designed to determine the comparative resistance of outside weathering is evaluating the rate changes in physical and chemical properties of worsted textiles differing in fineness and crimp. An investigation of the role of protein level in sheep nutrition is directed to determining its influence on the fineness, quality, and yield of wool.

Soybeans.

Basic studies seek to characterize the proteins and identify such biologically active components as proteolytic enzymes and their inhibitors. There is other work on identification of the proteins in soybean whey. Peptide structure of the individual purified proteins will be determined.

Other researches involve study of the basic mechanisms of the biosynthesis of proteins.

Station research on food and industrial utilization of soybean oil involves study of the chemical, physical, and nutritional properties of the oil. Investigations are directed to the isolation, fractionation, and chemical identification of the compounds responsible for the reversion flavor of soybean oil. Content of noncarbonyl and carbonyl compounds in stable cottonseed oil is being compared with reverted soybean oil in the search for clues to explain the flavor reversion and to provide practical methods for preventing or retarding its formation.

Oilseed processing conditions and methods of extraction and recovery of oil from oil-bearing seeds are under investigation. Other research involves fundamental studies on the enzymatic formation of fats and oils in plants, antioxidant mode of action, and the isolation of sulfur-containing lipids and glycolipids in plant tissues.

Marginally eligible for consideration in any discussion of chemurgy in the State agricultural experiment stations is the soybean story. Chick Phillips studied its use in hen diets at Purdue in the twenties. Harry Titus, Ned Ellis and I began studies of soybean as a major protein source for breeder hens at Beltsville in 1929. Since that time, soybeans have increased in acreage from about a million acres to about 35 million currently harvested for beans.

Landmarks in making possible efficient feed use of soybean meal include the work of Norris at Cornell and Bethke at Wooster, showing the need for added riboflavin; the work of Phillips at Wisconsin demonstrating the need for heat treatment; the work of Lyons and Insko at Kentucky demonstrating the need for added manganese to prevent perosis in growing chicks.

During the past 50 years, production of soybeans in the United States has increased from about 3 million bushels to more than 700 million bushels. More than 30 million acres of soybeans are ready for harvest, about $2 billion worth of soybeans. Soybeans are a major source of dollar export sales. Smith (1965) estimated recent annual increase in domestic use at 10 million bushels, and exports at 20 million bushels. Projected at this rate, 1975 production and use may exceed a billion bushels.

Soybeans were first grown principally for oil; the meal was a by-product. The use of more and more soybean meal for poultry feed, its principal present use, rests on a series of research discoveries and demonstrations. All are relevant to use of soybean protein in the human diet.

First, soybean meal must be mildly heated in order for its protein to be efficiently used by monogastric animals. This fact was established by Osborne and Mendel (1917) at the Connecticut Agricultural Experiment Station, and confirmed by Welgus et al. (1936), Heyward et al. (1937) for poultry.

Next, Kennard et al. (1922) showed that the calcium and phosphorus content of soybean meal was inadequate for poultry.

In 1936, Norris et al. demonstrated that soybean meal was deficient in riboflavin for breeding hens. The work establishing the role of B_{12} in hatchability and post hatching survival covers a span of about 20 years from work done by Titus-Byerly-Ellis at Beltsville in 1929, augmented by Bird's work at Maryland, and finally concluded by Bird and his colleagues at Beltsville.

While B_{12} was not finally identified until 1948 (cf. Rickes, E. L., N. G. Brink, F. N. Koniuszy, T. R. Wood and K. Folkers, 1948. Science 107: 396), its effects on hatchability and post hatching mortality, and the B_{12} deficiency of soybeans were well known before that (cf. Whitson, D., J. C. Hammond, H. W. Titus and H. B. Bird, 1945. Poultry Science 24: 408).

Nor was B_{12} enough to make soybean meal fully equal in nutritive value to animal protein concentrates. Baldini and Rosenberg (1955) showed that added methionine was needed for corn-soy high energy broiler diets.

Recently and currently, food use of soybeans has become a matter of intense interest. Chemurgy in industrial and public laboratories has isolated food-grade proteins of high nutritional and functional value. Methionine is the first limiting amino acid; theonine the second.

Protein plastics, fibers and glues have been made but are not hopefully competitive with petrochemical products. Meyer (1965) estimated that about 200 thousand tons of our 1963-64 utilization of 10.8 million tons of soybean meal, or about 2 percent, were used for food and industrial purposes. In light of world food shortages, research emphasis should be on the economical production of soy protein food products adequate as a major source of protein in the human diet. Methionine, B_{12}, functional properties, form and flavor, as well as product cost, may be determining factors in the food use of soybean protein. Meyer (1965) noted that preparation of soy protein concentrate yields a product with about two-thirds the weight of the soy flakes used. The remaining third appears as soy whey and soy solubles byproducts.

Cottonseed.

Station research on cottonseed utilization is directed mainly toward increased feed use of the oilseed proteins. Efforts to increase the wholesomeness of cottonseed meal are centered on aspects of the gossypol and cyclopropenoid problems related in part to toxicity and in part to nutritional adequacy. When protein quality is poor, usually the lysine in the protein has combined chemically with sugars, fatty materials, or in the case of cottonseed, with gossypol. Current studies are designed to determine the extent to which lysine, or possibly arginine or glutamine, have reacted. The investigations are aimed to better understand the reactions which interfere with proper utilization.

Experiments designed to elucidate the effects of proteolytic enzyme action on gossypol-protein complexes have revealed purified, stable peptide end products which contain gossypol bound through lysine. Laboratory synthesis of cyclopropenoids and polymerization of sterculic acid have been examined. Methods of destroying the cyclopropene ring are being investigated. Studies on the structure of the cottonseed pigment gossyverdurin are proceeding. Other studies include work on developing suitable methods and techniques for handling chemical residues of harvest aids in cottonseed.

The upgrading of cottonseed meal through chemurgic research has been under way for more than 30 years. Even old-fashioned hydraulic-pressed cottonseed cake is good feed for ruminants when supplemented with an adequate source of vitamin A activity. But for pigs and chickens, cottonseed meal usage has been limited by gossypol toxicity and by yolk discoloration in eggs also due to gossypol and associated pigments.

Apparently Schaible et al. (1934) were first to demonstrate gossypol yolk discoloration. After 30 years of processing and genetic improvement, Heywang et al. (1965) reported some discolored yolks in stored eggs produced by hens fed cottonseed meal containing the merest trace of free gossypol.

Lyman and his associates at Texas Agricultural Experiment Station have done a great deal of effective research to reduce gossypol toxicity and improve lysine availability of cottonseed meal. Progress reports indicate that 100 ppm of iron salts (ferrous sulfate) are highly protective against gossypol toxicity for pigs.

Animal Fats and Oils.

A limited program of work directed to the utilization of fats and oils is in progress at the State stations. More complete knowledge of the molecular structure and composition of the component glycerides is being developed and related to flavor stability. Chemical transformations are under investigation to minimize polymerization and conjugation during isomerization processes leading to industrially modified fats and oils.

Basic studies on minor constituents of animal and vegetable fats such as sulfolipids, phospholipids, and steroids are under way. Applied work to convert low-grade fatty materials into industrially valuable products has led to a potentially commercial method for producing the more stable elaidic acid from oleic acid. Related studies on the transisomerization of ethyl linoleate are being pursued.

Tobacco.

A modest program of research related to the utilization of tobacco is conducted by the stations. A number of studies on tobacco plant metabolism have been related to enzyme reactions and chemical intermediates produced during growth. Progress is being made toward identification of more than 150 compounds contained in the aromatic oil fraction of flue-cured tobacco. Development of analytical methods using gas chromatography and infra-red spectra has contributed to this work. Formation of hydrocarbons in the leaf wax, photosynthetic production of glycolic acid in seedlings, and enzymic degradation of fatty acids during seed germination illustrate the variety of station research approaches to tobacco plant chemistry.

Compounds of great importance to tobacco curing are under investigation both as to source during growth and to fate during post-harvest processing. Plant tissue conversion of amino acids into polyphenols has been demonstrated, and the rule of oxidases to further catalyze the oxidation of polyphenols is continuing to unfold knowledge on the mechanisms of curing and aroma development. Basic engineering data on specific heat transfer characteristics of tobacco leaves have been determined for use in curing studies and have been applied as well to work on plastic mulches for weed control in seed beds.

Fermentation studies on cigar tobacco are under way at Puerto Rico and other stations. Controlled modification of tobacco aroma is being explored via biochemical genetic approaches.

New Crops.

Discovery and preservation of valuable plant germ plasm is a continuing objective of the station program in new crops. Much of the research in this area is being done via four regional projects and in cooperation with regional centers. A large portion of the work is cooperative with USDA. Each year many plant introductions are grown and evaluated. Annual and perennial crops possessing potential for industrial or agricultural use are further evaluated for agronomic and chemical qualities. These include crops for paper pulp, pigments, drugs, tannins, essential oils, insecticides, polysaccharide gums, and oils rich in acids of unusual structure.

Assay of native and introduced tropical plants for products of economic value receives special attention. New varieties of fruits, vegetables, and grasses better resistant to disease and drought are continually sought.

Sugarcane.

Basic and exploratory research is carried out at the Puerto Rico station. Use of ion-exchange procedures for the production of sugars that may be utilized without further purification is under continuing study. Other work in progress involves development of pilot-plant fermentation procedures for fermenting molasses mashes to produce rum; development of distillation procedures for high efficiency rum distillation; search for new strains of yeast for use in fermentation of blackstrap molasses and other materials derived from sugarcane; and determination of factors affecting the sucrose content of cane.

Indiana station research seeks to synthesize analogues of important metabolic sugars wherein hetero atoms such as sulfur, selenium or nitrogen replace the normal oxygen atom. Sugar analogues and their derivatives will be tested for usefulness as medicines or as agricultural chemicals.

The State agricultural experiment stations cooperate with the U. S. Department of Agriculture research agencies and with one another in the propagation and testing of potential new crop plants. There is a regional new plant center in each of the four experiment station regions. A regional coordinator, a USDA employee, is located at each center. In addition, each of the cooperating States is responsible for propagation and testing of designated plant groups climatically suitable for the State.

Table 3. Regional new plant projects

Region	Center	Plant groups	Regional research fund allotment
North Central	Ames, Iowa	Grasses, legumes, maize, fruit, and industrial crops	$104,917
Northeast	Geneva, N. Y.	Grasses, legumes, vegetables, fruits, and ornamentals	67,550
Southern	Experiment, Ga.	Grasses, legumes, vegetables, industrial crops and ornamentals	176,431
Western	Pullman, Wash.	Grasses, legumes, fruits, vegetables, industrial crops and ornamentals	66,825
			$415,723

The safflower variety, Gila, was released by the Arizona Agricultural Experiment Station in 1958. This variety provides resistance to Phytophtera root rot and became the leading variety in the United States, Mexico, and Australia. Dr. DAvid D. Rubis of Arizona, who contributed to the development of this variety, has doscovered two mutants of hull properties--thin hull and striped hull--which greatly influence seed composition. Experimental lines now being tested in Arizona include types containing these mutants which approach Gila for yield, produce seed with 50 percent oil content, and produce meal with 35 percent protein and 18 percent fiber. Delayed anther dehiscence appears to be a pleiotropic effect of the thin hull mutant, and provides a mechanism for use in producing hybrid safflower.

A number of new and improved varieties of industrial crops have been developed cooperatively by the Oklahoma and Texas Agricultural Experiment Stations and the Agricultural Research Service of the U. S. Department of Agriculture. Some of these varieties are: Brooks, a disease-resistant guar which is a source of mannogalactan gum; Oro, a white-seeded and disease-resistant shattering type of sesame; and Hale, a dwarf-internode castor bean that is well suited for mechanical harvesting.

Among the new crops currently undergoing tests for agronomic value are Crambe and Vernonia as oilseed crops, and kenaf and tall sorghums as fiber crops. Reports from Iowa indicate a probable Crambe yield of about 1000 pounds per acre, and for Vernonia perhaps 500 pounds. Oregon irrigated Crambe yields may be about 2,000 pounds per acre. Kenaf and Sorghum almum may yield 2 to 7 tons per acre of dry stalks. (Mitchell, 1965)

Crambe is an excellent source of erucic acid, for which a potentially large market for industrial use seems apparent. John Creech, Head, New Crops

Branch, Crops Research Division, told me that about 1100 acres were grown this year and 5000 acres are expected to be planted in 1966. Yields indicate that more agronomic research may be necessary to make it competitive.

Kenaf and sorghum have interesting potentiality as sources of fiber for paper and bagging. Their ability to compete with wood pulp for paper and imported jute for bagging seems dubious.

Vernonia produces trivermolin, useful in plastic base paints and other surface hardening materials.

Forest Products.

Forest product utilization research at State forestry schools and agricultural experiment stations in 32 states currently totals the equivalent of 34 man-years annually. This represents projects conducted by scientists in State institutions on research in the following groups: (1) structure, physical and chemical properties of wood and bark; (2) manufacture, gluing, design, and uses; (3) preservation, seasoning, finishing; (4) pulp and paper, composite products; and (5) logging engineering, tree, log and lumber grades.

This total effort accounts for 23 Hatch projects funded with $133,308; 34 McIntire-Stennis projects, $52,393; and non-Federal estimated at $701,950.

Limiting Factors.

Chemurgy is severely limited by assembly costs of raw materials. Outlets for wood chemicals and charcoal presently reflect no more than about $3 per cord for wood at the stump. Picker-shellers leave the cobs in the field. Can furfural manufacturers pay enough for them to induce the farmer to bring them in? Flax straw is useful chemurgic material; all straws are. Will chemurgic outlets pay the cost of assembly for the half billion pounds of whey solids which constitute a waste disposal problem? Again cost of assembly is a determining factor.

But what of the opposite? How shall we disperse cannery and other processing wastes and feed-lot and poultry house manures, especially in water shortage areas? Eutrophication of our lakes is a major problem. Incineration, complete, is expensive; incomplete, it adds to our air pollution burden.

State agricultural experiment stations have conducted a good many trials with lagoons. A recent experiment in California used sewage-grown algae in swine, sheep, and steer feeding trials (Hintz et al., 1965). Digestibility of diets containing 10 percent algae substituted for vegetable protein concentrate and control were similar. Cost of harvesting algae may be high, prohibitively so. The algae in this case were Chlorella sp. and Scenedesmus sp.

The question of sanitation in feeding animal wastes is being raised more insistently and the question of chemical residues in such wastes continues to be a matter of concern. While poultry litter has been used in a good many cattle feeding tests, many people are concerned lest Salmonellae and chemical residues in the litter infect the cattle or cause residues in their flesh.

Regional Research.

North Central Regional Project NC-60, "Modification of starches for industrial use," was initiated in 1962. It was organized and is conducted in close cooperation with the Northern Utilization Research and Development Division. Its objectives include:

1. Isolation, purification and determination of mode of action on starch of selected enzymes.

2. Determination of fundamental reactions in nonenzymic dextrinization of starch.

3. Investigation of chemical polymerization of D-glucose derivatives for the production of new types of useful polymers.

4. Determination of the mode of action of oxidants on starch as a basis for production of new products.

Basic research under NC-60 promises to provide much needed information which may lead to increased industrial use of starch. For example, oxidized starches, produced commercially to the extent of about 200 million pounds per year, have many uses, with largest applications as textile, paper, and laundry sizes.

Hypochlorite is the principal industrial oxidant for starch and much work has been done on the action of chlorine, and its aqueous equilibrium components, on starch.

Whistler and coworkers at the Indiana station have investigated the mechanism of hypochlorite attack on starch fractions and have shown that, in alkaline conditions, extensive oxidation occurs at C_2 and C_3 positions of D-glucose units with change of the C_2-C_3 bond.

Opportunities for Chemurgic Research.

Senate Document 34, 88th Congress, first session, "Strengthening Research on Utilization of Agricultural Commodities," recognizes the role of the State agricultural experiment stations, which will continue to cooperate with USDA and industry, as USDA contractors, and as independent centers of research excellence in chemurgy.

Senate Document 34 outlines some of the opportunities for chemurgic research. These are:

Cereal and Forage Crops.

Starch--which makes up 70 percent of cereal grains--can find new outlets in paper, films, fibers, plastics, and coatings. New adhesives resist water and have great holding power.

Cotton and wool.

Chemical modification can improve cotton for hundreds of different uses: comfortable cotton garments that hold their appearance and truly need no ironing; attractive, durable cotton cloth that resists soiling and staining in our homes; strong fabrics that are economical for industrial use. Research can help to reverse the decline in cotton's markets in the face of competition from synthetic fibers.

Wool can meet the challenge of synthetics if its desirable characteristics are improved and new characteristics are imparted through research.

Oilseeds.

With the unique chemical properties that nature has built into vegetable oils, research can help them obtain a significant share of today's growing markets for industrial chemicals. Plastics, elastomers, surface-active agents, and other products are potential outlets.

New and Special Plants.

Tobacco can meet changing domestic requirements and increasing foreign competition, given more scientific knowledge of the composition of tobacco and its smoke.

Research can provide new markets for naval stores by developing industrial chemicals from turpentine and improved paper sizes from pine gum and gum rosin.

Exploration for new crops can have far-reaching results, as we have seen in the case of soybeans. Seeds containing unique oils are of particular interest. This is a vast field--only about 3,500 samples out of the 250,000 known species of plants have so far been analyzed.

Role of the State Stations.

The State agricultural experiment stations most certainly have the capacity for a larger role in chemurgic research. They are the training ground for many of tomorrow's chermurgists. Basic research, such as that organized under NC-60, will be one source of new leads and new ideas, some of which will be exploited in the State agricultural experiment stations.

Our millions of tons of animal wastes, cannery and other food processing and industrial wastes, wood and crop residues provide a challenge to engineering research on materials handling and assembly that will permit their upgrading, their transformation into new and useful products, or at least their partial salvage as a means of reducing our growing problems of air, water, and other environmental pollution.

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U. S. Department of Agriculture
Cooperative State Research Service

THE POTENTIALS OF ELECTROMAGNETIC RADIATION IN AGRICULTURE

Let us harness the sun. There are hungry people in the world; our crop plants use only a little of the sun's energy in photosynthesis. Why not more? Why not? Corn plants from seed planted parallel to the row extend their leaves into interrow spaces, there exposing a greater surface to sunlight. The geometry of crop plantings and plant growth, the movement of air, maintaining CO_2 concentration about the plant, may affect efficiency. The lower leaves of a plant may receive no direct sunlight. Lemon (1963) reported that only 17 percent of net radiation reached the soil in a dense corn crop.

Much of the sunlight energy is used for evapotranspiration from soil and plant. This helps keep the plant cool on hot days? But in the noonday sun many plant stomata close, transpiration is checked. But what of the effect on plant temperature?

In any case, agriculture is a lavish user of water. Water is often scarce during part of the growing season. Optimal use of water for plant growth depends on more effective use of sun's energy. Agricultural engineers are essential members of research teams, whether the research is conducted in growth chambers or in the field. Without their know-how the presumably controlled temperature, light, temperature, humidity and air movement and CO_2 concentration in the growth chamber may become irregular. Adequacy of field observations may not be obtained.

Talk by Administrator T. C. Byerly, Cooperative State Research Service, U. S. Department of Agriculture, given before the Conference on Electromagnetic Radiation in Agriculture, Roanoke, Virginia, October 18, 1965.

Dr. Hesketh (1965) at the University of Arizona has rated plants according to the amounts of CaO_{2A} assimilated under like environmental conditions. Corn, sorghum, tropical grasses generally, and pigweed had the highest rate of photosynthesis, using 50 to 70 mg CO_2 per dm per hour. Sunflower and cotton used 40 to 50 mg in terms of the same leaf surface. Most crop plants used CO_2 at a 20 to 40 mg per hour rate, but some, including tomatoes, soybeans and beans, were in the lower portion of this range. Northern deciduous tree species, citrus, grapes and house plants had a still lower rate of 10 to 20 mg per hour..

Generally, plants with few or no stomata on the upper leaf surface and those of few stomata anywhere showed a low rate of CO_2 use. Shade-grown cotton and sunflower used CO_2 at a lower rate than sun grown.

A common usage of plant geometry in maximum exposure of leaf surface to sunlight is skip-row planting, widely practiced by cotton growers. By planting two rows, then skipping a row, each row is a border row and yield per plant is increased.

Increased grape yields obtained by users of Geneva "double curtain" grape trellis is partly due to better leaf exposure. Alternate plants in the same row are trained on widely separated wires at about 6-foot height on arms from trellis posts (Shaulis, 1965).

Light energy is used in photosynthesis by green plants and some microbes to accomplish the synthesis of living substance from nitrogen, oxygen, carbon, hydrogen, and a few other elements. Research during the past few years has revealed pathways, compounds, processes by which photosynthesis is accomplished. With this and other new knowledge, chemists, physicists and biologists may be able to accomplish analogous synthesis without the use of biological organisms.

Green plants use water as a photoreductant in photosynthesis. Chlorophyll is used to absorb light. Absorbed light energy is transferred to chemical energy, which the plant can use (Whatley and Losada, 1964). Melvin Calvin of the University of California at Berkeley was awarded a Nobel prize for his contribution to knowledge of photosynthetic process.

True Hienton and his coauthors, Wiant and Brown (1958) stated a dictum which I shall state now and will state twice again before I finish. It is:

> "If electrons move, there is an electric current, and consequently an electromagnetic field."

Among the many sophisticated biophysical methods used in the study of photosynthesis is that of electron spin resonance (Zavorsky 1945; Commoner et al, 1954), with its application to plant physiology. The apparatus used is called an electron spin resonance spectrophotometer. According to Blois et al. (1964), it is sensitive enough to detect and give a basis for estimating unpaired electron concentration in living material under nearly normal physiological conditions. Its use has identified two sets of light related signals from chloroplast systems--one when illuminated, and another when light is removed. Blois et al. (loc. cit.) state that "The most significant contribution of this technique has probably been the unequivocal confirmation of Michaelis's prediction that biological oxidations are one electron transfers."

Electron spin resonance is measurable under conditions of paramagnetism, which occurs when an atom or molecule has one or more impaired electrons. There is life, we live, because there are unpaired, excited electrons. Too many of them and what we call excitement would hardly describe the disturbed condition which would result.

While photosynthesis is a major process in utilization and storage of electromagnetic energy from the sun, in general there must be a green plant in which photosynthesis can take place.

The reproductive and growth cycle of green plants is largely light dependent. The influence of day length on time of flowering was established by Garner and Allard about 1920. Flint and McAlister (1935) found that germination of lettuce seed was by red radiation and suppressed by radiation near the red limit of the visible spectrum. Further researches have demonstrated that stem elongation, leaf movement and expansion, seed germination, anthocyanin production, plastid formation and bud dormancy are all light dependent.

Parker et al. (1946) demonstrated that light in the near red (660 mu) and far red (730 mu) is involved. Further researches have established the identity of a blue pigment, phytochrome, which undergoes a reversible photoreaction in response to near and far red light exposure of appropriate time and intensity (Hendricks, 1964). Application of the information on plant photoperiodism is widely used to regulate growth habit and time of flowering by growers of flowers and ornamentals. Geneticists have selectively bred corn and soybeans adapted to the day lengths of various latitudes. Surely agricultural engineers will find wider opportunities for the use of this knowledge. One rapidly growing application is the arrangement for lighting of patio and parlor gardens according to the assortment of ornamentals used. Apparently, blue light may also control some photoperiodic reactions. A preliminary report by Raymond Lukens (1965) of the Connecticut Agricultural Experiment Station indicates that tomato early blight fungus may be prevented from sporulating by interrupting the night with blue light.

Plants may emit light, too. According to Chase (1964), luminescence in green plants was first demonstrated by Strehler and Arnold (1951), who made some beautiful quantitative measurements on the relatively dim light emission of three algae and two higher plants.

Hastings (1964) reported that the action spectrum for phase shift in Gonyaulax has maxima at 475 mu and 650 mu. Light at the red maxima is less effective than at the blue. Action spectrum corresponds roughly to absorption spectrum of chlorophyll c, but a causal relation not established. Hastings found no evidence of a reversal of the red effect (650 mu) by far red light (730 mu), and far red light alone was ineffective in causing a phase shift.

Light traps.

Light traps built to meet the determined responses of pest insects to light of specific wave lengths from U V to infrared seem to me to have a growing place in insect control. Combined with lures and baits containing chemosterilants, their effectiveness may be increased greatly.

Callahan (1965) has developed the hypothesis that corn earworm moths are attracted for mating and perhaps to host plants by high-frequency microwave electromagnetic radiation somewhere in that portion of the spectrum between extremely high-frequency (EHF) and far infrared (FIR), or intermediate infrared (IIR) radiation of 10^5 to 10^7 megacycles. This is an area of the spectrum for which sufficient instrumentation is lacking.

Work in England (Laithwaite, 1960) with the rusty tussock moth (vapourer), Orgyia antiqua, gave indirect evidence that this species is attracted to the opposite sex by high-frequency radiation. Laithwaite believes that the pectinated antennae of the male serve as defraction

grids for reception of (presumed) radiation from the female (wingless) in this species. It seems highly probable that if the moth antennae were to serve as defraction grids, or even tuned dipoles for EHF reception, a prerequisite for microwave electromagnetic transmission and reception would be in-flight stability of the antennal sensory unit. Furthermore, if the sensory pits of the noctuid antennae are to be considered as possible dielectric wave guides or resonators to infrared, the presence of in-flight antennal stability would be a necessity.

Callahan tested antennal in-flight stability by a series of ingenious tests and demonstrated such stability.

Further research was presented by Callahan at a AAAS symposium at Montreal in 1964. He reported that:

1. Newly emerged moths wander randomly at considerable heights.
2. These moths are attracted by IR emission and reflection into host plants.
3. The efficiency of plant or moth attraction is dependent on prevailing weather parameters which affect the IR transmission.
4. Moths near each other, either because a plant or a pocket having optimum thermal patterns attract them, vibrate their wings and send out FIR signals which are identified by the IR eye or certain tuned spines of the antennae of the opposite sex.

Host location and insect communication depend upon the detection of frequencies in the 1 to 18 u spectrum. Frequency transmissions in the 9 u region have been received, amplified, and recorded on an oscilloscope from moths in the families Noctuidae, Sphingidae, and Lasiocampidae. In addition, various species of Noctuidae have been attracted to a black body emitting in the 9 u region in a totally dark room.

The insect ocellus is a cup-shaped eye equipped with a lens and a pigment cup backing the receptors. The ocelli have never been considered as image-forming organs. They do, however, direct important behavior, including (according to Harker, 1950) diurnal activity rhythms and (according to Wellington, 1953) phototaxis.

The demonstration by von Frisch of the significance of polarized light in the behavior of bees was followed by work on other species. Kennedy (1964) stated that Kuwabara and Naka (1959) and Burkhardt and Wendler (1960) independently succeeded in penetrating the retinula cells of dipteran eyes with microelectrodes. Some recorded units showed polarization sensitivity; in the Burkhardt and Wendler experiment, a 90° difference in plane of polarization was equivalent to a 46 percent intensity difference in the case illustrated. Apparently, however, only certain cells show such selective responses.

Among the problems awaiting solution in this area is the fact that those retinula cells of Calliphora which discriminate plane of polarization do so well with blue stimuli, but do so poorly with red stimuli.

Kring (1965) has been investigating the behavior of aphids in flight. When aphids alight, they tend to choose yellow or a mixture of colors containing yellow much more frequently than other colors. A field test showed that fewer aphids in natural flight alighted on plants growing through black or orange plastics than on plants surrounded by base soil. Aluminum was also effective in repelling winged aphids, confirming results reported last year. These findings have obvious practical implication.

Photoperiodic effects, first reported by Rice (1920), important as they are in their influence on age at maturity, seasonal egg production, seasonal breeding patterns in mammals, are only one area of interest in animal photophysiology. The work of Lauber and McGinnis (1965), showing development of buphthalmos (protruding eyes) in chickens exposed to continuous dim light will surely motivate others to further research in this area.

Photosensitization in mammals is incompletely understood. Cancer eye and pink eye in cattle are cases in point. Sunburn in white pigs and burned udders from snowshine in cows are others.

Reflection of light from plants and animals varies widely and may have possibilities for engineering manipulation. The dull greens of sage-brush and of warm weather grasses on the plains may have adaptive value.

Goldblith (1965) believes that both surface and penetrating radiation will find a place as a means of preserving protein foods such as meat, and penetrating radiation will be used for preservation of fish and marine products.

Goldblith estimated cost and throughput of bacon sterilization by a 1 megarad $cobalt_{60}$ source as 1530 pounds per hour at an operating cost of 2.8 cents per pound. The estimated throughput with an insulated core transformer, 3 Mev 3 KW source, was 5216 pounds at an operating cost of 0.4 cents.

Shea (1964) reported that the Food and Drug Administration has approved at least six petitions for radiation preservation of foods or sterilization of packaging materials.

Wheat and products	CO_{60} - 20-50 megarad	28FR9208
Bacon	CO_{60} - 4.5-5.6 megarad	28FR1465
Bacon	5 Mev electron - 4.5-5.6 megarad	28FR9526
Bacon	Ce 137 - 4.5-5.6 megarad	28FR11797
White potatoes	CO_{60} - 5-10 megarad	28FR5588
Package materials	2.2 Mev or less - 1 or less megarad gamma energy	28FR11651

What of radiation induced mutation? It has been redundantly demonstrated that, under appropriate conditions, both ionizing and nonionizing radiation are mutagenic. Frequency of mutation is a function of dosage. But there is indirect evidence, absence of identified mutations in the progeny of irradiated large animals, that causes me to be sceptical of the importance of radiation as a genetic tool for livestock breeders. Even in plants, the array of useful, radiation-induced genes is meager indeed.

Electrophysiology is an old yet ever new field of enormous potential for discovery. Nerve transmission is one portion of it. Vision depends on it as well as on reversible photochemically induced pigment change. Reproductive physiology, mediated by hormones, generally influenced by photoperiodic changes, has an essential nervous component. Humane slaughter has involved research on electric stunning devices on the one hand, and the electrophysiology of apprehension, pain, and fear on the other. Our ignorance in all these areas vastly exceeds our existing knowledge. Speculatively, the identification of control areas in the brain by electric stimulus and by microcoagulation by electrocautery could lead to new patterns of induced behavior, telemetry and remote control.

Environmental control offers many opportunities for participation in exciting research and development for agricultural engineers. Electric heating and cooling of houses and livestock shelters is commonplace, but often expensive. Insulation and underground shelters offer opportunities for lower cost environmental control. Broilers have been reared in West Virginia and Indiana caves by the thousands. There are problems; among them materials handling problems and dust control. Perhaps solar heating and cooling, highly reflective roofs and other structural devices will carry us much farther in economic, effective environmental control and greater use of electromagnetic energy. I have great faith and admiration for the creative, imaginative skill and knowledge of agricultural engineers in this area. I am still amazed at the USDA-California agricultural engineers who measured the cooling effect of dissipation of heat from the body of a cow on the north side of the barn to the sky.

The Hienton, Wiant and Brown dictum I give you again:

"If electrons move, there is an electric current, and consequently an electromagnetic field."

I listened to Robert Oppenheimer at the Smithsonian celebration of the 200th birthday of James Smithson in Washington on September 15. He referred to the many "particles" now commonplace, but to me still a bit confusing. "Particles"(?) by name; energy? Dr. Oppenheimer discussed a great many things; changes. No change is permanent. But perhaps only two things are permanent; energy and change.

"If electrons move, there is an electric current, and consequently an electromagnetic field."

Of time and space and mass and movement; parameters--3 x 10^{10} cm/sec--the speed of light. The particles identified in the bubble chamber last more than 10 to 23 seconds. Agricultural engineers and the agriculturalists of tomorrow must expand their knowledge as well as their vocabulary (Chew, 1965). Leptons, pions, incretions, antiparticles may become part of our common language. What foreseeable uses of the energy named as the more than 100 "particles" of "particle physics" can we foresee?

The breeder reactor is on the horizon. One was dedicated in Idaho Falls on September 13, 1965 (AP). Madell (1965) predicted that during the next 30 years the United States will burn as much fossil fuel as was consumed in all preceding years.

1/20 q (q=quintillion BTU's or 1/2 10^{18} BTU's) consumed in the United States annually. Total reserves of fossil fuel in world, 124 q.

U_{235} (fissionable) in limited supply.

Fertile substances, e.g., U_{238} and thorium 232 constitute 250 times as large a supply as fissionable material. In a breeder reactor, 1 fissile neutron is captured by breeder reactor fuel and produces more. With plutonium as fuel, 2.74 fission neutrons per "fast" neutron are captured. Number must exceed 2 for breeding new fuel.

Harnessing the enormous energies of fusion may eclipse the energies from fission. What is agricultural engineering, anyhow?

I asked Walter Carleton to tell me. He responded by sending me three definitions and a copy of a Presidential address to the American Society of Agricultural Engineers by our friend, Gene McKibben. Walter expressed a preference for the first of the three definitions he provided. I like it, too. It is:

"Agricultural engineering is the science and art of the utilization of materials, energy, and men as applied to the problems of agriculture, the industry it serves."

What are the energy requirements of agriculture? How much of these requirements will be met by electromagnetic energy in the future? We have seen horses and men displaced by energy transmitted by machines very rapidly over the past 40 years without substantial change of net energy input into farming. The horse as a source of energy in farming has almost disappeared in the United States, though in many developing countries horses have increased during this period. Everywhere men have left the land for the cities. In the United States six million people work about eight billion hours on farms. With their machines, McKibben (1959) estimated that they move 250 billion tons of soil each year. They harvest a half billion tons of grain, hay, silage, cotton, and other crops. A like amount of manure and litter has to be moved.

Will electromagnetic energy be used for these Herculean tasks in the future? May we suppose that when breeder reactors become commonplace hydrogen and oxygen will be made at such reactors and distributed as LP gas is now--for use in fuel cells? Use of fuel cells should help reduce the air pollution problem. Will such fuel cells be used with wheeled or crawler tractors like we now use? Just as the first automobiles were engines installed in buggy-like vehicles, even some of them with whipsockets? Or will the engineers use electromagnetic energy in other ways, perhaps setting systems of transmission through the soil itself, restructuring soil aggregates, restoring tilth, increasing permeability--truly a new kind of tillage? Or, perhaps wide use of soil heating cables may permit the continuous biological cycling of crop residues and wastes to return them to soil nutrients and humus?

Large as are the energy requirements I have recited, still larger may be the energy requirements of the future for moving water uphill from enormous reactor desalinization plants at seaside. How much will we pay for energy in the future? How much must we pay for water? At what point may chemistry, using nitrogen from the air, carbon dioxide and minerals, sulfur and phosphorus and other structural essentials make our foods from these basic materials as an alternate to agriculture?

An area of enormous potential for application of electromagnetic energy is the elimination of permafrost in subarctic areas, including our own Alaska. Surely we don't need more cropland now. But I believe we need to know how to make and maintain more of it should need arise. Clearing black surface to absorb sun's energy may be enough to keep permafrost away, but it's mighty slow and expensive to get rid of it this way. How can it be done better, cheaper, quicker?

In conclusion: Opportunities for application of electromagnetic energy are limited by cost, need, and the state of the art. Those who anticipate change are prepared for it, will have opportunities for service, achievement, and reward. The only permanence is change itself, energy.

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STATEMENT OF T. C. BYERLY, ADMINISTRATOR, COOPERATIVE STATE RESEARCH SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE, ON S. 2916 TO PROVIDE FOR A WEATHER MODIFICATION PROGRAM TO BE CARRIED OUT BY THE SECRETARY OF COMMERCE, BEFORE THE COMMITTEE ON COMMERCE, UNITED STATES SENATE, ON MARCH 7, 1966.

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I appreciate the opportunity to appear before this Committee to present the views and some of the activities of the Department of Agriculture concerning weather modification and control.

Weather modification is of major importance to agriculture and forestry. The production of food and fiber, the protection of crops and forests, the full utilization of agricultural and forest resources, and the well-being of rural communities are all strongly influenced by weather and climate. Any program which may result in modification of weather and climate and in turn may influence agricultural and forestry activities is of interest and concern to the Department of Agriculture.

The Department endorses the development of research programs which will advance scientific knowledge and the technology for weather and climate modification. We believe, however, that the basic objectives and purposes of S. 2916 can be obtained under existing authorities and within the framework of recent recommendations by the Interdepartmental Committee for Atmospheric Science and of existing and developing plans within the Executive Branch. We plan to continue to strengthen our mission oriented research in this field, which includes the following:

1. Modification of lightning storms to reduce the occurrence and severity of lightning-caused forest fires.

2. Modification of hail storms to reduce damage to crops and other agricultural and forestry resources.

3. Energy-exchange processes in the earth-air interface and the modification of these processes by the management of vegetative cover on agricultural and forest lands.

4. Biological responses to weather modification with particular emphasis on ecological monitoring and computer simulation studies to predict effects on complex ecological communities of plants and animals found in forests and on other agricultural lands.

The need for continuation and expansion of such mission oriented research is emphasized by the recent reports of both the National Science Foundation Special Commission on Weather Modification and the National Academy of Sciences Panel on Weather and Climate Modification.

In the performance of such research the Department has a long history of cooperation with the Weather Bureau of the Department of Commerce and, more recently, the Environmental Sciences Service Administration of the Department of Commerce. We also cooperate closely with the National Science Foundation. The program of the National Science Foundation is of direct benefit to the weather modification research being done by the Department of Agriculture. We cooperate, too, with the Bureau of Reclamation in the Department of the Interior in its research program for increasing precipitation. These very beneficial cooperative relationships should continue and be strengthened.

The Department of Agriculture is making significant progress in weather modification research. The major research activity has been in the modification of lightning storms to reduce the occurrence and severity of lightning-caused forest fires. This research, known as Project Skyfire, is being performed by the Northern Forest Fire Laboratory of the Forest Service at Missoula, Montana. The research is focused on the severe lightning fire problem in western forests. Some 10,000 lightning-caused forest fires occur annually in the United States. These fires cause millions of dollars in forest resource damages and fire control costs. Project Skyfire is determining whether special weather modification techniques can reduce these great losses and costs.

Although Project Skyfire is a program of very modest size, it may be one of the most definitive research activities in weather modification. This research is doing the following:

1. Developing physical models of mountain thunderstorms.
2. Identifying and measuring the special characteristics of fire igniting lightning strikes.
3. Developing working hypotheses for the modification of lightning discharges through the introduction of seeding agents in cloud systems.
4. Testing working hypotheses and basic theories of lightning using both laboratory and field experimental methods.
5. Developing special instrumentation and equipment for the measurement of lightning discharges and the generation of silver iodide nuclei.

6. Developing special mathematical, statistical, and physical evaluation methods for the analyses of lightning modification through cloud seeding.
7. Performing field experiments in the modification of lightning discharges from thunderstorms over mountainous forest areas.

While much of this work is of a pioneering nature involving heretofore unexplored fields of research, the progress is encouraging. New knowledge has been gained of the basic mechanisms of fire igniting lightning strokes and of the action of ice forming nuclei on cloud electrification processes. High output, ram-jet type silver iodide smoke generators have been developed for use on aircraft and at ground stations. New technology has been developed for delivering large quantities of silver iodide nuclei to thunderstorm cloud systems and for measuring and evaluating the results. Data from three years of cloud seeding experiments in a specially instrumented test area show more than 30 percent reduction in cloud-to-ground lightning from treated storms.

This research is providing the essential foundation for a strengthened research effort and for the planning of larger scale experiments in lightning modification.

The second weather modification research area of major interest to the Department of Agriculture is hail suppression. In 1963, farmers in the United States purchased more than $2.8 billion of protection against hail. In 1962, farmers collected $81 million on their hail insurance. In the Plains and Mountain States, hail is an important adverse factor in the production of grain and forage crops. Production and quality of fruit and vegetable crops in many regions of the United States are influenced by hail. Entire crops can be wiped out by severe hail storms.

The results already achieved by Project Skyfire in lightning modification provide some of the background for projected Department of Agriculture research in hail suppression. Hail is often an element in lightning storms and some of the technology for modifying either phenomenon may involve similar approaches. Project Skyfire scientists have found that there is a relationship between hail occurrence and frequency of lightning discharges, the flash rate, and storm duration. More than twice as much lightning has been recorded during storms with hail than those without hail. Storms that produced the largest hailstones also produced the most lightning. The Skyfire results suggest that if cloud seeding reduces the size and amount of hail, it may also reduce the amount of lightning produced by the storm.

For these and other reasons, the research in modification of lightning and suppression of hail has common interests. The weather modification technology for either element may call for so-called "overseeding." Very high concentrations of seeding agents appear to be required. The concentration of silver iodide nuclei effective at -15° C. being introduced by Skyfire seeding technology into small cumulus clouds is about 3×10^4 per liter and in a typical thunderstorm about 5×10^3 per liter. These concentrations are greater than those believed needed to date in typical precipitation increase seeding activities.

As summarized in the report of the NAS-NRC Panel on Weather and Climate Modification, "overseeding" is one of the possible approaches to hail suppression. The Department of Agriculture expects to enlarge upon its already developed technology for "overseeding" in developing experimental approaches for reduction of hail damage. With very limited exceptions, the results of hail suppression research in the United States and in several other countries have not been conclusive. Well designed and carefully controlled hail modification experiments are needed. The Department hopes that such experiments may be performed at an early date in the Plains States or in other major agricultural areas where hail is an important factor.

Fundamental to progress in hail suppression research is better knowledge of the hail storm itself. As in the case of lightning modification activities, there is a need for both basic and applied research in the hail storm problem. The Department believes that the performance of its mission in this area of weather modification requires strong efforts in both types of research. Also, as in the case of lightning research, we expect to work closely with the National Science Foundation in the overall aspects of this research program. The assistance of the Weather Bureau and the Environmental Sciences Service Administration of the Department of Commerce will be needed in the weather forecasting and some applied research aspects of the problem.

A third area of mission oriented weather and climate modification research of particular concern to the Department of Agriculture is investigation of the energy-exchange processes in the earth-air interface. Management systems on agricultural and forest lands may have profound influences on weather and climate. For example, the arrangement and character of agricultural crops and forest stands can influence the convective activity which is part of cloud growth processes. Also, the vegetation itself makes an input of moisture back to the atmosphere.

At the earth-air interface, a complex set of interactions occur which affect both vegetation and the atmosphere. Here is where solar energy is incorporated into plant materials and thus enters the food chain. Agricultural research is aimed at obtaining the most efficient energy exchange through modifications of various elements of the environment in this zone. Changes in albedo, surface roughness, the geometry of field crops and forest stands, moisture relations, and other factors have a significant effect upon the production of food, fiber, and water. Studies under way include such things as wind movement, air turbulence, and energy budget as related to evapotranspiration, snow accumulation and melt, and photosynthesis.

The biological consequences of weather modification are of great concern to the Department. The best available information in the field of plant and animal ecology indicates that any significant large-scale modification of weather would be likely to result in extinction of some natural plant and animal communities and to increase weed species and insect and disease pests. The Department has a particularly strong background of competency and experience in the scientific disciplines that should be brought to bear in determining the biological effects of weather modification. A strengthened research program in this regard should be undertaken concomitant with the research directed at learning how to modify weather and climate. This is particularly urgent to avoid unforeseen, deleterious, and irreversible effects upon plant and animal communities.

Because of the apparent imminence of increasing success in weather modification, it is imperative that a major program of research be directed at the biological consequences of such activities. Research should include a well-conceived program of computer simulation studies. This would allow the maximum use of ecological information now available from different environments to develop functional relationships between soils, plants, animals, site, and weather. It would probably provide the most rapid way to obtain a first approximation of weather modification effects. At the same time, a well-financed, sustained program of studies of natural plant and animal populations, communities, and ecosystems as related to changes in the environment should be launched.

Thank you, Mr. Chairman; I will be glad to answer any questions.

U. S. Department of Agriculture
Cooperative State Research Service

THE RELATION OF ANIMAL AGRICULTURE TO WORLD FOOD SHORTAGES

Many other pencil-pushing scientists have concluded that the world's hungry people must be increasingly vegetarian, consumers of synthetic foods, or continue to go hungry. Generally, but by no means, universally, people like meat, milk, and eggs and eat them in such amounts as they are able to afford. It is quite possible that future generations may be persuaded to prefer synthetic paps with exotic, synthetic flavors, promoted for convenience and with promises of their efficacy in prolonging youth and beauty.

It is an obvious fact that young people of today are taller than people of my generation. The Food and Nutrition Board's "Recommended Dietary Allowances", in the 1953 revision, reduced the weight of the standard man from 70 to 65 kg. and of the woman from 56 to 55 kg. In the next, 1958, edition the standard man had grown 5 cm. taller and returned to 70 kg. weight, and the standard woman was 6 cm. taller and her weight was rounded to 58 kg. During the period from 1925-1950 we increased our daily per capita consumption of animal protein from less than 55 gms. to about 65 gms.

Slide 1 shows these changes in animal protein consumption in the United States. It is also Figure 1 in:

Byerly, T. C.

1966. the role of livestock in food production.

Jour. An. Sci. 25: pp. 552-566.

Talk by Administrator T. C. Byerly, Cooperative State Research Service, U. S. Department of Agriculture, given at the Annual Meeting of the Agricultural Research Institute, National Academy of Sciences, Washington, D. C., October 10, 1966.

In noting the coincidence between increase in height and increase in animal protein intake, I have implied a causal relationship. Such a relationship is reasonable but unproven. Vitamins, control of childhood disease, and causes unknown may be responsible. Also implied is that tallness is desired and desirable. This, too, is an unproven value judgment. To paraphrase President Lincoln, most human legs are long enough to reach the ground.

My purpose in this initial colloquy is to provide background for my own declaration, for which I claim no originality nor any official sanction. It is: animal products provide protein of good quality in preferred form accompanied by some other dietary essentials, especially cobalamine, not provided from usual vegetable food sources in unfermented condition. There is no known food essential in animal products which cannot now be provided from vegetable sources or by synthesis.

The role of livestock in world food production, therefore, and in my opinion, rests on the following determinants:

1. Inertial forces which include food habits, feed resources, and existing livestock populations and their nature and nurture.
2. The deliberate choices and actions of peoples constrained by technology present and potential resulting from research, experience, and discovery.

3. Competition and complementations among man, livestock species, and non-livestock species in utilization of food and feed supplies.

4. Economic and logistic factors determining food and feed distribution.

Man uses directly the food and fiber products of about 3 billion acres of land. He shares these products, directly or indirectly, with domestic livestock, birds, rodents, pets, bacteria, fungi, and insects. In addition to a share of the products of these crop acres, domestic livestock shares the products of more than 5 billion acres of uncultivated land. In the United States, livestock production constitutes the principal beneficial use of more than half our land area, more than a billion acres.

Since man is omnivorous, he competes with all other animals and to a varying extent chooses his portion of the available food supply. Man likes meat and, within the broad limits of appetite, he will pay more to get what meat he wants than for plant food products.

In the United States, in terms of corn equivalent feed units, we use about 360 million tons of feed annually. This represents about 600 million tons of dry matter consumed by livestock each year from pasture and range, from hay and other harvested forage, and from grain and other feed concentrates. The feeding of grain and other concentrates has increased rapidly during the past few years.

Roughage consumption averaged about 180 million tons of corn equivalent feed units in the 1915-19 period, dropped as low as 142 million in the 1930-34 period, and has exceeded the 1915-19 level only during the very recent period when it reached about 190 million tons per year. Concentrates used equaled about 104 million tons during 1915-19, 96 million during the 1930-34 period, and recently about 165 million tons or about 60 percent more than 1915-19 compared to 5 percent for roughage. Feed grains have been in abundant supply. Large quantities have been exported to Japan and to Europe where they have supported sharp increases in meat production in those countries. This trend has been coincident in the United States with the increase in volume and proportion of our beef produced in large commercial feedlots. Research has demonstrated that forage *per se* is not essential for ruminants. Transportation, assembly, harvesting, and other materials handling costs increasingly limit the use of forage in such feedlots and in large dairies.

The livestock inventory of the world consists of about a billion cattle, a billion sheep, three hundred fifty million goats, a hundred million buffaloes, eleven million camels, 550 million pigs, 64 million horses, 15 million mules, and more than 40 million asses.

Horse numbers reached a peak of 26 million in 1920 in the United States. From then on, we substituted a cow for a horse rather steadily until farm horses reached an insignificant level as a source of farm power. Horse numbers have declined in Europe since the war and cattle have increased.

In the underdeveloped countries, horse numbers have been maintained. The number of asses has increased. In many countries horse meat is acceptable, though I know of none in which they are produced primarily for meat.

During the past 15 years, world cattle numbers have increased rapidly. Increases have occurred in Europe, in the United States, Australia, and Brazil, but not in the Argentine. Pig numbers have increased sharply in Europe but not in the United States. Poultry production has increased rapidly in many countries, including the United States. Sheep production in the world has increased sharply but not in the United States.

Systems of production, as well as use of feed grain from the United States, are factors in change. Let's look at systems.

Europe produces beef and veal as an adjunct of milk production. For Europe as a whole, production of carcass meat per inventory head increased from about 90 lbs. in the 1950 period to about 140 lbs. in 1963. The United States increased from about 130 lbs. to about 165 lbs. during the same period. We've shifted proportions of beef and dairy cows pretty sharply during this period. We had about 41 million head of cows and heifers 2 yrs. old and over in 1950. Almost 60 percent of them were milk cows. In 1965, we started the year with about 50 million cows and heifers 2 yrs. and over. Almost 65 percent were beef cows.

In the United Kingdom and in Ireland, there has been and is a rapid shift to big Holsteins. In France, heavy calves are traditional.

France and the United Kingdom both appear to turn out more carcass meats per inventory head of cattle than we do, more than 180 lbs. compared to our 165 lbs. France has increased beef and veal production relatively more than we have during these past 15 years, has maintained an export gram positive, and a small surplus of meat production.

Production of milk per cow in France lags behind our own, about 5,700 lbs. in 1963 compared to our 7,500 lbs. United Kingdom production was then about 8,000 lbs. per cow.

I have labored beef and veal production in the United Kingdom, France, and United States because each has improved production efficiency under its own system.

Despite the fact that the world's swine herd consists of only half the number of the cattle herd, pork production almost equals that of beef and veal--about 30 million metric tons in 1963 compared to 32 million of beef and veal. North and South America, Europe, and some Asian countries have large and growing swine herds. The Near East, Africa, and Oceania have relatively few.

Sheep and goats tend to be most numerous in the areas where pigs are few, except for Latin American where all three species are numerous.

Poultry species have increased very rapidly in many countries during the past 15 years. American feed, breeding stock, and technology have been transplanted with many examples of massive increase of commercial production of poultry meat and eggs. The number of chickens in Japan, for example, has increased from about 20 million in 1950 to about 100 million currently.

Table 1 shows very large apparent differences in the efficiency of cattle and hogs in the production of food protein in various regions of the world. It is obvious that very large increases in animal protein production should be possible in the developing countries of the world without increase in herd numbers. How? At what cost?

TABLE 1. Apparent efficiency of edible protein production by cattle and hogs in various regions of the world. 1/

Region	Cattle Including Buffaloes	Hogs	Estimated protein Content of Beef, Veal, and Milk		Estimated Protein Content of Pork	
	Millions	Millions	Thousands of Metric Tons	Pounds Per Head	Thousands of Metric Tons	Pounds Per Head
Europe	118	109	5,870	50	1,400	29
North America	115	64	3,870	35	900	31
Latin America	212	84	1,930	9	200	5
Near East	37	0.1	450	12	---	--
Far East	309	39	1,700	6	200	11
Africa	112	5.3	680	6	30	12
Oceania	26	2.1	690	25	30	30

1/ Data from FAO Production Yearbook. Vol. 18. 1964.

Efficiency of livestock production in tropical countries is often low. Brazil, for example, apparently has increased its national cattle herd from about 50 million head to almost 80 million during the past 15 years. Yield per inventory head has apparently decreased. It was only about 45 lbs. in 1950 compared to about 90 lbs. in neighboring Argentine. The recent reported rate is only about 35 lbs.

The seeming great wealth of livestock in numbers in the less developed countries turns out to be a great poverty. In fact, the paradox is that not only would a much smaller number of well-kept animals produce more meat and milk but they would need less land for pasturage and forage crops, thus releasing land for growing food for ever-increasing numbers of humans.

A major factor limiting efficiency of cattle in tropical countries is low net reproductive rate, a puzzling contrast with the high net human population increase rate in many of these countries. There are almost as many cattle in the United States as there are in the vast African continent. Europe has a few more. It is not land that is limiting beef production. Europe, not including U.S.S.R., contains about 1.1 billion acres; the United States has about twice that; Africa, 5.5 billion.

The old argument as to which livestock species is the more efficient producer of human food will never die. Let's consider the advantages and disadvantages of each, in theory and practice. First -- range livestock, cattle, sheep, and goats -- Whether you like them or not. Perhaps we should add bison, jack rabbits, deer, caribou, antelopes, and horses too for good measure. All these creatures manage to survive on natural vegetation. Man may, if he chooses, substitute himself for these natural predators and judiciously harvest a variable meat supply, weather and disease dependent. No range scientist, to my knowledge, has found a way to avoid overgrazing during periods of prolonged drought save by herd reduction and use of harvested feed. But surely, range and herd management and research on which it is based can increase the sustained yield of meat from range and browse.

But these same species may be used in a managed pasture system. New Zealand and several European countries obtain very high nutrient yields from grass. Sure, they do have the troublesome task of harvesting, storing, and feeding some grass silage or hay. Energy required for roughage handling is a sharp constraint. Without harvest and storage much of the nutrient value of roughages is wasted. And just because grass is green doesn't make it of high feeding value. In our Gulf Coast area, perennial grass may provide 300 days' grazing. But only during about 100 days is the grass produced either grazed, used for soilage or silage or hay of sufficiently high nutritive value to be worth feeding to a cow yielding 50 lbs. or more of milk a day. So alright! Who wants to milk cows? Let's raise beef. Then consider the economics of beef production from grass on arable land priced on the bases of its cash crop productivity.

One hundred pounds live weight of animal marketed for slaughter from our cattle herd costs us about 1,000 pounds of corn equivalent feed units. That means at least 2,000 pounds of pretty good hay or its pasture equivalent.

In the present state of our technological knowledge, beef could be produced for about 7 pounds of corn equivalent feed units per pound live weight, that includes cow feed, calf feed, all feed. Sheep and goats could, but do not, do as well. Certainly, grass and browse will continue to afford the world some meat.

If we want beef and lamb enough to pay the feed handling charges, we can produce a lot of it on straw, stover, and other crop residues with a little urea or other nonprotein urea. How far we can substitute nonprotein urea for protein in ruminant feeding remains for further research to determine. As a feed additive, we may be able to recover a third of the nitrogen fed in meat or milk.

Application of urea as fertilizer doesn't do much better than that -- but remember, livestock isn't doing even that well now.

An acre of cereal grain may produce 500-600 lbs. of protein. Cereals are indeed, the principal source of food celones in the world. Perhaps genes such as the opaque 2 gene, discovered and developed by Mertz and Nelson and their colleagues at Purdue, in Maize may be discovered in cereals generally and make them lysine sufficient, er perhaps they will be supplemented with synthetic amino acids. Cereals respond to added urea with increased yield under appropriate agronomic practices. The efficiency with which they use it follows the law of diminishing returns. An average of 21 year-location tests in the Southeast yielded an increase of 1 bushel of corn for each 1.7 lbs. of nitrogen applied at the 50 lbs./acre rate in the spring. These data indicate a recovery in the grain of about half the nitrogen applied.

Pearson, R. W., H. V. Jordan, P. L. Bennett,
C. E. Scarsbrook, W. E. Adams and A. W. White
1961. residual effects of fall and spring-applied
nitrogen fertilizers on crop yields in the
southeastern united states.
USDA Tech. Bul. 1254.

Similar efficiencies have been reported with high-yielding irrigated Gaines wheat in the Columbia Basin in Washington. Application of 80 lbs. urea per acre increased yield about 22 bushels per acre over a 40 lbs. urea application rate. The grain thus retained about half the added urea applied.

Nelson, C. E.
1964. a management experiment with gaines wheat
under irrigation.
Washington Sta. Circ. 435.

Most wheat and maize used for human food is milled. The urea finally consumed by man would probably not exceed 35% of that applied as fertilizer even at moderate rates of application and much less at high rates.

So -- we'll produce beef conveniently with feed concentrates as long as the price is right and the supply available. At no less than 7 lbs.

corn equivalent feed units to one pound live weight; at no better than 10:1 carcass weight.

Milk, eggs, broilers, turkeys, and pork can all be produced at about half the cost of beef and lamb in terms of corn equivalent feed units conversion to protein equivalent foods. Commercial producers do produce millions of broilers on less than 3 lbs. corn equivalent feed units per pound live weight, our milk costs about 1 lb. corn equivalent feed units per lb. 4% milk. It takes about 3 lbs. milk to equal one of broiler on a protein equivalent basis, so this is about the same as the broiler. Many commercial egg producers produce them at 4.5 lbs. per dozen or 3 lbs. per lb. of eggs. Many performance-test pigs produce a lb. of live weight on 3 lbs. of feed from weaning to 220 lbs. live weight. Sow feed would bring net cost up to about 3.5 to 1 lb. live weight. Feed disappearance data indicate 5.5 in practice.

Livestock competes with man for food in two ways:

1. For use of arable land.
2. For use of nutrients in harvested crops.

Livestock also competes implicitly with food crops for the manurial and soil-conditioning values of crop residues. In many areas of Asia, competition is also present among feed, manurial, fuel, and industrial use of such residues.

The critical question is: Can developing countries increase their production of livestock food products for their own consumption concurrently with needed increases of subsistence food crops?

I believe that they can. In order to do so, research competence must be developed and used in underdeveloped countries. Technological information available or to be developed in the United States and in other more developed nations can and should be used as a basis for the problem solving research and application of resulting technology which, in my opinion must be done in the less developed countries by their own people, in their own institutions with such help as we and others can provide.

There is a very substantial and significant program of research, extension, and program action relevant to the production and protection of livestock and livestock products in the United States and in the more developed countries of the world. Even in the United States with about 2,000 scientists engaged in highly productive research in the laboratories of the U. S. Department of Agriculture and of the State agricultural experiment stations and at least an equal number in industrial laboratories, private nonprofit research institutions and in universities, there is general agreement that additional research is needed. Among the areas needing added emphasis are:

1. Animal health
2. Physiology of reproduction

3. Metabolism
4. Marketing especially transportation, market structure, and standards of product quality
5. Food protection
6. Environmental physiology
7. Production systems, including costs and benefits of scale, integration, and mechanization

National, private, and international programs in the developing countries are small in proportion to the tasks to be accomplished.

Genetic improvement, both from the standpoint of international trade in breeding stock and research use of germ plasm, is constrained by the necessity for restricting the movement of live animals and semen from countries where rinderpest, foot and mouth, African-swine fever, and other highly infectious diseases exist into countries, such as the United States which are free of them. Research has produced and regulatory agencies are now applying procedures which permit limited movement of bovine semen under prescribed conditions and under adequate and prescribed surveillance.

Since these diseases have been eradicated from or prevented entry into the United States, it seems feasible as well as desirable to eradicate them from the world. Heroic measures were used with apparent success to suppress an outbreak of African-swine fever in Spain a couple of years ago. Kesteven has reported that rinderpest seems to be yielding to vigorous programs in Ethiopia, Afghanistan, Cambodia, and Thailand.

Kesteven,[1] Director, Animal Production and Health Division, FAO, recently estimated that there are only 2,000 veterinarians in the whole continent of Africa, 1,500 of them stationed in the United Arab Republic and the Union of South Africa. Thus there are only about 500 in the remainder of Africa, which number may be compared with the more than 20,000 in the United States. Kesteven and many others have emphasized the presence in Africa of about 4 million square miles of potentially productive agricultural land in which the tsetse fly presently prevents the development of an efficient livestock industry.

It was my good fortune to participate for 20 years in the research that established soybean meal as the principal protein concentrate for poultry. The contributions made by research workers in the State agricultural experiment stations, in the U. S. Department of Agriculture, and the application of research findings by industry in the United States laid the boundary on which soybeans have increased 25 fold in 30 years.

Our free enterprise system can repeat, in some measure is repeating, the soybean example in helping the world increase the supply of animal products it wants. With present technology, the development of poultry and other commercial livestock enterprises in developing countries assisted by United States feed exports may be replaced by new technology based on use of much more limited supplies of current feed concentrates supplemented by feeds derived directly or indirectly from farm forest or other wastes. Research can and will develop the information on which such a changed feed technology can be based. Only industry can put it to work -- and make it pay -- for all of us.

1/Kesteven, K. V. L.
1961. the world is short of meat and milk.
Atlantis Monthly Magazine: pp. 31-38. Published Zwingliplatz 3, Zurich.

The United States produces about two thirds of the world's supply of soybeans and perhaps ninety percent of the world's experts. Among vegetable proteins, soy protein is pretty good. We use about 10 million tons of soybean cake and meal a year for livestock feeding -- more than four million tons of protein. We use about 3 million tons of meat, fish, and milk solids for animal feeding. These products contain at least 1.5 million tons of good protein -- good from the nutrient standpoint.

These soy and animal proteins now used for animal feed if prepared, distributed, and used for human food, would satisfy more than half the estimated existing food protein deficit in these countries. While these are many reasons why it is unlikely that these products will be quickly shifted from feed to food, it is surely desirable that research emphasis and appropriate program emphases should be given to their food use and to the development of and evaluation of alternate nitrogen sources for livestock.

The estimated consumption of animal protein stated in Table 1 of "The World Food Budget" indicate a world overage of about 20 gms. per capita per day which may be compared to the United States average of about 65 gms. per capita per day. Pehaps 5 gms. of the world consumption is from fish and other nonlivestock sources.

The "World Food Budget" estimates

Andersen, W.

1964. the world food budget, 1970

U.S.D.A., For. Agr. Econ. Rept. 19.

"The World Food Budget" projects a small increase in world per capita consumption of animal protein in 1970 as compared to 1960. "The World Food Budget" states (p.23) "There is no simple unit for measuring the nutritional quality of the diet. However, protein content, particularly the animal protein content, is a widely accepted indicator of nutritional quality,----a minimum allowant of 60 grams of protein per day--of which 10 grams should be animal protein." According to this standard, the food deficit countries of the world lacked the equivalent of 7.4 million metric tons of nonfat dry milk or 3.4 million metric tons of fish protein concentrate equivalent and could anticipate only slightly better animal protein supplies in 1970.

I wish here only to remind you that almost everybody has food preferences. Preference for a rare steak or prime rib cut over hamburger reflects more status difference than nutritive value. Most of us don't eat horse meat though I guess we'd choose it over crow. Most of us reject blood and guts. Why?

It is technologically feasible to accelerate the use of meat substitutes; to make them nutritionally fully equivalent to the animal products for which they are substituted.

I also believe that we can through research and application of the resultant technology maintain our own supply of animal products and help the developing countries increase theirs if we and they choose to do so and they will help themselves. Their restriction of their human conception rate would simplify the problem.

We might express the hope, in closing, for a parallel between the era of Mr. Lincoln a century ago and today's time of stress. The Department of Agriculture, the land-grant colleges and the State agricultural experiment station system emerged from that period of civil strife and reconstruction. The establishment of these institutions and the fruits thereof have been highly significant in our American agricultural revolution. Perhaps the present era will prove as fruitful to mankind universally by the emergence of similar institutions and discoveries necessary to alleviate the malnutrition and cultural deprivation still prevalent in many nations.

"If there is a history of this time, the era will be noted," as Toynbee has said, "not for its horrifying crimes or its astonishing inventions, but because it is the first generation since the dawn of history in which mankind dared to believe it is practical to make the benefits of civilization available to the whole human race."

BENEFITS AND USEFULNESS OF FOOD CHEMICALS: IN FOOD PRODUCTION IN RELATION TO WORLD POPULATION

Food production has become dependent on research-developed factory-made chemicals. The use of chemical fertilizers, chemical nutrients for livestock, pesticides of many sorts, and a welter of chemicals which do not fit neatly into these three major categories have become an essential component of food production. In my opinion they will continue to be.

I shall address myself rather narrowly to the benefits of chemical use. Costs, in terms of money, in terms of hazards, in terms of effects on non-target organisms and on the ecosystem are numerous and important. Efficacy for intended use should be safeguarded by conditions of use which impose minimal, known, and reversible changes in the environment.

Food production whether through agriculture, fisheries, food-gathering, chemurgy, consists of the natural or managed recombinature of chemicals. These chemicals may be elemental in origin as in the fixation of atmospheric N or the recombination of simple molecules as in photosynthesis and in assimilation of mineral nutrients by plants and animals. Or the chemicals may be complex molecules of living or dead organisms recombined to form new products such as milk, eggs or flesh or, through decomposition and recombination energy, metabolites and microbial substance as in fermentation processes in the production of alcohol or in the rumen.

In addition to these basic biochemical processes, organic chemical processes for factory food production from elemental materials and fossil fuels are increasing.

Comments of Dr. Theodore C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, presented during the conference on Use of Human Subjects in Evaluating the Safety of Food Chemicals held at the National Academy of Sciences, November 29-30, 1966.

Finally, myriad chemicals are used in increasing amounts to accelerate, to inhibit or to modify biological processes. In this category fall all of the many chemicals used in the production of food which are not incorporated as food components though they may and sometimes do accumulate in food products as residues or metabolites.

This great and varied group of pesticides, growth promotants, hormones, attractants, chemosterilants, defoliants, desiccants, disinfectants, sanitizers, drugs, adjuvants, synergists, emulsifiers, and carriers are of particular concern in our present discussion.

Everyone of them is limited to uses for which efficacy for the intended purpose and innocuity for the food-producing organism have been established. For all of them, acute and chronic toxicity information must be adequate.

What good do they do? Can we do without them? These questions can be answered only in terms of their contribution to the efficiency of food production and the quality of products. My discussion rests on the assumption that permitted use is and will be limited to conditions under which applicators are adequately protected, application is limited to intended target areas, residues are within established safe tolerances and damage to non-target organisms is appropriately limited. These assumptions, in my opinion, can be met, indeed usually are met in commercial agriculture.

Plant Nutrients

Healthy plant growth and maximum efficient yield of crop plants are dependent on adequate supply and proper balance of plant nutrients in the soil.

The ostensible role of lime is the establishment of a pH best suited to the particular crop plants to be grown.

Other effects include provision of some magnesium, some sulfur and some minor mineral nutrients as they occur in various kinds of limestone and other liming materials used. Liming may be used to correct aluminum toxicity; on some soils, it may induce manganese toxicity or, on others, iron chlorosis. On saline soils, calcium sulfate may improve soil structure by aggregating soil particles. Calcium is, of course, itself an essential plant nutrient and its level in legumes and roughages enhances their value in animal nutrition. In 1964, more than 27 million tons of liming materials were used in the United States. However, lime is still the most underused of the soil fertilizer chemicals or amendments.

Principal Plant Nutrients

Nitrogen, phosphorous, and potassium are the principal plant nutrients supplied by chemical fertilizers. Soils in large areas of the world are so low in phosphorous that the forage produced is inadequate to the needs of grazing animals. Cows fail to reproduce. In extreme cases, they develop abnormal appetites, eating bones when they can be found, and they become emaciated and worthless.

Potassium is an essential plant nutrient and limits crop production in many areas. Potassium plays an essential role in ion exchange in the soil and in the process of carbohydrate formation.

Nitrogen limits leafy growth of most non-leguminous plants. Nitrogen may be supplied from the air by symbiotic bacteria on the roots of legumes; some free-living soil bacteria also fix atmospheric nitrogen as do some blue-green algae. These latter may be essential to rice production on some soils continuously used for production of paddy rice without manure or mineral fertilizer.

In general, the addition of these three principal plant nutrients increase crop yields. The response to their application is limited by genetic capacity of the various crop plants, the disease status of the crop, the availability of water to the plant and the interaction of these variables.

The world used more than 40 million metric tons of N, P, and K during the 1964-65 crop year. Rates of application per hectare are shown in Table 1 for various areas of the world except Communist China.

FERTILIZER USE AND CEREAL YIELD 1/

ARABLE LAND (million hectares)		NPK (kg/hectare)		YIELD (kg/hectare)		CROP
		48-53	64-65	48-53	64-65	
Europe						
East	55.4	24	73	1200	1800	Wheat
West	96.6	60	134	1650	2250	Wheat
USSR	230	5	19	840	1090	Wheat
North & Central America						
U. S. Canada	227	20	47	1160	1600	Wheat
Other	34	5	23	850	2500	Wheat
South America	62	3	15	1070	1630	Wheat
Japan, Taiwan, Israel, and South Korea	9.5	95	255	3700	4500	Rice
Other Asia (Except Red China)	338	1	5	1260	1650	Rice
Red China	109	--	--	--	--	--
Africa						
UAR	4.9	25	60	3800	5000	Rice
Other Africa	255	1	2	1030	1320	Rice
Oceania	35	15	39	1010	1270	Wheat

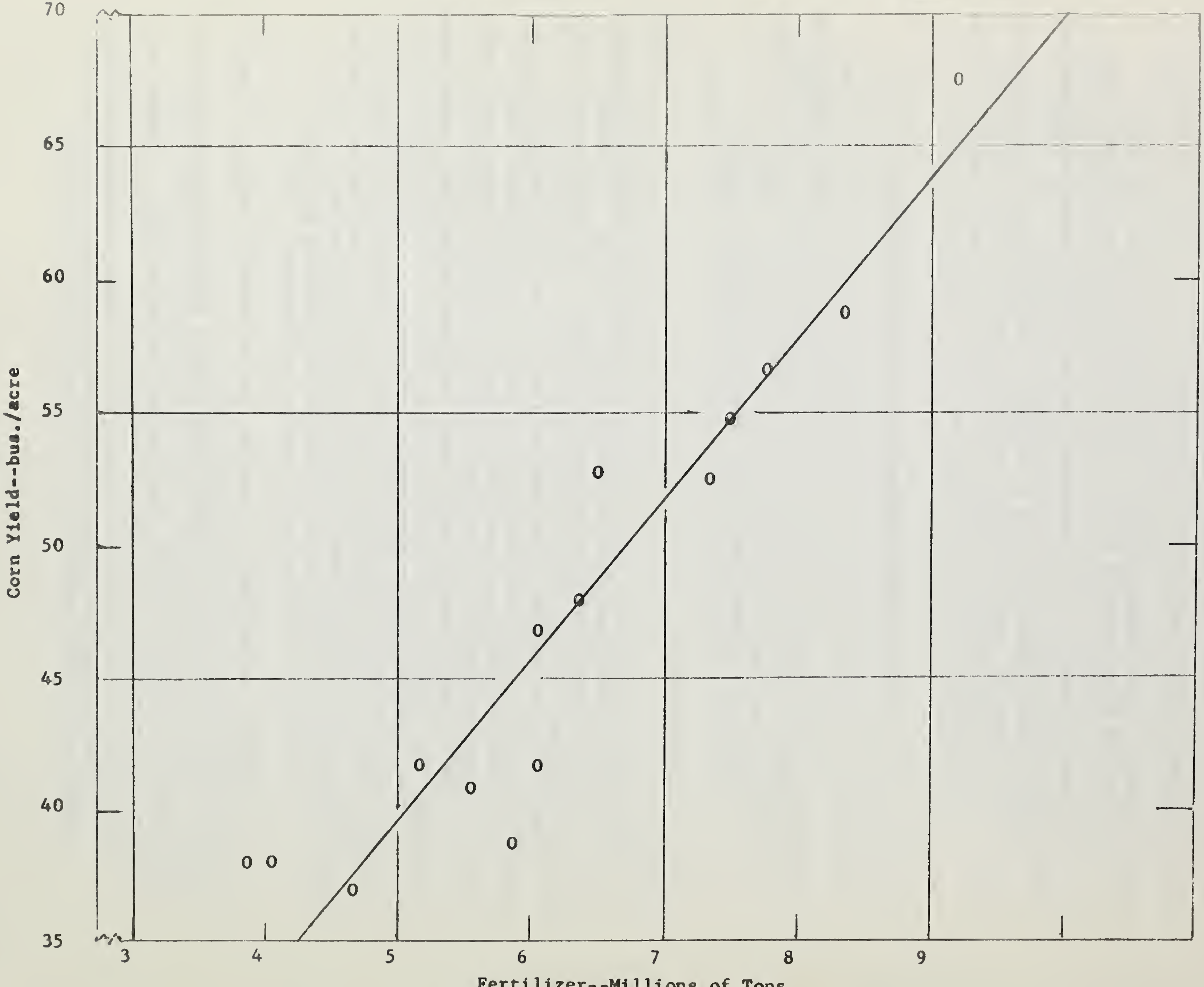
1/FAO Yearbook.

A recent summary of fertilizer use and yield response by Parker and Christensen shows that in the developed countries of the world, 44.3 kg. of N-P-K were used per hectare of arable land in 1962-63. In the under-developed countries only 4.37 kg. per hectare were used.

Parker, F. W. and R. F. Christensen
1965. fertilizers and the economics of crop production.
U. N. Inter-Regional Seminar, Kiev.

The values in Table 1 were calculated from data published in the FAO Production Yearbook 1965. There is an obvious relationship between fertilizer use and crop yield. Coincidence can only infer, not establish, a causal relationship. Thus reservation is equally applicable to Figure 1 which plots usage of N-P-K in the United States against corn yield from 1949-1963 from data published in Agriculture Statistics 1965.

FIGURE 1--Fertilizer Chemicals Used in the United States and Corn Yield 1949-1963.



FAO reports that examination of 400 response figures from several countries indicates a return of 12-13 kg. rice per kg. of N up to about 30 kg. N per hectare. Yield responses continue under optimal environmental conditions of genetic stocks with high genetic yield capacity up to 200 kg. N/hectare but the ratio of rice: N grows narrower as rate of N application increases.

Rice, the principal energy source for more than half the people of the world varies widely in yield. Yield in the United States is about 4500 kg. per hectare; Asia, as a whole, less than 2000 kg. per hectare. But among Asian rice growing countries, Japan (5200), Taiwan (3500), Republic of Korea (3300) exceed 3000 kg. hectare. These same countries used roughly 10 times as much pesticide and 10 times as much fertilizer per hectare as the other Asiatic countries. Coincidence does not establish cause, but it is reasonable to assume that pesticide and fertilizer contributed to increased yield.

In tests reported from Ghana, Iran, East Pakistan, and Turkey application of 22.5-60.0 kg. N per hectare increased rice yields about 2000 kg. hectare to more than 2600 kg/hectare.

1966. the state of food and agriculture.
FAO

Addition of both N and P in these amounts further increased yields by an additional 400 kg. per hectare. Addition of N-P and K added another 400 kg., thus addition of about 120 kg. of N-P-K resulted in an increase of 1400 kg. of rice, a ratio of more than 10 to 1 and a yield increase of 70 percent.

The world acreage of rice in 1964-65 was 123,900,000 hectares with an average yield of 2090 kg. per hectare. Application of fertilizer at the rates just cited would require about 150 million metric tons of N-P-K, more than three times present world use for all crops.

The argument is reinforced by several circumstances. First, a disease called "Blast" which causes yield losses from 20-80 percent. It is especially devastating when genetically susceptible, heavily fertilized rice is attacked. The International Rice Research Institute in cooperation with several national governments are evaluating genetic stocks for inherited resistance to Blast. They have already found some. In the meantime, Japan has adopted the use of phenyl mercuric fungicides. The loss from Blast has been cut in half since chemicals were introduced into Japan for its control in 1953.

Insect pests of rice include rice stem borers and rice bugs. These insects together can reduce rice yields as much as 30 percent. Organic insecticides provide effective control for the rice stem borer but side effects to applicators. Other side effects include damage to fish, a very important and increasingly important adjunct to paddy rice production in many countries.

Rice growers in the United States were made acutely conscious of another role of insects, that of disease vector, a few years ago. Hoja blanca (white leaf) disease made its appearance in the United States. This disease has caused up to 40 percent loss in the rice crop of Central and South American countries when it first appeared there. In our country, it was soon found that a leaf hopper-like insect, Sogata orizicola, spread the disease. Chemical control followed by a hard winter apparently eliminated the insect--and the disease.

The Philippines, for which the FAO 1965 Production Yearbook reports paddy rice yields averaging only 1250 kg/hectare may now show rapid increases. A report in "Lamp," 48:No3:11-15, published by the Standard Oil Company (New Jersey), states that in 1964, Filipino farmers used 294,000 metric tons of fertilizer. Only 30 percent of the farmers were using fertilizer on 22 percent of the 7.5 million hectares of cultivated land. Rice farmers used only 27 percent of the fertilizer supply and applied less than a quarter of the rate recommended by agronomists. A new fertilizer plant was put into operation this year capable of producing 390,000 metric tons annually.

Nematodes, weeds, rodents, and rice-eating birds take a varying and heavy toll of the rice crop. Chemicals are among the means available to reduce these losses but are not yet in general use for this purpose.

Rat damage is enormous, to growing crops as well as stored products. In Taiwan, cultivators were encouraged to use rat poison by payment of a bounty for each rat tail. In 1957, 6.9 million rat tails were turned in for bounty. Food saved was estimated at 140,000 tons, equivalent to 5 percent of the annual rice crop in Taiwan.

Moseman reported that grain losses from bird damage in the Sudan region amount to as much as 4 million tons per year.

Moseman in a paper presented at the NAS-NRC symposium on "Scientific Aspects of Pest Control" which it organized in cooperation with U.S.D.A., U.S.D.I., H.E.W., and other federal agencies, reported some striking estimates of food crop losses from pests in India. India has about 280 million acres under food crops. Insects, rodents, and other animal pests reduce food production by about 10 million tons a year. India hopes to increase chemical protection from the recent level of less than 20 percent of the food crop area to 60 percent by 1970-71.

Use of genetically high yielding cereal grains is limited by their susceptibility to pests. The new sorghum hybrid, CSH 1, developed through cooperative research by the Rockefeller Foundation and the government of India can produce yield increases of 3 or 4 tons per hectare when the sorghum insect pests, shoot fly, and stem borer, to which the new hybrid is susceptible are controlled.

Moseman, A. H.

1966. pest control--its role in the united states economy and in the world.
Scientific Aspects of Pest Control
NAS-NRC Publ. 1402: pp. 26-38

Moseman reported that insects, rodents, and other animal pests to food grains in the field in India consume about 10 percent of total production.

250 animal pests of crops occur in India.

India has 376 million acres of cropped lands, 283 million in food grains. Hoped to chemically treat with pesticides 40 million acreas this year and a 160 million by 1970-71.

TABLE II

ESTIMATED LOSSES IN SOME PRINCIPAL CROPS--POTENTIAL PRODUCTION 1/

Crop	Losses--Potential Production from				Tons
	Diseases %	Insects %	Nematodes %	Weeds %	(Millions)
Corn	12	12	3	10	37
Wheat	14	6	?	12	11.5
Rice	7	4	?	17	0.6
Soybean	14	3	2	17	3.7
Dry Bean	17	20	?	15	0.5
Snap Bean	20	12	5	9	0.3
Potatoes	19	14	4	3	4.7
Tomatoes	22	7	8	7	5.0
Apples	8	13	?	3	0.7
Oranges	12	6	4	5	1.5
Strawberries	26	25	?	25	0.2
Alfalfa	24	15	3	?	30
Pasture & Range	5	20	?	15	100*
Sugar Beets	16	12	4	8	5.9

* Estimated hay equivalent.
1/Losses in Agriculture, Agriculture Handbook No. 291, ARS, USDA, 1965.

Some of the estimated losses in potential crop production from pest damage in the United States are shown in Table II.

These losses occur in spite of very substantial expenditures for chemicals and their application. It is reasonable to suppose that without our current rate of use of chemicals that actual production of several crops would be reduced by amounts at least equal to the stated estimates of loss of potential production. Quality of the remaining production would be grossly reduced.

Estimated total cost of all pesticides preparations to United States users in 1965 was over a billion dollars. Farmers used pesticides costing an estimated $590 million.

About 35 million acres were treated for control of insects and plant diseases, about 85 million acres for weed control. More than 65 million head of livestock were treated externally for insect control.

<u>Fungicides</u>

Shepard, H. N., J. N. Mahan, and D. L. Fowler
1966. the pesticide review 1966.
ASCS, USDA

There were exported from the United States in 1965, about $17 million of fungicides, $29 million of herbicides and $81 million of insecticides. Canada, Mexico, Egypt, and Brazil were the leading recipients. Shipments to eastern European countries increased from about $220 thousand in 1960 to more than $5 million in 1965. Shipments of agricultural insecticides to India increased from about $300 thousand in 1960 to about $2 million in 1965.

<u>Weeds</u>

Losses of potential production imputed to weeds are enormous. Weeds compete with crop plants for space, for moisture, and for soil nutrients. Weeds interfere with harvest, e.g., combine harvest of cereals and soybeans, causing losses of product, too.

King, L. J.
weeds of the world.
Leonard Hill, London and Interscience Publ. Inc.
New York

King cites results of research by Vengris at the Massachusetts Agricultural Experiment Station who grew corn with and without weeds. Corn with weeds yielded from 57-67 percent of the yield of corn without weeds. Staniforth (1961) obtained about a third less corn from weedy plots in Iowa than from weed-free plots. Table II indicates an imputed loss of corn production of 10% or about 10 million tons annually with current systems of weed control. Assuming Vengris and Staniforth results to be typical, current weed control is responsible for the production of more than 25 million tons of the corn harvested in the United States this year.

Staniforth, D. W.
1961. response of corn hybrids to yellow foxtail competition.
Weeds 9:132-136

Herbicide use in the United States more than doubled from 1949 to 1959, from about 23 million acres treated in the former year to 53 million acres in 1959. Estimated use on food and feed crops, including pasture and range was about 75 million acres.

About 30 groups of herbicides have been discovered including some thousands of known active compounds. More than 100 of the best of them are now in commercial use.

Day, B. E.
1966. the scientific basis of weed control.
Scientific Aspects of Pest Control.
NAS-NRC Publ. 1402.

Insecticides

Domestic disappearance of DDT in the United States has declined from about 78 million pounds in 1958-59 to about 53 million 1964-65. Exports, principally for malaria control, amounted to about 76 million pounds in 1958-59, and increased to about 114 million in 1962-63. About 99 million pounds were exported in 1964-65.

Other chlorinated hydrocarbon insecticides--aldrin, chlordane, dieldrin heptachlor, and toxaphene as a group increased from 34 million pounds used in the United States to a level of about 80 million pounds during 1961-65. Exports rose sharply in 1965.

Use of organophosphorous insecticides in the United States amounted to about 60 million pounds in 1965. Probably more than 30 percent of these compounds are used on cotton.

Carbaryl, the principal carbamate insecticide, is widely used in Federal and State insect control programs as well as private use.

<u>Monoculture and Multiple Cropping</u>: Pest control problems are accentuated by every advance in production technology. Heavy applications of N fertilizer increase leaf surface, provide more food for foliar insects, and more hiding places for others. Continuous cropping provides a continuous food supply for ubiquitous pests adapted to several plant hosts. Irrigation and fertlization of pasture increase the density of livestock hosts and often result in a spiralling parasite population. Surface pools harbor snails, intermediate hosts for livestock parasites.

Monoculture is increasingly practiced because land best suited to particular crops is physically geographically, and ecologically limited. It tends, therefore, to grow crop after crop of the plant yielding highest economic return--in large areas of the United States corn, in limited areas vegetables. Corn is thus beset with root worms and stalk rot. Vegetables are beset with soil borne pathogens. Rotation, fumigation, chemical control, and resistant organisms increase the problem of control.

Both chemical and biological control of pests are counterbalanced by emergence of tolerant or resistant pests. In biological control, emergence of new virulent rust strains is commonplace. Resistant flies, lice, and other insects nullify the efficacy of one chemical pesticide after another. There is evidence that genetic resistance may be transferred from resistant microbes to widely unrelated commensals in the presence of antibiotics.

Coccidia are opposed by chemicals, contained toll host tolerance or immunity or pathogen resistance dominates or stalemate is achieved.

Until we know the nature of resistance, the mode of action of pesticides, the complete course of their metabolism by the host, and target organisms, researchers will cut and try, cut and try again.

Chemicals in Livestock Production

"Losses in Agriculture" states losses from disease, parasites, and insects in terms difficult to aggregate into tonnage. Selecting those causes of loss listed in Tables 26-32 for which in my judgment chemicals are now and are likely to continue to be principal direct or indirect means of control. I arrived at an estimated about 1.5 million metric tons live animal equivalent annual loss in potential production. This estimate I believe to be quite conservative. Chemically controllable loss from diseases, parasites, and insects are assumed to be about equal. It is reasonable to assume that our present chemical control measures protect a much greater quantity of our current livestock production.

Not included in this loss summary are the possible gains in efficiency which may be achieved some day through use of hormones to control time and rate of conception in mammalian livestock species.

The billion cattle, the billion sheep and the 350 million goats of the world depend chiefly on forage growing on non-arable land and on crop residues for their feed. In many and large areas of the world, soil deficiencies limit the kinds of plants that will grow as well as limit the supply of mineral nutrients available to livestock. Copper, cobalt and phosphorous are among the limiting elements. Soil and feed amendments of these and other chemicals have brought many grasslands in our own South, in Australia, in New Zealand and elsewhere to a high level of livestock production. Use of nitrogen on improved pastures especially in Northern Europe has made grass farms there as productive as grain farms. Among the problems of chemical interest associated with pasture and range livestock production are grass tetany, bloat, selenium deficiency and toxicity, molybdenum toxicity, parasite control and insect and other arthropod control.

Among the great scientific achievements of the U.S.D.A. and the cooperating states was the discovery that piroplasmosis, or tick fever, was in fact transmitted by ticks. The eradication of tick fever from the U. S. was accomplished by the use of arsenical deposits. Lice, various biting flies, mange and scab and other mites are kept in check with chemicals. Grasshoppers which appear in devastating clouds from time to time are also checked with chemicals.

On improved legume pastures, bloat has always caused sporadic, sometimes serious losses. Again, perhaps for the n'th time, an effective chemical for prophylactic use has been identified, through research at the Kansas State Agricultural Experiment Station. The proprietory "Poloxalene" is described as a non-ionic surfactant block polymer of polyoxypropylene-polyoxyethylene.

In the United States, in addition to, and in some part in lieu of, land based livestock production, large scale production of confined livestock has increased enormously during the past 30 years. Spear-headed by the broiler industry, egg production, turkey production, feed-lot beef production, zero-pasture dairy production and finally swine production in large-scale enterprises depending on formulated feeds are contributing a larger proportion of our meat, milk and egg supply.

The use of chemicals is essential to the success of this kind of livestock production. Micro-nutrients, whether vitamins or minerals must be supplied in the feed or manufactured in the gut. Mn, Zn, Fe, Cu, I, Mg, Se, are among the minor nutrients which must be supplied in the feed. Parakeratosis in swine was not recognized and was probably infrequent till swine were raised in confinement. It is primarily a zinc deficiency. The Pesticide Review 1966 notes that while zinc sulfate and zinc oxide have some fungicidal use, a principal use is in animal feed. Among the dramatic incidents demonstrating the essential role of chemicals was the discovery by Waddell during World War II that 7 dehydrocholesterol was an effective vitamin D source for poultry. This discovery came at a time when fish oils were in short supply and may be said without exaggeration to have made a continuous and increasing supply of broilers during that period a fact.

Only slightly less dramatic was the discovery of vitamin B_{12}. This vitamin is essential to normal embryonic growth and neonatal survival. It is formed by micro-organisms in the gut of all animals; it is not supplied by higher plants or their seeds. Ruminants with a cobalt source in their feed utilize efficiently the cobalamine made by rumen micro-organisms. Monogastric animals, man as well as chickens do not. Coprophagy is not a dependable source of vitamin B_{12} for large flocks or herds of animals maintained on vegetable diets and B_{12} must be added. This discovery was the final step in a series of discoveries which made possible the efficient use of soybean oil meal and cereals as the principal protein feed ingredients for confined poultry.

Intensive production of livestock equally intensifies problems of parasite and disease control. I know of no more persistent or pervasive group of parasites than the coccidia. Unchecked, they decimate flocks of lambs, calves, and poultry. It is possible to check outbreaks through sanitation. Because a few bones outside the body of the host are required for oocysts to become infective, complete removal of all litter each day for 3 or 4 successive days with sanitization can check losses. The cost of this method is often greater than the value of the flock.

So we have come to a kind of integrated control using a variety of chemical coccidiostats, sometimes a "vaccination" by ingestion of live organisms--indeed perhaps always fortuitously some of this--but based on the fine work of Edgar at the Alabama State Agricultural Experiment Station at Auburn it can be done in measured doses of predictable immunogenicity--and broiler enterprises cope with coccidiosis pretty well. Resistant organisms emerge, minor species of coccidia become of serious concern, but as of now, chemicals to help control coccidia seem to be essential to efficient production.

That ubiquitous various and still little understood group of chemicals called antibiotics play a large and continually challenged role in livestock production. Their prophylactic and therapeutic roles are dramatic. It has been demonstrated that antibiotic treatment can eliminate one kind of mastitis, only in frequent cases to be replaced by another kind of infection. Salmonellosis is an increasingly obvious problem in mass rearing of bucket-fed calves. Antibiotics will check but not eliminate the organism. Antibiotics are a part of control and eradication programs against a respiratory disease complex in poultry which continues to cause product loss of a 100 million pounds a year. Competing bactericidal chemicals are claimed to be equally or more effective without their use being accompanied by emergence of resistant target or commensal micro-organisms. But these are chemicals.

There is wide spread use of antibiotics and of organic arsenicals at low levels in formulated feeds as growth promotants. This use very clearly reduces the frequency of units and culls. Efficiency of feed conversion is improved. Successive flocks of untreated animals in the same premises tend to approach the treated animals in performance. The ecology of the microbes in the environments changes.

Hormones continue to be tried. Control of estrous and conception seems to be imminent--but it has seemed imminent for 20 years. Reproductive failure is indubitably the most important barrier to improved efficiency of livestock production. When and if, through chemical, or more probably through systematic chemical, nutritional health programs, all females bred will conceive on the date of choice, all rear vigorous healthy offspring all eggs hatch viable young, we can improve gross efficiency of livestock production by at least 20 percent.

For the present, thyro-proteins, gastrogens, androgens and growth hormones are not in general use. Only stilbestrol in beef production is. Its use clearly enhances rate of gain and feed efficiency.

But the most important use of chemicals in livestock production currently in tonnage, potentially as a means of increasing ruminant production and milk production in the world is the use of urea and other non-protein nitrogen sources for ruminants. Current usage in the U. S. may exceed 200,000 tons. Efficient use seems to depend on a substantial portion of the diet as starch or other readily available carbohydrate.

As a sample of the varied chemicals used in livestock production, I checked the advertisements in "Poultry Meat" for September 1966. Twelve firms advertized the following kinds of product: coccidiostats, histostats (against Histomonads in turkeys), fungistat, prophylactic antibiotics, a tranquilizer stated to prevent aortic rupture, an enzyme preparation to suppress manure odor and a chemical to wash such odor; an anti-oxidant to protect xanthophyll and vitamin A in feeds, dips, disinfectants, detergents and sanitizers are among the chemicals we have not discussed.

What of the future? Use of fertilizer has readied the stage of systems engineering. Efficient use depends on genetic capacity of crop plants, number of plants per acre, insect, disease and weed control, and moisture availability as well as soil test and fertilizer price. It seems obvious that fertilizer use, especially in the developing countries, must be quickly increased.

Insecticides, fungicides, rodenticides, nematocides, parasiticides--efficacy, selectivity and biodegradability will continue to determine efficient use. There are, of course, circumstances when a non-selective agent can be used with a sterilized environment as the end point. With a large array of biological agents, time is cheaper and thus the time honored practices of crop rotation and clean fallow. We also have pigs separated from their dams at or before birth to break the transmission of disease between generations. The hatchery and brooder didn't accomplish this feat for poultry--e.g.pullorum, mycoplasmia, etc.--but it helped.

We may anticipate increasing development and application of more specific and efficacious chemicals and patterns of use. Chemosterilants and attractants offer exciting possibilities in control of insects. With the wise use of chemicals, the world can continue to produce enough food, and food of its choice for the next generation while it decides how to adjust human population to its food supply or permits the adjustment to take place through the ancient biological process of death rates exceeding unplanned birth rates.

AGRICULTURE, RESEARCH, PEOPLE. 1/

Dean Larson, Members of the Faculty, Ladies and Gentlemen:

I am honorded to be here.

The three-word title I have chosen for this talk is intended to assert interdependence among agriculture, research and people. The time scale is, of course, past, present and future. I shall discuss problems, probabilities and projections. Both fact and fancy will have a place.

Agriculture has become a term of many meanings to many people. I shall discuss it in terms of processes, problems, purposes and productivity. Research I shall discuss in relation to these processes, problems, purposes and the productivity of agriculture. And because agriculture serves people and people are the determining component in agriculture and research--or can be--their interrelationship with agriculture and research is inescapable.

Research in agriculture is conducted to serve the missions of agriculture. We, the people, pay for it with our tax dollars, in the "convenience" products we buy, in the social costs we endure. In return, we enjoy an abundant, wholesome, varied food supply in forms we accept and in quality we choose or are able to recognize. Our fiber and forest product needs are generally met. We have an increasing area, variety and quality of beautiful forests, streams and lakes for our pleasure. Fish and wildlife are increasing in abundance. We have food to spare for the unfortunate at home and abroad. We have

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1/ Talk by T. C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, on the occasion of the Faculty Meeting, College of Agriculture, Pennsylvania State University, University Park, Pennsylvania, October 20, 1967.

commodities to sell abroad--about $5 billion this year for hard money

Research--and invention--produced the information on which the technology of agriculture is based. Technology is an increasingly important input into agriculture It has become the determining input. Research is done by people; research in agriculture is done to solve problems, that people may continue to enjoy the products of agriculture, find opportunities in agriculture and find opportunities to live well or to relax occasionally in a beautiful countryside.

Agriculture in Pennsylvania will be what you and your neighbors make it. It can be what you choose or what you permit it to become. The decision is yours. Laissez faire is not the worst of all possible courses; just middling. Can you do better? Will you? I don't know and you don't know. But I can give you a few facts, a few trends; define a few opportunities, a few constraints. I can tell you nothing new, but perhaps I can remind you of a few things you haven't thought about lately or have simply taken for granted.

As a first pontification, you can't afford to take anything for granted.

My first American ancestor on my father's side came to Lancaster County from the Palatinate, in 1737. The Pennsylvania Dutch change slowly; of the earth, earthy; of the faithful, unshakable. But change is inexorable and change we all must face. Man's supremacy in this world rests on his continuing ability to adapt to change.

So agriculture has changed and will continue to change. But eat we will, clothes we will wear--of changing sorts--, and in houses we will dwell. And we will not live alone.

In the continental U. S., inputs into farming have increased by about 2.5 X since 1870; outputs have increased more than 5 Xs. Thus, the efficiency of production has doubled. Increase in efficiency was slow during the 1870-1935 period. Most of the increase in efficiency has occurred during the period since 1935. Crop yield per acre and animal products per animal breeding unit have increased steadily but with wide variation among crops and livestock species. For example, corn yield per acre doubled during the 1950-1965 period while soybean yield increased less than 25 percent. Hay yield per acre increased only 30 percent.

Since 1935, horses and men have been rapidly replaced by machines--horses no longer supply a substantial amount of draft power, and man-hours are less than half the 1935 input. Fertilizer use has increased steadily. Pesticides have come into general use. Hybrid corn has replaced open-pollinated. Farms have grown larger and fewer. Where will we go from here?

Projections can be made in many ways. The simplest way is to project current trends to identify and quantify their determinants and their interactions. Not all the determinants of the recent past are relevant to the future. We can't replace horses because they are already gone. Hybrid corn is in general use; so are hybrid sorghums.

Current trends projected would give us average acre yields for corn of about 150 bushels in 1980. A great many knowledgeable people find this projection reasonable. It would give an average egg production per hen of about 270, and of milk per cow of about 12,000 pounds. The number of milk cows has dropped from 22 million in 1950 to about 13.5 million today, a 40-percent decrease. This would mean 8 million milk cows in 1984. Such a number seems to me to be highly unlikely--or is it? It seems unlikely that another 50-egg increment could be realized during the 1980-1995 period. All yields must become asymptotic somewhere, and simple projections of current trends become absurd after a few years.

Simple projections assume continuing action and interaction of determinants active during the base period. Obviously, with the horse gone and human labor largely replaced, and hybrid corn adopted, new technology and its application will assume a larger determining role in the future than in the past. And in the recent past it has been very large.

In terms of total tonnage, Pennsylvania production decreased in grain, hay, vegetables and tobacco between 1950 and 1965. Production increased in tree fruits, grapes, sweet corn, cattle and calves, milk, broilers and turkeys. Total egg production was about the same in the two years.

Acre yields of grain, hay, potatoes and tomatoes increased from 1950-1965, but the increase was somewhat less than the average increase for the U. S. Yields of milk per cow and eggs per hen increased by 35 and 25 percent respectively, again less than the national average. However, actual acre yields of barley and wheat exceeded the national average in both years, as did milk production per cow. Egg production per hen was 10 more than the national average in 1950 and just the national average in 1965.

There were 1,703,000 roughage-consuming animal units (cow equivalents) of livestock in Pennsylvania in 1950 and 1,652,000 in 1966. We have noted a small reduction in hay production. There has been a substantial apparent reduction in acres pastured (4.2 million in 1954--3.3 million in 1959).

There has been a sharp increase in the rate of concentrate feeding to milk cows-from 2,160 in 1950 to 3,550 pounds per cow in 1965. This increase of 1,390 pounds per cow is much more than enough to account for the 2,800 increase in milk production per cow realized during this period.

From 1955 to 1965 land in farms and land used for crops in Pennsylvania decreased about 10 percent. Acreage of corn and hay decreased about 7 percent. Number of milk cows decreased more than 15 percent. Eggs produced decreased more than 10 percent. Potatoes decreased about 10 percent and commercial vegetable production about 3 percent.

Production of cattle and calves increased. Broiler production increased by 65 percent. Milk production per cow increased by about 2,150 pounds, a little less than the national average increase. Apple production increased. The dollar receipts from greenhouse crops increased from about $47 million in 1955 to about $83 million in 1965. Farm income increased about $60 million, from about $801 million in 1955 to about $861 million in 1965.

All over the world people are leaving the land and going to the cities--where the action is. In the United States, traditionally, farmers have lived on the land they farmed. This, too, is changing. Of the hired labor used on farms, more live in villages, towns and cities now than live on farms. Farm operators, too, are moving to town.

As a whole, the rural population of the U. S. isn't changing very much; larger rural towns are growing, small ones generally are losing population and farm families are decreasing rapidly in number.

Only 10 percent of the people living in rural Pennsylvania in 1964 lived in farm households. Ninety percent were nonfarm residents.

This, then, is the way agriculture in the U. S. and Pennsylvania have come, and rural people. What of agricultural research?

I will bridge with a quotation from Nietzsche: "Our destiny exercises its influence over us even when, as yet, we have not learned its nature: it is our future that lays down the laws of our today." (Human, All Too Human (to Alexander Harvey). 7.)

The U. S. Department of Agriculture and the National Association of State Universities and Land-Grant Colleges jointly sponsored a study of needs and opportunities for agricultural research during 1965. That study found that about 10,330 SMYs 1/ were devoted to agricultural research in the USDA and the State Agricultural Experiment Stations during 1965. Their study of needs and apportunities led to a projection of ca 18,170 SMYs in 1977. About 60 percent of research effort is in the State Agricultural Experiment Stations, about 40 in the USDA. The ratio is not expected to change much by 1977.

The following table summarizes the Long Range Study inventory and projections:

RESEARCH INVENTORY NEEDS (From Table 17, A National Program of Research for Agriculture, October 1966)

1/ Scientist-man-years

	1965 SMYs No.	1965 SMYs %	1977 SMYs No.	1977 SMYs %	Increase over 1965 %
1. Resource Conservation and Use	1,313	12.7	2,300	12.7	75
2. Production, Protection, Processing & Marketing	7,596	73.5	12,035	66.2	58
3. Foreign Trade & Assistance	207	2.0	950	5.2	359
4. People--As Individuals, Families, Communities, & Consumers	1,214	11.8	2,885	15.9	137
Total or average	10,330	100.0	18,170	100.0	76

About 86 percent of effort in 1965 was directed to commodities, their efficient production, protection, distribution and use and the conservation and use of resources. About 12 percent of effort was directed toward problems of people. About 2 percent was devoted to research on foreign markets and technical assistance to less developed countries.

The Long Range Study divided all agricultural research into 91 research problem areas. It found none in which effort should be reduced. Estimates of needed increases varied widely. In general, it found a need for a 76-percent increase in SMYs by 1977. For the people areas the needed increase was estimated at 133 percent, but because the current effort is relatively small, the proportion of effort devoted to commodities and resources changes only from about 86 percent in 1965 to 79 percent of the total in 1977; and the people areas from about 12 percent in 1965 to about 16 percent in 1977.

There are very critical areas needing increased attention in each area.

In the area of resource conservation and use, research on alternate uses of land, on economic and legal problems in management of water and watersheds, and research on weather and weather modification were judged to merit very high priority for increased research.

Research on production, protection, processing and marketing commodities will continue to occupy a major portion of agricultural research scientists. There are many opportunities for redirection of effort as well as need for increase. For example, research on feed efficiency in production of meat, milk and eggs occupied 464 SMYs in 1965 and only a 19-percent increase, 86 SMYs, is projected for 1977. In my opinion, there is no area of research of greater importance and continual potential productivity than this one. But I support the Long Range Study conclusion that there is ample room for innovation and redirection within the resources presently allocated to this area.

Among the problem areas for which highest priority for increased effort is projected in the commodity research effort are: protection of plants and animals from harmful effects of air pollution, new and improved forest engineering systems, mechanization of fruit and vegetable crop production, systems analysis of field crop, fruits and vegetable production and competitive interrelationships in agriculture. Farmer bargaining power will be much discussed; hopefully, research can contribute information useful to decision makers in this problem area.

Research on foreign market development and on technical assistance to developing countries were deservedly assigned very high priority. The colleges and universities will surely continue to have an important role in this area. When and how and with what sources of support their role can be strengthened is still not clear.

In the "people" problem areas there are many areas recommended for large proportinnate increases. These include food protection and human nutrition. Very high priority is assigned to increasing research on causes and remedies of rural poverty. Closely allied problem areas, research on improvement of economic potantial of rural youth and adults and on individual and family adjustment to change were assigned high priority for increase. Other areas assigned high priority for increase include soil, water and air pollution--or waste management--forestland recreation and, of course, improved income opportunities in rural communities.

USDA and the State agricultural experiment stations and the forestry schools and departments cooperating under the McIntire-Stennis Act will continue to plan jointly for research budgeting using the Long Range Study as a guide. Each cooperating agency and State agricultural experiment station and forestry school must determine its own priorities. Regional research will continue to provide a useful mechanism for joint, sometimes interdisciplinary systems attack on problems of mutual concern.

Research management is responsible, together with participating research scientists and within policy guidelines of USDA and each of the cooperating institutions, for program planning, coordination and evaluation. Resource allocation must be consistent with program, but obviously must give due account to urgency, opportunity, feasibility and capability as well as need. Evaluation of proposals and of progress must include fund use and accountability as well as relevance, quality and productivity of research. Measurement of productivity is of continuing concern. Byron Shaw's recent paper demonstrates that we may not ignore publication rate as a first crude measure of productivity.

The vulgar phrase "Publish or Perish" will not be stilled. But is it better to perish than publish what is not worthy of publication cost or reader's time?

How shall we measure the value of research? And we must; research and development cost us more than 10 percent of our Federal budget, though funds for agricultural research seem to me to be pitifully small in relation to the importance of agriculture and its many problems.

One way, of course, is in terms of resources saved. We are confident that production of food, fiber and forest products in the U. S. will keep pace with increasing demand because research will produce new information for improved technology. That improved technology will enable us to produce all we need and all we can sell in foreign markets and continue to give some products to needy people in other lands. At our present level of technology we would anticipate necessity for bringing millions of acres of additional land under cultivation.

Only on this assumption of continued improvement of technology through agricultural research can we anticipate with confidence that the burgeoning demands of our urban people for recreation, hunting, fishing, and the job of a beautiful countryside--of natural beauty--can be met. On this assumption rests our hope for new towns with all the amenities of our great cities and the green space of the country.

"unto a land flowing with milk and honey; for I will not go up in the midst of thee: for thou art a stiff-necked people-:" (Exodus 33: 3, partim)

Can we know the joy of living in the country as spectators? The

The beauty of a country village, can we have it without its traditional stinks? Will it be real? The taciturn and self reliant country family, is it bound to go?

Many old villages are losing population or becoming bed-room towns for commuters. They are losing their role as trading and service centers. Rural America has one-half the Nation's poor housing and half its poverty. Unless communities plan and act, unless public support for planning and action, unless research produces information needed for wise planning and action, this condition is unlikely to improve. With 70 percent of our people now on 1 percent of our land, with cities continuing to grow and even farmers operating their farms from town or city, continuation of present trends will overwhelmingly make us a land without people, a people without land.

Certainly the flux of rural migrants to the cities has complicated problems there as well as failed to solve the problem of poverty in the rural communities from which they migrated. Certainly the country can be a wonderful place to live if opportunity and competence necessary to earn a good living are present. How can agriculture contribute to improvement of country living for rural farm and nonfarm people alike?

Pennsylvania has very real needs and opportunities. There were more rural Pennsylvanians in 1960 than in 1950--3.2 vs. 3.1 million. But: there were 147,000 Pennsylvania farms in 1950 and only 83,000 in 1960. Only about 10 percent of rural Pennsylvanians are in farm households.

F. D. R. is reputed to have preferred "Home on the Range," and our current crop of Eggheads, reverting to Jean Jacques, extol the State of Nature. Is there any other State?

Don't fence me in!

The Wild Blue Yonder!

Look to the Hills?

Is fantasy more real than reality? Ask the Flower Children? Or the Head Shrinker? Or are you able to make up your own mind? Do you know only what somebody tells you? Maybe they're putting you on. Maybe not.

More than 30,000 rural areas in the U. S. now lack central water systems and adequate waste disposal systems. Creation of such facilities in rural communities now lacking them, the development of improved health services, schools, libraries, and protective services will help to attract people to rural communities. To assist in community development, it is the policy of USDA to encourage proper use of land and water resources in implementation of zoning and other land use improvement measures, and to encourage economic planning that emphasizes human development as well as natural and economic resource development.

Not all towns need to be large. Many people prefer to live in villages. Lumber, feed fertilizer, seed, gasoline and other products used by farmers are efficiently supplied by plants close to the farmer customer.

Not all the farms of tomorrow need to be large, nor are they likely to be. Adequate income, commercial farms are the mainstay of American agriculture. They will continue to produce the bulk of the grain, livestock and livestock products.

But there should continue to be opportunities for people who want to farm on a part-time or subsistence basis. The farming system should enable young farmers to get started and remain in farming. People who want to farm and who have the necessary skills should have the opportunity to farm. Research can help provide the information needed by beginners and little farmers as well as that needed by big farmers.

Big farmers have tough problems. Some of them are becoming obvious to everybody.

Labor costs are not negligible. It took more than 80 hours per milk cow in 1965. Let's assume that labor can be had for $2 an hour--and that this big, efficient farm only requires 50 hours per cow, or $100 per year--that's a $100,000 a year payroll. Main problem is likely to be to get and keep a full, competent staff because a lot of people think there are easier ways to earn a living than tending milk cows.

Another point--the owner-operator of a thousand-cow dairy is likely to find himself fully occupied by the tedious business details of the enterprise. He'll either have to delegate this responsibility to some competent and trusted person or give up the real pleasure of managing cows and their problems

INPUTS			OUTPUTS	
	Tons	Acres		Tons
Corn, grain	1,825	65		
Alfalfa	2,000	500	Milk	7,300
Corn, silage	6,125	400	Manure	18,200
Pasture	(6,000)	375		
Buildings, roads, yards	- -	20		
Total	10,000	1,360		25,500

The table doesn't show water requirement nor labor. It does show 35,500 tons of materials to be handled during the year. Many a dairyman may be reminded of the refrain: "Sixteen tons, and what do you get--one day older and deeper in debt." Only it's a hundred tons a day for a 1,000-cow dairy.

Waste disposal

Traditional methods of dilution are obviously inadequate. Many lagoon systems have failed. Nitrogen in several concentrated forms is more convenient and economical than nitrogen from manure. Traditional methods of piling and field spreading cost more than the manure value in terms of cost than alternately available fertilizer.

These flat statements, perhaps too flat, pose one of the major problems of animal agriculture--dairy, broiler, egg-laying flocks, turkey production, beef feedlots and swine production. Three conditions seem to me basic to the solution of the problem (1) least cost disposal; (2) concentration, not dilution; (3) the land is the only available sink of sufficient capacity to meet continuous disposal requirements.

On the positive side, manure will always have value in crop production as a source of plant nutrients and especially as a soil amendment to maintain tilth.

Let me emphasize the problem: The excreta from one cow has a BOD equivalent to the excreta from about 15 people, or a 1,000-cow dairy produces a sewage load roughly equal to a city of 15,000 people. Conversely, cows enough to supply milk to a city at a pint per person per day would produce about a third the sewage load produced by the people of the city. Cost-wise, $600 per human has been given me as estimated cost of a modern sewage disposal plant; such a plant for a dairy would thus cost about $9,000 per cow. And it would still add nitrogen and phosphorus--useful on the land--to our streams, where they would lead to algal blooms; pollution. The solution to pollution is not dilution. Our supplies of available diluent are insufficient.

But enough of this dirty problem; let's soar a bit.

The character of people reflects the land of which they are a part. The land reflects the people, the people now, and those who were, who have lived on it, from it, used it, abused it. The land; ours to have, but not to hold. And learning?

As a baby grasps at sunbeams or a kitten grasps its tail, do we play at gaining knowledge, at giving it away. Is our purpose wisdom? Understanding? or only how to do and make it pay? There are those who look to chemistry to feed the future man. Indeed the chemical processes of living things always have fed him. There are those who seek directed genetic changes; mutagens interacting in appropriate environments at specific loci. They always have; only control and direction would be new.

Icarus flew too high. Many among us will fall to earth too soon. But, if we can, soar we must. Jules Verne put it: What the mind of man can imagine some man will do.

Some will justify--in terms of benefits to man--romote sensing as a tool for agriculture, for example. Yes, we must all sing for our supper; for the arrogant elite, it has been assumed that the public would pay for promises--in advance--for dreams. Columbus promised the wealth of the

Indies.

What promised are we prepared to make--and keep?

Are you smart enough to add apples, oranges, esthetics, morals and responsibilities and come out with a "right" answer? What answer are you looking for? A compulsive one which you must accept? Or one you want? That will enable the next generation to choose and seek to achieve with no more constraints than you endure? Or take what comes? Relax and enjoy it if you can?

Always, with or without regret, the passing generation may choose to boast of its little achievements to the next generation--looking backward, say, we have climed to dizzy heights. Or say, looking into the murk or empty space ahead--we've had it, carry on.

Truly, all that's past is prelude.

RESEARCH RECOMMENDATIONS OF "THE WORLD FOOD PROBLEM"

President Johnson directed his Science Advisory Committee to search out new ways to:

1. Develop inexpensive, high-quality synthetic foods as dietary supplements.
2. Improve the quality and nutritional content of food crops.
3. Apply all the resources of technology to increasing food production.

To carry out this charge, a PSAC panel was established under the chairmanship of Ivan L. Bennett, Jr., with then North Carolina State Research Dean H. F. Robinson as Executive Director. The panel consisted of 17 scientists. Thirteen sub-panels were established, each of which developed a substantial report. Finally, all the reports were brought together and published in three volumes in May 1967.

Within the few months that have elapsed since the report was published, good weather and bountiful harvests have eased the immediacy of the recommendations. However, neither those nor the phenomenal promise of genetically high-lysine corn and sorghum nor reported yields of IR-8 rice and Mexican wheat, nor of first-cross corn in Kenya have reduced the problems.

Indeed, there is currently less optimism that family planning is likely to, or even can, provide an ultimate balance between population and food supply. The intricate interacting forces which affect stabilization in numbers of animal, plant, and microbial populations are poorly understood.

Remarks presented by T. C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, before the International Agricultural Development Service Seminar, March 28, 1968, Washington, D. C.

And these forces do not include self-imposed, conscious family planning. The report is replete with variations of the dictum on page 16 "If the payoff is large enough, farmers will change." What is the payoff for voluntary population control?

The recommendations on research are oriented to the needs for problem-solving research, in general where each problem exists.

The report defines and directs attention to the declining condition of more than two-thirds of the human race. The Panel's detailed analysis of the world food problem led to four basic conclusions.

1. "The scale, severity and duration of the world food problem, are so great that a massive, long-range, innovative effort unprecedented in human history will be required to master it."

2. "The solution of the problem that will exist after about 1985 demands that programs of population control be initiated now. For the immediate future, the food supply is critical."

3. "Food supply is directly related to agricultural development and, in turn, agricultural development and overall economic development are critically interdependent in the hungry countries."

4. A strategy for attacking the world food production will, of necessity, encompass the entire foreign economic assistance effort of the United States in concert with other developed countries, voluntary institutions and international organizations.

The bulk of the increase in food supply must come from increased production of farm crops.

There are good opportunities for improved production of livestock, increased utilization of fishery resources, including fish farming, in the less-developed countries.

In Asia, increased yields from land now under cultivation will be mandatory.

The products of technology and knowledge "cannot be transferred directly to the developing nations."

In the meantime, world grain production is increasing steadily. It is increasing, percentage-wise, about as fast in the less-developed countries as in the developed countries. Total food production in the developed countries increased about 27 percent and in the less-developed countries about 24 percent during the past 10 years. But the less-developed countries population increase continues to outpace their food production. In 1959-60, the less-developed countries imported Ca 21 million tons of grain annually; in 1964-65, 29 million tons; by 1980 they may require more than 50 million tons of imported grain. Even so, there is likely to be a world surplus of 30 to 40 million tons of grain in 1980. Grain in excess of commercial or concessional movement--why?

For hungry people of the world to be well fed, most of their food must be locally produced.

We need to double our grain production by year 2000. This looks easy in light of recent increases and perhaps it is. Our interest here is the essential concomitant increase in use of pesticide and fertilizer chemicals. The most elegant, and, in my opinion, most probable course is predictable on the basis of three equations relating pesticide and fertilizer chemicals to yield and to each other on page 140, Vol. II of "The World Food Problem."

Letting P = g/ha of pesticides
F = kg/ha of fertilizer
Y = 1,000 (kg/ha) of cereals

Then $\log P = 0.949 \log F + 1.532$

$\log P = 2.575 \log Y - 5.683$

$\log F = 2.716 \log Y - 7.612$

r values for the data from India, Japan, and United States from which the stated values were derived were r = 0.989, r = 0.977, and r = 0.989, respectively.

These equations show definitively the requirements for pesticide and fertilizer chemicals with present technology. To double yield of corn in the Cornbelt, where N in groundwater may be a problem (cf. map, page 179, "Restoring the Quality of Our Environment") it will be necessary to redouble current N use from 80 lbs./acre to 320 lbs./acre. Pesticide chemical use would need to be redoubled, too.

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The most urgent needs in less-developed countries are an increased supply of calories and good quality protein. In some areas, specific vitamin and mineral deficiencies are prevalent and foods furnishing these nutrients must be made available." (Page 5, Vol. II)

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"The quality of protein in chick peas, pigeon peas, and lima beans is comparable to that of animal proteins." (Page 217)

Attention focused on basic food crops; such as wheat, rice, maize, sorghum, millet, potato, sweet potato, yams, cassava, banana, pulses, oil seed legumes.

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Mexican wheat--cf. Indian official report, Uttar Pradish yields.

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2. Tropics require annual production (multiple-crop concepts rather than seasonal as in temperate regions (Bradfield).

3. Since USDA, FAO, and Foundations lack a corps of tropical agricultural experts who can be assigned to respective less-developed countries on a career basis.

4. ". . .one, or more, tropical research and training institutes, supported by an appropriate agency of the Federal Government, be established in the tropics on United States owned or controlled territory. Such an Institute should support research in depth on all aspects of tropical crop improvement and production and it should function as a training center in tropical agriculture for scientists from the United States and foreign countries." (page 227)

Freshwater fish offer excellent opportunities for increasing quality and quantity of protein in less-developed countries. Present yields from rivers, swamps, and natural lakes are substantial in some countries. Annual catch from Mekong River swamps has been as much as 270,000 metric tons; from the Middle Niger in Africa, 45,000 tons. There are 150,000 acres of rice-fish culture in Indonesia producing 300 pounds per acre--a total of 20,000 metric tons.

Total current production of all freshwater fish is estimated at about 15 million tons. The year 2000 projection is 40 million. Most of the increase would come from pond fish culture. To increase fish from this source from the current 1 million tons annually to 19 million tons, adaptive research must be done in every country. Research on eutrophication with phosphates and sewage is especially needed. The balanced development of bacteria, phytoplankton and plankton to provide a sustained food supply for food fish can be highly productive. Ponds can be built and operated where food is most needed, catch can be consumed daily without refrigeration, capital costs are low.

Needed increases in fish pond acreage are estimated at about 10 million acres from a current base of about 4 million in Asia, Africa, and Latin America.

Game Versus Livestock

Published reports from Rhodesia and from Kenya indicate the desirability of further research on relative productivity of wild herbivores vs. livestock species and managed combinations of these. Disease research should have high priority. There is a dearth of knowledge of tropical range management and forage species nutritive value and ecology. Reproductive rates are critically low for livestock species and probably for game species, too.

Swine and poultry enterprises have been established in some less-developed countries. So long as feed grains are commercially available for such enterprises, these together with milling and other offals and wastes can and will produce large amounts of animal protein.

Such enterprises, broiler, egg, or pork, are likely to be packages of technology. Adaptive research will still be required to link them with other enterprises, e.g., pond fish culture and effective use of animal manures, in local crop production. Primitive methods traditionally used in Asia are highly effective but may become obsolete.

Marketing eggs, broilers, and pork obviously presents problems in less developed countries where the people who can afford such products are relatively few. Export markets may or may not be profitable?

Recommendations

The main goal for improving the world food supply must be that of increasing crop yields in the developing countries, especially in Asia--many developing countries must establish agricultural development as a national goal with relevant research, education, and extension programs to adapt the principles of plant and animal production to local conditions.

Two billion acres of uncultivated tropical land require research to develop soil and crop management systems for sustained food production in these areas.

Research to enhance accuracy of weather forecasting and to modify monsoon.

"It must be clearly recognized that--in addition to weather modification--there are other applications of knowledge of the atmosphere which may have equally beneficial results. An example of this is the prospect of achieving accurate, long-range weather prediction, which may have a benefit-cost ratio greater than that to be obtained by effecting modifications in natural weather phenomena." (NSF. 1966. Weather Modification. 8th Annual Report, page 18)

Imaginative experimentation is needed on ways to reduce the risks and uncertainty facing farmers in their decision-making and on ways to provide greater production incentives. (Vol. I, pages 13-19, Research and Education.)

There may be little direct relationship between my conclusions and the discussion preceding them. The conclusions are not derived from the argument but are nonetheless, in my opinion, relevant, compatible, and essential to an effective research program on the world food problem.

1. Calories and proteins can be supplied--this year good weather has eased supply shortages. Research can help assure continuous adequate supplies.

2. Calories and proteins are not enough. It may not be necessary nor even useful to be 6 feet tall and pubescent at 14, but, if some can through luxus diet, others will not willingly be denied.

Food is one of the important symbols of status. It is a mark of human dignity; to offer my guest the finest food.

3. Development of methods for optimizing output from interaction amongst principal parameters, water, seed, fertilizer, pesticide, energy and culture is of first order of importance in adaptive research.

RESEARCH RECOMMENDATIONS OF "THE WORLD FOOD PROBLEM"

President Johnson directed his Science Advisory Committee to search out new ways to:

1. Develop inexpensive, high-quality synthetic foods as dietary supplements.
2. Improve the quality and nutritional content of food crops.
3. Apply all the resources of technology to increasing food production.

To carry out this charge, a PSAC panel was established under the chairmanship of Ivan L. Bennett, Jr., with then North Carolina State Research Dean H. F. Robinson as Executive Director. The panel consisted of 17 scientists. Thirteen sub-panels were established, each of which developed a substantial report. Finally, all the reports were brought together and published in three volumes in May 1967.

Within the few months that have elapsed since the report was published, good weather and bountiful harvests have eased the immediacy of the recommendations. However, neither those nor the phenomenal promise of genetically high-lysine corn and sorghum nor reported yields of IR-8 rice and Mexican wheat, nor of first-cross corn in Kenya have reduced the problems.

Indeed, there is currently less optimism that family planning is likely to, or even can, provide an ultimate balance between population and food supply. The intricate interacting forces which affect stabilization in numbers of animal, plant, and microbial populations are poorly understood.

Remarks presented by T. C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, before the International Agricultural Development Service Seminar, March 28, 1968, Washington, D. C.

And these forces do not include self-imposed, conscious family planning. The report is replete with variations of the dictum on page 16 "If the payoff is large enough, farmers will change." What is the payoff for voluntary population control?

The recommendations on research are oriented to the needs for problem-solving research, in general where each problem exists.

The report defines and directs attention to the declining condition of more than two-thirds of the human race. The Panel's detailed analysis of the world food problem led to four basic conclusions.

1. "The scale, severity and duration of the world food problem, are so great that a massive, long-range, innovative effort unprecedented in human history will be required to master it."

2. "The solution of the problem that will exist after about 1985 demands that programs of population control be initiated now. For the immediate future, the food supply is critical."

3. "Food supply is directly related to agricultural development and, in turn, agricultural development and overall economic development are critically interdependent in the hungry countries."

4. A strategy for attacking the world food production will, of necessity, encompass the entire foreign economic assistance effort of the United States in concert with other developed countries, voluntary institutions and international organizations.

The bulk of the increase in food supply must come from increased production of farm crops.

There are good opportunities for improved production of livestock, increased utilization of fishery resources, including fish farming, in the less-developed countries.

In Asia, increased yields from land now under cultivation will be mandatory.

The products of technology and knowledge "cannot be transferred directly to the developing nations."

In the meantime, world grain production is increasing steadily. It is increasing, percentage-wise, about as fast in the less-developed countries as in the developed countries. Total food production in the developed countries increased about 27 percent and in the less-developed countries about 24 percent during the past 10 years. But the less-developed countries population increase continues to outpace their food production. In 1959-60, the less-developed countries imported Ca 21 million tons of grain annually; in 1964-65, 29 million tons; by 1980 they may require more than 50 million tons of imported grain. Even so, there is likely to be a world surplus of 30 to 40 million tons of grain in 1980. Grainin excess of commercial or concessional movement--why?

For hungry people of the world to be well fed, most of their food must be locally produced.

We need to double our grain production by year 2000. This looks easy in light of recent increases and perhaps it is. Our interest here is the essential concomitant increase in use of pesticide and fertilizer chemicals. The most elegant, and, in my opinion, most probable course is predictable on the basis of three equations relating pesticide and fertilizer chemicals to yield and to each other on page 140, Vol. II of "The World Food Problem."

Letting P = g/ha of pesticides
F = kg/ha of fertilizer
Y = 1,000 (kg/ha) of cereals

$$\text{Then } \log P = 0.949 \log F + 1.532$$
$$\log P = 2.575 \log Y - 5.683$$
$$\log F = 2.716 \log Y - 7.612$$

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SHALL WE EAT STEAK?

My fellow pitchmen, beaters of drums:

The question posed has an easy answer. For those of us who will and can, there will be steak to eat. Let us consider, then, the conditions and the costs and benefits. For, so surely as in year 2000, there will be steaks, so, too, will there be stews, and surrogates. And you and your congeners will help the people marvel at the wondrous merits of the spun and flavored protein of the soybeans--nutritious, cheap, cholesterol controlled--you can eat it, drink it, wear it, remove wrinkles with it--perhaps even make a poultice for a black eye.

The price of steak, whether measured in terms of sweat or in energy sources "cheaper" than human labor, is likely to be higher than the price of soy surrogates. That word "likely" slipped in from over exposure to prissy economists who hesitate to quote odds as the bookmaker does. But "likely" or "odds-on," it's all the same. In the year 2000, as is the case today, an acre of ground will produce more soy protein than beef protein, probably five times more.

We will have both the truly remarkable products of soy, sunflower, and other oilseed proteins, of the equally good proteins of high protein, high lysine corn and sorghum, and steak.

Talk by T. C. Byerly, Administrator, Cooperative State Research Service, U. S. Department of Agriculture, at the North East Regional meeting of the National Association of Farm Broadcasters, College Park, Maryland, March 30, 1968.

The steaks may have more variety. There is some evidence that in the vast subtropical savannahs of Africa and Brazil, there may be herbivores less susceptible to diseases borne by ticks, and by the Tsetse fly than is Bos. taurus. Too, some of these animals seem to have more lean, less fat, during periods of luxus nutrition than do our domestic cattle and sheep.

Talbot at the Smithsonian and others who have done and are doing research with large herbivores in Africa have published data indicating that some of them may be quite productive under conditions of good range management.

Then, too, in large areas in the United States, as well as other countries, browse can support deer as well as goats. And there are people who prefer venison to chevon or cabrito. Not that venison is "better" than stew meat or soy substitutes. But some folks will pay to get it. And steak and game will continue to be available to those willing and able to pay without diminishing the quantity or quality of food available to people generally.

Now let's look at our beef supply--where it comes from--what it costs--what can we do about it.

Traditional beef production is from grass. Most beef production the world over still is. And it takes a lot of it. About three tons hay equivalent to keep a cow for a year. Where land is free, grass and water for the asking, the price of beef is the cost of looking after the herd. It looked that way in the USA a hundred years ago and ranching boomed--to bust and blizzard in the '80's.

The old range cow is a wonderful beast but not quite indestructible. Going into the winter fat, she can make out as long as she can get range cured grass, dry and weathered to keep her warm. She'll lose a couple of hundred pounds by spring. She'll look pretty sorry with her calf till grass comes but she'll make it. Under good range conditions, she may raise a calf every year and the calf may reach grass fat, marketable condition as a three-year old.

On poor range, she may raise a calf only every other year and the calf may take five years to reach marketable condition.

In the world as a whole, in the United States, too, a lot of beef is produced from grass. In the U. S. we are, however, producing more and more of our beef in the feedlot. Currently, we produce about ten billion pounds, a third of our production, in the feedlot. We've doubled the production of feedlot beef during the past ten years. Where do we go from here?

In all directions, as usual; depending partly on the price of beef, partly on the price of grain and other inputs, partly on the state of the art.

The anticipated animal protein content of average food supplies per person per day for the year 2000 is 22 grams for the world, up 3; 99 grams for USA, up 35; 7 grams for the Far East, down 1.[1/]

In general people eat animal protein in amounts they can afford. Obviously, as income increases and consumption of animal protein approaches appetite for it, the rate of increase with income diminishes. Figure 1 illustrates this point. A straight line on log-log paper

1/ Food vs. People--The Crisis of the War on Hunger and Its Challenge to Economic Development. Excerpts from PSAC Report, AID 1106, October 2, 1967.

rather nicely describes the relationship between per capita consumption of animal protein and per capita GNP over a very wide range.

Pastoral countries such as Ethiopia, with a large portion of their people outside the market economy, have higher animal protein consumption than GNP would indicate. This is also true for the Argentine where abundant meat supplies for the people is a national tradition.

Data for a 25,000 person sample from Madras show a good fit for per capita income of $50 and more. The two lowest income groups, $17 and $20 per capita income were undernourished in terms of total protein intake as well as very low indeed in animal protein intake.[2]

The 1965 Food Survey shows the same trend in the U. S., in our affluent society, as in the world at large. As incomes grow larger, we eat more meat, especially beef, but not in proportion to our income. Amount spent for food at home and away from home obviously follow the same trends. Families with $20,000 a year after taxes spend about 15 percent of their expendable income for food while families with only $1,500 per year after taxes must spend 60 percent of theirs for food though spending less than one-third of the actual dollars for food by their affluent neighbors with the $20,000 after taxes.

Beef differs just as sharply--probably more--the $20,000 family eats three times as much as the $1,500 family at home and spends fifteen times as much for food away from home--a lot of it for beef.

2/ Revelle, R. and R. Frisch, 1967. "Distribution of Food Supplies by Level of Income." In "The World Food Problem," Vol. 3, pp. 43-54. The White House.

The data in Figure 2 show total land area, estimated area of arable land and of pasture, hectares of land per person and per animal unit in the several geographic areas of the world. Animal units are based on inventory numbers and are crude estimates of cow equivalents for other species of livestock. Communist Asia with only 0.4 hectares of agricultural land per person has a slightly larger estimated livestock population than the U. S. with 2.4 hectares of agricultural land per person. I stress this point because, in my opinion, human population pressure is not likely to eliminate livestock as producers of human food. Their scavenger role is an important one.

It is assumed that food, fiber, and forest requirements for the year 2000 will be approximately double the 1965 production. The U. S. will have more people to feed at home. We will continue to provide food for people in other countries, increasingly through market sales.

To this end fertilizer use must continue to expand. Recent rate of increase in nitrogen, for example, has shown a doubling time of about ten years. During the past ten years, corn yields have increased by about 25 bushels per acre, increase in fertilizer nitrogen has been a principal factor.

We can produce the year 2000 grain from the current harvested acreage of Ca 300 million acres. In order to do so, we will need to continue the present rate of increase in use of fertilizer nitrogen. In 1977, we would use Ca 12 million tons; in year 2000, Ca 50 million tons. We would anticipate doubling per acre corn yields by year 2000--and of other principal crops as well.

Now it is a long established fact that response to fertilizer follows the law of diminishing returns. So that efficiency of use of fertilizer nitrogen in year 2000 will be sharply lower than current efficiency. Grain is likely to be a limiting factor only as supply management programs may limit its production.

In the United States about two-thirds of our beef comes from grass and other forage, grazed and harvested. About one-third is produced in the feedlots largely from concentrates. Figure 3 shows how rapidly feedlot production has increased during the past few years.

Cattle are generally sold from the feedlot at liveweights of 900 to 1,300 pounds in choice condition. They enter the feedlot at weights of 400 to 1,000 pounds, usually from grass. The gain per head in the feedlot averages about 450 pounds with an average daily gain of two to three pounds per head.

The production of beef in the feedlot has quadrupled during the past 20 years. Figure 4 shows that it has grown exponentially during that period at an annual rate of about six percent. Growth in all production of cattle and calves has been at about three percent per year, not quite doubling in the past 20 years. How long will these rates of increase continue?

It costs more to produce beef, in terms of nutrients used, than it costs to produce pigs or chickens.

First, the beef cow produces a single calf per year; the sow may produce 15 pigs during a year; the hen, 150 chicks. Therefore, the one calf must bear the total cost of feeding the cow for a year. The brood cow requires about ten pounds of corn equivalent feed units per day for herself plus about ten pounds per day for four months to produce milk for her calf--a total of about 4,850 pounds CFU equal to almost five tons of fair quality hay. With best present technology, it will take more than a ton of CFU to feed the calf from weaning to 1,000 pounds liveweight or a total cost of seven pounds CFU per pound liveweight produced.

Pigs at 200 pounds liveweight or broilers at 3.5 pounds can be produced for less than four pounds CFU and less than three pounds CFU per pound liveweight, respectively.

A good deal, but a diminishing portion, of our beef supply comes from culled dairy cows. Lean beef from this source is excellent for sausage--makes good hamburger, too. It is principally this kind of beef we import from Australia, New Zealand, and Ireland.

In countries in Europe, cow beef and increasingly steers from dairy cows comprise most of the domestically produced beef supply. Veal calves and dairy steers need not be charged with maternal feed cost which is chargeable to milk, the primary product.

Efficiency of production is a real problem with limited potential improvement possibilities. We've reduced feed requirements to produce a pound of broiler by a third during the past 25 years. Feed disappearance figures shown in Figure 5 for beef production show no improvement for beef production feed efficiency during the same period.

There are alternate means of reducing feed cost.

1. Feedlot wastes and poultry droppings can be used up to one-third of ration of feedlot and stock cattle to reduce grain tonnage required in feedlots. In our country, hundreds of millions of tons of animal manures, garbage, wastes from canneries, cheese factories, canneries and packing plant and waste paper have become an enormous waste management problem. All these wastes have substantial nutrient value for cattle and other ruminants. Regulations restrain their feed use in the USA. Whether used directly as feed or used as fertilizer to produce algae for feed use, they present a large potential source of animal feed.

This alternate would greatly reduce the waste disposal problem since millions of tons would be handled in situ. The feed value could replace a substantial amount of other feeds, e.g., soybean meal.

Two principal arguments are used against this alternate. 1. Infectious agents will surely be transmitted through the feed use of feces, even those of other species--Salmonella, for example. Chemical residues in feces and litter would also be ingested. 2. Aesthetically, coprophagy is offensive to many people.

These problems may be evaluated by research. The problem of infective agents is present, though with less intensity, in any manure disposal process except incineration.

The aesthetic argument is meretricious--or will future generations forego meat?

Alternate 2. Reverse trend--extensive beef, dairy, and sheep production from grazing, crop residues, milling, and processing offals and urea.

Millions of tons of feed units are available from crop and livestock processing offals and roughages not used for human food which can continue to provide substantial livestock production in all countries of the world. Their amounts and potential productivity as meat, milk, or egg protein are shown in Slide 1.

If the state of the art improves, we may produce most of our beef in the year 2000 from corncobs, cornstalks, wood molasses, and urea. Presently, use of urea effectively is conditioned on a ready source of fermentable carbohydrate. Corn and urea go well together.

I said the old cow is remarkable in her capacity to winter on low feed intake. Her calf can go for three months on just enough feed to maintain weight, no gain, or even less without harm. And the old cow can recycle some of her own urea--filtered from the blood stream into the rumen and reused. Maybe we can arrange for her to do more recycling. In experiments conducted in Finland, dairy cows fed a ration of urea, potato starch, cellulose, and sucrose have produced up to 4,325 kg. of milk and 164 kg. of protein without any feed source of protein. At Beltsville, an Angus, 132 kg. put on purified diet with urea, no protein, gained 0.45 kg. per day to weight of 422 kg. and bore a calf.

Still a quick energy source is required, e.g., starch or sugar to capture ammonia as it is released by bacteria from their metabolism of urea in rumen. Just low grade roughage alone won't do.[3/]

Hydrolyzed roughage will help, biologically--economy?; specific ensiling procedures and controlled enzymatic breakdown of forage and wood fiber may be useful.

3/ Moore, L. A., P. A. Putnam, and N. D. Bayley. 1967. Ruminant Livestock. Their Role in the World Protein Deficit. Agricultural Science Review 5:1-7.

I began this talk by saying that there will continue to be steak for those who can afford it. The protein in steak, animal proteins generally, are good proteins. They can be, and increasingly they are being equalled by vegetable proteins genetically selected, processed, fortified.

It is clear that people whose diets contain a luxus supply of animal protein more nearly reach their genetic capacity for height than do those with a low intake. They mature earlier. For those of us who are 5 feet 7 inches or less, the advantages of being taller seem obvious, but to those 7 feet tall, I am told the disadvantages of that height are annoying. If it is protein quality in the diet that is responsible for added height, then it can be achieved by adequate proteins from vegetable sources.

Puberty occurs earlier in populations with a high level of animal protein in their diets. I know of no demonstrated advantage to such populations from this phenomenon. Nor am I sure that it has biological advantage to the individual. There is substantial evidence from research with livestock species that luxus nutrition during the growing period is not the best preparation for a long and efficient mature life.

While life expectancy is higher in human populations with a good supply of animal protein, most of this is clearly due to a higher survival rate during infancy and childhood. Clearly animal protein is no fortification against old age. Its accompanying fats are suspect.

A final word of caution. Animal proteins are good, and in moderate amounts, are good for us. Perhaps more importantly, they are attractive in natural form. They are accompanied by iron, niacin, riboflavin, and

cobalamin which we need. Milk is a principal source of calcium for those who drink it or eat its products.

All these things can be provided from other sources, increasingly from chemically processed materials. If vegetable and other proteins are to equal animal proteins in human nutrition, then these accessories must be provided.

It's been fun talking to you. Thanks.