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# UTAH

*Utah State University*



*Logan, Utah 84321*

# SCIENCE

AGRICULTURAL EXPERIMENT STATION • DEC. 1970 • Vol. 31, No. 4







## UTAH SCIENCE

Science today—agricultural practices tomorrow .....	87
Agriculture and social innovation, Dean F. Peterson .....	92
Management of crops for water use efficiency, R. J. Hanks and W. G. Dewey .....	94
Wildlife notes .....	95, 98
There is a computer in your future, Kent Bridges .....	96
Genetic engineering, Eldon J. Gardner .....	99
Utah Science index to volumes 30-31, 1969-70 .....	103
Timber Notes .....	107

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# SCIENCE TODAY

## AGRICULTURAL PRACTICES TOMORROW

Agriculture is among the most dynamic of our basic industries, having within it all of the forces for constant change that are inherent in living things. Although the process of transition has been continuous, the last four decades have seen it accelerate and produce an almost complete change in principles, technology and equipment. This period has recorded the evolution and adoption of all types of power machinery and the general use of fertilizers. Most of the available insecticides, herbicides, and other pesticide materials were discovered and placed into use for control of diseases, insects, weeds, and other pests within those years. Effective breeding practices based on the science of plant and animal genetics have produced superior new crop varieties and vast improvements in our different breeds of livestock.

Great as have been the changes of the past few decades, we can expect them to be equalled or surpassed in the years ahead. The purpose of this article is to explore likely events and discoveries that may affect agricultural practices over the next two decades. The briefly described possible developments are based on the ideas of a number of scientists at Utah State University. Admittedly some of these predictions may not be realized, but the possibilities are far more than idle speculations.

The roots of the future are in the past and the present, and many of the practices that will be common 10 years hence are now being studied in the fields and laboratories of Agricultural Experiment Stations and other research agencies. What is being projected, therefore, is the development and application of concepts now in the research stage and the extrapolation of these trends into the future.

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*This examination of future possibilities for agriculture was compiled as part of the process of critical program review and planning being undertaken by the staff of the Agricultural Experiment Station.*

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During the next 20 years, the world's population is expected to increase by approximately 2 billion, with 50 million of these being in the United States. On a world basis, this soaring population and its accompanying increased food requirements constitute the primary challenge to agriculture. Science now recognizes that insufficient protein in the human diet results in reduced physical and mental development. Mental development is influenced by nutrition primarily in fetal and early post-natal periods. Of equal or greater import, however, are the rising expectations of all people. These expectations are for more food and fibers, with greater variety and better quality. People also want personal access to the beauties of nature—situations that are often associated with agriculture.

Agriculture must, therefore, occupy an increasingly central role in the lives of people. It is not only the provider of food, it is the husbandry of land and water and of the accompanying plants and animals that add beauty and meaning to the lives of all people.

### GENERAL

There is general agreement that the trend toward fewer, larger and more specialized farms will continue. Less certain are the year to year patterns of that trend. Corporate or cooperative farms, each made from several smaller farms that are now, or in the future will be, too small for economic

operation seems likely. Increased use of special machinery to further reduce hand-labor appears inevitable. The need to have scientific control of water usage, fertility, pests and diseases will continue to make the inadequately informed farm manager less and less competitive.

An opposite trend is the flight of more and more people from urban centers, with a consequent increase in small, part-time subsistence and hobby farms. These operations will likely involve more people every year, but they are not apt to be major factors in total agricultural production. Operators of these small farms are people who become involved in agriculture because it represents an attractive way of life rather than a business or profession.

### INTERNATIONAL AGRICULTURE

The revolution in agriculture is gaining momentum in all lands and this will have many effects on the U.S. food market. Up to the present, the tropics have been a food deficit, impoverished region. But this vast region has a tremendous potential. Almost half of the unfarmed arable lands of the world are in the tropics. In addition, agriculture provides much of the immediate hope that people living within the tropical areas have of gaining a share of the world's wealth. The great variety of fruits and other crops that grow in the tropics are likely to become common on the American table. Breadfruit, papayas, mangos, casava and more varieties of bananas and plantains are only a few of the many products that may replace, in part, some of our present food.

International trade in agricultural produce will increase, and world regions of crop specialization will continue to develop on a world-wide basis.



## WEATHER PREDICTION AND CONTROL

Publicity given to developments in this area may have generated exaggerated expectations. Increasingly precise weather predictions that provide greater local detail will continue to become more commonplace. The informed farmer should eventually find that his first morning chore is to check the weather forecast before planning the day's work.

For Utah, weather modification practices will almost certainly substantially increase moisture storage in mountain snow packs and provide more water for the growing urban and industrial areas as well as for agriculture. A potential 20 percent increase in mountain precipitation could increase stream flows by a third. Also in the offing are better predictions and controls for hail and local frost.

Grand schemes that are being considered could modify the climate on a regional or even global scale. These, however, are so fraught with political controversy and uncertainties as to be largely unpredictable.

On a micro-scale, weather will continue to be modified by such directly farmer-managed processes as strategic use of irrigation water, more attention to microrelief in planting crops, and the use of heating cables in the ground. Plastic, inflated protective structures are becoming more popular for specialty crops. These can greatly conserve moisture and prolong the crop season in such areas as Utah.

## NEW CROPS, GENETIC ENGINEERING

Viewed as a factory, a farm converts energy from the sun, carbon dioxide from the air, and water and minerals from the soil into carbohydrates, proteins and other plant and animal products. Increased production, therefore, requires that arable land be kept occupied with efficiently growing plants as much of the time as

possible. Most crop plants have two basic limitations, an inability to capture and use more than a small part of the incoming energy in sunlight, and a slow rate of absorption of the small concentrations of carbon dioxide (0.03 percent) in our common atmosphere. An average crop utilizes only 2.5 percent of the sun's energy. The theoretical maximum utilization is about 10 percent. But crops vary. Corn, for example, is about twice as efficient as wheat, and there are potentials for increasing the efficiency of nearly all crops.

Studies of plant efficiency in utilizing light and carbon dioxide indicate that distinct gains can result from altering plant geometry, and plant breeders are working to take advantage of these insights. New crops are being bred to have more erect branches, and narrow, relatively thick leaves that stand almost vertical, and have small cells.

There are long-range potentials for developing quite different crops than those now available. The great discoveries about the secret of the genetic code have shown that four molecules, combined in specific ways to form long chains, constitute the genes and chromosomes that control the characteristics of all kinds of life. Pieces of such chains of genetic code can now be transferred from one organism to another. Also receiving intensive study is the fusing together of cells from different plant species. Such fusing, combined with established procedures for growing single cells into complete plants, constitutes a potential for developing new crops quite different from those we now know. While the potentials of these recent discoveries are tremendous, the time-table for reduction to practice is highly uncertain. Although presently unpredictable, these developments are too important to be overlooked by agriculturists with vision.

## PLANT HORMONES

Increasing knowledge of the internal chemistry of plants in relation to growth processes is opening other

doors to scientific farming. The processes of flowering and seed development have been found to be controlled by a hormone sensitive to light, named phytochrome. Even brief flashes of light can trigger the initiation of flowering or fruiting in certain species. Other hormones control swelling of buds, or growth of roots, or changes in plant composition. In the offing are opportunities to avoid frost damage in spring by delaying flowering or to hasten crop maturity in the fall. Various chemical treatments may be used to increase protein, oils or other desired crop components.

In the long-range, manipulation of plant chemistry may provide new avenues for disease control in crop plants. Many diseases have specific effects on certain enzymes or other vital plant constituents. Identification of the precise points of damage sometimes facilitates chemical treatments to relieve immediate damage. Such knowledge can also give a base for breeding crops resistant to such injuries. As such treatments are reduced to practice, the knowledge required to be a successful farmer will increase tremendously.

## BREEDING MORE NUTRITIOUS CROPS

The relatively low quantity and quality of protein in cereal grains is one of the primary causes of nutrient deficiencies in developing countries. Cereal proteins are commonly low in two amino acids, lysine and tryptophan that are essential for humans and animals. A leap forward was the discovery at the Indiana Agricultural Experiment Station that some corn seeds, uniquely resistant to light transmission, carried the inheritance factor for protein with double the usual content of lysine and a 65 percent higher amount of tryptophan. Protein deficient children fed on products from this corn responded as they would if fed a skimmed milk or meat supplement. Hogs fed on this corn made gains comparable to those attained with ordinary corn plus a protein supplement. The gene for high quality pro-



tein is now being bred into corn varieties adapted to world-wide growing conditions. The findings with corn have stimulated the search for new genes in wheat, rice, barley, sorghum and other cereal grains. Already a selection of wheat with a potential 50 percent improvement in lysine has been reported, and greater gains are anticipated. The results will affect feed rations dramatically, but of even greater importance is the potential help to the almost two-thirds of the world's population that depends primarily on cereal grains for food.

Studies at Utah State University are also indicating that some chemicals sprayed on plants can alter the chemical composition. Protein increases have been most pronounced but the potential for different results with other chemicals are great.

#### **DIRECT PROCESSING OF PLANT MATERIALS**

Questions are being asked about whether proteins and other food materials can be extracted directly from plant materials and processed into attractive foods to bypass the use of animals. Imitation bacon is a reality. So also are quality filled milk products using combinations of milk constituents and non-milk materials. Synthetic milks are under study but as yet such products will likely include casein or other milk derived substances. How about substitutes for other meat products, and eventually even roasts and steaks? The race is on between such factory developments on one hand and the breeding of more efficient livestock, along with the developing of better feeds and production practices, on the other. The real winner will be the consumer, who will have more food choices and reduced food costs.

#### **HORTICULTURE**

Mechanical harvesting of fruit is now extensive, but still in the development stage. The next major step for some fruits will be the use of dwarfing stocks and harvesting by mowing the top growth, followed by separation of

fruit from the mower-harvested material, grading, packaging and immediate movement of fruit into cold storage.

Chemical sprays can change the shape and color of some fruits. Avoiding frost damage by using chemical sprays to delay blossoming or hasten maturity should soon reach practice. Chemicals and controlled atmospheres are now prolonging storage potentials for fruits other than apples and more developments along this line are in the offing. Greater greenhouse production of vegetables and greater variety and possibly lower prices in winter months seem likely. Insulated growth chambers are replacing greenhouses in some areas. Claims are that savings in heat compensate for lighting costs.

The emphasis on ornamental horticulture will increase. People increasingly removed from nature in its wild forms are fighting back by seeking more natural beauty in their tamed surroundings. Home gardens will likely become increasingly popular centers of interest comparable to their counterparts in Europe. Highway cuts and fills must not only be stabilized against erosion, they must be made avenues of varied beauty. Public parks must increasingly be viewed as a central civic responsibility.

#### **ANIMAL REPRODUCTION**

As with plants, application of the newer knowledge concerning body chemistry has a potential for greater livestock production. Hormones have been found which control the estrus cycles in livestock. Through integrated treatments and management, the dates of calving and lambing are already coming under control. Hormone treatments plus careful breeding and selection may permit the harvesting of two lamb crops per year and an increased proportion of twins.

Knowledge of sperm morphology and activity and the ability to separate sperm carrying male traits from those with female inheritance offer the potential of sex control. There is

also the possibility of realizing short-cuts in animal breeding similar to those indicated for plants, although the complications inherent in animal reproduction will delay the date of general application. Artificial insemination is now an established practice for cattle, with increasing success for sheep, hogs, and other animals. This makes possible the rapid and widespread incorporation of high-production germ plasms in livestock. Fertilized egg transplants from quality cattle to inferior grades are feasible and could further speed up the improvement process.

Future goals of livestock breeding programs will include greater efficiency in conversion of feed to meat, better meat quality with less waste in fat and other undesired products, more disease resistance, faster growth rates, and more multiple births.

#### **POULTRY, TURKEY, AND EGG PRODUCTION**

Animal protein from avian species is economically produced, rivaling the efficiency of fish protein production. It is highly nutritious, and the quantity of production is flexible and controllable. The rapidity with which production can be increased or curtailed makes such meat sources adaptable to changing market situations. Poultry products are presently replacing some red meats in processed meat products. With the future prospects of better controlled housing, mechanized handling of broilers and turkeys and frozen semen in artificial insemination, the year round efficient low-cost production of poultry and turkey meat is almost here. Large scale production units for both poultry meat and egg production have revolutionized these industries. A continuation of this trend is foreseen.

#### **DAIRY PRODUCTION**

Past trends for more cows per farm unit, higher quality meat and milk products, and reduced markets for fats are likely to continue. A look at the future of dairying by University



of Wisconsin scientists resulted in a prediction that one-half of present dairy farms will be gone by 1980; the average number of dairy cows per farm will triple to about 75, milk production per cow will increase by 50 percent; total numbers of milk cows will decrease by 25 percent and essentially all milk will meet grade A standards and be bulk handled.

The development and use of milk substitutes, including filled and synthetic milks, will increase and more products will evolve in association with the processing of wastes from manufacturing cheese and other materials.

### HARVESTING RANGE

Every rancher knows that sheep and cattle have different grazing preferences. Also apparent are the marked reductions in grazing permits on much of the public range, while deer and elk populations increase and introductions are being made of big horn sheep, bison, antelope and other game species. The resulting controversies have generated questions and suggestions needing critical attention. Studies in Africa indicate that high yields of meat per acre on some arid land ranges can be obtained from selected mixtures of game animals; greater returns of meat from most ranges will be possible by selecting grazing animals better suited to the mixtures of plants on specific ranges. Advantages claimed for mixtures of several species of native animals include utilization of a wide range of vegetation, greater resistance to disease, lower water requirements, and better movement and range utilization even at great distances from water sources, and more efficient conversion of some plant materials to flesh. A new species that might be adapted to arid or semi-arid ranges is the Russian saiga antelope.

A related question involves the greater production and utilization for food of cold-blooded animals, such as reptiles, amphibians and invertebrates. Such animals waste less energy in maintaining body heat and there-

fore may be more efficient in converting plant materials to meat.

Regardless of the scale of use of a greater variety of animal species, the improvement of feed production on ranges through vegetation modification is a well established practice that will increase and become more effective as knowledge and understanding of the interactions of climate, soil, plant species, and management practices increase.

We can expect an expanded use of range land for many other uses. Recreation and aesthetic aspects will cause changes in both grazing use and timber production. Economic returns to range land operators and society from recreational activities needs to be balanced realistically against grazing returns. Multiple use as a continuing viable concept will require education and understanding on the part of the public. The role of managed grazing in controlling vegetation and maximizing water yields from mountain watersheds is, as yet, only partially understood and inadequately utilized in public land management.

### FISH PRODUCTION

Application of newer knowledge of fertilizing and managing inland waters for fish production is yielding startling results. Catfish production in farm ponds has become a major industry in Alabama, Arkansas, and other southeastern states. Now we seem on the verge of more intensively managed tanks of water with controlled temperature and food supplies for selected species of fish such as trout, bass, salmon and catfish. One claim from Pennsylvania studies is for production of one million pounds of fish per acre per year in silo-type tanks. Reported results are for a pound of fish production from 1.5 pounds of a feed mixture of sunflower seeds, soy beans and ground-up fish heads. The natural environment is harsh for fish, with losses of 95 percent of fingerlings being common. Managed waters can constitute dependable new sources of fish. Fish farming is increasing in importance.

### INSECT CONTROL

The rapid adaptation of insects to the various control practices devised by man, and ecological problems associated with application of control measures, continue to challenge our ingenuity. The demand for adequate quantity and quality of food and fiber requires that there be no relaxation of insect control. The concept of "insect management" has recently been developed in association with increased realization of our ecological responsibilities. We must control the pests, but while doing so, we must preserve and encourage the parasites, predators, and pollinators.

The central theme among entomologists working on pest control problems is integrated control, or pest management, in which various methods of pest reduction are combined to bring about the desired result. Parasites, predators, insect pathogens (bacteria, fungi, viruses), and plant resistance are used wherever feasible and chemical and cultural methods are integrated with these as necessary to control the pests. In Utah, the integrated approach to orchard insect and mite control is being recommended and currently practiced by many growers.

Integrated control is also being studied for use on forage crops. Here it has added benefits, especially in preserving the pollinators of seed crops. Insect management of pest insects must be synchronized with the management of the beneficial insects. Alfalfa offers some interesting possibilities for the near future. USDA entomologists associated with Utah State University have succeeded in selecting honey bee strains with an improved ability to pollinate alfalfa. They have also developed better techniques for managing two species of wild bees for pollination purposes.

Several new approaches to insect control are being developed for future use. Male sterilization has been successful in controlling the screwworm in the southern United States, and is



now being tried against the pink bollworm in Arizona and California. Of direct interest to Utah is the cooperative work in the western USA and Canada for codling moth control through sterilization. Research has provided the know-how; now wide-scale cooperation and financing are needed to put the procedure into practice.

Sex-lure chemicals also may aid in insect control in at least two ways. They make possible a much better sampling of insect populations so that insecticides can be applied much more precisely. They can also be used to attract insects to traps, baits, or other control devices. These attractants are highly specific and can be used to help control single species without affecting others. Still further in the future are the use of synthetic hormones to upset insect metabolism and development, and genetic manipulation through the release of male insects of non-adapted or non-resistant ecotypes to breed with females which have become adapted to a particular crop or have become resistant to control practices being used.

### HARNESSING THE SUN'S ENERGY

The most important process of nature and one of the most difficult to decipher has been photosynthesis. The extensive literature on this subject indicates that great strides are being made toward achieving controlled use of the reaction apart from living plants. The impact of an application of the growing knowledge about photosynthesis on agriculture is hard to estimate. Already within the realm of possibility, albeit still in the extended future, is the use of such a synthetic process to produce sugar, starches, cellulose, and even more complex materials. In fact, once light or other energy can be readily converted into chemical energy, a vast array of products can be produced with present technology.

### NEW WOOD PRODUCTS

We have all observed the rapid increase in costs of lumber and build-

ings. We also read of protests about the burning of wastes from sawmills and discharging of odorous paper mill wastes into streams or the ocean. Great strides have been made in fabricating strong, attractive building materials such as chipboard from materials previously considered wastes. Similar processes may help wood products cope with increasing competition from plastics, lightweight concrete and other substitute products.

More significant is the coming shift in production and processing methods used in wood industries. A transition is seen toward greater use of fast-growing trees such as poplars with machine harvesting and chipping, producing a mechanically manageable product that can go directly to the processing plant. The new criteria will be efficiency of harnessing sunlight, response to improved environment, quality of fibers, and ease of management. New processing techniques will make many softwoods available for products previously reserved for hardwoods.

This new technology provides a base for harvesting and using many woody plants previously considered of little value. The possible impact of this on the use of our western pinyon-juniper forests is not clear, however, because of their location and relatively low productivity per acre.

In addition, mass produced cellulose wood materials may be used for animal feeds. These materials can be hydrolyzed to sugars and starches, and fortified with minerals and such protein substitutes as urea to provide high energy feeds.

### ENVIRONMENT AND FARMING

The growing popular interest in the quality of the environment has had considerable impact on farming, but the future is even more foreboding. Consider such public-induced controls as banning of chlorinated hydrocarbons and other effective insecticides and herbicides, restrictions on burning of wastes, and regulations controlling the disposal of animal wastes.

Multiplication of such regulations may well be the most costly and difficult of all the problems confronting farmers in the next decade. As of now, farmers are faced with relocating barns and corrals and installing expensive waste management systems to prevent contamination of streams and other waters.

In the debate stage is the responsibility of farmers for pollen that may be troublesome to other people as a causative agent for hayfever. Injunctions will probably be issued requiring control of pollen-producing weeds such as ragweed. Some trees, grasses or even crop plants may be placed on restricted lists. Excessive soil erosion may eventually be grounds for punitive action against the responsible farmer.

In this melee, the farmer will also gain support. Damage to plants and animals from industrial, automobile, and even general public waste products such as sulfur oxides, nitrogen oxides, fluorides, lead, and oxidants will be even more stringently controlled and the weight of public opinion will give further support to those who seek protection and redress.



**PROTECT** your FARM with its quality FOOD and FIBER products from the ravages of insects, weeds, diseases and other destructive pests. Guard against hazards resulting from improper use of pesticides.



# AGRICULTURE AND SOCIAL INNOVATION

Economists have said "there is no food shortage." The argument is that, if there were, prices would rise; whereas, on the contrary, increased food production results in dramatic decreases in prices. This is another way of saying that the market will not absorb much additional food at current prices of production. The undernourished and the imminently starving simply do not have the income to buy food. Even if this situation were "economically" acceptable, it is certainly unacceptable in humanitarian terms. Something simply must be done.

Besides the basic social problem of income distribution or simply lack of income opportunity, there are many other problems which frustrate increased agricultural production in developing countries as agriculture tries to move from a subsistence to a market economy. All of the new inputs of seed, fertilizer, tools and water need to be purchased by the farmer. He must have cash or credit. There must be a market responsive and capable of supplying these needs and there must be incentive rewards and minimum risks.

These things have all been said before; they confirm the idea that the practice of agriculture is very much a social phenomenon and that the more advanced agriculture becomes, the more sensitive it is to social organization. In North America, most western countries and Japan essential social adjustments have been made. This does not mean that undernourishment or malnutrition have been eliminated even in these countries, but that at least the system works well enough so that agriculture is viable in a market economy.

DEAN F. PETERSON

Unfortunately, resources and capital have become so constrained in many developing countries that needed adjustments are extremely difficult or impossible. The small size of farm holdings, the heavy dependence of most of the population on agriculture as the primary source of income, and inadequate marketing systems are a few of these conditions which obstruct progress even when reasonably adequate technology exists.

## SOCIAL INNOVATIONS

Some experts have pointed out that new and highly significant social inventions or innovations might still occur and that these could greatly change agriculture. Social innovations, large or small, continue to be made. Fairly recent important ones include such things as the income tax, the credit card, sector planning income-output analysis, rapid transportation and instantaneous communication. In agriculture, a major early social innovation was the concept of private ownership of land. This protected the land from common encroachment and made control of the environment for cropping purposes possible. The industrial revolution was a major social innovation which positively affected agriculture in many ways, one of which was providing greatly enlarged cash markets for food products that were surplus to the needs of the producer's family.

More recently, the concept of price support plus commodity storage has

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removed from agriculture much of the risk of overproduction and resulting disastrous price drops thus stabilizing farm business with consequent benefits to the stability of the whole economy. Many such social actions can be cited; some are highly significant, others are relatively minor. However, almost all have occurred in politically stable, relatively rich countries. Capital has usually been a primary requirement.

## REVIEW OF PROBLEMS

A review of some of the problems in agricultural transition may provide examples of where social innovations might occur. One of the problems of traditional agriculture is that of small scale. Farms are generally very small. In East Pakistan, the average farm size is 2.4 acres. A large share of the farms are under 2 acres.<sup>1</sup> Since these holdings are fragmented, the average farm plot is less than 1/2 acre. Use of modern equipment except on some kind of cooperative basis is often impossible; likewise, such services and inputs as marketing and supply and credit are difficult to obtain. Fairly obvious answers include consolidation into large holdings, formation of rural cooperatives or agricultural communes. In developing countries, where 60 to 80 percent of the labor force may be on the farm, the first solution would create tremendous unemployment. Communes in Russia have been notable for their failure to produce. Cooperatives seem the preferred way, but there seems little evidence of their success so far. Is there another solution, or could simple changes in cooperative formation cause them to be much more effective? Again in East

<sup>1</sup>In this crowded country only 0.3 acre of cultivated land per person is available.



Pakistan, developments led by the Pakistan Academy for Rural Development have shown that farmer initiative, advance payments for pumps, identification of local "master farmers" and several other modifications of conventional practice have led to extraordinary success and considerable optimism.

Another very difficult problem is provision of credit. Most of the credit in developing countries is within the private sector at usurious rates. Institutionalized credit is greatly inadequate in supply, and much of it is never repaid. Is there some device that could somehow stimulate the development of essential credit preferably through increased savings of the farmers themselves? If ownership of all land were vested in the state, as in Israel, would there be more likelihood of reasonable, long term credit arrangements?

Turning to the problem of unemployment, with 30 to 40 percent unemployment, hunger problems are not going to be solved. In most densely populated developing countries, population increases can no longer be absorbed on the farms. Other sectors of the economy will have to provide employment. This will take capital, manpower training, technology, and markets that do not now exist. Paradoxically, there exists on one hand large supplies of labor at almost zero opportunity cost and on the other there are tremendous needs for physical infrastructure such as roads, housing and power development. In any solution capital appears to be an essential element. Since the specific technologies may not exist either, perhaps this example involves much more than social innovation. Nevertheless, could a social mechanism be invented that could help close the gap between unemployment and the need to create infrastructure capital?

In other areas of the world, the land tenure situation may be the opposite of the one cited previously. Holdings may be in large private estates inaccessible to development by a large percentage of unemployed or landless citizens. The best solution

may not be simple redistribution of land. Could there be devices by which the efficiency advantage of large holdings could be retained and employment with better distribution of income developed both within and without the agricultural sector?

One would have to be pessimistic if he were asked about the likelihood that some social innovation might lead to complete solutions of the problems resulting from the usually worsening situations discussed above. These may not be very fruitful areas in which to expect social innovations to occur. An obvious requirement in all cases is capital. Somehow no one has figured out how to cause development without it nor how to "grow it on trees." On the other hand, increased research on the socio-economic process of development related to identified problem areas could prove very fruitful. The Comilla experience in East Pakistan is a promising example.

#### THE AID THEORY

An innovation developed since World War II is the concept of capital and technical assistance, "aid", by the developed countries to the developing ones. The concept includes stimulation of the transfer of technology by technical assistance, and providing limited marginal capital to permit the introduced technology to reach a critical take-off threshold. Besides humanitarian objectives, the incentives of a more stable world and additional commerce and markets justify the efforts of the developed countries. *Aid* has taken a great many forms. Bilateral aid consisting of grants, low-interest loans, and technical advice as under the U.S. Agency for International Development; international bank loans, hard and soft, assisting through the UN agencies and through international lending or granting consortia are principal forms.<sup>2</sup> Sale of

<sup>2</sup>The private foundations, particularly Rockefeller and Ford, provide a special form of aid. Development of new varieties of wheat and rice are technological, however, the involvement of the foundations in designing a research program based on international needs and of implementing the results in concert with other forms of aid and local country assistance is a social innovation which has paid off in the form of the "Green Revolution."

surplus grain for local currency with subsequent allocation of the currency to incountry development, the "P.L. 480" is another example.

Presently, *aid* is somewhat in bad repute. Some feel that *aid* capital grants and loans have had little or no effect; technical assistance particularly is discredited in some circles. But the returns are a long ways from being counted and it is almost certain that the details of the best mechanism haven't been developed yet. Perhaps we haven't yet learned all we need to know about how to do "aid".

The basic developmental aspects of *aid* have been suborned by political motives internally and externally, and great impatience and red tape; and this is not exclusively true of the bilateral programs. Even though development clearly involves reallocation of in-country resources, a condition which tends to increase internal political instability, *aid* has been used as a reward for stability and its withdrawal as punishment for the reverse. Has the time now arrived when *aid* should be committed to a purely developmental objective regardless of political implications?

Perhaps *aid* is occupying too much of this discussion, but the great untapped market is in the agricultural sector of the developing and partly developed countries. Here are still most of the world's farmers, so what happens here cannot help but have tremendous significance to agriculture globally also.



**PROTECT** your WATER, SOIL, and AIR—our basic natural resources—from accidental contamination by pesticides or other chemicals on the farm, in the forest, or in the city.



# MANAGEMENT OF CROPS FOR WATER USE EFFICIENCY

R. J. HANKS AND W. G. DEWEY

With the increasing demand for water by non-agricultural users, farmers in the future will be forced to consider water use efficiency as a management factor. Consolidations of farms and the decrease in the number of farmers will enhance this trend.

Present-day management decisions involving crops, varieties, etc., are often made on rather general criteria estimating water availability and general plant and climatic characteristics. Future research will provide quantitative information on the complex behavior of a given crop as related to soil water and climate. Cooperative research by soil scientists, climatologists and plant breeders will be needed to produce the plant-soil-water-climatic blueprint that will allow management decisions to be made. Once these data are available as "fodder" for the farmer's computer he can simulate many management systems. This would be a useful occupation during the winter. This simulation technique will require a knowledge of the crop behavior as influenced by soil water level and climate (the basic blueprint) as well as the expected climatic and water supply factors for the coming season. Optimization of the best system will require information on expected return, production costs, etc. Present-day techniques are available for such optimization but much of the basic "blueprint" information is lacking. This type of management system will call for the establishment of commercial management firms with a large data bank of information and technical know-how.

Once a management system is chosen, day-to-day adjustments will be made in the management scheme

to allow for differences between the actual and projected climate and soil water and reservoir water conditions. If seasonal rainfall turns out to be much less than expected and/or irrigation water supplies are much less than expected, simulation of alternative choices can be made from the present conditions and expected water supply and climatic conditions until crop harvest. For example, it may be more profitable to eliminate one irrigation of alfalfa and irrigate the wheat at a critical stage of growth.

The blueprint will be sufficiently detailed to allow an accurate prediction of the effect of a given soil water and climate on ultimate saleable plant products. This blueprint will be basic information furnished by the seedsmen for every variety and crop sold. Once developed, the plant breeder will use the blueprint to guide him in developing varieties tailor-made to specific climatic conditions.

Future management schemes may also involve more coordination of natural production versus synthetic production of foodstuffs. It may be more economical in some instances to grow crops that produce large amounts of vegetative dry matter rather than those that produce grain. The crop dry matter may then be used as raw material for a food factory that will produce a grain-equivalent. The production of grain (or fruit) is much more subject to uncontrollable factors than is the production of bulk dry matter.

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Future management schemes may also provide for much wider use of chemical treatments to plants. Certain varieties of wheat, for example, have the capacity to translocate a greater proportion of the nitrogen from their leaves and stems to the maturing kernel than do other varieties thus resulting in higher protein and more nutritious grain. This genetic ability to transfer food materials from unused portions of the plant (in this case the straw and leaves) to the edible parts in greater than normal amounts may eventually be duplicated or even enhanced by the application of appropriate chemicals. Chemically controlled processes in plants trigger the cessation of the vegetative growth and initiate grain (or fruit) production. During years when water is in short supply the application of the right chemical at the right time might shut off vegetative growth and initiate grain formation much earlier than normal. Built-in plant protection against many of the diseases which presently take a heavy annual toll of crop plants will be provided by systemic fungicides of the future.

Physical treatments of plants may also be of wide use in the future. It may be better to cut crops at the right time to produce another vegetative crop rather than produce grain. Heating or cooling the plant at the current growth stage may force a more desirable product to be produced. This has the advantage of not adding pollutants to the environment.

The following is an example of the type of communication that may occur between the farmer and the management service. Peter is the management service's friendly computer.



Dear Pater, (Aug. 10, 1990) Please give me advice on crops to plant next year and management practices to use. Please note I have one less employee now since my son Bill has run away. Thanks—John Farmer 47-2139-7573

In reply John gets the following letter:

Dear John Farmer, (Aug. 20, 1990) We advise that you get ready to plant 200 hectares of winter wheat hybrid SK4 on Oct. 1-2. You should till with your HAR-7 to a 7" depth using TRA4 on Sept. 18-19. Plow the rest of your acreage before Nov. 15. Your sugar beet harvester BH-3 needs repair as we told you some time ago—do it now. Sorry about Bill. Could we help you with our social service plan? We suggest you adjust by using your wife, Mary, since she no longer has her cub scout job. Your 1990 net income looks like \$28,500. We project \$32,000 for 1991. You look better every year John—keep it up. Thanks—Pater.

Similar communications keep coming back and forth during the winter months with the John and Pater "hagling" in response to changes in conditions. A letter exchange in the spring may go something like the following:

Dear Pater, (March 10, 1991) Please advise what to do now that the irrigation reservoir level has not reached the expected level. The town board wants to buy my water for \$60 acre/foot—what do you think? I still don't like planting all of those tomatoes—are you sure the anti-freeze compound works? Everything else going as planned except scouts trying to get my wife again. I still don't want your damn social service. Thanks—John Farmer 47-2139-7573.

Dear John Farmer, (March 13, 1991) Irrigation reservoir level problem will probably make it necessary to cut one irrigation from your winter wheat. This will be the June 15-20 irrigation. Soil water storage in other fields will help to minimize problem.

Don't sell any water to the town board for less than \$105 acre/foot. We guarantee the tomato anti-freeze compound, so don't hesitate to plant. Last year's net income turns out to be \$28,748. We project \$30,000 in 1991, down because of possible water shortage. Suggest you repair your sugar beet harvester BH-3 now. Joe B and Co. will save you \$500 if you have the job done now during their slack season rather than waiting until mid-summer like you did last year. Status of winter wheat project yields 0.95 of potential, first irrigation scheduled May 15. Status of sugar beet projected yields 0.88 of potential. Plant on April 15. We are switching to variety MB-12 because of tight water situation. Status of ..... Have information that scouts do not need Mary. Thanks—Pater.

During the summer, communication from Pater to John is almost daily to update recommendations in response to changes in climate and other fac-

tors. A typical communication might be:

Dear John Farmer, (July 1, 1991) We advise you to spray your wheat with MON-423 spray to induce seed formation. Projected yields 0.62 of potential without spray or any more rain. Projected yields 0.78 of potential with spray. Use spray R1G-2 but change nozzle size to 0.2 cm. Status of sugar beets projected yield 0.85 of potential. Next irrigation scheduled July 4-5. Irrigate for 6 hours this time. Status of tomatoes projected yield 0.91 of potential. Next irrigation due July 8-9. Irrigate for 4 hours this time. Suggest you may need to clip tomato vine on July 15 with CHOP-4 to reduce vines and induce flowering. Plan on applying anti-freeze compound FR-101 Sept. 1. Glad to hear Bill, wife and baby have returned. It will cost you \$12,500 to take him in as a partner now. Status of..... Thanks—Pater.

## WILDLIFE NOTES

True eels are the only fishes with jaws and snake-like bodies.

The use of the words "frog" and "toad" is often confusing. In general, frogs have smooth skins and toads warty skins.

The mackerel is a swift swimmer and uses so much oxygen that in warm weather it must keep swimming all the time to maintain the necessary flow of water to its gills.

The California condor, largest living bird of North America, attains a wingspread of nine feet and a weight of 20 pounds.

Beaver have an average life span of 10 to 12 years.

The coyote ranges over more of the U.S. than any other single species of wild animal.

Leach's petrel, a bird the size of a robin but with legs so weak that they cannot support the body, can dig a tunnel six feet long in three nights.

Rattlesnakes shed their skins about three times a year, acquiring a new rattle each time.

The weasel is a very sound sleeper. It can often be taken up by the head, feet or tail and swung around for a considerable time before it begins to awaken.

The electric sparks from a cat's body when the fur is under friction are probably caused by the peculiar dryness of the hair which is free from the oily substances common to the coats of animals.

A 20-pound snapping turtle has a striking range equal to the diameter of a bushel basket.



# THERE IS A COMPUTER IN YOUR FUTURE

The future will witness the continued development of numerous technological devices. Computers will share, and in many cases cause, these advances. Few other machines, however, have the potential to produce more fundamental changes in our lives.

In spite of their importance to us all, computers are surrounded by a mystique. They represent one of the least understood technological devices with which the public has contact. Their super rapid, brainlike and impersonal processing of information, from stock inventories to credit card billing, bank statements, and the checking of income taxes just adds to this aura of strangeness.

## WHAT IS A COMPUTER?

The term "computer" in actuality describes a complex system of electronic machinery (called "hardware") and instructions which control this hardware. The main components of the hardware portion of the computing system are the central processing unit and the memory. Attached to the central processor are a variety of hardware devices which are used to transmit and store data. These devices are termed "peripherals," they commonly include card readers, printers, and magnetic tape units; these are the means of communication to and from the computer.

An important property of computers is that the central processor and memory are each made up of very few types of electronic components. These components may be thought of as building blocks. Instructions to the computer provides the arrangement of these "building blocks" into a specific functional system, much as actual building blocks are used to construct buildings following an architect's blueprints.

This means of computer construction has some very practical aspects.

## KENT BRIDGES

The cost of the computers can be reduced because of the unit cost reduction available by producing larger quantities of fewer types of elements. In terms of use, computers are also very general devices. Because their components may be reassembled into new functional systems, just with new sets of instructions, computers may be applied to problems which were not identified when the hardware was built. As a result, computers don't become obsolete in the sense of becoming functionally misadapted to new use requirements. The prime importance of this is that a computer can be made to appear as nearly any sort of device which performs a series of instructions. Computer hardware is replaced when the advancing technology improves the size, reliability, speed and operational cost of the entire system.

The decreased cost of computers will allow them to be programmed for many new applications. Some small, general-purpose computers now cost less than \$4000 and are well suited to perform numerous functions in laboratories, factories, and businesses. In addition to their processing of information, they may be used to control other machinery, thereby creating rather primitive robots.

Computers are made operational by sets of instructions, or programs which are read into them. These programs are called "software," a term which emphasizes the non-permanence of the programs. The magnitude of effort required for the development of programs is at least as large as that required for the development of the hardware. Because of this, computer programmers become highly trained specialists.

The programmers adapt the general devices to specific applications.

As greater expertise is developed in programming, the range and depth of applications increase.

## COMPUTERS IN SCIENCE

Computers will fill many roles in the sciences in the future. They will increasingly be used to perform the computations necessary to analyze the results of experiments, the application for which they are most widely used today. However, many new uses for computers are developing.

In the past, the great bulk of scientific effort has been analytical; investigations generally have been directed toward producing a greater understanding of increasingly more specialized problems. Studies which have attempted the quantitative synthesis of several analytical studies have been much less common. The sheer computational complexities have made many attempted syntheses unpractical. Computers, however, offer the means by which such syntheses may be made. Many of these studies rely on simulation modeling.

A simulation model creates a representation of a real system within the computer. This model may then be run, with various modifications, to learn more about the behavior of the system under study. The analytical studies are used to provide the information with which to build the model; the computer has the computational ability to synthesize these studies. This application can be illustrated by a research program in progress at Utah State University.

The Desert Biome program, part of the United States contribution to the International Biological Program, is a large-scale research program with the goal of producing a model of the deserts. Manipulation of the model will allow the prediction of effects of modifications of the desert, such as those produced by increasing the



number of grazing sheep, without actually changing the real desert. Studies such as this will allow us to gain a deeper understanding of the interdependencies of living things in the natural world.

All areas of the sciences are beginning to recognize the value of simulation modeling.

### COMPUTERS IN THE ARTS

Music and art (including movies) are two of the arts which are currently witnessing a surge of experimentation with computers. As with all arts, there is a period of time during which the artists learn to use their new medium. However, the experimental results already appear promising. In music, for example, the composer is able to directly supervise the entire production of his composition, whether it is based on a single "instrument" or a "full orchestra." This is accomplished by the production of simulated sounds by the computer, based on the physics of particular instruments, directly from the composer's notation. It is certain that this trend will greatly expand in the future.

### COMPUTERS IN SOCIETY

Computers will also be used in many new roles in society. Computer applications to other areas will generally be under the control of the group which will receive their benefit. The control that society will have over its relationship to computers will be less direct. There is a definite potential of "big-brother" control which society must guard against. Computers themselves will not be responsible for the violation of an individual's rights. It will be violated by people who may incidentally be using computers.

Most uses of computers that will benefit society in general will probably not be consciously associated with computers. For example, we scarcely think of computers performing the switching functions in a telephone system. We think that we are doing all that is required when we dial

the number. There will be a great proliferation of such behind-the-scenes uses of computers in the future, where the type of communication device will obscure the fact that a computer is involved in the process.

### COMPUTERS IN AGRICULTURE

We tend to think of computers primarily in an urban context, yet there are many potential uses of computers in agriculture.

The business aspects of agriculture will be the first area in which computers will be broadly used. Market analyses, equipment scheduling, and some comprehensive money management services for farmers and ranchers already exist. A wide variety of robot-like devices will follow. Equipment whose functions may be re-specified appear to ideally match the use requirements demanded by agricultural practice. The strictly controlled environments which used to be required of computers need no longer be met.

### USE OF COMPUTERS IN THE DAIRY INDUSTRY

Electronic computers are presently the backbone of the National Dairy Herd Improvement Program (production testing) and the National Dairy Sire Evaluation Program. Projections of future use of computers in dairy record keeping would include complete pedigree information on registered animals; summarization and evaluation of physical type traits; more complete information on sires for sire evaluation programs; computerized mating programs using all available information such as production, type, disposition, etc.; more complete management programs for dairy herds; total cost accounting for dairy operations; computerized feeding recommendations; and indexing or ranking cows in herds for culling and selection programs.

Computers will continue to play an increasingly important role in analysis of research data and the use of computers in collecting and summarizing

the management data listed above will, in essence, collect volumes of management data for use in research. Computers will be used to teach management decision-making through simulated computer programs. These programs will be useful for both resident and continuing education teaching.

The first use of computerized records in the dairy field originated at Utah State University in 1952 when Lyman Rich and Dr. Bliss Crandall teamed together to put the Utah DHIA records on the computer. This program has since spread worldwide and although Dr. Crandall has now established his own private business for computing dairy records, he is still considered one of the leading authorities in developing record keeping programs for dairymen. As such, he brings much recognition to the Utah dairy industry.

### USE OF COMPUTERS IN PLANT SCIENCE

Gene banks for almost all plant crops are being collected and stored on a national and international basis. The cataloguing and distribution of information of germplasm by computer systems will provide uniform coding and reporting. Criteria such as yield, maturity, disease resistance, etc., will be coded. The success of these efforts is dependent upon computers.

### USE OF COMPUTERS IN VETERINARY MEDICINE

For each cow in a large dairy herd, the physiological status (body temperature, respiratory rate, etc.) could be monitored continually or intermittently throughout the day and night and transmitted by telemetry to a computer. Daily weight could be automatically measured and recorded. Daily feed and water intake by groups could be recorded. The influence of weather, change of routine, and other environmental stresses would be part of the input.

These measurements would be stored and a printout made once or



twice a day. Changes in these physiological measurements from the expected norm could indicate an early signal of sickness in a cow or group of cows. These changes would occur 24 to 48 hours before visible signs of illness would be noted. The magnitude or duration of the change may have diagnostic value.

Such monitoring could be devised to determine the heat cycle of a cow for proper insemination time.

Similar monitoring could be adapted to any species of animal reared in confinement. Very refined monitoring would be an extremely useful research tool.

### COMPUTERS IN ANIMAL SCIENCE

There will be extended use of computers in livestock ration formulations. As more and better nutrition information becomes available, least cost rations and optimum gain rations will be widely devised by computers commercially.

Computers will be widely used in other decision making, in such things as devising breeding systems. With more genetic information becoming available, purebred breeders and commercial breeders, those considering crossbreeding as well as straight breeding, will project the genetic consequences of mating combinations for many generations in advance by application of Monte Carlo types of computation. It is not inconceivable that in the future most "genetic" decisions will be made by use of computers.

Management decisions will be largely made by computers in the not-too-distant future. Input information will become more refined and then computers will have an important place because the numerous components having input interrelationships can be properly balanced simultaneously and make better decisions possible.

### WILDLIFE NOTES

Birds are able to sleep, without falling from trees, by the muscles in their feet which close tightly around a limb when the leg is bent.

A single egg of some species of tiny wasps divides into a cluster of eggs.

Banding studies show that Canada geese live to the ripe old age of 20 years and more.

The average salamander does not have lungs. It breathes through its moist skin.

The windpipe of the whooping crane is two feet long.

The peregrine falcon's sharp wings enable it to dive swiftly from great heights when keen eyes spot its prey. It prefers small ducks and pigeons but will occasionally take larger birds.

The female condor lays no more than one egg every other year, and both parents spend an average of 45 days incubating the egg, five months brooding the chick, and nine months feeding it after the youngster has left the nest.

Some pupfish can survive in waters that have up to six times the salt content of sea water.

A dog hunts with his nose, not his eyes. He sees best when things move, and the rabbits, deer and pheasants he hunts seem to know this. They freeze when hunted.

Adult dragonflies snare mosquitoes in flight by folding their six legs into a net and straining the insects from the air.

The condor ranges from 40 to 50 miles daily in its search for food.

Trumpeter swans are the largest North American bird in weight, males sometimes reaching 30 pounds.

Among the best camouflaged forms of wildlife is the snapping turtle. Even its eyes are expertly hidden by a pattern of little spots similar to extra pupils.

Bears eat heavily during the summer months in preparation for winter hibernation. One male gained 92 pounds in 24 days during June and July.

The tiny shrew will consume its own weight in meat every three hours.

Young peregrine falcons mature in two years, but it is not known how long the birds live in the wild.

The whistling sound of the goldeneye in flight is created by its rapid wing beats. It is capable of traveling at speeds up to 50 miles an hour.

The water ouzel, a songbird of western U.S. streams, walks under water and feeds in streambeds.

Seals will nurse only their own young.

The vicuna is the smallest of the camel family and has never been domesticated owing to its wild and active nature.

The king vulture has one of the oddest heads in the bird world. Its bare, wrinkled skin is brightly colored, and there is a queer, ornamental wattle on the bill.

Sea lilies are really animals, but they look like the plant for which they are named.



# Genetic Engineering

ELDON J. GARDNER

Speculation on what might be done when the chemistry of the genetic material is well understood has gone on for many years. Enough is now known about gene action and genetic control to make some speculations a near reality. The real problem associated with altering and ultimately directing gene action is one that involves basic cell biology. How can enzyme action within a cell be added, removed, or altered? Enzymes that operate within a cell are made within that cell. It is true that chance mutations create new alleles that synthesize new enzymes in a cell. Thus far, however, no one has been able to control such changes at will and thus alter enzymatic activity in a directional pattern. One anxious father of two albino children had read widely about the affliction, albinism. He had learned that a pigment was not produced properly in the cells of his albino children and approached biochemists and human geneticists with the query, "Is it not possible to add the necessary enzyme and thus induce pigmentation in the children?" He was informed that this was not feasible. The chemical pathway is known and the particular place where the pathway for normal pigment production is broken has been recognized, but it is not possible to induce the proper pigment production in cells to cure albinism. Eventually this may be accomplished. Some other kinds of enzyme activity are being introduced into human cells.

Although genetics of man was the first aspect of genetics to attract interest, it has until recently been slow in its development. For critical applications, human genetics is based on experimental work with other animals. Now that this has been accomplished, human geneticists are learning to cope with genetic abnormalities and dis-

eases of man. Certain of these diseases have been recognized for a long time but their causes have been identified only recently. When causes are known, critical diagnoses, prevention and treatments become possible. Physicians today have opportunities to participate in one of those rare developments, the initiation of a basically new field of medicine, that deals with genetic diseases.

## MEDICAL GENETICS

Current progress in medical genetics is dramatic enough to be compared with the medical revolution of the last half of the 19th century that followed the establishment of the germ theory of disease. After years of basic accomplishments, the impact of genetics in medical practice is just beginning to be felt. This impact is bound to be a major one, not because the incidence of genetic diseases is increasing but the decline of infectious diseases has brought genetic diseases into new prominence. Infant mortality from congenital malformations is roughly the same as in 1900, about 5 per 1,000 live births. In 1900, however, the total infant mortality was 150 per 1,000 live births compared with 20 per 1,000 in 1970. While the incidence of congenital abnormalities has remained constant, these causes of death now account for about 25 percent of all infant mortality compared with only 4 percent in 1900. The incidence of congenital defects has not changed appreciably but vaccines, antibiotics and sanitation have decreased infectious diseases and the relative importance of genetic diseases has increased.

About one in every eight pediatric hospital beds in the United States is now occupied by a child with an ill-

ness in which genetic factors are involved. Not all of these conditions are inherited. It is true that both genetic and environmental factors are involved in some way in virtually all abnormalities. About 20 percent of all congenital defects are predominantly inherited, about 20 percent are initiated by environmental factors such as mutagenic agents, virus and bacterial infections (e.g. rubella), and some 60 percent are due to combinations of inherited and environmental factors. A main current problem is the transferring of research findings from the laboratory to the clinic without harming the patient by premature experimentation and without disruption of the research effort.

Instead of treating a small number of infectious diseases that affect large numbers of people, the physician must learn how to handle an enormous number of genetic diseases, each of which affects a relatively few persons. More than 1,200 genetic diseases are known, some of which have an incidence of one per 100,000 in the general population. A physician may only see a few patients with genetic diseases in years of practice. Obviously, specialization and a system of counseling centers and referrals is necessary for coping with this tremendous number of different rare diseases. No medical center can afford to specialize in more than a few. Cooperation among centers with expertise in particular diseases has proved to be an effective method of handling an otherwise formidable situation.

## ENGINEERING CELL ENZYME ACTIVITY

A major research problem of genetic diseases is a mechanism for the addition, deletion or replacement of



enzymes that operate with cells. Enzyme production is dependent on DNA specificity within the cell. In a procedure that has been described as the first attempt at "genetic engineering," DNA is being introduced into human cells by a virus. Stanfield Rogers of Oak Ridge National Laboratory has prepared the virus and H. G. Terheggen of Cologne is engineering the treatment of two young girls in Germany who suffer from low blood levels of the enzyme arginase. They are receiving injections of live Shope papilloma virus for the purpose of inducing arginase activity in their cells.

The Shope virus was discovered in cottontail rabbits of Iowa in the 1930's. Rabbits infected by the virus had wart-like growths at first called "antlers" originating in the epithelium of their ears. Domestic rabbits and other kinds of wild rabbits did not show the external growths which occurred only in the ear epithelium of one kind of rabbit. Rabbits infected with the virus were found by Richard E. Shope to have unusually high blood levels of arginase. The virus has now been purified and is being used to treat the German girls suffering from the disease characterized by low levels of arginase.

Viruses are one agency known to carry DNA (or RNA) into the host cells that they infect. Through transduction the virus DNA takes over the genetic machinery of the host cell and enzymes are produced according to the specifications of the virus. The present objective is to induce the production of a particular enzyme (arginase) into the cells of the German girls that is needed for restoration of their health. This pioneering effort may foreshadow the day when artificial viruses, tailored to correct specific enzyme deficiencies, will be used to treat genetic diseases.

#### **INTRODUCING MISSING ENZYMES THROUGH THE BLOOD**

A procedure in which a missing enzyme is bound to a cellulose membrane is being followed in the treat-

ment of Fabry's disease and Gaucher's disease. The metabolic defect causing these diseases apparently does not involve the cells as intimately as that responsible for arginase deficiency. Fabry's disease is characterized by periods of excruciating pain and the symptoms for Gaucher's disease include bone destruction. For this treatment, the blood of the patient is passed through the cellulose membrane where enzyme activity occurs. Other attempts to treat Fabry's disease are based on the introduction of normal blood plasma into the patient where the enzyme may be effective in offsetting the symptoms of the disease.

Although procedures for genetic engineering are only now being developed, the concept goes back to 1908, when Sir Archibald Garrod, physician to the British royal family, described several diseases as "inborn errors of metabolism." Among these diseases were alkaptonuria, cystinuria, porphyria, and albinism. Far ahead of his time, Garrod proposed that these diseases were dependent on recessive genes. Based on Garrod's discovery, it was possible to predict the probability of expression of a hereditary disease but methods of early diagnosis, prevention and treatment of these diseases are only now being developed with support from more recent discoveries of molecular genetics.

#### **PRENATAL DIAGNOSIS OF GENETIC DISORDERS**

In the late 1950's several obstetricians were attempting to improve the treatment for erythroblastosis fetalis. One approach was an analysis of amniotic fluid to determine whether the bilirubin content signifying destruction of red corpuscles was sufficient to justify delivery of the fetus prematurely. In their work with amniotic fluid, they observed that the fluid contained cells and that the cells were those of the fetus and not those of the mother. Fritz F. Fuchs in Copenhagen began examining the cells for Barr bodies that appear in the cells of the female fetus but not in those of the male. His purpose was to determine

whether the sex of the fetus could be determined prenatally. When Barr bodies were present, the fetus was a female with virtually no chance of inheriting a sex-linked gene such as the one for the disease, hemophilia. When, on the other hand, Barr bodies were not present in the cells, the fetus was a male and the chance was one-half that a defective sex linked gene would be inherited. Therapeutic abortions were performed in high risk cases.

#### **DETECTING CHROMOSOME IRREGULARITIES**

In 1965, Cecil B. Jacobson and others began karyotyping fetal cells in the amniotic fluid to detect chromosome abnormalities prenatally. A number of genetic disorders associated with chromosome irregularities could be diagnosed in utero. This made it possible to correct an abnormality by prenatal surgery or to terminate the pregnancy if the fetus was seriously defective. Abnormalities most successfully diagnosed in this way were those associated with structural and numerical disorders of chromosomes.

Diagnostic procedures for some diseases are now being conducted with virtually no risk to the mother. This assumes, of course, that the diagnoses are performed by persons well prepared for the task who have access to the appropriate facilities usually associated with large medical centers. Even so, accidents can occur because the techniques always carry the danger of needle damage, and infection can follow any disturbance of a normal fetus. These risks, however, are minimal when the procedure is utilized by skilled physicians. A balance can be drawn between the anticipated risks and values of an early diagnosis in each particular situation.

Tests of this kind are not simple, and immediate definitive results are not obtained. Diagnoses cannot be made quickly in a doctor's office because the procedures require the culturing of cells from the amniotic fluid. A few clinics in the world are



equipped to make dependable diagnoses. Fortunately, amniotic fluid can be prepared and shipped to distant laboratories without deterioration. A sample of amniotic fluid is obtained by inserting a needle into the amniotic cavity, the fluid-filled sac in which the fetus develops. Cells from the sample must then be grown in tissue culture for 10 days to 3 weeks before they can be subjected to diagnostic tests. Amniotic cells raised in tissue culture may then be processed and prepared for study during the process of cell division when the chromosomes are favorable for observation. Since the cells represent a sample of the fetus itself, any serious chromosome abnormalities will indicate an abnormal fetus.

If the diagnosis is attempted prior to the 12th week of pregnancy, the degree of risk is increased because only a small amount of amniotic fluid is present in early stages of pregnancy. When the total amount of amniotic fluid is minimal, both the mother and fetus may be endangered by the needle insertion and loss of fluid. Incorrect diagnosis might result if maternal cells are mixed with the small amount of amniotic fluid that is available. After the 12th week of pregnancy, the amount of amniotic fluid is generally adequate. An appropriate sample can be removed without injury to mother or fetus and a diagnostic test can be made with precision.

The volume of amniotic fluid increases by about 25 cubic centimeters per week after the 12th week, reaching a total quantity of about 400 cubic centimeters at the 34th week of pregnancy. Accuracy of the diagnostic test is thus increased if the fluid is taken after the 12th week. The 15th week is the period that is considered ideal by many physicians, if it is feasible to make the diagnosis of the particular disorder late in pregnancy. Diagnostic tests may be more satisfactory if the sample is taken even later in pregnancy, but the usefulness of the test is enhanced if it is made reasonably early. Prenatal surgery or termination of pregnancy is more easily accomplished early in preg-

nancy. Danger to the mother is considerably greater if termination is delayed beyond the 20th week of pregnancy.

### DOWN'S SYNDROME

One of the diseases being seen in a new light because of advances in genetics has been known until recently as "mongolism." This poor descriptive term came into being because of the characteristic oblique opening of the eye with the inner corner covered by the epicanthal fold. Other facial features of the patients could have been chosen for a name. Symptoms associated with mental retardation and congenital heart disease are far more serious than the shape of the eye. The syndrome was first described by the clinician, Langdon Down in 1866. But correlation of the condition with a chromosome irregularity had to await modern techniques. The chromosome identified as number 21 is replicated three times instead of being present as a single pair. Total number of chromosomes is thus 47 rather than 46, with the extra one being number 21. This chromosome irregularity has now been associated with physical abnormalities that have been recognized for a long time and recently named Down's syndrome. In the general population, this syndrome occurs about once in 750 people. It would be difficult to locate the fetus of the one in 750 that might be expected in the general population, but a maternal age differential makes diagnosis easier. The frequency is much greater among children of older mothers than among those of younger mothers. Expectancy of Down's syndrome in mothers below the age of 30 averages only about one in 2500 births. Since the incidence of Down's syndrome goes up rapidly with the age of the mother, screening of older mothers would be more rewarding in terms of locating cases than testing all age groups in the general population. One case in every 100 mothers of age 40, and one in every 50 mothers of age 45 might be expected. Four cases of Down's syndrome were detected in one actual series of 104 amniocenteses

performed by Henry L. Nadler's group at Northwestern University Medical School on pregnant women over 40. Therapeutic abortions were performed for all four. It has been suggested that all pregnant women of age 45 or over should be checked. On the average, about one in 50 of these would be expected to show a positive diagnosis for Down's syndrome.

Translocations between a chromosome from the so-called D group and one from the G group are more frequently encountered as the cause of Down's syndrome. Chromosome number 15 is the one from the D group that is involved in translocation. Disease-producing translocation follow a regular and predictable pattern of inheritance. Mothers carrying a translocation between a D and G chromosome have a 25 percent or one-fourth risk of having a baby with Down's syndrome. This risk is great enough to make it desirable for the fetuses of all expectant mothers known to have this kind of translocation to be tested. Sometimes the presence of a translocation can be determined by pedigree information and appropriate chromosome studies.

### IDENTIFICATION OF MALES WITH SEX-LINKED RECESSIVE GENES

Another serious inherited condition is congenital hyperuricemia (Lesch-Nyhan syndrome). Babies who have this disease appear normal at birth, but by about two months after birth they become irritable. By the second year of life, the nervous condition has progressed to a degree that self-mutilation occurs, manifested by lip-biting, finger-chewing, teeth-grinding, and marked swinging of the arms. Death is usually secondary to severe renal or neurological damage. Infants with the Lesch-Nyhan syndrome usually die within the first few years of life. This hereditary disease is dependent on a sex-linked recessive type of inheritance. This means that the mother contributes the defective X chromosome to the male infant. One-half of the male children of carrier mothers may be expected to inherit the syndrome.



The ratio of two enzymes, inosinate pyrophosphate phosphoribosyl transferase (IMP phosphorylase) and adenylate pyrophosphate phosphoribosyl transferase (AMP phosphorylase) from fresh amniotic fluid of pregnant women has been used successfully as a diagnostic test. IMP pyrophosphorylase is virtually absent whereas AMP phosphorylase is not decreased by the disease. Stability of the enzymes and consistency of results give support for this diagnostic procedure.

Effects of the disease are so devastating that an affected male child cannot possibly survive. It has, therefore, been suggested that until an entirely satisfactory diagnostic procedure is confirmed, all pregnancies involving male fetuses in mothers who carry the recessive gene should be terminated. There would be, of course, a 50-percent risk of terminating a normal male fetus.

Juvenile muscular dystrophy occurs in young boys, usually before they reach teen age, and the muscular deterioration progresses rapidly during the early teen years. Muscles of the legs and shoulders become stiff and the children usually become paralyzed and crippled during the middle or late teen years. Virtually all die before age 21.

The juvenile muscular dystrophy problem also involves a sex-linked gene. If the mother is known to be a carrier for this gene, about half of her male children would inherit the disease. Male fetuses can be identified by a chromosome study, as in the case of the Lesch-Nyhan syndrome patients. All female children born to such a mother would be expected to be normal, since the possibility for their being homozygous for a sex-linked recessive gene is virtually nonexistent. Some could, however, be carriers of the gene.

Another severe disease following the pattern of sex-linked recessive inheritance is Hunter's syndrome. It is characterized by mental retardation, coarse features, hirsutism, and a char-

acteristic facial appearance that includes a broad bridge of the nose and a large protruding tongue. Symptoms appear in early childhood. Again, in this syndrome it is possible to determine the sex of the fetus early in pregnancy. Beyond that, no diagnosis is possible on the basis of chromosomes. However, a more rapid chemical means of diagnosing this condition is now being developed. Certain constituents in the amniotic fluid indicate the presence of this disease, which is associated with an abnormal processing of mucopolysaccharides in early pregnancy. Mucopolysaccharides also accumulate in skin cells. When these cells are grown in culture and stained with O-toluidine blue, cell inclusions are stained pink. Cultured skin cells (fibroblasts) from persons who carry the recessive gene for Hunter's syndrome respond to this test whereas non-carriers do not. It is thus possible to identify carriers of the gene.

A number of other chromosome irregularities occur and can result in seriously defective children. It is estimated that about 1 percent of all infants at birth have some chromosome abnormality. In theory, all of these could be diagnosed and prevented. At this stage of our knowledge, even though it is not easy to recognize abnormalities that are less common and less well understood than Down's syndrome, a number of potential problems can be diagnosed from the amniotic fluid (amniocentesis).

The pattern of mucopolysaccharide metabolism by Hunter cells is so strikingly different from the normal that it can be used along with chromosome analysis for sex determination in prenatal diagnosis, a situation in which clinical observation is obviously impossible. Of the many cell types originally present in amniotic fluid, fetal fibroblasts are the only ones to multiply in culture. Like fibroblasts from skin biopsies, they show an excessive accumulation of radioactive mucopolysaccharide or stainable cell inclusions if the fetus is affected with the Hunter syndrome.

## DIAGNOSIS FOR METABOLIC DISORDERS

In general, metabolic disorders have not been as successfully diagnosed by amniocentesis as have chromosomal disorders. More uncertainty and risk is associated with diagnosis of metabolic diseases. However, much is being learned about the basic causes and conditions associated with a number of different metabolic diseases, and it seems likely that it will eventually be possible to diagnose metabolic disorders in the fetus.

Inherited metabolic diseases generate more interest and research activity than might be expected in view of their relatively rare occurrence. This is because genetic disorders afford a unique opportunity to combine genetic concepts with tools of biochemistry in trying to study the metabolism of man. A severe and well-known metabolic disorder is Hurler's syndrome, named after Gertrud Hurler who described it in detail in 1919. This is another of the group of mucopolysaccharidoses characterized by the accumulation of monopolysaccharides in cells. After several months of normal development, an infant with this syndrome deteriorates physically and mentally and gradually acquires an extraordinary appearance. The head becomes abnormally large with a flat bridge of the nose, wide-set eyes, large lips, and coarse tongue. Other external and internal abnormalities are a part of the syndrome but mental retardation is most prominent. Affected children usually do not survive past the age of 20. The disease can be diagnosed prenatally by the presence of cell inclusions and cell cultures of skin fibroblasts.

In-utero diagnosis of Type II Glycogenosis (Pompe's disease), a glycogen storage abnormality, is being developed by Nadler and his group. Activity of the enzyme 1,4-glucosidase was deficient in amniotic fluid, amniotic-fluid cells, and cultivated amniotic fluid cells obtained between the 14th and 16th week of pregnancy

*(Continued on page 107)*



# UTAH SCIENCE

## Index for Volumes 30-31, 1969-70

### AUTHOR INDEX

- Acord, Clair R.**  
Bloat on dry alfalfa hay and legume pasture 30(1):3-5 (joint author)  
Beef production on irrigated pastures—a profitable alternative 30(1):7-9  
Alfalfa pastures compare favorably with grass-legume pastures and other field crops in Utah 31(1):7-10
- Andersen, Jay C.**  
Economics of feeding grain to cattle—on pasture 31(3):78,83 (joint author)
- Anderson, J. LaMar**  
A new hybrid lupine for Utah gardens 30(4):87-89 (joint author)
- Anderson, Melvin J.**  
The use of milk replacers for raising dairy calves 30(3):80-82 (joint author)  
Hints for profitable silage making 31(1):29-31 (joint author).
- Barnard, John J.**  
Hints for profitable silage making 31(1):29-31 (joint author)
- Blake, Joseph T.**  
Animal body weight and body organs as biological indices 31(2):61-64 (joint author)
- Brennand, Charlotte P.**  
The unstable spice of life 30(4):109-111
- Bridges, Kent**  
There is a computer in your future 31(4):96
- Brown, Perry J.**  
Tourist spending patterns in Utah 30(2):44-47
- Butcher, John E.**  
Bloat on dry alfalfa hay and legume pasture 30(1):3-5 (joint author)
- Christensen, Rondo A.**  
Utah's farmland assessment act of 1969 30(2):33-36
- Cox, Lois M.**  
Utah's too salty earth 30(1):6  
Bighorns along the Wasatch 30(1):15  
The ecologies of Utah's watery lands 30(2):36-43 (joint author)  
Our versatile weeds 30(3):58-59  
Deciphering a desert 30(3):66-71  
Predators, pests, and poisons 30(4):90-91, 95  
Pets with a purpose 30(4):97-100  
What is a species worth 30(4):114-116 (joint author)
- Wet is not enough 31(1):16-20  
Getting the "inside" story 31(2):39-42  
Baffling behavior — a universal riddle 31(2):53-60  
Trying for twins 31(3):76-77 (joint author)
- David, Donald W.**  
Integrated control of apple pests in Utah 31(2):43-45, 48
- Davis, Lynn H.**  
Economics of feeding grain to cattle on pasture 31(3):78, 83 (joint author)
- Dedrick, Allen R.**  
A water storage structure for small systems 30(3):63-65 (joint author)
- Dewey, Douglas R.**  
Wide hybridization: a radical approach to grass breeding 31(1):3-6
- Dewey, Wade G.**  
Problems involved in the early summer seeding of fall wheat 30(2):49-52 (joint author)  
Snow removal without a shovel 30(4):92-95 (joint author)  
Two new barley varieties for Utah—Woodvale and Bonneville 70 31(1):11-12, 15  
Bridger—a new hard red winter wheat 31(1):21-22, 32  
Effect of loose smut infection and Vitavax seed treatment on barley yields 31(2):46-48 (joint author)  
Management of crops for water use efficiency 31(4):94 (joint author)
- Dobson, Donald C.**  
Influence of strain, age and weight on meat yield of turkeys 30(4):112-114  
Review of factors contributing to breast blisters 31(2):49, 51
- Follis, Thomas B.**  
Trying for twins 31(3):77-78 (joint author)
- Gardner, Eldon J.**  
Genetic engineering 31(4):99
- Hamson, Alvin R.**  
Kingston—a new lima bean variety 31(3):79 (joint author)
- Hanks, R. J.**  
Management of crops for water use efficiency 31(4):94 (joint author)
- Hansen, R. Gaurth**  
Malnutrition and the affluent society 31(3):67-75
- Hart, George E.**  
Reducing water use by trees—chemical sprays? 30(3):55-57
- Lamb, Robert C.**  
Estimated feed costs of raising dairy heifers from birth to freshening 30(2):27-30,48 (joint author)  
The use of milk replacers for raising dairy calves 30(3):80-82 (joint author)
- Lauritzen, Cyril W.**  
Soil cement linings for canals 30(1):10-14  
A water storage structure for small systems 30(3):63-65 (joint author)
- Lebaron, Allen**  
Protein payments for milk producers—trend for the future? 31(1):13-15
- Low, Jessop B.**  
The ecologies of Utah's watery lands 30(2):36-43 (joint author)  
About shoveller ducks 30(4):96
- Montgomery, Stephen J.**  
Aging animals by tooth cementum 30(2):32, 52
- Nielson, Rex F.**  
Problems involved in the early summer seeding of fall wheat 30(2):49-52 (joint author)  
Snow removal without a shovel 30(4):92-95 (joint author)
- Olson, Arland E.**  
Hereditary multiple exostosis 30(4):101-104 (joint author)
- Perkes, Lamont L.**  
Estimated feed costs of raising dairy heifers from birth to freshening 30(2):27-30, 48 (joint author)
- Peterson, Dean F.**  
Agriculture and social innovation 31(4):92
- Pollard, Leonard H.**  
A new lupine for Utah gardens 30(4):87-89 (joint author)  
Kingston—a new lima bean variety 31(3):79 (joint author)
- Riethmann, Otto**  
A new hybrid lupine for Utah gardens 30(4):87-89 (joint author)



- Sharma, R. P.**  
Hereditary multiple exostosis 30(4):101-104 (joint author)
- Shupe, James L.**  
Hereditary multiple exostosis 30(4):101-104 (joint author)
- Sigler, William F.**  
Electricity in fishery research and management 30(3):72-79  
Utah's wildlife resource 30(4):105-108
- Sisson, Donald V.**  
Animal body weight and body organs as biological indices 31(2):61-64 (joint author)
- Smart, Ross A.**  
Hereditary multiple exostosis 30(4):101-104 (joint author)
- Southard, Alvin R.**  
Surficial geology and land-use problems 31(1):23-28 (joint author)
- Spendlove, Rex S.**  
Getting the "inside" story 31(2):39-42 (joint author)
- Stoker, Golden L.**  
Effect of loose smut infection and Vita-vax seed treatment on barley yields 31(2):46-48 (joint author)
- Street, Joseph C.**  
Pesticides—the changing scene 30(3):59-62
- Summers, Paul**  
Surficial geology and land-use problems 31(1):23-28 (joint author)
- Thomas, Donald W.**  
Bloat on dry alfalfa hay and legume pasture 30(1):3-5 (joint author)
- Thorne, D. Wynne**  
Agriculture—food and people 31(2):35-38
- Van Epps, Gordon A.**  
A cropping system under irrigation—for certain problem areas 31(2):50-51
- Van Kampen, Kent R.**  
Hereditary multiple exostosis 30(4):101-104 (joint author)
- Williams, J. Stewart**  
Surficial geology and land-use problems 31(1):23-28 (joint author)
- Workman, Gar W.**  
What is a species worth? 30(4):114-116 (joint author)

## Index for Volumes 30-31, 1969-70

### SUBJECT INDEX

#### A

- About shoveller ducks 30(4):96
- Acord, Clair R. 30(1):3-5; 30(1):7-9; 31(1):7-10
- Aging animals by tooth cementum 30(2):32, 52
- Agriculture—food and people 31(2):35-38  
science today—agricultural practices tomorrow 31(4):87
- Agriculture  
agricultural and social innovation 31(4):92
- Alfalfa  
alfalfa pastures compare favorably with grass-legume pastures and other field crops in Utah 31(1):7-10  
bloat on dry alfalfa hay and legume pastures 30(1):3-5  
economics of feeding grain to cattle—on pasture 31(3):78
- Andersen, Jay C. 31(3):78, 83
- Andersen, Melvin J. 30(3):80-82; 31(1):29-31
- Anderson, J. LaMar 30(4):87-89
- Animals  
baffling behavior—a universal riddle 31(2):53-60  
animal body weight and body organs as biological indices 31(2):61-64  
louse-like keds cause sheepskin defects 30(1):16  
aging animals by tooth cementum 30(2):32, 52
- Apples  
Integrated control of apple pests in Utah 31(2):43-45

#### B

- Baffling behavior—a universal riddle 31(2):53-60
- Barley  
two new barley varieties for Utah—Woodvale and Bonneville 70 31(1):11-12, 15  
effect of loose smut infection and Vita-vax seed treatment on barley yields 31(2):46-48
- Barnard, John J. 31(1):29-31
- Bee studies planned 31(3):83
- Beef production on irrigated pasture—a profitable alternative 30(1):7-9
- Behavior  
baffling behavior—a universal riddle 31(2):53-60
- Bighorns along the Wasatch 30(1):15
- Blake, Joseph T. 31(2):61-64
- Bloat on dry alfalfa hay and legume pasture 30(1):3-5
- Breast blisters  
review of factors contributing to breast blisters 31(2):49, 51
- Breeding  
Trying for twins 31(3):76
- Brennand, Charlotte P. 30(4):109-111
- Bridger—a new hard red winter wheat 31(1):21-22, 32
- Bridges, Kent 31(4):96
- Brown, Perry J. 30(2):44-47
- Butcher, John E. 30(1):3-5

#### C

- Cardamon  
the unstable spice of life 30(4):109-111

#### Calves

- the use of milk replacers for raising dairy calves 30(3):80-82
- Canals  
soil cement linings for canals 30(1):10-14
- Celery  
dehydrated celery now puffed 30(3):83
- Chemicals  
reducing water use by trees—chemical sprays? 30(3):55-57  
chemical shearing field tests—encouraging 31(3):83
- Chickens  
review of factors contributing to breast blisters 31(2):49, 51
- Christensen, Rondo A. 30(2):33-36
- Colostrum  
the use of milk replacers for raising dairy calves 30(3):80-82
- Computers  
there is a computer in your future 31(4):96
- Cox, Lois M. 30(1):6; 30(1):15; 30(2):36-43; 30(3):58-59; 30(3):66-71; 30(4):90-91, 95; 30(4):97-100, 30(4):114-116; 31(1):16-20; 31(2):39-42; 31(2):53-60; 31(3):76-77
- Coyotes  
predators, pests, and poisons 30(4):90-91, 95
- Crops  
management of crops for water use efficiency 31(4):94
- Crop rotation  
A cropping system under irrigation 31(2):50-51



**D**

- DDT  
pesticides—the changing scene 30(3):59-62
- Dairy heifers  
estimated costs of raising dairy heifers from birth to freshening 30(2):27-30
- Davis, Donald W. 31(2):43-45, 48
- Davis, Lynn H. 31(3):78-83; 31(3):80-82
- Deciphering a desert 30(3):66-71
- Dedrick, Allen R. 30(3):63-65
- Deer  
pets with a purpose 30(4):97-100
- Deformities  
hereditary multiple exostosis 30(4):101-104
- Dehydrated celery now puffed 30(3):83
- Dewey, Douglas R. 31(1):3-6
- Dewey, Wade G. 30(2):49-52; 30(4):92-95; 31(1):11-12, 15; 31(1):21-22, 32; 31(2):46-48; 31(4):94
- Diet  
malnutrition and the affluent society 31(3):67
- Disease  
hereditary multiple exostosis 30(4):101-104  
genetic engineering 31(4):99  
getting the "inside" story 31(2):29-42
- Dobson, Donald C. 30(4):112-114; 31(2):49, 51
- Ducks  
how to poison a duck—miss your mark 30(3):82  
about shoveller ducks 30(4):96

**E**

- Ecology  
ecologies of Utah's watery lands 30(2):36-43  
deciphering a desert 30(3):66-71  
what is a species worth 30(4):114-116  
pets with a purpose 30(4):97-100  
baffling behavior — a universal riddle 31(2):53-60
- Economics of feeding grain to cattle—on pastures 31(3):78
- Effect of loose smut infection and Vitavax seed treatment on barley yields 31(2):46-48
- Electricity in fishery research and management 30(3):72-78
- Endangered species  
what is a species worth 30(4):114-116
- Estimated feed costs of raising dairy heifers from birth to freshening 30(2):27-30
- Exostosis  
hereditary multiple exostosis 30(4):101-104

**F**

- Farmers have a choice of taxes 31(3):80
- Ferret, black-footed  
What is a species worth? 30(4):114-116
- Fish

- Utah's wildlife resource 30(4):105-108  
electricity in fishery research and management 30(3):72-78
- Follis, Thomas B. 31(3):77-78
- Food  
agriculture—food and people 31(2):35-38  
the unstable spice of life 30(4):109-111
- Freeze-drying  
now we have freeze-dried sauerkraut 30(3):79
- Fruit  
integrated control of apple pests in Utah 31(2):43-45

**G**

- Game animals  
bighorns along the Wasatch 30(1):15  
Utah's wildlife resource 30(4):105-108
- Gardens  
a new hybrid lupine for Utah gardens 30(4):87-89
- Gardner, Eldon J. 31(4):99
- Genetics  
genetic engineering 31(4):99
- Geology  
surficial geology and land-use problems 31(1):23-28
- Getting the "inside" story 31(2):39-42
- Grain feeding  
economics of feeding grain to cattle—on pastures 31(3):78
- Grass  
wide hybridization: a radical approach to grass breeding 31(1):3-6

**H**

- Hamson, Alvin R. 31(3):79
- Hanks, R. J. 31(4):94
- Hansen, R. Gaurth 31(3):67-75
- Hart, George E. 30(3):55-57
- Hereditary multiple exostosis 30(4):101-104
- Hints for profitable silage making 31(1):29-31
- How to poison a duck — miss your mark 30(3):82
- Hunger  
malnutrition and the affluent society 31(3):67
- Hybridization  
a new hybrid lupine for Utah gardens 30(4):87-89  
wide hybridization: a radical approach to grass breeding 31(1):3-6

**I**

- Index  
Utah Science index for volumes 27-29 30(1):17-23  
Utah Science index for volumes 30-31 31(4):103
- Influence of strain, age and weight on meat yield of turkeys 30(4):112-114
- Insects  
new compounds block insect growth pattern 30(3):83

- integrated control of apple pests in Utah 31(2):43-45
- Integrated control of apple pests in Utah 31(2):43-45
- International Biological Program (IBP)  
deciphering a desert 30(3):66-71
- Irrigation  
beef production on irrigated pasture—a profitable alternative 30(1):7-9  
soil cement linings for canals 30(1):10-14  
a cropping system under irrigation 31(2):50-51

**J**

- Jackrabbits  
Utah's wildlife resource 30(4):105-108

**K**

- Keds  
louse-like keds cause sheepskin defects 30(1):16
- Kingston—a new lima bean variety 31(3):79

**L**

- Lamb, Robert C. 30(2):27-30, 48; 30(3):80-82
- Land Taxes  
farmers have a choice of taxes 31(3):80
- Land Use  
surficial geology and land-use problems 31(1):23-28
- Lauritsen, Cyril W. 30(1):10-14; 30(3):63-65
- Lead shot poisoning  
how to poison a duck—miss your mark 30(3):82
- LeBaron, Allen 31(1):13-15
- Lima Beans  
Kingston—a new lima bean variety 31(3):79
- Loose Smut Infection  
effect of loose smut infection and Vitavax seed treatment on barley yields 31(2):46-48
- Louse-like keds cause sheepskin defects 30(1):16
- Low, Jessop B. 30(2):36-43; 30(4):96
- Lupines  
a new hybrid lupine for Utah gardens 30(4):87-89

**M**

- Malnutrition and the affluent society 31(3):67-75
- Management of crops for water use efficiency 31(4):94
- Marshlands  
the ecologies of Utah's watery lands 30(2):36-43  
about shoveller ducks 30(4):96
- Mealworms  
new compounds block insect growth pattern 30(3):83



Microtubules  
getting the "inside" story 31(2):39-42  
Milk  
protein payments for milk producers—  
trend for the future? 31(1):13-15  
the use of milk replacers for raising  
dairy calves 30(3):80-82  
Montgomery, Stephen J. 30(2):32, 52

## N

New compounds block insect growth pat-  
terns 30(3):83  
New hybrid lupine for Utah gardens  
30(4):87-89  
New weed menaces desert ranges 30(2):31,  
48, 52  
Nielson, Rex F. 30(2):49-52, 30(4):92-95  
Now we have freeze-dried sauerkraut  
30(3):79  
Nutrition  
malnutrition and the affluent society  
31(3):67-75

## O

Olson, Arland E. 30(4):101-104  
Our versatile weeds 30(3):58-59

## P

Pastures  
bloat on dry alfalfa hay and legume pas-  
ture 30(1):3-5  
beef production on irrigated pasture—a  
profitable alternative 30(1):7-9  
alfalfa pastures compare favorably with  
grass-legume pastures and other field  
crops in Utah 31(1):7-10  
economics of feeding grain to cattle—on  
pasture 31(3):78  
Perkes, Lamon L. 30(2):27-30, 48  
Pesticides  
bee studies planned 31(3):59-62  
pesticides—the changing scene 30(3):59-  
62  
Pests  
predators, pests and poisons 30(4):90-91,  
95  
Peterson, Dean F. 31(4):92  
Pets with a purpose 30(4):97-100  
Plant Breeding  
Kingston—a new lima bean variety  
31(3):79  
Poisons  
predators, pests and poisons 30(4):90-91,  
95  
how to poison a duck—miss your mark  
30(3):82  
Pollard, Leonard H. 30(4):87-89, 31(3):79  
Population  
agriculture—food and people 31(2):35-38  
Poultry  
review of factors contributing to breast  
blisters 31(2):49, 51  
Predators, pests and poisons 30(4):90-91,  
95

Problems involved in the early summer  
seeding of fall wheat 30(2):49-52  
Protein payments for milk producers—  
trend for the future? 31(1):13-15  
Publications 30(4):116, 30(1):23

## R

Reducing water use by trees — chemical  
sprays? 30(3):55-57  
Reproduction  
trying for twins 31(3):76  
Resources  
Utah's wildlife resource 30(4):105-108  
predators, pests, and poisons 30(4):90-91,  
95  
Review of factors contributing to breast  
blisters 31(2):49, 51  
Riethmann, Otto 30(4):87-89

## S

Salinity  
Utah's too salty earth 30(1):6  
Sauerkraut  
now we have freeze-dried sauerkraut  
30(3):79  
Science  
Science today—agricultural practices to-  
morrow 31(4):87  
Science, Utah—index to volumes 30-31,  
1969-70, 31(4):103  
Sharma, R. L. 30(4):101-104  
Sheep  
chemical shearing field tests—encourag-  
ing 31(3):83  
louse-like keds cause sheepskin defects  
30(1):16  
Shoveller ducks  
about shoveller ducks 30(4):96  
Shupe, James L. 30(4):101-104  
Sigler, William F. 30(3):72-79; 30(4):105-  
108  
Silage  
hints for profitable silage making  
31(3):83  
Sisson, Donald V. 31(2):61-64  
Smart, Ross A. 30(4):101-104  
Snow removal without a shovel 30(4):92-  
95  
Sociology  
baffling behavior—a universal riddle  
31(2):53-60

## Soil

Utah's too salty earth 30(1):6  
soil cement linings for canals 30(1):10-14  
Southard, Alvin R. 31(1):23-28  
Spendlove, Rex S. 31(2):39-42  
Spices

the unstable spice of life 30(4):109-111  
Stoker, Golden L. 31(2):46-48  
Street, Joseph C. 30(3):59-62  
Summers, Paul 31(1):23-28  
Surficial geology and land-use problems  
31(1):23-28  
Synthetic ethers  
new compounds block insect growth pat-  
tern 30(3):83

## T

Taxes  
Farmers have a choice of taxes 31(3):80  
Thomas, Donald W. 30(1):3-5

Thorne, D. Wynne 31(2):35-38  
Timber notes 31(4):107  
Tourist spending patterns in Utah 31(3):80  
Traps  
predators, pests and poisons 30(4):90-91,  
95  
Trees  
reducing water use by trees—chemical  
sprays? 30(3):55-57  
Trying for twins 31(3):76  
Turkeys  
influence of strain, age and weight on  
meat yield of turkeys 30(4):112-114  
review of factors contributing to breast  
blisters 31(2):49, 51  
Two new barley varieties for Utah—Wood-  
vale and Bonneville 70 31(1):11-12, 15

## U

Unstable spice of life 30(4):109-111  
Use of milk replacers for raising dairy  
calves 30(3):80-82  
Utah's farmland assessment act of 1969  
30(2):33-36  
Utah Science index to volumes 30-31, 1969-  
70, 31(4):103  
Utah's too salty earth 30(1):6  
Utah's wildlife resource 30(4):105-108

## V

Van Epps, Gordon A. 31(2):50-51  
Van Kampen, Kent R. 30(4):101-104  
Viruses  
Getting the "inside" story 31(2):39-42  
Vitavax  
effect of loose smut infection and Vita-  
vax seed treatment on barley yields  
31(2):46-48

## W

Water  
wet is not enough 31(1):16-20  
a water storage structure for small sys-  
tems 30(3):63-65  
reducing water use by trees—chemical  
sprays 30(3):55-57  
Weeds  
new weed menaces desert ranges 30(2):  
31, 48, 52  
our versatile weeds 30(3):58-59  
Weight  
animal body weight and body organs as  
biological indices 31(2):61-64  
Wet is not enough 31(1):16-20  
What is a species worth? 30(4):114-116  
Wheat  
problems involved in the early summer  
seeding of fall wheat 30(2):49-52  
Bridger—a new hard red winter wheat  
31(1):21-22, 32  
Williams, J. Stewart 31(1):23-28  
Wide hybridization: a radical approach to  
grass breeding 31(1):3-6  
Wildlife  
Utah's wildlife resource 30(4):105-108  
Wildlife Notes 30(1):16; 30(2):47; 30(3):71,  
82; 30(4):104, 111; 31(1):6, 20, 22; 31(2):  
42; 31(3):77, 83; 31(4):95, 98  
Workman, Gar W. 30(4):114-116



(Continued from page 102)

of patients with Pompe's disease. After termination of pregnancy the fetus was found to have an absence of 1,4-glucosidase activity in all organs and cultivated cells. This confirmed the in-utero diagnosis of Type II Pompe's disease. Pompe's disease is inherited by an autosomal recessive gene. The disorder is characterized by intractable cardiac failure progressing to death within the first year of life. *a*-1,4-glucosidase activity is deficient in the liver, leucocytes, and cultivated fibroblasts of patients with this disorder.

#### DIAGNOSIS AND TREATMENT OF GENETIC DISEASES

Cystic fibrosis is the most common genetic disease among Caucasians. In the United States it occurs once in every 2,000 births. Staining cultured cells from cystic fibrosis patients has led to the identification of two and possibly three kinds of cystic fibrosis that are different on the cellular level. Hopefully a screening test will be developed for identifying affected fetuses as well as carrier mothers.

Phenylketonuria (PKU) for which most states require routine screening at birth occurs once in about 10,000 live births. The test is accomplished by a simple color change in treated urine. Massachusetts tests 97 percent of the babies born in the state for PKU. In 1969, eight infants were found to have PKU. Infants giving a positive reaction are placed on a particular diet for the first few years of life. Care must be taken to avoid side effects and malnutrition of babies subjected to this diet. All eight of the infants detected in Massachusetts in 1969 were treated and all have apparently escaped the mental retardation associated with PKU.

Massachusetts also requires a test on cord blood for level of galactose to detect galactosemia in newborn infants. In addition, the mother of a baby is requested to supply a sample of urine from the baby 3 or 4 weeks after she leaves the hospital. A kit containing a strip of filter paper is

given to the mother along with a pre-addressed envelope to the state laboratory. Instructions are given for precipitating the filter paper with urine and mailing it. At the laboratory chromatographic tests are performed to detect enzyme abnormalities associated with histidinemia, hyperlysine-mia, cystinuria, and several other genetic disorders.

Some genetic diseases have a built-in aid to screening because of the high incidence in certain population groups. Sickle-cell anemia, for example, is much more common among American blacks than among American whites. Some 97 percent of the victims of this disease in the United States are black. Eight to 10 percent of all American negroes carry the recessive gene for sickling. Red blood corpuscles of those with sickle-cell anemia are collapsed and sickle

shaped. They clog the capillaries and deprive the cells of the oxygen usually carried by the red corpuscles. About half of the sickle cell patients die before the age of 20, only a few live beyond 40, and most of these are crippled long before death. A solution of urea and invert sugar is now available for treatment. The urea breaks the bonds between hemoglobin molecules, reduces the sickling effect, and allows the corpuscles to return to normal shape.

In spite of the recent advances that have been made in techniques, especially in diagnostic techniques with reference to amniocentesis, much remains unknown about the hereditary abnormalities that are common in infants and growing children. No one can guarantee a perfect baby, even when all the tests that are now known have been run.

#### TIMBER NOTES

The U.S. Forest Service expects demand for timber products to double in 30 years.

Some of the nation's finest "old growth" forests now cover mountainsides that were blackened by natural forest fires in over-ripe timber during the time of early Western settlers.

Despite some widely held beliefs, many of the big redwood trees being harvested today on protected tree farms are the third crop to be utilized for houses, outdoor furniture and, today, even paper.

One of the worst over-time parking problems on record has just been discovered near Alder Point in the Northern California mixed Douglas fir and coast redwood timber country. A tree several feet in diameter has grown up through the frame of an abandoned 1921 logging truck, overlapping the truck on both sides.

The acetate fiber in your clothing was made from a tree.

Foresters must grow the equivalent of a block of wood 48 feet wide, 48 feet thick, and 1,000 miles long each year to meet America's forest products needs.

A generation ago only about half of each mature tree harvested found its way into wood products. Today industrial tree farmers can utilize virtually all of the tree for finished products used by everyone.

Under good timber management, three to five times the normal number of timber crops can be grown.

Four tons of oxygen per year are produced by one acre of growing forest, enough for 18 people a year. The rate slows as trees mature.

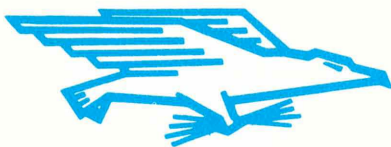
About 40 percent of earth's oxygen is produced by growing forests and other green land plants. Photosynthesis by ocean plant life produces most of the remaining supply.



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