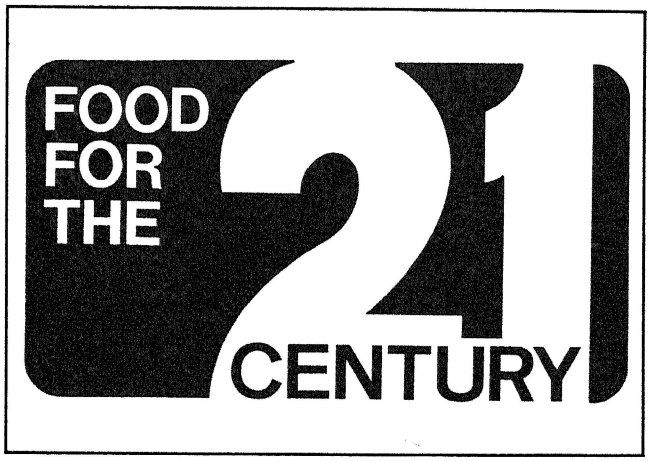
Food for the 21st Century

Recommendations for emphasis and priority in long-range research programs in food and agriculture at the University of Missouri-Columbia

1984 Edition



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Introduction

Food for the 21st Century is a long range planning effort in food and agriculture at the University of Missouri-Columbia. Its purpose is to identify research programs that should receive emphasis and priority in the years ahead.

The recommended research will play a critical role in the future of Missouri's food and agricultural industry. Our farms and agricultural industries must have the benefit of first rate research information if they are to thrive. In turn, all consumers will benefit from ample supplies of nutritious, healthful foods, plus increased knowledge of what to eat for long, productive lives.

The recommendations for priority research include three major emphasis areas:

1. Metabolic Regulation in Plants and Animals. We must learn more about the basic growth processes and insect and disease resistance in plants and animals in order to make most efficient use of limited soil, water, and fuel resources.

2. Alternative Sources of Food and Animal Feeds. In this emphasis area, researchers will (a) seek new ways to make use of waste and byproducts, (b) further develop food products already available; and (c) explore new production methods and other plants and animals not now being used in Missouri.

3. Specialized Human Nutritional Needs for Quality Life. Good nutrition can play a key role in helping people live long, productive lives. This research will study the nutrient needs of special groups such as persons "over 65" and those who face special life situations.

Only eight nations in the world (in white) consistently produce significantly more food than they consume, according to a recent report in a national magazine. A rapidly growing world population will put increasing pressure on this narrow base of supplies for food-deficient nations.

Food for the 21st Century

Identifying High Priority Research Needs In Missouri's Food and Agriculture Industry

Food. Enjoyed daily. Talked about often. Usually taken for granted. We go to grocery stores and restaurants with complete confidence that food will be available.

Eating is such an ordinary event that its extraordinary significance is often overlooked. Yet, there is much concern about our food supply for the future.

"Will There Be Enough Food?" That was the title of the 1981 USDA Yearbook of Agriculture. The answer in the book was, "Yes, if we act wisely. If there is scarcity, it will be because we have brought it upon ourselves."

Some world population experts, however, are much more alarmed about growing world food needs and our ability to supply them. They see a pessimistic picture—a population growing at the rate of 210,000 people a day putting pressure on world food supplies. A national magazine notes that only eight of the world's 173 nations consistently produce significantly more food than they consume. This is an extremely small margin of nations that can provide food for the world market.

Even in the United States where food supplies have been plentiful, people are becoming more concerned about what they eat as well as how much they eat. People want their food to keep them healthy—to help them work and play hard, and live a long, active life.

However, we still have many questions about human nutrition. What kinds and amounts of food do we really need? The public is barraged with conflicting dietary advice. How valid are scare stories about some foods being bad for you? How do different age groups, such as older persons, vary in what they need? How do different life styles and stresses affect the body's ability to use foods?

As medical science controls more of the major diseases, then good nutrition becomes even more important to long, healthy lives.

What Is the Food for the 21st Century Program?

"Will there be enough food? Yes, if we act wisely."

In order to act wisely is exactly why the Food for the 21st Century effort was born. It is the University of Missouri-Columbia's commitment to plan ahead in food and agriculture—to act wisely. A land-grant university has special obligations to look ahead—to ask which problems our farms, industries, and consumers will face 10 to 20 years in the future. What types of programs should be started now in order to have a flow of research findings coming on stream in time to be of most help? Responsible leaders must

Comments from Norman E. Borlaug, 1970 Nobel Peace Prize winner and leader of the Green Revolution:

Question: On a global basis, is the food-population battle being won or lost?

Answer: The last several years, we've held our own— but it's a precarious balance . . . So, even though globally we are near balance, there's no room for complacency. It's a constant struggle, since world population is growing by 76 million per year.

Question: Is that why you say the "food-energy" problem is more critical than that of fossil fuels?

Answer: Yes. Food is the first basic necessity for all of us, and there are no acceptable substitutes for food energy. When stomachs go empty, patience wears out and anger flares. If the world is ever to achieve social, economic and political stability, I assure you it won't be done on empty stomachs.

From *Context*, No. 2/1982

Missouri's Rank Nationally in Agricultural Production

Item	Rank (1981)
Purebred cattle and swine breeding stock	First
Feeder pig, production	First
Tall fescue seed, production	First
Lespedeza seed, production	First
Cattle farms, number	Second
All farms, number	Second
Orchardgrass seed, production	Second
Soybeans, production	Third
White corn, production	Third
Beef cows, number	Third
Hog farms, number	Third
Sorghum grain, production	Fourth
Catfish sold, number	Fourth
Soybean exports	Fifth
Turkeys raised, number	Fifth
Winter wheat, production	Fifth
Livestock slaughtering establishments, number	Fifth
Market hogs, number on farms	Sixth
Meat, exports	Sixth
Milk cow farms, number	Sixth
Rice, production	Sixth
Rice, exports	Sixth
All hay, production	Seventh
American cheese, production	Seventh

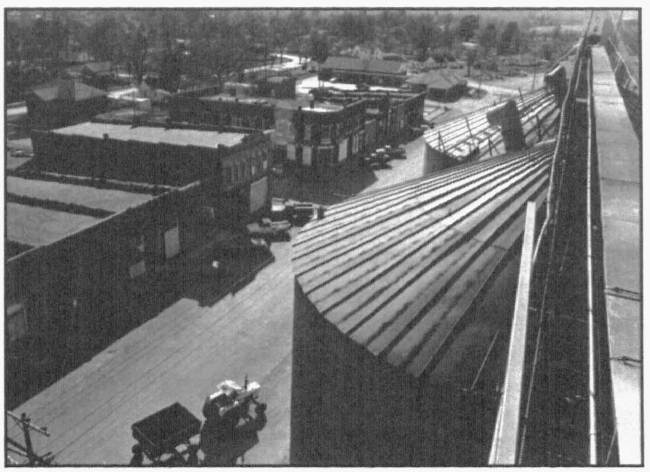
point out the needs and urge adoption of programs to meet those needs.

The Food for the 21st Century program is a cooperative effort of the Colleges of Agriculture, Home Economics, and Veterinary Medicine. It attempts to look 20 years into the future—the beginnings of the 21st Century—to see what major problems and constraints will face food and agriculture at that time. Purpose of the program is to identify research areas that should receive extra emphasis and priority in the University of Missouri's long-range commitment to a food and agriculture program. Research areas selected for priority are those considered to offer great promise of providing solutions to those important future problems and constraints.

Why Important?

The Food for the 21st Century program is critically important to Missouri for many reasons. It can help to:

1. Insure an ample supply of quality food at reasonable prices. One of the major thrusts of the program is to maintain and improve the efficiency of food production because natural resources are likely to become more limited and more expensive. And along with efficiency, the program will result in food



Tractors on main street! Agriculture is the economic life blood of many towns such as Laddonia in the east central part of the state.

The grain markets are a good example of the importance of Missouri agribusiness in world trade. Above, buyers and sellers meet at the Kansas City Board of Trade, the world's largest futures market in hard red winter wheat. Below, grain is loaded on barges in the Mississippi River at St. Louis for shipment to the Gulf. The Merchants Exchange of St. Louis is the world's largest cash grain market and is important in export trade.

products specifically bred, fed, and processed to more adequately meet consumer tastes and nutritional needs.

2. Provide the nutritional know-how to help citizens live long, productive lives. In addition, it can provide reassurance about the adequacy and safety of people's diets—provide scientific answers to scare stories and fad diets.

3. Stimulate the economy of the state:

a. Food and agriculture make up Missouri's largest industry.

b. Food and agriculture employ one out of five Missouri workers.

c. Missouri farmers and ranchers rank high among states in terms of production. A substantial amount of this production moves into important export trade channels.

d. Missouri is home base to thousands of agricultural industries and businesses. Some of the largest are known worldwide. At the other end of the size range, Missouri has thousands of smaller agribusiness firms located throughout the state. Included are some 107 meat packing plants, 76 dairy products plants, and 105 grain mills processing food and animal feeds.

It is essential that Missouri's food and agriculture industry have access to new technology if it is to stay competitive and grow. In fact, scientific advances are already making this a "high tech" industry. It will become even more so in the future.

4. Train scientists needed in Missouri's food and agriculture industry. A strong well-supported research program is the foundation for providing a quality education and training for scientists of tomorrow.

These young people who will be the scientific leaders of tomorrow can be from Missouri farms, towns, and cities if we will provide them the opportunity to get scientific training they need at our land-grant university.

5. Keep Missouri agricultural researchers and scientists in the forefront in developing cooperative programs and exchanges with leading scientists in other nations around the world. The economic health and vitality of Missouri's food and agriculture industry increasingly depend on international markets and competition. Some of our agricultural commodity groups and agribusinesses look to international markets as their primary opportunities for growth. Missouri gains much in these international exchanges and programs in terms of new ideas and techniques, breeding materials and markets.

Some Agribusiness Views on Role of University Research

(taken from discussions with commercial companies)

Most research now needs to be done by a team—individual efforts can't handle all of the ramifications.
Universities should put major emphasis on basic research. Need more information on "mode of action" in plants and animals.
Needs to be more emphasis on development of research techniques in universities.
Training students is an important aspect of university research.
Should be more opportunities for interaction between universities and commercial agricultural companies.
Many important research breakthroughs were developed without thought of immediate application or payoff. Universities must do some high risk, venture type of work.
Genetic engineering offers great possibilities to improve performance. Perhaps we have not applied genetic principles to feed efficiency and reproduction.
We are beginning to understand more about immunology. Will see great changes in this area. Need new and better animal models for research.
Need to have research on what is good for long-term health—geriatric nutrition is a good example. Universities have the objectivity and credibility to lay out the scientific facts.

How the Program Developed

The subjects of food and agriculture cross college and department lines. That's why the deans of the Colleges of Agriculture, Home Economics and Veterinary Medicine worked together in appointing the Food for the 21st Century planning group.

The group of eight faculty members immediately started gathering information and ideas. It held discussions with University faculty in agricultural economics, rural sociology, plant pathology, family living, biochemistry, and other subject areas. Purpose was to get wide-ranging viewpoints as to what the future holds.

Special efforts were made to hold discussions with six major commercial firms in food and agriculture—all heavily involved in national and international markets.

The discussion took this general format:

1. Identify the problems and constraints that will affect food and agriculture in the year 2000.

2. Which of these problems and constraints should receive research priority?

The planning group also considered recommendations which came out of the College of Agriculture Commodity Planning Process in mid-1982. As a part of this process, farmers and agribusinessmen throughout the state were invited to express their views on which research should receive priority. Although the goals of this process were shorter term in nature, the results provided an excellent summary of concerns of producers and scientists.

Basis for Recommendations

The Food for the 21st Century planning group considered at length all of the information, ideas, and opinions gathered from a variety of sources. It noted that looking 15 to 20 years into the future becomes an uncertain venture because change is coming so rapidly. Futurists say that we now have such abrupt changes that it is dangerous to make projections from trend lines.

It is one thing for futurists to speculate and hypothesize about what might happen. It is quite another to make specific recommendations on actions that should be taken. That's why the planning group chose to base its recommendations on fundamental needs and approaches that will keep pushing at the cutting edge of science.

The group resisted the temptation to recommend for emphasis all of the many areas that merit further research. Instead, it encourages building a solid base and "critical mass" in selected areas. This kind of concentration offers the greatest opportunity for significant scientific progress.

The group also considered its specific assignment—to recommend areas to receive extra emphasis and priority, not plan the total future research programs of the Colleges of Agriculture, Home Economics, and Veterinary Medicine. Many research areas not specifically identified in this report certainly merit continuing support in these colleges.

In addition, the planning group used the following criteria for selecting priority areas:

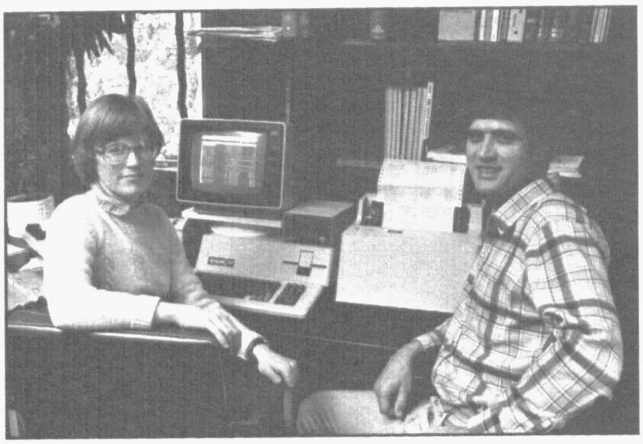
1. Is economically important to the state.

2. Is on the "cutting edge" of science with potential for major scientific contributions.

3. Builds on present strengths of the University, including opportunities for interdisciplinary work with other scientists throughout the University.

4. Provides scientists for the future.

5. Is appropriate to the University's goals and responsibilities.



Agriculture, including farm production, is rapidly becoming a "high tech" industry. Fran and Brian Schnarre, who farm near Centralia, use a computer for analysis and planning. Missouri farmers will need a continuing flow of research findings if they are to be successful. History shows that agricultural production moves to those areas which are first to adopt new technology.

Constraints to Progress

A rapidly growing world population will put pressure on food supplies in the 21st century, even though there may be temporary periods of surplus. The cost in both dollars and human misery from food shortages is unacceptable to a concerned society. Conversely, an abundant supply of wholesome, nutritious food ranks high in priority for quality of life.

Missouri will play a key role in providing this abundant supply if it takes steps now to overcome constraints that will limit its food and agricultural industry in the 21st century. History shows that the food and agriculture industry moves to areas that use the most advanced production and processing technology.

Constraints identified include:

1. Past advances in plant and animal production have been made by lengthy selection processes or by simple trial and error. The easy advances have been made. Potential gains to be achieved using old procedures are shrinking. New selection and development procedures based on improved understanding of basic plant and animal metabolic regulatory processes will be needed if we are to achieve major increases in yields and quality in the future.

2. The great variability and unpredictableness of Missouri's climate, and the disease and insect situation will continue to cause substantial losses in crop and livestock production. Heat, cold, drought, too much rain, and competition from weeds and parasites will put stress on plants and animals. Increased regulation of pesticide use and concern for a safe environment will challenge our ingenuity to develop new disease and pest management methods.

3. The effectiveness of many current agricultural production methods depends heavily on petroleum energy sources: tractor fuel, fertilizers, herbicides, grain drying. Such energy sources are likely to become increasingly scarce and expensive. More energy-efficient plants, animals and production methods will need to be developed.

4. Continued loss of topsoil at its present rate will limit Missouri's ability to produce food in the future. This will require development of different methods of production and crop plants with growth characteristics that help keep the soil in place.

5. We still lack knowledge of the nutrient needs for a lifetime of health and best human performance. Especially lacking is information about nutrient needs of persons under different living situations and stresses. This constraint prevents consumers from selecting their best possible diet and food manufacturers from developing products to meet special needs.

6. As the production, processing, and marketing of food become increasingly complex, the demand for highly trained specialists in industry and education may well outstrip supply.

7. The great variability in climatic and political conditions throughout the world results in uneven supplies of food from year to year and from country to country. Producers find themselves on a rollercoaster in terms of prices and income, and without adequate information on which to base their production and investment planning. Policy makers need the best possible information as to short term and long term effects of alternative policy decisions.

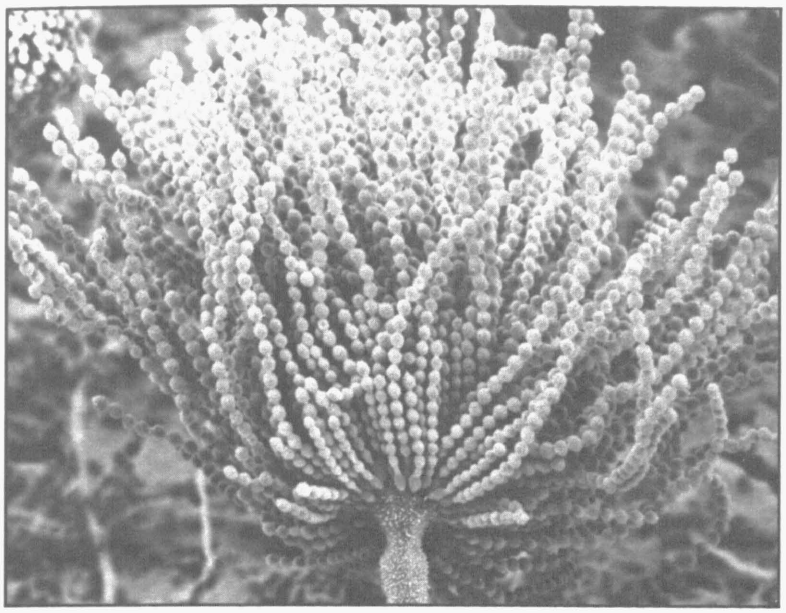
8. Agricultural research is a time-consuming process. Moreover, success in achieving major technological breakthroughs is neither guaranteed nor predictable. There is a risk that abundant food supplies at present and the current economic situation may cause the public to underestimate the need to invest in research for future needs. Waiting until food supplies are tight will be too late to begin research. It often takes 20 years or more for basic research to provide practical application.

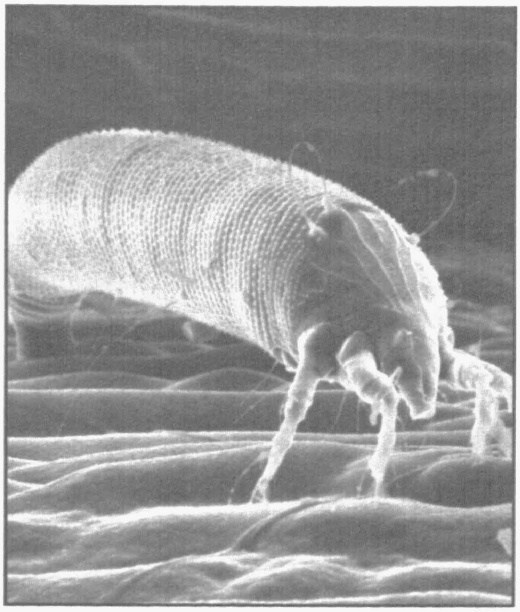
"The nation's future depends heavily on the ability of technology to devise methods of greater food production in the face of declining resources."

Kansas City Star, August 9, 1981

"Big breakthroughs in the future will depend increasingly on basic research. Yet in a depressed economy it is usually one of the first items cut from the budget by both industry and government. Such a strategy only aggravates the problem by reducing the potential for increases in productivity and for the development of new commercial products and processes."

Richard C. Atkinson, Chancellor, University of California at San Diego, *The Chronicle of Higher Education*, March 2, 1981.





Disease and insect problems continue to take their toll of Missouri crops and livestock. At left, magnified 420 times are spores of *Aspergillus flavus,* the fungus which causes aflatoxin contamination of grain in the field and in storage. This contamination can destroy the food and feed value of the grain. At right magnified 640 times is the mite vector (carrier) of wheat streak mosaic virus, which infects wheat plants. One major objective of the Food for 21st Century program will be to learn how to make plants and animals more resistant to diseases, insects, and other pests.

Short Term, Long Term Needs

Many problems and constraints in food and agriculture, including some listed earlier, cry out for immediate attention. They more nearly fit into a 3 to 5-year range of planning rather than long range 15 to 20-year planning. Examples include soil erosion, marketing and economic policy, land use, minimum tillage, crop rotations, water quality and use, and energy conservation and alternatives. Considerable work is already underway to attack these problems. Over the long term, the areas of research recommended for priority in the Food for the 21st Century program will provide key information about plants, animals, and the environment. This research will provide the foundations of knowledge and technology needed to help solve food and nutrition problems in the 21st century.

Goals Provided Direction

After considering the restraints and opportunities, the planning group set down three simple yet far-reaching goals for the research priorities it would recommend.

The first goal is to develop plants and animals that will most efficiently use the resources and environment available for producing food that we will need. Soil, water, and energy must be conserved in the years ahead as they will become increasingly limited and expensive. The biological input—plants and animals—offers the most potential for improvement within this production system.

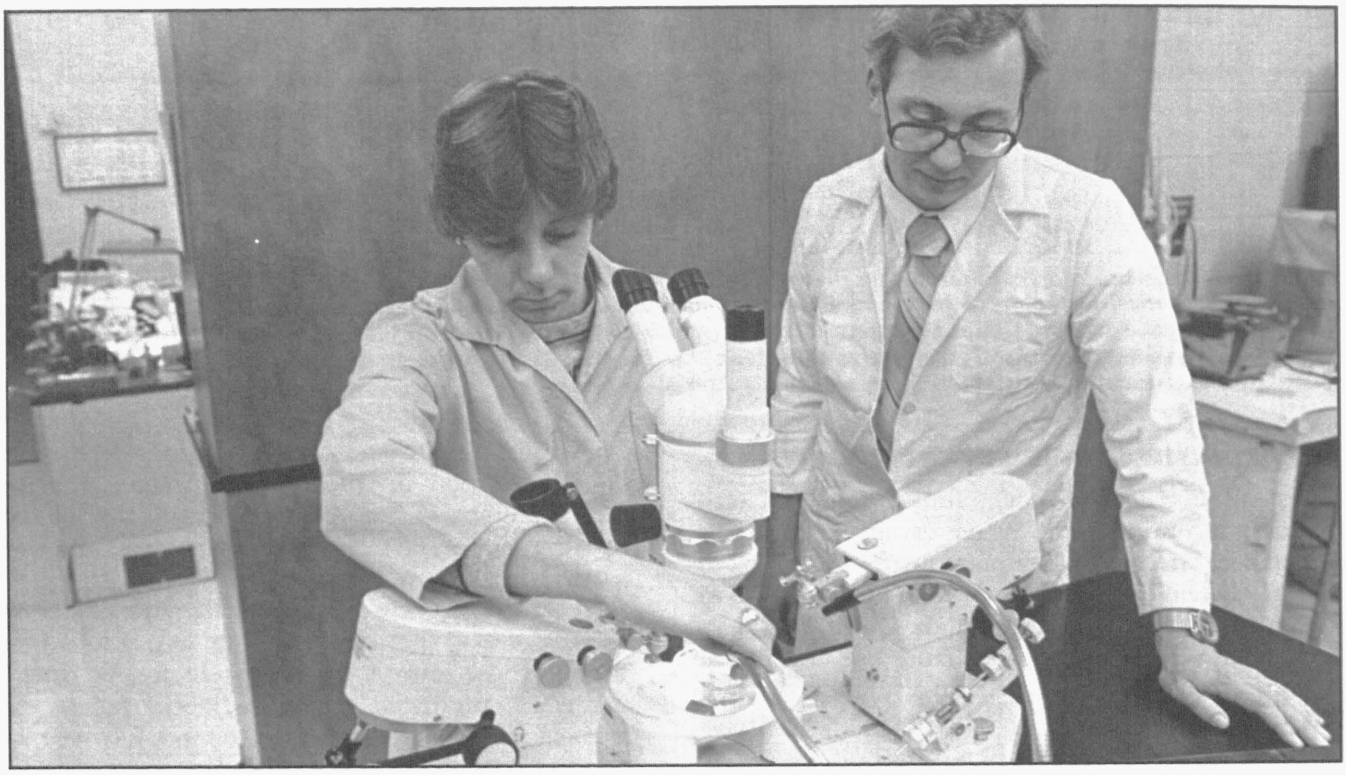
Along with adequate total food production, more stability in food production is desirable. A better understanding of how plants and animals interact with the environment will help reduce stress and level out wide swings in production.

A second goal is to determine if there are additional sources of food that can contribute to our total food supply. These sources might include organic materials, waste products, or nontraditional plants and animals. There also is potential to more fully use the traditional products now available.

Third goal reflects the ultimate use of food—to help people know how to use nutrition for the best possible health, performance, and longevity. Large gaps still exist in what we know about how nutrition affects the human body and mind, especially in different living situations.

> "A much higher percentage of the monies spent on agriculture has been for essential, practical work, and basic research has received very limited funding. The result of this spending policy is that there is a woeful lack of knowledge about basic processes in plants, especially the biochemistry, physiology and molecular genetics of plants."
>
> John T. Marvel, General Manager, Research Division, Monsanto Agricultural Products Company, in testimony before a subcommittee of the House Committee on Science and Technology, June 9, 1982.

Research Areas for Emphasis



UMC animal science researchers say embryo formation and cell differentiation are high priority areas for future studies. Reproductive physiologist Mike Smith and Ph.D. student Mary Ann Gall set up micro-manipulator—a lab instrument which will be used for genetic engineering studies in livestock. An additional benefit of such research is the training of future agricultural scientists.

The following three major research areas are recommended for emphasis.

Emphasis Area 1: Metabolic Regulation in Plants and Animals

There is still much to be learned about how a living organism makes use of its inputs—plant food, feed, water, and other essential elements. Even less well understood are the mechanisms that regulate the metabolism within an organism—the chemical changes in the cells and organs that provide energy for growth, maintenance, and reproduction. How are the metabolic processes regulated under the best of conditions and when the organism is under stress?

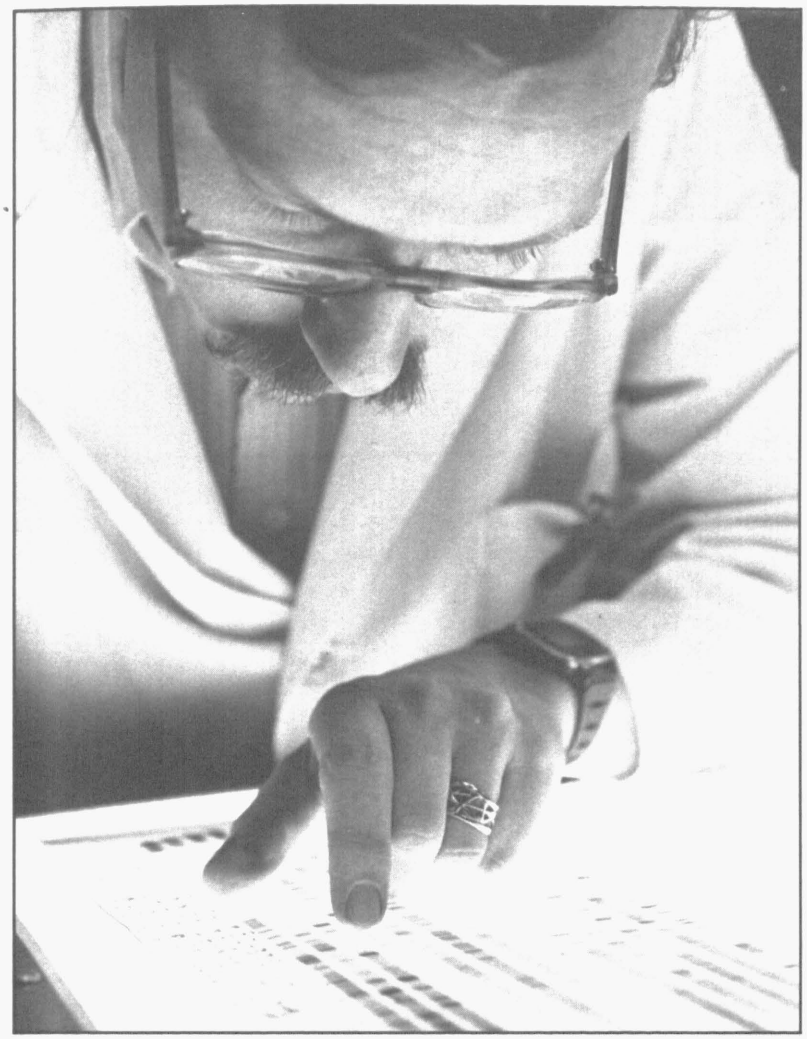
Here lies a key to future increases in food production. If scientists better understand these metabolic processes, they can bring about improvements through genetics and adaptation to the environment. They then will be able to make most effective use of new scientific technologies, such as genetic engineering.

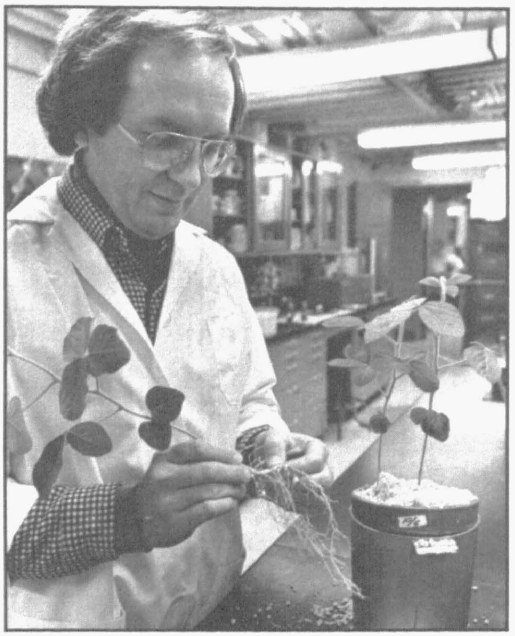
Practical applications would be numerous. For example, scientists might develop a corn plant that could effectively "shut down" through a drought period, then start growing again when rains come. Plants might be able to repel insect attacks by producing protective physical features and chemical substances.

In animals, it may be possible to develop more highly specialized individuals—a long life breeding animal engineered specifically for embryo production, or a fast growing meat animal engineered to produce specific ratios of muscle to fat.

Objectives:

1. To develop a more complete understanding of factors affecting metabolic processes in plants and animals, with special emphasis on hormonal control.





At left, Biochemist Francis Schmidt reads a DNA sequence to determine the chemical structure of an active gene. These basic findings are building blocks to further work in genetic engineering, gene cloning, and antibiotic resistance. Bacteria in nodules on soybeans may provide key to a greatly expanded understanding of plant growth regulators. Above, agronomist Dale Blevins says analysis of nodules shows that some bacteria produce 50 times more of gibberellin-like substances which can double plant height. UMC researchers want to determine how to use plant growth regulators to stimulate growth of roots so they can better penetrate compacted soil.

2. To determine the physiology and regulation of metabolism under abnormal genetic or stressful conditions.

3. To study the interactions involved in resistance of plants and animals to disease, insects and other pests.

4. To investigate the use of new biological "high tech" methods such as genetic engineering to improve growth and reproduction in plants and animals.

Emphasis Area 2: Alternative Sources of Food and Animal Feeds

As we look into the 21st century, we must broaden our basic understanding of conventional food production systems and, also, begin to examine the nonconventional.

Many sources of organic materials offer potential as food or feedstock. Among these may be such ordinary sources as sewage wastes, straw or brewery effluent and such exotic sources as coal, insects or algae.

Nontraditional methods of food production merit study to determine their potential for increased efficiency. Hydroponic growth chambers are already used commercially. However, research is lacking on a type of plant growth in which a plant gets its moisture and nutrients from air and rain.

For the more immediate future, we will be wise to make the most of what we have. That is, new and different products from our traditional plant and animal sources can likely be developed which allow more intensive use. For example, we can explore treatments which will make a wider variety of plant products more palatable and nutritious. Can grass-fed beef be made more desirable? Other work should emphasize processing methods which effectively use more of the raw product, reduce waste and spoilage, and increase storage life.

Finally, before any of these innovations can be adopted, the safety and nutritional value of any new food products must be evaluated. The consumer acceptability must be determined and developed.

Objectives:

1. To find additional methods and approaches to more fully use potential food sources such as wastes and byproducts.

Rolling hills covered with grass are a basic land resource in Missouri. Food for the 21st Century research will help develop plants and animals to make most effective use of this resource while conserving the soil and protecting the environment. Researchers will also evaluate other plants—forage, grain, horticultural—which could become profitable crops in Missouri.

2. To further develop and improve food products already available.

3. To explore new production methods and the potential of plant and animal species not now common in Missouri.

Emphasis Area 3: Specialized Human Nutritional Needs for Quality Life

Buoyant life throughout the lifespan is a worthy goal—a goal that people wish for themselves and their loved ones. Good nutrition can play a major role in achieving that goal; yet, much more needs to be learned. What is it that makes some older persons energetic dynamos while others seem to have no energy? The healthy feeling that lasts all day long, day after day, depends greatly upon the food supply and the nutritional quality of that food.

Improvement in the nutritional well-being of humans is limited by lack of knowledge in at least three areas: *nutrient needs* for a lifetime of optimal performance, *nutritive value* of food, and factors affecting *food acceptance* patterns. In the past, much nutrition research has been focused on the needs of normal, healthy adults. In the future, research must concentrate on special groups who have higher risk of poor nutritional status such as the older segment of the population or highly stressed individuals who may be prone to chronic, nutrition-related diseases.

Of particular concern in Missouri is the "over 65" age group. The proportion of the Missouri population that is 65 or over is well above the national average. This is a group whose numbers will increase markedly over the next several decades as the postwar baby boom passes into later adulthood. Also, it is a group in which changes in physiological state and life situation can affect both nutrient needs and intake.

As population increase puts additional pressure on food supplies, it will become increasingly important to have human nutritional needs more adequately identified. Such research results can be used to more efficiently guide food production and consumption.

Objectives:

1. To determine the specialized nutrient needs of human groups who face special life situations.

2. To study how different life situations affect what and how much people eat.

3. To determine effects of personal diet choice on health, and physical and mental performance.

4. To develop methods to increase adoption of improved nutritional habits.

Recommendations Build on Strengths

The recommendations for research emphasis build on already-present strengths in Missouri and its land grant University:

Good nutrition can add much to the quality of people's lives—energy to be active and doing things, health and strength to be independent into the older years (at left). Much still needs to be learned about special nutritional needs of groups living in special situations, including those of older persons. Above, UMC students take part in nutrition research aimed at finding improvements or alternatives to the standard hospital clear-liquid diet used immediately before and after surgery. A nutritionally complete diet is important to speedy recovery. Nutritionist Richard P. Dowdy (background) directs this research.

1. Missouri agriculture is a major producer of key plant and animal products. Predictions are that these major plant and animal species will continue to provide the bulk of food supplies into the 21st century. The recommended research will help minimize the constraints limiting expanded production of major commodities and explore possibilities for new approaches to food production and use.

2. Missouri has strong aggressive leaders and members in its farm organizations and commodity groups. They want and will adopt research findings quickly.

3. Missouri is home to numerous agribusinesses that are leaders in national and international agriculture. One of its urban areas, Kansas City, has started a development and promotion program to become known as the food capital of the world. The agribusinesses depend on University research and their own research efforts to provide the basis for their technology. There are excellent opportunities for cooperative efforts on research, training of future scientists and on-going professional improvement.

4. Missouri is strategically located and has access to ground, water, and air transportation for national and international trade.

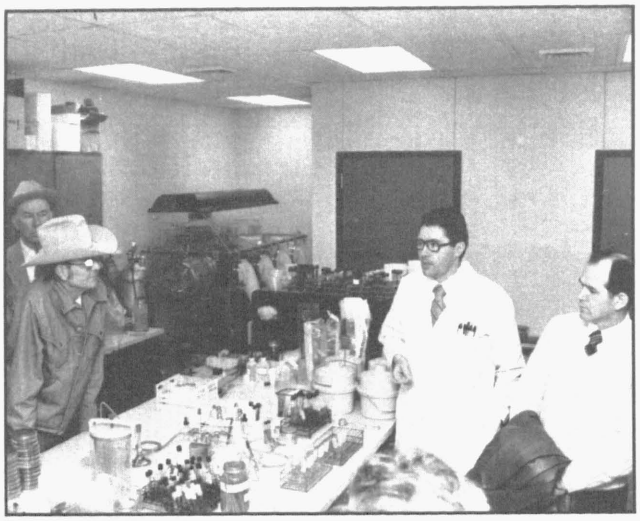
5. Food and agricultural scientists at the University of Missouri-Columbia are in excellent position to move more strongly into the research areas recommended for emphasis. UMC has a history of major scientific contributions:

Plant genetics and physiology—Work on cytogenetics of wheat (chromosome engineering) resulted in techniques to make it possible to transfer genes from wild grasses to cultivated wheat for disease resistance. Other work resulted in increasing protein content in corn, doubling the strength of the stalk, and developing an inbred line that has served as a parent for about one-eighth of all corn grown in the U.S. Other progress includes forages with improved nutritive value, and soybeans resistant to the cyst nematode.

The present UMC staff includes an excellent nucleus of biochemists, molecular biologists, and plant geneticists.

"Animal agriculture serves human needs. Three-fourths of the protein, one-third of the energy, most of the calcium and phosphorus and substantial amounts of essential vitamins and other minerals in the American diet are from animal products."

Animal Agriculture: Research to Meet Human Needs in the 21st Century, (p. ix).



The UMC Veterinary Medical Diagnostic Laboratory identifies livestock disease problems in Missouri through post-mortems and consultation with veterinarians and producers. Bacteriologist William Fales discusses organisms which cause shipping fever with visiting livestock leaders and veterinarians. This knowledge of current disease problems provides many opportunities for UMC veterinarians and animal scientists to cooperate on research and teaching programs.

Animal physiology—Some of the earliest work at UMC resulted in classic studies on causes of growth in cattle and development of growth standards. Later work in endocrinology studied the role of the thyroid, adrenal, pituitary and sex glands. These studies laid the groundwork for controlling reproductive processes, such as artificial insemination. More recent studies have pioneered controlled estrus in cattle and hogs to get planned breeding dates. Progress has also been made in embryo transfer and culture of embryos in test tubes.

Newly completed animal science research facilities at UMC are unmatched in the country, and will allow an excellent faculty to study the physiology of animals under controlled environmental and stress conditions. These facilities, along with the College of Veterinary Medicine and Animal Diagnostic Laboratory, offer a unique set of resources for further research important to Missouri's livestock producers.

Human and animal nutrition—Pioneering studies contributed greatly to the knowledge of the nutrients, including vitamins, amino acids, and minerals, needed for a complete life cycle. UMC work on discovery and identification of the vitamin B complex, including vitamin Bc, or folic acid, is internationally known. Major studies continue today on the role of zinc in human growth and disease resistance.

There is tremendous opportunity for further contributions to the knowledge of nutrition through interdisciplinary work in agriculture, home economics, medicine and veterinary medicine.

Summing Up

A recent study by the Joint Economic Committee of the U.S. Congress identified what factors influence high technology firms when deciding where to locate. The study showed that higher education, as well as secondary education, play the major role in helping a community or region attract high technology firms. Food and agriculture is rapidly becoming a high technology industry. The message is clear: strong research and educational programs are essential to enable the State of Missouri to grasp the opportunities ahead in the food and agricultural industry.

Examples of Many Major Agribusinesses Headquartered in Missouri

Monsanto, St. Louis. Large producer of agricultural chemicals.

Farmland Industries, Kansas City. Nation's largest farm co-op.

Ralston Purina, St. Louis. One of the largest animal food processors in the world. Is also a major grocery manufacturer.

Mid-America Dairymen, Springfield. One of the nation's largest dairy co-ops.

Pet, Inc., St. Louis. Widely diversified food processor and distributor.

Anheuser-Busch, St. Louis. Major food producer as well as world's largest brewer.

Kansas City Board of Trade. Largest futures market in the world for hard red winter wheat.

Merchants Exchange of St. Louis. Largest cash grain market in the world—important in export grain trade.

Farm Credit Banks of St. Louis. Headquarters for Federal Land Bank, Production Credit Associations and Bank for Cooperatives in three states: Missouri, Illinois and Arkansas.

MFA, Columbia. Regional agricultural co-op.

Paul Mueller Company, Springfield. Major manufacturer of stainless steel milk tanks

Agricultural Experiment Station
University of Missouri-Columbia

For more details on research recommendations of the Food for the 21st Century planning group, write to Dean's Office, 2-69 Agriculture, Columbia, MO 65211.

"Decisions made now will determine whether Missouri food and agriculture is a leader or a follower in the 21st Century."

Dean Roger Mitchell
College of Agriculture
University of Missouri-Columbia

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