5-1987

Biotechnology & Plant Agriculture: "Steps in Developing a New Product"

Kevin G. Mallon

LINDENWOOD COLLEGE

BIOTECHNOLOGY & PLANT AGRICULTURE: "STEPS IN DEVELOPING A NEW PRODUCT"

A CULMINATING PROJECT SUBMITTED TO THE FACULTY OF THE L.C.I.E. DIVISION IN CANDIDACY FOR THE DEGREE OF MASTERS OF SCIENCE IN BUSINESS ADMINISTRATION.

BY:
KEVIN G. MALLON

ST. LOUIS, MISSOURI
MAY, 1987

"ACKNOWLEDGMENT"

To Jack Kirk & Bernie Weinrich
Without their patience and understanding
this project would not have been completed.

To my family for support & encouragement

To Laurie A. Snay whom I love.
Thank you for all your help.

Sincerely,
Kevin G. Mallon

ABSTRACT

Biotechnology & Plant Agriculture:

"Steps In Developing A New Product"

This is a qualitative investigation of biotechnology and its relationship to plant agriculture and new commercial product development and an organizational form for carrying out a continuing program of new product development in biotechnological plant development.

The major goals are:

1) to present biotechnologies possible impact on plant agriculture,

2) to identify those market characteristics of new possible products,

3) to screen data on what will need to be done to develop and introduce new products.

4) to suggest an appropriate organizational form for new product development in biotechnological plant development.

This study specifically seeks to integrate new product development and introduction procedures from an organizational point of view and how it correlates to plant agriculture and what biotechnology as a new process can do to possible markets. Documenting the structural characteristics of the markets certainly promotes our fundamental understanding of future products; but it also sets the limits within which we may generalize from the experiences of past marketers. However, biotechnology is a new process which is becoming a reality and, therefore, an effective new product program demands high resolution of all relevant variables into a new type of organizational form for new product introduction.

TABLE OF CONTENTS

Table of Contents Cont'

CHAPTER I
INTRODUCTION

General Background

"The successful firm of the future will be one which is structured so both external and internal problems are given appropriate and continuous attention. Beyond this, the management structure will be conducive to innovation. The search for opportunities and problems wil be institutionalized and continuous, the internal productive cycle will be Research and Development oriented, manufacturing and marketing will be flexible and responsive to change in product-market mix."(1)

H. Igor Ansoff

Few developing technologies have generated as much interest, excitement, discussion and potential promise in corporate boardrooms and with corporate planners throughout the world as have genetic engineering and related biotechnologies.(2)

The term biotechnology has emerged recently to encompass both new and old processes and techniques which carry out manipulations of the genetic material (DNA) of living cells. The processes and techniques encompassed in this broad technology are recombinant DNA methods, genetic engineering methods, biocatalysis, cell fusion methods and fermentation. All of these processes and techniques do overlap in that they are all forms of intervention by man in the evolution of an organism.

(1) H. Igor Ansoff, Acquisition Behavior of U.S. Manufacturing Firms (Nashville: Vanderbilt University Press, 1971), p. 4.

(2) Technomic Consultants, A Technological & Business Opportunity Assessment of Genetic Engineering and Related Biotechnologies 1980-1990 1 vol. (Chicago: Technomic Consultants, 1981), p. I-1.

The end result or objective is the manipulation of a living organism to modify, metabolize or synthesize a commercially desirable product.

There is a need for more efficient crop production, and biotechnology can add some important new and very innovative, different and fascinating, practical, commercial techniques to plant agriscience. Among the goals of new technologies in plant agriculture are creation of drought resistant grains, living fertilizers, new crops, and perennial corn.

This report looks at and analyzes firms using biotechnology to enhance plant agriculture. It determines which industries will be most affected by the use of the technologies in crop production -- the seed industry, fertilizer manufacturers, chemical manufacturers, food industry, and other applications.

Also the organizational implication of the factors identified as important to this process of biotechnological innovation is considered. The analysis will look at the elements that are traditional to new production introduction versus possible new alternatives that bear upon the agribusiness. The purpose then of this paper is to examine new forms of organization for product introduction ito agribusiness.

Information is gathered from primary, original interviewers with scientists and industry leaders, both in person and by telephone; these are accompanied by a substantive literative search.

Overview of Agribusiness

Historically the world has gone to war to relieve the pressures imposed by political and economical factors that effect the world population. However, technological innovation is an alternative mechanism that could deter and inhibit this historical response. Some simple facts highlight why biotechnology could be a viable alternative.

Demand:

o World population has increased 25 percent over the past ten years and could increase another 50 percent over the next twenty years. The total world population is estimated to grow to six billion by the year 2000.

o Food shortages will occur more often and in more places over the next few years.

o Less developed countries are neither feeding themselves nor increasing their ability to buy what they need on world markets.

Supply:

o Essentially every acre of U.S. land used is producing the optimal crop using the most effective techniques.

o The amount of available land is decreasing.

o Production has fallen due to adverse weather.

o The amount of grain reserves are falling.

Market Effects:

o Prices have risen and will continue to rise.

o Exports will most likely increase, therefore, causing an increase in domestic prices.

o Projected population increases exceed projected increase in the food supply.

Source: Policy Research Corporation and The Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector (Chicago: Policy Research Corp. and The Chicago Group, Inc., 1981), p. 8.

The Potential for Genetic Engineering

One original goal in producing this report was to develop a qualitative understanding of the various forces which affect the economic development of genetic engineering in the agricultural sector. The evidence assembled clearly shows that political and economic forces outweigh scientific issues in determining the directions for commercial research and development (R&D) in genetic engineering. (3)

The Agribusiness Sectors

Agribusiness is the term that has been used to describe the specialized segmented organization of agriculture and its affiliated industries as they evolved in the United States and the other technologically advanced nations over the past fifty to one hundred years.

(3) Business Communications Co., Improving Agricultural Yields Using Biotechnology, (Stamford, CT.: Business Communications Co., Inc., 1983), p. 17.

In the U.S. economy, agribusiness accounts for 20 percent of Gross National Product (GNP), amounting to $550 billion per year. Figure #1 shows the main components of total agribusiness output.

Figure #2 describes the various players in agribusiness: suppliers, producers, processors, and distributors:

o Suppliers, provide the materials for modern agricultural practice.

o Producers, farm and raise livestock.

o Processors, modify the products into more salable form.

o Distributors, bring the products to the consumer.

GeoPolitics

With the technology and marketing, the purpose of agribusiness with all of its anomalous characteristics, is to produce enough food for all to live.

The U.S. agribusiness is under increasing pressure to produce more food, not only for itself, but to offset imbalances in the world, to provide leverage in politics, and to supply fuel as a substitute for oil.

Today all of the best land is under cultivation. U.S. grain is selling at high prices abroad and grain reserves are low. U.S. policy makers are faced with a dilemma. Grain along with technology are the two products in which the U.S. holds a comparative advantage in world markets. However, increasing grain exports have a negative domestic effect. The more that is exported, the less there is available at home and the faster domestic prices rise.

FIGURE 1: THE U.S. AGRIBUSINESS SECTOR

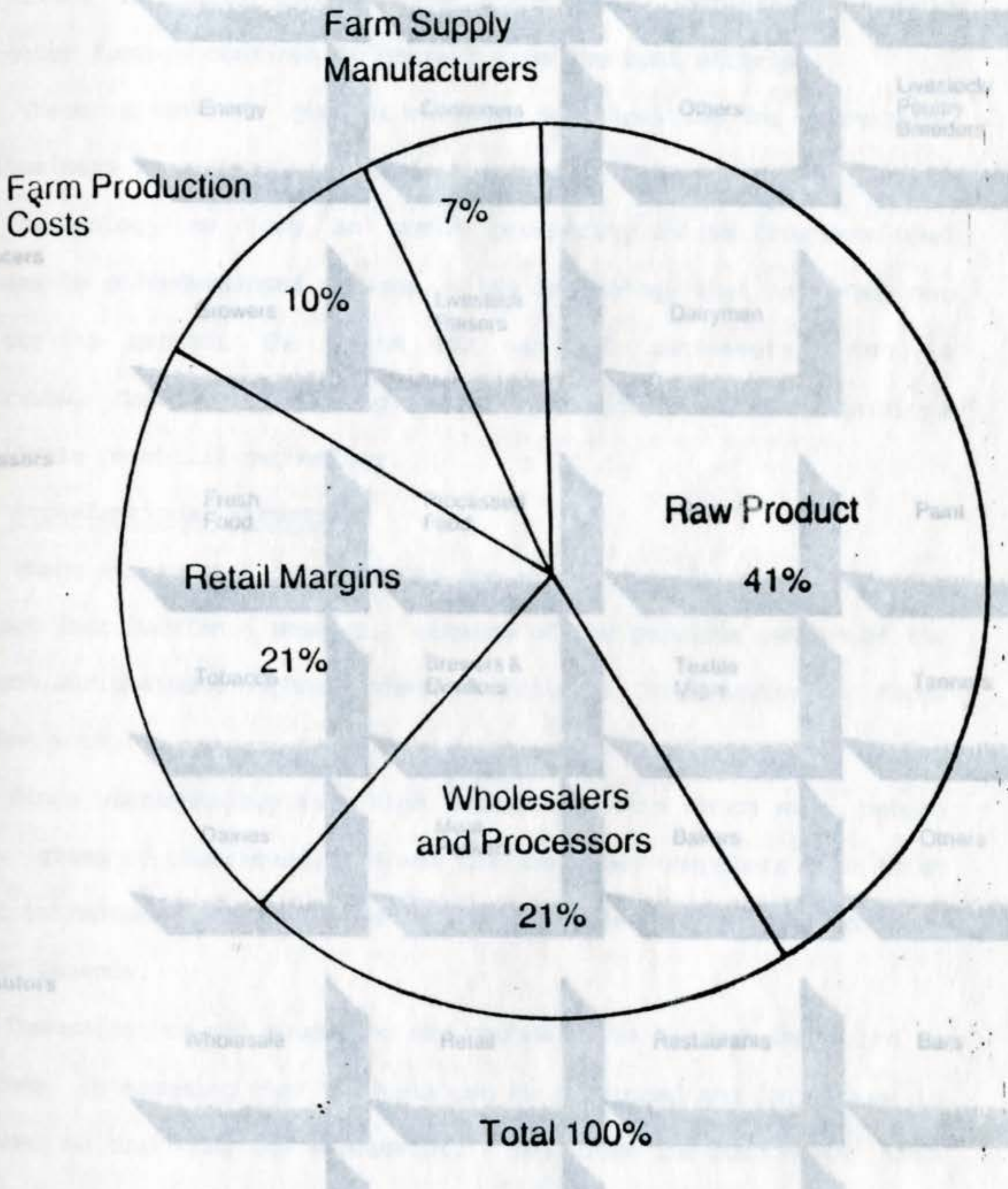
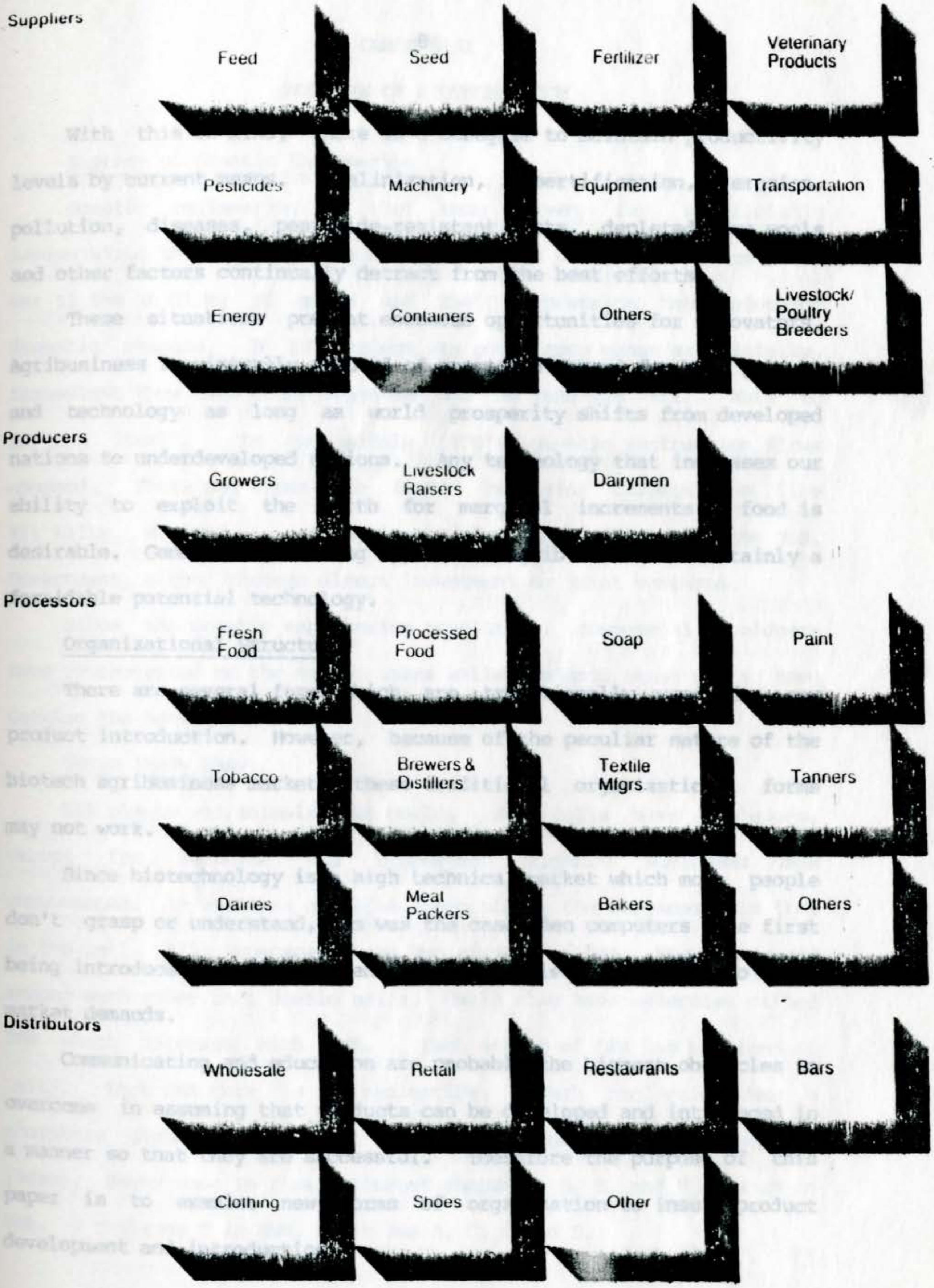


FIGURE 2: AGRIBUSINESS PARTICIPANTS



With this in mind, there is a struggle to maintain productivity levels by current means. Salinization, desertification, erosion, pollution, diseases, pesticide-resistant pests, depleted gene pools and other factors continually detract from the best efforts.

These situations present enormous opportunities for innovators. Agribusiness is virtually assured of continued demand for both product and technology as long as world prosperity shifts from developed nations to underdeveloped nations. Any technology that increases our ability to exploit the earth for marginal increments of food is desirable. Genetic engineering applied to agribusiness is certainly a formidable potential technology.

Organizational Structure

There are several forms which are traditionally used for new product introduction. However, because of the peculiar nature of the biotech agribusiness market, these traditional organizational forms may not work.

Since biotechnology is a high technical market which most people don't grasp or understand, as was the case when computers were first being introduced and their potential must be flexible enough to meet market demands.

Communicating and education are probably the biggest obstacles to overcome in assuming that products can be developed and introduced in a manner so that they are successful. Therefore the purpose of this paper is to examine new forms of organization to insure product development and introduction.

CHAPTER II

OVERVIEW OF BIOTECHNOLOGY

History of Genetic Engineering

Genetic engineering is the term given for artificially manipulating the hereditary material of living organisms. Since World War II the handling of genes and their expression has undergone dramatic changes. By 1970 scientists could copy genes artificially, transplant them into other organisms and the gene was still able to express itself. In the middle 1970's genetic engineering firms emerged. These new firms were funded by major corporations like Eli Lilly, Monsanto, and National Distillers along with the U.S. Government, either through direct investment or joint ventures.

Since the genetic engineering revolution, commercial developers have concentrated on the easier tasks while academic researchers have tackled the harder problems.

Genes (Made Easy)

All plants and animals have cells. Most cells have nucleuses, except for bacteria and blue-green algae. Nucleuses have chromosones. In bacteria and blue-green algae, the chromosone is free in the cell. All chromosones have two strands of DNA. They are wound around each other in a double helix. Cells also have molecules called RNA which interact with DNA. Each strand of DNA has billions of units. Each DNA unit is a nucleotide. Each nucleotide has a phosphate group (P), a sugar (S) and a nitrogen-containing compound (Base). Bases come in five different shapes A, B, G, and T show up in DNA. U replaces T in RNA, so it has A, C, G and U.

Because of their shapes, the bases always pair up in the same way. Base-pairing holds the two strands of DNA together in the chromosone. Each DNA strand has many genes, each hundreds to thousands of nucleotides long. Each gene has a plan for one protein. When a cell needs a protein, it sends a signal to the chromosone. After the signal, the two strands of DNA separate. Then RNA enters the process. A strand of RNA builds itself by base-pairing with nucleotides of the gene for the protein that's needed. This RNA is called messenger RNA, because it carries the message for the protein. When the messenger RNA has copied the gene, it leaves the nucleus and goes to the ribosones, in the cells cytophasm (the material outside the nucleus). Ribosones are protein factories. Proteins are strings of amino acids, just as RNA and DNA are strings of nucleotides. Three nucleotides on the RNA carry the message for each amino acid in the protein. Transfer RNA brings the amino acid to the ribosone. The ribosome moves along the messenger RNA and translate the nucleotide message into amino acids on the protein.(4)

In order to engineer genetic expression you must first find the protein you want and determine the order of amino acids in it. It may take months, even years for large ones. Then translate the order of amino acids into the order of nucleotides that spell it out on the messenger RNA. Put the messenger RNA together nucleotide by nucleotide. It usually takes weeks or months. The process is to work backwards and make complementary DNA from the artificial RNA.

(4) Policy Research Corporation and The Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector (Chicago: Policy Research Corp., and The Chicago Group, Inc., 1981), pp. 20-40.

When complete, it is an artificial gene. Besides the DNA on the chromosones in the nucleus, some cells (bacteria) have small strings of DNA elsewhere, called plasmids.

Scientists can take a plasmid out of the bacterium, cut it open, graft the artificial gene on the plasmid, and put it back in the bacterium. When the bacterium divides into two during reproduction, so do the nucleus and plasmids. Bacteria multiply in minutes. In hours, there are hundreds of copies of artificial gene. These copies are clones, the clones are attached to the genes of a natural bacterial protein. The new combined gene is then grafted on the bacterial chromosone. The bacterium makes the combined protein from the combined genes. Separate the protein originally desired from the rest of the combined protein. The bacteria have become protein factories.

Bacteria with extra genes are less competitive than natural bacteria. It's hard to keep them alive. The more extra genes they have, the less competitive they are. They are selected against in natural environment. So the new genes die out.

Most desirable results involve more than one gene, perhaps a dozen. Genetic changes should be permanent, the organism must survive. Nobody knows how multiple gene processes work.

This process is important because if plants can be genetically engineered new species can be produced to help meet agricultural demands in the world.

Biocatalysis

Biocatalysis is the incorporation of enzymes which may be secreted by microorganisms to convert biological molecules, (a substrate, into another biological molecule or product. It must be emphasized that processes are specialized one-step conversions.

Successful biotechnological innovation depends on selecting the most suitable biocatalyst, optimizing its structure and deploying it in an environment which optimizes its function.

For most processes, efficiency and overall economics are improved by extending operational life for reuse. This may be done by continuous flow or fed-batch fermentation or various types of immobilization technology. Biocatalysts are and will be used, in a wide range of contexts - chemical transformations, chemical synthesis, analysis medicine, food and beverage processing and effluent detoxification. (5)

Cell Fusion

Cell fusion is actually what its name implies. It is the fusion of two cells to form a cell with two or more nuclei with a single cytoplasm. An example of this is the production of monoclonal antibodies obtained by fusing antibody producing lymphocytes (from the spleen of mice immunized with a particular antigen) with malignant

(5) A.T. Bull, Geoffrey Holt and Malcolm D. Lilly, *Biotechnology-International Trends and Perspectives* (Paris: Organization for Economic Co-operation and Development, 1982) p. 55.

rapidly proliferating myeloma cells. These hybrid myeloma cells or "hybridoma" expressed both the lympho-cytes' specific antibody production and the myeloma property of continuous proliferation. (6) The process is similar for plants, a protoplast (a cell deprived of a cell wall) is fused into cell-wall bearing strain where regeneration occurs.

Fermentation

Fermentation is the primary method of production using microorganisms.

It has been used by various industries to produce commercial products. A successful fermentation requires optimizing various parameters including temperature, PH, stirring velocity, volume, flow rate and nutrient medium. However, the most important part of fermentation is the microorganism. Microorganisms can be genetically engineered to synthesize new commercially significant products or to produce existing compounds more efficiently, at greater purity and higher yield.

These processes and their procedures culminate what is popularly called biotechnology. Although biotechnology has applications in all sectors of the economy where organic chemicals are extensively used, this paper will discuss their current status in plant agriculture only.

(6) Ibid., p. 30.

Biotechnology for agriculture is being explored by companies of all types, many of which are not traditional agribusiness firms. This technology could even make farming as practiced today obsolete through the hydroponic cultivation of vegetables and the development of single cell protein cultures which could eventually replace meat or soybeans as a cattle feed. Biotechnology may make agriculture more productive by making agriculture, in effect, a branch of nonfarm industry. More importantly, the logic of the development of the new production processes will not be determined by farmers and, perhaps, may even exclude the smaller agribusiness firms.

The determining influence will no doubt be the large multinational corporations. These firms will be in the best position to control the allocation of capital to biotech research and to ongoing and future production of biotech substances. For the foreseeable future, the course of biotech development will be largely shaped by these firms' industrial and marketing strategies. (7)

Seeds

Plant breeding is directed toward getting the best from each type of plant. Selection of the seed of hearty plants to produce new robust generations has been ongoing since the beginning of agriculture; DNA-centered selection technologies promise to intensify, particularize and systematize selection.

(7) Online Publications Ltd., Biotech 83 (Northwood, U.K.: Online Publications Ltd., 1983), p. 476.

The widespread use of these technologies could add needed diversity to our sources of germplast, help combat crop disease, increase tolerance to the weather and harsh soils, decrease the need for fertilizers and greatly speed the production of hybrid parent lines. Most of these improved qualities will be encapsulated in seed. (8)

Improving Plant Strains: Traditional Breeding

Since the 1920's, plant breeding has involved increasingly sophisti-cated methods of hybridization. This has changed the seed industry from one of processing and trade to one primarily engaged in research and development. The continual development of new hybrid lines makes seed production now one of the most research-intensive tasks of all agribusiness sectors. The new genetic technologies will further intensify this trend.

Hybridization represents genetic manipulation as it today relates to crop production. It has been at least 50 percent responsible for the 400 fold increase in corn yields since its introduction, and will maintain a critical position vis-a-vis the new biotechnological methods for changing, controlling, and improving strains.

(8) Business Opportunity Report, Improving Agriculture Yields Using Biotechnology, (Stamford, CT: Business Communication Co., January 1983), p. 17.

What is a Hybrid?

A hybrid is the result of a fortiutous crossbreeding of two separate parent plants to yield a plant better than either parent. The seed from the new plant is sold to farmers. Plants from this seed are predictably uniform, of high quality (in terms of heartiness & yield) and better than either of the parent plants individually.

Producing the parent plants is the major part of producing a hybrid. Selection and breeding require as many as ten or more generations. Therefore, most companies who breed plants for seed operate in climates which allow for two or more growing seasons per year, so that the new parent line may be developed in four or five years. This briefer period still represents a significant investment of time. This type of production intensity is not often predictable for the individual farmer, and is one of the reasons why independent growers can no longer compete with large companies in developing parent line.

Screening methods for parent lines are not only lengthy but are also complex. Some of the most common methods are pedigree, backcrossing, and single seed descent.

Improving Plant Strains Through New Biotechnologies: Beyond Hybridization

Two independent advances in cell and molecular biology -- the refinement of tissue culture techniques for propogating whole plants from leaf or other somatic cells, and the development of recombinant

DNA technology which allows genes from one organism to be incorporated into the DNA of a completely different organism -- have created the potential for a new approach to plant breeding. The potential exists for super crops and faster breeding. Together these techniques suggest a way of tailoring crops to the environment.

Our current tendency is to manipulate the environment, not the plant, through the use of herbicides, insecticides, irrigation and fertilizer; and to exercise patient human selection of plants over as many as ten or more generations.

The potential influence of the new biotechnologies on improving crop yields lies in the possibility of creating heartier strains with built-in disease resistance and drought tolerance; more efficient plants which might store more protein within seeds or fixed nitrogen instead of requiring fertilizer; and in more efficient breeding, whereby greater numbers of plantlets could be grown and screened in a smaller amount of time. Gene insertion also promises to take some of the guesswork out of traditional methods.

The constraints on the rapid development of these awaited supercrops pivot on the lack of knowledge about which genes govern which traits, on the difficulty of multiple gene insertions, and on the difficulty of achieving gene expression (protein synthesis) in the new organism, once the genes have been identified and inserted. These key areas are apparent from observing the weight of government-funded projects involving recombinant DNA and agriculture.

Because much of what still needs to be known is in the realm of basic rather than applied science, and because much of this research is plant specific and must therefore be replicated for use with each new crop, universities and government research programs will continue to generate significant advances in the genetic engineering of crops, sometimes in collaboration with the new biotechnological firms.

Potential products from the combinations of DNA and tissue culture include breeding stock for new cultivars, plantlets from single cell culture, seeds developed from cloned plants, improved strains of nitrogen fixing bacteria, symbiotic herbicide-plant variety packages, patent licenses for new processes and new plants.

Chapter III

APPLICATIONS, TIME HORIZONS & MARKET VALUE

Long Range Goals for Crop Production

"Two aspects of plant life have most intrigued scientists interested in improved crop yields: photosynthesis and nitrogen fixation. In each case certain crops exist which are more efficient than others, which suggests room for improvement of the laggardo could be engineered for efficiency to resemble the better plants". (9) Alfalfa, for instance, can fix its own nitrogen, however, corn can't and therefore fertilizer must be used which could account for one fourth of the cost for crop production. On the other hand, corn is an efficient photosynthetic plant whereas wheat loses energy through photorespiration. Since 1930 corn yields have increased by 400 percent yet wheat yields have only doubled. There is much that can still be done to improve yields of grain.

The following sections will not deal with all the applications agribusiness for which genetic engineering has been proposed, but will only deal with the plant aspect of agribusiness. Simple protein manufacture is the most advanced in which genetic engineering is propitious. Growth factors and hormones are in this category.

(9) Business Opportunity Report. Improving Agrigulatural Yields Using Biotechnology, January 1983, p. 70.

Multiple gene processes are less advanced than simple protein manufacture. Nevertheless, research continues its approach from two viewpoints:

- o "Finding the single most influential part of the biological process and manipulating the genes that control it".
- o "Unraveling the whole complex mechanism and changing whichever genes need to be changed".(10)

The bulk of the research is done by academic scientists. However, many companies have developed research departments where financial rewards are potentially great for new discoveries in simple protein synthesis.

For each application I will give a sketch of its background, an indication of the size of the market involved, the direction and progress of the genetic engineering going into it, and the possible implications of a successfull genetically engineered product.

All of the applications are being actively investigated where social/ economic incentives are high for these applications.

Research Goals of Agriscientists (Plants)

The U.S. Department of Agriculture has anticipated technological objectives for its crop production program which fairly well articulate the general priorities for plant genetics. These objectives are listed in Table 1.

(10) Policy Research Corporation and The Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector (Chicago: Policy Research Corp., and The Chicago Group, Inc., 1981), p. 61.

TABLE 1

Technological Objectives Associated With Physiological And Biochemical Technology To Improve Crop Production

1. Improve biological conversion of solar energy for increased crop production by increasing the efficiency of photosynthesis, translocation, and associated metabolism.

2. Improve nitrogen fixation efficiency of bacteria-plant associations and develop nitrogen-fixing capabilities in crops lacking this capability in order to reduce energy requirements for crop production.

3. Develop new and improved cell and tissue culture technology for plant improvement through increased genetic diversity and rapid vegetative propagation.

4. Develop technology for improving the absorption, translocation, and utilization of nutrients and water to increase crop production efficiency.

5. Improve technology for better crop production under environmental stress.

6. Develop new technology for control and regulation of biochemical, physical, and morphological processes of plants.

Other research goals revolve around combatting the natural hazards inherent in plant growth: pests, disease and the weather. Together these goals are often referred to as improving stress tolerance in plants. Breakthroughs in these areas especially in the area of disease resistance are expected to come before systemic changes (like improved photosynthesis) can be accomplished. This is because:

- Disease resistance is often controlled by only one gene.
- Genes for resistance to disease are found naturally in various crops. Rye, for instance, possesses many genes which govern resistance to diseases which infect wheat. Wild strains may also be used.
- Test for resistance to pathogens are now speedily accomplished in the lab by introducing the pathogenic agent into a tissue culture medium. The survivors (with resistance) are then grown into whole plants.
- Some stress tolerant features (like short stems in wheat) are already accomplished via traditional breeding.
- Salt tolerance and tolerance to temperature and moisture may also be tested in the lab with tissue culture.

Source: U.S.D.A. Annual Report 1981, Crop Production Research, Technological Objectives Associated with Physiological and Biochemical Technology to Improve Crop Production.

APPLICATION

PROTEIN ENRICHMENT

Background

The most important nutrients in food are proteins. These proteins are digested into their constituent parts "amino acids" and reassembled in cells into proteins that can be used.

> "Each type of food has its own mix of amino acids. There are 20 or 25 that we eat with come regularity. Some mixtures are more valuable to us (or our livestock) than others, more or less insofar as the proportions in our own bodies. The difference in food value between protein mixes has vast consequences, both economically in the prices that people will pay for high-grade protein (beef or wheat) versus low-grade versus high-grade diets on the health, development and well-being of individuals and populations". (11)

Research

Efforts are directed at enriching proteins in the foods we eat by changing the amino acid content of the proteins. The closer the amino acid mix parallels our own needs, the more useful the protein.

Scientists can locate a gene for a specific protein on a plant chromosone. One particular protein, zein, in corn is highly studied. Another is gliadin in wheat.

> "The amino acid mix of zein can be learned by conventional methods and the nucleotide sequence of the zein gene can be learned by genetic engineering techniques. The amino acid mix of zein can be enriched by substituting nucleotide sequences for "superior" amino acids for the sequences in the normal gene". (12)

(11) & (12) Policy Research Corporation and the Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector, (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981, p.71.

At present a normal zein or gliadin gene can not be removed and substituted into a higher organism but this is not a wild fantasy because genes from other plants have been removed and substituted into bacteri and expressed the desired result. Of course, these type of changes are not entirely clear yet on what effect this will have on a plant or us the final consumer. Much more basic research is needed.

Implications

Assuming it is practical to change a protein we may have more nutritive plants in ten or fifteen years. Corn hybrid seed is already a $400-$500 million business a year. A commercial hybrid for wheat (there is none now) could be created. This then would create for a greater potential in genetic engineering of multiple gene systems in all crops.

APPLICATION

FERMENTATION PRODUCTS

- o Amino Acids
- o Growth Promotants

Background

Amino acids are used as food supplement to enrich proteins and assist in protein formation. The current world market for amino acids is $1-1.5 billion.

Growth promotants include hormone-like substances such as zeranol (trade name: Railgro). Zeranol is encysted in the ears of ruminants to stimulate growth. These products are made by fermentation.

A feed stock of say protein, sugar and minerals is prepared at proper levels of acidity and temperature. The feedstock is inoculated with a culture of bacteria or fungi that make the desired product in part of their life cycle. The fermentation process is continued until it reaches an optimum level of product. The product is extracted with a solvent, concentrated and purified". (13)

Research

Modification of bacteria is a primary offshoot of genetic engineering. Designing sythetic genes is just an extension of existing technologies. Japan is the world leader in amino acid production. Several genetically engineered bacteria have been developed with improved yields.

The genetic engineering firm's first commercial products may also be amino acids. Both Genex Corporation and Bethesda Research Laboratories are designing bacteria to make acids which sell for $20-$80 per pound, depending on complexity.

Implications "The advantage offered by genetic engineering here is in improving the efficiency and economy of fermentation processes. It also offers the possibility of making feasible the fermentation of products that either have never been made commercially or that have been adapted to chemical synthesis from an original fermentation process.

Bethesda Research Laboratories has estimated that its bacterial amino acid manufacturing process might lower the price of one amino acid to $4-$5 per pound. If that estimate proved true, it would lower feed costs and perhaps extend the marketability of amino acids as feed supplements." (14)

(13) & (14) Policy Research Corporation and The Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981, pp. 75 & 76.

APPLICATION

PHOTOSYNTHESIS

Background

Photosynthesis is the process where plants convert sunlight into chemical energy in food. Through a complex cycle carbon dioxide along with water and nitrogen is changed in the plant to chemical (food) energy.

There are basically two types of plants when it comes to photosynthesis: C4 and C3 species. The C4 species are efficient in converting light energy into chemical energy. Less efficient C3 species which include crops like wheat, soybeans, sugar beets and tobacco waste half the CO_2 originally absorbed in the process.

$CO_2 + 2H_2O$ + LIGHT------$(CH_2O) + H_2 + O_2$ = 112 kcal/g atom of CARBON

C4 out-produce C3 by ratios of 2 or 3 to 1 in yields and growth rates.

C_4 Crop	Yield/Acre	Dry Weight M^2/Week	C_3 Crop	Yield/Acre	Dry Weight M^2/Week
Corn	87 Bu.	4,872 lb.	Soybean	26 Bu.	1,560 lb.
Sorghum	49 Bu.	2,744 lb.	Wheat	30 Bu.	1,800 lb.

There is a protein involved in photsynthesis known as ribulose biphosphate carboxylase/oxygenase (RVBP). The carboxylase/oxygenase in its name reflects its dual function in photosynthesis. From the stand-point of efficiency, the carboxylase aspect is good, leading to more CO_2 incorporation, but the oxygenase part is bad because it leads to photorespiration.

Research in recent years has been trying to find chemicals that block the oxygenase synthesis but there has been no practical breakthroughs.

Research

Genetic engineering is still another tool to be tested on this long-standing problem. Most of the efforts merely suggests future avenues for today and the near future, though a vast amount of basic research needs to be done. There are no guarantees that photorespiration is dispensible or that the current hypotheses about how to eliminate or reduce its effect are correct. Each variety of plant would have to be engineered separately, although if a single protein like RUBP was the culprit in photorespiration it could be changed in the same way for all varieties.

Implications

The stakes in gambling on improving photosynthetic efficiency seem worth far more of a wager than the level of research funding today would indicate. Nevertheless there are reasons to go slowly.

- "Changing the efficiency of photosynthesis on a broad scale changes the world ecology. Green plants recycle carbon dioxide and oxygen (O_2) in the earth's atmosphere. Removing more CO_2 and absorbing it in plant tissue means exhaling more O_2. The effects of such a change in the atmosphere are unpredictable, but some scientists have warned that burning fossil fuels was increasing the CO_2 content of the atmosphere and threatening another Ice Age.

- If photosynthesis becomes more efficient, plants will require more water and nutrients as well as more CO_2. The availability of water in many growing areas is severely constrained today. The same applies to nutrients, although they can sometimes be supplied by commercial manufacturers.

- Making photosynthesis more efficient means massive social changes in less developed traditional cultures and significantly greater complexity for the already highly artificial agriculture practices of advanced countries".(15)

(15) Policy Research Corporation and The Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981, p. 85.

Application Nitrogen Fixation

Background

Nitrogen is an essential element, comprising most of the atmosphere. During photosynthesis, plants combine nitrogen with other ingredients into amino acids which in turn make up proteins.

The productivity of plants is proportional to the availability of nitrogen. There are several ways in which nitrogen becomes available to plants.

In nature, nitrogen may be provided either by help of bacteria which live in the soil or in nodules on the roots of some plants. No plant can "fix" nitrogen by itself; that is, take nitrogen from the air and convert it into amino acids. All of them depend on bacteria to fix the nitrogen in intermediate compounds. The plants provide the bacteria with protein food. The two live symbiotically, whether the bacteria live in the soil or in the roots.

In farming, humans supplement bacteria by adding nitrogen to the environment in order to promote plant productivity. Manure was probably the first nitrogen-supplying fertilizer.

Scientific chemistry eventually isolated and identified the active element of these natural fertilizers. That, in turn, led to the commercial manufacture of nitrogen fertilizers, ammonia and nitrate and nitrite compounds.

Scientific biology uncovered the role of nitrogen-fixing bacteria. It was recognized that certain crops like corn tend to deplete the soil of nitrogen and leave the land more infertile, than other crops like soybeans, which produce their own nitrogen levels. Farmers, therefore, rotate their crops, alternating between corn and soybeans or corn and alfalfa for silage.

Modern agronomy combines knowledge of such things as soil conditions, crop rotation, fertilization, and economic parameters like crop/nitrogen fertilizer price ratios to calculate requirements and yields.

Research

Research involving genetic engineering has taken several approaches. Some of them apply to the plant, such as changing the gene which regulates the membranes inside the plant or the one that controls production of chemical intermediates. Most of this research has been directed at improving the efficiency of nitrogen fixation in soybeans.

For example, about 20 percent of the soybeans grown in the U.S. have the gene for an enzyme that in effect prevents nitrogen gas from leaking out of the plant. If genetically engineered hybrids can be produced that have this gene it will increase protein yield more than 15 percent.

By preventing formation of intermediate compounds that inhibit fixation or strengthening the internal membranes of the plant to slow gas transfer, some scientists hope to adjust the balance of plant chemistry so that more nitrogen is fixed.

More speculative research has aimed at inducing non-legumes, cereal plants which do not live with nitrogen-fixing bacteria in their roots, to begin to do so. There are two approaches: one is to transplant a gene for the nitrogen-fixing enzyme to chromosones of the plant itself; the other is to introduce a new gene to the bacteria now innoculated into soybean seeds.

The hypothesis is that it would be easier to induce a plant to make its own nitrogen than to accept bacteria as symbiots and learn how to use their nitrogen. The second approach is more elaborate, it involves setting up the whole family of genes that regulate nitrogen-fixing symbiosis in the plant.

The other approach involves introducing a new gene to the bacteria that are now inoculated into soybean seeds. The new gene would encourage hydrogen uptake which helps maximize nitrogen fixation.

Nitrogen fixation is complicated. Although it can be discussed in an academic way as if it were an independent process of the plant, in reality it is closely involved with all the complex processes of the plant so that its self-fertilizing is like changing corn into green beans.

Nevertheless, serious work is being done and not only in academic circles. While university scientists are tackling more ambitious projects like cloning the whole family of nitrogen-fixing genes of a higher plant in yeast, researchers at Allied Chemical Corporation are trying to promote soybean yield by hybridizing the anti-leaking gene.

Most of the eventual success of improving or starting nitrogen fixation in a plant will probably depend on developing a method of transplanting genes into higher plants and getting them to express themselves. Adding hydrogen uptake genes to current bacteria strains, while closer to the state of the art today, still faces formidable obstacles.

Implications

Let us assume that it becomes possible to introduce nitrogen fixation in non-nitrogen fixing plants. The current expectation is that such a development will initiate a series of trade-offs.

Increased ability to self-fertilize may result in less photosynthetic productivity or a significantly different fruit or seed. How acceptable such trade-offs are depend on conditions at the time and place where the crop is grown or sold.

Making nitrogen fertilizer for artificial fertilizer consumes alot of energy. Even today, farmers decide on how much ammonia to apply by the ratio of product price to fertilizer cost. If fuel becomes scarce and expensive, lower-yielding, poorer-tasting, strange looking plants or plant products may be tolerable. The main market for such genetically engineered plants would be in marginal areas which are not cultivated or, if they are cultivated, not fertilized today. The primary use for the crop might be livestock feed as it is for soybeans today. Alternative uses could be to produce cellulose for alcohol or direct burning as fuel.

World nitrogen fertilizer consumption (including natural fertilizer) was estimated at 42.7 million English tons in 1974, the last year for which statistics are available through the USDA. U.S. consumption was 8.5 million tons or approximately 20 percent, down from 26 percent ten years earlier, even though absolute U.S. consumption itself has almost doubled.

These changing proportions reflect the gradual spread of technology to less developed countries. Since 1974, consumption has continued to increase, especially abroad, as resource-rich less developed countries buy nitrogen fertilizer plants to held improve their diets.

Even so, as recently as 1973 the average world application of nitrogen fertilizer was small--12 pounds per acre. An Illinois corn grower might apply 100-200 pounds per acre. The implication is that the demand for nitrogen fertilizer will remain strong, limited mainly by the ability to pay for it. Enhanced nitrogen fixation through genetic engineering would stand to have an almost unexhaustable market for any foreseeable period of time.

APPLICATION

DESERIFICATION/SOIL SALINITY

Background

About 500 million out of the 3,500 million acres of the world's arable land is irrigated by one method or another.(16) Much of that irrigated land includes the most valuable and productive growing regions.

Land that is irrigated regularly accummulates salt from evaporation. As the level of salt in the soil increases productivity decreases.

> "The 100-125 million acres of irrigated land that salinization threatens, there are another perhaps 1,000 to 2,000 million acres of more or less arid land with saline soils. There are alarming estimates that vast areas of arable land, tens of millions of acres, are being lost to desert each year". (17)

One attempt to answer the problem has been the development of salt-resistant plant species. Salt-resistant species do exist in nature. Barley is more salt-resistant than wheat and some varieties of tomato are quite good.

Conventional research has concentrated on evaluating the salt sensitivity of both very sensitive and very insensitive varieties for classification and breeding purposes. It has also looked into the biology of the halophytes, naturally occurring but usually non-commercial species, that grow in salt environments, like marshes and seashores. Even these plants can provide biomass which may be useful for such purposes as fuel, either directly by burning or indirectly by conversion to alcohol for gasohol.

(16) & (17) Policy Research Corporation and The Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector, (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981, p. 87.

Research

Genetic engineering has been applied to the salinization problem to a limited extent. The most straight forward approach has been to attempt to identify plant genes that regulate osmosis.

Osmosis is the process by which water diffuses through porous tissue from the side of the tissue with the most dilute salt concentration to the side with the highest salt concentration. In such situations where the concentration levels are different, the difference in concentration itself (along with differences in pressure and the concentrations of other compounds) tends to produce the osmotic effect. It creates a difference in pressure, too, from the low concentration side to the high concentration side.

Living creatures have various mechanisms to maintain the differences between the two sides of the tissue. Each creature has an optimum range of salt concentration in which it thrives. Extremes beyond that range inhibit survival or kill the beast.

Porous tissue contains organs that function like pumps to maintain optimum salt levels and structural elements to withstand the pressure exerted against the tissue by the concentration difference. Regulating osmosis requires energy from the organism.

Changing the whole system of osmosis regulation (osmoregulation, for short) by genetic engineering is similar to changing photosynthesis or nitrogen fixation. It involves families of genes so it, too, is beyond the capability of genetic engineering at present. Not only is the problem complex and not thoroughly understood, but it also runs up against the common difficulty of grafting genes into cells with nucleuses. The most immediate hopes would be either to find a single gene that governs a controlling trait like tissue thickness or a mutant variety with greater salt-resistance whose genes can be transplanted.

Implications

Assuming that one of these possibilites can be realized one major draw-back remains. Any plant with greater salt-resistance will necessarily have to spend more energy to achieve that benefit. The most likely trade-off for that additional energy will be in its fruit or seeds, the most easily accessible product of that plant. The same trade-off is observed in nature now between the same species grown in relatively salty and relatively sweet soils. The plant from the salty environment yields less product than the one from the sweet environment.

If desertification continues to worsen and salinization becomes more of a threat to overall productivity, as they most likely will, the incentive to develop or find salt-resistant species will grow. The shrinking supply of water for treating saline soil virtually dictates more emphasis on genetic research into salt-resistant plants. As genetic engineering learns new skills in manipulating families of genes in higher plants its importance will increase here, too.

APPLICATION

PESTICIDES AND PESTICIDE RESISTANCE

Background

Many pesticides are used in agriculture to control weeds, fungi, and insects. They are selective poisons for one or more of these pests. Their use is indispensable to the controlled total environment of modern farming.

Pests tend to become resistant to pesticides over time. As the pesticide kills off the least resistant individuals, the more resistant ones are preserved. The pesticide must be used in ever-increasing concentrations until eventually it becomes ineffective.

"Biological" pesticides already enjoy a small sector of the market. A-bacillus is used against heliothis in cotton and tobacco. Pheromones, natural sex attractants, are effective against boll weevils and other insects. Pyrethorum, the dried, powdered flowers of chrysanthemums, is used as an insecticide in many crops.

In at least one case a pesticide raises difficulties with other commercial crops. Atrazine is a herbicide widely used to control weeds where corn is grown. It is highly specific and effective. Corn growers typically rotate their crops every two or three years with soybeans or alfalfa. If atrazine is applied in the year before growing the soybeans or alfalfa, it limits productivity. Most growers cut back their application in that year, but reducing or not using atrazine in the pre-soybean or alfalfa year lessens corn productivity because other herbicides are less effective than atrazine.

Research

Beyond the current study of plant pathology, which seeks ways of controlling plant diseases, genetic engineering offers a tool for controlling weeds and insects through developing viral or bacterial agents that selectively attack pests. In theory, such pesticides would adapt along with the pest because they have established parasitic relationships with their pest hosts.

Naturally occurring viruses and bacteria have long been recognized as effective insecticides. Exposure to the sun, however, neutralizes their activity. Research at Battelle Columbus Laboratories have developed a protein/RNA "time capsule" delivery system that shields the organism from the sun and releases it inside the insect when eaten.

Regarding atrazine resistance, it has been suggested that developing a variety of atrazine-resistant soybeans or alfalfa is a relatively simple problem involving one or at most a few genes. It has also been suggested that controlling many plant diseases is equally simple.

So far, most work into these matters remains at the conceptual stage. Whether or not they are as simple as supposed remains to be seen.

Implications

The implications of genetic engineering in pesticides are speculative at best. If it proves feasible to produce biological pesticides like those described above, such a development would have an obvious impact on manufacturers of today's chemical versions. The market for such products amounts conservatively to $5 billion worldwide.

Bacterial pesticides face resistance from established chemical products aimed at the same applications. The ecological consequences of unleashing such new organisms on the environment, let alone giving them a niche in the human food chain, have not begun to be understood.

Atrazine-resistant soybeans or alfalfa would be desirable, if much more limited, product. The potential demand is much less than for a salt-resistant wheat or barley, for example; and, consequently, the incentive is weaker to stimulate research.

APPLICATION

GASOHOL

Background

One immediate consequence of the energy crisis of the 1970's was an emphasis on alternative fuels. The first of them was gasohol, the common version of which in the U.S. is 90 percent gasoline and 10 percent alcohol. The alcohol in question is ethanol, produced by the fermentation of corn.

The fermentation process was adapted from the conventional technology for producing potable alcohol.

Government subsidies for gasohol in the form of tax reductions and construction loan guarantees have been stimulating production since the mid- 1970's. $376 million in loans will help finance 264 million gallons in capacity in 19 states. Many distilleries will be small grass-root plants on the farm but others will be large-scale commercial ventures.

The reception gasohol received ushered in much more ambitious plans for gasohol in the U.S. long range energy plan. Gasohol was projected to provide 10 percent of the country's fuel requirements by 1990.

U.S. automobile fuel consumption in 1979 was approximately 100 billion gallons. That amount of gasohol would require 10 billion gallons of power alcohol, which in turn would require 4 billion bushels of corn. The record corn crop of 1979 was 7.94 billion bushels, so the 10 percent gasohol goal would have used more than half of it.

Obviously, such a huge demand would play havoc with agribusiness and the national economy in general. Even with multi-billion dollar government subsidies to encourage the power alcohol industry, no one expects power alcohol production to exceed 2 billion gallons, requiring 800 million bushels of corn, by 1985-1990.

800 million bushels is still a significant fraction of the crop. Its diversion to power alcohol will either reduce the surplus for export or create domestic shortages and higher consumer prices or both.

Several solutions have been offered. For one, there were four million acres out of production as part of the set-aside program a few years ago, and rising corn prices would bring less productive land, and land occupied by other crops, into corn production.

Both effects aggravate the ratio of capital equipment to end-product. Batch processing needs more in fermentation vats than a continuous process needs in plumbing to yield the same amount of alcohol. Low alcohol tolerance in yeast demands more vats than if the tolerance were higher to produce the same volume.

Research

Genetic engineering has approached the technology of fermentation from several angles. Yeast is probably the most popular subject of study for academic molecular biologists, biochemists, and similar scientists using genetic engineering techniques and government funding. Some of their research concerns itself with alcohol metabolism. Unfortunately yeast, despite being a single-cell organism, is a far more complicated creature than a bacterium and it has a nucleus. Designing a more efficient yeast still waits development of a technique of grafting genes on eukaryotic cells.

National Distillers and Cetus have collaborated on the design for a continuous alcohol process, and National plans to spend $100 mllion on its construction. Although the new design does not result from genetic engineering of yeast, it does represent an approach to greater fermentation efficiency. Cetus may license the technology.

The key to continuous processing is embedding the active catalyst (yeast, bacterium, enzyme) in a suitable matrix where it can survive and work on the feedstock stream passing by. A substantial amount of research has concerned itself with identifying suitable matrices. Several different ones have appeared.

Yeast is not the only organism that produces alcohol. Many bacteria do as well. The preference for using yeast has been due partly to its higher alcohol tolerance, along with other factors like taste which are not relevant for power alcohol.

Scientists have been looking at one bacterium, <u>Zymomonas mobilis</u>, as a substitute for yeast. If it is immobilized in a matrix, it can be kept at a greater cell density than yeast and it may produce alcohol faster.

Bacteria are of course the prime guinea pigs of genetic engineering. Improving their productivity in making power alcohol, at least today, is more feasible than it is for yeast. Bacteria for this kind of process is sometimes referred to as "immobilized enzymes", even though the living organism is present.

In a related area, work has also been done on using less expensive feedstocks to make gasohol. Such waste products as wheat straw, whey, and the cellulosic material in municipal garbage are all under study with funding from the federal Department of Energy.

When the potential feedstock is mainly cellulose, which is a polymer of many molecules of glucose like those needed for alcohol fermentation, it must undergo preliminary processing. The cellulose must be digested or broken down into its consituent molecules of glucose. The means for digestion is supplied by other bacteria which secrete an enzyme specifically for that purpose. These other bacteria are fit subjects for genetic engineering or chemical splitting.

Implications

Any improvement in power alcohol synthesis might have dramatic effects on the global economy, particularly as food supplies continue to shorten. A 5 percent improvement in the conversion rate of corn to power alcohol based on genetically engineered microorganisms means a potential savings of 40 million bushels of corn per year in the 1985-1990 period.

For every gallon of alcohol produced by a contemporary wet-milling operation, there are several significant by-products: 3.7 pounds of gluten, 1.3 pounds of cornmeal, and 0.6 pounds of corn oil. The gluten and cornmeal are direct competitors with soybean meal. More economical power alcohol production due to genetic engineering means more demand and more by-product, which may result in a negative effect on soybean meal prices.

If imported oil prices continue to rise, then gasohol will become an increasingly effective substitute. However, as more grain is diverted to gasohol, less export money is available to buy the oil that makes up 90 percent of the gasohol.

Under ordinary conditions, the priority of food over fuel will probably cause a shift in consumer spending away from gasoline and gasohol toward corn for livestock feed and human consumption. However, with gasohol subsidies, ordinary priorities may be distorted in favor of fuel in the short run. The winners would be the distillers and gasoline refiners. The losers will be grain processors and exporters, along with consumers domestically and abroad.

SUMMARY: APPLICATION TIME HORIZONS AND MARKET VALUES

Time Horizons

In reviewing the areas where genetic engineering is being applied to agribusiness, it has been shown that some applications are closer to realization than others.

Now let's clarify the applications according to their degree of current feasibility into three categories.

(1) Applications which are realizable today. They include products whhich are approaching commercial manufacture or which, based on an under-standing of their complexity, could be synthesized with existing technology. They include bacterial synthesis of simple proteins and engineering of viral and bacterial organisms.

- o Single cell protein
  - o More efficient methanol-eating bacteria
  - o Bacteria utilizing other feedstocks
- o Fermentation products
  - o Amino acids

(2) Applications which are not currently feasible - they require techniques that have not been perfected, but seem to require changing only one gene in the organism.

- o Pesticides and pesticide resistance
  - o Viral and bacterial insecticides, herbicides and fungicides
  - o Pesticide (and by implication disease) resistant cultivators
- o Gasohol
  - o Bacterial fermentation agents
  - o Improved strains of yeast
  - o Cellulose digesting bacteria

The likely time frame for the commercialization of these applications is five to fifteen years. The projection assumes that it is possible to predict the pace of scientific discovery. The breakthrough that should herald their implementation will be the successful product targeting using grafting of genes in cells with nucleuses (eukaryotes).

(3) "Blue sky" applications. These applications involve transplanting families of genes that specify different functions in higher organisms. Their successful implementation would entail major changes in the life of the organism with unforeseeable consequences.

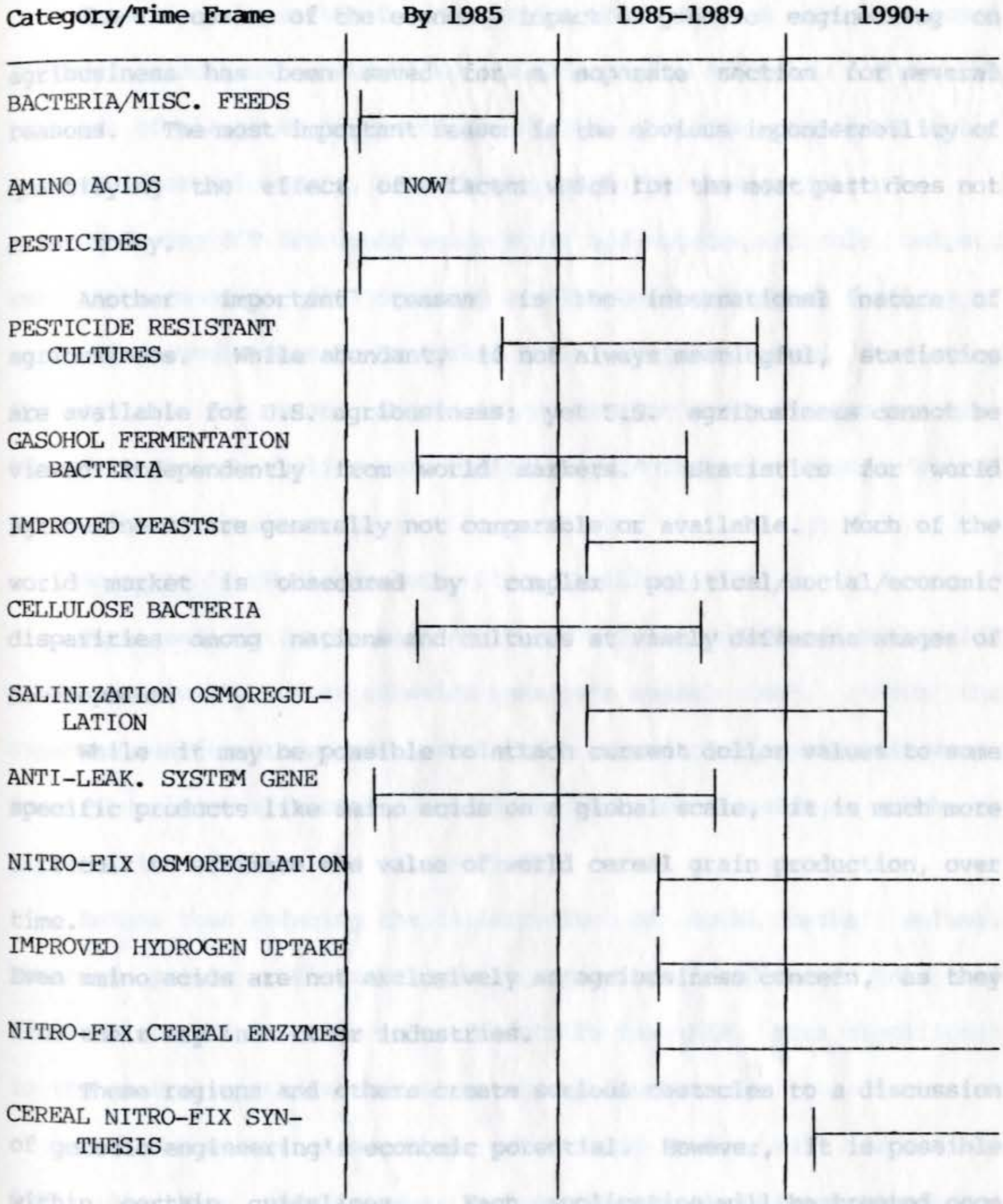
- o Desertification/soil salinity
  - o Improved osmoregulation
- o Nitrogen fixation
  - o Anti-leaking in soybeans
  - o Improved osmoregulation
  - o Improved hydrogen uptake
  - o Nitrogen fixation capability in cereals
    - o Nitrogen fixing enzyme
    - o Symbiosis capability
- o Photosynthesis
  - o Inhibited RuBP oxygenation
  - o Suppressed photorespiration

Category (3) applications will probably begin to be realized ten or more years from now, again assuming predictable technologies progress. The key breakthrough will be successful grafting and control of multiple gene families. Much research needs to be done on the natural biological processes involved before significant results can be obtained.

Figure 3 shows the time frame for all of these applications. Note that several of them infact overlap between categories. The bars are not meant to suggest literal chronology. Rather, they suggest when genetic engineering can begin to be used practically in connection with each application and when commercial products may begin to be available. Major technical breakthroughs or unforeseeable setbacks may shift the whole scheme significantly forward or backward. External events affecting changes in the political or economic importance of individual applications certainly alter how R&D efforts are directed.

Figure 3

GENETIC ENGINEERING APPLICATION TIME FRAME



SUMMARY: APPLICATION TIME HORIZONS AND MARKET VALUES

Potential Market Values

The discussion of the economic impact of genetic engineering on agribusiness has been saved for a separate section for several reasons. The most important reason is the obvious imponderability of quantifying the effect of a factor which for the most part does not exist today.

Another important reason is the international nature of agribusiness. While abundant, if not always meaningful, statistics are available for U.S. agribusiness; yet U.S. agribusiness cannot be viewed independently from world markets. Statistics for world agribusiness are generally not comparable or available. Much of the world market is obsecured by complex political/social/economic disparities among nations and cultures at vastly different stages of development.

While it may be possible to attach current dollar values to some specific products like amino acids on a global scale, it is much more difficult to estimate the value of world cereal grain production, over time.

Even amino acids are not exclusively an agribusiness concern, as they find their way into other industries.

These regions and others create serious obstacles to a discussion of genetic engineering's economic potential. However, it is possible within certain guidelines. Each application will be treated once again, listing the assumptions that went into the valuation calculations.

Potential Market Values

o Bacteria Eating Other Feedstock (incalculable):

Some of the possible feedstocks for which SCP has been proposed include agricultural wastes like slaughter house effluent. There are hundreds of slaughter houses in the U.S., besides countless other sources of organic waste, for example, municipal sewage plants.

Producing SCP from such waste would add another salable output, but the economics of installing a suitable fermentation facility at each source would need to be worked out. Progress toward developing SCP systems for waste materials are farther along with pulp mills. The whole concept applies more comfortably to the more industrialized phases for agribusiness.

o Amino Acids (World Market: $1-1.5 billion):(17)

Japan sells a large share of the 20 million pounds of amino acids produced annually, most of which goes into animal feed. Both the Japanese manufacturers and several U.S. genetic engineering firms are developing improved bacteria to make the amino acids, which is expected to reduce prices substantially.

Rather than reducing the dollar value of total market volume, lowering prices will probably bring amino acid supplements into some indirect competition with other feedstuffs like SCP. More significant is the general upgrading effect on animal diets.

Informed estimates say that amino acid sales will double by 1985.(18) Many manufacturers are considering these developments and contemplating entering the market.

(17) & (18) Policy Research Corporation and The Chicago Group, An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector, (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981), p. 114.

o <u>Improved Yeast/Gasohol Fermentation Bacteria</u> (Incalculable):

Improved strains of yeast and gasohol fermentation bacteria affect agribusiness indirectly. Their own value is negligible compared to the markets they affect and lies outside of agribusiness proper.

Both yeast and bacteria produce power alcohol. Whatever efficiency arises from genetically engineered strains will be passed along in pricing. Gasohol will be competing with gasoline. Any very rapid rise in oil prices will provide an incentive for more alcohol use, even beyond the 10 percent in gasohol. Brazil is committed, for example, to using 30-70 percent power alcohol for its automobiles.

o <u>Pesticides</u> (World Market: $5+ billion):(19)

Any and all existing pesticides may be replaced by bacterial or viral substitutes in theory. If one insecticide, herbicide or fungicide is introduced successfully, it will be the harbinger of many more.

Assume that an ecologically safe, selective viral pesticide has been developed that proves effective against a given pest. Therefore, a parasitic disease will have been introduced to the pest population which we believe will at least suppress its activity and at best eliminate the pest.

(19) Policy Research Corporation and The Chicago Group, <u>An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector</u>, (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981), p. 116.

This type of pesticide may differ in several important respects from conventional pesticides. The most important difference is that the viral pesiticide may need to be applied only once. Thereafter it may live off the pest host until pest and virus establish a dynamic equilibrum or they both disappear when the pest dies out.

Viral pesticides may not need to be applied as broadly as chemical pesticides. The disease may spread contagiously through the pest population.

Both of these difference suggest major changes in the pesticide industry. It would seem doubtful that they can be avoided, given the basic assumptions. Whether pesticide manufacturers, governments or academic researchers develop these new pesticides, they will be tested and implemented if they are effective.

o <u>Pesticide Resistant, Soil Salinity Resistant, Nitrogen Fixating Seeds and Enhanced Photosynthesis</u> (U.S. Market: $500M):(20)

The market estimate quoted here is conservative based on the value of hybrid seeds sold today.

Developing seeds with the characteristics mentioned -- pesticide resistance, soil salinity, nitrogen fixation, and/or improved photosynthesis -- amount to adding product features. That would be true regardless of whether the technology involved individual genes or families of genes.

(20) Policy Research Corporation and The Chicago Group, <u>An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector</u>, (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981), p. 117.

The benefits to seed-growers, like DeKalb Ag-Research of Pioneer Hi-Breds, would be marginal value added and would justify marginal price increases. Much of the potential market for improved cultivars would be outside of the effective distribution penetration of these companies in centrally planned and primitive economics. Even that sector of the market that can be sold effectively, such as desertified areas of California or Texas, would require massive agricultural renewal to get effective programs in motion. Aside from those areas where dissemination of improved hybrids could be subsidized by local governments, the major market for these new products would remain the regions where hybrids are commonly planted today.

Pesticide resistant cultivars/chemical pesticide systems would compete with the application of bacterial and viral pesticides and conventional hybrids. Nitrogen fixing cereals would compete with conventional hybrids and chemical fertilizers.

The scope of these changes in agricultural practices, not to mention implementing hybrids with improved photosynthesis and the kind of support systems that development will probably entail, is colossal. Viewed as a whole, they suggest a growth environment that is completely human engineered from soil bacteria to soil conditioning to seed preparation, all the way through the mature plant. The only logical approach to such broad and deep manipulation of the environment would seem to be across whole growing areas under more or less centralized planning.

This is a slight glimpse where these trends are leading. Whether the guiding force behind them will be the interest of individual farmers or government or huge manufacturing/growing/processing conglomerates remains to be seen.

In these same areas, work continues toward more particular products, such as the anti-leaking gene for soybeans, soybean bacterial inoculates with improved nitrogen fixation characteristics, improved hydrogen uptake genes, RuBP oxygenase inhibition, and many others. Although such specific research sheds light on the whole complex of problems associated with improved agricultural productivity, it will not prove successful on a significant scale unless they are incorporated into the broad and deep manipulative planning scale mentioned above. When the change to be made involves the whole plant and the regional or world ecosystem, it should be coordinated on a higher level.

Overview:

Potential Market Value

o <u>The Economic Impact of Genetically Engineered Products on Agribusiness</u>

All of the dollar estimates given in this section are based on genetically engineered products gaining a 20 percent market share within the time frame where they become available and a 50 percent market share during the next time frame.

Figure 4

ANNUAL GENETICALLY ENGINEERED PRODUCT MARKET VALUES, BY PERIOD OF EXPECTED COMMERCIALIZATION (in $ millions)

Category/Time Frame	By 1985	1985-1989	1990+
BACTERIA/MISC. FEEDS	10	100	
AMINO ACIDS	250	1,000	
PESTICIDES	50	500	
GASOHOL/FERMENTATION BACTERIA	SEE TEXT		
IMPROVED YEASTS	SEE TEXT		
PESTICIDE RESISTANT			
SALINITY RESISTANT			
NITROGEN FIXATION	-----	-----	SEE TEXT
PHOTOSYNTHESIS			

Source: An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector, (Chicago: Policy Research Corporation, The Chicago Group, Inc. 1981), p. 120.

CHAPTER IV

REVIEW OF CONCEPTS IN MANAGING TECHNOLOGICAL INNOVATION

In this chapter, we shall consider the organizational implication of the factors identified as important for the process of technological innovation. We will look at some of the elements that bear upon the innovation process and finally evaluate how strategy may be effective in different organizational situations. I shall conclude that managing technological innovations during the 1980's will be more complex and will require better planning by the corporation to manage, control and adjust strategies to an increasingly unpredictable environment.

What do we mean by "an organization?" In some minds, the word is equated with similar words like firm, company and corporation. Lippit, defines an organization as the arrangement of people in patterns in working relationships so that their energies may be related more effectively to the large job!(21)

Four systems within the organization have been identified in order that energies and resources may be used effectively. They are authority, communication, power and control. The system must work in order to give the factors contributing to successful technological innovation a reasonable chance of success.

(21) Gordon L. Lippitt, Organizational Renewal (New York: Appleton-Century-Crofts, 1969), p. 43.

FACTORS CONTRIBUTING TO SUCCESSFUL
TECHNOLOGICAL INNOVATION

The most critical factors for success are:

1. An organization receptive to innovation.
2. A source of creative ideas.
3. Relevance to the organization's corporate objectives.
4. An effective project selection and evaluation system.
5. A market orientation.
6. Effective project management and control.
7. Commitment by one or a few individuals.(22)

Technology has to be discussed as a conversion process in order to make a distinction between invention and innovation. The difference has been defined as:

INVENTION - To conceive the idea.

INNOVATION - To use the idea; it is the process by which an invention or idea is translated into the economy.

Thus an invention must make it to the market-place to become an innovation. Therefore, what is needed is a linking of Research and Development and marketing in a meaningful way to have a successful technological innovation. Before this can happen, however, the idea for the new product or process must be conceived and its feasibility established. The resource for this is human, and success depends upon the technological competence and skill of the research and development (R&D) workers, their creativity, their motivation and identification with the project.

(22) Brian C. Twiss, Managing Technological Innovation (London, New York: Longman Group Limited, 1980), p. 6.

An Organization Receptive to Innovation

Innovation means a change in course. Thus it can be treated as a threat and opposition may rise against it from people who may be affected. The psychologist Schein states:

> Organization planners or top managers often naively assume that simply announcing the need for a change and giving orders that the change should be made will produce the desired outcome. In practice, however, resistance to change is one of the most ubiquitous organizational phenomena. Whether it be an increase in production, or adaption to a new technology, or a new method of doing the work, it is generally found that those workers and managers who are directly affected will resist the change or sabatoge it if it is forced upon them.(23)

There is one important relationship that must occur to achieve innovation. That relationship is combining organizational factors with interpersonal factors in order to reach a common goal. Innovation will bring change to the organization. Therefore, innovation cannot be isolated from its immediate environment. The management of organizational change is a topic related to technological innovation of which management is finally becoming aware. Once management is receptive to innovation it must create a climate that provides for creative ideas.

The Source: Creative People

Creativity can not be divorced from innovation and people can not be divorced from the organization. Therefore, recruitment and retention of creative people by management is essential. In doing this management is unconsciously initiating a second important point, namely that of the creation of a working environment which encourages creativity. Once a creative idea has taken shape it must be relevant to the company's objectives.

(23) Edgar H. Schein, Organizational Psychology (Englewood Cliffs, NJ: Prentice Hall, 1980), pp. 1-274.

Relevance to Objectives

With business conditions rapidly changing planning becomes essential. In the past it was possible to adapt to environmental changes when they occurred. Nowadays when change is more rapid and the gestation period for many technological products is longer, it is necessary to anticipate rather than react. The acceptance of this belief has led to the growth of formal corporate planning.

> Anticipation of possible products and markets upon which future growth will be based is an important element of any corporate plan. In formulating a corporate strategy attention is paid to the organization's own capabilities in relation to the threats and opportunities which have been identified in the business environment. It follows that some potential new products, attractive as they may appear in their own right, are inapproriate for development by a particular company because it does not have sufficient resources or does not wish to enter or extend its operations in certain markets. Furthermore, without clearly stated objectives, strategies and plans, there is no standard of reference against which changes can be evaluated. Thus, the corporate plan is the standard of reference against which R & D performance is measured. The validity of planning must, therefore, be judged by only one criterion -- whether it adds or substracts from the effectiveness of the organization. There is little doubt that the imposition of a high degree of centralized planning on R & D can be counter-productive. But inflexible planning which stifles innovation is bad planning. On the other hand, planning can make a contribution if it ensures that innovations are only accepted when they are consistent with company objectives with the proviso that attitudes are sufficently flexible to permit modifications of the strategy in exceptional circumstance. The main stimuli for innovation originate as ideas from the R & D department or from the definition of market needs. In the latter case the formal definition of future market and types of product stimulates a systematic examination of potential market needs which might be satisfiable through new products. By contrast the generation of ideas within R & D is much more random. Consequently, some proposals may have to be rejected, not because of any intrinsic shortcomings, but on the grounds that their development would necessitate a shift of the company's growth in an undesirable direction.(24)

(24) E. P. Hawthorne, The Managment of Technology, (London, New York: McGraw-Hill, 1978), pp. 1-186.

Later in this chapter, project selection and corporate development and planning will be related by means of a strategy.

<u>An Effective Project Selection & Evaluation System</u>

The most critical area for the Research and Development manager is on project selection and evaluation techniques. There are many techniques that the R & D manager can use for evaluation of a project, from a single checklist to highly quantitative techniques. The main problem with any technique is uncertain data fed into the evaluation. Therefore, most managers are reluctant to adopt any technique. Why should this be? Examination of projects that fail or are prematurely terminated leads to the conclusion that many of them should not have initiated in the first place. The reason for failure is that information at the time of the selection of the project was either ignored or not used properly.

The conclusion to be drawn is that a formal selection procedure is necessary and Research and Development managers should use it more often. This does not imply though that it should be applied as a simple routine procedure. A manager's decision is critical therefore he should use every possible piece of information or data that is systematically collated and analyzed in order to help in the decision process. Some of these techniques are trend extrapolation, precursor trends and curve matching, Delphi method, scenarios, relevance trees, technology monitoring and cross impact analysis.

Market Orientation

Companies depend largely on market-oriented information. Information in this context refers to all of its aspects including such sources as management information systems, published information, information services, and internal reports. Recently, companies have recognized the importance of information as a key factor in minimizing errors, combating competition and reducing risks. Management should also recognize the burden that too much information creates for managers. Therefore, management should treat it as a proper corporate function to centralize its control. The use of information is an essential factor but is a topic within itself and will not be expanded upon any further in this paper.

Effective Project Management and Control

> The need for effective project management is self-evident. Inadequate control results in cost escalation and time overruns. Cost escalation may not only destroy a project's financial viability but, more seriously, in a major project, it may lead to financial demands which are beyond the company's resources irrespective of the eventual economic regards which might be expected from a successful completion of the development.(25)

(25) P.S. Johnson, The Economics of Invention and Innovation, (London, NY: Martin Robertson, 1975), pp. 156-188.

With this factor we are concerned with the elements which are needed in planning and controlling a project. Therefore, attention and discussion will be limited to these elements. The planning elements required are several. Project definition is a clear statement of the objective and includes criterion by which success can be measured. Another element encompasses the technical performance required, cost limitations and project duration. Still a third element involves portfolio planning, a concern with the effective use of available resources and assurance that the progress of the project is not hampered by shortages of resources. The project plan can be summarized as the allocation of resources in relation to the portfolio, definition of the program of work in terms of activities, resources and time, identification of critical events, identification of critical tasks, and the integration of all the activities within an overall plan, using the planning techniques most appropriate to the stage of the project.

Control encompasses the use of accurate and timely information to assess the progress of each task in terms of cost and duration, to identify tasks which are falling behind schedule and to assess the likely effect they will have on the overall progress of the project, i.e., delays in the critical activities of the network, and to measure the progress of the project as a whole in relation to the planned cost and completion date. Resource management is associated with the efficient allocation of resources and staff motivation which is self explanatory.

Commitment

Innovations do not happen, they are made to happen. This statement implies that behind every successful innovation there are people who are responsible for translating the idea into practice. There are requirements to assure a systematic and methodical approach. They are as follow:

1. Definition of a corporate strategy stating the types of business, products, and markets in which the company intends to engage.
2. Formulations of a strategy for R & D to ensure that the work of the R & D department is integrated with the corporate strategy.
3. A formal project selection system which would evaluate proposals in relation to specific financial and organizational objectives.
4. A statement of detailed project specifications against which subsequent performance can be measured.
5. Periodic evaluation of the project to assess whether the stated objectives are being met.
6. Managerial control procedures to ensure that the resources allocated to the project are being used effectively.

With such a system, good management working within a formalized system should ensure the successful conduct of the project. It is now possible to examine different organizational structures and assess their merits in relation to the factors identified.

The scientific management model is based on a discipline structure where work is organized in departments which are further subdivided into subspecializations. This model is well suited for the acquisition of knowledge but is difficult where there is need to inspire a sense of urgency. This model's most serious drawback is that is implies that innovation is most likely to result by pushing back the frontiers in a specific discipline.

Matrix Model

The matrix organization is a development of project management designed to avoid disadvantages of the simple project management organization by separating clearly the managerial and professional responsibilities. The purpose of this model is the retention and extension of the company's long term technological capital. However, this model appears to conflict with two rules of traditional management teaching, namely that no person should report to more than one manager, and that responsibility and authority must be equated.

Schon's Model

In Schon's model (26) there is a central unit, comprising the financial and technological capital of the company, and it is surrounded by a group of small technology-based satellites. The advantages are freedom to pursue long-term objectives, avoidance of duplication of work relevant to more than one division, centralization

(26) Donald A. Schon, Technology and Change: The New Heraclitus, (New York: Delacorte Press, 1967), p. 121.

of experience, and resources to investigate new technologies which do not fit into the existing divisional structure. Disadvantages include remoteness from market forces, reduced profit consciousness, demarcation and communication difficulties.

Future Models: Biological Model and Hybrid Model

Better understanding of the innovation process and organizational research are leading to a realization that greater flexibility and finer tuning of the organization structure to particular circumstances are necessary. New organizational forms are emerging. One such model is the biological model or systems approach. This model is composed of "self-maintaining units" -- cells capable of surviving on their own, able to respond to change in better ways than firms broken down by function, job or project. These firms thus guarantee themselves:

- The ability to adapt to a changing environment, changing themselves if necessary to survive in it by entering new technologies and markets.

- The involvement of their employees through understanding and accepting company objectives, resulting in both higher quality goods and services, and a higher quality working life.

Another future model is a hybrid model where four different organization types are used. They can be identified as central research, matrix, venture, and joint equity approaches when most suitable. The purpose is to avoid imposition on any part of the organization which inhibits the process of innovation.

We have looked at the factors that are needed for technological innovation and the types of organizations that can inhibit or enhance technological innovation. Now, we will look at the external environmental factors that can also affect technological innovation.

THE EXTERNAL ENVIRONMENT

There are five facets to be considered in the external environment which affect innovation and technological advances. Each facet shall be examined in some detail. They are economic, technological, social, political and legal, and ethical. These facets can be either domestic, overseas or both.

Economic

There are basically six elements that make up the economic environment. They are capital, labor, productivity, government fiscal and tax policy, customers and price levels. (27)

Capital. Every organization needs capital, that is, machinery, buildings, inventories of goods, office equipment, tools and cash. Every organized enterprise is dependent on suppliers, whose job it is to produce the many materials and other items of capital that an organization requires for its operation.

(27) Harold Koontz, Essentials of Management (New York: McGraw-Hill, 1978), pp. 32-36.

Labor. Another important input from the economic environment is the availability, quality and price of labor. The price of labor is extremely high and should be considered carefully.

Productivity. Productivity is an elusive, complex subject. There are many factors that contribute to productivity. Some examples are technology, job design, human factors and of course managerial factors. In its most basic form productivity refers to the input-output ratio within a time period with due consideration given to quality.

Government Fiscal and Tax Policy. Although government policies are aspects of political environment, their economic impact is tremendous. Government control of the availability of credit through fiscal policy has considerable impact on business. The way taxes are levied is also important. For example, if taxes on business profits are too high, the incentive to go into business or stay in it tends to drop and managers will look elsewhere to invest in their capital.

Customers. The most important factor for success of the organization is its customers. Without them, a business cannot exist.

Price Levels. Inputs to an enterprise (labor, material, capital) are clearly affected by price-level changes. If prices go up fairly rapidly like in the early 1980's, the turbulence created in the economic environment can be severe. Inflation not only upsets businesses but also has a highly disturbing influence on every part of the organization through its effects on costs.

Technological

Companies that spend relatively large amounts on R&D tend to be relatively quick to begin producing a new product, even if they are not the innovator. Technology provides a window opening to the environment and enables a firm to evaluate external developments and react more quickly to them. The use of technology is aimed at a quick response to rivals by clever modification, adaption and improvement of its form, therefore, it should be consistently monitored. (28)

Social

It is extremely difficult to separate the social, ethical and political environments. The social environment is made up of the attitudes, desires, expectations, degrees of intelligence and education, beliefs and customs of people. Managers are always being criticized for not being responsive to social attitudes, beliefs, and values. This variety of factors makes it difficult for managers to design an environment conducive to performance and satisfaction. It is even more difficult to respond to these forces when they are outside the enterprise. Yet managers have no choice but to take them into account in their decision making.

(28) Edwin Mansfield, Research and Innovation in the Modern Corporation (New York: W. W. Norton and Company, 1972) p. 8.

Political and Legal

Government affects virtually every enterprise. In respect to business, it acts in two main roles, it both promotes and contrains business. It promotes business, for example, by stimulating economic expansion and development, subsidizes selected industries, gives tax advantages in certain situtations, supports research and development, and even protects some businesses through special tariffs.

The other role of government is to constrain and regulate business. Every manager is encircled by a web of laws, regulations and court decisions. There is relatively little that a manager can do in any organization that is not in some way concerned with and controlled by a law or regulation. Therefore, managers should know the legal restrictions and requirements applicable to their actions.

Ethical

The ethical environment is really part of the social environment. In Websters Dictionary, ethics is defined as "the discipline dealing with what is good and bad and with moral duty and obligation". The ethical environ-ment, then, includes sets of generally accepted and practiced standards of conduct. Often ethical standards are enacted into laws. But ethical behavior is just and fair conduct which goes beyond complying with laws and government regulations. It means adhering to moral principles, being guided by particular values, and behaving in ways in which people ought to act.

In recognition of the factors needed for technological innovations and the elements and forces that form the external environment that influence innovations, strategic planning is the missing link that is needed at the corporate level to ensure successful marketing of technological innovations.

RESEARCH AND DEVELOPMENT ROLE

There is a changing pattern of innovation in the world today. The world no longer looks solely to the U.S. for technological advances, but alsoto others especially Japan and Western Europe. Where, in the late 1950's, 82 percent of all major innovations were introduced in the U.S., by the mid-1960's, this figure reached only 55 percent and the decline continues.

Techniques of Research and Development

Short of establishing their own research and development facilities, there are ways by which companies can seek to enhance their technological base. Nine techniques are available of which four are closely related to the ongoing responsibilities of the research and development function: scanning (or monitoring); connections with academia; the use of external public and private sector organizations that support corporate research and development work; and research and development in the context of the corporation's international business-related joint ventures.

While the five remaining techniques are often the major responsibilities of corporate functions other than research and development, there is nonetheless close coordination with the research group. These are: licensing (licensing department); increasing the external technological visibility of the firm to attract outside innovation (public relations department and external technology consultants); contacts with customers and suppliers (marketing department); technological forecasting (planning department); and cooperative research agreements (planning department and senior executive interest).

Centralizing versus Dispersing Research and Development

Two fundamental issues govern the choice between centralization or dispersal of research and development, which will be discussed in further detail. One is protection of the company's technology; the other is response to market requirements. Centralization of R&D provides efficiency, cost effectiveness, and control. On the other hand, adequate responsiveness to market conditions often requires research and development proximity to the market. The degree of centralization or decentralization of a company's R&D is a function of many variables such as: the industry; a firm's history and the length of time it has done business overseas; the priorities of its management; the company's market orientation; its geographic spread; technical diversity and whether the company's technology is basically high, medium or low level; the role of technology in the firm's general business strategy; size and product diversification; kinds of acquisitions; and presence or absence of overseas manufacturing facilities.

Some companies choose not to establish research and development units outside of their country for various reasons. The main reasons are: (1) the company's market orientation and product development are strongly geared to domestic considerations; (2) research and development costs are minimized by one central lab which serves an entire corporation; (3) centralized research and development provides for maximum control and coordination of a company's research and development program; (4) desire to maximize the protection of the company's technology; (5) a firm's central laboratories are well established, and have been operating for years and there is no desire to change the company's <u>modus operandi</u>; (6) senior management wants research and development run in a centralized manner; and (7) the fact that a company can provide international inputs into its research and development program even though the laboratories are centralized domestically.

The Management of Research and Development

The following issues are central to the management of a company's research and development operations and how they are resolved:

(1) Organization

(2) Methods of coordination and control.

a. Reports

b. Coordinative positions

c. Liaison jobs

d. Project-team basis

e. Exchange R&D professionals

f. Training programs

g. Committees

h. Meetings

i. Additional means of communication such as mail, telephone, cable, telex and leased channel.

(3) Planning, and Research and Development

(4) Management style

(5) Productivity and innovation

(6) Research and development performance measurement: unit and individual

(7) Staffing

(8) Costs and funding

Input Techniques of R&D External to the Corporation

This section deals with techniques for R&D through inputs external to the corporation's own research and development effort -- as distinct from inputs internal to the firm in whatever form.

The following examples are sources of business-related scanning.(29)

(1) Input from the parent's subsidiaries, joint ventures, licensees and new business ventures;

(29) Business International, Management Strategies for Research and Development: The Need for International Dimensions (New York: Business International/ Management Practices Research, September 1979), p. 17.

(2) Inputs from other individuals within the firm where a company's organization has been structured to promote scanning.

(3) Information gleaned by the sales and marketing staff from customers as well as from market studies and trend analysis;

(4) Planning department work -- especially analysis of the implications of the implications of acquisitions of one company by another;

(5) The company library (or "information services system") as well as external libraries;

(6) Information obtained through close association with suppliers and vendors;

(7) Discussions with overseas competitors;

(8) Membership in a patent search service;

(9) Membership in industrial or trade association (which provide personal contacts and information obtained from meetings and publications);

(10) Participation in industrial conferences and in international technology fairs; and

(11) Employment of consultants -- especially technology brokers.

The use of a project team approach by a division of a firm is also used. The teams travel abroad both to seek business and to handle work assignments. Research and development people are normally part of such teams.

The matrix organization helps to activate the amount of monitoring and also to channel information quickly back to the corporate level. Much of the monitoring of scientific and technological innovation occurs at the regional business team level. The responsibility for all forms of planning is held by the business team director. A key portion of the input he requires to plan comes from the managers responsible for marketing and research and development, respectively.

Sales people in this industry tend to be technically-oriented. They assist in monitoring new developments. One of the marketing people at Monsanto recently learned that a competitor was coming up with a new material. However, the company was able to duplicate, and even improve on this product in a very short period of time, which resulted in no loss of market position. Indeed, it is ultimately expected to strengthen the company.(30)

(30) Ronald P. Thompson, statement made during meeting of the New Employees Committee of Monsanto Agricultural Company, "Steps In Developing A New Product", St. Louis, MO, December 1983.

Professional Scanning

Professional scanning is gathering information relating to technical/scientific matters from professional technical/scientific sources.

1. Employment of scientists of high caliber or of exceptional promise.
2. Subscribing to external sources of technical information.
3. Appointing "gatekeepers" as official monitors.
4. Creating a company technical advisory panel.
5. Hosting in-house seminars and inviting leading international scientists to speak.
6. Holding technical conferences for external and internal specialists at company locations.
7. Permitting staff scientists to take leave of absence as visiting faculty members of universities.
8. Encouraging company scientists to deliver papers at professional conferences and to publish research results.
9. Encouraging technical managers and scientists to join professional research and development management organizations.
10. Participating in university-sponsored information and liaison programs.

11. Developing external company information programs to advise outsiders, especially inventors, of areas of interest and receptivity to their ideas.
12. Channeling information derived from cooperative international rearch and development projects with one or more partners.
13. Acquisition of a research company.
14. Using external experts such as professors and renowned scientists in a consultant or project-input capacity.

Many of these techniques are well-known and/or will be discussed more extensively later.

The Academic Connection

The overview of corporate experience has shown that relationships with universities are useful to firms and many have evolved a significant web of relationships internationally.

For high-technology world-market-oriented companies physical proximity to a university with strength in fields relevant to their needs is a key location factor. Other firms may establish useful connections without placing an research and development facility nearby, in the form of work contracts.

Licensing

Many companies augment their internal research and development effort by acquiring external technology via licensing. The most important technique of monitoring and generating innovation outside of a company's own research and development was licensing.(31)

A strategy of acquisition of technology from outside sources can be particularly helpful to a firm seeking new products and ideas to boost its current operations or to enter into new businesses. Licensing is an essential component of many high-technology, research-oriented industries in which new products are constantly emerging. Licensing can also help forestall competition, as well as obligate the licensee to share its future technological developments with the licensor.

Some large companies give a licensee a straight patent license, for which it promises to give royalty-free cross-license benefits in the specific field in which the patent was issued. This is a standard way for corporations to retain control of technological developments. Finally, some firms seek to protect their trademarks and patents by working them, sometimes even unprofitably for a while. A firm in a high-technology industry may occasionally grant a patent license to a technologically sophisticated firm that could design around the patent; others grant licenses as a safeguard against patent infringements.

(31) Management Practices Research, Management Strategies for Research and Development: The Need for International Dimensions, (New York: Business International, 1979), p. 44.

Obviously, the licensing in-route also has drawbacks, including the possibility that a licensee might become a competitor of the licensor during, or, more commonly, upon the expiration of an agreement; misunderstandings and disputes that may arise requiring prolonged discussion or even arbitration or litigation; and, the fact that licensing is a "chancy" proposition: "The fee may be high and the question of whether the technology or the product has sales potential may be difficult to answer at early stages".(32)

Other Means of Increasing Receptivity to External Technological Developments

Other than scanning and licensing, one way for companies to take advantage of external ideas and development is to expand their awareness of what the next innovations in specific technologies are likely to be by means of careful technologies forecasting. Developing a system of technological forecasting is a time-consuming and possibly costly undertaking depending on the methods used. Its advantage is that -- to the extent that the forecast is accurate -- a company will know where to expend R&D funds over the near term. The many methods that exist today make technological forecasting possible within certain limits of occurancy.

(32) Management Practices Research, Management Strategies for Research and Development: The Needs for International Dimensions, (New York: Business International, 1979), p. 45.

Another important technique is for firms to let it be known that their firms give serious inventors a speedy and fair evaluation of their ideas. Some common methods of doing this include: participation in technology trade fairs which are increasingly being organized around the world; the preparation of published material illustrating the range of company products and the various types of inventions that could be of interest; and providing input to computer data banks that have been organized to facilitate interface between prospective buyers and sellers of technology.

Contacts with Customers and Suppliers

Some companies in this study have acquired extremely useful technical inputs from customers and suppliers. In some cases the interaction is fairly formal through meetings and conferences, while at other times it is simply the result of normal business interchange.

Conferences, symposia, technical seminars and training sessions are held by company research and development organizations for a variety of purposes: to gain contact with customers and knowledge of their needs, to scan new technology, to discuss technical problems, to acquaint customers with ways to use their products, and to upgrade the customer's technical proficiency.

R&D in the Context of Business-Related Joint Ventures

A firm's research and development normally takes on a distinctly different role depending on whether it owns a minority or a majority in its manufacturing joint ventures. In a minority situation, the affiliate and its majority parent are treated as outsiders. The joint venture is at liberty to undertake research on its own, but its relationship with corporate labs is circumscribed. The corporate unit may, for example, undertake research projects on request, but usually only after a formal contractual relationship has been put in place. On the other hand, a majority-owned affiliate is treated almost like a member of the corporate family. Research results are shown, support is provided and know-how is available as needed.

Points to Remember When Entering Into a Cooperative Research Project(33)

(1) Choice of partners

Criteria to be examined include the following factors: the nature of the partner, areas of activity, diversification and importance of partner; geographic location; identical or different markets; the relative importance of research and other functions; special technical capabilities and know-how; equipment; licenses and patents; financial condition of partner; and the compatibility of the leading personalities in each company.

(2) Preparation of the agreement

In defining the program, the means and the financing, the management of both companies should agree on the objectives which should be clearly specified.

(33) Management Practices Research, Management Strategies For Research and Development: The Needs for International Dimensions, (New York: Business International, 1979), pp. 64-65.

After the generalities have been defined, a detailed program must be created. It is advisable to create a "direction committee" composed of senior representatives of the partners; and a "coordination committee" composed of representatives of the research/technical services of each partner.

Next, the coordination committee agrees to a working program in its different phases: research, development and the construction of prototypes and pilor apparatuses. This program must establish all activities brought into the project from the partners.

Next, an evaluation of the complete budget and duration of the project can be finalized. The modes of financing and the methods and frequencies of payments should be set forth.

The agreement should contain clauses relating to its causing termination or cancellation in case of failure, overspending, or other events which could be cause for the cooperative project to cease. It would be customary for the mutual secrecy obligation to remain in force for a specific period.

The finalized agreement must then be submitted to the direction committee for review and finally passed to top management of the partners for final approval.

(3) Management of the project

Management procedures must be standardized for the project to include methods of planning, organizing, control and budgeting. Regular meetings of both the direction committee and the coordination committee should be held to review progress and management matters.

(4) Post-project phase

Methods of exploitation, distribution of benefits and review procedures must be established.

CENTRALIZING VERSUS DISBURSING R&D GEOGRAPHICALLY

This section deals with the factors that motivate firms to centralize or disperse their research and development geographically. It also analyzes this issue with firms -- that conduct no research and development outside their organization.

Motivations For Not Having Outside R&D

Although most companies still centralize research and development there are two fundamental issues affecting the choice between geographic centralization or decentralization of research and development. One is protection of the company's technology, the other is response to market requirements. Technology may be a company's most important asset and therefore compromising it may have dire consequences. But the demand for a firm's products in any given market is critical to its prosperity, and thus research and development work must be market-oriented. In general, centralization of research and development provides efficiency, cost effectiveness and control, while adequate responsiveness to market conditions often requires research and development proximity to the market.

The shorter the period of time a firm has been in business -- particularly manufacturing -- and the smaller this business is vis-a-vis domestic operations, the more centralized corporate research and development is likely to be because of not wanting to expose their business.

Motivations for Establishing Outside R&D

The key findings regarding motivations can be summarized as follows.

First, a commitment to international operations and a substantial degree of overseas manufacturing are the basic prerequisites for overseas research and development. For example, US firms have begun to look to international operations as a key growth area. While the domestic market still has potential, the population level is stagnating, whereas, overseas the company feels it has an opportunity to broaden its product lines and to move successful products from one country to another. Some of this expansion is not the responsibility of research and development -- obviously it falls under marketing and product development, but research and development can help to identify new technological developments as well as create new products and process technology to meet the challenge of competitors and to produce quality products that will sell.

Secondly, market size and importance breed outside research and development. If it is necessary to be responsive to market conditions by altering existing products and/or creating new ones, proximity of R&D is required; and if a firm's growth is vitally related to certain foreign markets, research and development support will not be withheld. "Research and development abroad is related to market size. When the market gets above a certain critical mass, you need innovation market people, a stronger quality control and an research and development facility".(34)

Finally, seeking innovation technological talent is a powerful motivation for a relatively limited number of companies.

Secondary reasons for locating R&D units included: the usefulness of dispersing development both for purposes of product adaption and "corporate citizenship" while keeping research centralized; the desirability of attracting local individuals with specialized skills; and monitoring foreign developments in relevant scientific and technological fields.

Further reasons are:

1. To assist in the transfer of domestic technology to foreign operations.

2. To modify and sometimes to develop products for the foreign market. Companies with a host-market approach generally establish research and development.

(34) Management Practices Research, Management Strategies for Research and Development: The Need for International Dimensions, (New York: Business International, 1979), p. 86.

3. Often outside research and development grows because the subsidiary management wants to increase the size and contribution of its operation. A few research and development units gain entree to the corporation as the result of a acquisition.

4. Some research and development units are created by firms with a world-market orientation to undertake basic (fundamental) research and are highly integrated in the corporate or divisional R&D system.

Strategic planning is not an end in itself because plans alone do not bring change. It is only a framework for a change in corporate behavior. To be effective, strategic planning has to lead strategy implementation and, ultimately, to management by strategy.

First, what do I mean by "managing by strategy"? Managing by strategy means shaping or adapting the management process of the corporation to its strategy system. By corporate strategy system, I mean the set of systems, processes and procedures which ensure:

- o That conguent business and corporate plans are formulated;
- o That their operating and financial consequences are detailed and costed;
- o That they are translated into specific action plans for implementation;
- o That their effectiveness is measured on a continuing basis.(35)

In other words, the corporate strategy system consists of four elements: strategy development, strategy planning, strategy implementation and strategic performance measurement. Managing by strategy means, therefore, that the strategy system just defined is the core of the whole corporate management process. This implies that the resource allocation process, its organization, budgeting, reporting control, performance measurement and reward, management

(35) Bernard Taylor and Kevin H. Hawkins, Handbook of Strategic Planning, (London: Longman, 1972) p.

information systems, internal communications and management development process, are all linked to, and shaped by the corporate strategy system.

I now propose to go back to the various elements of the corporate management process and describe briefly how each is affected by the strategy system in the following discussion as based on Bernard Taylor and Kevin H. Hawkins.(36)

Resource Allocation

- o Resource allocation is always a corporate decision.
- o Resource allocation is the culminating point of the strategic planning process and must be done before the start of the budgeting process.
- o All resources - not just money - must be allocated.
- o Resources must be allocated directly not in the traditional way in successive cascades through the organizational structure.
- o Resource allocation should be zero-based.
- o All resource allocation should flow from -- and thus should be identified with -- specific and approved strategies.

Organization

- o Projects and programs have to be explicitly identified and recognized.
- o Managers have to be appointed if they don't already exist.
- o Whenever possible projects and programs should coincide with strategy centers.

(36) Bernard Taylor and Kevin H. Hawkins, Handbook of Strategic Planning, (London, Longman, 1972) pp. 1-456.

Budgeting

- o Budgets are derived from and linked to the strategic plan.
- o Budgets should take account of long-term strategies.
- o Zero-based budgeting should be used whenever possible.

Reporting and Control

- o Financial statements should be prepared by each project and program.
- o Each project and program must be measured which involves selecting performance measures, setting performance standards and designing reports.

Performance Evaluations and Rewards

- o Differential management performance measures are introduced.
- o Managers are judged on the basis of strategic performance.
- o The execution of difficult strategies are rewarded.

Management Information System

- o Formally links
  - Planning and control;
  - Strategic planning and other planning sub-systems

Internal Communications

- o A common strategic language should be developed and used throughout the operation;
- o The internal corporate dialogue focusses on strategy;
- o Strategy can be communicated convincingly to interested groups.

Management Development

- o The strategy development process is the key management development tool;
- o Management appointments take into account specific strategic skills.

Now with a completed and rapid review of the implications of managing by strategy on the various elements of the corporate management process I am left with a question. What is required to make the system work?

The answer was provided to me by an article in the Journal of Business Strategy. The first, and most important is to have positive values for innovation. The actions of management must reflect a positive value for innovation, then employees will believe management supports innovation. Second, there should be no rigid lines of responsibility, but rather a loose coupling interaction should be incorporated so that free crossing of boundaries can take place when the situation dictates. Third, there should be persistance and high standards of performance. Without these there are temptations to be back to a "business-as-usual" mentality. Finally, a climate of confidence and cooperation must be adopted to inspire teamwork. If these principles are adopted the managing of technological innovations during the 1980's will be easier.(37)

(37) Michael A. McGinnis and M. Robert Ackelsberg, Effective Innovation Management: Missing Link In Strategic Planning, Vo. 4, No. 1 (The Journal of Business Strategy: Warren, Gorham & Lamont, Inc., Summer 1983) pp. 61-65.

SUMMARY

In Chapter IV concepts in managing technological innovation were reviewed. Critical factors for success were receptiveness, creative ideas, relevance to objectives, selection and evaluation systems, market orientation, project control and commitment.

Organizational models were introduced as possible frameworks to achieve the innovations and introduction process of new products. The different models were the, scientific model, matrix model, Schon's model and future models such as the biological and hybrid models.

In selecting an organizational framework or model for technological innovation, the external environment must be considered. Factors like economic, technological, social, ethical and political and legal will affect the decision process.

In considering new products or innovation, the research and development role is a high order of importance. The best techniques were discussed and their involvement in achieving corporate goals. Keys to success appear to be in licensing, monitoring customers and suppliers, appointing regional or nationwide product research and development coordinators, and effecting temporary transfers of outsiders into home country labs, joint ventures and academic connections.

Centralizing versus disbursing research and development geographically was also discussed with the idea that applied and fundamental research usually remain at the corporate labs.

The final focus in this chapter was on "Strategic Planning" which is the incorporation of everything previous to achieve corporate objectives. Various elements were looked at and described briefly on how each affects the system. With all of this in mind this takes us into the next chapter which covers the influences in new product development and introduction.

CHAPTER V

INFLUENCES IN NEW PRODUCTS DEVELOPMENT & INTRODUCTION

Discovery

Research advances in molecular genetics and related biotechnologies have occurred at an exponential rate in the last ten years. Publicity about the potentially lucrative commercial applications of these technologies have caused biotechnology firms to be founded at an equally rapid rate. (38)

In August 1977, a fledging corporation, Genentech, Incorporated, became the first commercial firm to announce the successful development of a recombinant bacteria capable of producing human protein, somastostatin, as a result of gene splicing manipulations. This announcement served as a catalyst to galvanize both the formation of new venture companies and initiation of research programs by established corporations in the chemical and pharmaceutical industries. (39)

Companies now active in biotechnology have begun to tap the resources of academic institutions to obtain the experience, personnel, and research facilities these universities provide. At the same time, universities have been calling on industry to support biotechnology research in face of reduced federal funding of this research. (40)

(38) Biotechnology News, V. 2, #13, July 1, 1982, p. 5.

(39) Technomic Consultants, 1981, p. III-1.

(40) Biotechnology News, V. 2, #13, July 1, 1982, p. 5.

Seventy-five percent of the research being done by academic institutes is federally funded through grants and agencies like the National Institute of Health (NIH) or the National Science Foundation (NSF). Approximately five percent of the research in universities is supported by industrial and private institutions.(41) Recent university-industrial collaboration has caused much concern with government officials and academicians who feel deleterious effects will occur. Critics fear that scientists which have financial interests in a company which funds their research are very susceptible to alter the direction of their research away from problems of profound long-term significance and toward subjects of intermediate-term commercial significance to the company funding the research.(42) Additional allegations include: 1) the fear that industry will fail to respect the need for unfettered basic research and open communication between scientists; 2) "brain drain" which means the concern that genetic engineering firms are hiring many of the top academic researchers at the expense of the universities; and 3) the implications that medically or socially useful information will be kept from the public in favor of financial gain from the sponsoring institution. (43)

(41) Biotechnology News, V. 2 #13, July 1, 1982, p. 5.

(42) Chemical Week and Biotechnology Newswatch. Research to Reality - Business Opportunities in Biotechnology. October 26-27, 1981 Remarks by Howard Schneiderman of Monsanto.

(43) Chemical Week, op. cit., Sanders, Charles A. "The Medical Academic Industrial Complex".

There have been a number of university-industrial collaborations with one of the largest being between Monsanto and Washington University for $23.5 million over a five year period. In 1982 federal hearings occurred on this subject which prompted the American Association of Universities (AAU) to put together a model code of ethics to be followed. This code is not expected to present unmanageable agreements. Most people familiar with university-industrial collaboration feel that research contracts can be formulated to protect everyone interested: the university, the company, and the public.

There are many companies now participating in the area of biotechnology and they are segmented as follows: (44)

- o Established Venture Companies - This category includes Genentech, Incorporated, Genex Corporation, Biogen S.A., Cetus Corporation and Collaborative Genetics, Incorporated. These companies have established strong research capabilities, in some cases with impressive track records, while attracting additional capital from public offerings or corporate investors to assure future growth.
- o New Entrants - This category includes companies that have recently initiated R&D programs as a result of recent incorporation or diversification activities. Bethesda Research Laboratories and Genetic Systems, Incorporated characterize this group.

(44) Technomic Consultants, A Technological & Business Opportunity Assessment of Genetic Engineering and Related Biotechnologies 1980-1990 1 Vol. (Chicago: Technomic Consultants, 1981), p. IV-30.

o <u>Major Corporations</u> - This category includes corporations such as Dupont, Monsanto, Abbott Laboratories, and Upjohn who are clearly established in the chemical, pharmaceutical, petrochemical or agribusiness industries and who have established in-house research programs in this technology.

Let's step back for a minute and look at some practical problems that lie between discoveries and commercial exploitation, including:

1) The economics of production. Many schemes to produce bulk chemicals or fuel biotechnologically cannot (currently) compete on a cost basis with traditional processes using hydrocarbon feed-stocks.
2) The problems of scale-up. It can be a huge step from the laboratory flask to the industrial fermentation tank. Many apparently promising developments will never make this transition because they will not be efficient in commercial production.
3) The delays inherent in the commercialization of new processes. This is apparently true in the case of human health products, even if regulatory authorities generally do now appear to be taking a more relaxed view of drug introductions. (45)

(45) Sittig and Noyes, <u>Genetic Engineering and Biotechnology</u> (Kingston, NJ: Sittig and Noyes, 1981/1982), p. A-2.

With the way things are in the business world today, there are serious questions of how to get into this field and stay in. Some answers to this question are provided in the following tabulation adapted from a paper by J.R. Murry of Policy Research Corp.

How To Get In(46)

Possible Corporate Responses	Possible Price Tags
(a) A joint venture with a biotechnology firm in a product segment where the firm has position and market knowledge.	$2 million and up
(b) Obtain an equity option from the biotechnology firm.	$1 to 5 million
Possible Corporate Responses	Possible Price Tags
(c) Make a parallel project - specific university research grant, with exclusive commercial rights.	$20 to 50 million
(d) Try to get at least two molecular geneticists for in-house R&D.	$2 million for initial laboratory $0.5 million/year
(e) Establish some sort of access to a molecular biologist consultant.	$20,000/year and up

(46) Ibid., p. A-2.

One way to get in and stay in (without litigation at least) is to license the basic Cohen-Boyer patent(s) from Stanford University at $10,000/year. A listing of U.S. licensees of these patents is as follows: (47)

U.S. Cohen/Boyer Licensees

Abbott Laboratories
Advanced Genetic Sciences
Agrigenetics
Allied Corp.
American Cyanamid
American Home Products (Wyeth Labs)
Baxter Travenol
Beckman Instrument (Smith Kline Beckman)
Biogen
Biologicals
Biotechnical International
Boehringer Mannheim
Bristol Myers
Burroughs-Wellcome
Cambridge Plan (The)
Carter-Wallace, Inc.
Cetus
Chiron
Codon
Collaborative Research
Corning Glass Works
CPC International
DNA Plant Technology
DNAX
Dupont
Engenics
Genentech
Genetics Institute
Genex
Genzyme
Grace, W. R.
Hoffman La Roche
Integrated Genetics
Inter'l Minerals & Chemicals
Inter'l Plant Research Institute
Johnson & Johnson
Koppers Company
Lilly, Eli & Company
Microlife Genetics
Miles/Bayer AG
Molecular Genetics
Monsanto
Nabisco/Standard Brands
National Distillers
New England Biolabs
Novo
Pfizer
PL Biochemicals
Polybac Corp.
Repligen Corp.
Revlon
Salsbury Labs
Schering Plough
Searle, G.D.
SmithKline Beckman
Stauffer Chemical
Synergen
Texaco
UOP
Upjohn
Virogenetics

(47) Ibid., p. A-2.

To do a comprehensive report on what each company is doing in biotech-nology is outside the scope of this paper. Therefore, only the most leading manufacturers will be covered as well as noting a table of documented investments many companies have made in biotechnology's new venture companies.

Allied Chemical - Has 10 percent interest in Biologicals, a Canadian firm and has a small program at their Syracuse labs.

American Cyanamid - Has 20 percent equity in Molecular Genetics with an in-house program starting.

Dow Chemical - Invested $5 million in Collaborative Genetics and presently building in-house program.

DuPont - Large in-house program with collaborative effort with California Institute of Technology.

Gulf Oil - Modest in-house program plus cooperative agreement with unspecified Japanese company.

Monsanto - Extensive program, including $20 million investment in Biogen, a contract agreement with Genentech and minor equity holdings through Innoven of Genentech and Genex.

Shell Oil - Has contract with Cetus.

Standard Oil (Indiana) - Equity holding in Cetus with intensive in-house program.

Stauffer Chemical - Upgrading fermentation process with unconfirmed recruiting activity for California research center.

Other companies doing heavy recruiting are Abbott Laboratories, BRL, Boehringer, Genentech, Haber, Hoffmann-LaRoche, Lilly Research, New England Nuclear, Novo Laboratories, Ralston Purina, and Synergen.

Documented biotechnology investments total about $500 million.

Biotechnology Company	Investor(s)	$ Millions
Adria Laboratories	Hercules	$ 1.0
	Montedison	1.0
Advanced Genetic Sciences	Rohm & Haas	12.0
Applied Molecular Genetics	Abbott Laboratories	5.0
	Tosco	3.5
Bethesda Research Laboratories	Private	8.0
BioCell Technology Corp.	Public Offering	2.6
Biogen	Schering-Plough	8.0
	Inco	12.0
	Monsanto	20.0
	Grand Metropolitan Ltd.	10.0
Bio-Response	Public Offering	5.0
Biotech Research Laboratories	Ethyl Corporation	1.0
Calgene	Allied Corporation	1.0
Cetus	National Distillers	5.0
	Standard Oil of California	13.0
	Standard Oil (Indiana)	10.0
	Public Offering	120.0
Collaborative Genetics	Dow Chemical	5.0
Collaborative Research	Dow Chemical	5.0
	Public Offering	13.0
Collagen Corp.	Monsanto	1.0
Cytox	Public Offering	3.0
DNA Plant Technology Corp.	Campbell Soup Company	10.0
DNAX Corp.	Private	1.0
	Alza Corporation	1.0
Engenics	Bendix, General Foods, Koppers, Mead, Noranda Mines, Elf Aquitaine	10.0
Enzo Blochem	Public Offering	4.0

Biotechnology Company	Investor(s)	$ Millions
Genentech	Lubrizol	25.0
	Monsanto	2.5
	Fluor Corporation	9.0
	Public Offering	35.0
Genetic Engineering	Public Offering	4.0
Genetic Systems Corp.	Private	1.0
	Public Offering	6.0
Genetics Institute	Private	5.0
Genex	Koppers	25.0
	Monsanto, Emerson Electric	10.0
Hybritech	Kleiner, Perkins, Caulfield & Byers; Sutter Hill Ventures; Asset Management Company	13.0
Interferon Sciences	Public Offering	10.0
Molecular Genetics	Private	1.0
	American Cyanamid	5.0
Repligen	Private	5.0
Salk Institute Biotechnology Corp.	Phillips Petroleum	10.0
Southern Medical & Pharmaceutical Corp.	Public Offering	23.0
	Key Energy Enterprises	7.3
Viragen	Public Offering	9.0
Viratek	Public Offering	4.0
TOTAL:		$502.9

Source: Sittig & Noyes, Genetic Engineering and Biotechnology Firms (Kingston, NJ: Sittig and Noyse, 1981/1982)

Regulations

Early in the development of genetic engineering technology, both the potential risks to the public safety and the potential economic benefits of the technology were recognized by the research community, commercial firms and the government. Since genetic engineering presented opportunities for novel organisms which never existed before, policies regarding research guidelines, worker safety, and environmental protection were needed. (48)

Recombinant DNA is the only biotechnology having formalized guidelines. The formulation of the NIH Guidelines for recombinant DNA research was initiated in 1975 by the Asilomar Conference and promulgated by the National Institute of Health in 1976. Since 1976, the guidelines have been relaxed twice. The first modification occurred in December, 1978, lowering the physical containment requirements for DNA experiment facilities; the second occurred in January, 1980, again lowering restrictions from the 1976 guidelines. The current regulatory environment covering recombinant DNA research and applications include the following:

- o The revised 1980 NIH Guidelines for Research Involving Recombinant DNA Molecules (45 Federal Register 6718, 45 Federal Register 6742).
- o The Physical Containment Recommendations for Large Scale Uses of Organisms Containing Recombinant DNA Molecules (45 Federal Register 24968).

(48) Technomic Consultants, A Technological & Business Opportunity Assessment of Genetic Engineering and Related Biotechnologies 1980-1990 1 Vol. (Chicago: Technomic Consultants, 1981) p. IV-35-38.

o Other federal regulations including Good Manufacturing Practices (GMPs), Good Laboratory Practices (GLPs).

o Tort law regarding negligence and strict liability.

Compliance with the NIH Guidelines is mandatory only for institutions receiving NIH funds for recombinant DNA research. The NIH Guidelines are not legally enforceable against private companies. However, all commercial firms in the U.S. indicate voluntary compliance. (49)

Despite expressions of concern for worker safety in installations conducting recombinant DNA research, no agency or regulation had been specifically charged with this responsibility. The Center for Disease Control has published guidelines for workers, but they do not have the force of statute. The Federal Interagency Advisory Committee on Recombinant DNA has a subcommittee called the Industrial Practices Subcommittee (IPS) which is considering issues on occupational health andother federal responsibilities while also reviewing the recommendations of the National Institute for Occupational Safety and Health Center for Disease Control. There is a strong likelihood that Occupational Safety and Health Administration (OSHA) would apply any recommendations from IPS but will continue a low profile if the industry safety record continues favorable. (50)

(49) & (50) Ibid., p. IV-35-38.

Patenting of Biotechnology

Until recently, the United States Patent and Trademark Office had routinely rejected claims to living microorganisms on the basis that they were not within one of the statutory classes of subject matter as set forth in 35 United States Code 101 for which a United States patent could be granted. (51)

The Code states: "Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent, therefore, subject to the conditions and requirements of this title". The main issue was whether genetically-engineered organisms could be patented. The Patent Office now up-holds that processes employing living organisms are patentable and subject to law and protection.

The controversy started when the following two patent applications were filed.

- o The patent application of the Upjohn Company for a "Process for Preparing Linconycin" which used a new microorganism, Streptonyces vellosus in the production process. Application of Bergy, 563 F2d1031 (1977).
- o The patent application of General Electric for a patent for a bacteria that can be used for cleaning up oil spills. Application of Chakrabarty. (1972). (52)

(51) C. Harold Herr, Recent Developments in the Patenting of Microorganisms, (Presented at the 12th International Congress of Pacific Industrial Property Association, November 4, 1981) p. 1.

(52) Technomic Consultants, A Technological & Business Opportunity Assessement of Genetic Engineering and Related Biotechnologies 1980-1990, 1 Vol. (Chicago: Technomic Consultants, 1981), p. IV-7.

The application of Bergy was turned down by the Patent and Trademark Office on the basis that the product was a subject of nature not covered in the Code 101 provisions.

The Court of Customs and Patent Appeals (CCPA) then considered the Bergy case strictly on the issue of whether the uncontraverted fact that a biologically pure culture was alive removed it from the categories of inventions in Code 101. The CCPA held that mircroorganisms are more similar to inanimate chemical compositions such as reactants, reagents and catalysts than horses and honeybees; and stated that it could see no sound reason to refuse a patent. (53)

The Patent Office then appealed to the Supreme Court, but Upjohn avoided a review and cancelled its claim.

In the application of Chakrabarty, the Patent and Trademark Office again refused to grant a patent because the bacteria was alive, again the CCPA reversed the decision. The Patent and Trademark Office appealed to the Supreme Court; this time the case went to court and on June 16, 1980, the Supreme Court ruled that man-made organisms are patentable under the code because microorganism constitutes a "manufacture" or "composition of matter". However, Congress may still modify or override the decision. It is believed Congress will take no action but allow the law to develop on a case-by-case basis. Because of the Supreme Court's decision, other problems must be considered.

(53) Ibid., p. IV-11.

First, a patent on a specific recombinant organism may be too specialized to provide legal protection since the microorganism can be modified in numerous ways to produce a functionally equivalent cell. Secondly, the "doctrine of equivalents", which states that changes must be nontrivial to avoid infringing on a patent, may be applied to discourage some researchers from making minor modifications to produce a functionally equivalent, yet unique, organism. (54)

Companies, however, do have an alternative in that they can rely on trade secrets to maintain an edge. On December 2, 1982 a broad patent was issued to Drs. Stanley Cohen and Herbert Boyer covering gene splicing and cloning methods. The second part of the application is still pending on the use of the technique. The respective universities of the doctors have an underlying patent cutting across all commercial work related to genetic engineering which they are receiving royalties. At present, both patents could be challenged in the courts by related industries. However, this activity is not considered to have significant impacts on research activities. (55)

There were early concerns about recombinant DNA research as being dangerous, but new research findings and a good safety record by institutions have caused this to dissipate. Existing regulations are suffi-cient and all institutions are meeting the NIH Guidelines. This should be sufficient for biotechnology.

(54) & (55) Ibid., p. IV-17-24.

The U.S. Supreme Court has affirmed that man-made life forms can be patented. Firms, however, may choose to retain biotechnology information as trade secrets. The American Association of Universities has drawn up a code of ethics for university-industrial collaboration, but this is not expected to restrict academic institutions or companies from making progress in biotechnology.

The exhaustion of energy supplies should increase the importance of finding new feedstocks which should bring reduced costs for the world's energy needs. Existing methods and new methods will provide long-term benefits to many companies and industries producing new products that will close in on the world's major problems of malnutrition, disease and environmental pollution. If biotechnology takes account of social and political factors, it should provide an initiative for development in a time when stagnation is gripping the world.

SUMMARY

In this chapter the aspect of "Discovery" was covered. It showed that the biotechnology industry is very young with chemical and pharmaceutical companies just starting to develop this new technology. However, academic institutions are still doing most of the research, therefore university-industrial collaboration is on the rise.

It was also pointed out that biotechnology is a segmented market. There are the venture companies, major corporations and new entrants who will all organize in a different manner that fits their corporate objectives. The industry though does have its problems between discoveries and commercial exploitation, such as: economics, scale-up and inherent delays.

Other concerns like regulations and the ability to patent a new product or process will automatically delay introductions. The point here is that biotechnology firms need to be well organized in a manner that will help expedite introduction. Because this technology is very complicated, and good understanding and communication is of the essence, a corporation must have a formalized format for bringing different operational groups together. There must be some way of coordination and cooperation between research and development, manufacturing, product development, law departments and marketing. The next chapter will cover this aspect.

CHAPTER VI

ORGANIZATIONAL CONCEPTS FOR

MARKETING NEW PRODUCTS

In this section the traditional forms of new product introduction will be discussed from an organizational viewpoint. However, because of biotechnologies' effects on agriculture and its possible implications into the market place, an organization may have to change in order to be successful. This will be looked at and discussed with a final conclusion being drawn from all available information and research.

The first question to look at is, "Why is new products organization a special problem?"

There are three reasons why special interest is given to new product management.

1. New products management is one of two corporate activities, the other is general management.

2. There are massive uncertainties throughout the entire new products process.

3. It is virtually impossible to measure the correctness of any particular new products organizational format.

"New products management involves all functions of the organization at all levels. And even if a "separist" format is chosen for new products, for example venture groups, we have only reduced the size of the company focus, not its completeness." (56)

(56) C. Merle Crawford, New Products Management (Homewood, Ill.: R. D. Irwin, 1983), p. 145.

C. Relevant Concepts as Inputs

Certain concepts are relevant as inputs to organizing. There are essential ideas and beliefs that have strong influence on organizational format.

A. Situational givens:

1. Industry practice, a constraint that can be bypassed but is ignored at risk.

2. Commitment to cost.

3. Organization for established products, for example the industrial firm is greatly influenced by a product management format.

4. General style of a firm's management. Hopkins (57) cites these factors: the opinions and judgement of the person actually in charge, the firms current thinking on the blending of decentralized decision making with centralized control, the degree to which the firm has accepted the marketing concept, and the general degree to innovation is encouraged. Quinn and Mueller (58) are more specific, citing such factors as company policy on risk taking, involvement in the technical program, interchange of personnel, reward for change, appraisal of research performance, and competition between operating units.

B. There is no one inherently superior method.

(57) David S. Hopkins, Options in New Product Organization (New York: Conference Board, 1975), p. 2-3.

(58) James Brian Quinn and James A. Mueller, Transferring Research Results to Operations (Boston: Harvard Business Review, January-February 1963), p. 59.

C. Certain variables are the source of variety.

1. Risk

2. Communication pitfalls.

3. Behavior change required.

4. Team and leader process is that one person must be in charge and responsible for what happens.

5. Evolution:

a. As a firm grows it will move from a simple to a more complex structure.

b. Firms will move from old to new structures.

c. There should be a planned series of formats "These combined evolutions can produce highly fluid and highly confusing situations."(59)

6. Twin streams: Bringing a product to market requires a sequence of events that take two paths. One is the marketing path the other is the actual physical production of the product.

7. There must be objective control.

8. Formal versus informal. "Informal included in the formal structure increases the design task but helps assure necessary control".(60)

(59) C. Merle Crawford, <u>New Products Management</u> (Homewood, Ill.: R. d. Irwin, 1983) p. 149.

(60) Ibid., p. 149.

9. Four-location rule is that firms are involved in four different activities:

a. Product improvements.

b. Near line extensions.

c. More distant line extentions.

d. Entries into businesses new to the firm.

In this paper everything discussed falls into the fourth category. Usually a separate group other than a product manager handles this activity.

10. Miniaturization. This concept is that the smaller the team the better. Bureaucracy is believed to be inherently inefficient and really should only be used to increase lines of communication.

This next section covers the participants and their roles and is best expressed in the following diagram:

	Participants	Activity
1.)	Strategist	Long range, managerial, entire program.
2.)	Inventor	Creative scientist, idea source.
3.)	Project Manager	Leader, integrator, translator, mediator, judge, arbitrator, coordinator.
4.)	Champion	Supporter, spokesman, pusher.
5.)	Rationalist	Objectivity, reality, reason, financial.
6.)	Sponsor	Senior manager, support, endorser assuring hearing.

The participants fit into particular organizational structures which have been widely developed. It seems best to lightly discuss the basics which have formed these structures. Within every organization there are three dimensions that must be discussed - level, function, and form. The options are shown in the following chart:

Dimension	Alternatives
Level	All at corporate
	Mixed - some at both corporate and division
	All at division
Function	General management
	Technical-research & development/engineering
	Marketing
	Other
Form	Individual vs. committee
	Matrix bond
	Committee
	Product manager team
	Task force
	Project team
	Matrix team
	In-house venture
	Venture group

LEVEL OF NEW PRODUCT RESPONSIBILITY

"There is only one level in which to place the ultimate responsibility for new products. Granted the task may be delegated by the company head, but if so, this is a functional decision, not a level decision. However, when biotechnology firms are divisionalizing, it is either by fractionalization or by conglomeration. In this case we fine more general managers and thus the level option is a serious decision set, in three ways - overall program, specific projects, research & development."(61)

(61) Ibid., p. 156.

Overall Program

1. New products is corporate matter, and divisions have no program. This is not a good option unless in commodities.

2. New products program is split between corporate and division. This is usually the case.

Specific Projects

1. Specific project or research program may be activated at corporate level.

2. It may be assigned to one division.

Research & Development

Lowell Steele found available alternatives to the new products debate to centralize or decentralize.(62)

1. Centralize at corporate labs.
2. Centralize but at divisional level.
3. Organizational centralization with geographic decentralization.
4. Centralized research but decentralized development.
5. Some centralized, some decentralized.
6. Centralize research & development for new business, decentralize research & development for existing business.
7. Decentralize all research and development but head with a small corporate staff.
8. Complete decentralization.

(62) Lowell W. Steele, Innovation in Big Business (New York: Elsevier, 1975), pp. 118-120.

Function

Three options are felt to exist for new products programs: marketing, research & development or a separate department for organizing and meeting goals.(63)

The decision process is as follows:

1. Should the responsibility for new product development stay at the general management level, or should it be assigned to one of the functions?

2. If to a fuction, which one?

   a. Marketing

   b. Research & Development

   c. Other

3. If to general management, which of these?

   a. General manager

   b. A separate new products department (nonfunctional).

There are some basic conclusions that can be drawn. First, the more activity towards new markets as with biotechnology, the more the responsibility must stay above individual functions. Second, if the risk is high, the responsibility should fall on the general manager. Third, the more complex the projects, again the more general management should be responsible. Fourth, the time frame is important. If the period for introduction exceeds time frame, then again general management should be responsible. Finally, objectivity without coordination at a higher level again possibly at the general manager level there is no direction.

(63) C. Merle Crawford, New Products Management (Homewood, Ill.: R. D. Irwin, 1983), p. 159.

Knowing that the general manager has the authority for delegation, to whom does he delegate? Normally it is made between technical and marketing with manufacturing or finance and law departments occasionally getting the call. However, the decision between technical and marketing isn't as difficult as it would seem.

First, what is the source of the essential innovative element? Second, how well do the technical people understand needs, desires, attitudes and behaviors of the marketplace? Most assignments of new products go to marketing. However, if technical aspects are overwhelming, then research and development as with biotechnology should be given the power and take the responsibility if the product or project fails.

So the responsibility falls on general management as to how is it handled. Committees now are a very popular form of operation usually chaired by the general manager. However, there is a growing practice of new product departments that report to the general manager. On organization charts the position is usually drawn level with functions, however it is a staff position.

Form of New Product Responsibility

Having made the level and function decisions we now move to form a structure. Remember introducing new products requires team work with objective control. As you will see, many methods have been designed to achieve this goal.

Knowing that the general manager has the authority for delegation, to whom does he delegate? Normally it is made between technical and marketing with manufacturing or finance and law departments occasionally getting the call. However, the decision between technical and marketing isn't as difficult as it would seem.

First, what is the source of the essential innovative element? Second, how well do the technical people understand needs, desires, attitudes and behaviors of the marketplace? Most assignments of new products go to marketing. However, if technical aspects are overwhelming, then research and development as with biotechnology should be given the power and take the responsibility if the product or project fails.

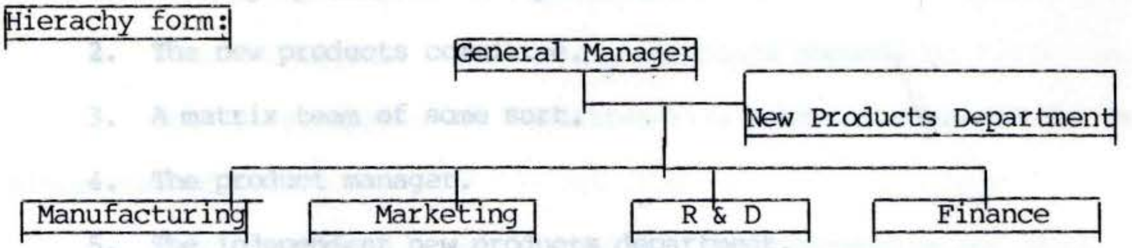
So the responsibility falls on general management as to how is it handled. Committees now are a very popular form of operation usually chaired by the general manager. However, there is a growing practice of new product departments that report to the general manager. On organization charts the position is usually drawn level with functions, however it is a staff position.

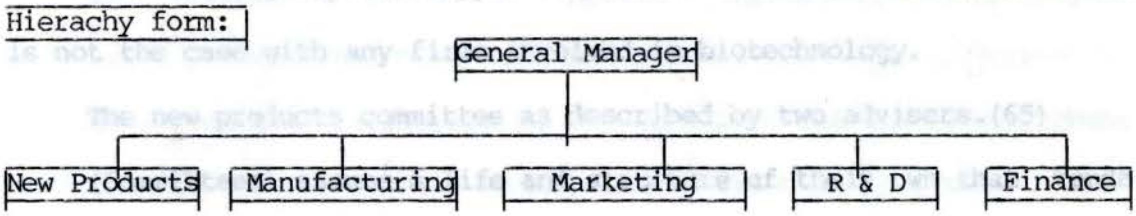
Form of New Product Responsibility

Having made the level and function decisions we now move to form a structure. Remember introducing new products requires team work with objective control. As you will see, many methods have been designed to achieve this goal.

In the question of hierarchy versus matrix, the traditional form is heirarchy which is rigid and formalized with power at the top of the pyramid. Authority is passed down, decisions are passed up and communication flows vertically. For efficiency and flexibility matrix management was developed. Whether committee, project team, task force or venture group, the principle combines two dimensions. It utilizes vertical relationships along with horizontal for the need of coordination between functions. See diagram heirarchy versus matrix on the following page.

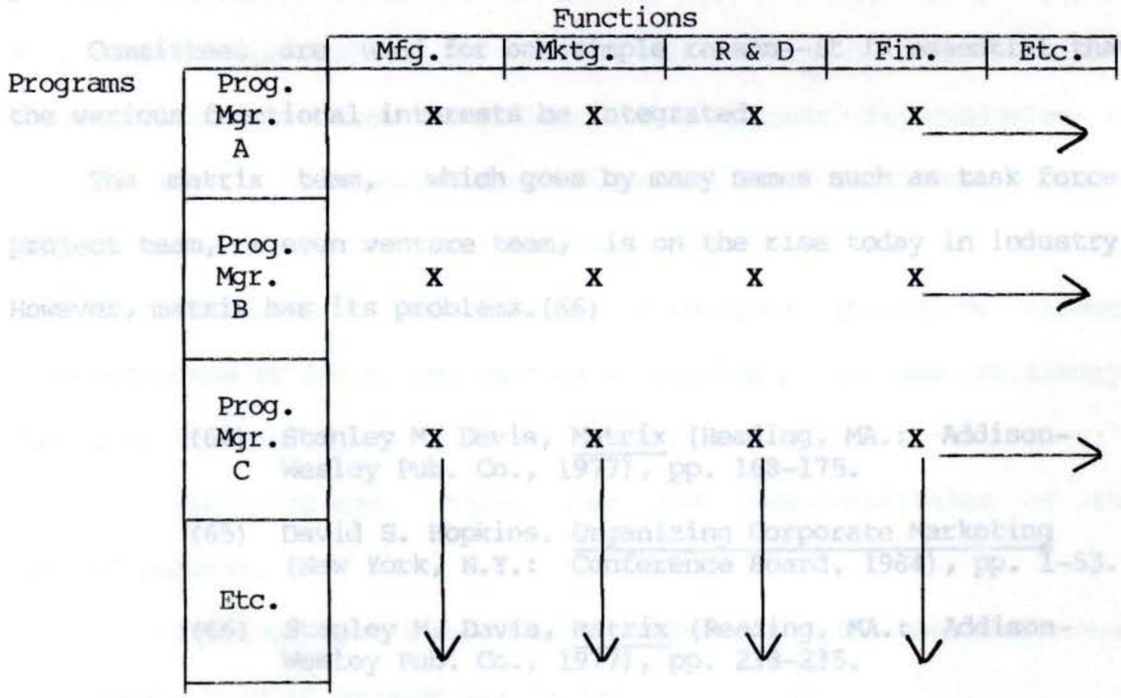
Diagram I shows alternatives on the dimensions of form.





Matrix

Explanation: Each functional department provides one representative to each of the program teams. That representative is responsible both up and across.



Operating characteristics of matrix bond points are shown in diagram.

There are five common structures used by organizations today.(64)

1. Nothing special for new products.

2. The new products committee.

3. A matrix team of some sort.

4. The product manager.

5. The independent new products department.

The nothing special approach is used when firms are small which is not the case with any firms involved in biotechnology.

The new products committee as described by two advisers.(65)

[Committees] assume a life and structure of their own that tends to overrule the problem-solving approach that is uniquely required for each [new product] problem;

[Committees] are a necessary evil to be used as little as possible.

Committees are used for one simple reason--it is essential that the various functional interests be integrated.

The matrix team, which goes by many names such as task force, project team, or even venture team, is on the rise today in industry. However, matrix has its problems.(66)

(64) Stanley M. Davis, Matrix (Reading, MA.: Addison-Wesley Pub. Co., 1977), pp. 168-175.

(65) David S. Hopkins, Organizing Corporate Marketing (New York, N.Y.: Conference Board, 1984), pp. 1-53.

(66) Stanley M. Davis, Matrix (Reading, MA.: Addison-Wesley Pub. Co., 1977), pp. 233-235.

1. Tendencies towards anarchy. (Two losses is worse, not better, than having one).

2. Power struggles. Conflicting interests abound.

3. Severe "groupitis". Committee-like behavior where matrix is misunderstood.

4. Collapse during economic crunch. It is expensive and slow.

5. Excessive overhead. Upfront expenses are heavy only if successful productivity recaptures investment.

6. Decision strangulation. Matrix is the opposite of power management, which is often a consequence of too much democracy.

The product manager, although traditional is used. The key question here is should product managers work on established products and new products? The answer should be no. New product managers usually come out of research and development and are active until full-scale commercialization where they should be replaced with a manager to achieve sales and goals. This format is conducive to biotechnology. In many cases you could say that the new products manager could really be a matrix team leader.

The independent new products department should be strong, corporate-wide in focus, and capable of pushing into new territory. Two types that exist:

1. The alter ego. Takes over the responsibilities of the general manager.

2. The idea is independence being free of the functional influence a product manager has to face.

There are supplemental forms to any structure. This could include outside organizations, upstream and downstream coupling and in-house competition. Outside organizations offer objectivity but suffer from "not-invented-here" syndrome. Insiders resent outsiders. Security and expense are all problems from outside intervention.

Another "outsider" organizational option that is growing is one where the supplier or customer firm has an interest in the new product development program. All manufacturers relate to customers or suppliers at various stages but what we are discussing is a proprietary role in the development effort for an equity position. From the manufacturer's situation an application like biotechnology would be a downstream coupling if a customer firm were brought in or on upstream coupling if a supplier firm had the proprietory role.

In-house competition is rarely mentioned and rarely used. It is seen as excessive cost.

In summary, preferences are highly individual but guidelines such as the Booz, Allen and Hamilton (67) announcement state that there should be:

1. Clearly defined assignments of all new products responsibility to one executive within the company or business unit.

2. Use of multidisciplinary teams.

3. A seasoned new-products manager with broad general management skills.

4. The encouragement and recognition of product champions.

(67) Booz, Allen and Hamilton, Management of New Products (Chicago: Booz, Allen & Hamilton, 1968).

THE DECISION PROCESS CONCERNING ORGANIZATIONAL STRUCTURE

"Organizational structures are not created in a logical and systematic manner. Infact few firms ever devise a total structure, because the usual option is to alter the one already there. And the allowable change is limited by the institutional, cultural, and personal constraints inevitably present. Yet there is a sequence for thinking through new product organization."(68)

The level decision is first:

Rule 1: Assign everything to divisions that can be assigned to them.
Break down the overall operation into business units.
Locate the power point which is the activity or decision point that is critical to success.

For every program there is some activity or decision point that is far more critical to ultimate program success. In the case of biotechnology being introduced into plant agriculture, a firm is committed to technical excellence as its sole base for new products. But more often than not a firms new items must be a clever blend of technology and marketneed-market-driven and technology-driven. Therefore, the power point should be a partnership. The power point decision then settles the first two dimensions/options: level and function which will provide a functional mix.

(68) C. Merle Crawford, New Products Management (Homewood, Ill.: R. D. Irwin, 1983), p. 180-181.

As with biotechnology, if research and development is the key, some way must be found to add manufacturing, finance, marketing, and other relevant departments such as marketing research, sales and customer service. Assembly and integration should enhance decisions.

In designing the structure there will be power point differences and functional balancing, but trouble really begins when one tries to combine a group of ideal, and different formats into one firm-wide structure.

At this point several devices are used.

First, product innovation charter may be narrowed to remove demands that cause irreconcilable organizational conflict.

Second, spin-off, divisionalize, sell off, join with another firm or segregate via venture group.

Third, formats can function side-by-side.

Fourth, formalize differences by following a two-, three-, or four-location rule.

SUMMARY

Early in this chapter the question was asked, "Why is new products organization a special problem? It was pointed out that it definately is a problem. Now, how does this relate to biotechnology in agriculture? In Chapters I-III it was shown that this technology is highly sophisticated and hard to grasp. There are massive uncertainties in the agricultural market and whether biotechnology can solve some or any of its problems. However, in Chapter V, venture corporations were introduced along with academia institutions to reduce the size of the focus. Also, in Chapter V the major corporations emerging were in the chemical, pharmaceutical, petrochemical and agribusiness industries where their respective industries can have constraints. However, new firms can emerge depending on how the firm has accepted the marketing concept and the general degree to which biotechnology is encouraged.

Two streams were discussed on bringing a product to market. The more important stream at this time with biotechnological agricultural products lies in physical production with estimates being five to ten years before products are introduced commercially. Now, bureaucracy is believed to be inherently inefficient but is needed to increase lines of communication with biotechnological concepts between research and development with manufacturing, marketing managers, general management and upper management. In order for this to be accomplished, the level of responsibility should be mixed between corporate and divisional levels.

The final part of the chapter discussed function and form. However, the responsibility should be that of the general manager. How the general manager handles or chooses what form is to be used is important. Five options were presented as common structures for organizations. Do nothing new, form a new products committee, form a matrix team, let sole responsibility be at product manager levels, or form a new products department. Good and bad points to each were presented. Finally, the chapter ends with a few thoughts on how to handle the decision process concerning organizational structure.

CHAPTER VII

CONCLUSIONS & POSTULATES

Biotechnology is a very interesting and new form of technology that is opening new doors for many industries. The different processes involved in biotechnology have a natural fit in agriculture, either to improve old products or bring new products to market.

The biotechnology industry consists of new companies, chemical companies and pharmaceutical companies who have put millions of dollars into research and development to invent new products or improve existing products. To manage this new technology three key words kept coming up in the literature searches and interviews. They are communication, planning and strategy.

In bringing new technology to the market place, first of all there must be the scientific breakthrough needed to make a change which is presently being accomplished at the academic and corporate levels.

Therefore, new product development lies with the main components of this area who are the researchers and developers and the commercial people assessing the market. From the corporate standpoint managing this development is critical. From an article taken from the Management Review the role and definition of new products, and product development processes was addressed.(69) It found that companies must establish a specific approach, driven by objectives

(69) Thomas D. Kuczmarski and Steven J. Silver, Strategy: The Key to Successful New Product Development, (New York: Management Review, July 1982), pp. 26-28, 37-40.

with a well defined strategy. Two key points came out of this article. First is the question of who must establish an environment or management style with or within an organizational structure conducive to achieving objectives. Second, there must be long-term commitment to suport innovation and new product development. Also, this article established a criteria for new product programs to meet corporate objectives with an environment to meet individual goals. So to create a supportive environment the elements listed below should be the guidelines.(70)

NEW PRODUCT PROCESS ENVIRONMENT

New Product Opportunity	Organization Structure	Mgmt. Style	Responsibility	Top Mgmt. Support
New to the world products	Venture Team	Entrepreneurial	General Manager ↑	High ↑
New Product Lines	New Product Department			
Additions to Existing Lines Improvements/ Revisions	Marketing or Reseach & Development	Collegial		
Repositioning Cost Reductions	Functional	Managerial	Functional Manager	Moderate

With this format in mind, products coming from the introduction of biotechnology into plant agriculture would be new to the world or new product lines for agricultural companies.

(70) Ibid., p. 40.

Chapter I provided an overview of the agribusiness with the potential that biotechnology can and will affect its future. However, the agribusiness is under increasing pressure to produce enough food efficiently. Therefore, corporations are under pressure to utilize new technologies and introduce better or new products. Traditional corporate formats are then faced with the challenge to expedite ideas, innovation, new processes and products to help to meet demand by the agribusiness market.

Chapter II's purpose was to show the complexity of what scientists, researchers and developers are trying to do. Again, however, these technologies are not easy to understand by the layman. If an everyday individual has trouble understanding, then the same kind of questions will arise from people in manufacturing, corporate law, marketing, sales forces, general managers and even corporate executive officers. Communication is of the most consequential magnitude, first, to corporate employees working to achieve a goal, and second to the consumers of the product. Not only this but academia and corporations have the responsibility to educate the public so hopefully there can be acceptance to biotechnology and its future.

Chapter III provided applications, time horizons, and possible market values for these new products. This chapter's purpose was to provided the answers to who are the players, and who will be affected. Also, many pressures are put on research because many of these ideas are not yet reality today.

Corporations then must lay the framework for the future and present to give these ideas, innovations and products a chance. They need to be organized in a manner that doesn't stagnate and continues to move ahead because change is unavoidable. Corporations can either be prepared or be surpassed by competitors.

Chapter IV and V provided a view of the external environment corporations are facing. But, it also pointed out what an organization needs to do to be receptive to innovation and provided examples of organizational models that can be used to achieve corporate objectives.

Chapter VI described what corporations can do to integrate biotechnology into their corporations. Research and development must be an essential part of business objectives that must be carried through product development programs.

Therefore, again for corporate success there must be an integration of strategic and technological goals. Questions a company needs to ask itself are listed below.

1. What are the projected growth rates in plant agriculture?

2. What is the company's competitive position for these markets?

3. What is the present state of the firm's technology versus competitors?

Some of the answers or direction for these answers were presented in the text which could provide the solution for integrating strategic planning and technology. Answers are needed to these questions to provide direction options. Use of a matrix diagram 2 such as the one exhibited is an essential tool.

DIAGRAM 2

Business Objectives	Hold/Harvest			Grow Present Business			Extend Present Business		
Technology Inputs									
Apply the state of the art	0	1		0	1				
Extend states of the art			2						
Competing Technologies					1		2		
New Alternative Technology to Supplant old									

Source: C. Merle Crawford, New Product Management, (Homewood, Ill.: R. D. Irwin, 1983) p. 114.

The Matrix diagram 2 is known as a product innovation chart, its purpose is to supply direction. By assigning numerals or letters they can supply meaning to the direction. For instance:

0 = We currently operate in this arena.

1 = We need improvements.

2 = We want to be in this arena.

Blank = No current or planned activity.

In bridging strategic planning with technology a corporation must have a management and organization format suitable for such transitions. With the complexity of biotechnology and its use, lines of communication are very important.

In an interview with Monsanto's Director of Biotechnology, the following conversation about plant agriculture took place.(71) "What has to be done differently to market a biotechnology derived product?" The answer was a need for increased communication between the industry and the consumer to educate and achieve credibility.

"How can this be done?" His answer was that research and development must work closely with marketing so that communication to the end user is valid and understandable. The point here isn't really the questions or the exact answer, but the emphasis that researchers and developers must work with marketers to achieve a common goal.

(71) Ernie Jaworski, statement made during interview, Director of Biotechnology, Monsanto, St. Louis, MO., Spring 1984.

To achieve the introduction of a new product, there are sequential activities in the process. The following diagram 3 was taken from a journal in Industrial Marketing Management, April 1975, by Robert Cooper.(72)

DIAGRAM 3

Technical Production Activities	Evaluation	Market-Oriented Activities
	Product Idea Generated	
	Initial Screening	
Preliminary Technical Assessment	Financial Analysis	Preliminary Market Assessment
Product Development (R&D)	Financial Analysis	Detailed Market Study
Prototype Testing In-House	Financial Analysis	Prototype Test with Customer
Pilot Production	Financial Analysis	Test Marketing
Production Start-Up		Product Launch

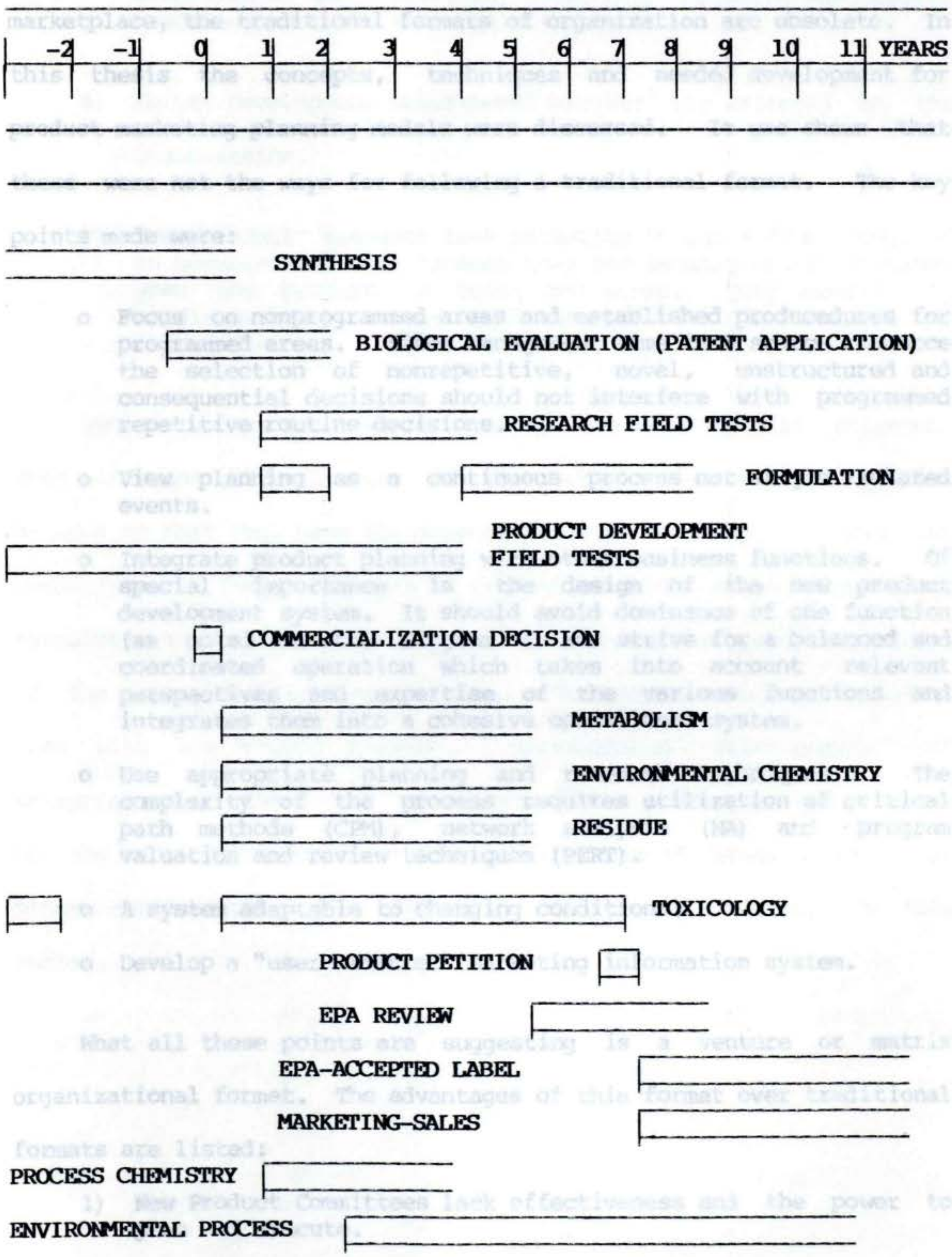
This article showed that industrial product firms suffered from inward orientation. The overall essence of the article showed that every market-oriented activity was reported to be much less completely carried out than its corresponding technical/production activity.

This failure to work together along with the lack of proper communication is exemplified with a diagram of the process of bringing a product to market. Diagram 4 is the traditional format.

(72) Robert G. Cooper, Why New Industrial Products Fail, Industrial Marketing Management; Amersterdam, Netherlands: Elsevier Scientifc Publishing Company, April 1975) p. 317.

DIAGRAM 4

PRODUCT DEVELOPMENT -- DISCOVERY TO SALES



With products which are new to the market looking to get to the marketplace, the traditional formats of organization are obsolete. In this thesis the concepts, techniques and needed development for product-marketing planning models were discussed. It was shown that these were not the ways for following a traditional format. The key points made were:

- o Focus on nonprogrammed areas and established producedures for programmed areas. Since management time is a scarce resource the selection of nonrepetitive, novel, unstructured and consequential decisions should not interfere with programmed repetitive routine decisions.
- o View planning as a continuous process not single isolated events.
- o Integrate product planning with other business functions. Of special importance is the design of the new product development system. It should avoid dominance of one function (as noted in the Diagram 4) and strive for a balanced and coordinated operation which takes into account relevant perspectives and expertise of the various functions and integrates them into a cohesive operational system.
- o Use appropriate planning and research techniques. The complexity of the process requires utilization of critical path methods (CPM), network analysis (NA) and program valuation and review techniques (PERT).
- o A system adaptable to changing conditions.
- o Develop a "user-oriented" marketing information system.

What all these points are suggesting is a venture or matrix organizational format. The advantages of this format over traditional formats are listed:

1) New Product Committees lack effectiveness and the power to plan and execute.

2) New Product Departments don't have authority to control. They lack financial and functional autonomy because usually they are set up to oversee, but they are not a pooling of resources from functional groups.

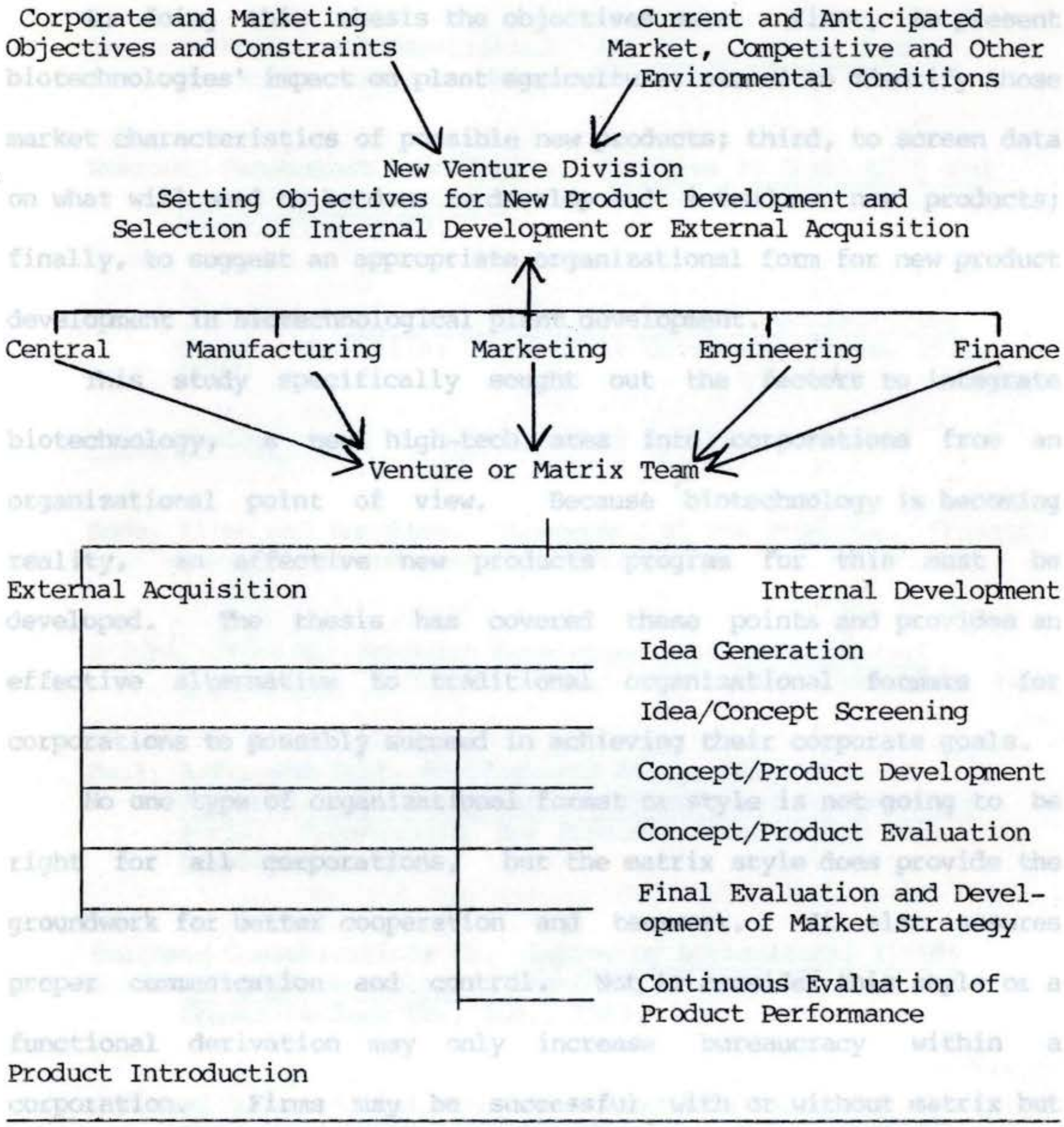
3) Long-range Planning Departments can't give undivided attention to the short-term; their major concerns are capital budgeting, mergers and acquisitions.

4) Market Development Departments are strictly oriented to the environment of the status and political problems of the organization.

5) New Product Managers lack authority to guide from inception to commercialization because they are usually only involved when the product is being introduced. They usually only handle market problems such as price, distribution, and merchandising.

Venture and matrix teams, however, are market/profit oriented. They increase effectiveness of research and development to provide balance so that they have the maneuverability to adopt to changing conditions. Their strength is innovation which allows change to be formulated and implemented successfully when organizational structures of the traditional type are binding. Therefore, the venture/matrix team with its single mission, unstructured relationship and entrepreneurial thrust is an organizational concept uniquely suited for the task of product innovation in the area of biotechnology for plant agriculture. The following diagram is an example to this format.

DIAGRAM 5



This diagram shows who needs to be involved in a venture or matrix team and what their responsibilities entail.

Source: Mack Hanan, <u>Venture Management</u>, (New York: McGraw-Hill Co., 1976) p. 118.

In doing this thesis the objectives were: first, to present biotechnologies' impact on plant agriculture; second to identify those market characteristics of possible new products; third, to screen data on what will need to be done to develop and introduce new products; finally, to suggest an appropriate organizational form for new product development in biotechnological plant development.

This study specifically sought out the factors to integrate biotechnology, a new high-tech area into corporations from an organizational point of view. Because biotechnology is becoming reality, an effective new products program for this must be developed. The thesis has covered these points and provides an effective alternative to traditional organizational formats for corporations to possibly succeed in achieving their corporate goals.

No one type of organizational format or style is not going to be right for all corporations, but the matrix style does provide the groundwork for better cooperation and teamwork. It also assures proper communication and control. Not to consider this style or a functional derivation may only increase bureaucracy within a corporation. Firms may be successful with or without matrix but timing and introduction or new products is a major factor where matrix management can at least assure stability and mastery of this variable.

BIBLIOGRAPHY

American Management Association. New Products/New Profits. New York: American Management Association, 1964.

American Management Association. Problems in Developing and Launching New Products. New York: American Management Association, 1952.

Ansoff, Igor H. Acqusition Behavior of U.S. Manufacturing Firms. Nashville: Vanderbilt University Press, 1971.

Biotechnology News, V. 2, # 13, July 1, 1982.

Booz, Allen and Hamilton. Management of New Products. Chicago: Booz, Allen and Hamilton, 1968.

Bright, James R. Research Development and Technological Innovations Richard D. Irwin, Inc., 1964. Homewood, Il.:

Bull, A.T., and Holt, Geoffry, and Lilly, Malcolm D. Biotechnology - International Trends and Prospectives. Paris: Organization For Economic Co-operation and Development, 1982.

Business Communications Co. Improving Agricultural Yields Using Biotechnology. Stamford, CT.: Business Communications Co., Inc., 1983.

Business International/Management Practices Research Management Strategies for Research and Development: The Need for International Dimensions. New York: Business International/Management Practices Research, 1979.

Carson, J.W., and Ricards, T. Industrial New Products Development: A Manual for the 1980s. New York: John Wiley and Sons, Inc., 1979.

Chaffray, Jean-Marie, and Lilien, Gary L. Market Planning For New Industrial Products. New York: John Wiley and Sons, Inc., 1980.

Crawford, C. Merle, New Products Management. Homewood, Ill.: Richard D. Irwin, Inc., 1983.

Davis, Stanley M. Matrix. Reading, Mass.: Addison-Wesley Publishing Co., 1977.

Dunne, Patrick and Obenhouse, Susan. Product Management a Reader. Chicago: American Marketing Association, 1980.

Fredeiuxon, Martin S. An Investigation of the Product Life Cycle Concept and the Application to New Product Proposal Evaluation Within the Chemical Industry. PH.D. dissertation, Michigan State University, 1969.

Hainer, Raymond M.; Kingsbury, Sherman; and Gleicher, David B., Uncertainty in Research, Management, and New Product Development. New York: Reinhold Publishing Corporation, 1967.

Hanan, Mack. Market Segmentation, The Basis for New Product Innovation and Old Product Renovation. Chicago: American Marketing Association, Inc., 1968.

Hanan, Mack. Venture Management. New York: McGraw-Hill, 1976.

Hawthorne, E.P. The Management of Technology. London; New York: McGraw-Hill, 1978.

Herr, Harold C. Recent Developments in the Patenting of Microorganisms. Presented at the 12th International Congress of Pacific Industrial Property Association, 1981.

Hopkins, David S. Options in New Product Organization. New York: Conference Board, 1975.

Hopkins, David S. Organizing Corporate Marketing. New York: Conference Board, 1984.

Johnson, P.S. The Economics of Invention and Innovation. London: Martin Robertson, 1975.

Koontz, Harold. Essentials of Management. New York: McGraw-Hill, 1978.

Kosuge, Isune; Meredith, Carole P.; and Hollander, Alexander. Genetic Engineering of Plants: An Agricultural Perspective. Volume 26. New York: Plenum Press, 1983.

Kotler, Phillip. Principles of Marketing. Englewood Cliffs, NJ.: Prentice-Hall, Inc., 1980.

Kuczmarski, Thomas D. and Silver, Steven J. Strategy: The Key to Successful New Product Development. New York: Management Review, July 1982.

Lippitt, Gordon L. Organizational Renewal. New York: Appleton-Century-Crofts, 1969.

Mancuso, Joseph. Technology Products: Managing Technology Products. Artech House, Inc., 1975.

Mansfield, Edwin. Research and Innovation in the Modern Corporation. New York: W. W. Norton and Company, 1972.

McGinnis, Michael A., and Ackelsberg, M. Robert. "Effective Innovation Management: Missing Link In Strategic Planning?" The Journal of Business Strategy. Vol. 4., No. 1., 1983.

Online Publications Ltd. Biotech 83. Northwood, UK.: Online Publications Ltd., 1983.

Policy Research Corporation and The Chicago Group, Inc. An Assessment of the Global Potential of Genetic Engineering in the Agribusiness Sector. Chicago: Policy Research Corp., The Chicago Group, Inc., 1981.

Quinn, James Brian, and Mueller, James A. Transferring Research Results to Operations. Boston: Harvard Business Review, 1963.

Quinn, James L. A Categorization of the Methods and Techniques of Measuring Industrial Research and Development Activities. Wright-Patterson Air Force Base, OH.: U.S. Department of Commerce, 1971.

Roseman Consulting Company. Profitable New Product Development. Santa Monica, CA.: Roseman Consulting Company, 1980.

Schein, Edgar H. Organization Psychology. Englewood Cliffs, NJ: Prentice-Hall, 1980.

Schon, Donald A. Technology and Change: The New Heraclitus. New York: Delacorte Press, 1967.

Sittig and Noyes. Genetic Engineering and Biotechnology Firms. Kingston, NJ.: Sittig and Noyes, 1981/1982.

Steele, Lowell W. Innovation in Big Business. New York: Elsevier, 1975.

Taylor, B., and Hawkins, K. Handbook of Strategic Planning. London: Longman, 1972.

Technomic Consultants. A Technological and Business Opportunity Assessment of Genetic Engineering and Related Biotechnologies. 1 vol. Technomic Consultants, 1981.

Twiss, Brian C. Managing Technological Innovation. London, New York: Longman Group Limited, 1980.

Uman, David B. New Product Programs: Their Planning and Control. New York: American Managment Association, Inc., 1969.

U.S.D.A. Crop Production Research Technological Objectives Associated with Physiological and Biochemical Technology to Improve Crop Production. Annual Report, 1981.

University Microfilms International. Launching The New Industrial Product. Ann Arbor, MI: University Microfilms International, 1983.

Vinson, Donald E. and Aciglimpaglia, Donald. The Environment of Industrial Marketing. Columbus, OH.: Grid, Inc., 1975.

Weber, John A. Growth Opportunity Analysis. Reston, VA.: Reston Publishing Company, Inc., 1976.