THE ECONOMIC POTENTIAL OF BIOTECHNOLOGY

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The discovery of the DNA molecule structure in the 1950s introduced genetic engineering, also known as biotechnology. That is the branch of molecular biology that studies the use of micro-organisms to produce genetically modified bio-structures and the transfer of genes to unrelated species. This is aimed to better diagnoses and treatment of diseases and the development of agricultural products with improved attributes.

This article investigates some of the challenges and opportunities facing the emerging biotechnology industry, and highlights the coloration between different role players from diverse disciplines. Various benefits of biotechnology are listed to counter some of the cynicism that surrounds biotechnology. In spite of these developments in the science of gene technology, the concerns of groups of consumers hamper rapid progress. The article concludes with reporting on an empirical investigation undertaken with post-graduate business students.

Key phrases: biotechnology, DNA, genetic engineering, genetic modification

THE DEVELOPMENT OF BIOTECHNOLOGY

Crops and animals have been selectively bred for centuries to produce novel strains of use to humans. This conventional selection by breeding is a very slow process and is also restricted to those organisms that could be “gender-crossed” (Murrell & Roberts 1989:9). In the 1950s James Watson and Francis Crick discovered the molecular structure of Deoxyribonucleic Acid (DNA). Their discovery opened the door to biotechnology (genetic engineering). Genetic engineering deals directly with modifying the genetic composition that determines the structure of all organisms, but without the limitations of conventional breeding. Genetic engineering allows for the transfer of genes directly and immediately to totally unrelated species, for example between humans and bacteria.

Genes are the basic units of inheritance – according to Murrell & Roberts (1989:24) it consists of specific lengths of interlocking double stranded DNA, and consists of only four different nucleotides, which is adenine (abbreviated as A), cytosine (C), guanine (G), and thymine (T).

The DNA molecule is held together with the different nucleotides, which function in pairs as chains between the DNA’s double helix (resembling a spiral staircase). The particular gene codes function as the blueprint for the production of a particular protein or part of a protein. These proteins could order embryonic development; other proteins function as enzymes (catalysts which control the cellular metabolic reactions) and others become part of the body structure.

The visible appearances of the actions of genes are called traits. The trait may be one gene or a combination of many genes. A good example of a genetic trait is the colour of the eyes. Whenever the DNA (comprising of genes) undergo a structural change or modification, the gene codes are modified to be compatible to the altered protein, which is referred to as mutation.

THE POSSIBILITIES OF GENETIC ENGINEERING

Genetic engineering creates the possibility to design organisms to a specification for carrying out industrial processes, for example, placing enzymes in petrol and diesel engines to monitor the exhaust gases and send the data, regarding the degree of pollution, to a microprocessor that will adjust the engine to rectify the pollution; also to use microbes to gather valuable trace metals from the ocean water (Toffler 1980:146).

However, to put the use of genetic engineering in perspective, the most successful commercial applications of genetic engineering to date involves the diagnosis and treatment of diseases, and the development of agricultural products with improved attributes.

In the agricultural industry there have been 4,600 genetic modifications recorded of organisms field-tested. This includes 9 modifications on carrots, 11 on apples and numerous modifications on tomatoes (Mann 1998: Internet). In the pharmaceutical industry drugs like insulin (for diabetics) and tissue plasminogin activator (for heart attack victims), as well as animal growth hormones like bovine, are being produced by bacteria that have received the appropriate human, cow, or pig gene (Webber 1996: Internet). Crops and medicine are not the only areas where genetic manipulation have been evident; scientists have been attempting to clone sheep for 20 years to guarantee sheep that are robust and reliable to ensure a vibrant and long-living herd. Dolly, the first genetically cloned sheep, appeared in Roslin, Scotland in July 1996 as a perfect copy of another sheep (Boles 1997: Internet).

THE CHALLENGES FACING THE BIOTECHNOLOGY INDUSTRY

Genetic engineering allows scientists, businesses and governments to manipulate the natural world at the genetic level. It allows them to transfer genes between totally unrelated species and across all biological boundaries – plant, animal, and human – creating new life forms. Companies are jumping on the "*gene wagon*" for commercial success through clonal propagation, mass-producing countless replicas of their creations and releasing this into nature.

In the continuously changing business environment genetically engineered foods will bring new challenges and opportunities to the micro-, market-, and macro-environments of business. The major players in the industry, Monsanto and DuPont, are finding that operating within the biotechnology industry presents numerous difficult challenges.

Biotechnology companies must redesign their business, financial and Merger & Acquisition (M&A) strategies and make large Research & Development (R&D) investments with uncertain returns (Enriquez & Goldberg 2000:102).

On a corporate level, biotechnology organisations must enter into complex partnerships and affiliations and in the market environment biotechnology organisations must contend with negative consumer attitudes toward genetically engineered products.

Biotechnology organisations rely heavily on R&D for success. The R&D strategies of biotechnology organisations require large capital spending to thoroughly develop and test any potential new product. Uncertainty and expense usually accompany the R&D programmes. R&D programs do not guarantee success, and coupled with a large capital outlay, the biotechnology organisations are facing a demanding challenge.

The R&D strategy should also be in line with the organisation's strategy. The M&A strategy of a biotechnology organisation also serve as a powerful method of R&D. Smaller, research based, biotechnology organisations are being acquired by the large biotechnology organisations for the valuable R&D that they have done. However, not only biotechnology organisations are interested.

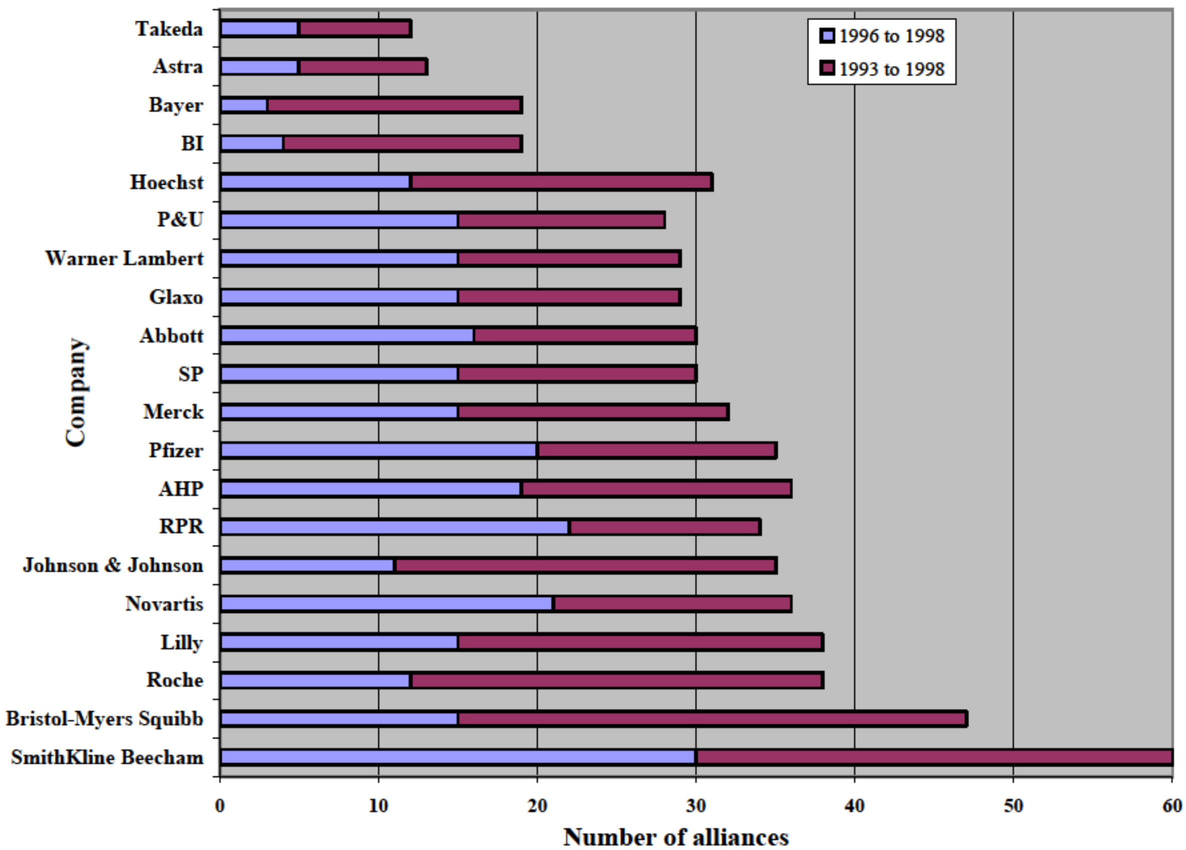
Pharmaceutical and chemical companies are acquiring smaller biotechnology organisations. Genetically engineered seeds form a direct threat to chemical companies because seeds can be genetically engineered to resist pests and diseases, which mean that chemical companies are becoming redundant. Farmers would be able to reduce their dependency on expensive chemicals and reduce the negative impact these chemicals usually have on the environment.

Just as crops can be designed to have higher nutritional value, they can also be designed to have higher medicinal value. Broccoli, for instance, is known to have anti-neoplastic characteristics (to stimulate the body's defences against cancer). Some biotechnology organisations are currently researching the characteristics of a wild Italian broccoli, which appears to be 100 times more effective in building up cancer defences, and eventually to engineer these into commercial varieties.

The benefits of genetic engineering are also evident to pharmaceutical companies, which is the reason why Novartis, Roche and SmithKline Beecham and many more pharmaceutical companies are also attempting to acquire biotechnology companies. Figure 1 shows the number of R&D alliances by the top 20 pharmaceutical companies.

The relationship between the "*giant*" pharmaceutical and biotech companies are one of mutual dependency. The large pharmaceutical companies need to "*tap*" into the innovations all around them. Biotech companies provide this innovation. Likewise, biotech companies are usually provided with the capital and validation that an alliance with a large pharmaceutical company brings. This relationship between the pharmaceutical and biotech companies is shaping the future of the biotechnology industry. The alliances and mergers taking place in the industry create a dynamic industry which changes shape frequently.

Figure 1 Number of R&D alliances by top 20 pharmaceutical companies



Source: Adapted from Lynch 2000:981

THE BENEFITS OF BIOTECHNOLGY

Much speculation and cynicism surrounds biotechnology and the alleged benefits they provide. To put the benefits of biotechnology in perspective, the following list presents some of the most recent advances in biotechnology around the world (Monsanto 2001:Internet).

- French scientists have developed a genetically modified potato that produces 19 times the normal amount of fructose, a key ingredient in soft drinks and sweeteners

- The Dutch elm disease has destroyed more than 20 million trees across Britain in the past 30 years. Scottish scientists have developed a genetically modified English elm tree that are resistant to fungus. The elm trees have been cultivated under strict laboratory conditions and have not been introduced into the environment. Scientists are waiting for approval to release the genetically modified elm into the environment to resist the destructive Dutch elm disease.

- In Hawaii, the annual papaya production fell in the span of four years from 1993 to 1997 from 26 million kilograms to 12 million kilograms, thanks to the papaya ring spot virus. In 1998 a new genetically engineered papaya was introduced which brought the production level back to 24 million kilograms by 2001.

- Indonesian farmers are reporting a productivity increase in cotton production. The genetically modified cotton averages 2.2 million kilograms per hectare, compared with 500 000 kg using conventional varieties.

- In Kenya, the first harvest of genetically engineered sweet potatoes achieved a resistance to the feathery mottle virus, which was devastating to farmers, destroying up to 80% of a crop.

- Biotechnology allowed a 50% reduction in the number of chemical sprays on cotton in Australia. Australia is also expecting that the second variety of genetically modified cotton will reduce the number of chemical sprays by as much as 90%.

- In 1998 Eastern China faced an outbreak of bollworm that threatened their cotton crops. In 2000 farmers started to grow genetically enhanced cotton to resist these pests. The cotton has saved in labour and reduced the need for pesticides, as well as minimising the risk of poisoning.

THE CONCERNS OF BIOTECHNOLOGY

Regardless of the considerable progress in gene technology, the concerns of consumers are one of the biggest challenges facing biotechnology organisations. Consumer fears are particularly strong in Europe, where a series of food scares, ranging from mad cow disease to contaminated Coke, have undermined consumer’s trust in the European regulatory authorities. While 90% of Americans believe the US Department of Agriculture statements on biotechnology, only 12% of Europeans trust their national regulators. Many European companies like Nestlé, Danone, Marks & Spencer and Unilever are responding to the consumer concerns by marketing products free from any genetic modification, but stating that biotechnology does have significant benefits (Enriquez & Goldberg 2000:102). The concern of consumers, which also represents some of the possible disadvantages of biotechnology are mainly found in religion, environmental impact, animal welfare, safety, guidelines, need, fairness, patenting and labelling (Ellahi 1994:3-14).

Religious dietary restriction is an obvious and very serious threat to the biotechnology industry. The main concerns are from the Muslim faith stating that the transgene retains its human or animal nature and remains subject to dietary restrictions. This means that Muslims do not accept any copy genes transferred between organisms, humans and animals. Hindus for example do not consume beef and therefore transfer of a cow gene to any product holds dietary restrictions on religious grounds.

The direct effects of releasing GM plants into the environment have raised some concerns. For example the transfer of genes between plants is a natural process. If plants that have been genetically modified and are tolerant to herbicides, it has been suggested that a "*super-weed*" of plants can emerge, which cannot be controlled with conventional herbicides. Some of the requirements of a genetically engineered plant should address these issues to ensure that the above speculation never becomes a reality.

Animal rights groups (for whom animal welfare is fundamental to any decision concerning genetic modification programmes) are totally against any type of modification to animals.

The safety of the products is another very important concern. People with allergies have expressed concern that genes could be transferred from a particular food to another might cause allergic reactions. Such modification should be avoided or if used it must be clearly labelled. Guidelines, legislation laws and procedures of an "*unbreachable*" nature are necessary to ensure the genetic modification programmes are safe from any harm to humans and nature.

The concern is, if conventional products already exist, is there a true need for genetic engineering to take place and will it not suggest that jobs will be lost if the genetically engineered products are more productive. The fairness of genetic modification was also a concern because the impact of multinational biotechnology organisations on the economies of Third World countries can be seen as a form of international imperialism over the genetic pool of the world.

Patenting is an ongoing concern. The organisations or plant breeders that develop genetically engineered products argue that patenting is necessary to reap the rewards of the research and to fund further research. From a religious perspective the patenting of life forms indicate ownership of life and is forbidden by Judaism.

Labelling is another very important concern. Labelling should take on a positive form. The purpose of labelling is to inform and even educate the consumers to make an informed choice and avoid foods that raise any ethical concerns. The extent of genetic modification that requires labelling is another concern. GM additives, derivatives of GM crops, GM feed used for animals that produce consumer products, pastes, vegetable oils and many more types of indirect modification to products raises the question of labelling even more. The labelling issue is an ongoing debate and still needs some form of closure.

Consumers should be able to make an educated and informed decision on whether or not to purchase a genetically enhanced product. This is crucial to the biotechnology industry. Awareness of genetic engineering is low and is associated with high risks and low benefits. Consumers need information on the safety, guidelines, approval procedures and tests these products must endure before they are released onto the market or into nature.

An increase in public awareness is necessary to facilitate the acceptance of genetic engineering but it will also allow consumers to make informed choices in the selection or rejection of genetically modified products and contributes to a large extent to the development of the technology. Influential people need to be educated because they are in the position to influence the public opinion. Journalists, retailers, businessmen, consumers, media of all sorts and influential individuals need to be educated to report the facts rather than the fantasy. Projects to educate scholars and teachers about the basics of genetic engineering are also needed to educate consumers about genetic engineering. Leaflets, forums, exhibitions, labelling, workgroups, seminars and any other applicable forms of education are needed to educate all applicable parties involved.

Addressing and resolving these ethical and moral issues are the critical factors of the biotechnology industry. If the biotechnology industry aims to develop to its full potential, then these issues should be on top of their priority list.

THE ISSUES ON THE MACRO-ENVIRONMENT

The macro-environment directly and indirectly influences all the other business areas. Especially developments on the technological environment, like supercomputers that can analyse, interpret and map the genomes of organisms, have made advances in biotechnology possible and will become the ultimate tool for future research. IBM has estimated that selling computer equipment to the biotechnology industry over the following three years to be a $43 billion opportunity (Stone 2001:44).

The organisation's home country's regulatory institutions determine the requirements genetically engineered food must meet. South Africa proposed a national biotechnology strategy in June 2001. The strategy identified the areas of importance and proposed a regulatory structure for the future biotechnology industry in South Africa. The most important aspect of the strategy was the establishment of the BAC. The BAC sets out to be the advisory body of biotechnology in South Africa, implement the national strategy and basically manage all major issues regarding biotechnology (Parker *et al.* 2001:61). Biotechnology organisations in South Africa and abroad need to consider the regulatory environment of the country they intend to do business. The regulatory environment is not just the ultimate approval body of genetically engineered products but it is also a measuring tool of the requirements the products must adhere to.

An in-depth knowledge of the regulatory institutions of South Africa’s international trade partners is very important if South Africa aims to export their genetically engineered products. The EU is one of South Africa’s largest export markets. The regulatory environment of the EU and the procedure to place genetically engineered food products on the EU market is of great importance to South African biotechnology organisations if they ever want to export products to the EU market.

The US is the biggest player in the biotechnology industry. Most of the major developments have been done on US soil. The regulatory environment is well developed and is of a logical nature. The USDA, FDA and EPA regulate genetically engineered products and have set minimum requirements that must be met. Knowledge of the minimum requirements will prove valuable if South Africa exports products to the US and more importantly South Africa needs to adopt the US as a “*mentor*” to assist South Africa in developing the local biotechnology industry. The US is on the forefront of biotechnology and has the potential to greatly assist South Africa in tapping into the biotechnology “*fast lane*”.

THE RELATIVE IMPORTANCE OF DIFFERENT DEPARTMENTS IN A GE ORGANISATION

The specific role functional level strategies play in a biotech organisation becomes increasingly important because budgets, staff and resources must be allocated to a specific department. Many can argue that all departments are equally important but in a biotech organisation there is a definite fluctuation in the level of importance between different departments.

A typical biotech organisation is a very small company that focuses mostly on R & D. The biotech industry is also very capital intensive. A continuous supply of capital becomes a very needed resource for small biotech companies. Manufacturing, marketing, operations and human resources are obviously also present in these organisations, but might not receive high amounts of resources because they are not as crucial to the success of a biotech company.

EMPIRICAL RESEARCH

A survey of post-graduate students of the Rand Afrikaans University was conducted through the use of a questionnaire. The strategic impact of genetically engineered foods were to be tested, therefore students with strategic management and business management backgrounds were preferred. Therefore 31 students from the B Com Honours (Strategic Management) programme and 35 students from the M Com (Business Management) programme were chosen since these students have the necessary strategic management and business management backgrounds, and might in the future be involved in decisions about biotechnology.

The questionnaire was divided into five sections:

Section A

Section A contained nine questions on the biographical background of the respondents. Closed questions were used (a closed question refers to where a respondent must choose from one or more alternatives). The biographical information of the respondents are summarised as follows:

- *More male (59%) than female (41%) respondents.*
- *Most of the respondents were in the 18 to 25 years category (52%), not married (60%), from the Christian religion (95%) and from the white demographic segment (79%).* [The Christian religion has no real dietary restrictions. Therefore, the answers of respondents were based on personal reasons and not on religious dietary restrictions.]
- *Many of the respondents were studying (72%) while pursuing a full time career (73%).*
- *The respondents represented many different industries and the majority had 3 to 5 years of work experience.*

Section B

Section B of the questionnaire contained 16 statements on genetically engineered foods. The purpose of Section B was to test the respondents' opinions on genetically engineered foods. A six-point Likert scale was used in Section B. The statements were responded to on a six-point Likert-scale where numbers were associated with different responses (the responses are easily classified between strongly disagree or strongly agree). The six points were as follows: 1= strongly disagree; 2= disagree; 3= disagree somewhat; 4= agree somewhat; 5= agree and 6= strongly agree.

The principle-axis factoring (common factor analysis) identified two factors in Section B:

- Factor B1 – The respondents have a positive attitude towards GE products.
- Factor B2 – The respondents are concerned about GE products.

Factor B1 and B2 declared 66.098% (> 50%) of the variance. This means that Factor B1 and Factor B2 represents 66.098% of all the statements in Section B. The variance declared a significant percentage of the statements in Section B. Any variance in the region of 50% is good, however a variance of 66.098% is an extremely good variance.

Factor B1 consisted of eight statements (1, 2, 3, 4, 5, 11, 12 and 13) in Section B. Factor B1 had a Cronbach alpha coefficient of 0.8330 (> 0.7). This means that Factor B1 was deemed reliable. On the 6-point Likert scale Factor B1 had a mean of 3.4038.

Factor B2 consisted of three statements (8, 9 and 10) in Section B. Factor B2 had a Cronbach alpha coefficient of 0.7499 (> 0.7). This means that Factor B2 was also reliable.

On the 6-point Likert scale Factor B2 had a mean of 4.1244. The mean indicates that on the 6-point Likert scale the respondents were somewhat concerned about the usage of GE products.

A very significant statistic also appeared. When the correlation was tested between Factor B1 and B2, the Pearson correlation value was -0.0426. This meant that the more positive the respondents' attitudes were (Factor B1) the less concerned the respondents will be about GE products. Although the assumption is logical, it is an extremely important statistic to prove the validity of the research.

The results indicate that the respondents had a slightly negative (and almost neutral) attitude towards genetically engineered products and were somewhat concerned about genetically engineered products.

Section C

Section C contained 17 statements on genetically engineered foods and how it relates to the South African situation. The purpose of Section C was to indicate the respondents' perspectives on how susceptible South Africa is to embrace genetically engineered foods on a large scale. The statements were also answered on the six-point Likert-scale (identical to Section B).

The principle axis factoring (common factor) analysis identified two factors in Section C:

- Factor C1 – Genetically engineered food will benefit South Africa.
- Factor C2 – Genetically engineered food should be properly approved before use.

Factor C1 and C2 declared 68.745% (> 50%) of the variance. This means that Factor C1 and Factor C2 represented 68.745% of all the statements in Section C. The variance declares a significant percentage of the statements in Section C. A variance of 68.745% is an extremely good variance for Factor C1 and C2.

Factor C1 consisted of six statements (1, 2, 3, 6, 10 and 11) in Section C. Factor C1 had a Cronbach alpha coefficient of 0.8397 (> 0.7). This meant that Factor C1 was deemed reliable. On the 6-point Likert scale Factor C1 had a mean of 3.8484. The mean indicates that on the 6-point Likert scale the respondents agreed somewhat that GE products will benefit South Africa.

Factor C2 consisted of four statements (8,9, 16 and 17) in Section C. Factor C2 had a Cronbach alpha coefficient of 0.8234 (> 0.7). This meant that Factor C2 was deemed reliable. On the 6-point Likert-scale Factor C2 had a mean of 3.5405. The mean indicates that on the 6-point Likert-scale the respondents agree somewhat that GE products should be properly approved.

The Pearson correlation value was 0.558 between Factor C1 and C2. A positive correlation value between Factor C1 and C2 indicate that the more benefits GE food holds for South Africa the more it is necessary to properly approve GE food

The results indicate that the respondents indicated that South Africa will benefit slightly from genetically engineered products and agreed that genetically engineered products should be properly approved before usage and/or release into the environment.

Section D

Section D contained 18 statements on how important certain business aspects are for genetically engineered foods. The purpose of Section D was to indicate the respondents' opinions on how important certain business factors are for organisations trading in genetically engineered foods. The statements were answered on a five-point Likert scale where numbers are associated with different responses (the responses are easily classified between extremely important or totally not important). The five points are as follows: 1= extremely important; 2= very important; 3= important; 4= not important and 5= totally not important.

The principle axis factoring (common factor) analysis identified three factors in Section D:

- Factor D1 – Importance of internal organisational strategies.
- Factor D2 – Importance of external organisational strategies.
- Factor D3 – Importance of information sharing strategies.

Factor D1, D2 and D3 declared 69.947% (> 50%) of the variance. This means that Factor D1, D2 and D3 represents 69.947% of all the statements in Section D. The variance declares the biggest percentage of statements of all the sections. A variance of 69.947% is an extremely good variance for Factor D1, D2 and D3.

Factor D1 consisted of five statements (1, 2, 3, 4 and 5) in Section D. Factor D1 had a Cronbach alpha coefficient of 0.8402 (> 0.7). This means that Factor D1 was deemed reliable. On the 5-point Likert scale Factor C1 had a mean of 2.1808. The mean indicates that on the 5-point Likert scale the respondents view internal strategies of a GE organisation as very important.

Factor D2 consisted of six statements (6, 7, 8, 9, 10 and 11) in Section D. Factor D2 had a Cronbach alpha coefficient of 0.9390 (> 0.7). This means that Factor D2 is very reliable. On the 5-point Likert scale Factor D2 had a mean of 2.1932. The mean indicates that on the 5-point Likert scale the respondents view external strategies of a GE organisation also as very important.

Factor D3 consisted of seven statements (12, 13, 14, 15, 16, 17 and 18) in Section D. Factor D3 had a Cronbach alpha coefficient of 0.8794 (> 0.7). This means that Factor D3 is reliable. On the 5-point Likert scale Factor D3 had a mean of 1.7169. The mean indicates that on the

5-point Likert scale the respondents view the importance of information sharing strategies as extremely important.

The Pearson correlation value was 0.707 between Factor D1 and D2. A relatively strong correlation exists between Factor D1 and D2, which indicates that the more important internal strategies are for a GE organisation the more important external strategies will become.

The Pearson correlation value between Factor D1 and D3 was 0.623. The correlation between Factor D1 and D3 is not a very strong correlation, but still exist as a weak correlation. The correlation indicates that the more important internal strategies are for a GE organisation the more important information sharing strategies will become.

The Pearson correlation value between Factor D2 and D3 was 0.502. The correlation between Factor D2 and D3 is not a strong correlation. The weak correlation indicates that the more important external organisational strategies are the more important information sharing strategies will become.

The results indicated that the respondents viewed internal (e.g. departmental strategies) and external strategies (e.g. mergers, acquisitions, alliances and joint ventures) as very important. Information sharing strategies were viewed as extremely important for organisations trading in genetically engineered products.

Section E
Section E contained a list of 6 possible departments of an organisation trading in genetically engineered foods. The purpose of Section E was to rank the departments from 1 to 6 in order of importance for an organisation trading in genetically engineered foods. The departments are ranked on a six-point Likert scale where numbers are associated with different responses (the responses are easily classified between most important or least important). The six points are classified as follows: 1= most important; 6= least important and 2 to 5 lie on equal intervals between 1 and 6.

The respondents ranked the department as follows:
#1 = R&D
#2 = Manufacturing
#3 = Marketing
#4 = Finance
#5 = Operations and
#6 = Human resources.

CLOSURE

Biotechnology provides the world with the means to change life at the genetic level. The biotechnology industry has the potential to be one of the world's largest industries because any organisation dealing with living organisms will have a common business. Agriculture, pharmaceuticals, petrochemicals, pesticides, cosmetics and many more other industries will merge to form the biotechnology industry. The biotechnology industry is already showing "*birth pains*" of a major industry.

Humankind has opened the "*Pandora's box*" of opportunity and should now manage it correctly to benefit from biotechnology. But the technology is met with criticism, mistrust, fear and serious ethical and moral issues that are threatening the biotechnology industry to reach its full potential.

Widespread speculation and cynicism surrounds biotechnology and the alleged benefits they provide. Because of the negative attitude towards GE food, the concerns of consumers are the single biggest challenges facing biotechnology organisations. If these organisations cannot prove to consumer that their products are safe, they are doomed for failure.

Organisations need to manage their business strategically if they aim to overcome the negativity towards the technology. These organisations need to identify the critical issues at all the business levels. The empirical research aims to identify these critical issues, however broad it might be.

Humankind cannot ignore biotechnology, merely because humans, animals and nature can greatly benefit from the use of biotechnology. But it will not be easy. Science has evolved faster than mankind could adjust to the evolutionary changes. Even a small portion of this market can benefit the South African economy. Therefore, the susceptibility of South Africa to embrace GE products, technologies and usage is also very important to benefit from the economic value of such products.

BIBLIOGRAPHY

BOLES D. 1997. Sheep Cloning: Sheep Cloning. [Internet: http://www.goinside.com/ 97/3/sheep. html].

ELLAHI B. 1994. Genetic engineering for food production – what is it all about? *British Food Journal*, 96(8). [Internet: http://www.emerald-library.com/brev /07096hb1.htm.]

ENRIQUEZ J & GOLDBERG RA. 2000. Transforming life, transforming business: the life-sciences revolution. *Harvard Business Review*, March – April. Boston: Harvard Business School.

LYNCH R. 2000. Corporate strategy. 2nd ed. Essex: Prentice Hall.

MANN CC. 1998. Genetic engineering: dream or nightmare? The brave new world of science and business. *Foreign Policy*, Winter. [Internet: http://www.findarticles.com/cf_0/m1181/113/ 53590470/ print.jhtml].

MONSANTO. 2001. The biotech advantage. [Internet: http://www.biotechknowledge.com/ advantage/ index.html]

MURRELL JC & ROBERTS LM. 1989. Understanding genetic engineering. West Sussex: Ellis Horwood.

PARKER I, BOTHA F, HIDE W, JEENAH M, MADOLO N, MUGABE J, SIBARA M, THOMSON J, WALWYN D & WINGFIELD B. 2001. A national biotechnology strategy for South Africa. June. Pretoria: Department of Arts, Culture, Science and Technology.

STONE B. 2001. Wanted: hot industry seeks supergeeks. Newsweek, 30 April. Johannesburg: CTP.

TOFFLER A. 1980. The third wave. New York: WC.

WEBBER GD. 1996. Regulation of genetically engineered organisms and products. Project BIO (Iowa State University), June. [Internet: http://www.biotechknowledge.com/ showlib.php3?uid=3339 &country=us.]