Biotechnology's Role in addressing the DST's Five Grand Challenges

In 2008, the Department of Science and Technology (DST) published a Ten-Year Innovation Plan. The aim of their strategy is to drive South Africa towards a knowledge-based economy, where the production and spread of knowledge bring economic benefit to the country through innovation and entrepreneurship. Five Grand Challenges were identified as key areas of focus that will utilize South Africa's natural resource base and that will enhance current knowledge and research, producing technologies in fields that are now in the developmental phase.

Biotechnology plays a key role in addressing the five grand challenges as an integral cog in the sustainable strategies that will see South Africa into the future. Biotechnology is reshaping the way we live. It offers solutions to address some of the major global problems such as healthcare, food security, environmental degradation and limited energy supplies. By using sustainable biotechnology, it is possible to promote economic growth in industries while at the same time saving precious resources such as water and energy and also producing less waste and minimizing the effects on the environment.

Grand Challenge 1: "From Farmer to Pharma": Life Sciences and Health

The "Farmer to Pharma" Challenge focuses on using biotechnology to capitalize on South Africa's rich biodiversity and indigenous knowledge systems in order to bring economic growth to the country. South Africa's biodiversity is the third largest in the world. We are home to nearly 10% of the world's plants and 7% of its reptiles, birds and mammals, despite being only 2% of the world's land area. The depth of our microbial biodiversity is also immense. We have a great depth of indigenous knowledge and a strong industrial base.

In harnessing these assets it is aimed that by the year 2018 South Africa will be one of the top three emerging economies in the global pharmaceutical industry. South Africa aims to be a major producer in the pharmaceutical, nutraceutical (food supplements with additional health benefits), flavour, fragrance and bio-pesticide industries. Within this Grand Challenge, focus areas such as phytomedicines and botanicals (herbal remedies and medicinal preparations), food production and industrial biotechnology are also encompassed. The use of biotechnologies such as bioprospecting, gene sequencing, bioinformatics, genomics and agricultural biotechnology, including genetically modified plants, will drive the progress in these areas.

- Pharmaceutical and Nutraceuticals:

  Many medicines have been discovered in plants, microorganisms and other living organisms. Aspirin (acetylsalicyclic acid) was developed from salicin, the compound found to be the active ingredient in willow bark that was used to treat headaches pains and fevers. Penicillin, the first and still one of the most widely-used antibiotics, is derived from *Penicillum* fungi.

Bioprospecting, with biotechnology at its core, will delve into South Africa's wealth of biodiversity and indigenous knowledge. Bioprospecting refers to the search for new genes and products in living organisms that have potential commercial value. This is one of the most important sources of new pharmaceuticals that will contribute to the growth of South Africa's pharmaceutical industry. Scientists often look at natural remedies that indigenous people have used for centuries to find the ingredient which treats symptoms or cures people. A well-known example of bioprospecting in South Africa is *Hoodia*, a plant used by the San people for centuries as an appetite suppressant. Researchers at the CSIR (Council for Scientific and Industrial Research) identified the active ingredient responsible for its effect and developed it into a weight management product.

African ginger (*Siphonochilus aethiopicus*) is also being investigated by the CSIR. It is one of the most popular indigenous medicinal plants in South Africa and is used as a natural anti-inflammatory. Their roots and rhizomes are chewed fresh to treat colds, coughs, flu and asthma. The plant has been over-harvested for medicinal use but still occurs naturally in limited numbers in Mpumalanga and Limpopo. The CSIR is currently researching the plant to scientifically validate its therapeutic properties. In the process, they have discovered a new method for the treatment of allergies which has been patented. They are in the process of developing medicinal products. All such efforts need to be harnessed to develop a productive industry in support of the Farmer to Pharma Challenge.

- Food Production and Agricultural Biotechnology

Genetically modified crops are providing potential solutions to many stresses that are affecting food production. By introducing new and novel genes into crops, scientists are producing crops that are more resistant to environmental stresses such as drought, crops that have improved yields, require less fertilizer, pesticides and water, or have enhanced nutritional value. The results of biotechnology efforts are potentially improved yields of more nutritious crops using fewer natural resources. Biotechnology programmes exist to improve crops such as maize, cotton, sorghum, potatoes and sugarcane. Genetically modified crops not only improve food security but also can enhance the production of medically important and industrially important substances.

- Industrial Biotechnology

Industrial biotechnology efforts make more effective use of natural resources and waste materials. They improve industrial processes, often offering less harmful bioprocesses as an alternative to traditional chemical processes. Industrial biotechnology will play a role in the pharmaceutical industrial development and production to optimize processes. Bioprocessing will be an important tool in the production of drugs.

The DST has established a number of Platforms and Centres of Competence that are supporting the aims of the "Farmer to Pharma" Grand Challenge. These include the Preclinical Drug Development Platform, the Bioprospecting Platform, the Functional Genomics and Bioinformatics Platform, the Structural Biology Platform, the TB Centre of Competence (CoC), the HIV Prevention and Treatment Platform, The South African Malaria Initiative (SAMI), Pilot Plants and Manufacturing Platforms, the Cancer CoC, the Diabetes, CoC, and human and animal vaccine initiatives.

Grand Challenge 2: Expanding the Limits of Space Science and Technology

Space science refers to the study or use of everything above the surface of the earth, from the atmosphere to astronomy. The South African National Space Agency (SANSA) has three main objectives, namely; environmental and resource management, safety and security, and innovation and economic growth. While biotechnology is not a dominant tool in space science, it is being used to study the prospects of life in space. It has contributed to understanding factors affecting life in outer space as well as understanding fundamental questions about life on earth such as the effect of gravity. Molecular and cellular structures of life on earth may require gravity for survival. Answering these questions through biotechnology applications may be fundamental to further exploration of life and activity in outer space. There have been reports about disturbed immune function and reduced reactivity of blood lymphoid cells in space which may also be due to the loss of gravity. It raises the question of whether gravity is essential for life on earth, and also looks at how this phenomenon may be treated in space to advance human activity in space.

Grand Challenge 3: In Search of Energy Security

There are three main global energy challenges. These are sustainability and energy security, protecting the environment from high levels of fossil fuels emissions, and access in the developing world to clean, safe, affordable and reliable energy. The main areas of focus in this Grand Challenge are clean coal technologies, nuclear energy, hydrogen and fuel cell technology and renewable energy technologies such as biofuels. Among the objectives for 2018 is that 5% of energy used in South Africa will come from renewable energy sources such as biofuels.

Biofuels are energy sources based on biomass (i.e. organic matter from living or recently living organisms). Biofuels are being developed to reduce the use of fossil fuels like oil and coal, which are in limited supply and will run out in the future, and which also contribute to the problem of global warming through the release of greenhouse gases. The first biofuels that were developed used crops like sugarcane, maize and soyabeans, but newer developments are using non-edible plants, crop waste and even algae. There is some debate on the environmental impact of biofuels, but with improved processes and practices they will certainly be a viable alternative to fossil fuel based energy sources.

Grand Challenge 4: Responding Adequately to Global Climate Change

It is now widely accepted that climate change is inevitable and represents a huge challenge to the world. The response to climate change should be a multi-pronged approach, including both adapting to the effects of climate change as well as limiting further impact on the environment from human activity.

The effects of climate change are predicted to affect food production and development, health and water scarcity. By 2025, it is estimated that about 1.8 billion people will be living in regions facing water scarcity. The temperature in South Africa is projected to increase by between one and three degrees Celsius. The overall rainfall is projected to decrease by five to ten percent, while the east of the country will become wetter and the west will become drier. Rainfall will begin later and be characterised by more extreme events, thereby affecting the growing season of crops and leading to a decrease in the amount of available surface water.

Scientists have been working to prepare for the changing weather patterns and the environmental stresses that will accompany global warming and climate change.

- Food Production

  "Green biotechnology" is being applied to agriculture and food production, contributing to the response to climate change through reducing greenhouse gas (GHG) emissions, facilitating the adaptation of crops and the protection of crops against climate change, and producing higher yields with fewer natural resources.

  Agricultural practices contribute to about 25% of GHG emissions. Farmers can reduce their GHG emissions through the combined use of GM crops and non-tillage farming practices whose positive effects include the prevention of wind and water erosion and loss of ground moisture, improvement of soil biodiversity, increased soil fertility, and reduced carbon emissions. Plants are being developed with improved nitrogen efficiency which will reduce the need for fertilizers, thereby reducing GHG emissions and reducing the effects of run-off on water resources. GM crops were shown to reduce GHG emissions in 2007 to the equivalent of removing 6.3 million cars from the road for one year.

  To improve and reduce the amount of GHG in the atmosphere, genetically modified microbes and plants can take up carbon from the atmosphere and sequestered in the soil. This also improves soil fertility and water retention. Furthermore, the use of biofuels and alternative energy sources can reduce the output of GHG into the atmosphere

  Climate change will affect the availability of water and arable land. Solutions must be developed to adapt crops to new conditions, including different types of soils or harsher climate conditions such as drought. Using biotechnology to genetically modify crops can produce crops that are better adapted to these conditions. Drought tolerant and water efficient crops can provide higher yields while saving water resources. Drought-tolerant genetically modified (GM) maize has been developed by researchers in South Africa and is in testing phase. The GM maize contains four genes from the indigenous, desiccation-resistant *Xerophyta viscosa* plant (the resurrection plant). These genes act as a signal for the maize to go into survival mode when it becomes dehydrated, so that it can survive conditions such as late rains that normally reduce the maize harvest. New GM crops are also being developed to tolerate salinity in the soil and heat.

- Health

  Climate change is expected to affect health through the direct effects of extreme weather patterns such as heat and flooding, as well as through changes in disease prevalence in different regions. Certain important diseases are particularly sensitive to changing temperatures and rainfall. These include diseases such as malaria which are carried by insect vectors. The South African Malaria Initiative (SAMI) is directing resources to malaria research in South Africa. They are supporting projects running in the discovery and development of new drugs against malaria, new methods of diagnosing malaria and also understanding the relationships between the malaria parasite and the mosquito. Biotechnology is a critical tool in all aspects of malaria research.

- Water Scarcity

  Addressing the problem of water scarcity involves the prevention of water pollution and the treatment of polluted water and wastewater management. **Environmental biotechnology** is a key instrument in addressing this problem. For example, South Africa has a significant problem of water pollution due to acid mine drainage. **Bioremediation** is being used to treat acid mine drainage, to clean contaminated water and preventing further pollution of water resources. Bioremediation refers to the use of living organisms, primarily microorganisms, to degrade environmental contaminants to less toxic forms.

- Measuring and Understanding Climate Change

  The study of the history of Antarctica's climate and environment provides a context to understand today's climate and environmental changes. Examining Antarctica's ecosystems undergoing changes plays an important role in understanding the biological response to climate change. There is evidence that climate change occurs at a much faster rate at the poles. It is therefore important to measure and understand their biodiversity if we are to understand the larger global impacts of climate change.

  South Africa has maintained an Antarctic base since 1960. The South African National Antarctic Programme (SANAP) has, among its key research themes, a focus on climate variability in which they are investigating the interactions between physical and biological oceanographic processes and global climate. It also has a key focus area on biodiversity in understanding the biodiversity responses to variability in earth systems, including climate change.

Grand Challenge 5: Human and Social Dynamics

Human and social dynamics are at the core of nearly every major challenge facing South Africa and developing nations. Science and technology can play a growing role in addressing socioeconomic problems, such as delivering affordable sources of energy and health, and access to clean and safe drinking water and sanitation. Biotechnology plays a significant role in improving the health services to poor communities. For example, the development of rapid diagnostic kits for various diseases will provide fast results for more efficient services in rural clinics. Biotechnology can provide tools to assist in alleviating poverty, for example, the use of GM crops potentially providing improved food security. Biotechnology touches all facets of our lives and it can potentially improve the socioeconomic problems that face South Africa.

For more detailed information on various biotechnology tools mentioned, visit www.pub.ac.za to download fact sheets and other resources.