DRAFT

COFISA Biotechnology Foresight:
1st Western Cape Workshop Report

CONTACT PERSON	Thembinkosi Semwayo
POSTAL ADDRESS	Knowledge Crucible, Suite 604, 125 Bandwidth Barn, Buitengchracht Street, Cape Town 8001
TELEPHONE No.	(021) 409 7084
FAX NUMBER	(021) 409 7050
CELL No.	076 103 1399
e-MAIL	thembi@kcrucible.co.za

Table of contents

TABLE OF CONTENTS **2**

1 INTRODUCTION **3**

1.1 BACKGROUND 3

1.2 OVERVIEW OF COFISA 3

1.3 OVERVIEW OF THE COFISA BIOTECHNOLOGY PROCESS 6

2 BIOTECHNOLOGY TRENDS ANALYSIS **9**

2.1 GENERAL ISSUES 9

2.2 PROVINCIAL TRENDS 9

2.2.1 Food, Agriculture and Animal (Livestock) Biotechnology *9*

2.2.2 Health: Animal & Human biotechnology *11*

2.2.3 Industrial biotechnology and the environment and natural resources *14*

3 BIOTECHNOLOGY SCENARIOS **17**

3.1 GROUP 1: MEGA KNOWLEDGE CITY PROTO-SCENARIO 18

3.1.1 Group 1: First Level Futures Wheel *18*

3.1.2 Group 1: Second Level Futures Wheels *20*

3.1.3 Group 1: Biotechnology Scenario Fragments *22*

3.2 GROUP 2: ELITE EDUCATION FOR THE PROVINCE PROTO-SCENARIO 24

3.2.1 Group 2: First Level Futures Wheel *24*

3.2.2 Group 2: Second Level Futures Wheels *26*

3.2.3 Group 2: Biotechnology Scenario Fragments *27*

3.3 GROUP 3: KNOWLEDGE-BASED PROVINCE PROTO-SCENARIO 30

3.3.1 Group 3: First Level Futures Wheel *30*

3.3.2 Group 3: Second Level Futures Wheels *31*

3.3.3 Group 3: Biotechnology Scenario Fragments *33*

ANNEXURE 1: WORKSHOP DELEGATE DETAILS

ANNEXURE 2: WORKSHOP PROGRAMME

ANNEXURE 3: DRAFT BIOTECHNOLOGY TRENDS ANALYSIS

ANNEXURE 4: THREE PROTO-SCENARIOS FOR THE WESTERN CAPE – 2030

1 Introduction

1.1 Background

Biotechnology is one of the "grand challenge" areas that have been identified in the ten-year innovation plan published by the Department of Science and Technology (DST), and supported by Cabinet. As such, significant public-sector investments will be made in biotechnology. Its cross-cutting nature means that in the next 20 years there is significant scope for new opportunities to emerge in the intersections between biotechnology and a wide range of other disciplines and sectors. There is every reason to believe that stakeholders in the Western Cape will be well-positioned to play a leading role in exploiting some of these opportunities, provided that they are identified early enough. Foresight is the method of choice by which early insights may be had into such opportunities.

From November '07 to March '08, the Cooperation Framework on Innovation Systems between Finland and South Africa (COFISA) held a successful Foresight exercise that focused on the future of the Western Cape as a whole, with a particular emphasis on the role of innovation in that future. Following on from this, and in support of DST's biotechnology "grand challenge", COFISA decided to hold a biotechnology Foresight exercise for the Western Cape during late 2008 and early 2009. The objectives of this exercise are:

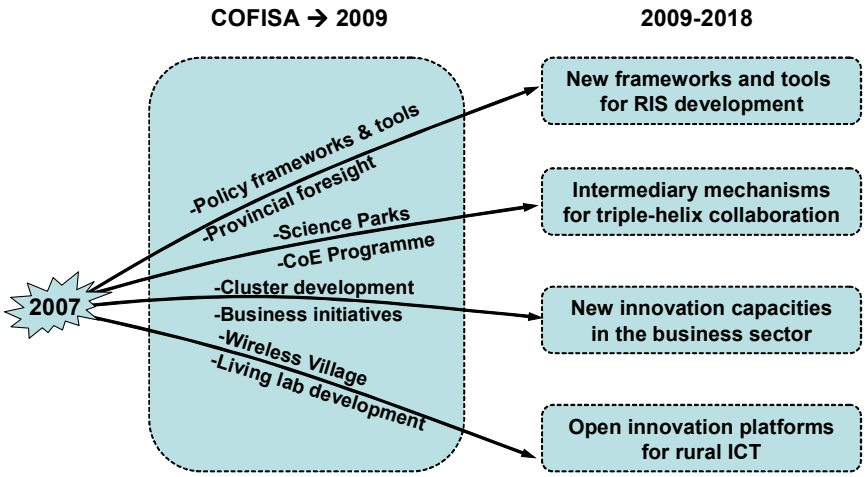
- To anticipate emerging areas of opportunity related to biotechnology, with a particular focus on the Western Cape;
- To support existing and encourage new biotechnology SMMEs in the Western Cape.

The exercise began with a two-day (residential) workshop that took place on Tuesday the 21st and Wednesday the 22nd October 2008, at Devon Valley Hotel in Stellenbosch. The details of the workshop are covered in this report.

1.2 Overview of COFISA

During the introductory session, Mrs. Nirvashnee Seetal, the COFISA South African National Coordinator provided an overview of the aims and objectives of the COFISA programme. COFISA is a programme that has been developed jointly by the Governments of SA, through the Department of Science and Technology, and Finland, through the Embassy of Finland in Pretoria. Its objective is to contribute to the enhanced effectiveness of the national system of innovation contributing to economic growth and poverty alleviation. COFISA's three pilot provinces are Gauteng, Eastern Cape

and Western Cape. The figure below illustrates four key areas of innovation system development, grouping together key COFISA activities into four strategically important lines of action focusing on building structures and competences at the Provincial level. These form the basic building blocks of the COFISA contribution to SANSI development and link the Project to the national 10-year plan.



New frameworks and tools for regional innovation system development:

The concept of a regional innovation system or policies related to its development is relatively new in South Africa. Yet, it is widely accepted that complementing a national innovation policy with a strong regional development focus has been successful in many countries in developing regional capacities to benefit from national or supra-national flows of resources.

National innovation policy must find concrete manifestations at the regional or local level. Furthermore, innovation processes occur between a large number of actors, such as companies, R&D organisations and the public sector. Regional innovation policy should exist to provide platforms for cooperation between these different actors.

Intermediary mechanisms for triple-helix collaboration:

The triple helix model postulates that collaboration among private, academic and public institutions is key for the promotion of innovation in a knowledge-based economy. Innovation intermediaries are entities providing infrastructure and services to undertakings involved in innovative activities. These almost universally include Science Parks and in specific cases programmes such as the Centres of Expertise (CoE) programme in Finland. Collaboration between the triple-helix players has to be actively promoted and resourced.

New innovation capacities in the business sector:

A specific characteristic of the innovation environment in South Africa is the relatively modest involvement of the private sector in innovative activities. This is especially true of the SMME sector, whereas large companies are often well-resourced to carry out R&D and to innovate. The role of innovation in strategic business plans needs to be highlighted and the SMME sector needs to be drawn into collaborative settings with other innovation players.

Open innovation platforms for rural ICT:

ICT-based rural development and rural innovation are currently carried out within individually funded project settings, resulting in challenges in terms of the sustainability of the models, practices, products or services. New platforms for open, user-centric innovation, testing and piloting of solutions and sharing of resources are needed.

Flagship Projects

- **Provincial and Sectoral Foresight** –Foresighting focuses on "what can be" and then directs efforts towards systematically developing the desired futures. COFISA has conducted a broad provincial foresight initiative in the Western Cape, Eastern Cape and Gauteng. In addition to the Biotechnology foresight exercise in the three Provinces, COFISA will also be supporting foresight activities for the ICT and boatbuilding sectors of the Western Cape;
- **Centre of Expertise Programme** –the pilot Centre of Expertise Programme in Gauteng, adapted from successful Finnish experience, focuses on encouraging triple-helix collaboration in innovation-based projects. The aim is to assist in bridging the innovation chasm though the translation of research into useful products, services or businesses in a more direct and effective way;
- **Science Parks** – COFISA has been instrumental in increasing awareness and understanding of the role of Science Parks as key innovation-enabling mechanisms across South Africa, and in addition to conducting studies related to their co-ordination and development;
- **Dwesa Living Lab and a Network of Living Labs** – The Living Lab platform will focus on promoting open, user-driven innovation in rural ICT services and applications; and
- **Knowledge and Innovation for Rural Development Platform (KIRD)** – KIRD is an initiative which intends to build on European, and particularly Finnish, experience and expertise in turning the Eastern Cape from being the core of South Africa's rural (and urban) poverty, to becoming an exemplary region of socio-economic stability and growth based on environmentally sustainable urban-rural balance. The idea for the KIRD arose out of the Foresight exercise conducted during the first year of the implementation of COFISA, wherein the need for sustainable interventions for stimulating innovation in rural areas in the Eastern Cape was identified.

Why is Foresight Important to COFISA?

- There are insufficient foresight capabilities at national and provincial level;
- Foresight is a good tool in helping to create commitment, enhance collaboration and build common ground;
- To help creative proactive policies and strategies that respond in time, learn in time and are able to adapt and evolve; and
- The long time horizon used in the foresight process neutralizes contentious issues thus facilitating cooperation between diverse actors as well as consensus building.

Through the foresight processes, COFISA thus aims to achieve the following:

- Grow the understanding and awareness of foresight;
- Facilitate the establishment of networks;
- Transfer knowledge and skills;
- Facilitate the initiation of relevant projects related to the foresight exercises that may be collaboratively implemented or driven by specific role-players e.g. an SMME's; and
- Feed into strategic processes at the government level.

1.3 Overview of the COFISA Biotechnology Process

Preparation for the Workshop

The quality of the outputs of any Foresight process depends to a large extent on the mix and appropriateness of the expertise and experience of the delegates and reference groups that participate. This is particularly the case for such a widely cross-cutting area as biotechnology. Significant effort, therefore, was put into identifying within the Western Cape a broad range of people with either generalist or specialist expertise in biotechnology, as well as practitioners in biotechnology related private sector activities, and public sector stakeholders. The details of the participants who attended the workshop are provided in Annexure 1.

To optimise the productivity of the carefully selected delegates during the 2 day workshop, they were asked to study two documents which were circulated to them prior to the workshop:

- *Biotechnology Trends Analysis:* Prepared for COFISA by Dr Sibongile Pefile, this draft report provides an overview of Biotechnology Trends at several levels: Developed economies and multinationals; Emerging economies; and South Africa. (See Annexure 3).
- *Three Proto-Scenarios for the Western Cape - 2030:* Prepared for COFISA by Non-Zero-Sum Development, these proto-scenarios were synthesised from the contents of the first set of Futures Wheels created during the previous COFISA Western Cape Foresight process. (See Annexure 4).

Workshop Processes

The workshop began with brief self-introductions of all the delegates, an Overview of COFISA (see above), and a description of the processes to be followed over the two days (see Annexure 2 for full programme). Following this introduction, two main items were pursued:

- Western Cape **Biotechnology Trends:** Following a slide presentation by Dr Sibongile Pefile based on her previously circulated "Biotechnology Trends Analysis" document (presentation available at www.cofisa.org.za), the delegates were asked for the rest of the first morning to add any relevant knowledge they had, particularly related to current or emerging biotechnology activities anywhere in the Western Cape. To achieve this, they were asked to choose one of 3 groups based on the following sub-components of biotechnology:
    - Food & Agriculture;
    - Animal & Human Health; and
    - Industrial Biotechnology, Environment and Natural Resources.

- Western Cape **Biotechnology Scenarios:** Following a slide presentation by Dr Bob Day based on the previously circulated "Three Scenarios for the Western Cape - 2030" document (presentation available at www.cofisa.org.za), the delegates were asked for the remaining 1.5 days of the workshop to participate in foresight activities which began to convert these proto-scenarios into full Western Cape Biotechnology Scenarios. To achieve this, they were asked to choose one of 3 groups, each based on one of the proto-scenarios. Each group was then employed to produce two levels of biotechnology futures wheels for their particular proto-scenario. Finally, based on the most important issues that they had highlighted in their futures wheels, the groups then wrote fairly detailed biotechnology proto-scenario fragments.

Post-Workshop Activities

Following the first workshop the following activities will be undertaken by the COFISA Foresight Team, supported by the workshop delegates and the broader reference group:

- The modifications to the biotechnology trends review will be summarised into a brief document which will be distributed electronically amongst the workshop participants and the wider reference group, and feedback solicited. A final COFISA Biotechnology Trends Analysis document will be produced for general distribution.

- The set of biotechnology proto-scenario fragments will be crafted into the related original proto-scenario to produce preliminary drafts of each of three Western Cape Biotechnology Scenarios. Material from these draft scenarios will be distributed electronically amongst the workshop participants and the wider reference group, and feedback solicited. The feedback will be

incorporated into each draft scenario to produce Version 1 of the set of Western Cape Biotechnology Scenarios. These will form the primary input to the second workshop, when Biotechnology Road Maps, and Action Plans to Stimulate Biotechnology SMMEs will be developed.

The Foresight exercise will be concluded following a second two-day residential workshop to be held in February - March 2009.

2 Biotechnology Trends Analysis

As described above in section 1.3, the delegates were asked to add any relevant knowledge they had, particularly related to current or emerging biotechnology activities anywhere in the Western Cape, to the draft Biotechnology Trends Analysis report produced by Dr Sibongile Pefile. The ***UNEDITED*** inputs from the three working groups are provided below under the biotechnology sub-component headings used to define the groups:

- Food & Agriculture;
- Animal & Human Health; and
- Industrial Biotechnology, Environment and Natural Resources.

2.1 General issues

During discussions, a number of issues, that are important for the success of intended biotechnology initiatives in the Western Cape, were raised. A brief description of each topic is provided next:

- The need to create centres of competence
- Bio-control and bio-safety measures are required
- Management capacity needs to be developed
- It is important to understand the value chains – for example, wine-fruit-grain-biomass
- It is necessary to leverage local resources in the form of the existing biodiversity. In particular plants and microbes
- It is essential to improve the carbon footprint and leverage trends for Western Cape agriculture.
- Bridging the gap between research & production (SMMEs)
- Funders demand innovation but see proposals as blue skies – evaluating scientists not skilled enough to evaluate new ways of doing things
- Appreciation of the need to take risk lacking
- Understanding the full value chain is critical
- Value added has to be interrogated
- Biotechnology always has an underlying science, biotechnology is the tool
- Management trends analysis, tool trends.

2.2 Provincial trends

2.2.1 Food, Agriculture and Animal (Livestock) Biotechnology

- Biomarkers in the fruit industry for predicting quality - a lot of fruit and money are lost as a

result of spoiling from harvest to shelf life

- Non invasive methods of checking quality control diagnostics bio-control, preservation
- Transfer of knowledge critical between research and producer's deciduous fruit trust – producers not innovative; do not seek new ways of doing things.
- Food = health
- Need for consumer, activist mind shift towards GMOs - the way forward is towards GM & organic combinations.
- Grow the domestic market to eat healthy & sustainably. At the moment people eat what's cheap. Lots of good healthy food abound. Food preparation is the challenge
- Bio – Africa working with small scale farmers to test technology *in situ*
- Most biotech is too high tech for direct use on the farm – service providers (pvt. Co's) should bridge the gap.
- Quality is a market qualifier, price becomes the selling factor
- Need to identify niches, differentiator, added value, need based
- Biotech cannot keep up with the needs
- GMOs for the future is the next big thing
- PlantBio funds biotech projects that can be commercialised in areas such as food development projects, drought resistance

- Bio-fuels research, 2nd generation, use of waste materials (away from food crops, e.g. grass)
    - Technologies in the wine industry – mature cluster network collaboration – industry, research, farm requirements analysis. At the moment the process is science driven
    - Novel wine yeast technologies
    - Novel yeast extracts
    - Consumer market – health & wellness products – using GM technologies – introducing neutraceutical (combinations of wellness & feel good – through the use of anti-oxidants)
    - Indigenous plants
- New possibilities areas use of extracts rooibos to obtain active useful ingredients
- Aqua – culture – production / breeding side, opportunities – fish farms being developed on wine farms
- Lobster feed research
- Horticulture (Citro Gold funded) – cultivar development germ plasma development
- Barley & Hops SAB research projects
- SUN – animal improvement research
- Esselenberg – agricultural research
- Snoek heads paste

- Fish eggs – high protein
- Centres of competency approach – collaboration – PlantBio encouraging such collaboration
    - Medical devices
- Mushroom (Cape Gourmet Mushroom) – specialised products
- Bio Pesticides,
- Agri – business driven by consumer preference

2.2.2 Health: Animal & Human biotechnology

- Focus on infectious diseases that are in fact dominant in the Province – TB and HIV AIDS.
    - TB first because we have a particularly unique TB problem here
    - TB – diagnostics (molecular diagnostics predominantly) through to therapeutics and management – a holistic view
- Illness/disease trend
    - high infant mortality
    - Gap – lots of diseases in the W Cape falling into gaps e.g. immune-based diseases such as asthma
    - W.Cape particularly bad for allergy development
- Therapeutics
    - Disease mechanisms
    - Potential markers and targets
    - Strong focus on natural products using bio-prospecting
    - Radio-pharmaceutical/nuclear medicine
- Diabetes discovery platform
- General research on disease mechanisms (2 big medical schools)
    - Good infrastructure for clinical trials
    - Effective bench to bed value chain
- Western Cape is the hub of human vaccine development
    - Platform development strong – can be applied to different health areas
    - HIV vaccine
    - Bacterial based vaccines
    - Vaccine development from plants – edible vaccines
    - Also being tested for animal vaccines (e.g. rabies) although being developed for HIV and HPV
    - Manufacture of vaccines – pilot and larger scale for human health
- Value Chain
    - Basic science-very strong at the Universities
    - Manufacturing side being addressed by Biobac

    - Clinical side – various units at the Universities and private companies
    - Plant-based production methods for bio-pharmaceuticals – large experimental farms exist
    - So quite a lot of aspects of the value chain being covered.
        - Putting the research through to a candidate is a big gap
            - No high throughput screening
            - Formulation of the drug
            - Ability to put the medicinal chemistry together is missing
            - Not focused enough to get from the idea to the product
            - On the research side quite a wealth of work but not making it out to sustainable, profitable companies (especially in therapeutics). Often the research spins-off into companies run by the scientists (not too successful).
- Diagnostics
    - Existing businesses and projects as pre-cursors to other businesses
    - Molecular and medical device-type diagnostics crossing various disease areas
    - Moved into the commercial sphere – many diagnostic companies that have sprung up
- Biotechnology service centres
    - E.g. Synexa and CPGR – offer analytical-type services and also infrastructure for basic research.
- Plant based/herbal medicines
    - Nutraceuticals
    - Cosmeceuticals
    - Plant-based medicines
    - Making use of WC biodiversity
    - Lots of discovery and translation happening.
- Medical devices
    - Digital x-rays
    - Digital mammography
    - Heating devices
    - TB diagnostics (imaging)
    - Moved beyond just the research. Many companies are making money in this sector.
    - Biotechnology-enabled imaging solutions
    - Implants (cervical, etc)
- Well-being industry (upper and middle class)
    - Biomarkers
    - Nutritional, lifestyle, exercise

- Bioinformatics
    - Strong in the W.Cape in terms of feeding into drug development, etc.
    - Small amount of expertise in medicinal chemistry
    - Increasing clinical trial capability
    - High performance computing centre
    - Ribbon diagrams etc. – rational drug design
    - Computational biochemistry
- Cardio Health
    - Heart valves
- E-health and Telemedicine
    - Not very much happening in this area in WC
    - Nanotech and biochemistry combined with cell phone technology – important for point-of-care
    - Medical device diagnostics being developed so that they are telemedicine enabled. Players in this field very tapped into the "at-home" health trend.
    - MRC very involved here.
    - Area with huge potential for the country.
- Bio-prospecting
    - Indigenous knowledge
    - Marine resources
- Generics
    - Generics becoming stronger and more confident.
    - Cheaper ways of producing the active ingredient.
        - Exploiting patents coming to the end of their lifecycle
- Growing interest of international companies (especially small Biotech companies) to set up in the Western Cape. But local funding not geared to set up foreign companies. The extent of technology transfer will be great.
    - Government focuses too heavily on SA. Need a balanced portfolio.
- Stem cells
    - Insufficient infrastructural support for stem cell research (high-tech work)
    - Red tape
    - Heart stem cell work
    - Race horse tendons
    - Harvesting from umbilical cords for storage
    - Stem cell technology from using fat cells
    - Neuro-biology
- Personalised medicine – Pharmacogenomics

    - Predictive testing for genetic-based diseases
    - Linked to well-being industry
    - Total health industry
    - Strong affluent community that can spend money on this
- Directed Evolution
    - Trying to improve on chemicals by emulating a genetic evolution environment
        - Selection of mutants that fulfil certain criteria
        - Optimising enzymes
    - Could be used for bio-prospecting
- Antibodies to peptides/polypeptides
- Generic biopharmaceuticals platforms using the in-bound technology transfer
    - Bring in the technology for generic production and establish a research capability to extend that to other novel biopharmaceuticals
- Animal Health Biotech – primarily in Pretoria
- Cyclotron (iThemba)
    - Markers
- X-Ray Crystallography
- Drug delivery systems (not necessarily biotech) – mostly chemical
- Cancer
    - Focus mostly on the basic research side
    - Oesophageal cancer
    - Mycotoxins
    - Ovarian and cervical cancer
- Sports Medicine
    - Tendon risk injury
    - High performance
    - Nutritional enhancement
    - Genetics around top sports people

2.2.3 Industrial biotechnology and the environment and natural resources

- Bio-control - biological control for diseases, residue free products
- Carbon credits – wine industry under pressure to demonstrate carbon neutral- ness / carbon footprints through use of bio-control

WHY?

- Social implications (using three earths and have a growing population)
- Triple bottom line, profitability. Technology is 'cool'.
- IndieBio not about using biotech in EVERY process, but having the option of using the BEST

option in every step in the process.

- Including fossil based raw materials - complementary technologies
- IndieBio is looking at the whole production cycle, life cycle analysis, and industrial ecology.
- Instead of a forced move away from petroleum, a more natural transition to bio-based is suggested. It is pertinent to make economic sense to be a profitable process (in the short term) but petroleum companies should not be alienated.
- Energy is not the total thing, there is a cost of cleanup, that with most energy sources are not considered. Industrial Ecology needs to be crucial in this process - Industrial Biotechnology can contribute to this. Pricing for clean up must be considered, and there biorefineries can become more profitable than fossil refineries when this is also considered.
- Waste resources as another renewable resource.
- Renewable vs. recyclable... rate of regeneration?
    - E.g. coal is not renewable as it cannot be regenerated at a fast enough rate.
- Plants can be renewable because they re-use the same CO2, but they can be non-renewable because once a forest has been burnt down, it's gone. The CO2 gets recycled, but it is not a closed system.
- Biotech processes affect clean-up. Safer, cleaner, less waste biotech-related products can be better. E.g. petroleum companies and the R&D environment (SASOL) research and pilot plant in sludge dams clean up, GMO's still an ethical issue. Genencor's textile processing biotechnology. Also R&D in acid mine drainage (AMD) and bioleaching research and implementing is currently being done in SA (e.g. CeBER, UCT).
- Biofuels and algal biodiesel research.
- Cleaner production: less raw material, less wastes and better quality waste.
- How does council use these technologies, e.g. CT 0% waste policy implementation??
- Entrepreneurship? Tender structure needs to change profitability and finance structures. Social needs to drive research at universities. Pull and push thing.
- Disconnect between the finances, budget, business issues and university. Lack of vision in councils. Who pushes this type of research implementation? Need more SMMe - to close innovation chasm.

The environment

- Whole lifecycle needs to be considered. Need to close the loop 'mentally'.
- Biotech can be profitable while restoring the environment; investor friendliness.
    - E.g. Issue of 'fixing' dongas. Seasonal floods and soil erosion can be fixed through biotechnology to improve rural livelihoods. Is research being done at the moment? Yes, the Dept of water affairs. However, there seems to be a lack of awareness between what biotechnology can offer and the problems at hand. Also invasive tree

species that drink too much water.

- Focus on this section is STILL very much (just) energy, but needs to be more on biotech to improve livelihoods. This section is very much Eurocentric; there are trends in SA that are not mentioned here. (But do not know exactly what or where these are). Drivers of research are company/profit based, not society. We would like to see India research projects and implementations of environmental biotech.
- There is an emerging trend in SA energy strategy to set up a rural development driven biofuel economy. E.g. small scale biofuels production subsidized through government. Big companies will/should get involved in development and education, being involved in the whole process, and becoming suppliers/distributors later. This also contributes to sustainability. e.g. the paper suppliers, who have losses due to 'chop-and-go' practices, and try to remedy this by public education and buy-in to community initiatives (I think SAPPI).

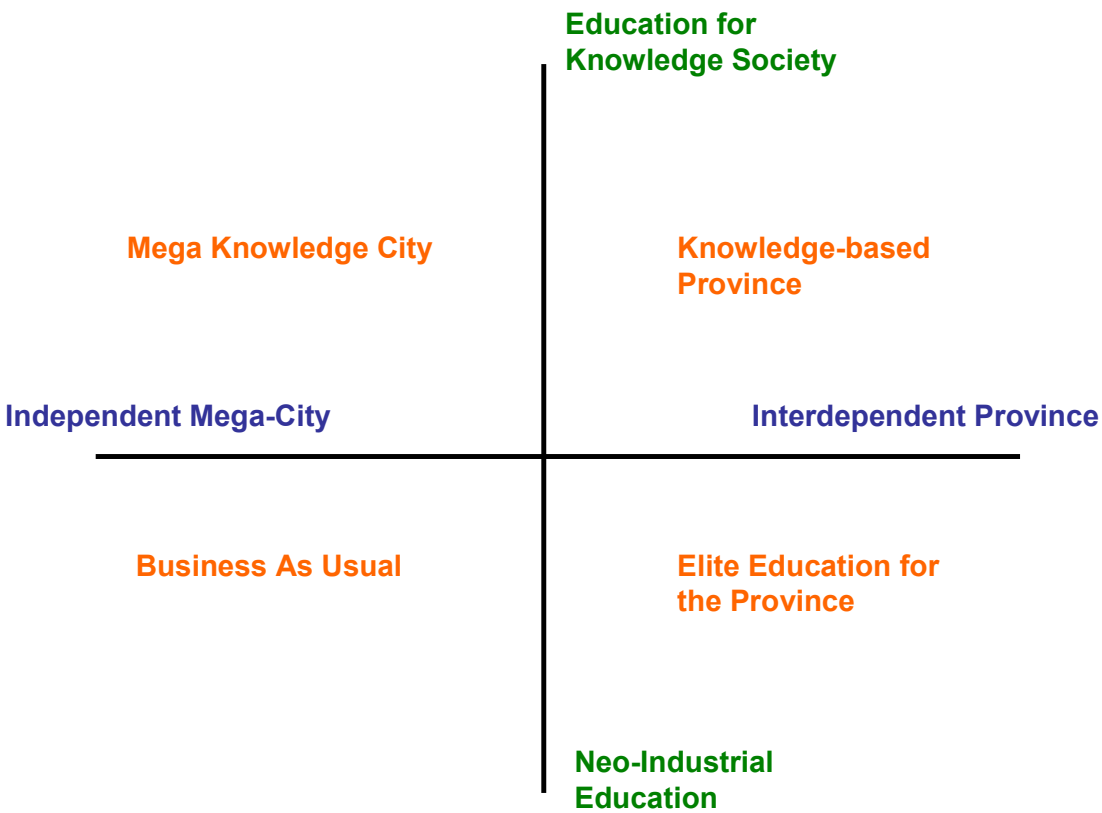
- **Global emphasis on:**
    - US: biofuel, energy security
    - Euro: environment (green)
- **SA: rural / social driven strategy**
    - International practices
        - e.g. product used on gravel roads to increase lifetime of the road, to reduce erosion (bio-compound). This is an international trend/product that is not implemented here, and should be.
    - Bio-based vs. destroying natural resources.
    - There is not enough land.
    - BUT shouldn't think we will totally go away from fossil fuels (social impacts).
        - E.g. Choice of trees for biofuels in arid conditions that could be used for food.
        - E.g. Oversupply of maize that cannot be used for biofuels due to policies - need to relook policies for SA situation.

3 Biotechnology Scenarios

As described in section 1.3 above, the delegates were asked to participate in foresight activities aimed at converting the proto-scenarios distributed earlier into full Western Cape Biotechnology Scenarios. The three proto-scenarios were built from the futures wheels produced during the earlier COFISA Western Cape Foresight process. The contents of these futures wheels were combined and synthesised, revealing two major areas of contrast, i.e.:

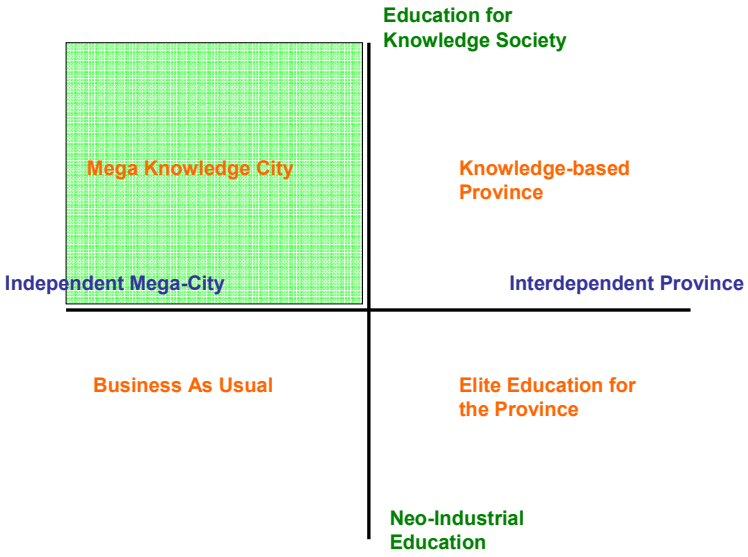
- Independent Mega City approach versus the drive for an Interdependent Province
- Creating Education for the Knowledge Society versus a Neo-Industrial Education approach

These axes were then used to create the following quadrant diagram, and each quadrant provided the basis for one of the three Western Cape proto-scenarios.



To convert these proto-scenarios into full Western Cape Biotechnology Scenarios, each delegate was asked to choose which of the three proto-scenarios provided them with the opportunity to best represent their expertise and ideas. Three working groups were then formed, each based on one of the proto-scenarios. Each group was then employed to produce two levels of biotechnology futures wheels for their particular proto-scenario. Finally, based on the most important issues that they had highlighted in their futures wheels, the groups then wrote fairly detailed biotechnology scenario fragments. The ***UNEDITED*** inputs produced as a result of these three activities by each working groups are provided below.

3.1 Group 1: Mega Knowledge City Proto-Scenario



3.1.1 Group 1: First Level Futures Wheel

To produce the following futures wheel, the delegates were asked to "dump" (with little group judgement being applied at this creative stage) those biotechnology related ideas that had come to mind as they imagined themselves living and working within this 2030 scenario. At the end of the session, the group was asked to discuss and agree upon the most important 2 – 4 issues within their futures wheel. It was emphasised that the delegates should feel strongly about (even be excited by) these issues, since they would be working on them for the remainder of the workshop.

- Brain chips → genetically modified dolphins used for transport → humans learn to speak to them and other animals
- Biochips in brain for better memory → or have pre-coded memory
  → Finance → Bio-ID

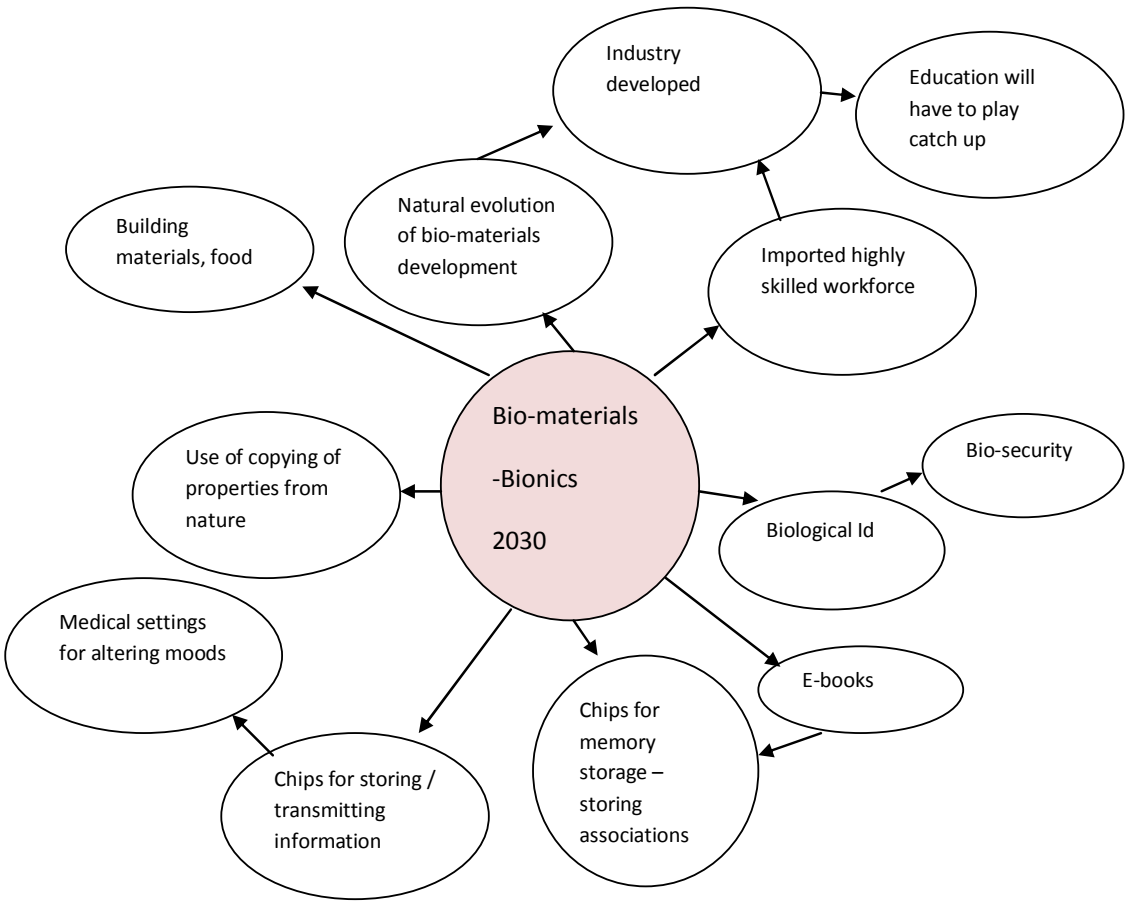
- 2010 ⟶ Stadiums and many sports people ⟶ Sport science institute is an international resource
- Cheese industry booms because of moulds ⟶ antibiotics
- Regionally – can help the city centre regenerate ⟶ new wine areas using old biotech
- Success not shared with the poor ⟶ resentment due to economic inequalities

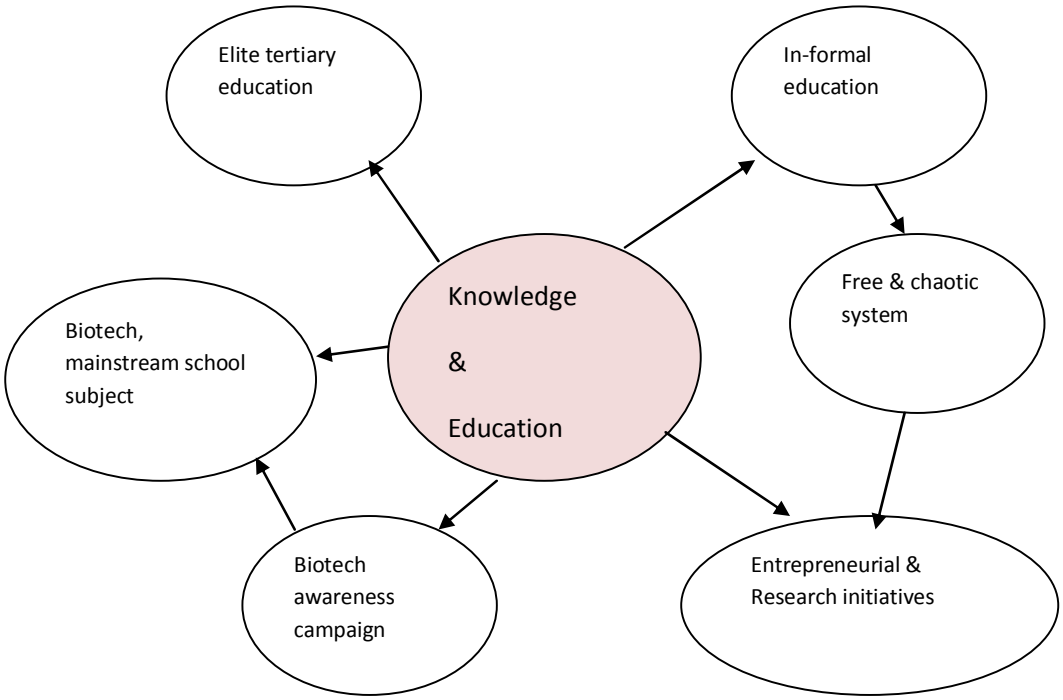
3.1.2 Group 1: Second Level Futures Wheels

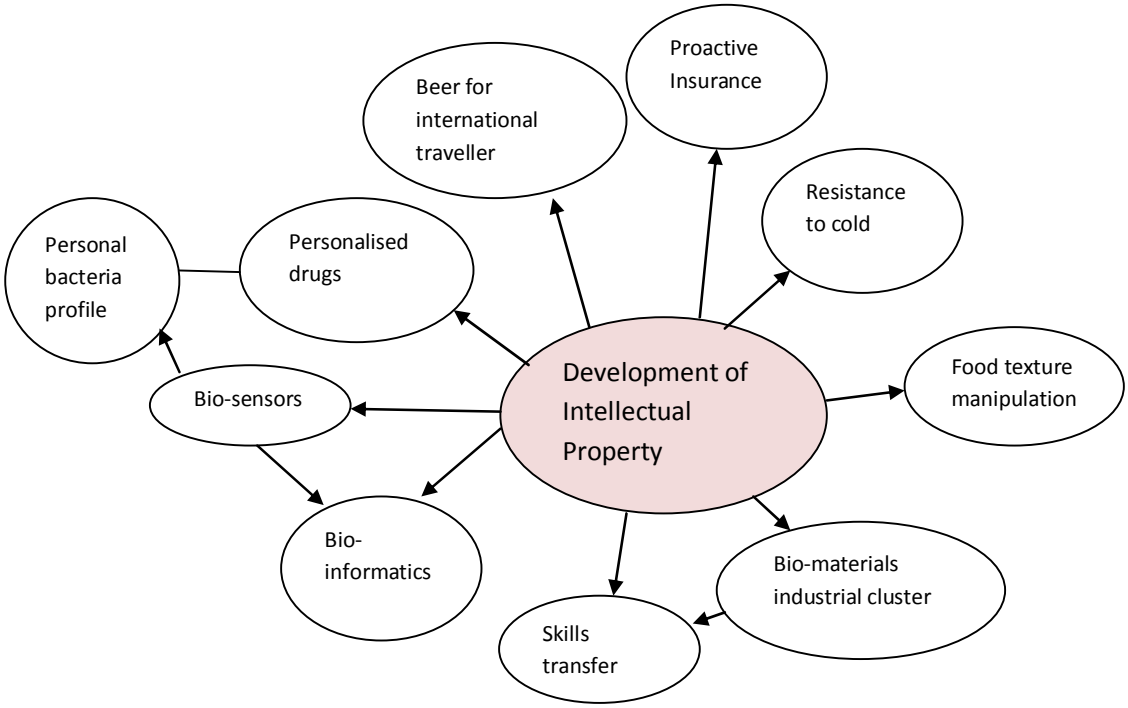
The delegates were now asked to create more detailed futures wheels for each of the issues they had prioritised at the end of the previous session. Again, they were asked to focus on biotechnology related ideas within the context of their 2030 scenario.

Group 1 produced the following three second level futures wheels:

- Biomaterials-Bionics futures wheel
- Knowledge and Education futures wheel
- Development of Intellectual Property futures wheel




Elite tertiary education
In-formal education
Knowledge & Education
Free & chaotic system
Biotech, mainstream school subject
Biotech awareness campaign
Entrepreneurial & Research initiatives


Beer for international traveller
Proactive Insurance
Resistance to cold
Personal bacteria profile
Personalised drugs
Development of Intellectual Property
Food texture manipulation
Bio-sensors
Bio-informatics
Bio-materials industrial cluster
Skills transfer

3.1.3 Group 1: Biotechnology Scenario Fragments

Biomaterials-Bionics

- Industry developed
- Natural evolution of bio-materials development (bionics) occurs
- Use or copying of properties from nature
- Use of marine environment, dolphin transformation
- Building materials, food, education
- Education will have to catch up
- Medical settings for altering moods, depressions, schizophrenic
- Bio-security

Knowledge and Education

- Education & learning takes place in a mostly non-formalised fashion even though formal education and training still takes place
- Free & chaotic system of learning - gives rise to huge growth in number of entrepreneurial and research initiatives, healthy & vibrant competition in the Biotech industry
- Awareness of biotech – prominent for society at large, not just by the elite
- Biotech activities are a subject of interest at home, kids are exposed, interest heightened
- Bright ones / elite go for tertiary formal training, otherwise biotech becomes part of everyday general knowledge for the kids
- What about the proportion of the unskilled ? Still remains a proportion of the unskilled, it gets absorbed
- E-books
- Education system transformed, biotech taught at an early age – like what has happened in ICT – cell-phones have bridged the IT learning gap
- Support systems in Biotech – awareness becomes prominent
- Entertainment – memory implant –speeds up learning
- Learning is not about memorising it's about creating associations & remembering them

Development of Intellectual Property

- Use of properties from nature, copying & creating, e.g. in building materials
- Genome manipulation, e.g. resistance to the cold through genetic expression
- Personalised drugs – ensure drug is targeted to specific cells at specific times
- Food manipulated to give specific texture the way things are digested
- Putting Knowledge into practice - information types of solutions
- Development of biomaterials industry – cluster
- Skills transferred through collaboration & intervention

- Unequal skilling levels – inequality gap does not decrease
- Improvement of quality of life
- 2030 – Brain mapped
- Instead of reading ebooks, these are implanted to impart knowledge
- Bio-security – biomarkers be used for identification to screen access to micro-chips
- Messy soup of opportunities & dangers
- Legislative issues to control what is possible as opposed to what is desirable
- If legislative environment is restrictive then Biotech innovators will go elsewhere
- Tensions between elite research & education
- Pro-active insurance through genome profiling
- Personal bacteria profile, link this to identifying the right foods for individuals
- Bio-sensors to monitor changes in individual profiles
- Viruses and bacteria that are engineered to protect the individual
- Use of engineered bacteria
- Bacterial removal of alcohol (beer for the international traveller – sorts out gastro problems & jet lag)

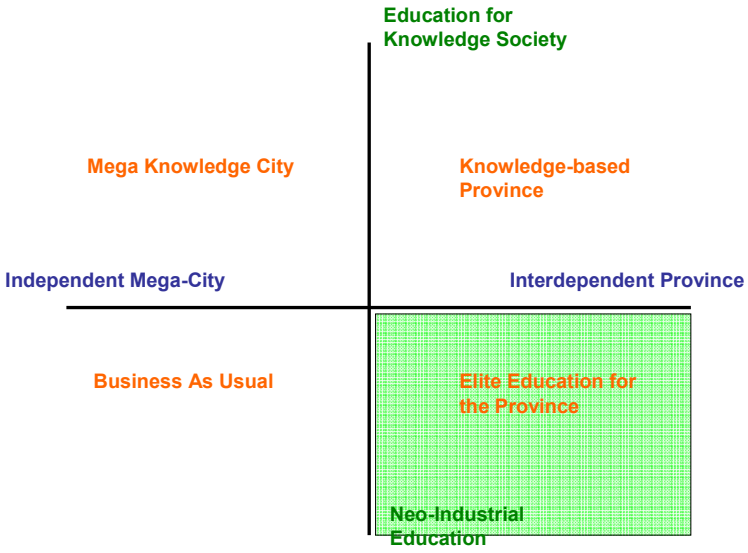
General

Meditating a little about what brought us to the way things are now in 2030, and particularly technologically – wise, and how all these technologies have transformed our lives. I cannot avoid to think about the huge impact that Bionics, and particularly Brain Bionics has had on us. I think it was around 2021 when a small research lab announced their breakthrough in the understanding of the way we process visual information and the potential applications of this technology.

I still remember that it took about 3 years before the first modest industrial products came to be, partly due to pressure from the military sector that realised immediately the potential to use this for individual targeting and surveillance, and partly because of in-fighting around IP issues.

Finally, after a whole year wasted, our company, which had very deep ties with both the military and academia, managed to close a deal that would allow us to buy a majority stake in the technology as well as to obtain the rights to further develop it and commercialise derived products.

3.2 Group 2: Elite Education for the Province Proto-Scenario



3.2.1 Group 2: First Level Futures Wheel

To produce the following futures wheel, the delegates were asked to "dump" (with little group judgement being applied at this creative stage) those biotechnology related ideas that had come to mind as they imagined themselves living and working within this 2030 scenario. At the end of the session, the group was asked to discuss and agree upon the most important 2 – 4 issues within their futures wheel. It was emphasised that the delegates should feel strongly about (even be excited by) these issues, since they would be working on them for the remainder of the workshop.

A = ENVIRONMENT

B = AGRIC

C = HEALTH

S = SOCIAL

E = ECONOMIC

F = FOOD

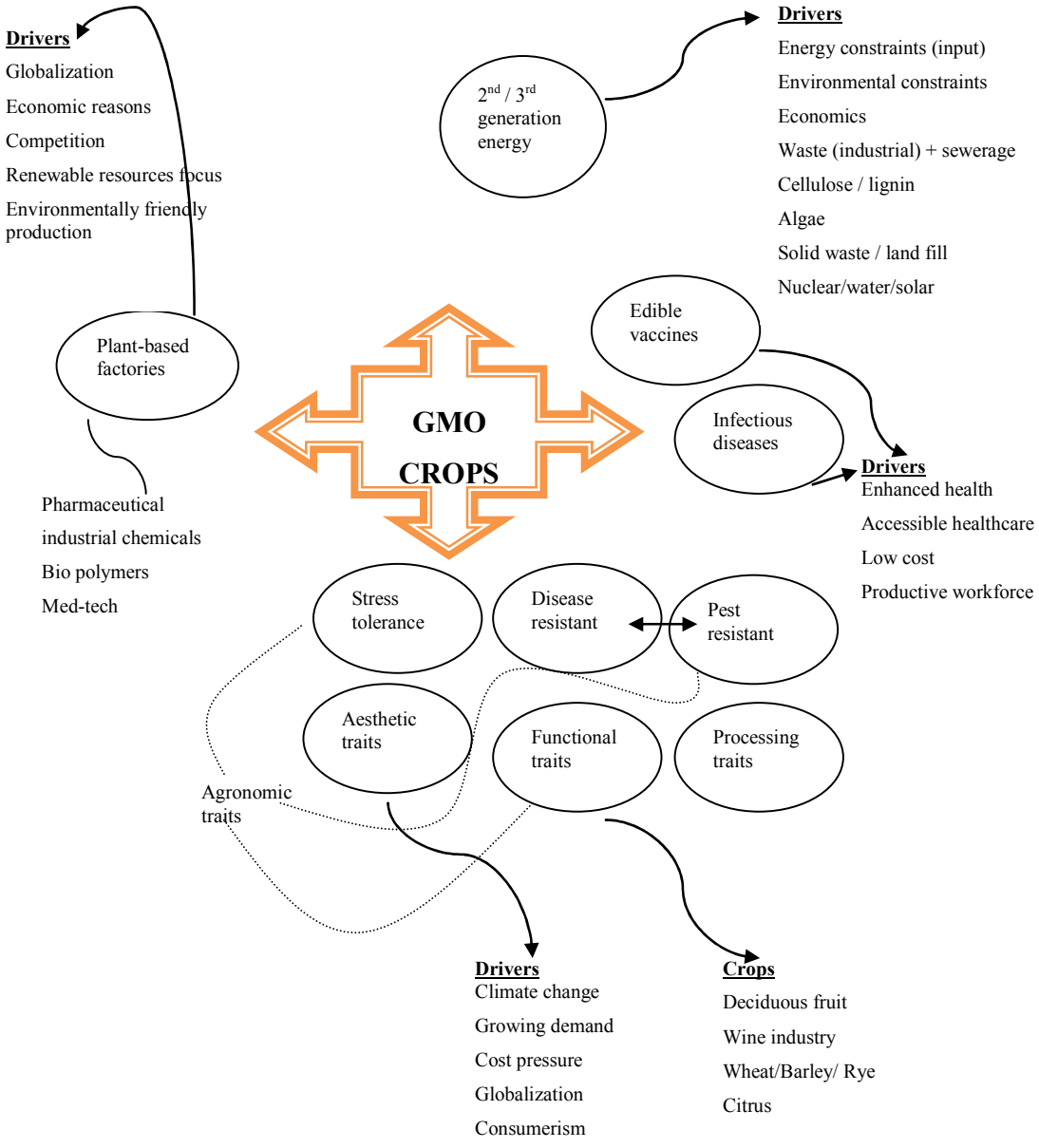
- Risk averse society (doers)
- Top down planning intensive
- Academic – first world research excellence
- System does not reward development

3.2.2 Group 2: Second Level Futures Wheels

The delegates were now asked to create more detailed futures wheels for each of the issues they had prioritised at the end of the previous session. Again, they were asked to focus on biotechnology related ideas within the context of their 2030 scenario.

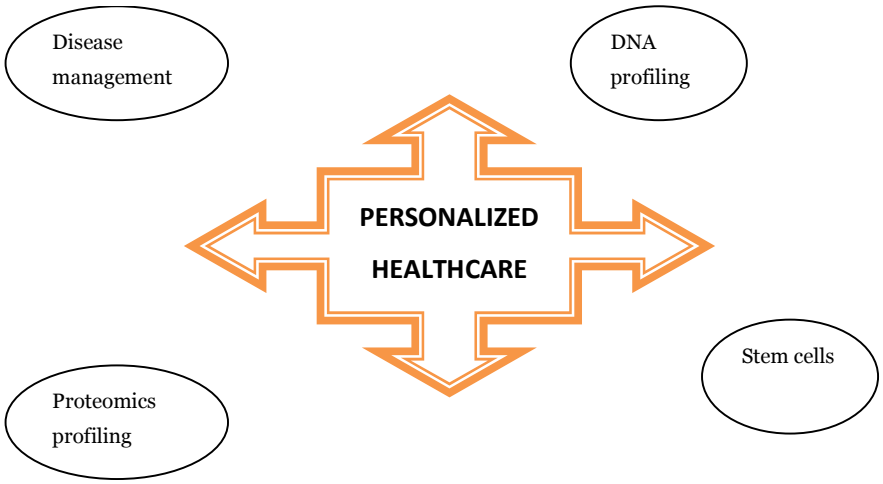
Group 2 produced the following two second level futures wheels:

- GMO crops
- Personalised healthcare



- Biomarkers
- Disease progression
- Virus mutation/drug resistance

- Embryo selection
- Disease application
- Security/crime
- Genetic counselling



Drivers

- Convenient healthcare
- Longer life
- Optimized
- Enhanced quality of life
- Security
- In-house management
- Proactive healthcare

Body parts

- To treat disease
- cosmetics

3.2.3 Group 2: Biotechnology Scenario Fragments

GMO crops for the Western Cape

Using plants as factories to produce metabolites and compounds:

What does the technology look like?

Two potential technology applications:

- Using GM plants (grasses, other plants with short growth period) to produce metabolites, grow these plants and harvest and extract these for the particular metabolite as opposed to chemical production
- Using plant cell culture or plant tissue culture to grow GM plants and harvesting these from the lab cultures

What are the applications?

- GM plants and GM plant cell cultures will be developed to produce needed pharmaceuticals, - industrial chemicals, biopolymers, bio materials, other medical applications
- The active compounds of the indigenous biological resources have been identified and are being produced in plant based factories

How did it get there?

- The need for cost-effective production of the pharmaceuticals, industrial chemicals, etc.
- Global competitiveness required for industrial production
- Fewer consumer acceptance issues as the technology is used for industrial production
- Need for environmentally friendly production practices
- The need for an economic argument for further development of this technology is still to be fully established to fully implement this technology

What was the influence of the scenario?

- The Elite drive the development of this technology as there is an economic benefit for the elite and there is capital that is pushed into this
- Elite education for the province leads to a focus on research technology that has global impact, rather than focus on the inherent needs of the Western Cape
- Not developed to its full potential due to lack of sufficient implementation

GMO crops for agriculture and medical applications

What does the technology look like?

GMO crops developed for various agriculture and medical applications:

- Edible vaccines
- Disease and pest resistance
- Stress tolerance
- Processing traits
- Functional traits
- Aesthetic traits

In various crops that are important to the Western Cape province:

- Deciduous fruit (pome and stone)
- Grapevine (table grape and wine grapes)
- Citrus

- Grains (wheat, barley, rye)
- (non-fruit, other staple crop for vaccines)

How did it get there?

20 years prior many focus areas identified according to various drivers. Incorporated by various universities and private biotech companies, but not well co-ordinated.

The agricultural drivers include:

- Climate change (drought and pests)
- Growing demand and consumerism
- Cost pressures
- Globalisation (international competitiveness)
- Focus on Western Cape needs
- Political framework (land expropriation and the need to help farmers by using technology advancements)

Drivers for edible vaccines:

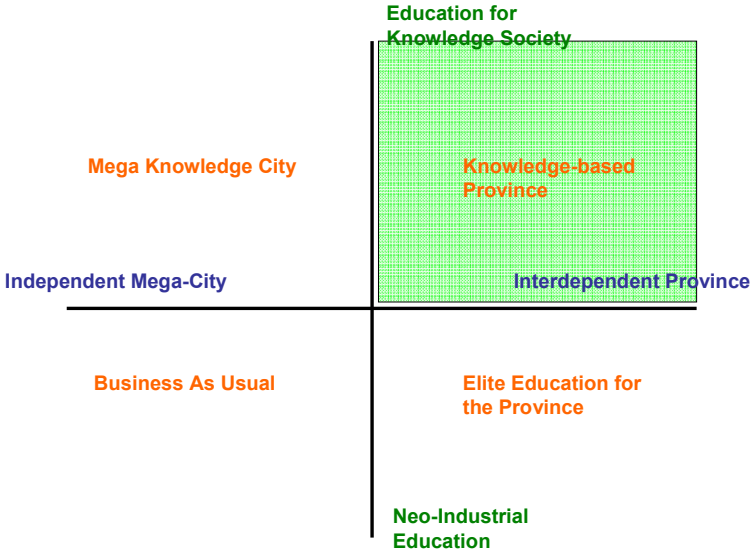
- Enhanced health/longevity
- Accessible healthcare for all
- Increased work force productivity-less sick staff
- Low cost of production of pharmaceuticals

What was the influence of the scenario?

- Management nurtured development
- Had vision to become world-class (in terms of economy and quality of life) and need to develop rural areas (agricultural importance)
- Education system delivered very bright and skilled people
- Projects started on GMO crops for edible vaccines and agricultural applications
- Unfortunately projects not co-ordinated well, broader public did not understand the technology and vision
- Many promising projects not commercialized as top people left
- Public resistance to technology
- TB and mould outbreak finally convinces public that GMO crops should be accepted.
- Attitudes begin to change after the mould outbreak, but too late to save industry due to economics of re-planting the orchards and vineyards

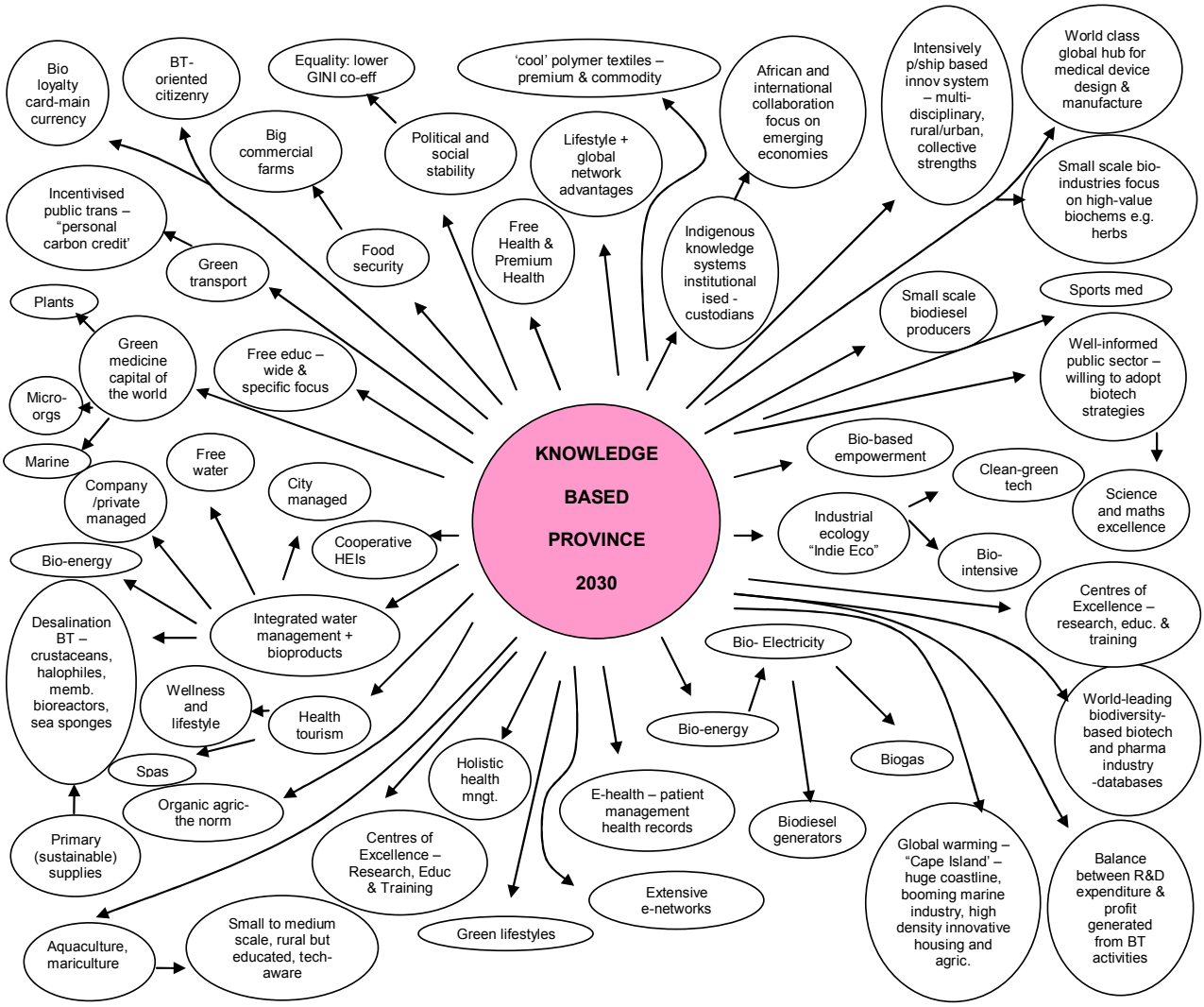
The mould that developed highlighted the need for a proactive approach to research and the need to focus research activities in the Cape Town area as opposed to diluting the effect of the research by spreading it throughout the province

3.3 Group 3: Knowledge-based Province Proto-Scenario



3.3.1 Group 3: First Level Futures Wheel

To produce the following futures wheel, the delegates were asked to "dump" (with little group judgement being applied at this creative stage) those biotechnology related ideas that had come to mind as they imagined themselves living and working within this 2030 scenario. At the end of the session, the group was asked to discuss and agree upon the most important 2 – 4 issues within their futures wheel. It was emphasised that the delegates should feel strongly about (even be excited by) these issues, since they would be working on them for the remainder of the workshop.

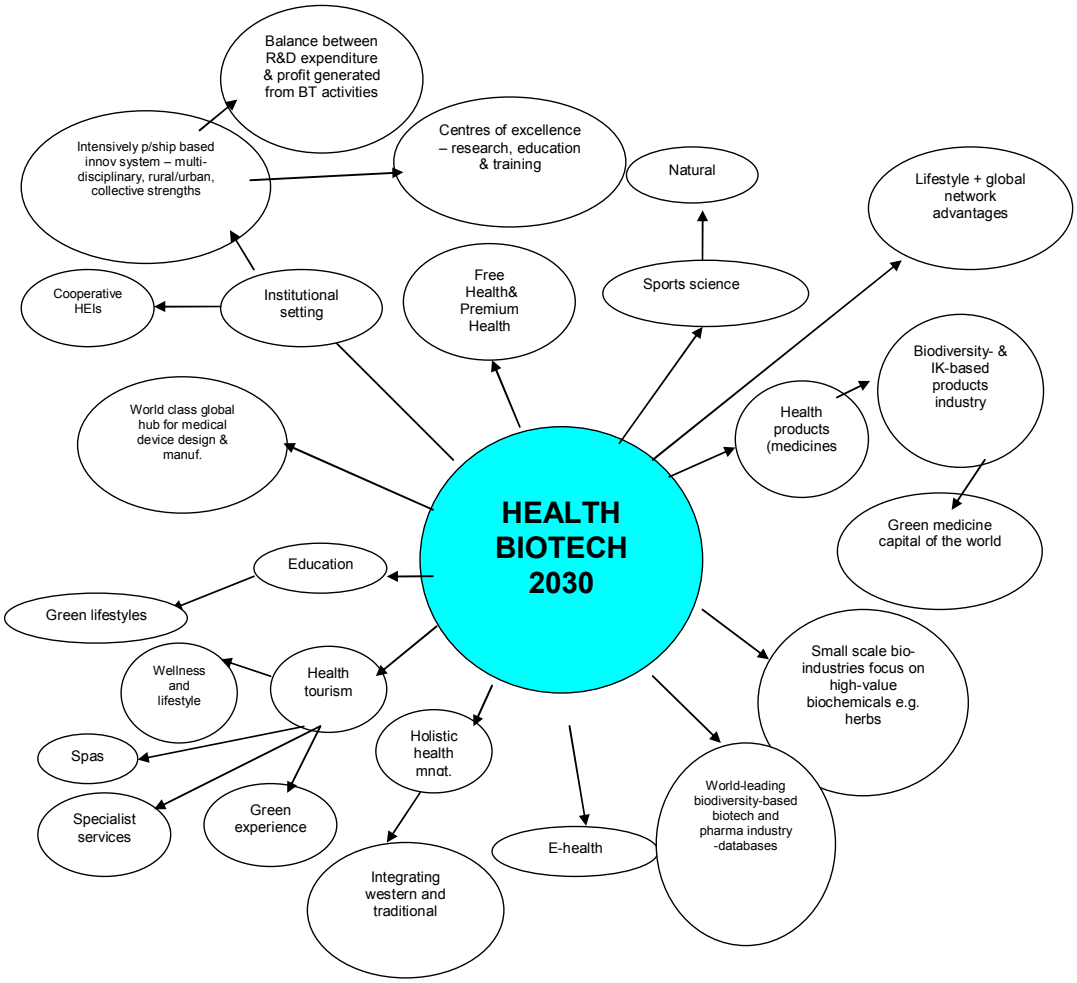


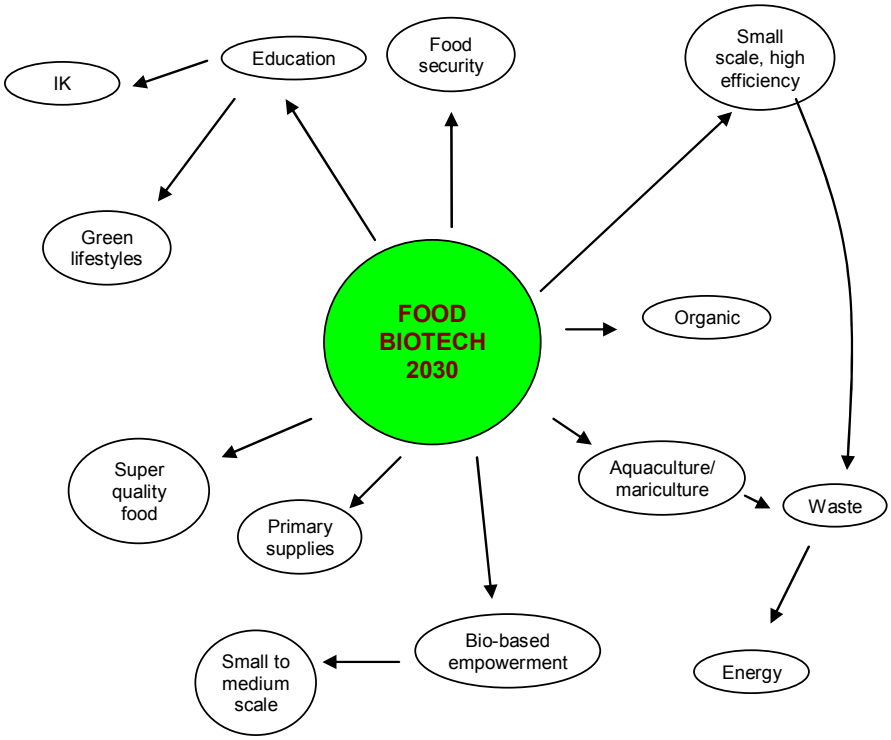
3.3.2 Group 3: Second Level Futures Wheels

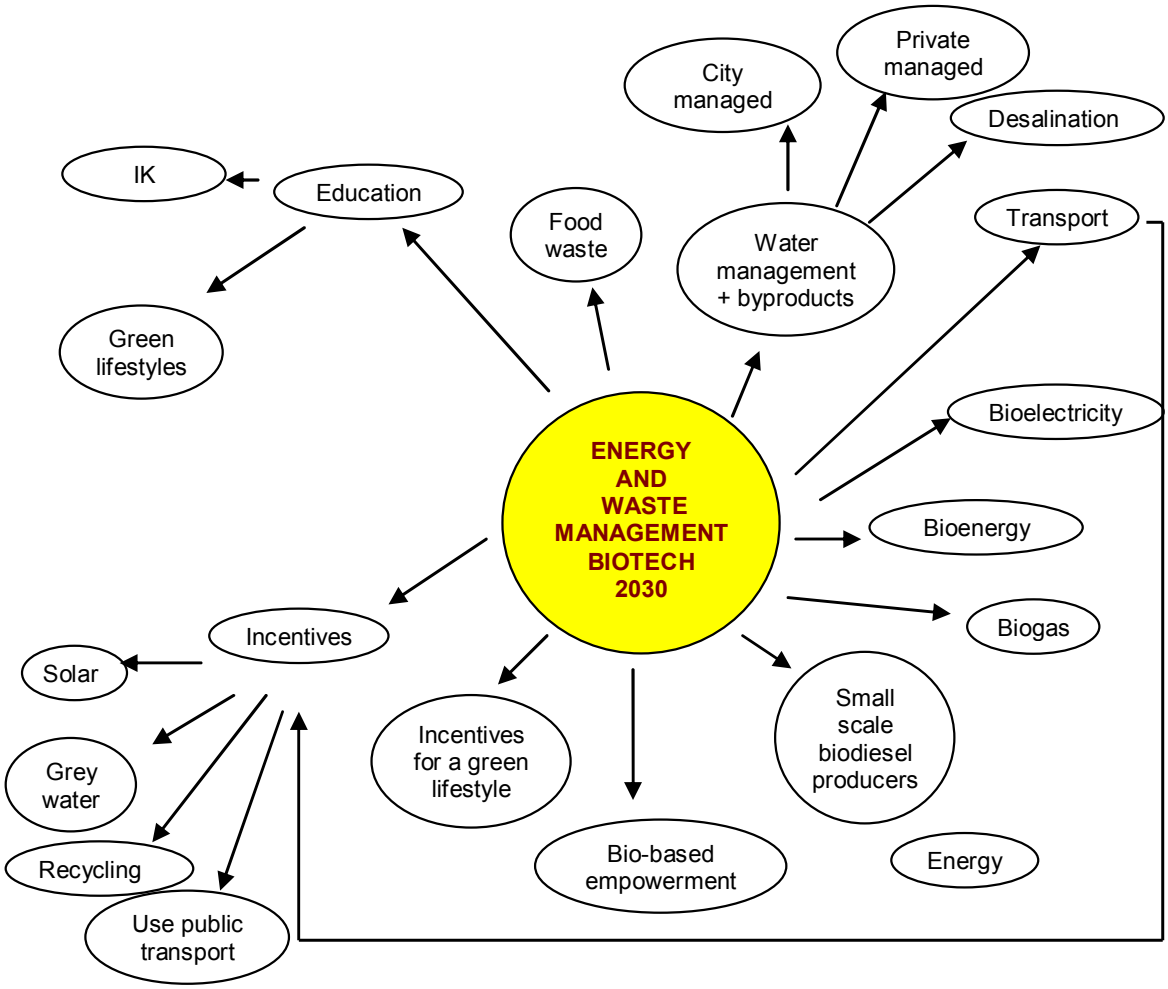
The delegates were now asked to create more detailed futures wheels for each of the issues they had prioritised at the end of the previous session. Again, they were asked to focus on biotechnology related ideas within the context of their 2030 scenario.

Group 3 produced the following three second level futures wheels:

- Health Biotech
- Food Biotech
- Energy and Waste Management


HEALTH BIOTECH 2030
Balance between R&D expenditure & profit generated from BT activities
Intensively p/ship based innov system – multi-disciplinary, rural/urban, collective strengths
Centres of excellence – research, education & training
Natural
Lifestyle + global network advantages
Cooperative HEIs
Institutional setting
Free Health& Premium Health
Sports science
Biodiversity- & IK-based products industry
World class global hub for medical device design & manuf.
Health products (medicines
Green medicine capital of the world
Education
Green lifestyles
Wellness and lifestyle
Health tourism
Small scale bio-industries focus on high-value biochemicals e.g. herbs
Spas
Holistic health mnat.
Specialist services
Green experience
World-leading biodiversity-based biotech and pharma industry -databases
E-health
Integrating western and traditional


FOOD BIOTECH 2030
IK
Education
Food security
Small scale, high efficiency
Green lifestyles
Organic
Super quality food
Primary supplies
Aquaculture/ mariculture
Waste
Small to medium scale
Bio-based empowerment
Energy



3.3.3 Group 3: Biotechnology Scenario Fragments

Drivers/Enablers for Scenarios

EDUCATION

- Free education
- Cooperative universities
- Centres of excellence
- Biotechnology-oriented citizenry
- Science and maths excellence
- Well-informed public sector

GREEN LIFESTYLE

- solar applications
- recycling
- grey water recycling
- public transport
- organic living
- Incentives for pursuing these lifestyles through 'Bioloyalty Cards'
- concept of 'Waste to Raw' material, closing of material and energy cycles

INNOVATION
- Partnership based
- Multidisciplinary
- Rural and urban collaboration, buy in.
- A balance between R&D expenditure and profit from biotech.

INDIGENOUS KNOWLEDGE
- Institutionalised custodians.
- African and International collaboration.

"Starfish": Industry, University, Government, Community, Indigenous Knowledge.

Health

The Western Cape has created a world renowned lifestyle and culture that draws tourists who want to enjoy life and nature, and do so responsibly. Independently, or perhaps because of this, the Western Cape also has world class healthcare, medical devices, speciality health services and top rated research. This has resulted in a sort of "health tourism", which the provincial government was quick to capitalise on and develop into a formally supported strategy.

The attractions in the health tourism industry are spa's with uniquely Cape herbal treatments, indigenous knowledge packages, health safari's solely for dental work, plastic surgery, fertility treatment and so on, with crosstalk from seemingly unrelated industries, leading to health and yacht safari's, health and wildlife safari's, health and adventure sports, contributing to a very pleasing green experience. The rural community in particular bought into this, and offers a diverse range of activities based on indigenous cuisine, cultural experiences, traditional healing, all supported by collaborative research.

The health of the people actually living in the Western Cape was not left behind. The province adopted an approach based on wellness, and a holistic lifestyle is considered. An extensive

infrastructure exists to inform the public around issues of nutrition, predictive factors and personal managed healthcare through e-health. E-health provides infrastructure to take advanced healthcare to remote locations, which improves the well being of the population. Traditional, alternative, western and indigenous medical practises are far more integrated, with more knowledge available on the different options. Quality control and credibility on this fusion of medical practises are maintained through careful regulatory processes and councils. Individuals take ownership of their own health, through a healthy lifestyle, being well informed, and managing their own health records. This has resulted in some individuals who obfuscate their health records, either intentionally or by mistake, which on occasion leads to fraud. There is continual development to improve this system.

Improved healthcare has managed to reduce time to diagnosis, reduced recovery time, and the healthy lifestyle has reduced the health burden overall. E-health technology facilitates earlier discharge, allows the patient to recover at home while still being monitored, and being able to manage their own health. Innovative health solutions have improved patient outcomes as a whole, and these technologies have resulted in free healthcare available to all Western Cape citizens. A premium option is available to fast track some services and to provide non-essential services at a fee.

Because of the Western Cape lifestyle, the concentration of relevant expertise and the natural beauty, athletes have flocked to the Western Cape to cash in on the world renowned Sports Science Hub. This hub, in keeping with the Province policy, has a holistic and natural approach to Sports Management. This includes eating plans, treatments, natural performance enhancement, injury management and personalised programmes. Scientists at UCT have combined the secrets behind Kenyian speed, San endurance and South African perseverance to reach new levels of performance, and world records are being shattered by the athletes that went through their programmes. This, along with the superb infrastructure here, has led to the Western Cape being selected for the 2032 Olympic Games.

The combination of the expertise and biodiversity led naturally to the Western Cape being the world capital in the development and production of plant-based medicines and healthcare products.

Food

Organic: There is a consciousness about clean living and the link between natural, organic way of approaching nutrition, and the nutrition and health of a population, permeating through all levels of the population, from individuals, food producers and policy makers.

Food is being produced organically, using bio-based pesticides, pest-resistance plants, and this results in a cleaner environment, healthy wildlife, birds and natural fauna returns to the agricultural

scene. This organic agriculture is both genetically modified plants that are resistant, and wild type plants that are managed organically, or even in a protected environment like hydroponics systems and greenhouses.

Small scale food producers are intensive, niche-market targeting foodstuffs like truffle mushrooms, rare herbs, spices and so on. This has special interest to exploiting the natural biodiversity for profit and wellness, and is well suited to the rural areas, so that the rural farmers can participate in the economy without the urbanisation, thereby spawning economic growth. This also causes less pressure for urbanisation, and promotes a healthy community, so that family units are also maintained (the youth doesn't disappear to the cities). This approach means a greater exposure to the biodiversity found in rural areas, further maximising bio-mining. These rural communities have economic upliftment without sacrificing their indigenous practises, are empowered through biotech, leading to an improvement of the GINI coefficient. All of this rests on the drivers of education, biotech awareness and trust and buy-in of the rural community. To achieve this, the implementers have been well trained in user-centric, living lab approaches and are sensitive to the indigenous practises.

From a commercial point of view, food security exists in well-managed large-scale commercial farms that are technology intensive, but favours organic practises as far as possible. The food is bred for superior quality, high nutritional content, as well as being best suited for the African arid environment. The crops are fully balanced in terms of trace elements, that can be consumed on its own (doesn't need supplementation), for example improved sorghum, cassava and madumbi cultivars, and some tree based food farms also exist.

Because of the Western Cape's extensive coastline, and the severe effects of the depletion of global fish-stocks, the mari-culture industry along the coastline is a booming industry. It is very much a lifestyle choice as well, with small and medium scale mari-farmers being very status conscious for trophy fishing and valuable performance wind-driven vessels being very fashionable. This is seeing a growing tourism trade. This new generation tourists are rich, eco-conscious, sustainable adrenaline junkies, mostly. The informal fishing communities fish in mari-reserves that are managed as a nature conservation park with breeding facilities to manage stocks, based on a permit system. There are some tensions between the rich and sustenance farmers, and the tourists still don't understand to keep the kite surfers away from the marine farms, and think these farms are great stunt areas. Public understanding and dedicated stunt areas are in planning.

A network of aquaculture shareholders that run their own small and medium scale farms produce fish for food sales, but also feed their fish wastes into local fish processing plants (that they have

shares and input in), that use the wastes to produce valuable fish-based neutraceuticals, like omega-3 oils. The aquaculture system has a 0% waste policy, and the highest profit margins have the unusual origin of the fish waste! The treated water from the waste process gets recycled back into the system, with the purge streams and too contaminated water being used in fertiliser. The solid waste gets used in pet food. Communication between the processing plant and the shareholders are crucial and includes having representatives on the board.

The commercial fisheries like I&J has the financial clout to achieve major marine and aquaculture infrastructure. These industries have the fortunate position of being allowed to fish in deeper water, with R&D fees and management fees to manage breederies that fall under the nature conservation's mandate. These industries have their own processing plant, R&D divisions and are still run as a profitable company. The understanding between the commercial fisheries and small scale network is beneficial, with the fisheries benefiting from economy of scale while the smaller guys have more niche products that generally are more labour intensive, with input from universities. The commercial fisheries have contracts with informal individuals and communities to exploit the inherent inefficiencies in the large scale processes, in a mutually understanding manner that links in to the commercial fisheries 0% waste policy. The Department of Sustainability policy includes the condition that no wastes whatsoever may be pumped into the ocean, treated or untreated. This includes fishing vessels.

The fishing communities input have contributed to a great improvement in the Western Cape GINI coefficient, and are happy that their way of life did not become threatened when the fish stocks were depleted. They have taken ownership of the ocean, and take personal pride in restocking the fish reserves, in collaboration with the Marine Reserve Management and caring for the planet, while still having a profitable, quality lifestyle.

The wastes that cannot be used for value-added activities get converted to biogas that help offset energy requirements. Most other energy needs come from solar, wind and nuclear sources. Algal Biodiesel is booming as a niche industry, with main profit from the side streams coming from high value oils and skincare treatments. Waste that can be used to generate energy is traded for energy credits under the Department of Clean Energy policy, and converted to energy in a central bio-energy plant, of which several facilities are dotted along the coastline.

Energy & Waste Management

As per the Clean Energy policy, most waste from the Western Cape gets used as raw material somewhere in industry. The rest is converted to harmless waste through bioremediation. The general opinion is that 'Waste' has become a commodity, and is being imported from other

provinces, converted to valuable products and exported out at a premium price. Olive waste is a highly publicised example of this.

Waste management permeates every level of society. It has become a culture, and has made the Western Cape the clean green destination of choice for tourists. Industry has both government and public, profitable management organisations, and civil society have the Bioloyalty card that is a social past time. Credits get loaded to this card as a recycling incentive. The incentive is based on subsidising your income, by recycling, and is mostly targeted to households, but corporate competition and 'green teams' have become "all the rage".

This recycling includes grey water, plastic, tins, glass and so on. Public transport gives extra credits per swipe. Solar applications purchase, 'green technology' investments also give credits, and can fast track your green status. Elite clubs based on how many credits you have exist, and fashionable shopping malls with premium products are available only to the big credit crunchers. The credits can be used to buy food, commodities, holiday time shares etc. Debits are linked to flying, fuel purchases and unsustainable practises. Public transport systems are well developed though, and flying is unfavourable, while tele-conferencing and train-safari's/corporate meeting areas are favoured. People are generally less stressed, drive less, cycle more, are fitter, and pollution is at lowest levels in 50 years. There is an incentive system for calories burnt (through watch logging systems), that also links into the recycling incentive system.

Water management is a crucial venture, as the scarcity of water has made it one of the most valuable commodities these days. On a provincial level there are desalination plants to manage the water situation, and both city managed and private water management companies exist. These companies operate on a break-even-model, generating energy from the waste using biotechnology, and feeding this into the industrial version of the bioloyalty card; the incentivised energy credits system. The water management systems are run on membrane bioreactor principles, and no chemicals are used in the process. While water is still a limited resource, it is well managed and water supply is regarded as secure. The proprietary technology, developed with rural expertise from natural ecosystems incorporating pre-treatment technology to increase the life of the membranes, has been licensed, and the Western Cape water treatment expertise is earning royalties from this.

Energy and waste is closely linked in the Province's mind, and the premise is to be self sufficient as far as possible. Global tension around oil and gas fields in politically unstable areas internationally was seen as an unnecessary risk early on, and policies were implemented to reduce energy dependence, with emphasis on clean energy production, preferably recycling wastes in order to achieve this.

Bio-energy is used extensively to provide energy to the grid from an industrial point of view, with government pushing independent producers to contribute. This is achieved through electricity being generated through biogas and biodiesel driven turbines, as well as solar, wind and nuclear systems. While alternative energies are well developed, the advantages of biosystems are that human, food and agricultural wastes can be digested to produce biogas.

The provision of energy still did not meet demand, and an incentive system was introduced to get small scale biodiesel producers on board. This involved selling biodiesel to the transport system in return for public transport credits, subject to complying with fuel standards. This also fuelled analytical technology advances to supply kits to ensure this from the producer's side. This increased an already well functioning public transport system. The public feels a personal ownership and understanding of the energy cycle.

….and everyone lived happily and greenly ever after.

Annexure 1: Workshop Delegate Details

Project	:	BIOTECHNOLOGY FORESIGHTING PROJECT	Project No.	:	COFISA02
Subject	:	BIOTECHNOLOGY FORESIGHTING PROJECT	Date	:	6 November 2008
Place	:	Devon Valley Hotel, Stellenbosch	Time	:	09hr00

Name	Surname	Organisation	email	Phone	Mobile phone
Reinette	Champonis	Genetwister	info@genetwister.co.za	021 887 5485	082 358 9174
Brian	Goemans	Sitwala Tech	brian.goemans@sitwala.com	021 442 3780	083 458 7924
Fadl	Hendricks	CapeBio	fadl.hendricks@capebiotech.co.za	021 442 3780/87	083 644 0422
Quinton	Johnson	UWC	qjohnson@uwc.ac.za	021 959 3033/2627	
Craig	Landsberg	CapeBio	craig.landsberg@capebiotech.co.za	021 442 3633	082 410 7046
Michelle	Mulder	Consultant	Michelle.Mulder@mrc.ac.za	021 938 0457	072 392 8828
Heather	Sherwin	Bioventures	heather@bioventures.co.za	021 462 2152	083 260 8307
Bernelle	Verster	Marah Mas Industrial Biotech, UCT, BERU	bernellev@gmail.com	021 650 5524	083 545 4993
Mapitso	Molefe	DST	mapitso.molefe@dst.gov.za	012 843 6877	082 8092246
Sandile	Ncanana	Plantbio	sandile@plantbio.co.za	033 846 1999	083 720 0099
Nelisha	Naidoo	Plantbio	Nelisha@plantbio.co.za	033 846 1999	079 986 2227
Shingairai	Masango	Biotech industry researcher	sgm157@bham.ac.uk		
Aki	Ekenberg	COFISA	Aki.Enkenberg@hcg.helsinki.fi		082 889 6981
Viresh	Ramburan	SunBio/TCA Lab, Stell Univ	ramburan@sun.ac.za	021 808 3770	084 408 6067
Fernado	Matinez	Softlech Corporation	fernando@softlech.com	021 845 5665	082 520 4424
Duduzile	Molefe	MRC	Duduzile.Molefe@mrc.ac.za	021 9550924	
Benedict	Bapela	MRC	Nchinya.Bapela@mrc.ac.za	021 9550924	
David	Lefutso	Kayamandi Informatics	david@kayamandi.net	043 726 2650	082 863 7866
Dorcas	Mokalapa	COFISA	DMokalapa@csir.co.za	012 844 1150	082 615 1419
Nirvashnee	Seetal	COFISA	nirvashnee.seetal@dst.gov.za	012 844 1143	079 511 7565
Sibongile	Pefile	Smart Innovation	spefile@smartinnovation.co.za	011 883 0173	083 630 7097
Thembinkosi	Semwayo	Knowledge Crucible	thembinkosi@kcrucible.co.za	021 409 7050	076 103 1399
Bob	Day	NZSD	bday@scientia.co.za	0129988456	082 458 9119

Annexure 2: Workshop Programme

Western Cape Biotechnology Foresight Workshop

Preliminary Programme

21 – 22 October 2008

Tuesday , 21 October

09h00-09h30: Registration and Coffee

09h30-10h45: Introductory Session (in plenary)

- Welcome
- Overview of COFISA
- Explanation of workshop processes
- Presentation and discussion of ***Biotechnology Trends Analysis***

10h45-11h00: Tea/Coffee Break

11h00-12h15: Trends Analysis Session (in working groups)

- Contextualise and consolidate the biotechnology trends analysis

12h15-13h00: Trends analysis report back (in plenary)

13h00-14h00: Lunch

14h00-14h45: Presentation of Western Cape Proto-Scenarios (in plenary)

14h45-16h00: 1st Scenario Session (in working groups based on macro-scenarios)

- Develop a futures wheel from a biotechnology perspective.

16h00-16h30: Futures Wheel report back (in plenary)

19h00-21h30: Networking Supper

Wednesday, 22 October

09h00-10h30: 2nd Scenario Session (in working groups based on macro-scenarios)

- Develop second level biotechnology futures wheel(s)

10h30-10h45: Tea/Coffee Break

10h45-11h30: Futures Wheel report back (in plenary)

- Consolidate the main future biotechnology issues for Western Cape

11h30-13h00: 3rd Scenario Session (in working groups based on macro-scenarios)

- Produce biotechnology proto-scenario fragments.

13h00-14h00: Lunch

14h00-15h30: 3rd Scenario Session (in working groups based on macro-scenarios)

- Produce biotechnology proto-scenario fragments.

15h30-16h30: Wrap-up Session (in plenary)

- Report back on scenario writing
- Discussion of process
- Identification of additional participants for the 2nd Foresight workshop
- Identification of additional members of Western Cape Reference Group
- Thanks

Annexure 3: Draft Biotechnology Trends Analysis

SOUTH AFRICAN BIOTECHNOLOGY FORESIGHT INITIATIVE: TRENDS ANALYSIS

Prepared by: **Sibongile Pefile**
Prepared for: **COFISA**
Date: **October 2008**
Version: **Version 1.1**

Introduction

Over the last ten years there have been dramatic developments in basic research and in applications of biotechnology. This report provides a picture of the major trends in biotechnology that are taking place in South Africa and the rest of the world. The focus is on biotechnology developments in the areas of health, food security, agriculture, animal biotechnology, industry and the environment and natural resources. An overview of emerging disciplines including bioinformatics, genomics, marine and terrestrial microbial biotechnology, nano-biotechnology, stem cell research, and biodiversity is provided and the report ends with a brief summation of emerging biotechnology fields that are providing new applications and uses.

One of the more important benefits of biotechnology is its contribution towards addressing the needs of the poor, particularly in the area of human health (including HIV/AIDS, malaria and TB), food security and environmental sustainability. Many developing countries are harnessing biotechnology tools to improve local socioeconomic conditions. However more can be done to accelerate efforts and increase impact to provide a real benefit to marginalised members of society.

Definition: Because of its crosscutting nature, and ever growing influence, there are numerous definitions of biotechnology. The OECD uses the following definition. Biotechnology is "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or nonliving materials for the production of knowledge, goods and services".

Biotechnology involves a diverse collection of technologies that manipulate molecular, cellular and genetic components and processes with a view to developing products and services for commercial and other purposes. The hallmarks of biotechnology are cellular and genetic techniques that manipulate cellular and subcellular building blocks for applications in various scientific fields and industries such as medicine, animal health, agriculture, marine life and environmental management.

Biotechnology has developed through three major phases.[1] Each phase builds on the science and knowledge of the previous and for this reason it is difficult to determine the exact point in time at which subsequent generations became mainstream activities. As a result, one finds that first generation applications are used in second and third generation biotechnology.

[1] A National Biotechnology Strategy for South Africa, 2001.

The first generation largely involves the use of selected biological organisms to produce food and drink (such as cheese, beer, and yeast). The main cluster of techniques in this generation is fermentation, plant and animal breeding and the clonal propagation of plants.

The second generation is the use of pure cell or tissue culture to yield new products. This generation is associated with the production of metabolites such as antibiotics, enzymes and vitamins. Major developments in this generation include the exploitation of a growing body of scientific knowledge relating to the properties and characteristics of microorganisms such as fungi and bacteria. A characteristic of this generation is that mutagenesis and the selection of strains and cultivars are used to improve metabolite and crop yields.

Third generation, modern biotechnology, emerged in the last 30 years and is associated with recombinant DNA technology. It involves the "application of *in vitro* nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of nucleic acid into cells or organelles.

Distinctive Attributes: Biotechnology is characterised by a number of distinctive attributes.

Firstly, it is a *crosscutting* technology. It is subject to wide application, across many sectors and biological boundaries. For example, a technique developed for and applied in human health can prove equally or even more useful in agriculture, and *vice versa*.

Secondly, the biotechnology industry is a *research-intensive* industry. While the chemicals and the pharmaceuticals industries do some biotechnology research, traditional biotechnology companies tend to be more research intensive and spend between 40% and 50% of revenue on R&D. Historically, it was the interests and enthusiasm of individual scientists and scientific institutions that led to the establishment of the biotechnology industry, sometimes in the absence of a market-pull. This close relationship between research institutions and the new biotechnology industry remains today. Economies interested in diversifying and moving towards a competitive edge in biotechnology need to take measures that will stimulate the emergence and growth of R&D-intensive biotechnology companies.

Thirdly, the development and application of biotechnology techniques requires the convergence of a variety of disciplines. It requires appropriate combinations of biochemistry, genetics, information technology, engineering and several other specialised areas. It is thus a *multidisciplinary* field.

A brief history of SA biotechnology

South Africa has a long history of biotechnology research and development largely dominated by first generation applications that have led to the successful establishment of the brewing, food and wine industries. Recent government policies and strategies are creating promising opportunities for third generation 'modern' biotechnology which includes research in gene therapy, molecular modelling, pharmacogenetics, and structural and functional genomics. Industrial applications that use biotechnology techniques and processes can be found in pharmaceuticals, agriculture, speciality

chemicals, bioremediation and cleaner production methods. The earliest applications in pharmaceuticals targeted the production of proteins such as insulin, diagnostics and vaccines for viral and bacterial diseases. In agriculture the application of recombinant DNA technology has focused on the genetic improvement of crops.

In the past, biotechnology was poorly exploited in South Africa resulting in missed opportunities for benefiting socially and economically from this technological base. This is beginning to change as national and provincial initiatives in support of biotechnology activities gain momentum. An important area of investment is biotechnology for social application and uses.

The DST 10-Year National Innovation Plan sets out to accelerate South Africa's transition towards a knowledge economy. The Plan aims to establish five R&D investment areas that are expected to result in innovation and positive outcomes for the economy. Strengthening the bioeconomy is one of the five focus areas. The vision for 2018 in respect of biotechnology is captured in the excerpt below.[2]

By 2018 South Africa anticipates that it will:

Be one of the top three emerging economies in the global pharmaceutical industry, based on an expansive innovation system using the nation's indigenous knowledge and rich biodiversity

Have designed and created the appropriate technology platforms, and R&D and innovation infrastructure (including structural biology, functional genomics, etc.) that facilitate diagnostic and medical solutions

Have created and funded five theme-specific consortium–based centres of competence that focus on the five top national health priorities, linked to the growth of the local pharmaceutical industry

Increase foreign investment in South African health-related R&D (excluding clinical trials) through reinvigorated health research, with particular emphasis on pharmaceutical R&D

Have designed and created a platform in 3rd generation biotechnology for application to plant/animal improvement and biofarming

Invest in animal vaccine development and manufacturing facilities to strengthen animal health and production

Have created an active biosafety platform providing regulatory guidance and support for product development in 3rd generation plant and animal biotechnology

A key feature of this bioeconomy is that it should contribute towards addressing national priorities in terms of access to and the affordability of health care, the provision of food security, job creation and environmental protection.

Main areas of investment (emerging)

While the industrial (mainly food and beverage) and agroprocessing field continue to play a dominant role in biotechnology applications in South Africa, a new area of biotechnology investment

[2] DST 10 year National Innovation Plan, 2008.

is emerging in human health applications, particularly involving: gene therapy; genetic engineering; nanotechnology; pharmacogentics and drugs; vaccines; and diagnostics research to address the challenges of communicable diseases, namely malaria, tuberculosis and HIV. [3]

In the energy sector, biofuels are creating great interest and to an extent, so are biotechnology applications based on South Africa's local biodiversity. In the agricultural and food security arena, genetically modified crops and foods have increased in importance and application.

Global context

On the international front, the Human Genome Project has made a significant impact on the advancement of genomics globally, and as a consequence, has resulted in major impacts in respect of practices and production processes that are based on living organisms. Even though the human genome project was said to be complete in 2003, it will take much time to determine and map the 28 000 to 35 000 genes identified and to understand how they interact with one another. The project has generated an unprecedented amount of knowledge about human genetics and health. This is made evident by the proliferation of genomics research clusters globally. Although the US leads in biotechnology research, there are excellent scientific groups in the developing world, including Cuba and Brazil in Latin America, as well as China, Korea and India in Asia.

Biotechnology in the health sector is expected to continue delivering incremental changes at least for the next five years. This is based on the preliminary analysis of global clinical trials which indicate that an average of 15 new biopharmaceuticals will be introduced into the market annually up until 2015. While biopharmaceuticals have historically offered a significant therapeutic advantage over small molecule therapeutics, they will continue to account for a relatively small share (approximately 14%) of all new pharmaceuticals. Despite this, in years to come, biotechnological knowledge will be so pervasive, for example for the identification of drug targets, that all new therapies could be based in part on biotechnology.

In agriculture, the use of biotechnology techniques, including both genetically modified (GM) cultivation and marker assisted selection (MAS), is a major success story even though many governments have been reluctant to support these applications. The share of all crops planted that use biotechnology has been rising rapidly over the past 10 years and this trend will likely continue into the future. If it does, well before 2030, all major food crop varieties will have been developed using some form of biotechnology and these crops could account for approximately half of the global output of food, feed and feedstock crops. In some respects, genetic engineering is not much different from other types of genetic manipulation that are routinely carried out to create organisms with desirable characteristics. After all, conventional plant breeding also involves the controlled transfer between organisms of genes that code for economically valuable traits. Where genetic engineering differs from conventional breeding, however, is in allowing genes to be transferred more easily across taxonomic boundaries. With genetic engineering, genes can be transferred not only between closely related organisms (for example, when a gene coding for disease resistance is transferred from a wheat plant to a rice plant), but also between completely different organisms (for

[3] Ernst and Young South African Biotech Review: Discussions with industry stakeholders

example, when a gene coding for cold tolerance is transferred from a fish to a strawberry plant). In conventional breeding, biological reproductive processes impose limits on genetic recombination by erecting barriers against the successful crossing between biologically distinct organisms; either the crossing fails completely, or else the progeny are sterile. With genetic engineering, the "natural" limits do not always have to be respected. For this reason, some people consider genetically-modified organisms (GMOs) to be "unnatural" organisms that violate the laws of nature. Others consider this distinction arbitrary, countering that most foods consumed today have been radically modified over thousands of years through deliberate selection or accidental mutation.Industrial applications of biotechnology are growing rapidly to incorporate unique processes involving enzymes and probiotics technologies Furthermore, a partial shift from petroleum feedstocks to biomass will depend on the economic competitiveness of industrial biotechnology compared to other solutions. While in some regions biofuels could play a substantial role, local supply and geographic conditions may lead to other technologies, such as solar and wind, being deployed (these are more environmentally benign sources of carbon neutral energy). Policy will need to be carefully designed to promote the most environmentally and economically efficient solutions. [4]

KEY BIOTECHNOLOGY SECTORS

Current global biotechnology activities

1. ***Health***

   Research and development activities in human health are broadly directed at therapeutics (e.g., biopharmaceuticals such as biotechnology-derived proteins, antibodies and enzymes, and genetic therapies), medical diagnostics (e.g., tests for specific gene or protein markers), and preventives (e.g., new vaccines developed through recombinant DNA methods).

   Human tissue engineering is an emerging, multidisciplinary biotechnology technique focusing on the regeneration of diseased human tissues. The development of this novel biotechnology promises to change medical practice profoundly and heralds new treatment possibilities for patients.

   Important contributors to the total disease burden are infections like HIV/AIDS, tuberculosis, malaria, respiratory infections and chronic diseases affecting the heart and blood vessels, neuro-psychiatric disorders, diabetes and cancer. The development of vaccines against infectious diseases will be guided by increasing knowledge about pathogen genomes and subtypes, host responses to infectious challenges, molecular determinants of virulence and protective immunity, a better understanding of the mechanisms underlying escaped immunity, and ways to develop novel immunogens. Translational research and the ability to rapidly evaluate multiple candidates in clinical trials can help accelerate the pace of vaccine development.

[4] OECD Biotechnology review

Biotechnology offers promising health solutions for the treatment and diagnosis of HIV/AIDS, tuberculosis and malaria, all of which are major diseases that mainly affect the poor. By understanding the cellular and molecular actions associated with these infectious diseases it is possible to produce more effective, efficient and safe treatment, prevention and diagnostic technologies.

Other emerging areas of biopharmaceutical research as seen in Europe, Canada, the US, Japan and Finland include:

- Prevention, diagnosis and treatments of diseases to improve public health
- Personalised or patient-targeted medicine
- Biodiagnostics, bioinformatics, and medical technologies
- Identification of biomarkers combined with molecular imaging (diagnosis and treatment uses)
- Development of broad reactive synthetic vaccines for human health, especially for the treatment of infectious diseases
- Regenerative medicine – disease-specific stem cells; precursor cells
- Therapeutics for heart disease, arthritis, and rare diseases
- New anti-aging and anticancer drugs
- Neurobiology and brain research.

2. Food

Despite the negative consumer response to GM foods in Europe and some other parts of the world, genetically modified crops are emerging to be an important technology with respect to food security and industrial opportunities. The first generation of genetically modified crops focused primarily on improving agronomic traits for the benefit of the farmer, such as herbicide tolerance and pest resistance. The second generation is expected to try to improve food attributes such as nutritional value, colour, texture, flavour and processing properties.

Several US-based biotechnology companies are involved in agroprocessing. Many products are created by applying natural or engineered microbes to products in order to preserve, extend shelf life or enhance nutritional characteristics.

In India there is significant food biotechnology research being undertaken, including the development of:

- tools for evaluating food safety;
- rapid diagnostic kits for the detection of various food borne pathogens;
- analogical methods for the detection of genetically modified foods and products derived therefrom;
- nutraceuticals, health food supplements, and functional foods for holistic health;
- pre-cooked, ready-to-eat, nutritionally fortified food for school-going children;

- suitable pro-biotics for therapeutic purposes;
- biofood additives.

Reducing micronutrient malnutrition of the poor is possible through enhancing the iron, zinc, and vitamin A content of basic food grains. Fortified crops can significantly improve the health, immunity and well-being of the poor who cannot afford to eat more expensive foods for these nutrients.

3. Agriculture

India, together with many African countries, is conducting extensive research on agriculture, soil and water conservation, animal husbandry, fisheries, dairying, forestry and agricultural education. Special research activities on plant biotechnology have been established at several research institutions where work on staple crops such as soyabean, maize, cassava, potato, rice, cotton, brasica and brinzal is being carried out. Many countries, including India, South Africa, Tanzania, Uganda, Kenya, and Ethiopia, have a growing seed industry where the main type of activity is the production of hybrid seeds for improved crop production and pest resistance. Some research institutions within these countries are beginning to enter the field of DNA fingerprinting, and they also provide identification facilities for viral diseases in plants and animals. Some are starting to employ data mining techniques to harvest additional value from their existing databases. Other areas of research include the production of biofertilisers, as well as the development of better formulations and cost–effective, commercially-viable biopesticides including microbial pesticides, parasitoids and bacteria.

The application of modern biotechnology methods to agriculture has been hailed as the next agricultural revolution, capable of sustaining agricultural production to meet the dietary needs of an expanding world population, as well as increasing demands for improved food and environmental quality. Most commercial agricultural biotechnology products have production-enhancing traits that complement or replace traditional agricultural chemical inputs. Crops generally are designed to be herbicide-tolerant or pest-, virus-, or fungus-resistant. Biotechnology is also used to improve agronomic characteristics of crops, including crops that use nitrogen more efficiently or are developed to better tolerate stress, such as drought, alkaline soils, or frost. Nutraceuticals and health benefits from agricultural products are another growing research area. Such applications play an important role in enhancing food security and access to nutritional crops in developing countries.

In the US, agricultural biotechnologies are increasing crop yields significantly while reducing reliance on chemical herbicides and pesticides. For example, the addition of vitamin A to rice has the potential to save the lives of millions of children in the developing world each year. Similar advances in bioagriculture will help feed a rapidly growing world population with healthier foods.

The US and Canada in the developed world, and China, India, South Africa, Argentina and other Latin American countries in the developing world, are showing a wider adoption of transgenic crops and transgenic crop cultivation. Across the globe, biosafety regulations are being established and implemented to monitor the large-scale and commercial application of GMOs.

Applying biotechnology to marine "farming" (aquaculture) also promises to improve aquaculture production, a goal that has become more critical for meeting increased consumer demand as natural seafood stocks have dwindled.

4. Animal biotechnology

The broad objectives of biotechnology applications related to animal health are largely the same as in human health applications, that is, applying advances in genetics and molecular biology to discover and create new and more powerful:

- therapeutic products (proteins, antibodies, enzymes, genetic therapies),
- diagnostic tools (e.g., for gene or protein markers of disease conditions), and
- preventive measures such as vaccines.

Infectious diseases such as foot and mouth, SARS, avian flu and BSA are a great public health concern due to the increasing emergence of diseases transmitted from animals to humans.

In addition, biotechnology is providing powerful new tools for improving farm animal breeding programmes, including genetic mapping methods to identify both disease-resistant animals and certain specific genes related to animal health weaknesses and defects. In livestock production, biotechnology is being used to develop animals that have better growth and muscle mass and improved disease resistance, and that can utilise feed more efficiently.

Two complementary initiatives have been launched by the European Commission in the area of animal biotechnology. The one is a project aiming at stimulating an informed, public debate across Europe on farm animal cloning and ensuring public participation in the forming of policies. The second is a study on animal cloning and genetic modification and derived products. The studies aim to provide a comprehensive, worldwide picture of research and commercial activities involving animal cloning and/or genetic modification and current and future products that may be obtained, and:

- to identify the potential benefits, risks and socio-economic impacts;
- to compare regulatory frameworks worldwide, and
- to assess new policy implications of the developments of these technologies and of the commercialisation of their products in the EU.

The next phase of agricultural biotechnology products promises improved quality and end-user traits. Some examples of quality-enhanced foods that are being developed include foods with lower saturated fats, increased vitamin content and improved flavour and shelf

life. Biotechnology applications in aquaculture will be able to produce larger fish with less feed, improve spawning, and reduce the time for fish to gain market weight.

On the laboratory side, genetically modified mice and other laboratory testing animals are important tools in modern biomedical research. They provide valuable information on gene functions and serve as models for human diseases. Countries such as Finland have established laboratory facilities for the physiological analyses of transgenic animals. The focus of such facilities is to develop methodologies for small animal physiology studies with an emphasis on the investigation of, for example, cardio-vascular function *in vivo* and *in vitro*.

5. Industrial biotechnology

Industrial biotechnology refers to the use of biotechnology techniques and processes in manufacturing (chemicals, materials, energy) at every stage in the process, from the supply of raw materials to end-of-pipe and clean-up. For instance, industrial biotechnology research is expected to provide a smooth transition from a fossil-based economy to a bio-based economy. Canada, the US and Japan are providing strong support to industrial biotechnology while several European countries have launched their own initiatives and public-private partnerships to promote industrial biotechnology. An international dialogue is also taking place at the OECD level.

One aspect of industrial biotechnology (also referred to as white biotechnology) involves the use of biological systems for the production of useful chemical entities. This technology is mainly based on biocatalysis and fermentation technology in combination with recent breakthroughs in molecular genetics and metabolic engineering. This new technology known as biorefinery, has developed into a main contributor to so-called green chemistry, in which renewable resources such as sugars or vegetable oils are converted into a wide variety of chemical substances such as fine and bulk chemicals, pharmaceuticals, biocolorants, solvents, bioplastics, vitamins, food additives, biopesticides and biofuels such as bioethanol and biodiesel. The biorefinery concept is analogous to today's petroleum refinery, which produces multiple fuels and products from petroleum. By producing multiple products, a biorefinery takes advantage of the various components in biomass and their intermediates therefore maximizing the value derived from the biomass feedstock. A biorefinery could, for example, produce one or several low-volume, but high-value, chemical or nutraceutical products and a low-value, but high-volume liquid transportation fuel such as biodiesel or bioethanol. The biorefinery simultaneously could generate electricity and process heat, through combined heat and power (CHP) technology, for its own use and perhaps enough for sale of electricity to the local or national grid. A significant amount of research is taking place in the area of biomaterials, especially of biomaterials that display multiple uses and biodegradability.

A European – US collaboration has been established to bring together experts from plant and industrial biotechnology to identify opportunities with respect to plant-based bioproducts. Research that is taking place includes enhancing plants for the purpose of producing bio-based products and bioenergy as well as creating value from renewable biological resources. As a renewable energy source, biofuels can supplement hydrocarbon fuels, assist in their conservation, as well as mitigate their adverse effects on the climate. Two major biofuels for the transport sector, bioethanol and biodiesel, are fast becoming popular in many countries around the world. While bioethanol (called ethanol) is produced from raw materials such as molasses, beet, sugarcane juice, grains and tubers, biodiesel is produced from oil (derived from oil-bearing seeds such as *Jatropha curcas*, *Pongamia pinnata* i.e.karanja).

Given Finland's abundant forest resources, it is well placed to utilise biomass as an energy source. Finnish technology is already in use to make efficient use of biofuels. Botany and plant breeding as well as genetic engineering are being harnessed for the development of biofuel production. South Africa is also making use of biotechnology to improve the quality of forest trees, however in this case, for higher-quality paper and furniture production.

Advanced measurement methods and technologies are used both in bioprocesses for purposes of producing chemicals and new materials, for quality control purposes in the food industry and in studies on the state of the environment. In industry, new measurement technologies are needed for instance in bioenergy production.

Biological processes offer the prospect of cheap and renewable resources, lower energy consumption and less waste products. They also raise opportunities for zero greenhouse gas emissions, reduced dependence on (imported) petroleum and new markets for agriculture.

6. The Environment and Natural Resources

Biotechnology has tremendous potential for application to a wide variety of environmental issues including the conservation and characterisation of rare or endangered taxa, afforestation and reforestation. It can help in many ways, including:

- the rapid monitoring of environmental pollution,
- eco-restoration of degraded sites such as mining spoil dumps,
- treatment of effluents discharged by industries (oil refineries, dyeing and textile units, paper and pulp mills, tanneries, pesticide units etc.),
- treatment of solid waste.

In the US, biofuels represent an important avenue, not only to reduce dependence on oil, but also to improve the quality of the environment. In addition, enzymes identified or designed through biotechnology offer ways to clean up waste while reducing pollution caused by industrial processes or accidents.

Several companies in the US are actively researching bioleaching, biopulping, biobleaching, biodesulfurization, bioremediation and biofiltration. The economic and social impacts of environmental applications can include greater manufacturing efficiency and lower production costs, less industrial pollution, and resource conservation. Enzyme-catalysed processes are generally more efficient than chemical processes because input yields are higher and fewer steps are involved. Much of the current environmental biotechnology research is focused on the manipulation of enzymes or enzymatic reactions. However, research groups, especially in the US, are working to create new industrial products from engineered bacteria or cells. In the immediate future, the most promising applications may be in plastics and fuels.

Examples of biotechnology applications that have impact on the environment and natural resources include:

- Air, water and soil quality (e.g., biofiltration, diagnostics, bioremediation, phytoremediation)
- Energy (e.g., microbiologically enhanced petroleum recovery, industrial bioprocessing, biodesulphurization)
- Mining (e.g. microbiologically enhanced mineral recovery, industrial bioprocessing, biodesulphurization)
- Forest products (e.g., biopulping, biobleaching, biopesticides, tree biotechnology, industrial bioprocessing)

The conflict between food and fuel is, at base, an environmental issue. There are many ad hoc initiatives that are attempting to address usually one or other of these, but are in reality counterproductive, at least in the long term. There are also already moves towards much more integrated and coordinated strategies, such as the IAASTD.

EMERGING DISCIPLINES

1. **Bioinformatics. genomics and proteomics, pharmacogenetics, bioimaging**

Bioinformatics:

India, Korea, and to a lesser extent South Africa, have established substantial infrastructures for bioinformatics. Specific techniques include gene shuffling, protein engineering, extremeophiles, molecular breeding, high-level gene expression and protein expression, high-throughput screening, fermentation research, creation of DNA libraries, and subsequent assay development. Bioinformatics holds out strong possibilities of reducing the cost and time of development of new products such as new drugs and vaccines, plants with specific properties and resistance to pests and diseases, new protein molecules and biological materials. As the full genome sequences, data from micros arrays, proteomics as well as species data at the taxonomic level became available, integration of databases formed during genome research require sophisticated bioinformatics tools. Organising these data into suitable databases and developing appropriate software tools for analyzing the same are some of the research challenges.

Genomics and proteomics:

Genetic testing is a growing discipline within the genomics field. Genetic profiles are used to determine an individual's health predisposition. In Europe new applications of genetics are emerging that lie at the interface between *in vitro* fertilisation techniques and pre-implantation genetic diagnosis. Amongst others, Korea is involved in extensive genome and gene therapy research (e.g., gene identification, gene constructs, and gene delivery).

Japan has been concentrating on the development of functional genomics related to health and food and to regenerative medicine and post-genome research. Several countries in Europe (Denmark, Norway, Estonia and Sweden) and also some in the developing world have established biobanks to store information generated during genetic tests.

Pharmacogenetics:

Pharmacogenetics is the study of inter-individual specific genetic variation related to response to medicines. It is often said that pharmacogenetics might enable the pharmaceutical industry to significantly enhance the productivity of drug discovery and development, allowing also the re-evaluation of drugs that have failed because of low response rates in the general population.

India has elected to focus on programmes for understanding the processes underlying molecular genetics and control of gene expression, genetic manipulation of microbes, recombinant DNA products, engineering new protein molecules/new chemical entities, development of immuno-diagnostics and biotechnology of prospective medicinal and aromatic plants.

One important area of research is disease susceptibility gene identification, especially for communicable diseases like leprosy and tuberculosis, noncommunicable diseases such as rheumatic fever, and genetic diseases such as thalassemia.

Bioimaging:

Bioimaging research is an interdisciplinary area that concentrates on developing imaging techniques ranging from molecular to cellular, from single molecule to whole animal imaging, from single-cell analysis of sub-cellular events to high-throughput screening. Living systems have the ability to respond to changing environmental and physiological conditions in a dynamic fashion. Imbalance of these processes leads to disturbed development and disease. The complex cellular and molecular signalling and regulatory processes underlying development and homeostasis can only be understood comprehensively by analysis in the intact living organism. Molecular interactions are frequently transient and context-dependent, necessitating *in vivo* analysis to generate relevant insights into the molecular mechanisms. Biomedical research and drug development have thus an increasing need to

analyse and monitor these dynamic processes in cellular physiology, development and disease in the living organism using bioimaging technologies.

Molecular imaging technologies are being developed to examine the integrative functions of molecules, cells, organ systems and whole organisms. The organisms range from viruses to bacteria to higher order species, including humans, and in each case, molecular imaging is used to examine the structure and regulatory mechanisms of their organised functions.

Biomedical imaging refers to methods that open new ways to see the body's inner workings, measure biological functions, and evaluate cellular and molecular events using less invasive procedures. While X-ray imaging is a familiar example, it represents only one aspect of this fast growing field. Biomedical imaging allows physicians to detect disease and injury at their most curable stage and enables the delivery of less invasive and highly targeted medical therapies. Cellular and molecular imaging techniques combine new molecular agents with traditional imaging tools to capture pictures of specific biological pathways and processes in a living organism. These approaches help researchers study normal biological processes and to diagnose and manage diseases.

Advanced, multimodal imaging techniques, powered by new computational methods, are changing the face of biology and medicine. These new imaging modalities produce information about anatomical structure that is linked to functional data, as described by electric and magnetic fields, mechanical motion, and metabolism. This integrated approach provides comprehensive views of the human body in progressively greater depth and detail, while gradually becoming cheaper, faster, and less invasive. As a result, imaging becomes more common and more familiar, which in turn produces new scientific specialties that rely on particular combinations of imaging, computer science, and medicine.

2. Marine and terrestrial microbial biotechnology

In the US, Canada, Germany and Japan, there is a growing number of institutions involved in the research of microbial biotechnology applications. The application of biotechnologies to micro-organisms is a relatively new area in the discipline. In the expanding search for biological organisms that can be used in the prevention, diagnosis, and treatment of diseases or for industrial applications, companies are investigating marine and terrestrial organisms that have adapted to extreme conditions such as high pressure or heat, or total darkness. In the oceans and in extreme conditions on land, these types of "extremeophiles" and other, better-known types of microorganisms are beginning to provide some commercial biotechnology products. For example, recent studies and research suggest that products derived from diverse microorganisms, including green algae and a painkiller derived from snails, have the potential to be potent weapons in fighting cancer. Other applications include:

- processes related to fermentation, bioprocessing, and biotransformation extractions, purifications, and separations;
- microbiology, virology, and microbial ecology; and

- diagnostic tests and antibiotics.

Inspired by the mechanisms of sea urchins and Venus flytraps, researchers in the US have developed a new gel that could be used to make microscopic drug releasing devices and water-repellent clothes.

The economic potential of the sea as a source of novel genes and gene products, biopolymers, novel enzymes, new therapeutic leads, and other value-added products such as osmo-tolerant crops, has hardly been explored. Marine organisms also present immense potential as biosensors for pollution monitoring as well as bioreactors for production of novel products. The study of deep-sea organisms including marine microbes may well have tremendous implications for human health. Bioprospecting from marine bioresources are common research activities in South Africa, Korea, New Zealand and Australia.

In Finland, facilities have been established to offer support and services in bioprocess development and production of biomolecules by way of different fermentation strategies with micro-organisms, plant cells and eukaryotic cells. The activities include molecular genetic work, production of recombinant proteins and purification of cellular components.

3. Nano-biotechnology

Nanosciences and nanotechnology are important for underpinning the advances in life sciences and biotechnology. The convergence of inorganic nanotechnology and biotechnology into nano-biotechnology has the potential to yield breakthrough advances in medical diagnosis, targeted drug delivery, regenerative medicine and chemicals screening.

Europe is establishing a nanotechnology research platform and the priority research areas chosen include:

- nanodiagnostics including medical imaging
- targeted drug delivery and release
- regenerative medicine.

Integrated nanotechnology research is increasing. An example of such research is the application and integration of nanotechnology, advanced materials and computer science. Nearly every country with a biotechnology strategy is targeting nanotechnology research initiatives that mainly comprise activities in medical applications.

Researchers in India and South Africa are working on developments in novel biomaterials for micro-particle and nano-particle encapsulated drugs, proteins and other molecules. These offer improvement in quality of many therapies with minimal side effects. Nanoscale structured materials and devices hold a great promise for advanced diagnostics, biosensors, targeted delivery and smart drugs. The application of nanotechnology in bioengineering together with biotechnology offers a wide new range of advanced biomaterials with

enhanced functionality; and combined with tissue engineering, it has the potential to provide true organ replacement technology.

4. Other

Bionics:

Bionics is an area related to biotechnology where ideas are taken from nature and implemented in new applications and machines. Bionics (also known as biomimetics, biognosis, biomimicry, or bionical creativity engineering) is the application of biological methods and systems found in nature to the study and design of engineering systems and modern technology. Examples of bionics in engineering include the hulls of boats imitating the thick skin of dolphins; sonar, radar, and medical ultrasound imaging imitating the echolocation of bats.

In the field of computer science, the study of bionics has produced artificial neurons, artificial neural networks, and swarm intelligence. Evolutionary computation was also motivated by bionics ideas but it took the idea further by simulating evolution in silico and producing well-optimized solutions that had never appeared in nature. Countries such as Korea have invested extensively into biosensors, biomimics and biomems.

Biodiversity:

Biotechnology is widely utilised to add value to traditional knowledge, as well as to tribal and folk medicine. Medicinal plants are the prime targets of bioprospecting initiatives. The tools of biotechnology are being used for conservation and genetic characterisation of plants. Research efforts of this nature are taking place in Korea, South Africa, India and many other countries in Africa and Latin America. Most research effort is directed at special programmes for the collection, assessment and preservation of the genetic sources of biodiversity.

Stem cell Research:

Stem cell research continues to be a hotly debated and contentious area of biotechnology. Stem cell research involves taking human cells either from human embryos that are less than two weeks old that will never be transplanted into a woman's body, or from the blood in umbilical cords. These stem cells can be used to grow new cells to treat certain diseases in any part of the body. Embryonic stem cells hold promise for the development of organs of the body. Denmark, Italy, UK, Hungary and the Netherlands are the leading European countries in this area of research.

Stem cells are not only obtained from embryos, but can also be taken from adult tissues and organs such as bone marrow, fat from liposuction, regions of the nose, and even from cadavers up to 20 hours after death. These stem cells can grow or differentiate into different cells and tissues of the body. Stem cells have been used in cancer treatments either to grow new healthy cells or eliminate cancerous cells through inducing the generation of a "new"

immune system. Thus said, the use of adult stem cells is limited by the fact that there are very small quantities of adult stem cells in the body and they are difficult to isolate. Furthermore, adult stem cells may not have the same capacity as embryonic stem cells to multiply in the laboratory, and they may only be able to develop into certain kinds of tissues.

Concluding remarks

The next generation of biotechnology research involves combining advanced technologies in fields such as nanotechnology, materials and electronics with technologies and know-how in the life sciences. Countries that have a high level of research expertise in biomaterials, bioenergy, bio-ICT and bioinformatics, and the integration of these different fields will be well-positioned to capitalise on opportunities that open up in the intersections of these fields.

Bibliography

- A National Biotechnology Strategy for South Africa, 2001, Department of Arts, Culture, Science and Technology.
- Masiga, D K and Isokpehi, R D, Opportunities in Africa for Training in Genome Science, 2004, *African Journal of Biotechnology,* Vol 3(2), pp. 117-122.
- Life Science and Biotechnology – a Strategy for Europe. Third Progress Report and Future Orientations. The European Commission, 2005. [COM (2005) 286 Final]
- Cahturvedi, S. Status and Development of Biotechnology in India: An Overview, 2002. RIS-DP # 28/2002.
- A survey of the Use of Biotechnology in U.S. Industry, 2003, U.S. Department of CommerceTechnology Administration Bureau of Industry and Security.
- Daggett, B. Biotechnology Trends, 2007. International Centre for Leadership in Education. Views You Can Use, Vol VI no. 8.
- National Biotechnology Development Strategy, Department Of Biotechnology, Ministry Of Science & Technology Government Of India.
- http://www.nap.edu/catalog/12216.html. Accessed 09 September 2008.
- May, M and Heebner, G. Drug Discovery and Biotechnology Trends. Nanotechnology: Giant Successes from Atom-size Devices, www.science-benchtop.org.
- Rhee, K S, Korean initiatives on Biotechnology: Challenges and Opportunities, Korea Research Institute of Bioscience and Biotechnology, 2004.
- Europeans and Biotechnology in 2005: Patterns and Trends, Eurobarometer 64.3 on Biotechbology, 2006.
- Pray, E C and Naseem, A, Biotechnology R&D: Policy Options to Ensure Access and Benefits for the Poor, ESA Working Paper No. 03-08, 2003. www.fao.org/es/esa.
- Stenberg, L, Policies for Life Sciences and Biotechnology in Japan. Strategy Development Division, VINNOVA and Faculty of Engineering, University of Tokyo, 2007.
- OECD Biotechnology Update Internal Co-ordination Group for Biotechnology (ICGB), OECD Newsletter No. 19, 30 April 2008
- National Biotech Survey, eGoliBio Life Sciences Incubator. 2003.
- Gastrow, M, Great expectations: The state of biotechnology research and development in South Africa; African Journal of Biotechnology, Vol 7 (4), pp 342 – 246, 2008.
- Maheux, H, Canadian Trends in Biotechnology, 2nd edition. 2005.
- Key Issues on Biotechnology, United Nations Conference on Trade and Development, UNCTAD/ITE/TEB/10, 2002.
- Seiler, A ,Biotechnology and Third World Countries: Economic Interests, Technical Options and Socio-economic Impact , Briefing Paper No. 9, Third World Network,
- Alhassan, W.S. The Case for Biotechnology In Africa's Agriculture, Knowledge for Development, 2004.
- www.biotech.ca
- South African Biotech Review: Discussions with Industry Stakeholders., Ersnst and Young, 2006.
- FinnSight 2015: The Outlook for Science, Technology and Science, 2006
- CCPL, India Biotech and Pharmaceutical Report 2008,
- DST 10 Year Innovation Plan towards 2018, DST, 2007.
- Canadian Biotechnology Strategy, accessed from: http://www.tbs-sct.gc.ca/rma/eppi-ibdrp/hrdb-rhbd/dep-min/ic/cbs-scb/2005-2006_e.asp

- Hernandez-Cuevas, C and Valenzuela, P, Strategies to Capture Biotechnology Opportunities in Chile, 2004. Accessed from: http://www.ejbiotechnology.info/content/vol7/issue2/full/6/index.html
- http://www.scidev.net/en/latin-america-and-caribbean/
- http://www.scidev.net/en/search/results?term=Biotechnology

Glossary of terms

Bioinformatics	Bioinformatics derives knowledge from computer analysis of biological data. Such data can consist of the information stored in the genetic code, but it can also be experimental results from various sources, patient statistics, and scientific literature. Research in bioinformatics includes method development for storage, retrieval, and analysis of the data. Bioinformatics is a rapidly developing branch of biology and is highly interdisciplinary, using techniques and concepts from informatics, statistics, mathematics, chemistry, biochemistry, physics, and linguistics. It has many practical applications in different areas of biology and medicine.
Biomass	Plant material, vegetation, or agricultural waste used as a fuel or energy source.
Biopharmaceuticals	Simply put, biopharmaceuticals are drugs created by means of biotechnology, especially genetic engineering. They are products which are derived using living organisms to produce or modify the structure and/or functioning of plants or animals with a medical or diagnostic use.
Enzyme	A protein (or protein-based molecule) that speeds up a chemical reaction in a living organism. An enzyme acts as a catalyst for specific chemical reactions, converting a specific set of reactants (called substrates) into specific products.
Gene	The basic biological unit of heredity. A segment of deoxyribonucleic acid (DNA) needed to contribute to a function.
Gene therapy	The goal of gene therapy is to cure a genetic disease by repairing the damaged gene responsible for the disease. It involves introducing a normal copy of the gene into cells containing the damaged version. The cells then can produce the normal protein.
Genetically Engineered Microorganism (GEM)	This term refers to bacteria, fungi, yeast or other microorganisms that have been genetically altered using molecular genetics techniques such as gene cloning and protein engineering. GEMs are a subset of GMOs.
Genetically Modified Organism (GMO)	This term refers to plants, animals or microorganisms that have been genetically altered using molecular genetics techniques such as gene cloning and protein engineering.
Genome	All of the genetic information, that is the entire genetic complement and the hereditary material, possessed by an organism. It is the total DNA present in the nucleus of every cell of an organism.
Genomics	The study of genes and their function. Genomics aims to understand the structure of the genome, including mapping the genes and sequencing the DNA. Genomics examines the molecular mechanisms and the interplay of genetic and environmental factors in disease.

Human tissue engineering	Tissue engineering / regenerative medicine is an emerging multidisciplinary field involving biology, medicine and engineering, and entails restoring, maintaining, or enhancing tissue and organ function. In addition to having a therapeutic application, where the tissue is either grown in the patient, or outside the patient and then transplanted, tissue engineering can have diagnostic applications where the tissue is made *in vitro* and used for testing drug metabolism and uptake, toxicity, and pathogenicity.
Immunogen	A substance that produces an immune response when introduced into the body.
Nano-biotechnology	Nano-biotechnology sits at the interface between the chemical, biological and physical sciences. It is concerned with nanometre-scale systems that may be produced from either a top-down approach, where larger units are disassembled, or a bottom-up approach involving component assembly. Utilising nanofabrication and/or processes of molecular self-assembly, nanotechnology allows the preparation of a range of materials and devices including tissue and cellular engineering scaffolds, molecular motors, and arrays of biomolecules for sensor, drug delivery and mechanical applications.
Pharmacogenetics	The merger of pharmacology and genetics into a field that pertains to the hereditary responses to drugs. It is the is the study of how the actions of and reactions to drugs vary with the patient's genes
Probiotics	Bacteria that are beneficial to a person's health, either through protecting the body against pathogenic bacteria or assisting in recovery from an illness. Probiotics counter the decimation of helpful intestinal bacteria by antibiotics. Probiotics given in combination with antibiotics are therefore useful in preventing antibiotic-associated diarrhoea.
Proteomics	The study of the proteome, the complete set of proteins (their roles, their structures, their localisation, their interactions, and other factors) produced by a species, using the technologies of large-scale protein separation and identification. Proteomics analyses, for example, the proteins of human fat cells , corn leaves, or an organism like the bacteria .

Annexure 4: Three Proto-Scenarios for the Western Cape – 2030

Three Scenarios for the Western Cape

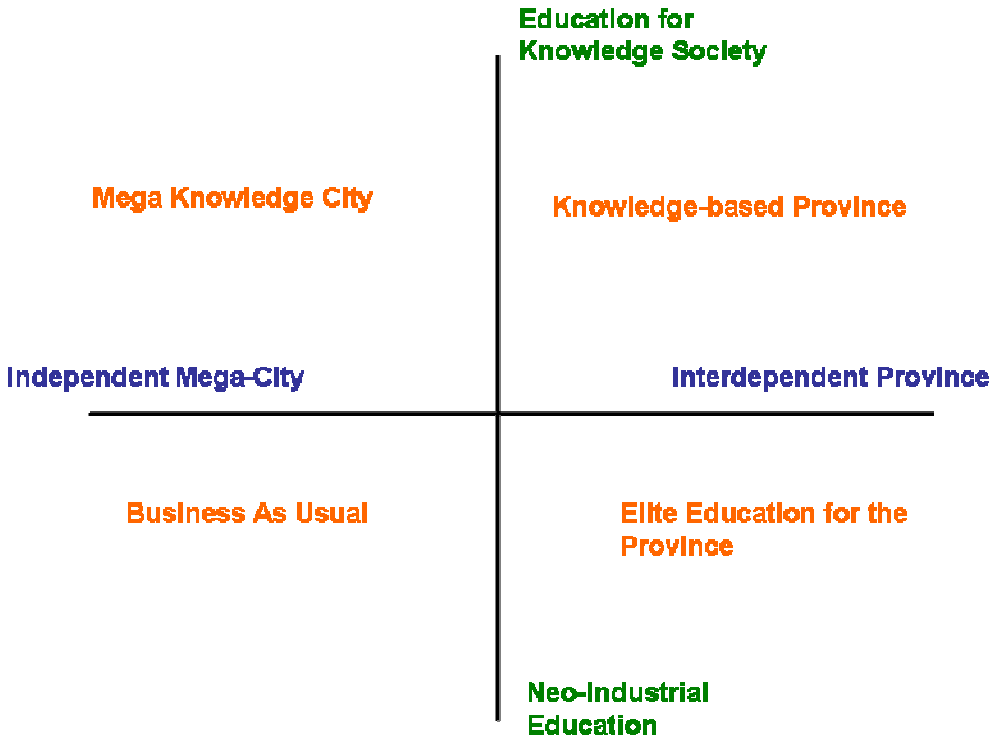
16 October 2008

Introduction

Between November 2007 and February 2008, COFISA undertook a Foresight exercise involving a series of three workshops to investigate realistic and implementable futures in the context of the development of regional systems of innovation in the Western Cape. In the first of these workshops, each of four working groups produced a "Futures Wheel" providing their combined insights into the Western Cape in 2050. The contents of these futures wheels were combined and synthesised, revealing two major areas of contrast, i.e.:

- 'Independent' Cape Town versus Interdependent Province;
- Education for a Knowledge Society versus Neo-Industrial-oriented Education

These axes were then used to create the following quadrant diagram. The three scenarios set out below in this document are based on three of these quadrants.



It is important that the delegates familiarise themselves with each scenario prior to the workshop, since they form the basis of several activities to be undertaken which are intended to result in three Western Cape Biotechnology Scenarios. These activities are highlighted in yellow in the following preliminary agenda:

Workshop agenda

Day 1

In plenary
- Overview of COFISA
- Explanation of process to be followed
- Presentation of biotechnology trends review

In working groups
- Contextualise and consolidate the biotechnology trends review
- Plenary report back

In plenary
- Presentation of the provincial macro-scenarios

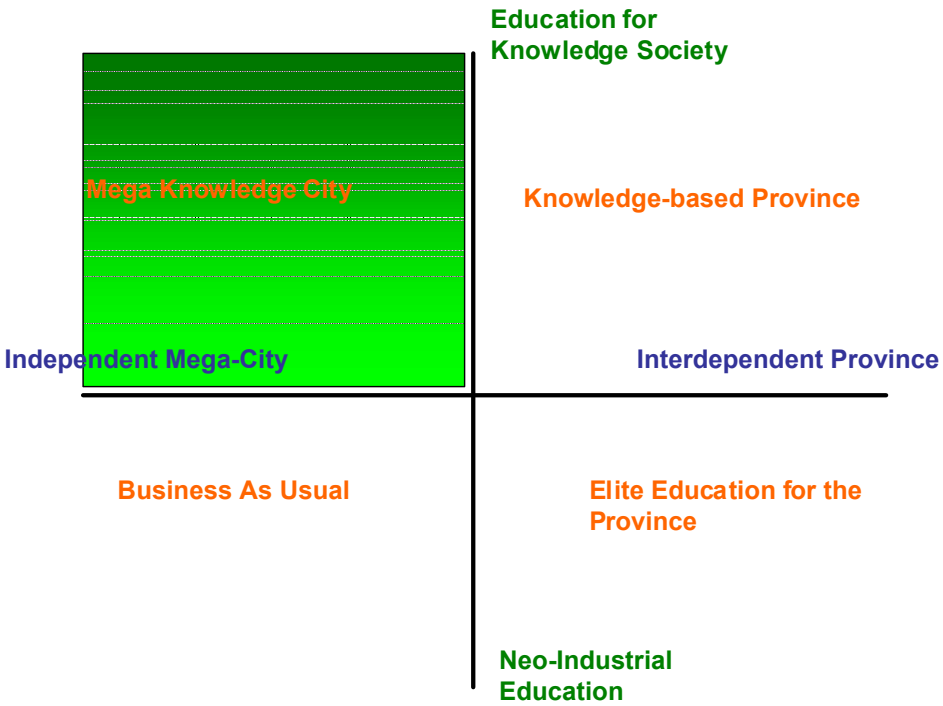
In working groups (each focused on one macro-scenario)
- Develop a futures wheel from a biotechnology perspective.
- Plenary report back

Day 2

In working groups (each focused on one macro-scenario)
- Consolidate the main biotechnology futures issues;
- Write proto-scenario fragments.
- Plenary report back and wrap up discussion.

Please note that it is also important that each delegate spend time prior to the workshop on the trends analysis document which was distributed a few days ago. Your insights and additions to this document as we contextualise it for the circumstances (now, *and in the future*) of the Western Cape are the basis of the other main process during the workshop (highlighted in green).

Scenario 1: Mega Knowledge City



The years: 2009 to 2019

At the close of the first decade of the century, as global signs of the emerging knowledge society became increasingly clear, many in Cape Town realised that for it to prosper in this transforming environment, major strategic decisions were necessary. With remarkable foresight and resolution for the time, Cape Town's local government embarked on an innovative strategy to transform the city into a premier example of a knowledge society. It was widely believed that to attempt to devise such a strategy that included the whole province would be an exercise in futility. The province was too diverse, and it was feared that such an approach would result in a strategy that was limited to the lowest common denominator. Cape Town has never been afraid to plot its own course, and this strength came to the fore in resisting the call to what was perceived to be mediocrity. Instead, the focus was on world-class excellence, and this became the mantra of all.

Cape Town was fortunate to be endowed with excellent educational facilities, and

these formed the basis of the strategy: all educational efforts were focused on promoting and enhancing a metropolitan knowledge society. Multiple opportunities were created for people to advance their learning, across a wide range of subjects and skill sets. Cape Town's citizens, from all sectors, rose to the challenge and embraced a lifestyle of lifelong learning. It was most gratifying to see how those from Cape Town's poorer suburbs refused to be left behind in the pursuit of knowledge. By 2018 productivity levels had risen dramatically, driven by remarkable improvements in the skill profile of the workforce, so much so that Cape Town had to encourage unskilled immigrants to take on the less desirable jobs.

It was not only the unskilled that saw opportunity in Cape Town. The population burgeoned with young and highly-skilled knowledge workers from South Africa and the rest of the world who thrived in the exhilarating atmosphere. This began with the 2010 World Cup, when many young visitors vowed to return, and began to influence the transition from afar. The promise of the knowledge society, namely benefits for all, seemed to be being fulfilled.

It is true that 'all' did not benefit with complete equality. There was still a considerable differentiation between those who had the means to pay for private education, and those who made use of publically-funded schools that did not charge the learner. Private education at a primary and secondary school level was a growth industry, and the academic levels achieved by these institutions matched the best in the world. In contrast, most state-funded schools were mediocre in the quality of education that they offered. At a tertiary level a world-class education was available to all, and scholarships were plentiful for those who could not afford the relatively modest tuition fees, but the differentiation at primary and secondary levels still left its mark.

A similar pattern was evident concerning health care: private health care facilities compared well with the very best in the world, while public facilities provided somewhat adequate service, at nominal cost to those who could not afford to pay for the cost of treatment.

A key mechanism for unlocking the benefits that the knowledge society promised was an emphasis on partnerships and on working together, across the private and public sectors, education, NGOs and civil society. As the fruit of this approach was experienced, more and more joined in. There was a wide understanding that only a win-win approach was viable. People were focused on creating a better future for themselves, but not at the expense of others. They focused on the best interests of the city along with what was beneficial for themselves.

For ten years Cape Town went from strength to strength. It was viewed by many as the premium place to live in South Africa, with the right balance of economic prosperity, service provision, and quality of lifestyle. Entrepreneurs abounded, and it was only a half joke that the lifestyle for many of the highly-skilled youth consisted of coding, creating or consulting in the morning, surfing in the afternoon, and blogging in the evening.

The sectors that experienced the most growth included ICT, legal, research (including biotechnology) and entertainment (especially digital, and including interactive multimedia and multi-user). Advanced manufacturing also saw major gains, and the beginnings were made of an aqua-farming industry.

There were many immigrants from other parts of the country, and also from further afield. In particular, people from Western Cape's rural areas streamed in, but only a subset could benefit from the education and healthcare as the large numbers exceeded the ability of the facilities to handle them.

These large numbers of economic refugees, living in crowded conditions around Cape Town in combination with global warming, created an ideal environment for amplifying and accelerating the emergence of new strains of infectious diseases. In 2013 a very virulent new strain of TB emerged, which preferentially attacked young babies and the very old.

The outbreak of TB was attacked with first-world remedies, but these proved ineffectual due to it being a new strain, and also the lack of compliance by patients being treated. Traditional medicines were rejected by the city's medical authorities without being seriously considered. As the death toll rose to over 150,000 in 2014, the impact on Cape Town's reputation, not to mention the increased medical bill was hurting the city's growth, including tourism.

The TB outbreak did generate top-quality research by UCT's Medical School, with a stream of 1st world research citations and awards. But, research results did not filter down to the realities of the poor for many years. Although UCT researchers were involved in the research which eventually found a cure (involving substances found in herbal treatments in the Far East), the commercialisation of the research took place in India. The disease was eventually controlled in 2024, but the treatment remains an expensive import to this day.

Energy independence was a major concern for the city, especially because of the distance between Cape Town and the nation's traditional source of energy: coal. Innovative energy solutions were successfully implemented, and Cape Town's spirit of independence was strengthened. This also meant that Cape Town's

hinterland was largely taken for granted. After all, many from those parts were benefitting from Cape Town's success by becoming new Capetonians! But little attention was paid to the essential resources provided by the rural areas, such as food and water, despite these being essential components for sustaining the urban areas.

Such an independent mindset did not sit well with the national Government, which increasingly interpreted it as a direct challenge to its authority. By this stage, the Western Cape Provincial Government had become little more than an extension to Cape Town City local Government. The Provincial Government was increasingly being bypassed by both of the other levels.

The years 2021 to 2030

It was particularly the young who flocked to Cape Town. They enjoyed the bohemian lifestyle that was developing, the opportunities to enjoy the sea and other attractions. Cape Town enjoyed an image of being a fun place to live and work, and it attracted highly-skilled knowledge workers from far and wide. Older Capetonians often felt that their established and more conservative way of life was threatened by these newcomers. A sense of alienation grew amongst the older segment of the population, and they constantly agitated for more controls on the wilder aspects of the subculture that was mushrooming in places such as Observatory and Green Point. By 2025, many of these Cape Town elders had moved on to other coastal towns (such as Hermanus and George), and their absence amplified the downturn once it set in.

In contrast to UCT, UWC tried to extend its learning resources into some of the rural areas by setting up several learning centres and developing locally Open Distance Learning (ODL) materials of high quality and relevance. A few outstandingly talented individuals emerged from this approach. However, UWC over-stretched its resources in this experiment and with insufficient support, the initiative to move into the mainstream faltered.

There were several confrontations between Cape Town and the national Government in the twenties over the way Cape Town forged ahead on its own path. When the national level began imposing budget restrictions, in an attempt to rein in this unruly 'child', Cape Town was initially in a position to shrug them off, such was the metro's economic success. For indeed, the growth phenomenon was not restricted to Cape Town city itself. Surrounding areas including Stellenbosch, Gordons Bay and Melkbosstrand were all part of the boom. However, outside these areas the picture looked very different. There were growing signs of decay in many of the more rural towns and communities. They

were mostly excluded from Cape Town's success, and had no sustainable strategies or, especially, human capacity to chart their own course. The Provincial Government was so weak that it had no power to ensure a more equitable, and hence a more sustainable approach.

One exception to the neglect of the Western Cape interior was the attention that was paid to the wine industry. Wine had always been an essential ingredient of the Cape's lifestyle, and so special arrangements were made to ensure that the wine industry prospered, not only to supply Cape Town's need for a secure supply of good-quality wine, but also for growing exports.

What no one had reckoned on was outbreaks of moulds that devastated first the vines in 2023, and then both the vines and citrus plants in 2025. Later research demonstrated that these moulds had emerged in the valleys of the Western Cape with their great biodiversity of flora. Due to global warming and the consequent lack of freezing temperatures, the valleys had become perfect incubators for many new strains of mould. A plethora of fungal infections was generated that overwhelmed the resources of the authorities.

In fact the first outbreak in 2023 had been contained remarkably well through the use of imported expertise. But when the second struck in 2025 there was a false sense of confidence that proved very costly. The multiple virulent moulds refused to yield to imported and costly treatments. Initially the research and other resources in Cape Town used their best efforts to crack the problem, but after little success the focus of their priorities changes. It was felt that the problem was not Cape Town's, that the city should not be expected to shoulder the problem. Instead, they (perhaps cynically) expected the Provincial Government to provide the necessary resources. But the Government was in no position to do so. The result was the significant decline of the wine and citrus industries. There was even a negative impact on tourism because of the restrictions imposed on tourists who wished to visit wine farms, and the "tainted" image that South African wines now carried.

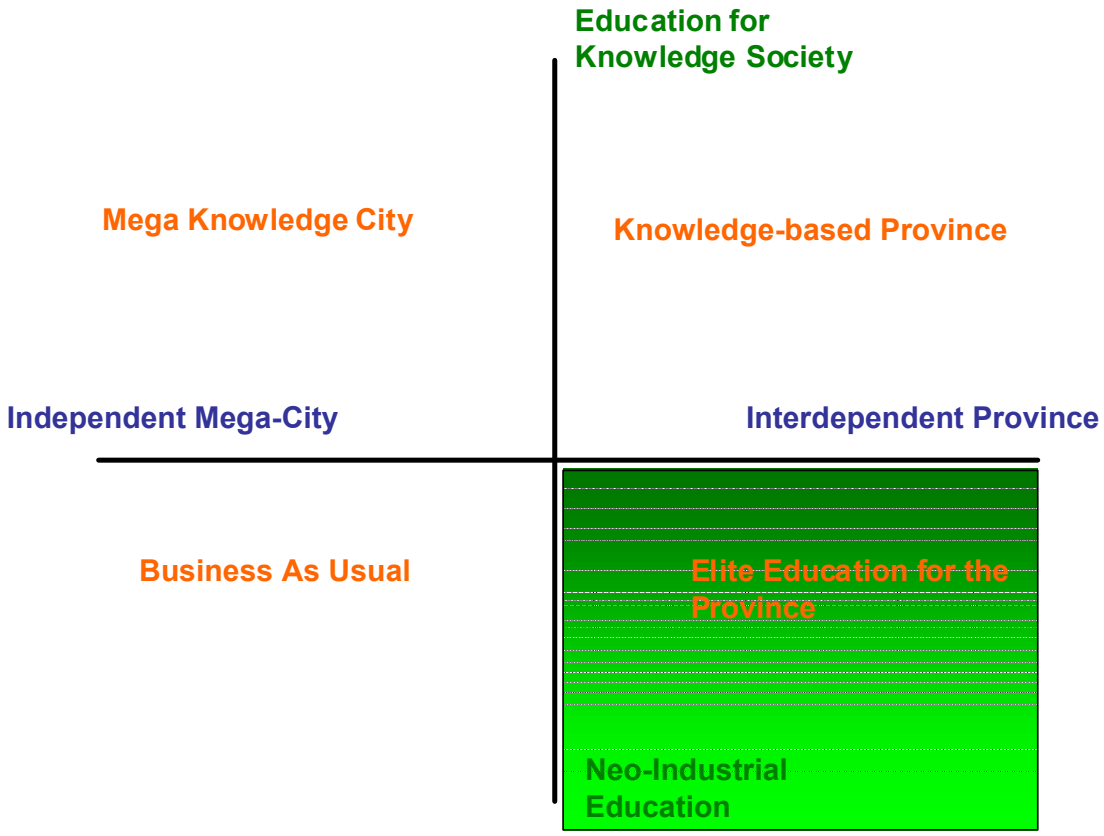
The decline of the wine industry was the worst in living memory. Urban areas that had previously been just comfortable economically now slipped below the poverty line. Sadly, when Cape Town appealed for help their cries fell on deaf ears. The ongoing conflict had generated such bad blood that even the sight of malnourished children could not sway opinions. After all, poverty was an ongoing feature for much of South Africa's population.

Cape Town experienced further pressure when new regulations were promulgated in 2026 that allowed much greater discretion on the part of the

national Department of Education in allocating funds to the universities. These changes were brought into being specifically to address the problem (as seen by the national Government) with Cape Town. In 2027 the universities of Cape Town, Western Cape, Stellenbosch and CUT took on average a 35% cut in funding, which was in a word, disastrous. After huge protests the funding was increased, but only to a level that corresponded to an 18% cut. The universities hobbled along during 2027, dipping deeply into their reserves, but when the budget was announced that funding levels would be increased by only 2% for 2028 (in the face of an inflation rate of 9%) the result was that scores of teaching staff were retrenched at the end of 2027. The quality of the education nosedived.

Cape Town's resources for providing top-class learning opportunities had been the engine room for a decade or more of growth, but now the engine was running out of fuel, the terrain being traversed was increasingly difficult, and a solution was not in sight. Was it time for a new vision and strategy?

Scenario 2: Elite education for the province



The years 2009 to 2020

The growth and development strategy of the provincial Government of the Western Cape sought to nurture development across the whole province. The strategy recognised that uneven development, concentrated for example in the major urban centres, would not be sustainable. The provincial Government pursued this strategy with the (limited) resources at its disposal, both financial and human.

Cape Town was run by a comparatively small elite, who were highly educated but represented a fairly narrow section of the population. Nevertheless, they believed that for the long term sustainability of the vision they had, namely that Cape

Town should become a world-class city in terms of economics and quality of life, it was essential to develop the region as a whole. Cape Town clearly depended on its hinterland for food, water, energy and unskilled labour, and these resources needed to be reliably secured for the long term. In other words, what was needed was a certain balance between rural and urban development.

Thus on one level, Cape Town was aligned with the provincial Government's approach to development.

Cape Town has always benefited from strong educational institutions, and in their approach to development, this legacy was built upon and extended, but within a framework of seeking to achieve academic excellence for a comparative few who would provide the necessary leadership and expertise. All of Cape Town's universities, to a greater or lesser extent, but particularly UCT and the University of Stellenbosch, laid great emphasis on finding the brightest students to enter their classrooms. There was little concern for the 80% who did not achieve top marks. Instead, the focus was on the top 20% who would provide the managerial class, and even more so on the top 2% who would provide the overall visionary leadership.

In this competitive environment universities had little incentive to collaborate, but instead competed strongly, for funding, students, staff and resources. Duplication abounded, and scarce resources were not pooled. Because revenue from the state was tied to the number of students graduating, the universities undertook ever-more-sophisticated marketing campaigns,

Cape Town's top management elite understood well that their vision would take years of commitment and investment to realise, but their theories and models convinced them that the benefits would be worth the time and cost. While most of the population lived with a short-term focus on what served their best and current interests, the elite focused on long-term strategic thinking and planning that grappled with all the complexities of systemically growing both Cape Town and the province. In their minds it was only they who appreciated what was in fact necessary to achieve the much vaunted "quality of life for all".

Growth was slow (as was anticipated by those at the top). Considerable investments were made in both rural and urban areas to promote long-term growth. Much of the investment went into strengthening the existing education system. While a high-quality of education for all was the stated policy, and was pursued on a superficial level, the subtle but clear focus remained on identifying the small cadre of top performers at school, and then nurturing them with special programmes and facilities. Competition for inclusion in these favoured

programmes was fierce, and the achievements of those youngsters who made the grade were often outstanding, comparing favourably with the best in the world.

Both the slow growth of Cape Town itself, and what many termed as inadequate investment in the city due to priorities in the province as a whole, were the cause of increasing dissatisfaction on the part of many of the brightest and best in the city. It is true that at the very top this dissatisfaction was almost non-existent, but that could be ascribed to the special privileges and incentives that had been put in place over the years for this select group. (This was, of course, an integral part of the long-term strategy. If the long-term thinkers were not successfully retained, then all would come to nought. It was therefore in the best interests of everyone that they have the needed incentives to remain in Cape Town until the benefits of the strategy were realised, making such incentives no longer necessary). But aside from the very elite, there were signs that cracks were forming as highly-skilled people began leaving Cape Town for other parts of the world. Those who had the most attractive alternatives began to leave – a process which selects for mediocrity.

In 2014 a TB epidemic struck. The combination of the lifestyle lived by many around Cape Town, along with the effects of global warming, created an ideal environment for the development of a new strain of TB. It turned out it was an extremely virulent strain that wreaked havoc amongst the very young, and the elderly. The death toll in the first year alone was 120 000. Subsequent research showed that this figure would have been much higher had it not been for the use of a local herb which, while not curing this form of TB, did ameliorate the effects such that most people could survive the initial acute attacks. It was largely in the rural areas where this herb was used, by those who had been infected in the city, and had subsequently returned to their rural community.

The elitist education and research system was not willing to recognise this approach based on a traditional remedy, and consequently very little research was undertaken into its potential healing properties. Deaths in the city were therefore much higher than they needed to be, compared with the rural areas. Instead, expensive external treatments were imported, which were not very effective.

This strain of TB became a chronic problem in Cape Town, and there was no effective response by the city.

Another contributing factor to Cape Town's woes was the fact that the city just didn't seem able to compete globally in sectors that had been selected as focal growth points. Huge investments had been made, for example, in the electronic

games/entertainment industry, along with major efforts in the boat-building industry. Somehow the products and outputs of these industries repeatedly compared poorly with their overseas competitors. There were voices of criticism that pointed to the cause of this deficiency as being the rigid approach to education, which neglected creativity and innovation but instead favoured highly-structured and goal-oriented thinking and behaviour.

Cape Town was stagnating, and even deteriorating in some areas. The situation was mirrored in most small towns, not because of a lack of strategies and related implementation plans, but because there was such a shortage of appropriately educated individuals with the ability and self-belief to effectively manage projects and solve problems as they arose. The vast majority of people in positions where decisive action was required were instead determined to avoid risk and simply show that they had carried out orders (via output-oriented indicators), rather than seek to have real impact.

The years 2021 to 2030

The effects of the education deficit became more evident. The leadership and management cadre of the province was increasingly filled with graduates from especially Cape Town's elite universities. They came up with wonderfully efficient and precise plans for the development of the province, and promoted these with great energy and commitment. However, those saddled with implementation were continually overwhelmed by the complexities of their constituencies, and seldom succeeded in motivating the overall support and buy-in that was needed to move forward.

Interestingly, it was often in the towns and rural areas that were not part of the provincial focus of development that signs of growth were evident. This was often driven by locals who had received a university education in Cape Town, although they had seemingly not excelled in the academic environment. If truth be told, many of them had been perceived as mavericks and nonconformists by their lecturers and professors. Some (not by any means all) of them had returned to their home towns or communities filled with enthusiasm concerning the role that knowledge and innovation could play in making a difference, and after many ups and downs, their successes were beginning to show.

A related phenomenon was that clustering began to take place amongst these points of growth. Those involved realised that the mindset in Cape Town was not conducive in practice to a knowledge society that valued innovation. The people in Cape Town talked the talk but didn't walk the walk. They knew all the right buzz-words and were undoubtedly sincere, but they failed to appreciate the

inherently elitist position that was their point of departure (all they saw was their focus on excellence). The 'mavericks' in the hinterland saw through this position, and realised that cooperation with Cape Town, while being desirable in many ways because of the relative depth of resources that Cape Town offered, was doomed to failure because of the elitist and controlling mindset which restricted opportunities for genuine collaboration and the emergence of interdependence. So instead they cooperated amongst themselves, and this further stimulated slow but sustainable growth.

What no one had reckoned on was an outbreak of moulds that devastated first the vines in 2023, and then both the vines and the citrus plants in 2025. Later research demonstrated that these moulds had emerged in the valleys of the Western Cape with their great biodiversity of flora. Due to global warming and the consequent lack of freezing temperatures, the valleys had become perfect incubators for new strains of moulds. A plethora of fungal infections was generated that overwhelmed the resources of the authorities.

In fact the first outbreak in 2023 had been contained remarkably well through the use of imported expertise. But when the second struck in 2025 there was a false sense of confidence that proved very costly. The multiple virulent moulds refused to yield to imported and costly treatments. Despite the mobilisation of substantial local resources, at both a provincial level, and using Cape Town's best research facilities, there was no breakthrough in producing a practical remedy for the moulds. A few years after the second outbreak, and in the face of the lack of progress in dealing with it, criticism by world experts was levelled at the research approaches taken. The gist of the criticism was that the search for a remedy had been too constrained by assumptions that were later seen to be highly questionable. But local researchers responded making it clear that they felt that such criticism was unjustified. The result was the significant decline of the wine and citrus industries.

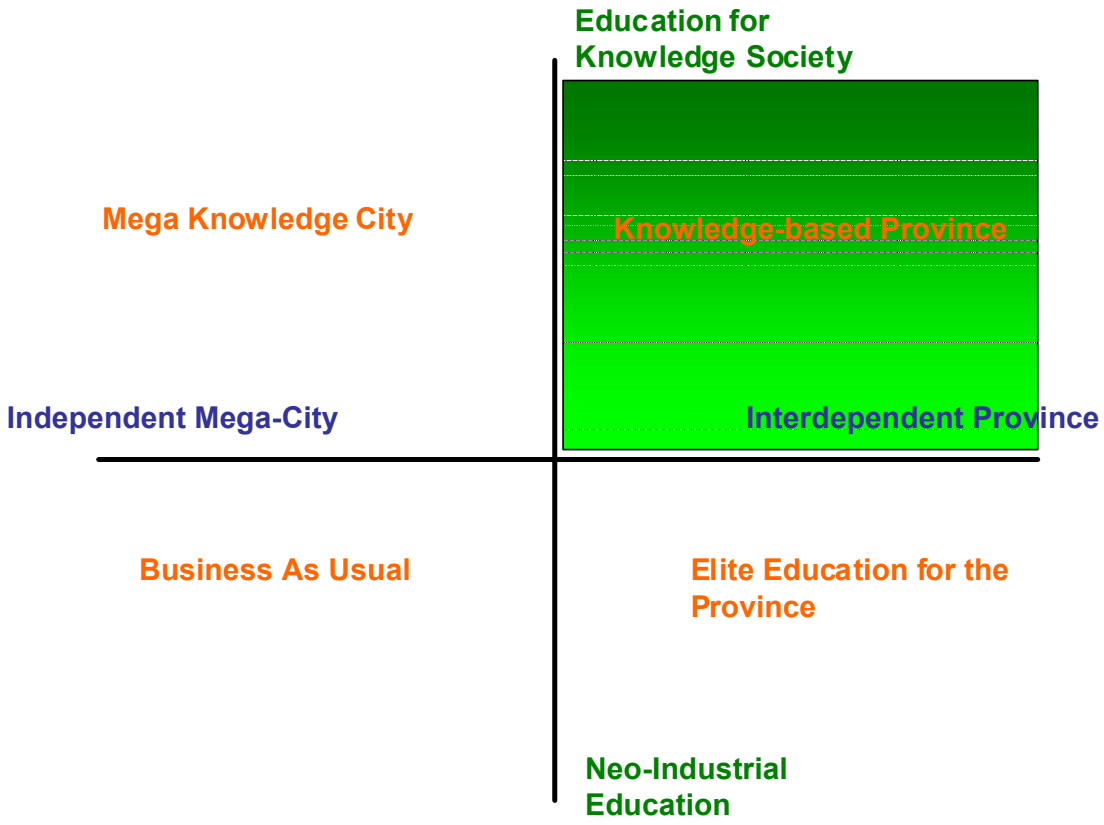
Meanwhile, the stagnation that Cape Town was experiencing was becoming harder and harder to justify by appeals to long-term benefits. Many in Cape Town voted with their feet, especially those who had more recently moved to that part of the world. However, amongst the majority who had deep roots in Cape Town, there was a rising tide of impatience, and a determination that something should be done.

The initial focus was to have the Provincial Government and even the national Government introduce special subsidies and other incentives to stimulate growth in Cape Town. But this approach fell on deaf ears. So Cape Town changed tack and began to put pressure on the Provincial Government to redirect investment

in the rest of the Western Cape to Cape Town itself. The focus was on raising the level of innovation, and several projects to achieve this were initiated. For example, in 2026 a Science Park was built near Mitchell's Plain, amidst much fanfare. The expectation was that many high-technology companies would relocate to the Park because of the superb facilities and infrastructure that it offered. After three years it had attracted only a quarter of the planned number of companies, and the facility was sold at a huge loss to a real estate developer.

By 2030 the province showed all the signs of slow decline, and it was evident that on the whole, those in leadership in both the public and private sectors did not have the vision or creativity to reverse this trend.

Scenario 3: Knowledge-based Province



The years: 2009 to 2019

In 2010 the provincial Government took the lead, encouraged by both the international community and the national Government, to develop an integrated strategy for developing a knowledge-based society and economy for the province as a whole, both rural and urban. For the next three years the policy was drafted using an iterative and interactive process involving a wide range of stakeholders. The successes and failures of similar policies in other countries were closely studied so that the best learning could be brought to the exercise.

Flowing out of this initiative, in 2012 a strategic Partnership for Learning was set up between UWC, CUT, the provincial department of education, several

education-oriented NGOs and several private-sector education-oriented companies. Their vision was to transform the educational landscape of the province by 2020. They tried to get UCT and US on board the partnership, but these two universities had other priorities and after two years of discussions the partnership moved on (leaving the door open for the future). As a result of the partnership, a vibrant culture of innovation began to develop in some segments of the education sector, many ideas were generated for realising the vision, and some were tested.

The vision included several components. One involved making skills-based learning available in many small towns and rural areas, as well as in the economically-depressed urban and peri-urban areas. A system of community learning centres (CLCs) was set up in the major towns. These centres offered a range of skills, both practical through apprenticeships, and knowledge-oriented. A basic curriculum was provided by all the CLCs and in addition, certain CLCs specialised in particular directions. The centre at Worcester, for example, had a strong emphasis on wine farming, and became well-known for its expertise in knowledge systems and innovative technologies for the wine industry.

Both the CLCs, and the learning materials they used, were well-integrated into their local economies, referring to both economic activity in the immediate town, and in the outlying areas that it served. Learners would spend large portions of their time working in one or other local SMME or larger company.

This integration into the economic and social life of the community, allowing learners to learn what they wanted, when they wanted, and at their own pace, meant that the boundaries between formal and informal learning became more and more blurred.

A marked characteristic of the education provided by the CLCs was their focus on a wide range of ICT skills. Learners not only became thoroughly familiar with word processors and spreadsheets (the primary focus was on the OpenOffice suite, but Microsoft Office was also touched on), they also were involved in setting up blogs, Facebook pages and other web sites, and creating and formatting their own content, both text and multi-media. A competition for best personal pages was run every three months. Judging was performed by the web community (with certain checks and balances to prevent abuse).

Another aspect of vision to transform the educational landscape addressed the population who did not reside in towns, but lived in more sparsely populated areas. Here the particular challenge was to provide access to learning opportunities, but at a low cost. The approach used was to set up Multipurpose

Community Centres (MPCCs) that amongst other services, provided access to an extensive range of multimedia-based learning materials. Each MPCC was connected to the nearest large town using a high-bandwidth wireless link. This link provided access to the Internet, and hence to web-based resources that were provided by the universities, the CLCs, and others.

The focus on multimedia materials (voice, video, animation and some text) allowed many cultural and language barriers to be crossed. Literacy was not a pre-requisite for engagement with the services. Applications addressed real-life issues such as banking and pension collection. Information modules, using the latest Learning-Object technology, enabled people to learn what and when they wanted. This technology also facilitated local content creation, which was targeted particularly at children and the youth, and at women. Learning facilitators were deployed across the province to assist particularly the adults with the technology. By and large the youth needed no such assistance, and in fact were often the ones who helped their elders (when the elders allowed them to).

By the end of the decade the level of ICT literacy amongst the general rural population had increased dramatically.

The rise in levels of skills and expertise across the province did not come without a heavy price, and it was largely Cape Town (being the wealthiest city) who paid it. Because of the need to develop the more rural parts of the province, Cape Town's share of provincial expenditure and investment declined from the levels it had enjoyed prior to 2012. This is not to say that such expenditure dropped dramatically, but the decline was sufficient to take the edge of Cape Town's growth. Perhaps what was even more significant was that there was a redistribution of expenditure within Cape Town, with the less well-off areas receiving a greater share. The focus of this expenditure was on lifelong learning and needs-based training, which by its longer-term nature, did not show immediate economic results.

In short, Cape Town's growth stagnated during the teens. Fortunately, that was not the whole story for the province, for in the more rural areas the fruits of the investment in learning and skills training began to show towards the end of the teens. The ready access to information services, along with enhanced computer skills that were more and more common, began to pay off. There was direct benefit for small-scale farmers and other entrepreneurs having access to information about markets. Better prices were secured for produce. Small contractors and labour brokers were able to respond rapidly to the need for services in different parts of the province. The skills and expertise that had been

acquired by many over the years proved to be useful in practice, and this gave them increasing confidence that they could apply their newly-acquired skills with success in even unfamiliar contexts. It became quite common to find people in rural areas who had a thorough understanding and practical experience of technology-based domains, such as energy production from biomass, water purification and storage, horticulture, agriculture, and so the list may continue.

An increasing level of innovation was evident in outlying communities, often commercially motivated, but also driven by social needs. An example was the development of a herb-based skin cream for reduced hair loss. The cream was developed through the initiative of an individual who had grown up on a farm in the eastern part of the province, where this herb had been used as a remedy for various skin conditions. She realised the potential of this herb while studying at UWC, and initiated a collaborative research project that led to the commercialisation of the cream. A production facility was established near her home village.

Another sign of innovation was the fact that no less than 24 rural community centres were established between 2017 and 2019, and all at the initiative and with the drive of members of the communities.

Innovation was also evident in what can only be described as a tragedy that engulfed the Western Cape for two years. In 2014 a TB epidemic struck. The combination of the lifestyle lived by many around Cape Town, along with the effects of global warming, created an ideal environment for the development of a new strain of TB. It turned out that it was an extremely virulent strain that wreaked havoc amongst the very young, and the elderly. The death toll in the first year alone was 120 000. Subsequent research showed that this figure would have been much higher had it not been for the use of a local herb which, while not curing this form of TB, did ameliorate the effects such that most people could survive the initial acute attacks. It was largely in the rural areas where this herb was used, by those who had been infected in the city and had subsequently returned to their rural community.

Because of the levels of expertise that had developed in the rural areas, and the networks of relationships that existed between urban and rural people, the significance of the positive impact of this herb on a TB sufferer was soon realised. A collaborative research project was immediately established involving UCT, UWC and several communities, and within eight months the active agent had been identified, and a commercial product was developed. Many lives were saved by this remedy.

Towards the end of the decade, and despite the outbreak of TB, basic indicators of the quality of life enjoyed by the population began to show definite signs of improvement. Child mortality and HIV/AIDS infection rates showed a steady decline. The numbers who owned their own homes, and even farms, increased. Alcoholism levels decreased, and the associated 'dop' system became much less common.

The years 2021 to 2030

Following the evident success of the Partnership for Learning, both UCT and US realised that they stood to gain a great deal by participating. Thus in 2021 US became an active member of the partnership, and UCT followed in 2025. Their presence was welcomed, although by that stage the partnership was sufficiently mature that their joining did not have the degree of (positive) impact that it would have had ten years prior. Other educational institutions in South Africa also joined the partnership, and so its influence spread within South Africa. The model was replicated in Limpopo province, and also in Tanzania and Uganda.

It was during the early twenties that the long years of investment in and stimulation of the poorer areas of Cape Town, and the province as a whole, began to show clear evidence of paying off. Levels of crime were reduced, and local economic activity flourished, particularly in the form of micro-enterprises. The economic buoyancy of the regions surrounding Cape Town provided significant stimulation to enterprises in the city. This all had a knock-on effect on Cape Town's economy which started experiencing rates of growth that it had not seen in 15 years.

Cape Town reached such a degree of economic success that it was able in 2027 to offer completely free and top quality education at both primary and secondary levels.

Much of this growth in the metro area was related to interactions with Cape Town's hinterland. After lying in the doldrums, there was a resurgence in the tourism sector. Cape Town and the Western Cape became a popular destination for visitors from China and India, and many of them returned to live in Cape Town or in its surrounding areas. They were able to enjoy all the benefits of a modern city, and at the same time remain engaged with rural life. In fact, a few rural areas were starting to resemble the rural pattern of life found in Central Europe.

The Western Cape became world-renowned as a health destination. The combination of a variety of climatic regions, a wide biodiversity, mountains and

the sea made the Western Cape an ideal location for promotion as a place to experience a healthy outdoor lifestyle in the context of natural foods and health remedies, such as teas, herbs and creams, all locally produced. A network of health resorts developed, as well as a reputation for endurance and extreme sports.

By the mid twenties almost all rural areas were prospering sufficiently so that they no longer were considered to be impoverished. While economic advancement had brought a significantly improved quality of life, there was also an acknowledgement that the efforts and warnings of a few cultural champions had borne fruit: much of the cultural heritage of the communities had been preserved, albeit sometimes in a transformed form.

Most significantly, the level of farm ownership by former farm workers had risen dramatically, and continued to rise. While this phenomenon had been the cause of some tension between erstwhile farm owners and the recent entrants, in many areas there was substantial collaboration through cooperatives.

However, the story of the growth and development of the rural areas in the Western Cape was not one of unbroken triumph. What no one had reckoned on was an outbreak of moulds that devastated first the vines in 2023, and then both the vines and the citrus plants in 2025. Later research demonstrated that these moulds had emerged in the valleys of the Western Cape with their great biodiversity of flora. Due to global warming and the consequent lack of freezing temperatures, the valleys had become perfect incubators for new strains of moulds. A plethora of fungal infections was generated that overwhelmed the resources of the authorities.

In fact the first outbreak in 2023 had been contained remarkably well through the use of imported expertise. But when the second struck in 2025 there was a false sense of confidence that proved very costly. The multiple virulent moulds refused to yield to imported and expensive treatments. Once this was realised, a programme of research was implemented that involved collaboration between UCT, UWC and US, as well as with local farmers and also international partners. After two years of intense research a remedy was developed that was hailed for its innovative approach. Within another two years the incidence of mould was down to the levels experienced five years prior. During those five years the wine and citrus industries had suffered severely; they emerged bruised, but not beaten. The one positive spin-off was the local industry that was spawned around producing the mould remedy. Similar outbreaks of mould around the world meant that there was an ongoing demand for research and the development of products in this area.

The problem of the new TB strains continued to receive attention. Further research, in collaboration with India, resulted in what appears to be a cure. Field trials are still underway, but the evidence is that the drug treats successfully all strains of TBs, within 7 to 10 days. This short treatment period means that noncompliance with the treatment regime is no longer a factor, and thus far resistance strains are not evident.

An unexpected phenomenon was that, with the increasing prosperity, the Provincial Government became less important. Local and national Government were the major public agents, and their cooperation grew while the provincial level atrophied. While this was no doubt of great concern for Provincial Government employees and elected officials, for most people the need for a provincial level of Government was questionable. There was great respect for and confidence in the local Government level across the province. They way it had cooperated with the national Government, often gaining what were perceived to be important concessions for the Western Cape, found general acclaim.

At the end of the day, what counts is quality of life, and the remarkable success of the Western Cape in this area meant that most people are getting on enjoying that quality of life. But perhaps there is a hint of complacency now, which will be addressed only by a tough challenge, such as was provided by the outbreaks of plant moulds and TB.