Bionanoscience Landscape in South Africa and its Implications in the Development of a Post-Graduate Curriculum

Presented at UWC – Nano-biotechnology Seminar.

Dr. Raymond Sparrow
Manager of the SynBioTIC Programme.

CSIR – Synthetic Biology ERA.

20th November 2009
Nanoscience:
The study of phenomena to understand the effects, their influence on the properties and the manipulation of materials at the atomic, molecular and macro-molecular level.

Nanotechnology:
The design, production, characterization and application of devices, structures and systems with novel properties and functions due to their nanoscale size.
• There is a constant drive to reduce the size of components and machines.

• The properties of materials at the nanoscale are very different to the properties in their bulk phase.

• Technology using components on the nanometer scale.

• Utilising and manipulating individual atoms or molecules.

• Bio-nanotechnology uses biological materials or systems.
Bionanotechnology

• Many problems of nanoscale mechanisms have been overcome in nature.

• Act at the nanoscale.

• More energy efficient.

• Hence a great interest in investigating biological materials and systems.
  • Actin, Myosin, Kinesin (mechanical)
  • ATP synthase, Photosynthetic pigments (Energy transduction)
  • Many biological systems are self assembly (Protein/DNA/Membranes)
1st: Passive nanostructures (1st generation products)
   a. Dispersed and contact nanostructures. Ex: aerosols, colloids
   b. Products incorporating nanostructures. Ex: coatings; nanoparticle reinforced composites; nanostructured metals, polymers, ceramics

2nd: Active nanostructures
   a. Bio-active, health effects. Ex: targeted drugs, biodevices
   b. Physico-chemical active. Ex: 3D transistors, amplifiers, actuators, adaptive structures

3rd: Systems of nanosystems
   Ex: guided assembling; 3D networking and new hierarchical architectures, robotics, evolutionary

4th: Molecular nanosystems
   Ex: molecular devices ‘by design’, atomic design, emerging functions
Composite materials

Mussel shells.
The motor: Flagellum
Nano-magnets biogenically deposited magnetite

(Aróto et al., 2005).
Molecular self-assembly

Zhang 2003
Deposition of metal nano-wires

Zhang 2003
Optical fibres and lenses

Zhang 2003
Research Inputs and Potential Applications

- Bio-nanoscience
- Environmental reclamation: Heavy metals, pesticides
- Drug delivery: HIV/Cancer/TB
- Light harvesting & transfer
- Communications: Telecommunications, computers, data transfer
- Nano-surgery: Eye, lung, alimentary canal, brain
- Ultra-fast opto-electric switches
- Novel genes/biochemical pathways
- Physics: Biophysics, laser physics
- Chemistry: Biochemistry, molecular biology, microbiology, physiology, pharmacology, systems biology
- Materials science
- Engineering
- Analytical techniques
- IT/mathematics modeling
- Power supply for micro & nano devices
SYNBIOTIC

Priorities:

• Skills development.
• Scientific excellence.
• Recruitment of high quality candidates.

Recruitment:

• Recruiting high skilled students at all levels.
• Focus on research of scientific excellence.
• There will be a separate / complementary Post-Doctoral programme.
Skills development training programme to include:

• Individual learning programmes.
  • Focused on research project.
  • the student undertaking the project.

• Short courses, workshops, seminars – invited presenters who are leaders in the field.

• Cross disciplinary environment that supports Synthetic Biology.

• Develop programmes with Universities and other Institutes.
  • e.g. with UWC, iThemba Labs, NWU, US, UP.

• Student / Researcher exchange programme.

• An academic based QA system.
  • Developed an internal and external verification process.

• Assessment and Tracking of skills development and progress.
  • Evidence derived from the research being conducted.
Synthetic Biology Training Programme – Pathway.
<table>
<thead>
<tr>
<th>Specialization</th>
<th>Topics</th>
<th>Content</th>
<th>Description/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanobiotech.</td>
<td>Biology for non-biologists</td>
<td>Biomolecules (proteins / nucleic acids / lipids / carbohydrates)</td>
<td>Actuators, motors, sensors, containers</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metabolism</td>
<td></td>
<td>Self-assembly</td>
</tr>
<tr>
<td></td>
<td>Bio-energetics</td>
<td>Light activated</td>
<td>Photosynthetic - Light Harvesting. Bacteriorhodopsin Rhodopsin</td>
</tr>
<tr>
<td></td>
<td>Transfer / transport</td>
<td>Electron, proton, ion, channel.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mechanical</td>
<td>Actin, myosin, kinesin, ATP synthetase.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Techniques</td>
<td>Imaging (microscopy)</td>
<td>Fluorescence, confocal, non-linear, EM (TEM/SEM), AFM</td>
</tr>
<tr>
<td></td>
<td>Spectroscopy</td>
<td>UV-VIS, CD, FTIR, Raman, NMR.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Isolation / purification</td>
<td>HPLC / Affinity / centrifugation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Physics</td>
<td>Quantum mechanics</td>
<td>Molecular level interactions / dynamics</td>
</tr>
<tr>
<td></td>
<td>Coherence phenomena</td>
<td></td>
<td>Energy transfer</td>
</tr>
<tr>
<td></td>
<td>Thermodynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mathematics for Nanoscience</td>
<td>Modelling and computation.</td>
<td>Molecular level interactions / dynamics</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy transfer</td>
</tr>
</tbody>
</table>
Thank you
NANOTECHNOLOGY

ADVANTAGES

• New materials
• New properties
• Greater efficiency
• Reduced size (compactness)

PROBLEMS

• The assembly of components.
• Interconnecting components into working mechanisms
• The control of components