CLIMATE CHANGE AND BIOTECHNOLOGY: ISSUES AND CHALLENGES

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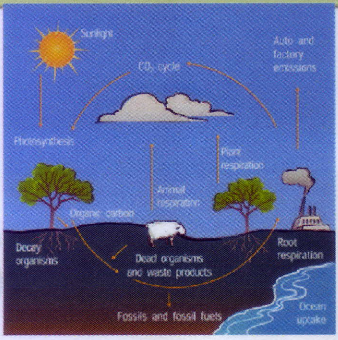
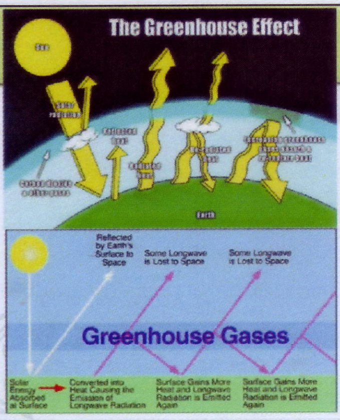
Carbon Dioxide Cycle





Green-house Gases

- Carbon dioxide (CO_2)
- Nitrous oxides (NO_x)
- Methane (CH_4)
- Aerosol

Global Warming

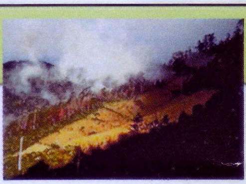
Accumulation of green-house gases lead to global warming

Automobiles

Factories

The Culprits

Power-stations



HAKISAN GENETIK & PEMUSNAHAN

Plantation/Agriculture

- Greenhouse emission:
  - Industrialized inputs
    - Machinery
    - Fertilizers
    - Pesticides

- Climate change is one of the most pressing challenges facing the world in the 21st century
- New technologies and strategies must be implemented to mitigate the factors causing climate change and to adapt to its effects

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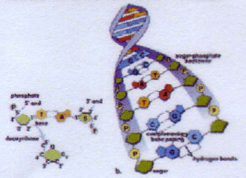
Biotechnology

- "Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use."
- Modern biotechnology is the term used to describe a range of processes and techniques especially at the molecular level.

DNA: Structure and Function

Watson and Crick produced their double helix model in 1953. "Modern" biotechnology began with their discovery.

Watson and Crick model of DNA

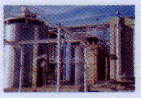


Modern Biotechnology

- *(a) in vitro* nucleic acid techniques, including recombinant deoxyribonucleic acid (DNA) and direct injection of the nucleic acid into cells or organelles; or
- *(b)* fusion of cells beyond the taxonomic family, that overcome natural physiological reproductive or recombination barriers and that are not techniques used in traditional breeding and selection
- **BIOSAFETY ACT 2007**
- **Biosafety (Approval and Notification) Regulations 2010**

Biotechnology

- Crops
- Forest
- Conservation of BioD
- BioFuel
- Industrial biotechnology



Crops

- Potential solution to climate problems through the creation of crops that are designed to meet the challenges of a new climate era
- Potential of genetically modified crops
  - to transcend agriculture's contribution to climate change
  - to help mitigate the impacts of climate change.

Transgenic crops

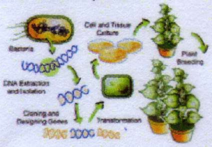
- To improve the current system of agriculture through reduced greenhouse gas emission
  - Less pesticides, less fertilizers
  - Nitrogen Use Efficiency
  - In 1998, 8.2 million fewer pounds of active [fertilizers] were used on corn, cotton, and soybeans than in 1997 and corresponded to an increase in the adoption of genetically engineered crops (Wolfenbarger & Phifer 2000).

Transgenic Crops

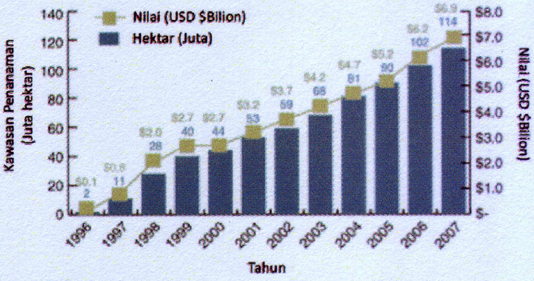
- Increased adaptability to climate change
  - drought resistance (water efficient)
  - Rice, maize, canola
    - Reduce level of key stress-related proteins
    - Genes from plants already highly drought resistant
  - Resistant to salt
  - More space-efficient plants
  - Increased yield
    - World population - 7 billions in 2020
    - 9 billions in 2050.
  - Increased in yield is crucial by 2050

Acceptance

- Acceptance of modified crops
- Transgenic crops now cover over 100 million hectares of arable land in >20 countries, and this trend toward increased uptake and deployment is growing at a steady rate



Jumlah kawasan yang ditanam dengan tanaman transgenik meningkat sebanyak 12% dalam tahun 2007, dengan anggaran nilai tanaman meningkat sehingga USD $700 juta



Lawrence, S. 2008. Brazil surpasses US in new transgenic crop plantings. Nature Biotechnology 26(3): 260.

Challenges

- The regulatory bottleneck
- Anticipated lack of market acceptance
- Market rejection or lack of demand
  - Some countries and markets
- Reexamination of the balance between potential risks versus foregone societal benefits
- Public awareness

Forest Biotechnology

- Understanding the carbon storage and sequestration mechanisms of forest trees and forest soils
- Identifying and conserving rare or valuable germplasm threatened by climate change
- Developing trees that are more easily processed into fiber or or biochemicals
- Breeding trees able to grow faster in elevated carbon dioxide concentrations and capable of withstanding stresses due to changing climate.

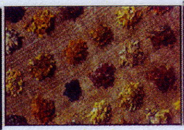
Fenning et al. 2008 Nature Biotech 26:6:615-617

Conservation Biotechnology

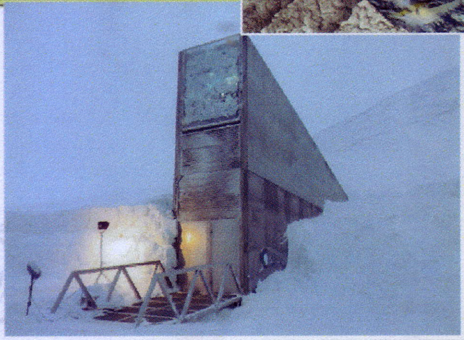
- Significant contributions to ameliorate some of the consequences of climate change
  - Provision of planting stock of germplasm that cannot be conserved by conventional seed storage practices
  - Fundamental and applied research to develop crypreservation technologies for the *ex situ* conservation of BioD at risk from climate change, particularly storage of recalcitrant germplasm and endangered species (Berjak et al. 2011)

Orthodox Seeds

- Tolerant to desiccation and low temperature
- Seed moisture content 6-8% and storage temperature -18ºC (Bioversity International)


Svalbard Global Seed Vault, Norway

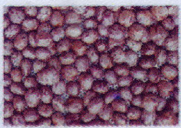
RDA Genebank Korea


Problem Materials

- No seed produced
  - *Musa* spp.
- Vegetatively propagated
  - *Manihot esculenta*
- Recalcitrant seed
  - *Garcinia mangostana*

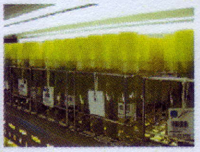
Recalcitrant Seeds

- Not tolerant to:
  - Desiccation to as high as **12- 31% moisture content**
  - Low temperatures (Roberts 1973)

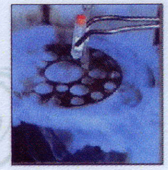
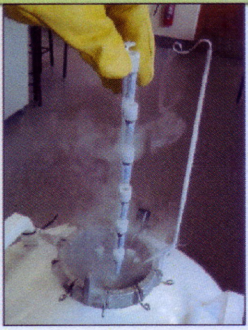


...then how to store?

- Field genebank
- *in vitro* genebank
  - slow growth
  - cryopreservation


Cryopreservation (-196°C)

RDA Genebank



Laboratory of Tropical Crop Improvement of K.U.Leuven

Conservation Biotechnology

- Aid the safe and secure cold storage of non-viable and/or non-reproductive biological resources
  - DNA, blood products, cells, bone, feathers, foliage materials for use as 'type' materials
- Such materials will provide invaluable reference specimens for climate change-associated conservation research, wildlife management and genetic studies such as the barcode of life programme (Berjak et al. 2011)

Cryobionomics

- The study on cryoinjury and how it affects the genome and genetic stability
- Fundamental and applied research in the study of biophysical, molecular and genetic stability
- Reintroduction into the environment of organisms recovered from cryopreserved germplasm.

(Berjak et al. 2011)

Industrial Biotechnology

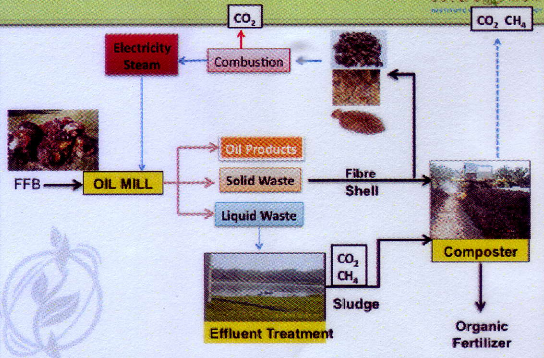
- Enzymes, microorganisms
  - To make biobased products : chemicals, food and feed, detergents, paper and pulp, bioenergy
- Renewable raw materials
  - Save energy
  - Reduce CO_2 emission
  - Biotechnology processes and biobased products:
  - Mitigation potential between 1 billion and 2.5 billion tons CO_2 equivalent per year by 2030 (WWF 2009)

Biofuel

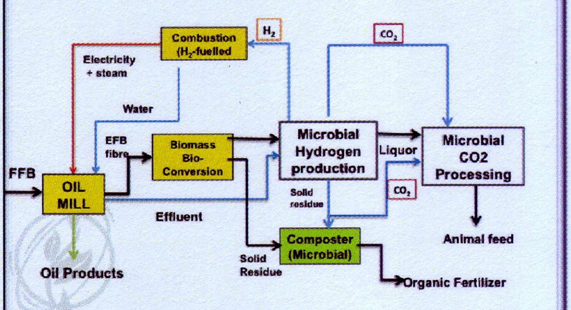
- *Nature Biotechnology* ***27, 1128 - 1129 (2009)*** ***Engineering direct conversion of CO_2 to biofuel***

  <u>Genetically engineered cyanobacteria harvest light energy to directly produce isobuteraldehyde and isobutanol.</u>
- Recycle CO_2 directly into fuels or chemicals using photosynthesis
- Overexpression of Rubisco

<u>Oil Palm Processing & Green-house Gases</u>



<u>Oil Palm Processing – Biotechnology in the Reduction of Carbon Footprint</u>

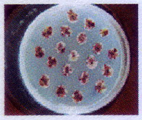


Zero waste, zero carbon signature, self-sustaining operation

- Mitigation & role of biotechnology/microbial
  - Bioconversion of solid oil-palm waste/biomass
  - Production of biohydrogen from biomass
  - Use of biohydrogen for power & steam generation : water as product of combustion, Zero carbon signature, free electricity
  - Sludge from biohydrogen will be converted / composted to organic fertilizer
  - CO_2 release from composting is trapped & utilized by microbial processing. The product form this process will be used as animal feed

- *Nature Biotechnology* ***26, 169 - 172 (2008) doi:10.1038/nbt0208-169 How biotech can transform biofuels (Lee et al.)***

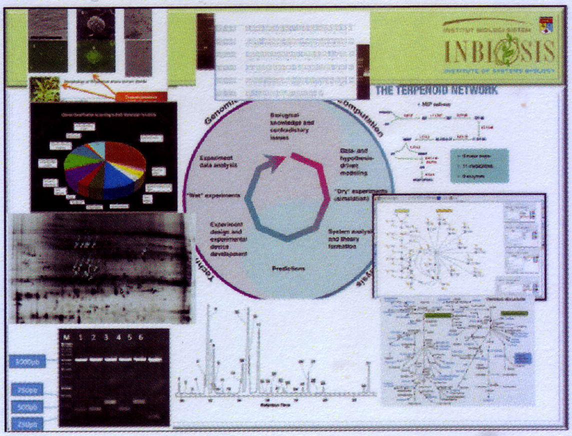
For cellulosic ethanol to become a reality, biotechnological solutions should focus on optimizing the conversion of biomass to sugars

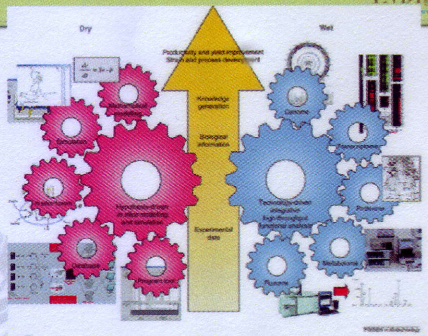


Biotechnological Approaches

- The most powerful approach to address the dual challenges of biomass recalcitrance and large scale sustainable production
  - Systems biology
  - Imaging and computational tools

(Lee et al. 2008)





Lee et al. 2005

Synthetic Biology

- Biological building blocks

  Synthetic biology: Living quarters

Synthetic biology could offer truly sustainable approaches to the built environment, predict Rachel Armstrong and Neil Spiller [Nature 467, 916–918 (21 October 2010)](#).

New form of architecture that incorporate the dynamic properties of living systems

Conclusion

- Biotechnology presents a feasible solution to climate change mitigation and adaptation
  - ✓Sustainability in agriculture
  - ✓Forestry
  - ✓Conservation of BioD
  - ✓Biobased products
  - ✓Biofuels