Bio-energy as Renewable Energy Resource: Problems and Prospects

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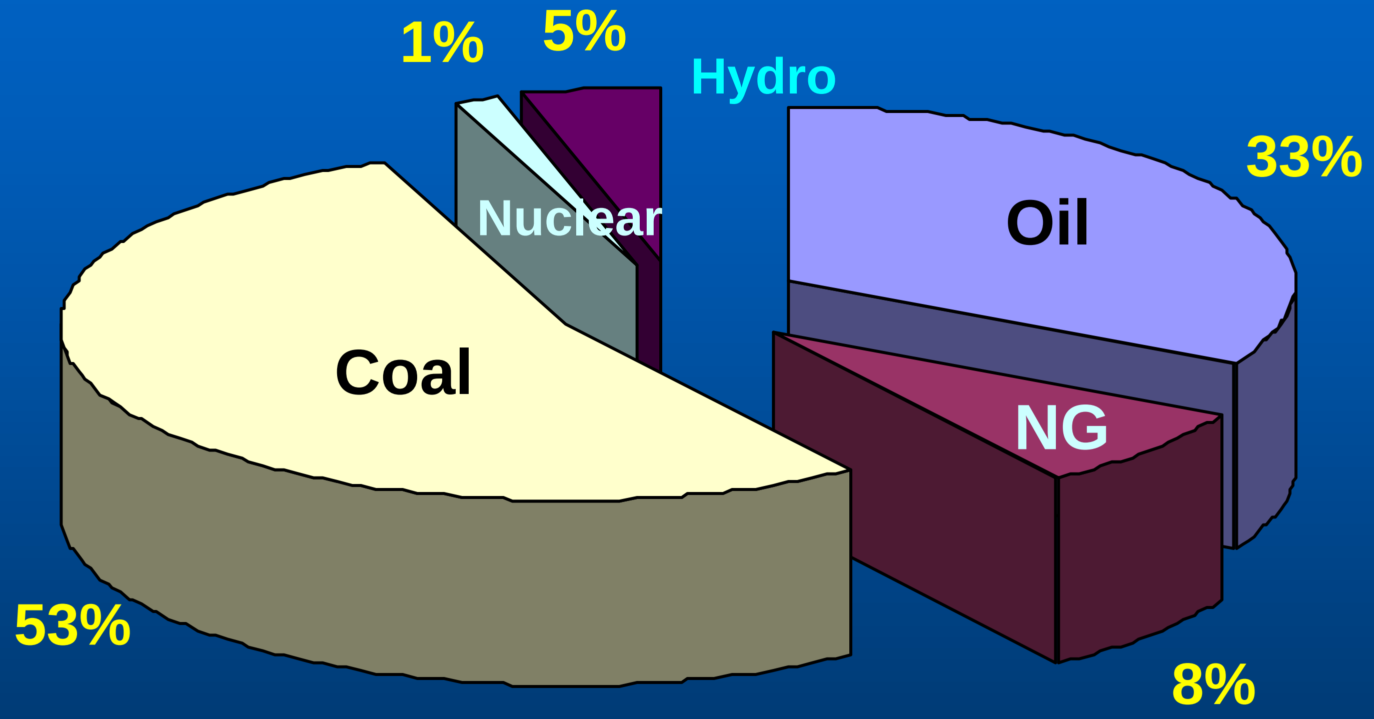
Awareness and Capacity Building on Sustainable Energy , Aug. 6, 2010

Fuel sources and world energy demand

Source	Global energy demand met
Coal	**25%**
Petroleum	**34%**
Natural gas	**21%**
Nuclear	6.5%
Hydro	2.2%
Biomass and waste	11%
Geothermal, Solar and Wind	0.4%

[Source: Ansolabehere *et al.*, 2007]

Energy Sources – Indian Scenario



Primary Energy Sources
India - 2003 (BP Energy Review)

WHAT ARE FOSSIL FUELS…??

- Fossil fuels are hydrocarbons, primarily coal and petroleum (fuel oil or natural gas), formed from the fossilized remains of dead plants and animals by exposure to heat and pressure in the Earth's crust over hundreds of millions of years.

Alternative fuels for transportation

Drivers:

- Transportation is fast growing energy consuming sector
- Increased price of oil
- Shortage of fossil fuel
- Dependence of imported fuels
  National energy security
- Air quality (air pollution)
  Increased CO_2 emission

↓ Required

Alternative fuels !!!!

BIOENERGY

The energy derivable from biomaterials:

1. Bioethanol
2. Biodiesel
3. Hydrocarbons
4. Biogas
5. Hydrogen
6. Microbial Fuel Cells

GROSS ENERGY CONTENT OF BIOFUELS

FUEL	APPROX. GROSS ENERGY CONTENT
ETHANOL	30.6 MJ / kg
METHANOL	23.8 MJ / kg
BIODIESEL	57.1 MJ / kg
METHANE	55.5 MJ / kg
HYDROGEN	142 MJ / kg

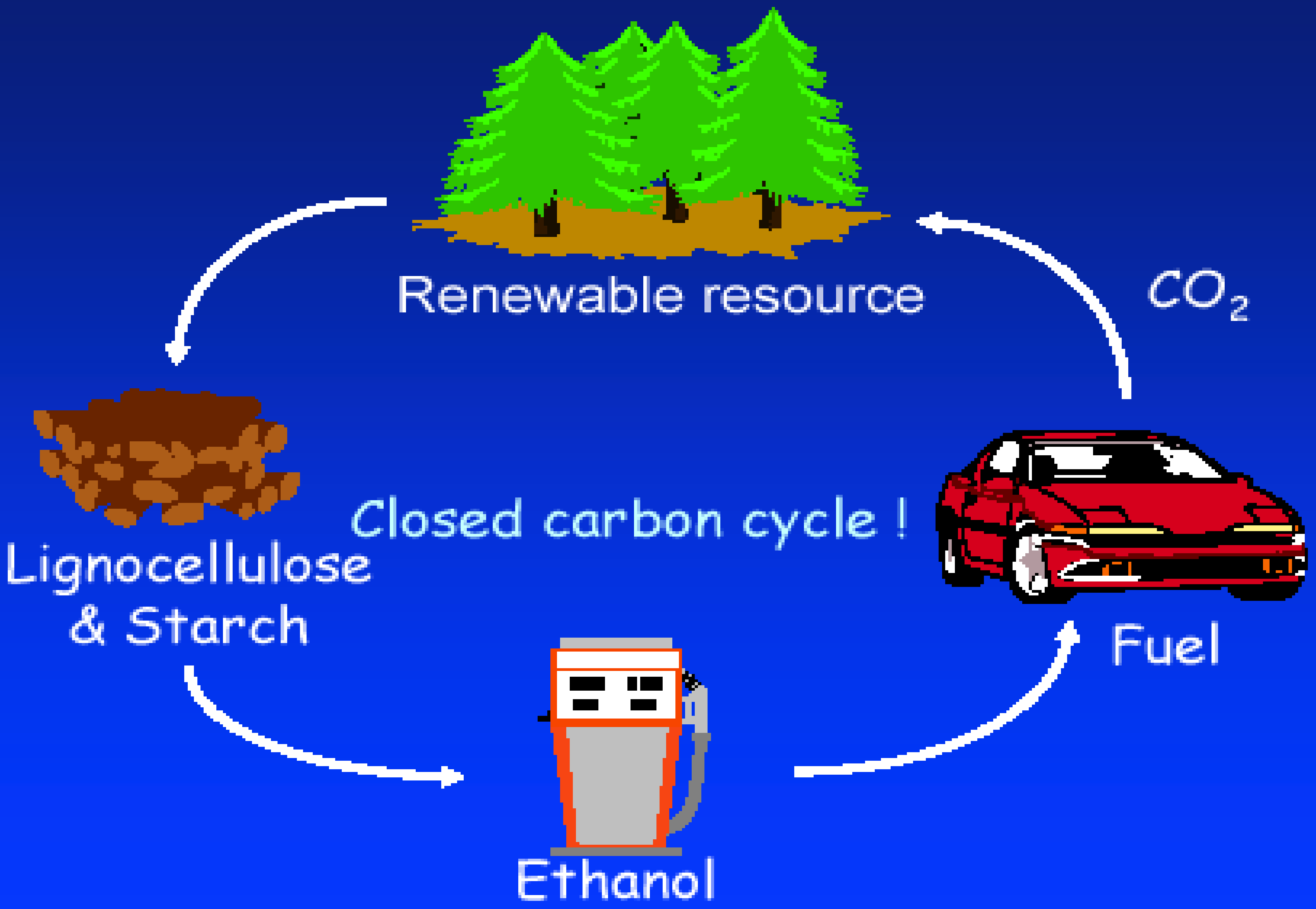
THE 50 HOTTEST COMPANIES IN BIOENERGY 2009-2010

1. Solazyme
2. POET
3. Amyris Biotechnologies
4. BP Biofuels
5. Sapphire Energy
6. Coskata
7. DuPont Danisco
8. LS9
9. Verenium
10. Mascoma
11. Novozymes
12. UOP Honeywell
13. Gevo
14. Range Fuels
15. Abengoa Bioenergy
16. PetroAlgae
17. Synthetic Genomics
18. Petrobras
19. Bluefire Ethanol
20. ZeaChem21. Virent
22. Qteros
23. Iogen
24. Algenol
25. Enerkem
26. Genencor
27. Shell
28. Ceres
29. ExxonMobil
30. Cobalt Biofuels
31. Aurora Biofuels
32. Joule Biotechnologies
33. Syngenta
34. KL Energy
35. Codexis
36. IneosBio
37. Renewable Energy Group
38. Rentech
39. Praj Industries
40. Neste Oil
41. LanzaTech
42. OriginOil
43. Choren
44. Solix
45. Chemrec
46. Dynamotive
47. Terrabon
48. Fulcrum Bioenergy
49. SG Biofuels
50. Inbicon

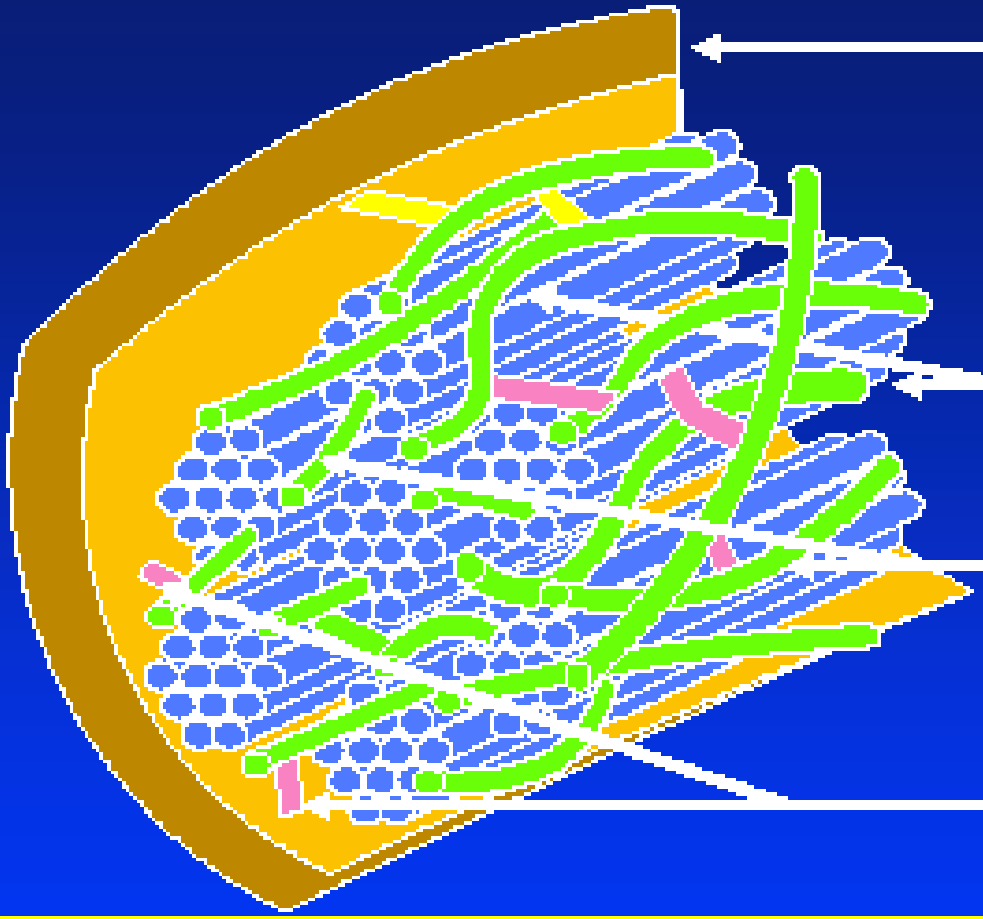
CHEMIST'S PRAYER

Lord I fall upon my knees
And pray that all my syntheses
May no longer be inferior
To those conducted by Microbes

Alternative fuel

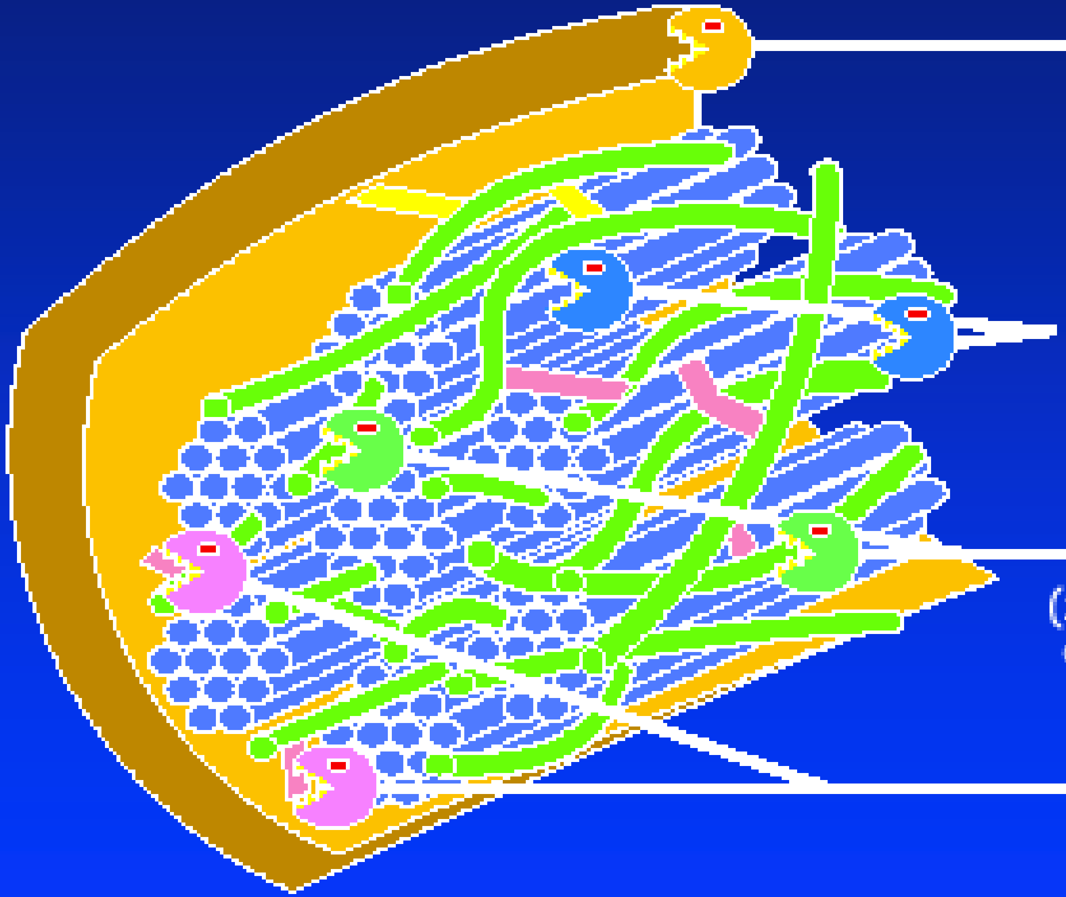


Renewable biomass



Wood is 70 - 80% cellulose and hemicellulose -
the most abundant renewable carbon sources on earth; 10-50 x 10^9 tons annually produced with about 4 x 10^9 tons annually available for conversion to energy and feedstuffs!

Renewable biomass (2)



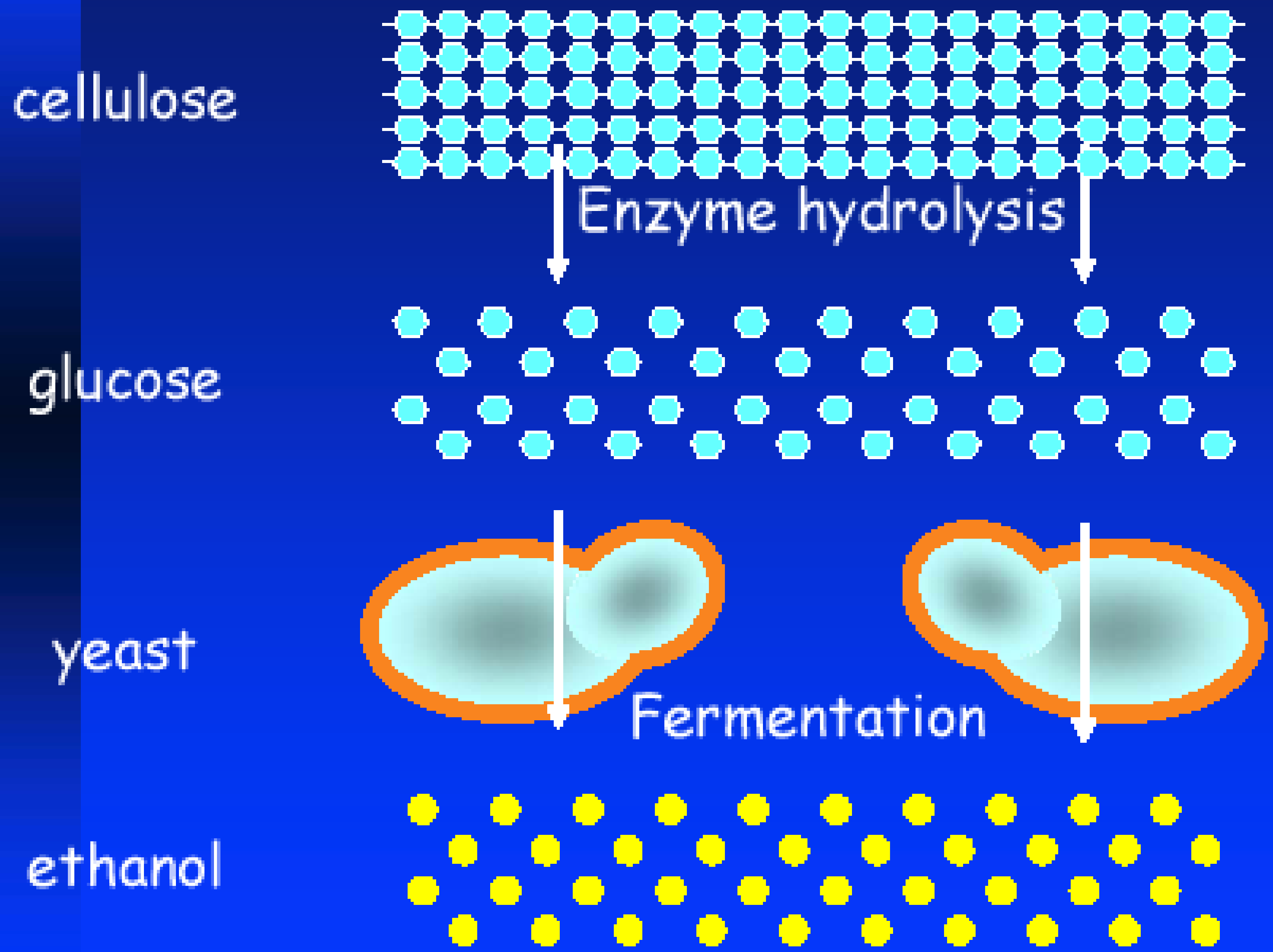
Ligninases
(laccases,
lignin peroxidases,
Mn-peroxidases)

Cellulases
(endoglucanases,
cellobiohydrolases,
β-glucosidases)

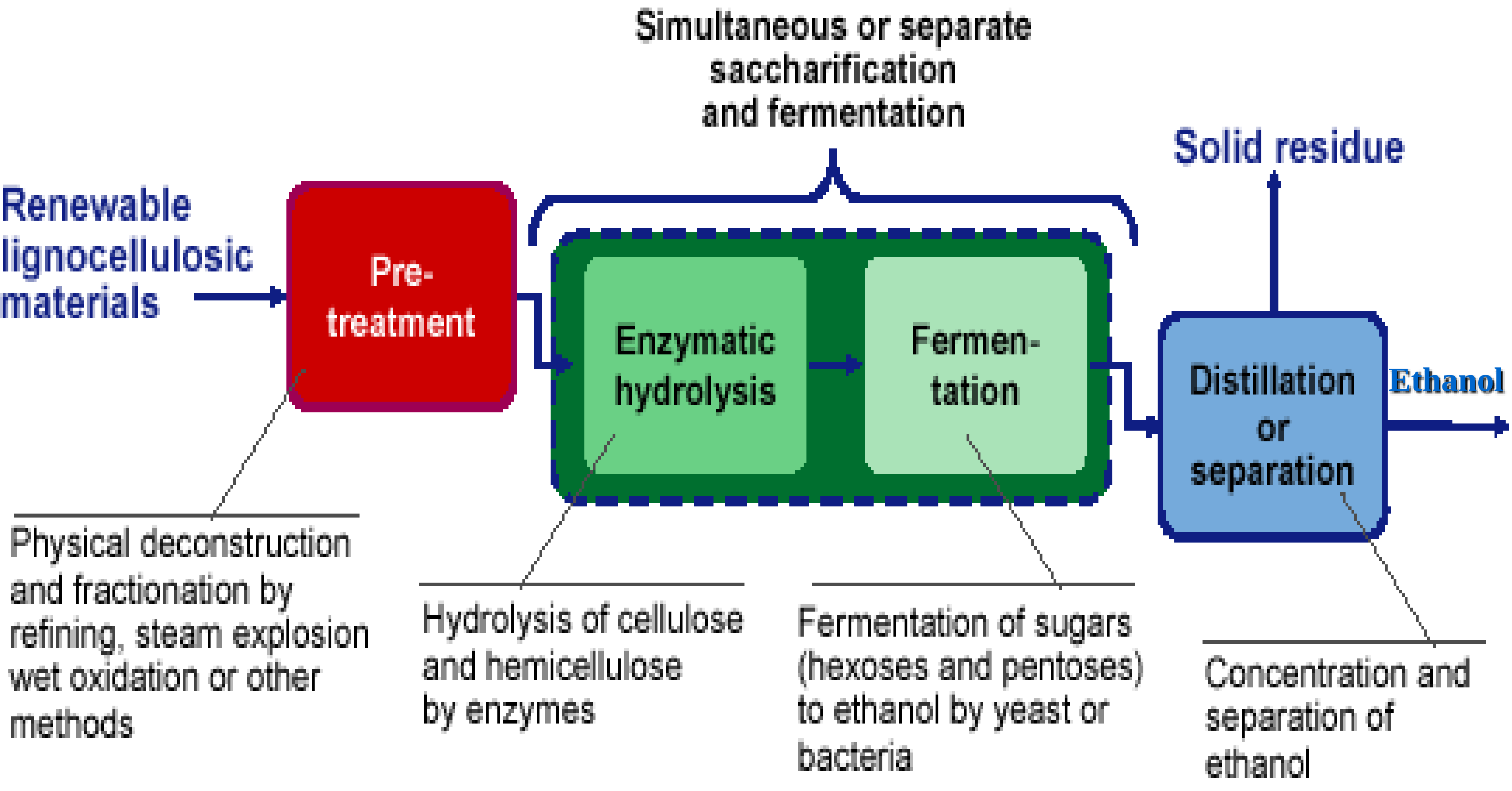
Hemicellulases
(xylanases,β-xylosidases
α-arabinofuranosidases
α-glucuronidases)

Esterases
(feruloyl esterases,
coumaroyl esterases)

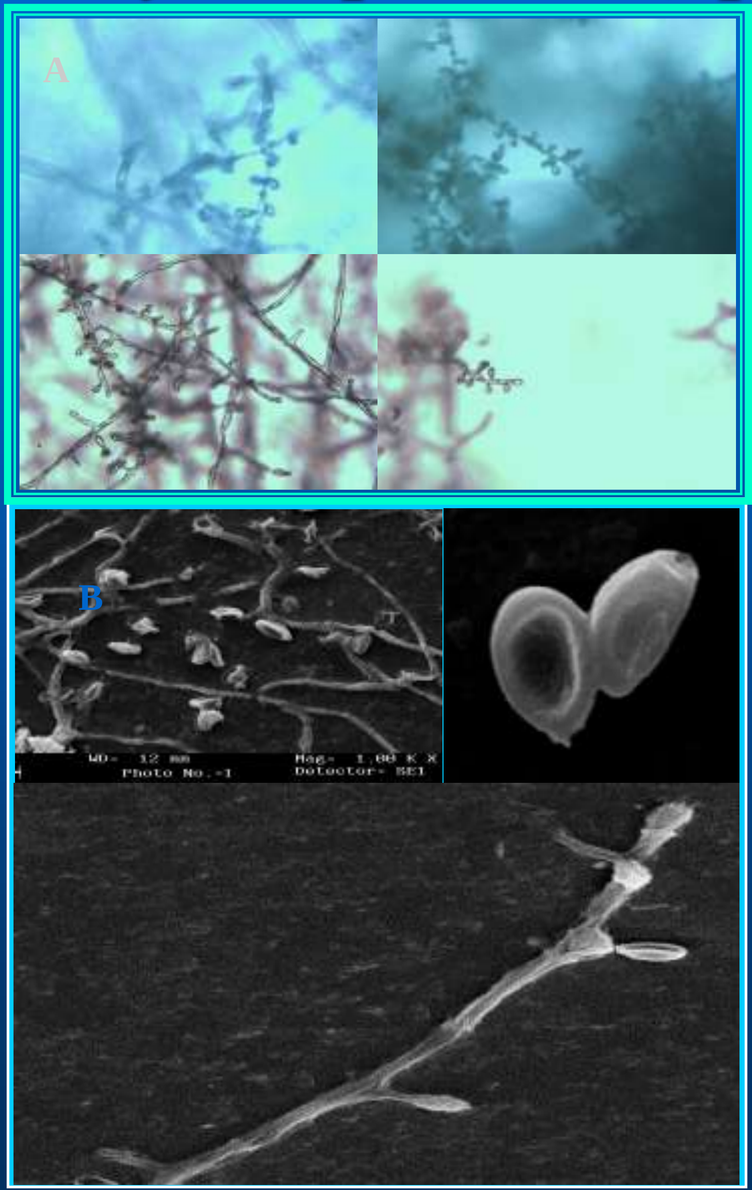
Cellulose hydrolyses and fermentation



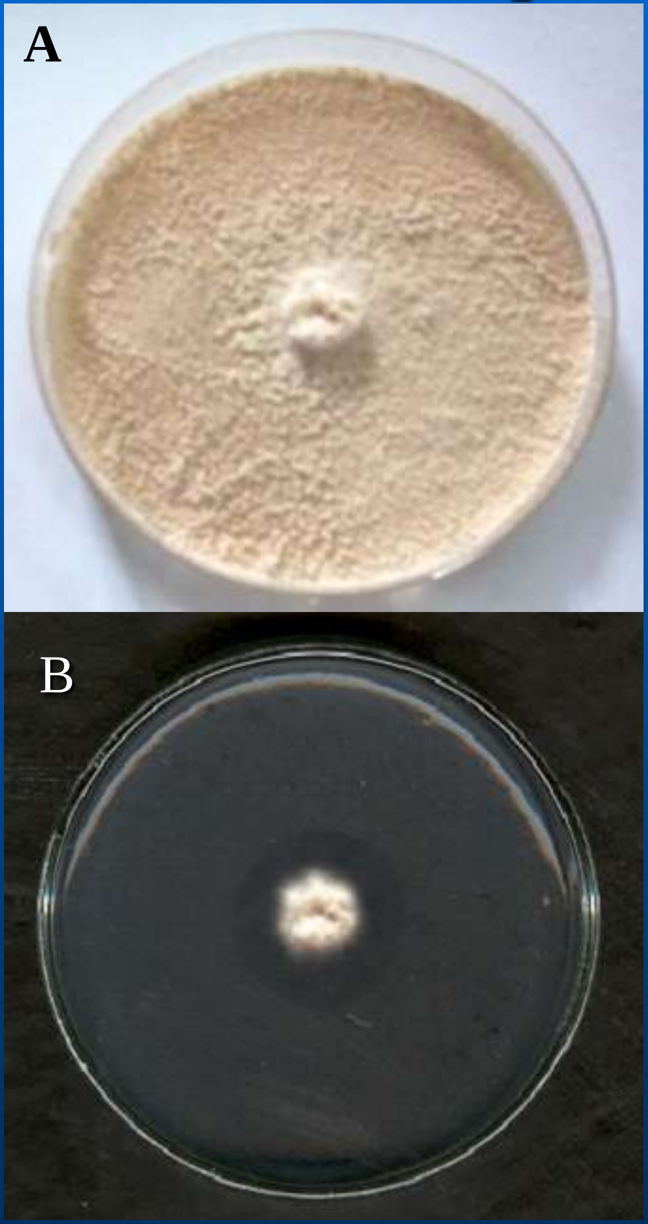
MAIN PROCESS STEPS IN LIGNOCELLULOSE-TO-BIOETHANOL PROCESS



Myceliophthora (Sporotrichum) thermophila



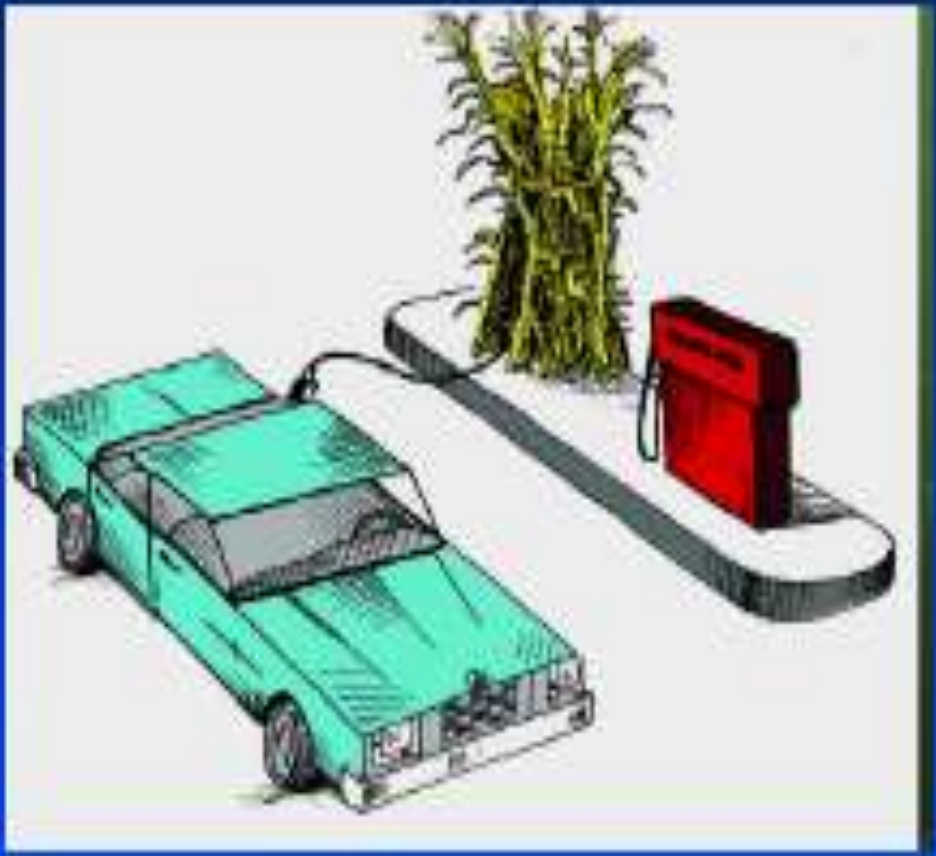
Morphology of the *S. thermophile* observed under compound (A) and electron microscope (B)



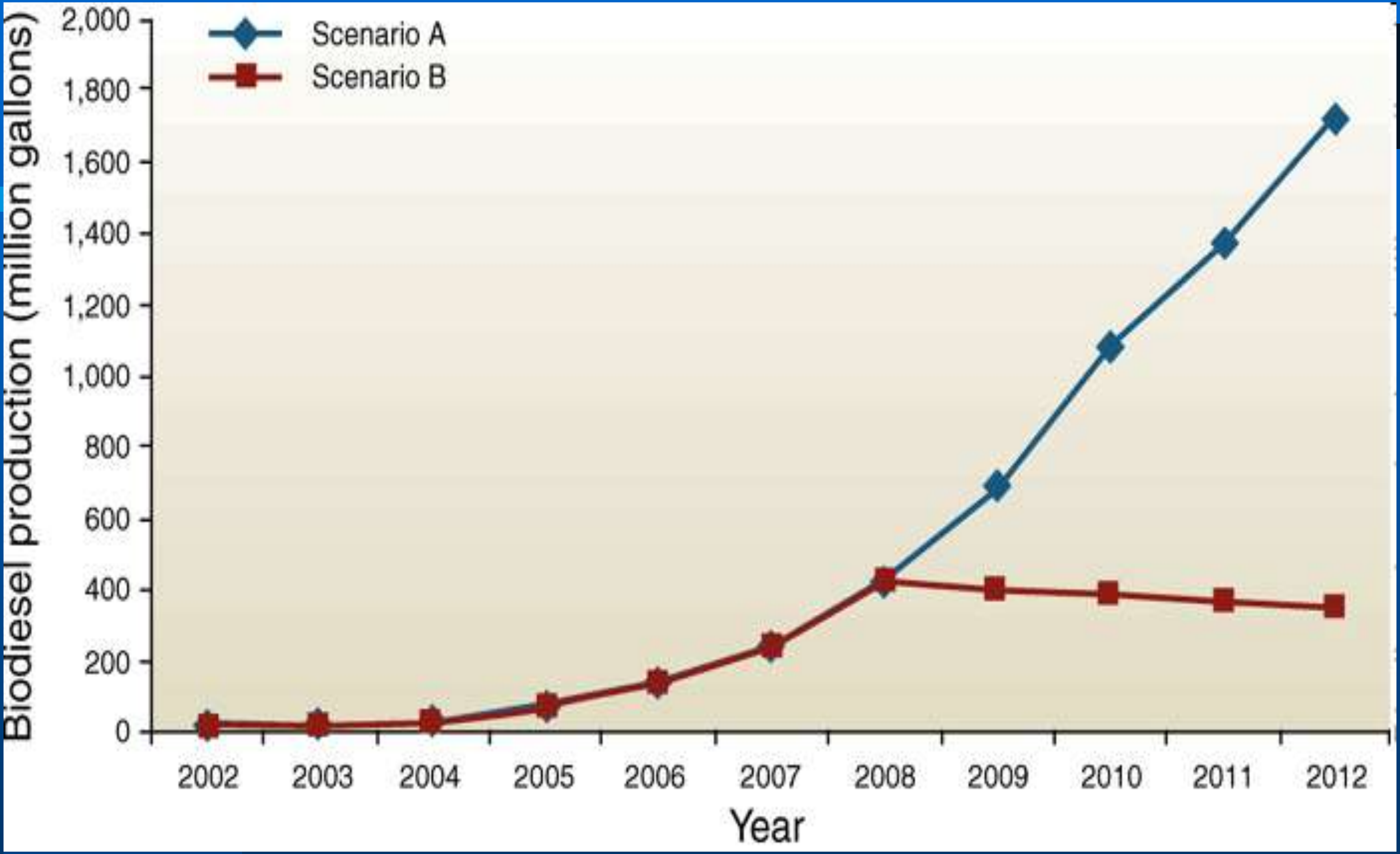
- *M. thermophila* grows rapidly when cultured on MEA reaching a diameter of up to 9 cm after 3 days of incubation at 45°C.
- *M. thermophila* produces thermostable enzymes that can be used in industrial high-temperature bioprocesses.
- Several extracellular lignocellulolytic thermozymes of *M. thermophila* have been characterized including: endoglucanase, β-glucosidase, exoglucanase, laccase, endoxylanase, cellobiose dehydrogenases and feruloyl esterase. Other interesting enzymes isolated from M. thermophila include: β-glycosidase, pectinases, lipases, amylases, phytases, glutathione S-transferase and malate dehydrogenase

Sugar/ethanol Plant at Piracicaba (Brazil): Produces electricity from bagasse

Soon people may be saying
"Fill it up with corn stalks or wheat straw please"



Estimated biodiesel market in North America 2002 - 2012



Scenario A: high price for crude oil

Scenarioo B: Decreasing international price of crude oil

JATROPHA CURCAS

FLOWERING

PONGAMIA PINNATA

INDIAN COMPANIES INTERESTED IN BIODIESEL

1. Indian Railways
2. Reliance Industries (A.P.)
3. Shiva Distilleries Ltd. (Tamil Nadu)
4. Dharani Sugars & Chemicals Ltd. (TN)

OIL YIELD

Pongamia pinnata

900 – 9000 kg Seeds Per ha (100 trees per ha)

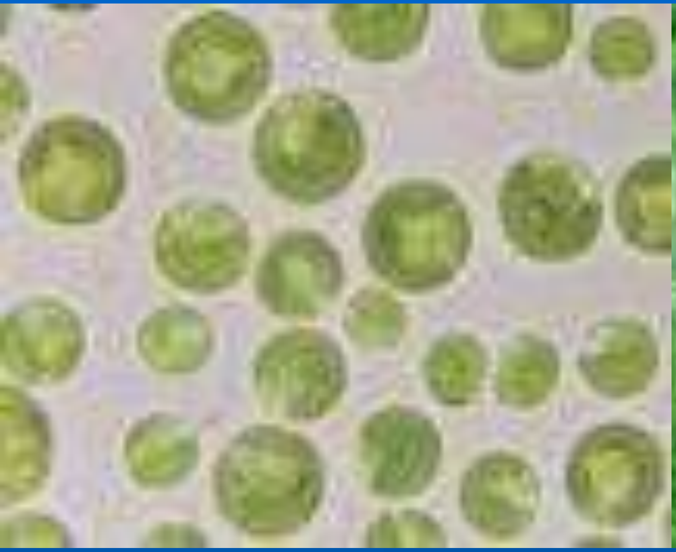
18 – 45 % oil in seeds

(palmitic, stearic, oleic, linoleic, lignoceric, eicosenoic, arachidic and behenic)

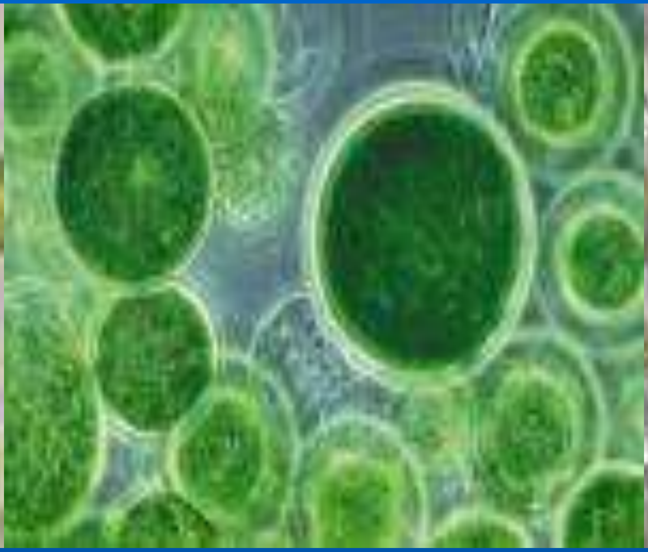
Jatropha curcas

23 – 45% of oil in the seeds

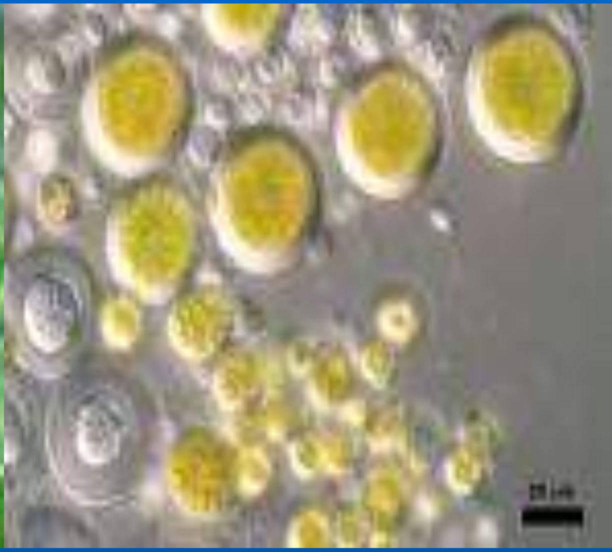
Chlorella



Haematococcus



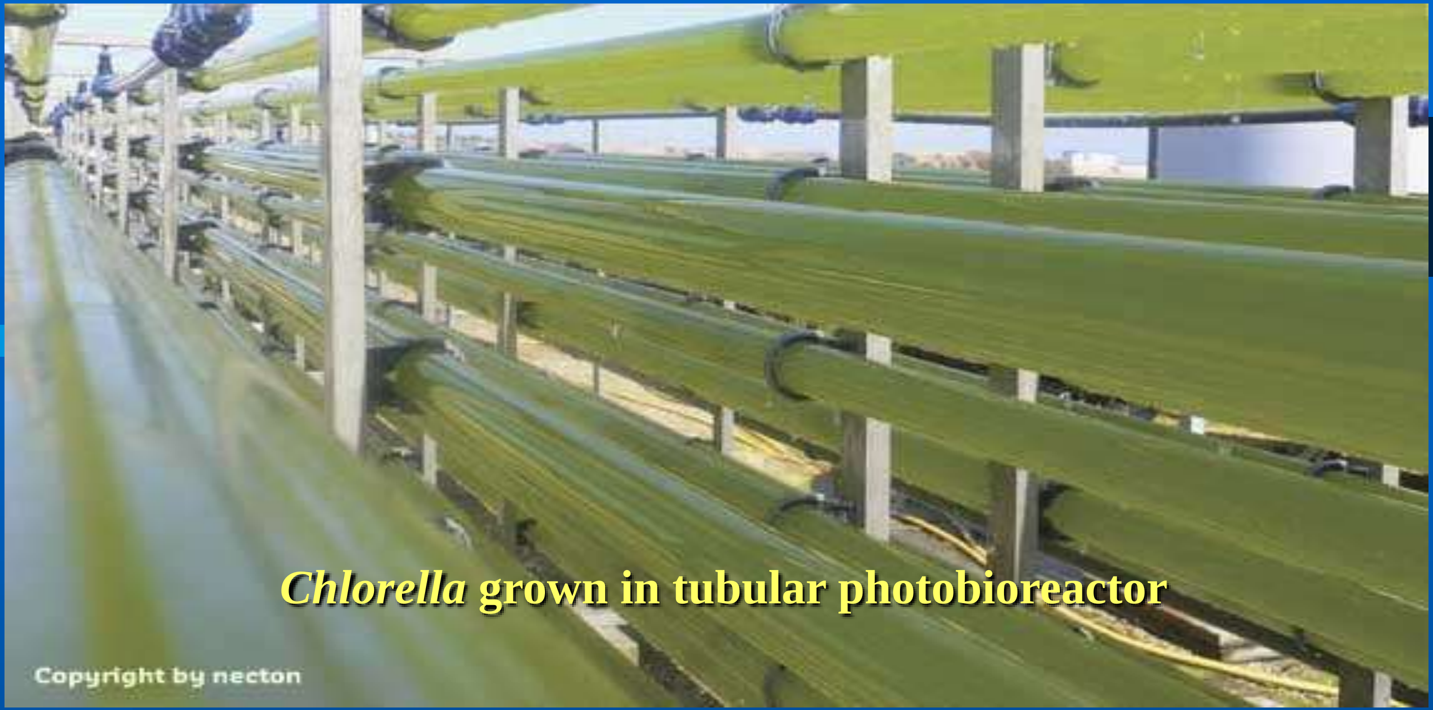
Chlorococcum



Scendesmus

Botryococcus

Dunaliella


Chlorella grown in tubular photobioreactor
Copyright by necton


Mass cultivation of *Botryococcus*

FIRMS/COMPANIES INVOLVED IN ALGAL FUELS

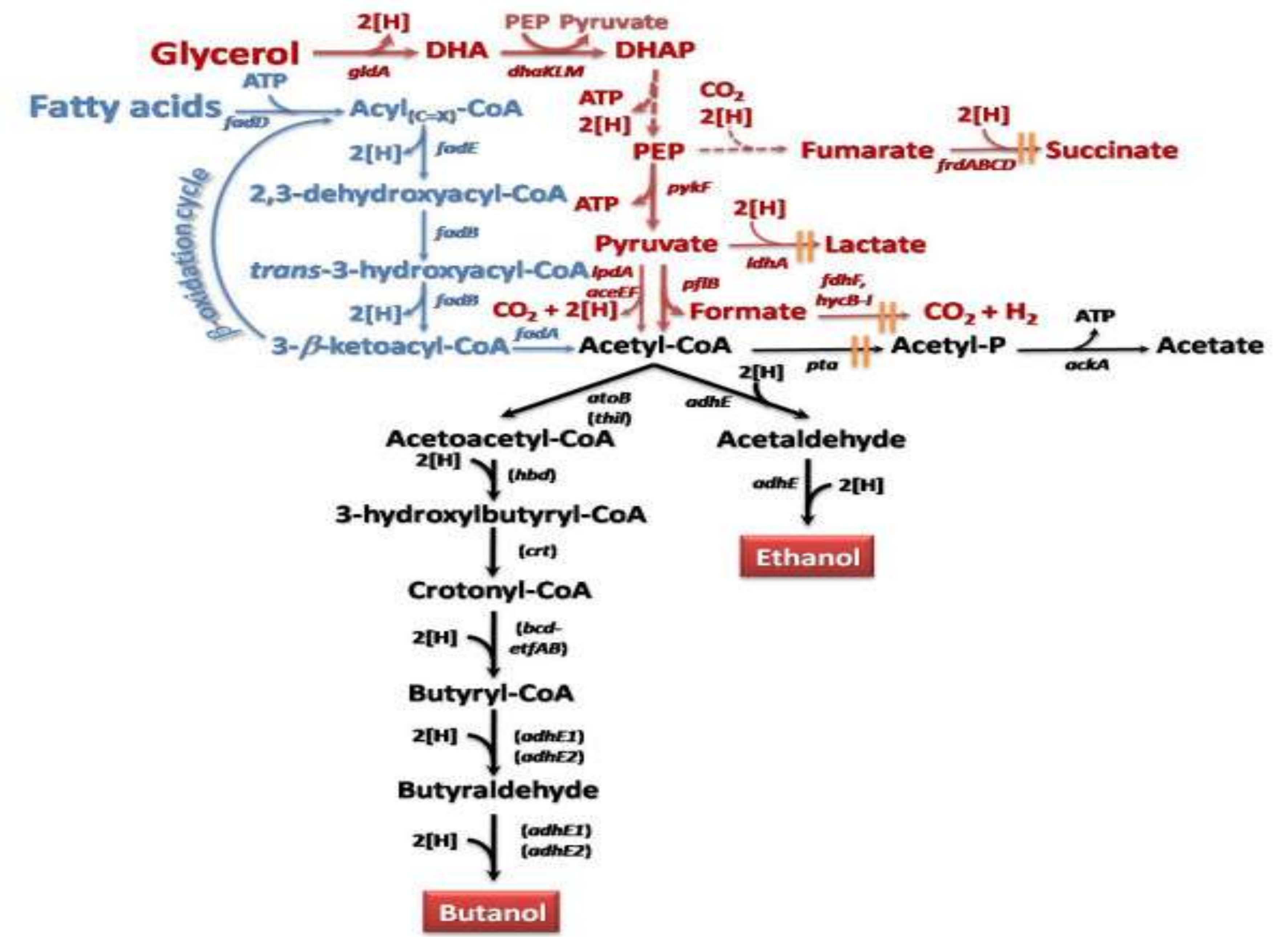
1. Saphire Energy, San Diego
   (Raised US $ 100 million)

2. Phycal, St Louis, Sayre

(Indian Express, Aug. 1, 2010, p. 15)

Algae: the next big source of Green Energy

Pathways for microbial production of biofuels from bio-oil constituents glycerol and fatty acids



ALTERNATIVE USES OF GLYCEROL

Klebsiella planticola	Ethanol
Clostridium pasteurianum	Butanol
Recombinant *E. coli*	Butanol
K. pneumoniae	1,3-Propanediol
Propionibacterium acidipropioni	Propionic acid
Pseudomonas oleovorans	PHA (microbial plastic)
Candida bombicola	Biosurfactant (soap and detergents)

Occurrence of alkanes in cyanobacteria

Cyanobacterium	Alkanes present
Synechococcus elongatus	Heptadecane, pentadecane
Synechocystis sp.	Heptadecane
Prochlorococcus marinus	Pentadecane
Anabaena variabilis	Heptadecane, methyl-heptadecane
Nostoc punctiforme	Heptadecane
Gloeobacter violaceus	Heptadecane

Schirmer *et al*. 2010 (Science 329: 559 – 562)

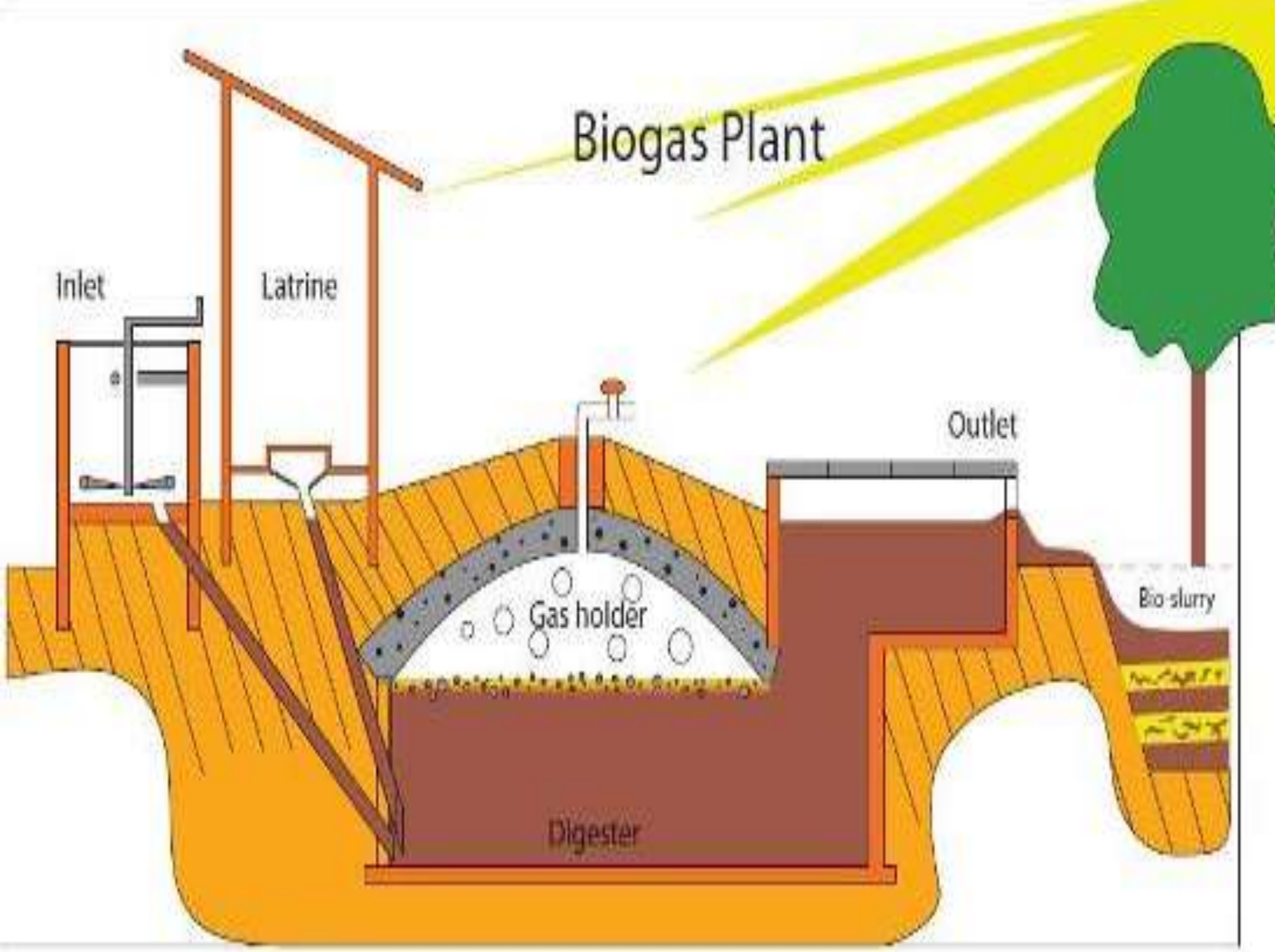
Cloned cyanobacterial genes encoding acyl ACP reductase and aldehyde decarboxylase from a cyanobacterium in *Escherichia coli*.

The recombinant *E. coli* secretes a mixture of alkanes and alkenes (C13 – C17) [diesel-like fuel] from glucose.

Biotechnology company LS9, South San Francisco (California) is now scaling up this process.

Philip Hunter (2010). EMBO Reports 11: 583 – 586.

The future of sustainable energy might lie in farming the oceans, rather than in using land to grow fuel plants.


Biogas Plant
Inlet
Latrine
Outlet
Gas holder
Bio-slurry
Digester

Composition of biogas

Compound	Chem	%
Methane	CH_4	50–75
Carbon dioxide	CO_2	25–50
Nitrogen	N_2	0–10
Hydrogen	H_2	0–1
Hydrogen sulfide	H_2S	0–3
Oxygen	O_2	0–2

Biogas Potential of food processing wastes

	Biogas l/kg
Vegetable processing wastes	450
Distillery wastes	550
Pressed grape skins	400
Brewer's grains	500
Fats from skimming tanks	1000

Chemical weekly, Jan. 1999

USES OF BIOGAS

The gases methane, hydrogen and carbon monoxide can be combusted or oxidized with oxygen.

(I) The energy release from combustion of biogas allows biogas to be used as a fuel. Biogas can be used as a low-cost fuel in any country for any heating purpose, such as cooking.

(ii)Biogas can be compressed like natural gas, and used to power motor vehicles.

In the UK for example, it has been estimated to have the potential to replace around 17% of vehicle fuel.

Biogas is a renewable fuel, and thus, it qualifies renewable energy subsidies.

Hydrogen is considered to be a non-polluting synthetic fuel which could replace oil, particularly for transport Applications, and it would be a good transport fuel because:

(1)It has the highest energy-to-mass ratio of any chemical, and thus used to propel rockets.

(2) Hydrogen is carbon-free, non-toxic, and its thermal or electro-chemical combustion with oxygen yields energy and water only.

(3) The main source is water, which is essentially an unlimited resource.

In order that hydrogen becomes a widely used fuel, three crucial steps are needed:

(i) Economically viable methods must be developed for producing large quantities of hydrogen, ideally using renewable energy sources

(ii) Hydrogen distribution and storage systems are necessary

(iii) Development of technologies and devices for converting the chemical energy stored in hydrogen into more useful forms of energy.

HYDROGEN PRODUCING ALGAE AND CYANOBACTERIA

Algae	***Chlamydomonas reinhardtii, C. mewusii*** ***Chlorella, Scenedesmus, Porphyridium***
Cyanobacteria	***Anabaena cylindrica*** ***Nostoc commune*** ***Oscilatoria brevis*** ***Calothrix scopulorum***

HYDROGEN PRODUCING BACTERIA

Bacillus licheniformis

B. coagulans

Clostridium thermocellum

Rhodopseudomonas

Rhodospirillum

Ruminococcus albus

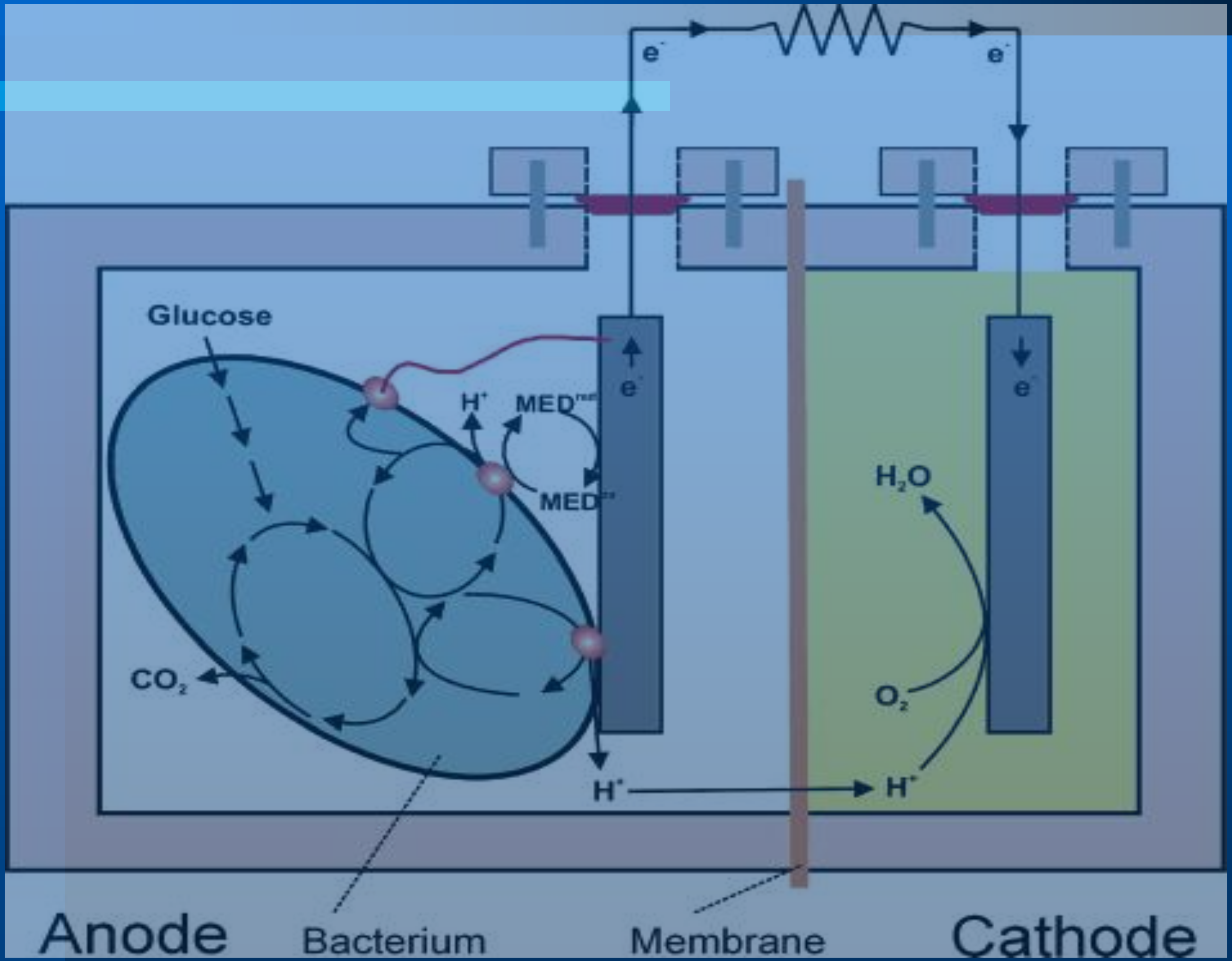
Selenomonas ruminantium

Hydrogen production from industrial wastes

Source of waste water	Organism used
Alcohol factory	*Clostridium butyricum*
Sugar refinery	*Rhodopseudomonas palustris*
Straw paper mill	*Rhodospirillum molischianum*
Waste-water containing organic acids	*Rhodopseudomonas rubrum*
Whey from dairy industry	*Rhodopseudomonas gelatinosa*

Hydrogen fuelled buses are already running in Berlin

MICROBIAL FUEL CELL

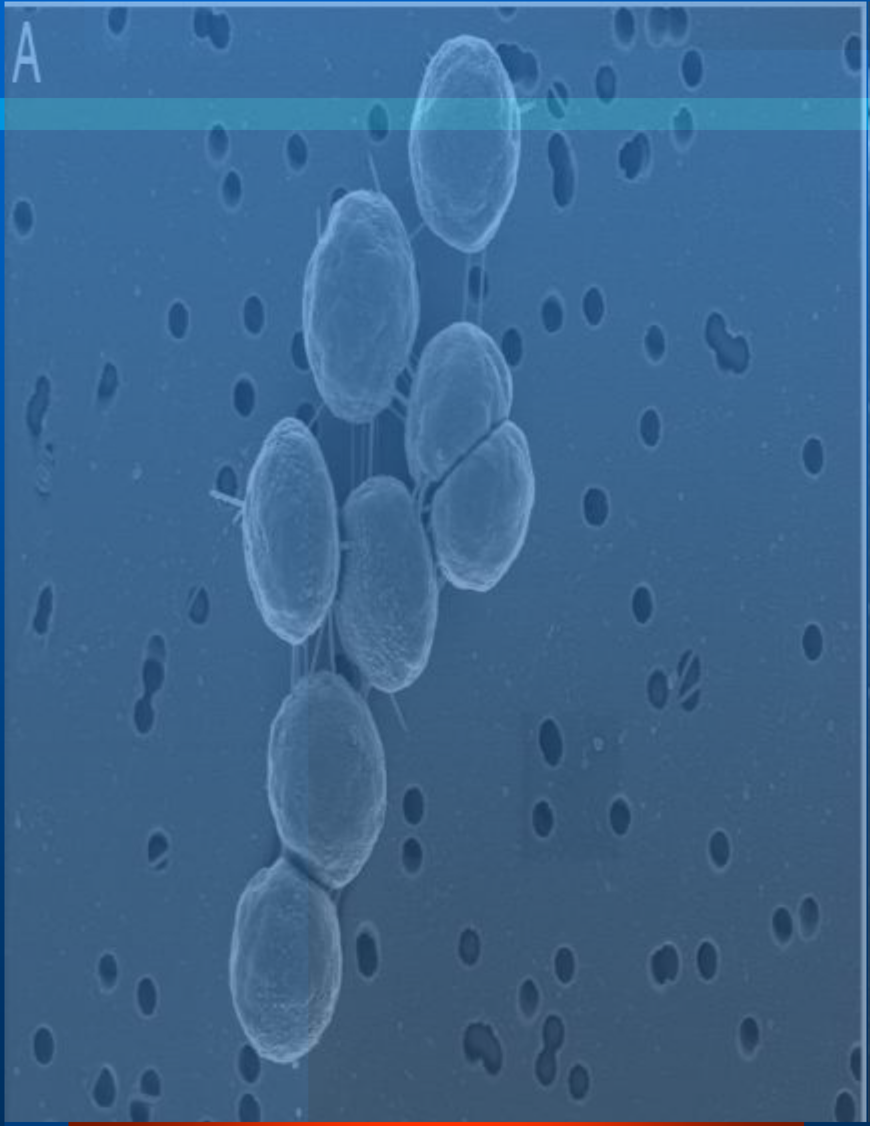


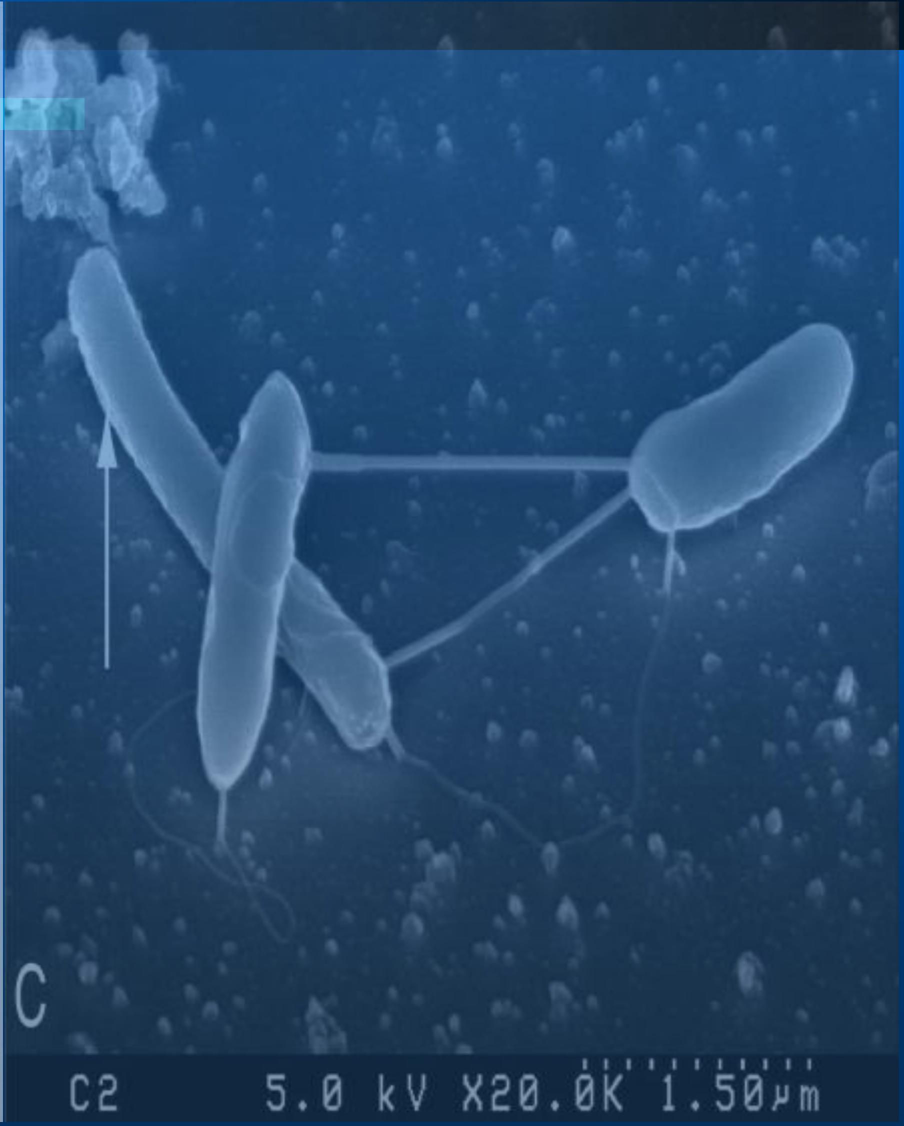
Generation of current by Microbial Fuel Cells

Bacterium	Substrate	Current (mA)
Proteus vulgaris	Glucose	0.8
Shewanella puterefaciens	Lactic acid	0.04
Geobacter sulfurreducens	Acetate	0.4
Rhodoferax ferrireducens	Glucose	0.2
Escherichia coli	Lactate	3.3

Nanowires produced by

***Synechocystis* sp.** ***Methanothermobacter* sp.**





CONCLUSIONS

1. Biomaterials have a great potential for developing renewable bioenergy.

2. There is a need to do basic research to understand the underlying mechanisms of energy generation to develop technologies.

3. Government and private partnership is necessary in basic research and developing technologies.


Thank You