ENVIRONMENTAL BIOTECHNOLOGY

Purdue-Mexico Workshop on Sustainability

April 29 - 30, 2013

Sergio Revah
Departamento de Procesos y Tecnología
Universidad Autónoma Metropolitana-Cuajimalpa
srevah@correo.cua.uam.mx
http://www.cua.uam.mx

UNIDAD CUAJIMALPA

UAM

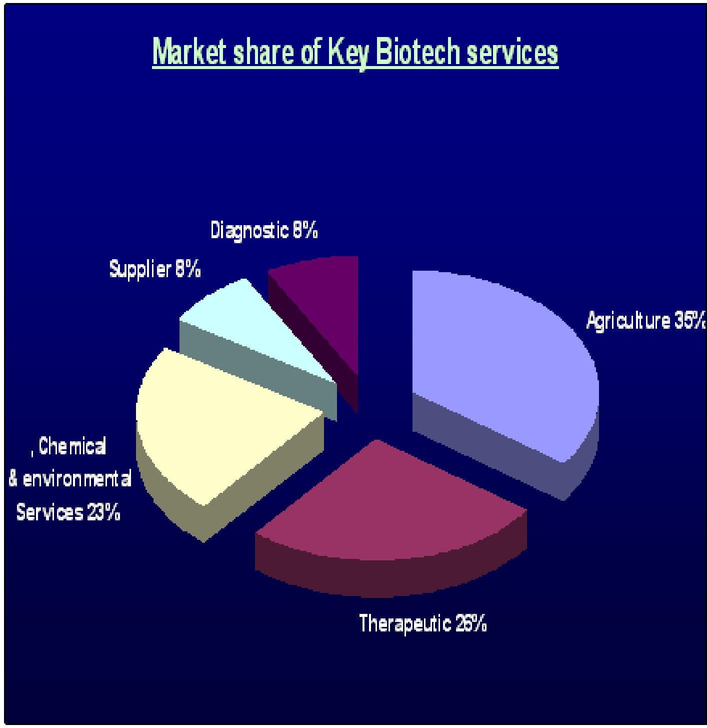
- Azcapotzalco, Xochimilco, Iztapalapa, Cuajimalpa and Lerma
- 51K Bachelor, 630 Master, 280 doctor and 2900 academic personnel
- Around 40 million/year in projects (most gob.)
- Sustainability program
- Sustainability in Social Sciences, philosophy, economics, law, biology
- Environmental engineering, biotechnology

biotechnology

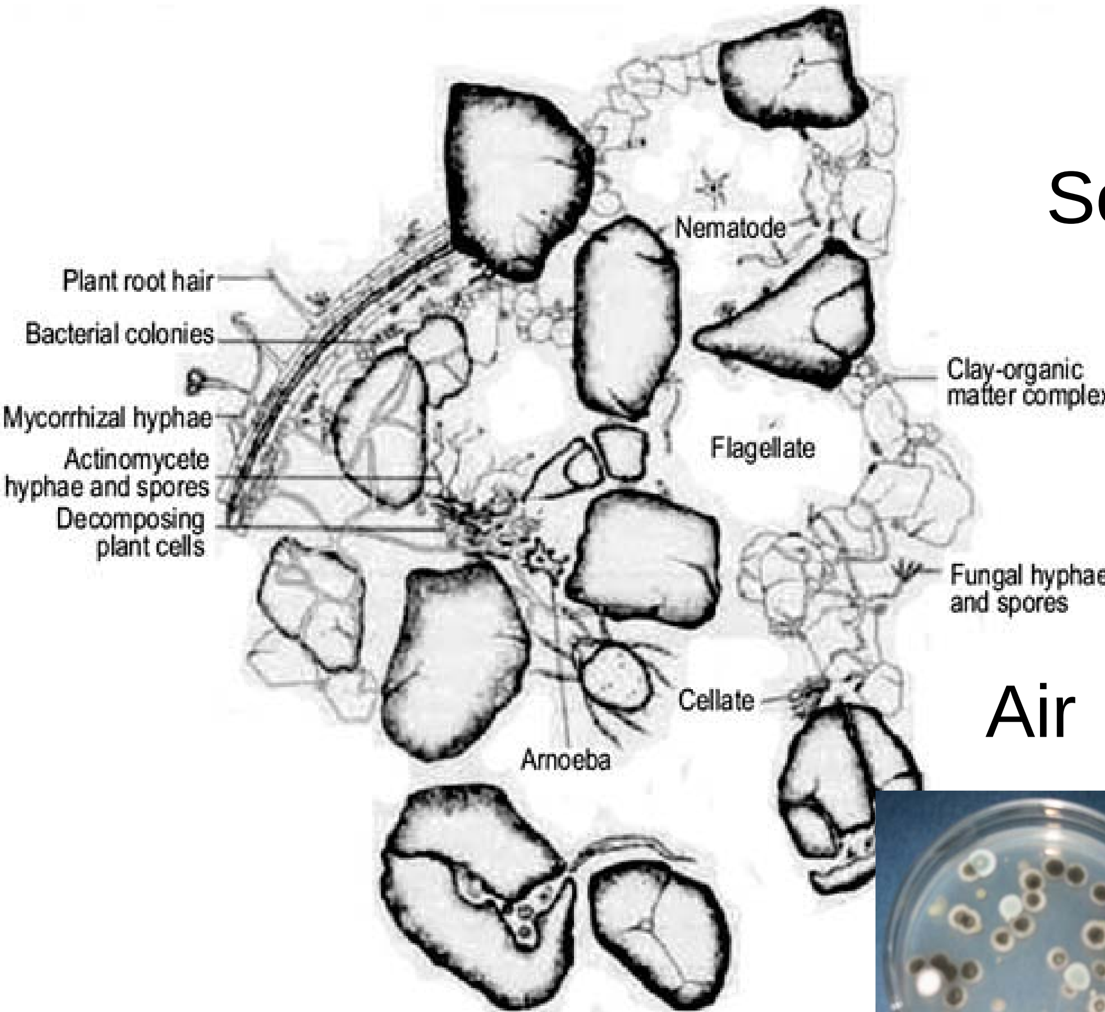
- The application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.

Biotechnology in strategic areas

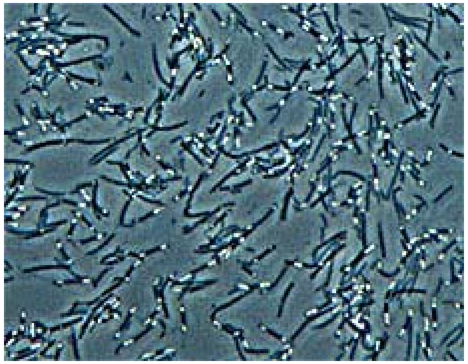
- Agriculture & food
- Health
- Livestock, marine and aquaculture
- Industrial
- *environment and biodiversity*



Microorganisms: main inhabitants of the earth

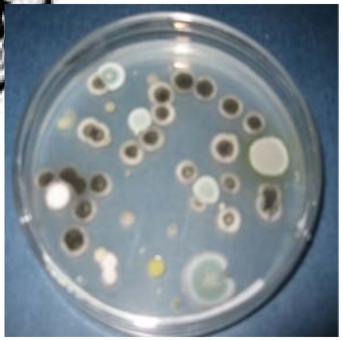


Soil $10^8 – 10^{11}$ /g

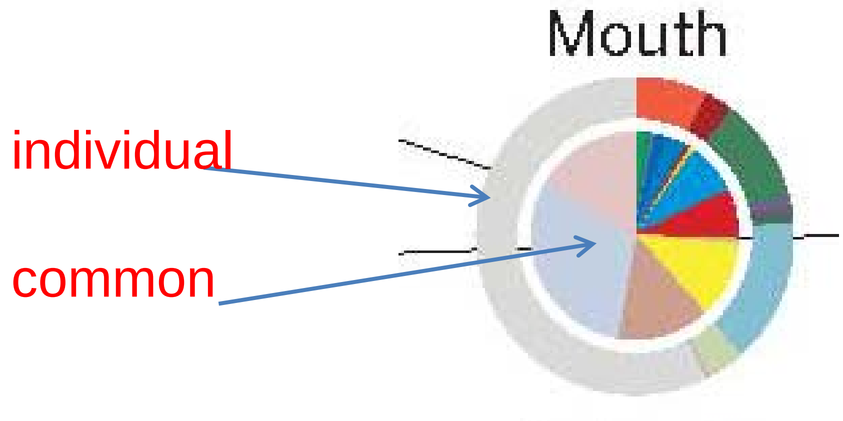


Air

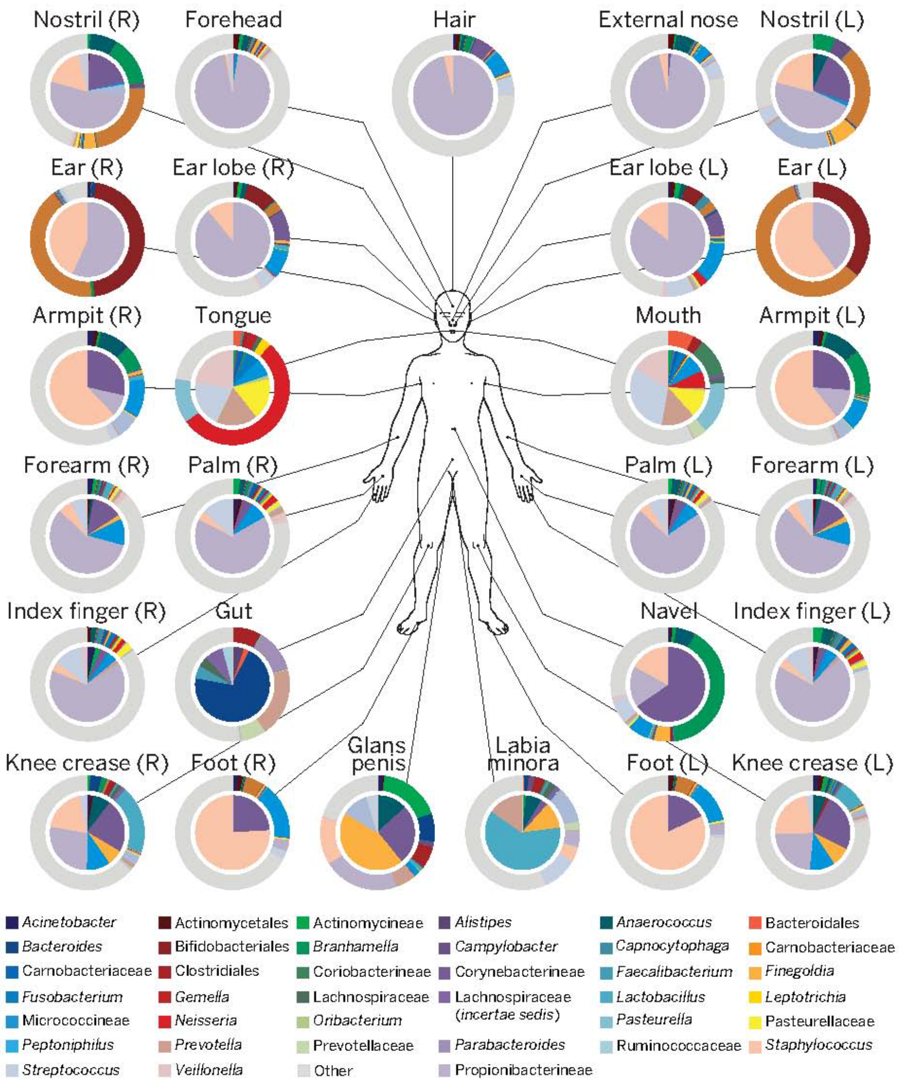
Water



Microbiome



MAP OF MICROBIOME In a survey of bacteria from 27 sites in nine healthy adults, researchers found that certain lineages of bacteria were common to all subjects (represented in the inner circles), whereas many more bacterial lineages were found in some people but not others (represented in the outer circles).



The human microbiome:
Protects against persistent pathogens,
Produces essential vitamins and digestive enzymes

Many of our seemingly human characteristics depend on our bacterial envelope: excess weight, smell

We have 10 times more microbes than human cells and its genome is 100 times more varied than the human

WWW.CEN-ONLINE.ORG 33 DECEMBER 13, 2010

Global environmental problems

- The destruction of the ozone layer (CFCs, HFCs…).
- Global warming, accumulation of greenhouse gases, mainly CO_2 and CH_4.
- Waste accumulation.
- The pollution of oceans and national water bodies, eutrophication
- Loss of biodiversity
- Degradation/depletion of natural resources: desertification, salinization, deforestation and fisheries.

Climate change

Nitrogen cycle

biodiversity

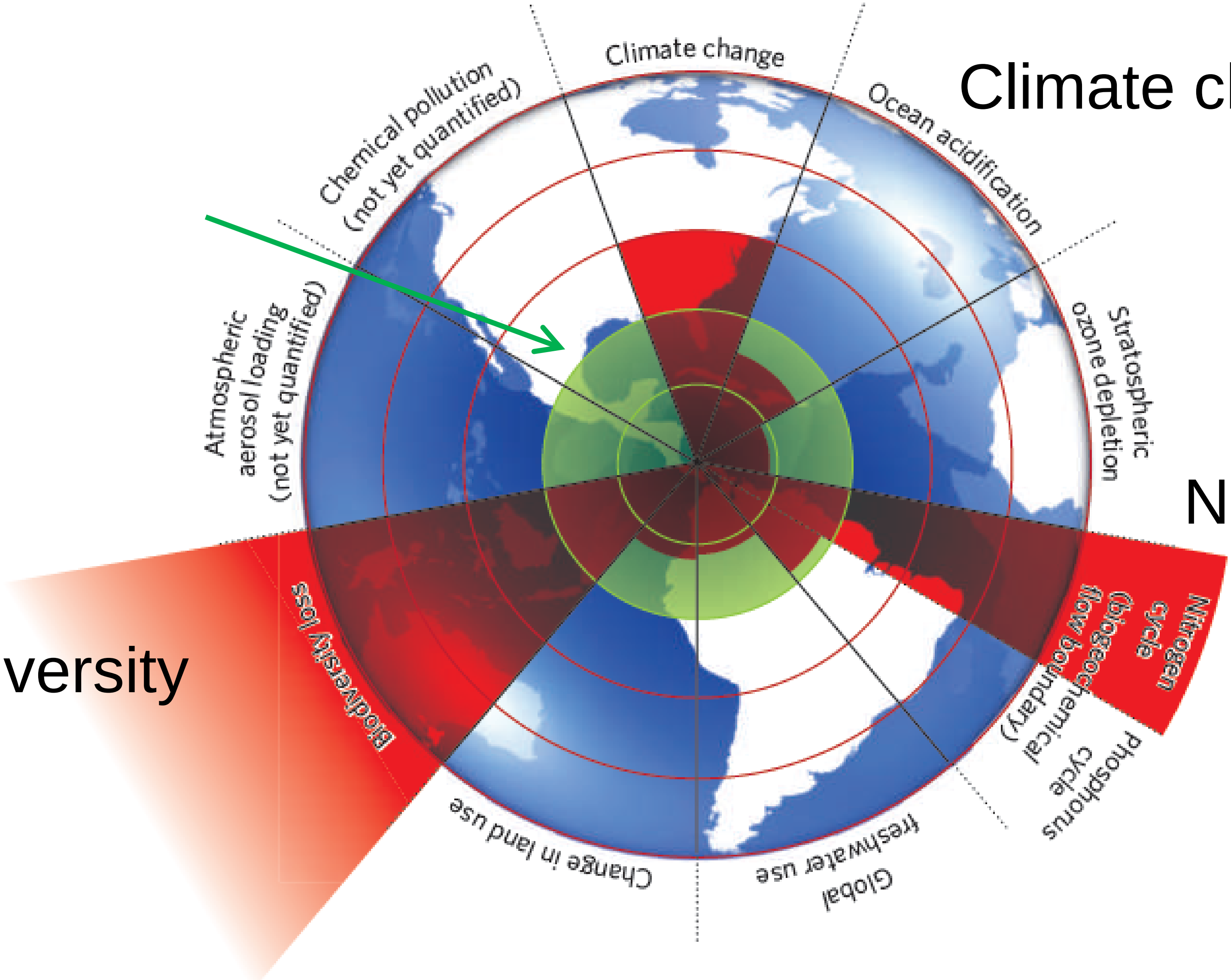


Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

Nature, 2009

Role of biotechnology

- **Prevention**
- **Technologies: Remediation & treatment (with resource recovery)**
- **Detection**
- **Biodiversity**

Probably better

$$I = aP^{a}A^{b}T^{c}$$

I=PAT

Environmental impact (I) = **Population (P)** **X** **Affluence (A)** **X** $\boxed{\textbf{Technology (T)}}$

$$I = Population \times \frac{Economic\ good}{Population} \times \boxed{\frac{Pollutant}{Economic\ good}}$$

Credited to Ehrlich

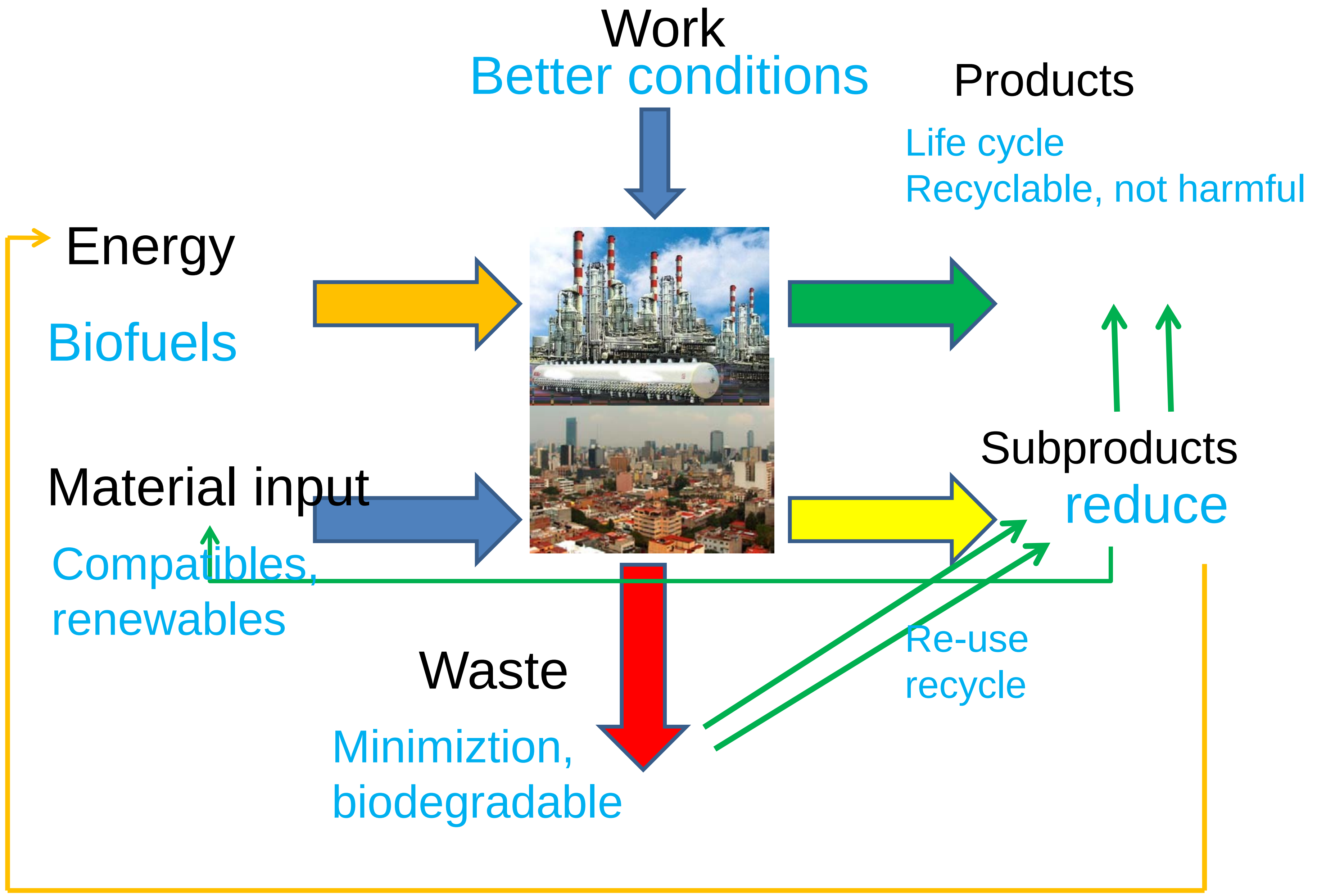
How? (1)

- **Processes** that **add value** to waste producing useful compounds reducing the demand for natural products,
- Through terminal (end of the pipe) treatment processes where polluted streams are recycled to nature without harmful effect.
- implementing strategies for **environmental restoration**, including soil and polluted water bodies,

How? (2)

- developing new materials and processes that have less environmental impact,
  - new biological processes that generate less waste,
  - use less material and energy resources,
  - replace hazardous substances and
  - operate under milder conditions
- and contributing to the generation of tools for detecting contaminants and species.

Instruments



Bioprocesses are (tentatively!) sustainable :

- Rely on renewable resources,
- Are "soft“:
  - less occupational risk to the community,
  - minimize power consumption,
  - Reduce the use of hazardous and persistent substances
- Yield products, services and wates that are compatible with the environment (recyclable, reusable, degradable ...)

- But reactions and microbial growth are slow, not necessarily efficient and require plenty of water.

State of the art

Traditional treatment methods:

- *Water* (effluent)
  - aerobic / anaerobic, mixed, (energy)
- *Solids*
  - digestion, deposits, activated sludge (energy)
- *Contaminated soil and groundwater*
  - in situ: bioremediation, natural attenuation, fertilization, bioaugmentation, bioventing, phytoremediation, bio-barriers
  - ex situ: bioslurry, biopiles, composting
- *Air and gases from stationary sources*
  - Biofilters, bioscrubbers and trickle bed reactors

microbial ecology

- Most often the job is made by mixed non axenic cultures (only around 5-10% culturable) and is assumed as a ‘single specie’
- Self organizing, self sustaining
- Main challenges
  - Which are the organisms present? (identity and numbers)
  - Capability of transformation (genotypic/ phenotypic potential)
  - Which functions are actually happening
  - Understand interrelationships among microorganisms and with the environment (materials and energy flows, spatial distribution..)

- Structure changes with time: stability & resilience
- New (since mid 80’s) techniques allow now:
  - Phylogenetic ID (small subunit16s rRNA),
  - Fingerprinting * (DGGE) community structure
  - Quantification of community structure or phenotype potential
  - Fluroscence hybridization gives spatial data (coupled to microscopy,spectroscopy, cytometry..)
  - Reverse transcription PCR-community function through expression (mRNA) of a target gene

*Denaturating gradient gel electroph.

If it works… why fix it?

- The limits of treatment (how thorough) are not scientifically supported and vary with new information → **Risk**
- Traditional treatments generate secondary pollution: odors, sludge, methane, leachate
- Not integrated: there is transfer of contaminants (water ↔ air ↔ solids).
- Traditional treatments are inefficient: they require large spaces
- Recalcitrant xenobiotics in environment (>> 100,000 compounds including pesticides, polyaromatic, biphenyls, dyes, metals, CFC, endocrine disruptors, drugs)
- New problems →global warming, spills, pollution of aquifers (BTEX, MTBE, nitrates), metals ...

If it works… why fix it?

- New materials for biofilm supports, membrane s to retain biomass
- New ‘big problems’ : non point pollution, recover energy
- New more powerful molecular biology tools (ie.high throughoutput data) should allow to distinguish ‘lead players’

Challenges in environmental bioprocess

- knowledge integration for prediction and extrapolation to new problems
- Measuring the effectiveness, reliability, reproducibility and safety of biological processes to achieve the necessary technological validation and compete with other non-biological processes.
- Emerging contaminants varied chemical nature: explosives, radioactive materials, pathogenic organisms, siloxanes, endocrine disruptors.
- Valuing biodiversity: finding new interesting organisms (or genes) with degradative capabilities : fungi, bacteria producing surfactants, phytoremediation.

Challenges in environmental bioprocess (2)

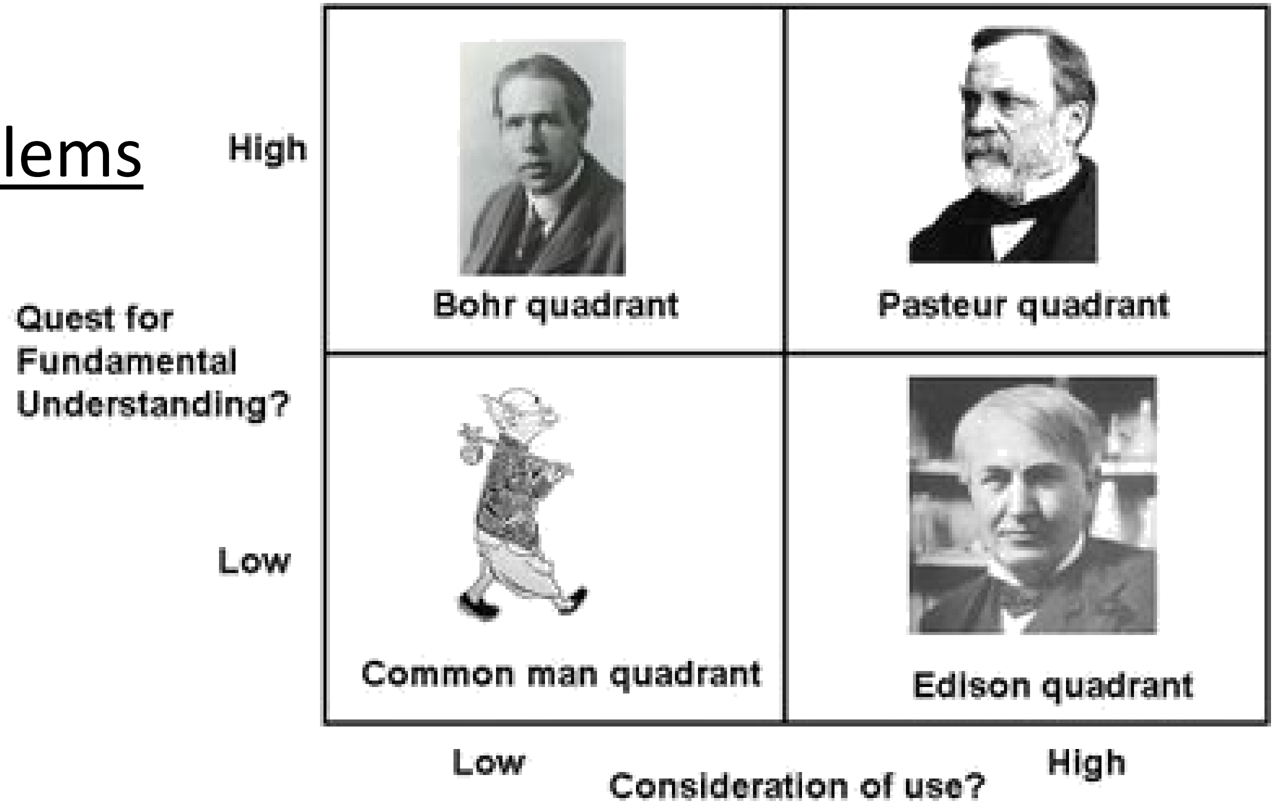
- Using enzymes instead of hazardous chemicals: ligninolytic, laccases, peroxidases
- Treatment in extreme conditions: cold regions, extreme acidity / alkalinity / metals
- Adequate on-site detection of contaminants ecotoxicity of microorganisms (especially GMOs) and their activities. This allows for:
  - Define scope of treatment compatible with the environment and health.
  - Study locally contaminant bioavailability. This information is required to determine the kinetics of degradation and have a very important to assess the risk to health
- Integrate –omics: genomics, transcriptomics, proteomics, metabolomics, excretomics
- Go beyond “Stamp collecting image”*
-

* From Rittman

Challenges in environmental bioprocess (3)

- designing GMO capable of eliminating contaminants under "natural" conditions. Biosecurity management.
- Metabolic engineering: process optimization based on knowledge of mixed populations, physiology, and energy exchange of genetic material
- Integration techniques to optimize physicochemical biological degradation and to minimize migration of contaminants between phases ..
- Modeling and simulation
- Synthetic biology
  - the design and construction of new biological parts, devices and systems,
  - the redesign of natural biological systems for utilitarian purposes

Research in environmental problems



- Basic science/ technology/ innovation
- Public and private R&D laboratories
- Market/ legislation pull, very little science push

Projects UAM

- Air/gas bioprocess: sulfides, biogas sweetening, fungi, two-phase reactors, extremophiles (pH, salt), advanced oxidation- biological processes.
- Resource recovery, PHB, selected proteins, oils, hydrogen, CO2 sequestration, biomass utilization
- Micro algae: photoreactors, (unsteady state approach)
- Pesticides,

Environmental biotech on different media

	Prevention (1)	End of the pipe (2)	Diffuse treatment (3)	Detection monitoring
Air/ gas	- (+)	+ (+)	- (-)	- (+)
Water	+/- (+)	+ (+)	+/- (+)	+/- (+)
Soil	+/- (+)	+ (+/-)	+ (+)	- (+)
Solids	+/- (+)	+/- (+)	+ (+)	- (+)

+ --> relevance, ( ) perspective

(1) Pollution prevention, integration, clean production

(2)On site treatment, add-on, recycling technologies.

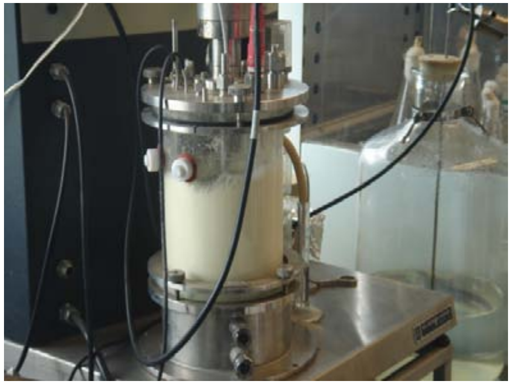
(3) Diffuse sources, remediation..

fuente: OCDE

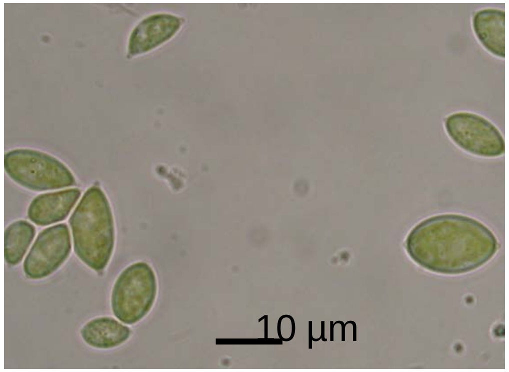

Thanks!
Looking forward for cooperation
10 µm

Proyectos

- H_2S : eliminación de aire y agua → ciclo biológico del azu
  - Análisis de poblaciones extremófilas (alcalo-, halófilas)
  - Biofiltros -Biolavadores – reactores
  - Corrosión
- Biofiltración: microbiología y proceso
  - Nuevos biofiltros: textiles, espuma
  - Aplicaciones (tradicionales)
  - Gases de combustión, uso de organismos halófilos.
  - Estudio de microambientes: interiores
  - Uso de microorganismos extremófilos: alcalófilas, acidófilos, halófilas
  - Secuestro CO2



- Degradación/proteómica
  - Cinética de degradación, estudios de biología molecular para caracterizar las actividades enzimáticas de cepas.
  - Proteómica Aplicaciones de microorganismos halófilos Estudiar capacidades degradadoras de volátiles (organosulfurados, parafínas, aromáticos, amoniaco, MTBE/TBA).
- Remoción de metales de DAM. Sulfatoreducción y precipitación (con Cenica/ UArizona)
- Remediación asistida
  - Degradación de DDT de suelos. (CENICA, Hospital de Pediatría, Mor)
  - Contaminación por cromo
- Biocombustibles
  - Algas acumuladoras de aceites
  - Etanol de 2ª. generación



reconocimientos

CONACyT
Grupo Cydsa: Víctor Morales, Walter Hugler
Cyted
IMP (Elías Razo)
IRD

Corporación Biotec
Degremont
Proagua Potosi
3M
IBTech

Marc Deshusses, Raul Muñoz

Armando González
Sergio Hernandez
Alberto Vergara
Sergio Alcántara
Sonia Arriaga
José Rocha
Inés García
Juan Antonio Velasco
Jesús Espinoza
Roel Meulepas
Rufino Trinidad
Alma Toledo
Luis Arellano
Guillermo Baquerizo
Wenceslao Bonilla
Sylvie Le Borgne
Tomás Viveros

Gracias