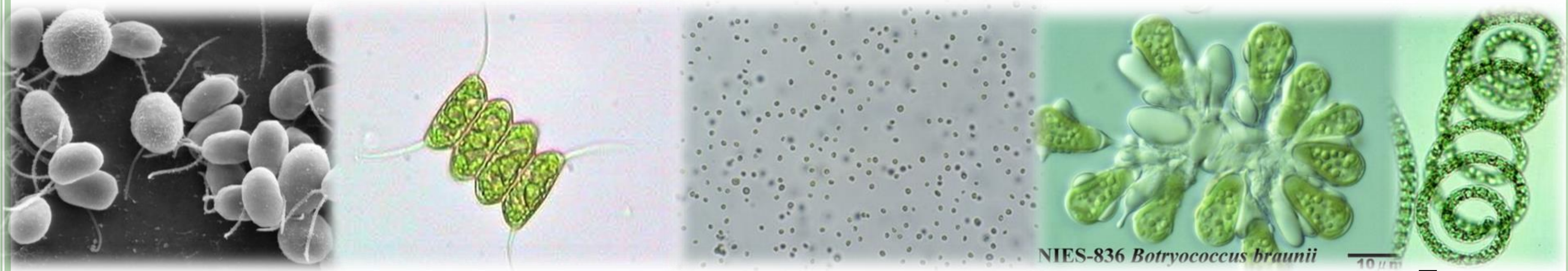
Corso di laurea in Biotecnologie Industriali, 09 Aprile 2019

Produzione di microalghe e cianobatteri a scopi energetici, ambientali e per la produzione industriale

Eleonora Sforza, PhD
Prof. Alberto Bertucco
Ing. Elena Barbera, PhD

Le microalghe

<u>Definizione</u>: in ficologia applicata riferito alle alghe unicellulari che operano fotosintesi ossigenica (spesso inclusi anche i Cianobatteri)



Fonte: web

Gruppo eterogeneo di organismi

- **Diversa organizzazione cellulare:**
  - **Unicellulari**
  - **Coloniali**
  - **Filamentosi**
- **Mobili o immobili (presenza di flagelli)**
- **Ecologia: acqua salata o acqua dolce**
- **Ampia distribuzione**

<u>DIVERSI CAMPI DI APPLICAZIONE</u>

Vantaggi delle microalghe

- <u>**accumulano grandi quantità di oli/carboidrati o proteine**</u>
- **sfruttano energia solare**

$$6CO_2 + 12\,H_2O + LUCE \longrightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$

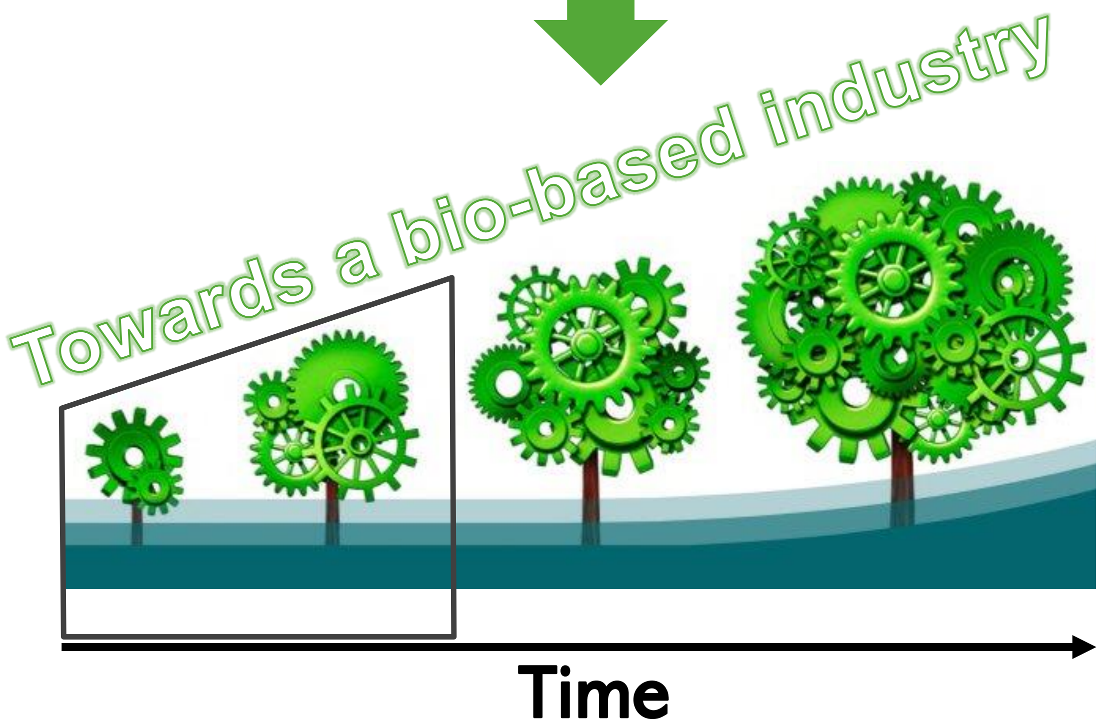
- **assorbono CO_2 ➔ no gas serra**
- **crescono velocemente**
- **non sono stagionali (come le piante superiori)**
- **non sfruttano terreni coltivabili e acqua potabile (no competizione)**

Microalgae for industrial applications

Large scale production

Fonte: web

Biobased industry



Our approach

Experimental measures

Kinetic models

Process simulation

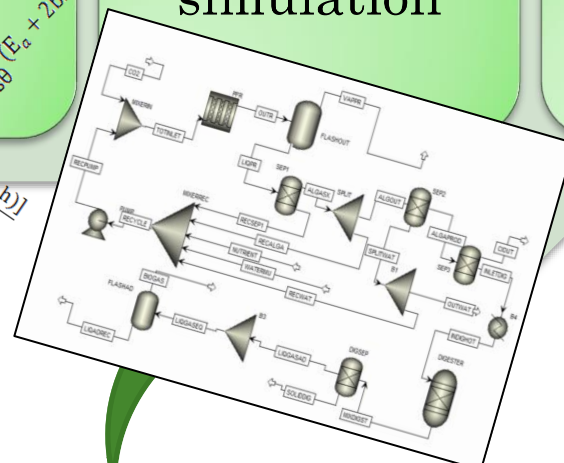
Economic and feasibility analisys

$$r_{x,z} = \rho_m \frac{K}{K + I(z)} \Phi E_a I(z) c_x - \mu_e c_x$$

$$\alpha = \sqrt{\frac{E_a}{(E_a + 2bE_s)}}$$

$$\frac{I(z)}{I(0)} = \frac{2(1+\alpha)\exp[-\delta(z-h)] - (1-\alpha)\exp[\delta(z-h)]}{\cos\theta\,(1+\alpha)^2\exp(\delta h) - (1-\alpha)^2\exp(-\delta h)}$$

$$\delta = \frac{\alpha c_x}{\cos\theta}(E_a + 2bE_s)$$



Tests in real scale plants Collaboration with Italian companies

Research topics

Environment

- Microalgae for urban/industrial wastewater treatment
- Microalgae bacteria consortia
- Augmentation approach: species specific interactions
- Bioremediation : synthetic biology of *Synechocystis* sp. for PFAS removal (Prof. Filippini, UniPD)

Energy-CO_2 capture

- Integration of microalgal cultivation and biogas production
- Sequestration of CO_2 from flue gas
- Exploitation of digestate from FORSU
  - Production of lipids
  - Production of carbohydrates

Optimization of microalgal growth

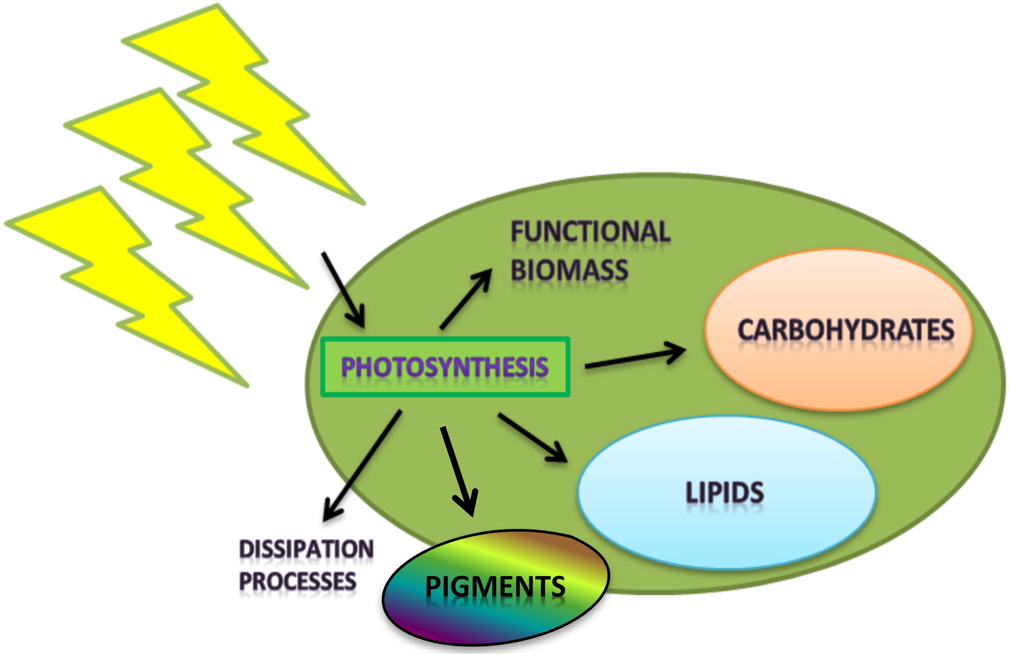
Products of interest

- Production of Spirulina in PBR (with Alghitaly)
- Production of Fucoxanthin from diatomeae (with Prof. Tredici, UNIFI)
- Production of pigments from cyanobacteria (phycocyanin)
- Production of protein for food and feed

Modeling and simulation

- Respirometry for kinetic parameters determination
- Modeling of mixotrophy
- Inhibition due to oxygen in closed PBR
- Microphotobioreactors
- Integration of ASM model (with Prof. Ficara, POLIMI)
- Raceway monitoring (with Prof. Mezzanotte, BICOCCA)

Microalgal composition

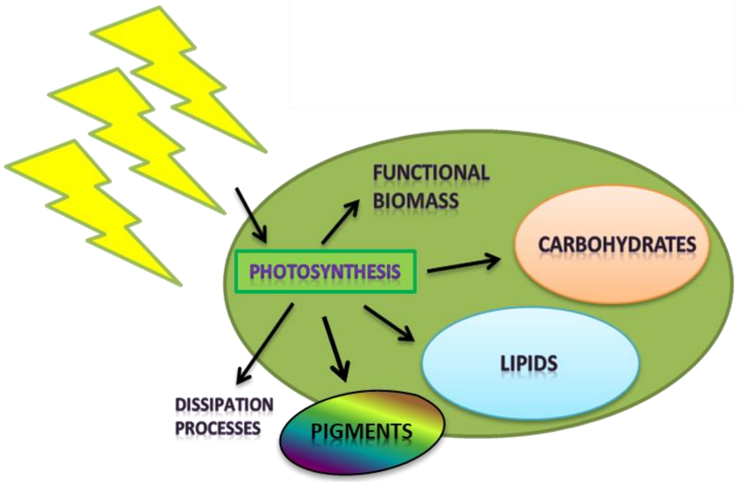


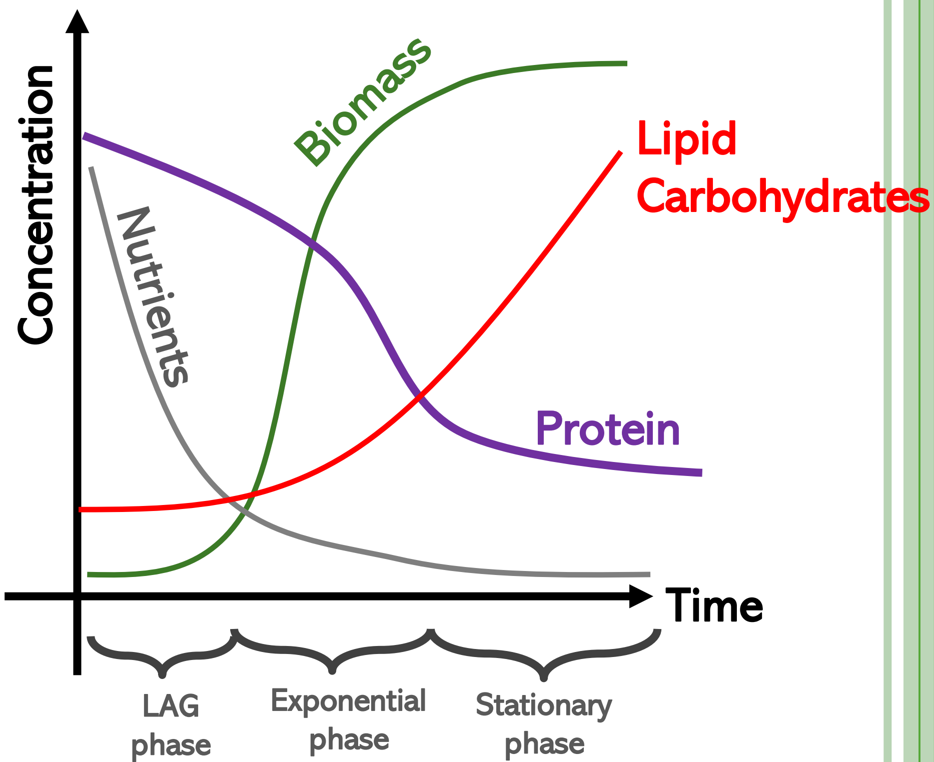
Microalgae can accumulate many compounds of industrial interest.

The biochemical composition of microalgae may depend on:

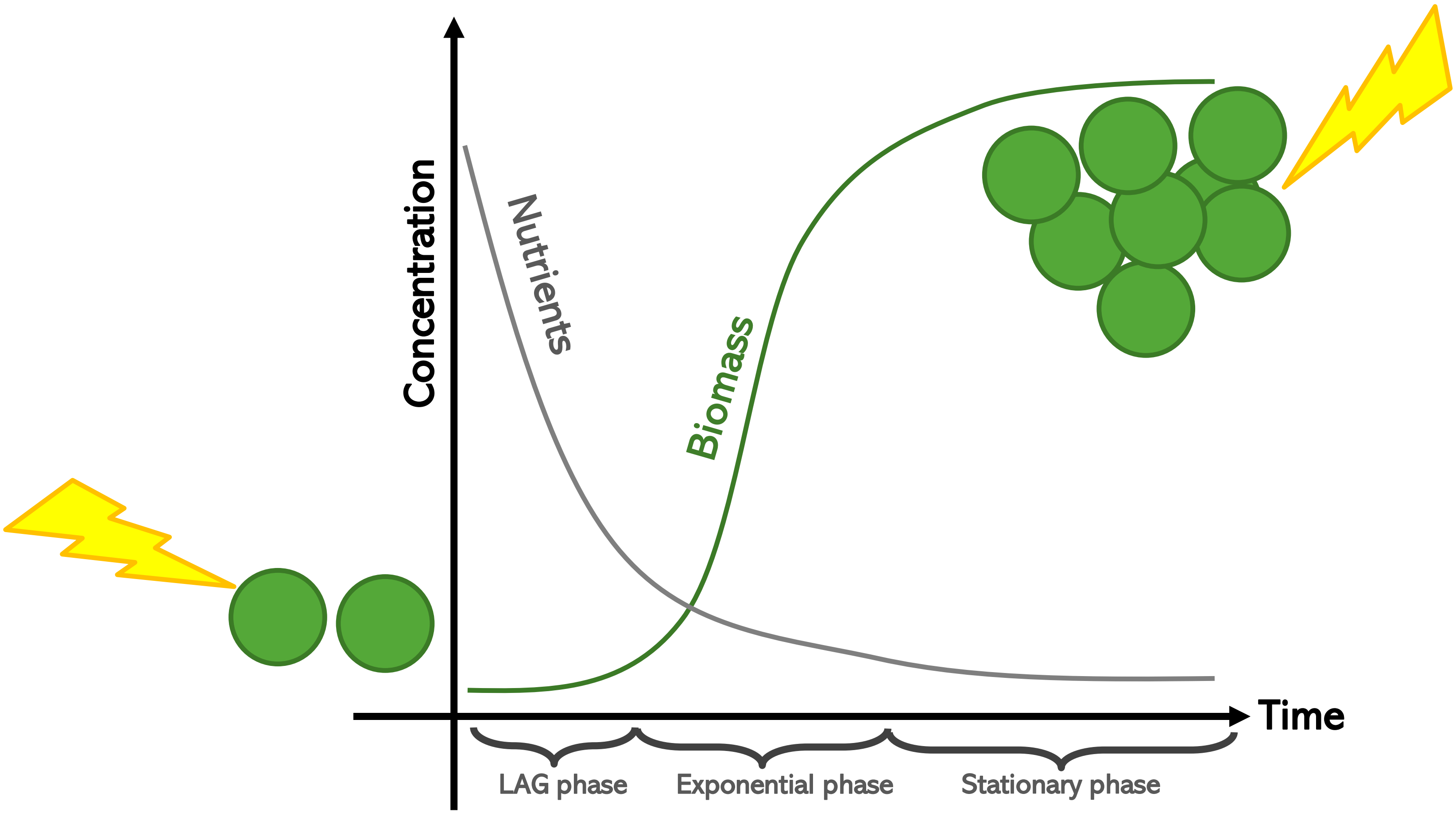
- Species
- Light intensity
- Nutrient availability
- Growth phase
- Metabolic pathways

Batch reactor: biochemical composition

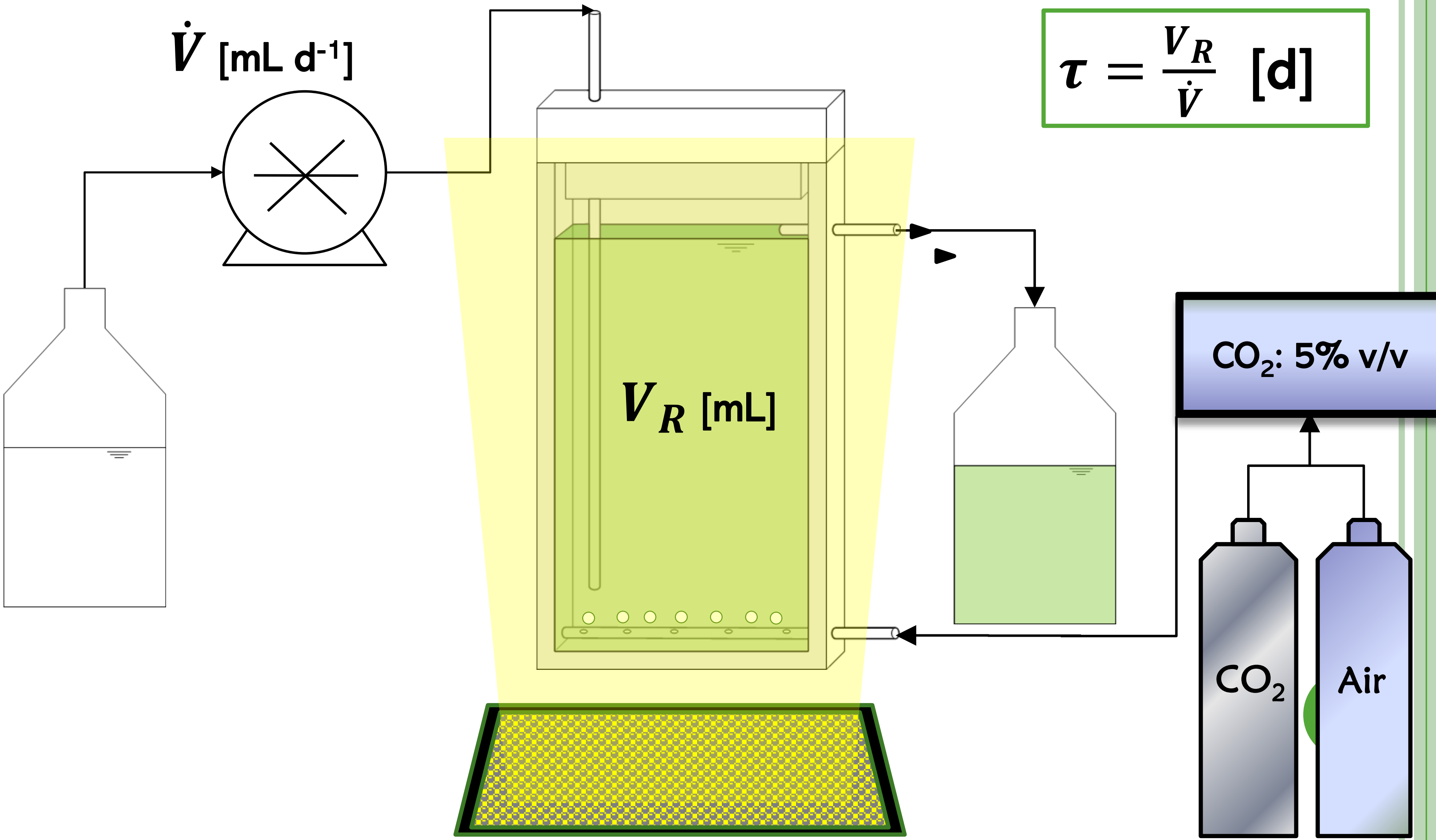




Batch reactor: light

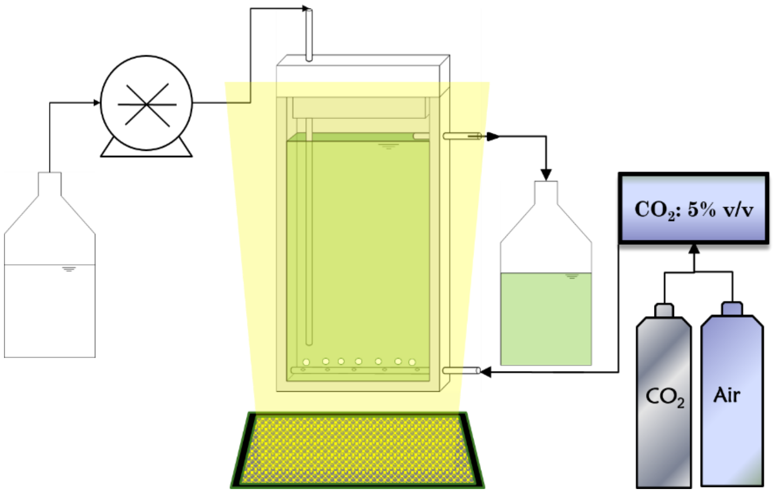


CONTINUOUS REACTOR



$$\tau = \frac{V_R}{\dot{V}} \quad [d]$$

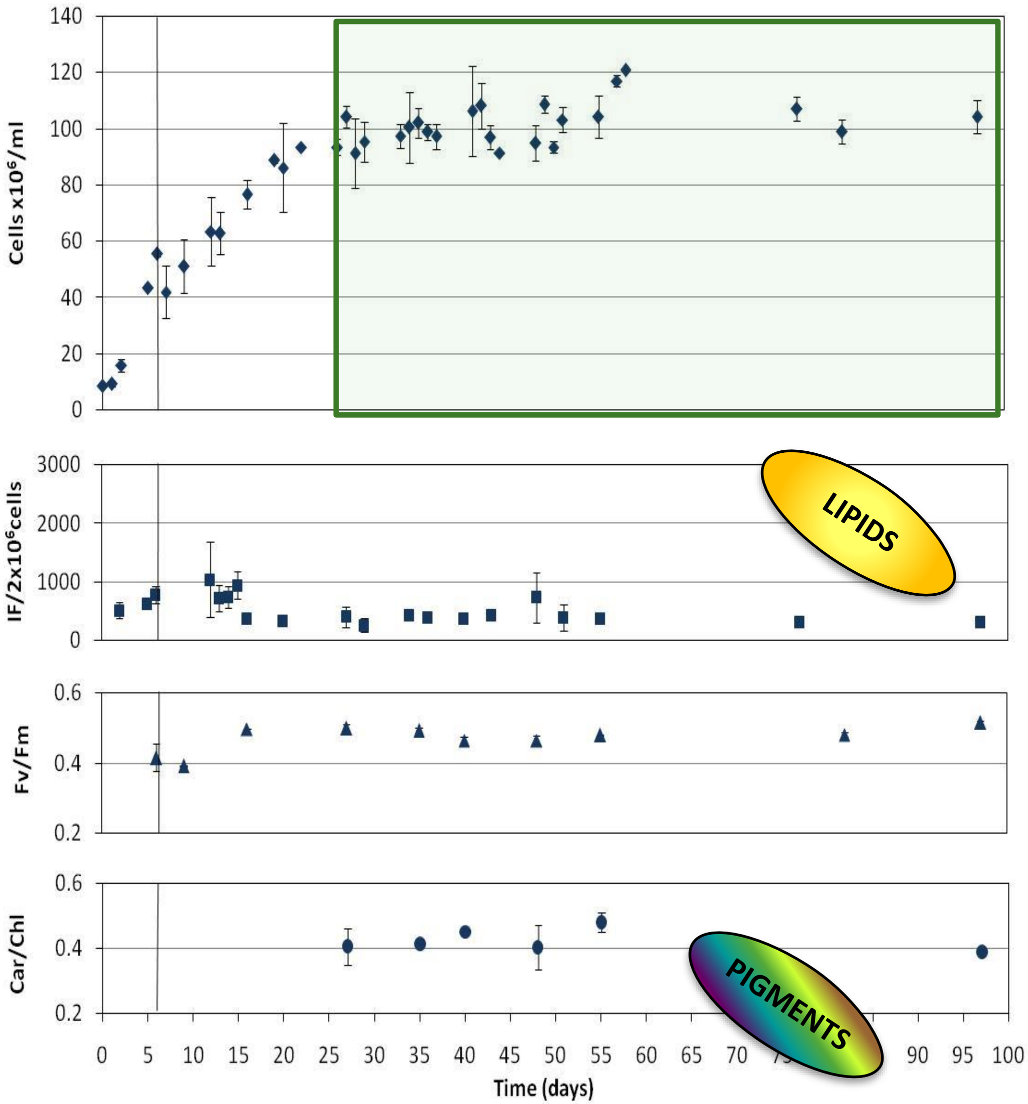
Continuous experiments



$$\tau = \frac{V_{pbr}}{Q}$$

RESIDENCE TIME

$$\mu = \frac{1}{\tau}$$



TOPIC 1: Wastewater treatment by microalgae

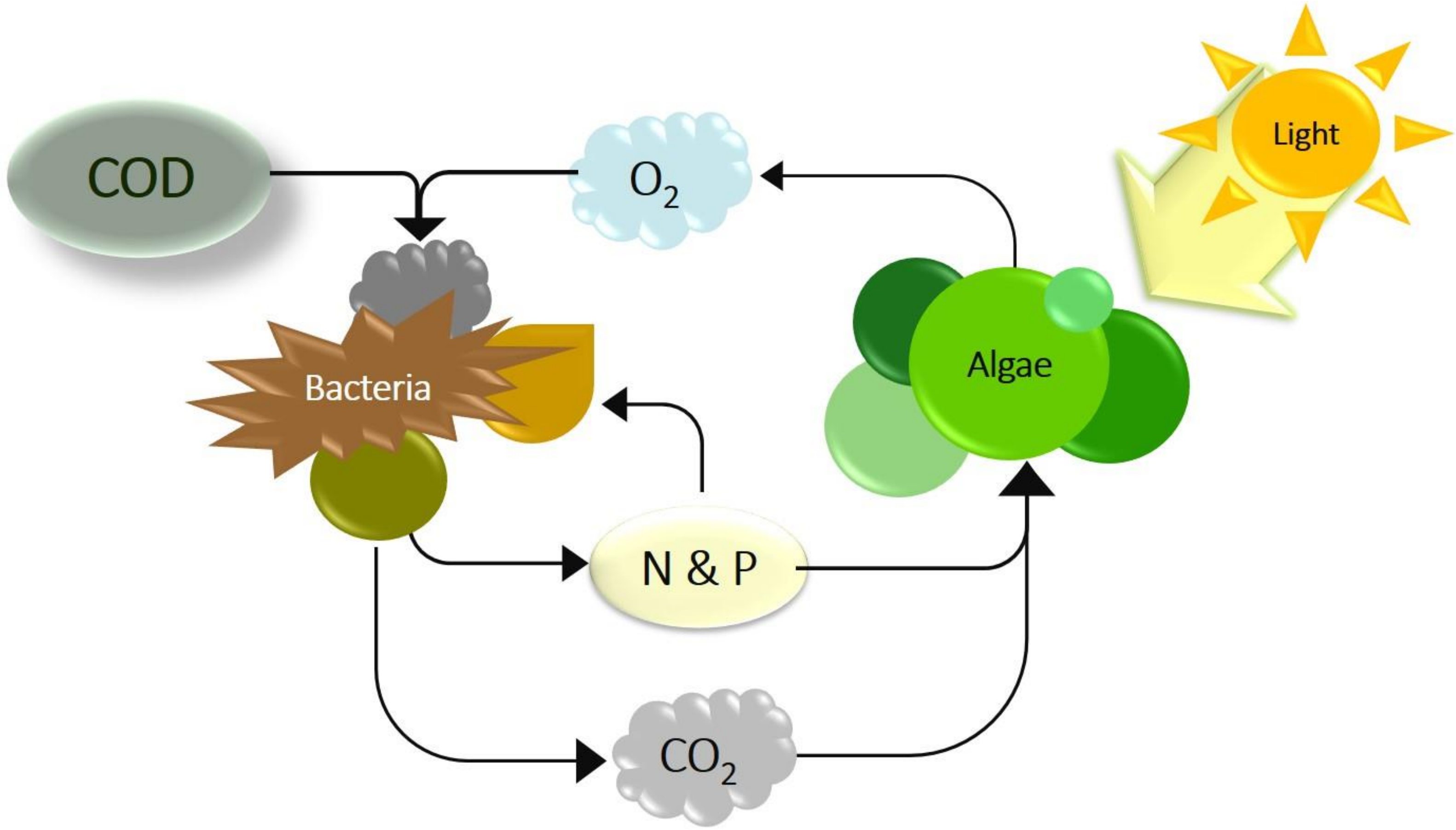

Images from web

*The continuous **growth of the population** and the increasing amount of wastewater generated by **human activities** from one side, the **water scarcity** and the increasing demand for high quality from the other, make **freshwater availability** as one of the greatest future global challenges of our modern society*

Conventional wastewater treatments, *although efficient and implemented for a long time, are usually rather expensive. One of the major issues of current wastewater treatment processes is related to **the energy consumption***

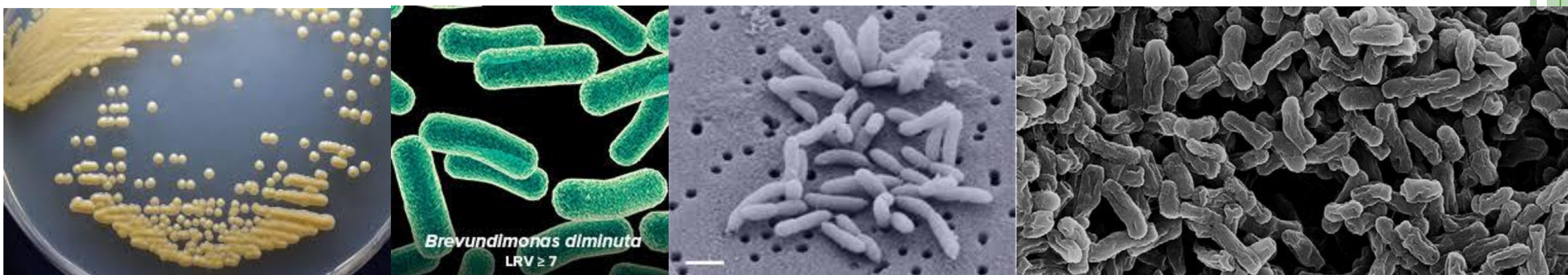
TOPIC 1: Wastewater treatment by microalgae

Microalgae use CO_2 and a part of nutrients dissolved in wastewater (N and P) to grow, releasing oxygen as byproduct. Aerobic bacteria use this dissolved oxygen to consume organic substrate. The CO_2 produced is used by microalgae for photosynthesis, closing this biological circle.



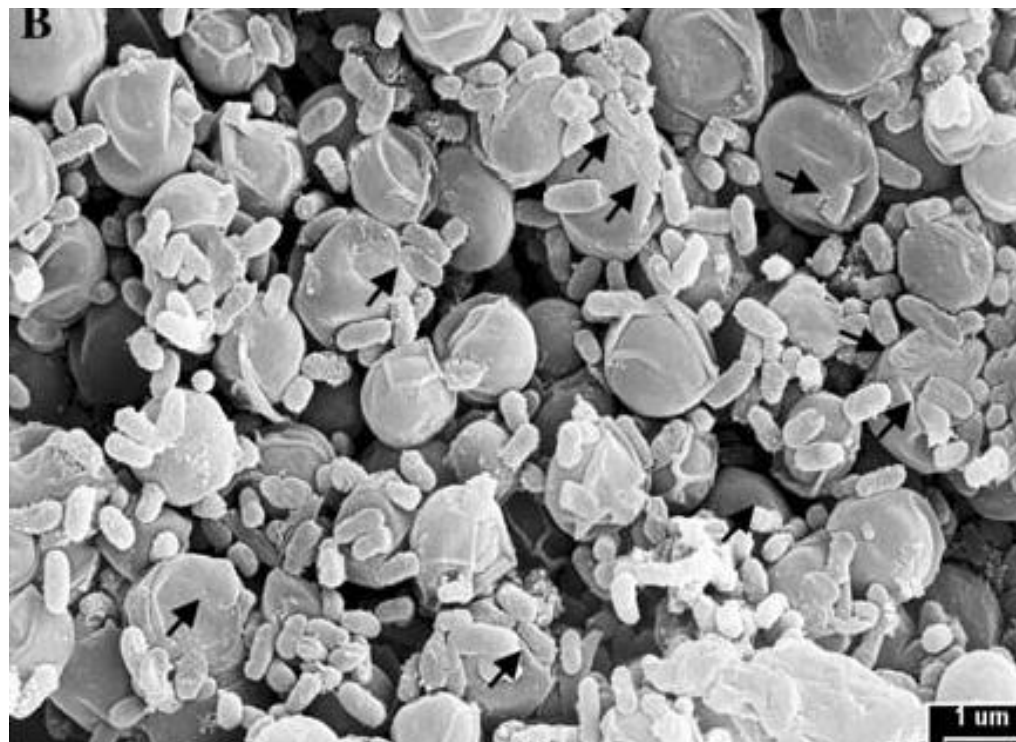
Topic 1B: Species-specific interactions BIOAUGMENTATION

Brevundimonas diminuta



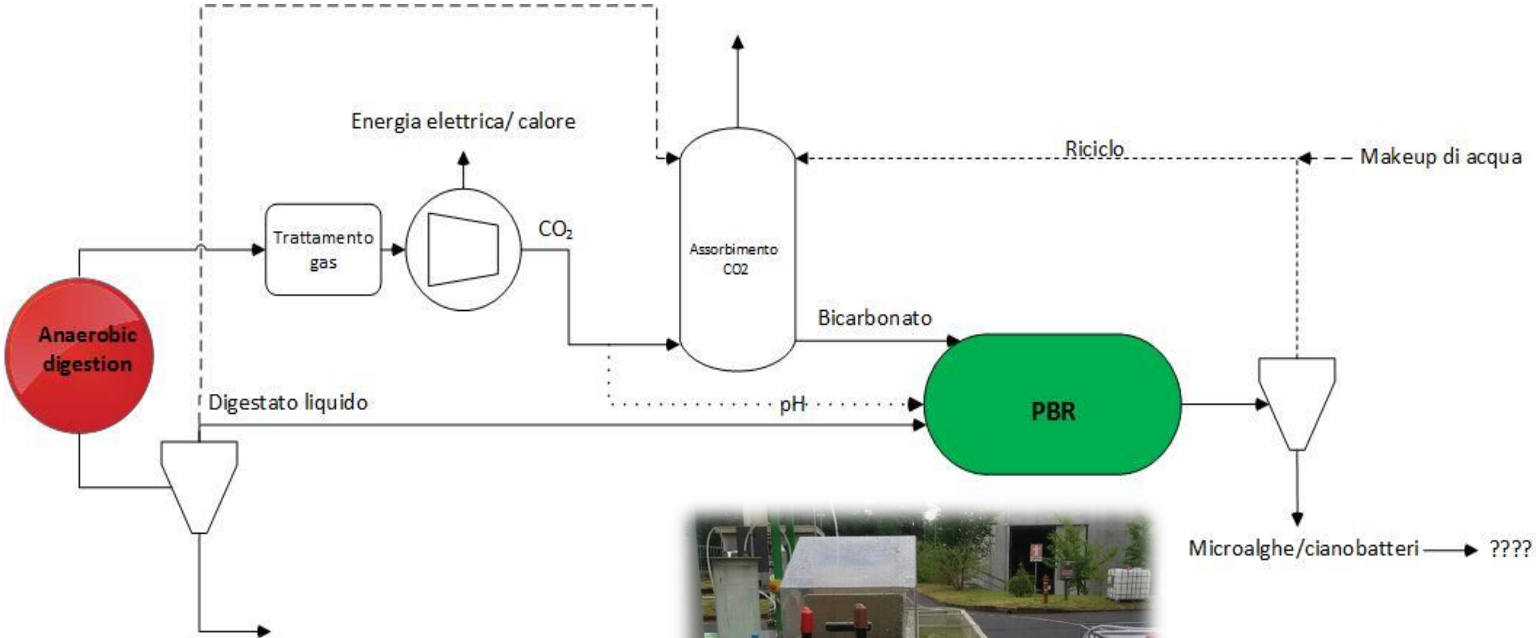
Micrographs of the scanning electron microscopy of *Brevundimonas diminuta.*
(Ji et al., 2016)

- Gram negative, *Caulobatteraceae*
- Optimal growth conditions: pH = 7 and temperature 30-37 °C
- Motile
- Aquatic



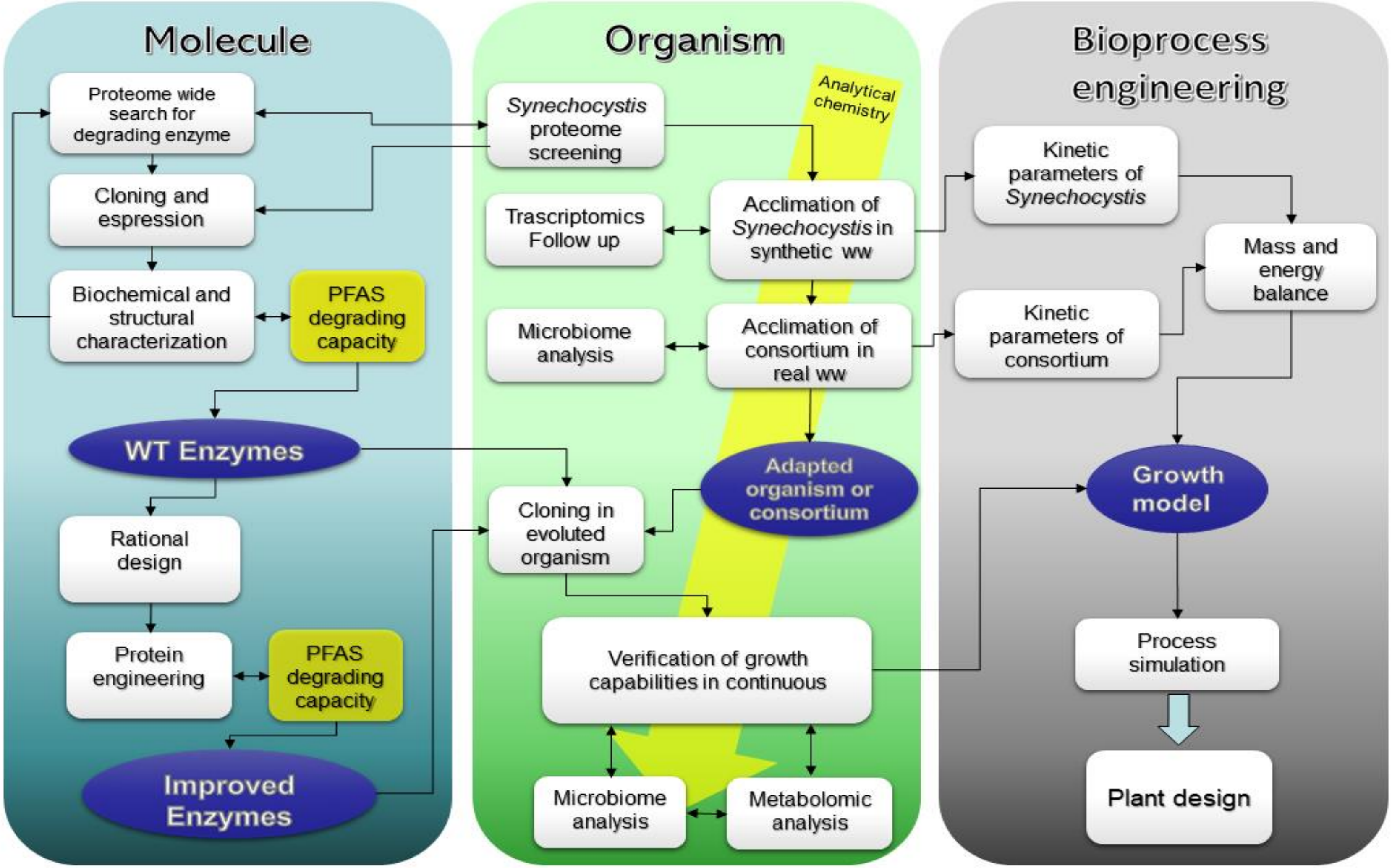
Scanning electron microscope pictures of the *C. ellipsoidea* culture either with *Brevundimonas* sp (Park et al., 2008)

TOPIC 1B: Exploitation of liquid fraction from anaerobic digestion for microalgal/cyanobacterial production and integration with biogas production



TOPIC 1B: BIOREMEDIATION

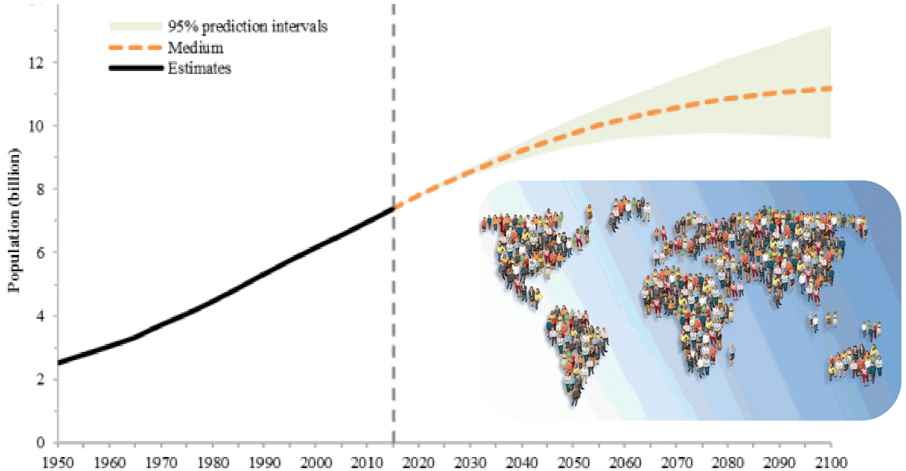
Prof Francesco Filippini
Prof. Elisabetta Bergantino
Prof. Laura Cendron



TOPIC 2: BIOBASED INDUSTRY

World population

- Global population has been increasing
- It is expected to increase up to > 9 billion people by 2050 (and maybe > 11 billion people by 2100)
- Food production will have to increase by at least 60%

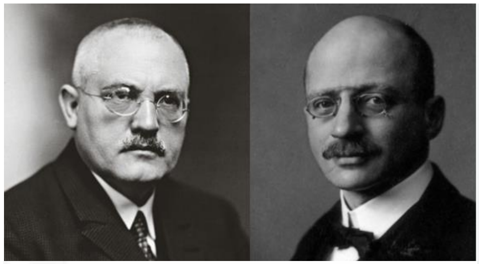


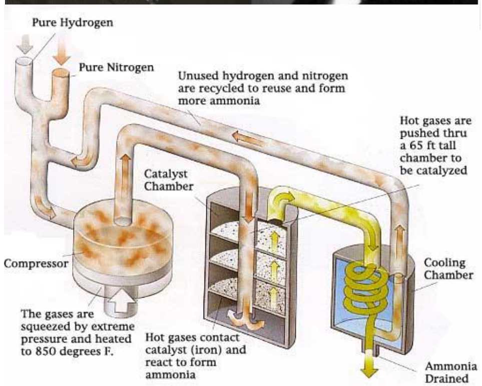
Source: United Nations, Department of Economic and Social Affairs, Population Division (2017). *World Population Prospects: The 2017 Revision*. New York: United Nations.

Fertilizers

- In 2013-2014 the N fertilizers demand was of 110 Mton/y
- Fertilizers demand is expected to increase by 1.6% per year until 2021

TOPIC 2: N-fixing cyanobacteria





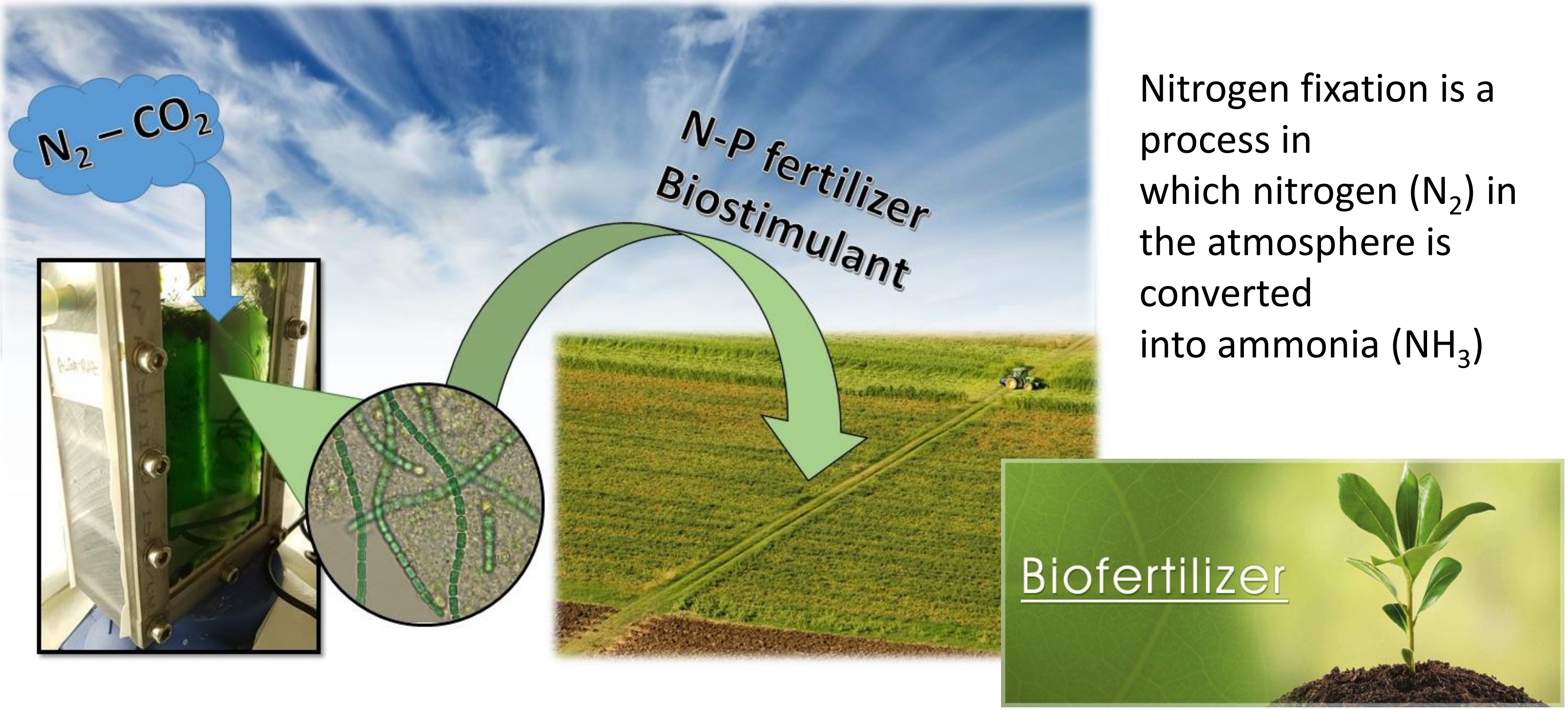
Chemical N fixation

$$N_2 + 3H_2 \rightarrow 2NH_3$$

The Haber-Bosch process

- High temperatures (700K) and pressures (100-200 atm);
- 300 Mt of CO_2 emissions each year;
- Exploits 2% of global natural gas reserves;
- Has reached its maximum energy efficiency

TOPIC 2: N-fixing cyanobacteria



Nitrogen fixation is a process in which nitrogen (N_2) in the atmosphere is converted into ammonia (NH_3)

Blue green algae belonging to a general cyanobacteria genus, *Nostoc* or *Anabaena* or *Tolypothrix* or *Aulosira*, fix atmospheric nitrogen and are used as inoculations for paddy crop grown. *Anabaena* in association with water fern *Azolla*, in rice fields, can fix over **1kg N ha^{-1} day^{-1}** (Rascio and La Rocca, 2013).

Can N-fixing cyanobacteria be exploited for industrial application?

Contatti:

ELEONORA SFORZA, PhD

eleonora.sforza@unipd.it

PROF. ALBERTO BERTUCCO

alberto.bertucco@unipd.it