Marine Biotechnology in the 21st Century

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Marine Bioproducts: Actual and Potential Markets

- € pharmaceuticals
- € nutritional supplements
- € cosmetics
- € agrichemicals
- € molecular probes
- € enzymes
- € fine chemicals
- € proteins
- € biofuels

Contents

- Marine drugs
  - Ocean as source of novel bioactive compounds
  - Unique chemistry (anti cancer drugs, new antibiotics (against MRSA)
  - Biological production methods
- Food and Fuel
  - Marine biomass (seaweed, microalgae…)
  - No use of fresh water for production
  - Separation processes for bulk products: biorefinery

The "potential" of marine biotechnology

Colwell (2002):

- "Marine Biotechnology is poised on the edge of a period of tremendous potential"
- potential for drug discovery
- potential for drug development
- potential for drug design

Initial focus on drugs; now the potential is much larger: food **and** fuel!

Several marine drugs have been available for decades

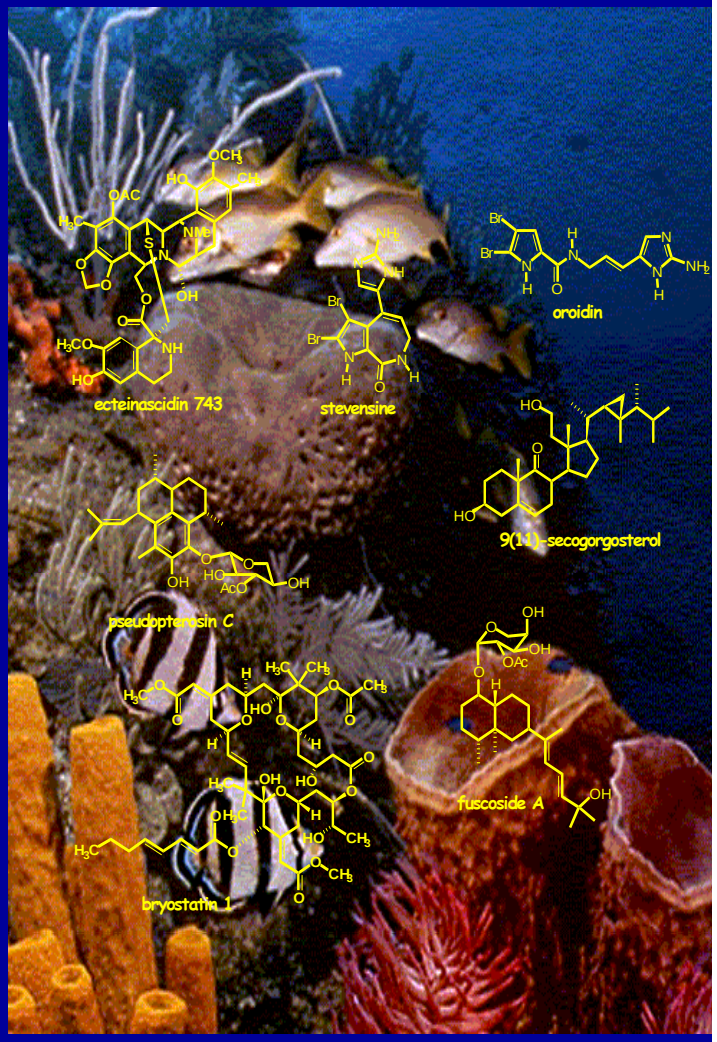
- Bergmann (1950): extracted novel nucleosides from sponges (*Cryptothetya crypta*)
- Synthesis of antiviral drugs and anticancer drugs
- AZT (zidovudine, Terovir®): anti HIV
- Acyclovir (Zovirax®): anti herpes
- Ara-A (Vidarabine®): antiviral
- Ara_C (Cystosar-U®): anti leukemias

The "potential" of marine biotechnology

An early discovery from the 1950's — an antiviral chemical derived from a marine sponge—now used to treat herpes infections

Synthetic or "natural" drugs?

- Major effort from pharmaceuticl companies to develop synthetic drugs
- Marine natural products still provide unusual and unique chemical structures
- potential for drug development
- Recently 2 marine natural compounds have clinically been approved



- Prialt ™ (aka Ziconitide, SNX-111) is a synthetic analog of the omega-conotoxin MVIIA
- 100-1000x more potent than morphine
- It has been approved for use by the FDA for chronic pain associated with AIDS and cancer

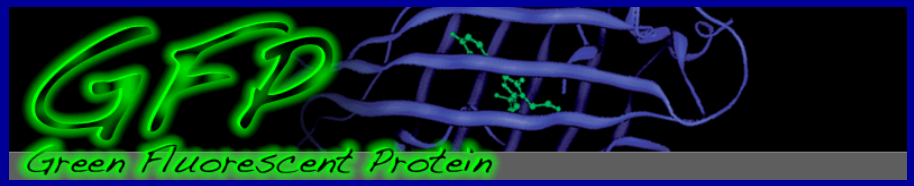
Yondelis®

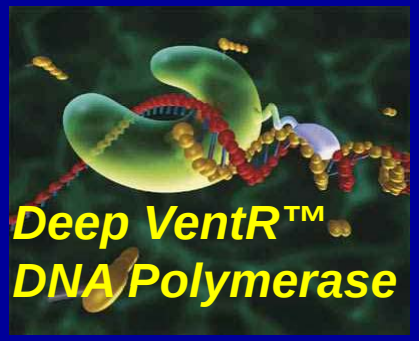
- Antitumor drug derived from the colonial tunicate *Ecteinascidia turbinata* and now produced semi-synthetically
- Developed by PharmaMar in partnership with Johnson & Johnson Pharmaceutical R&D
- Marketing authorization from the EC for the treatment of soft tissue sarcoma and ovarian cancer
- PharmaMar is marketing Yondelis in Europe; Ortho Biotech Products, L.P. will market it in the U.S. and the rest of the world, once approved.

Non-pharma applications

Cosmetics

Nutritional supplements





Biomedical research probes & fine chemicals

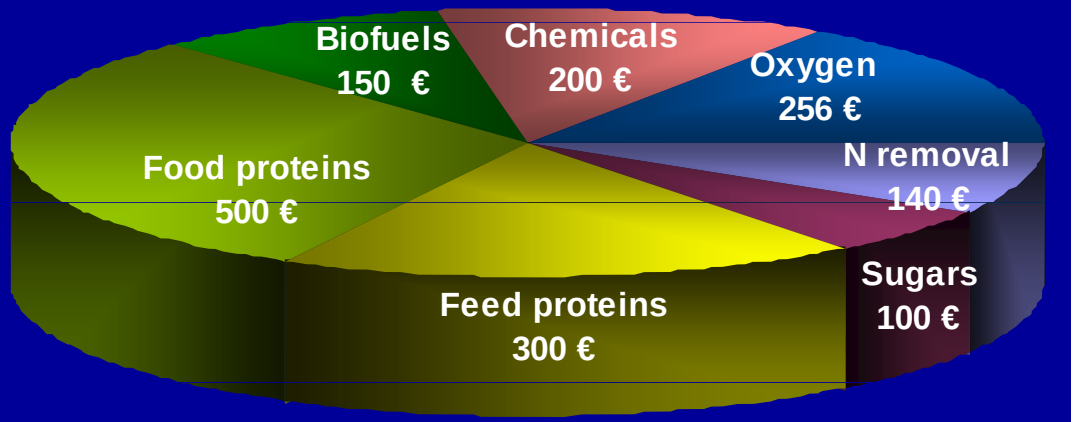
Biodiesel from algae

- High productivity
  - 20,000-80,000 l/ha/year
  - Palm oil: 6,000 l/ha/year
  - Salt water
  - No competition with food
- Many activities in US and Europe
  - ExxonMobil, Sapphire, Aurora, NREL…
  - Shell, AlgaePARC, Carbon Trust…

Economical Viability: biorefinery

Bulk chemicals and biofuels in 1,000 kg microalgae

- 400 kg lipids
  - 100 kg as feedstock chemical industry (2 €/kg lipids)
  - 300 kg as transport fuel (0.50 €/kg lipids)
- 500 kg proteins
  - 100 kg for food (5 €/kg protein)
  - 400 kg for feed (0.75 €/kg protein)
- 100 kg polysaccharides
  - 1 €/kg polysaccharides
- 70 kg of N removed
  - 2 €/kg nitrogen
- 1,600 kg oxygen produced
  - 0.16 €/kg oxygen
- Production costs: 0.40 €/kg biomass
- Value: 1.65 €/kg biomass

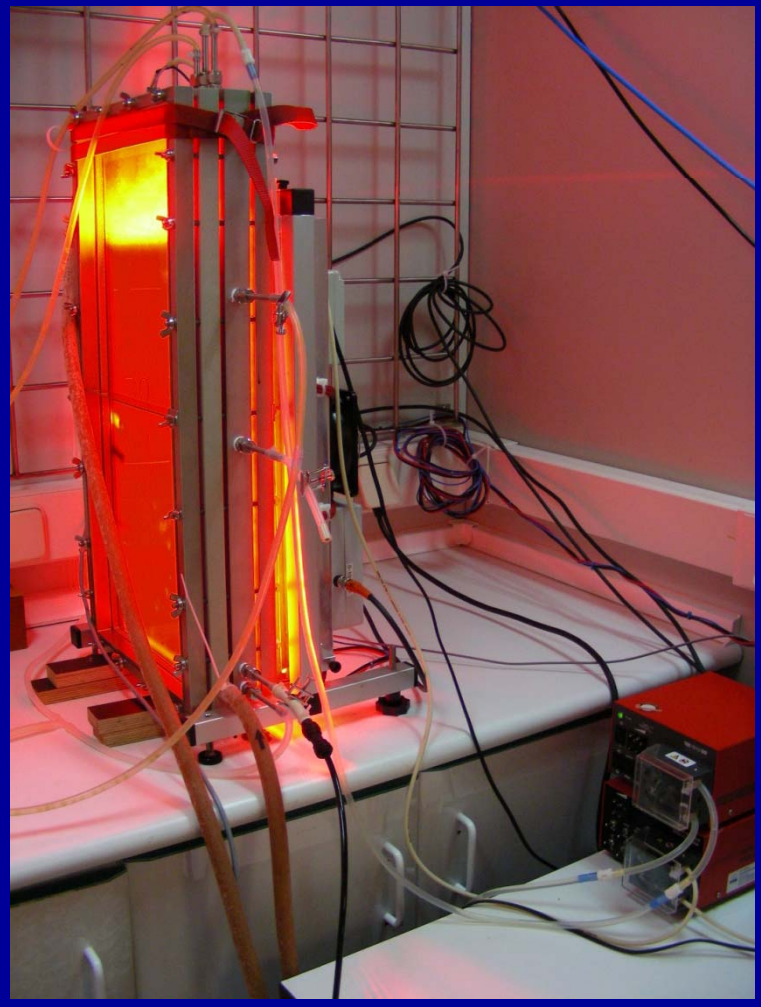


To replace all transport fuel in Europe

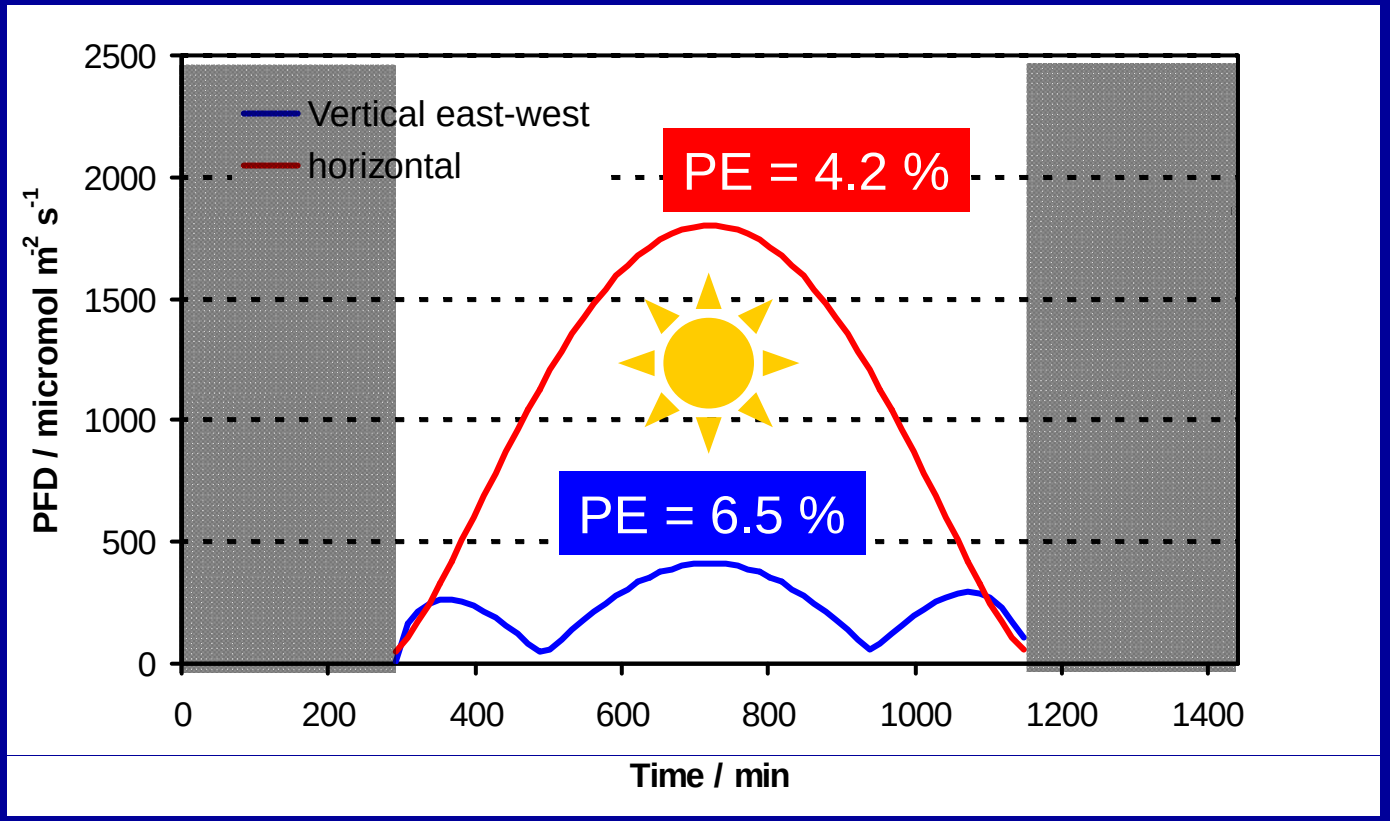
- 400 million m^3 lipids needed
- 9.25 million ha surface area
- Equivalent to surface area of Portugal
- 400 million tons of proteins produced
- 20 times the amount of soy protein imported in Europe

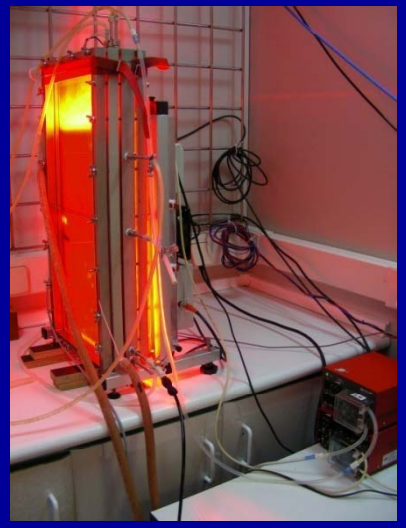
Light dilution in the lab

- Dilution of light
- By vertical flat panels
- Imitation of day/night cycles
- Model system: *Chlorella sorokiniana*
- 1.4 cm panel reactor



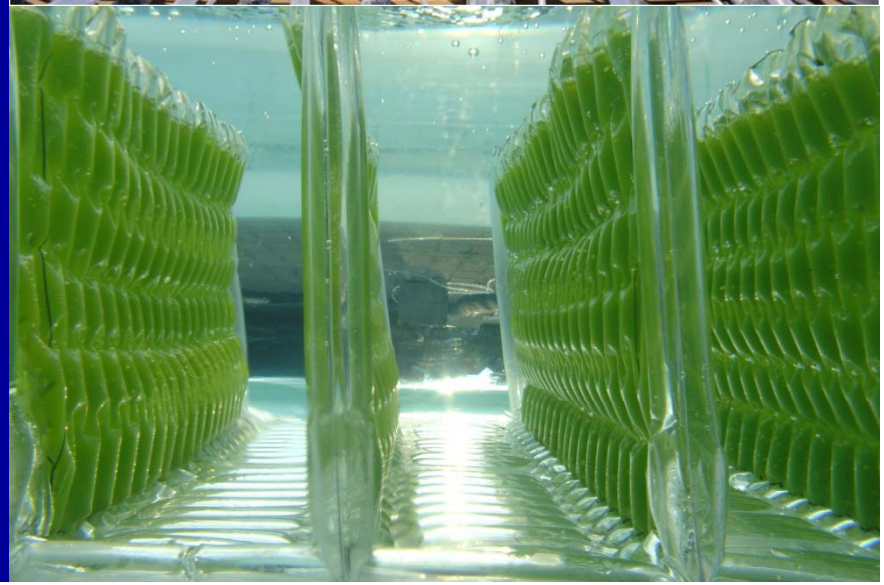
Light dilution in the lab

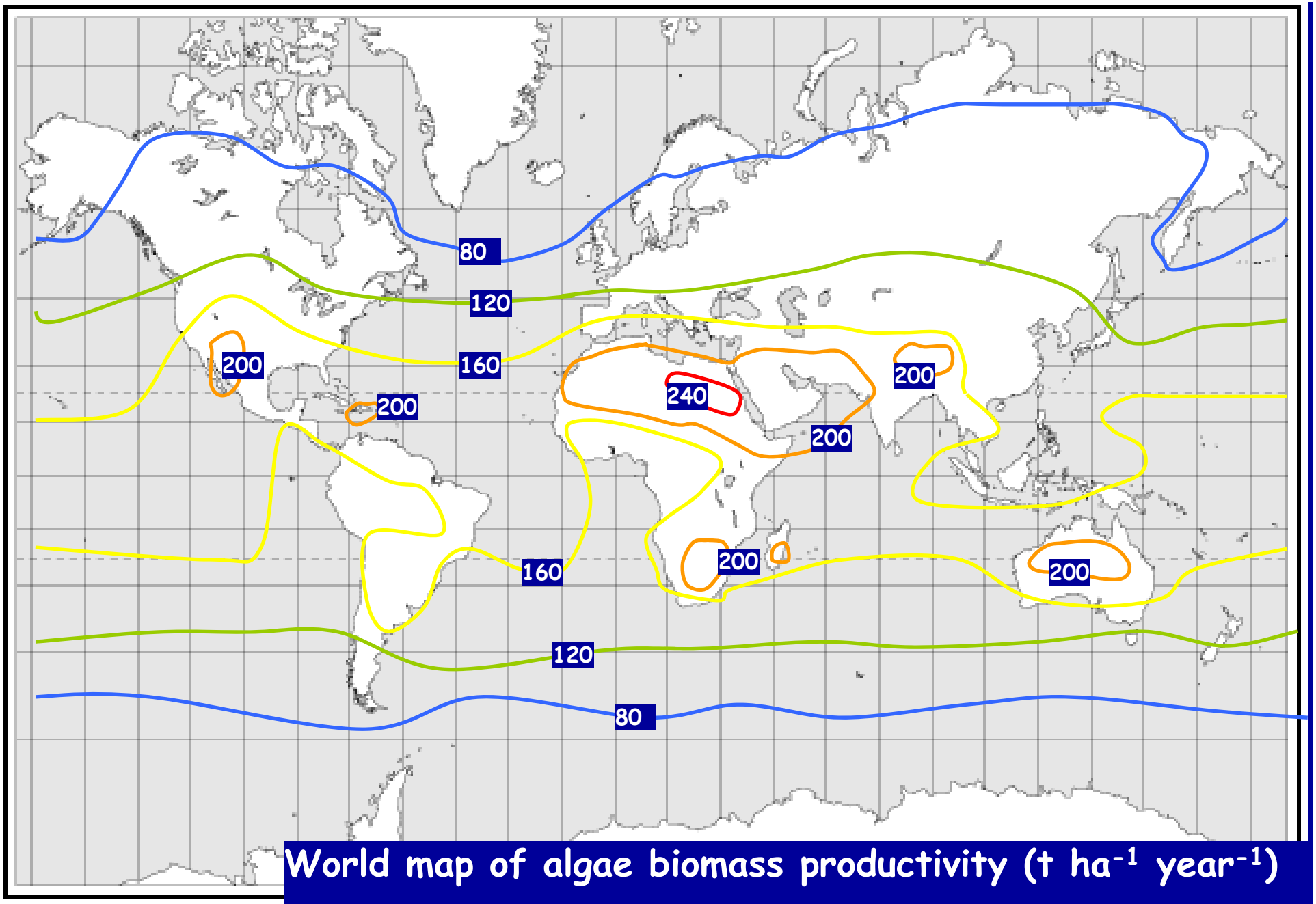




Light dilution in practice

- Vertical panels
  - Submerged (Solix Biofuels): US
  - Inflatable bags (Proviron): EU



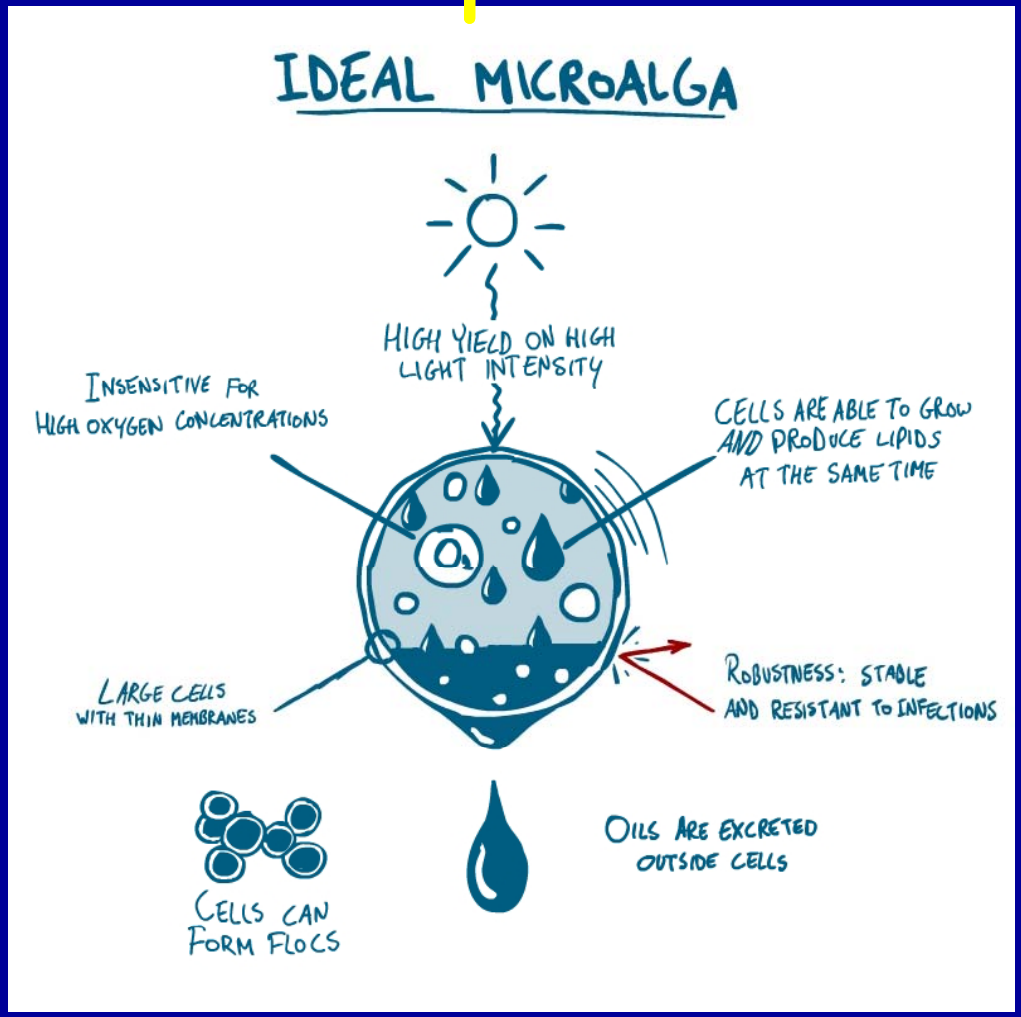


World map of algae biomass productivity (t ha^{-1} year^{-1})

(at 5% photosynthetic efficiency and 20 MJ kg^{-1} dry biomass)

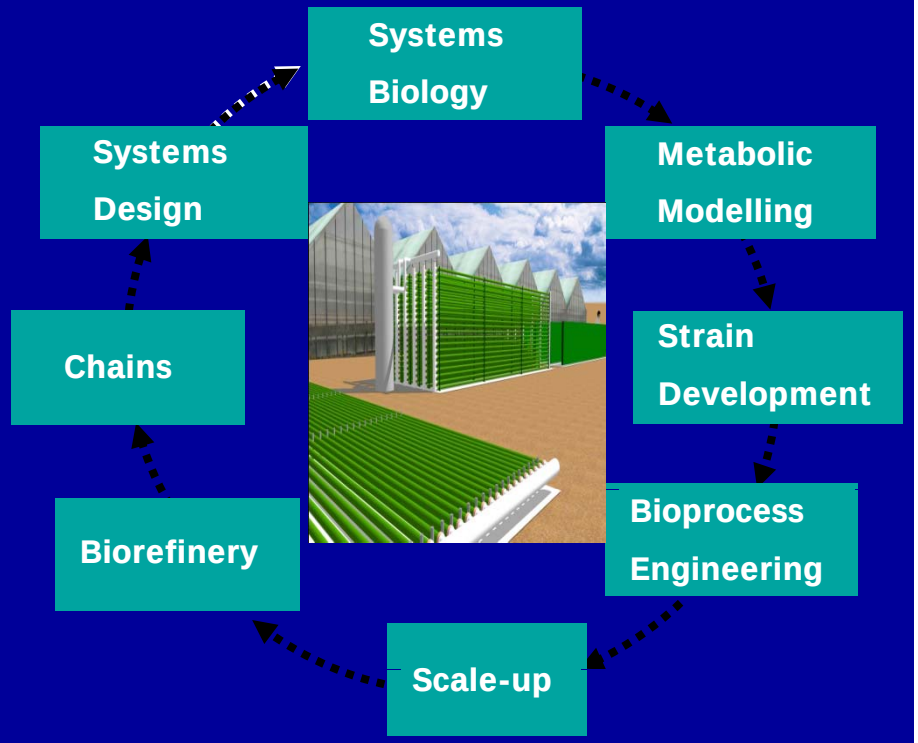
Source: Prof. Mario Tredici (Italy)

Not only production system needs to be improved



What we aim at

- We are developing a new technology for cost-effective production of fuels, foods and chemicals from algae
- Requires a multidisciplinary approach
- We should be active and collaborate in all these disciplines



Summary

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  - Source for novel bioactive compounds
  - Unique chemistry (anti cancer drugs, new antibiotics (against MRSA)
  - Biological production methods
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US-EU Collaboration in Marine Biotechnology: the Past Two Decades

- Collaborations:
  - Marine natural products drug discovery and development; sustainable development of marine resources
  - Universities, research institutes, private sector
- Funding:
  - Developed independently by PI's
    - EU scientists funded from EU member state science foundations and/or from EC
    - U.S. participation funded independently by U.S. agencies
    - Programs to support workshops and travel, but not linked R&D

US-EU Collaboration in Marine Biotechnology: the Next Two Decades

- Explore new mechanisms for collaboration
  - U.S. agency programs for matching support for U.S. participation in linked EU-US projects
  - Facilitate non-conventional collaborations & interdisciplinary approaches
  - Provide funding for high risk research that could lead to innovative and transformative technologies