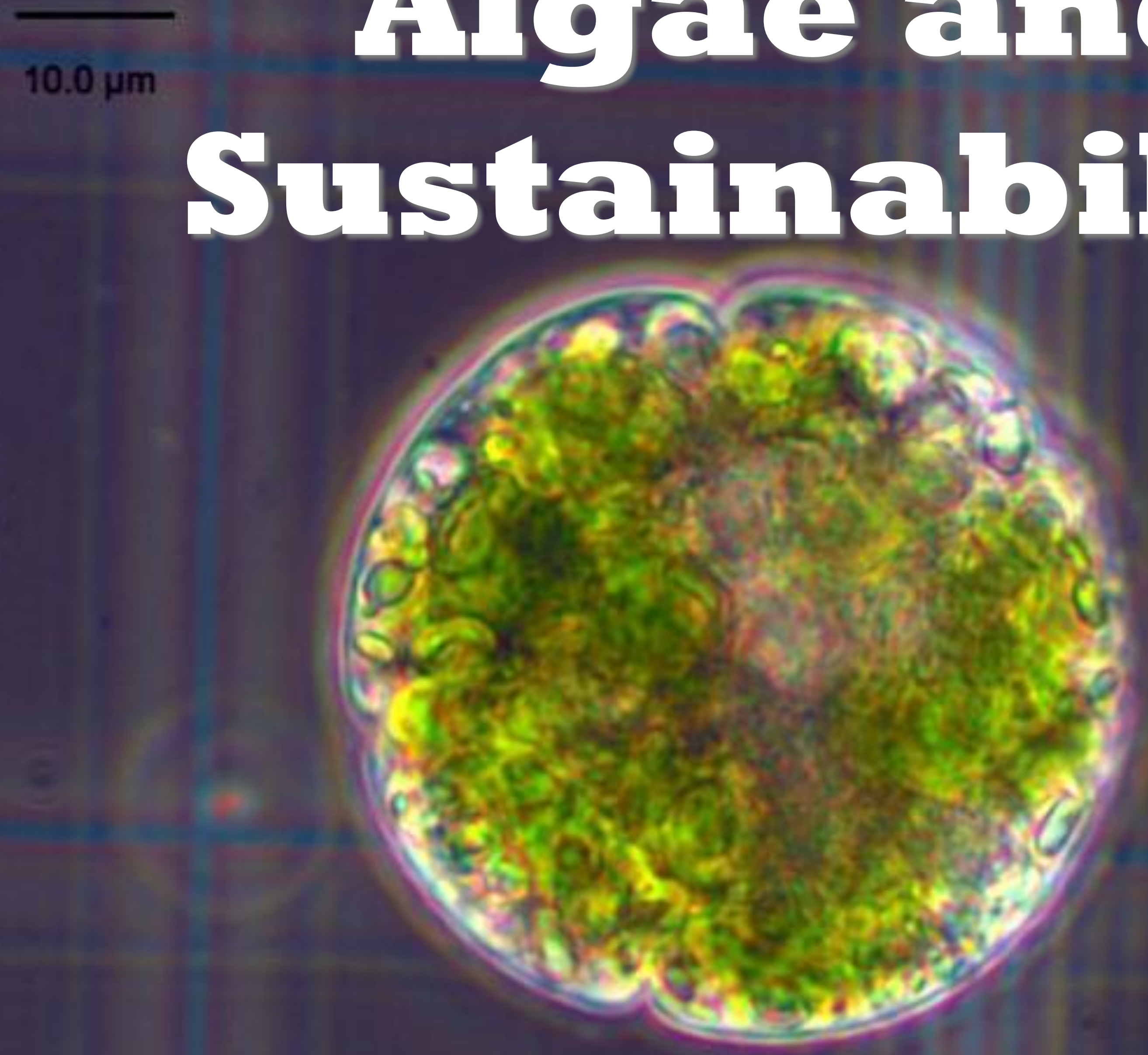
Algae and Sustainability

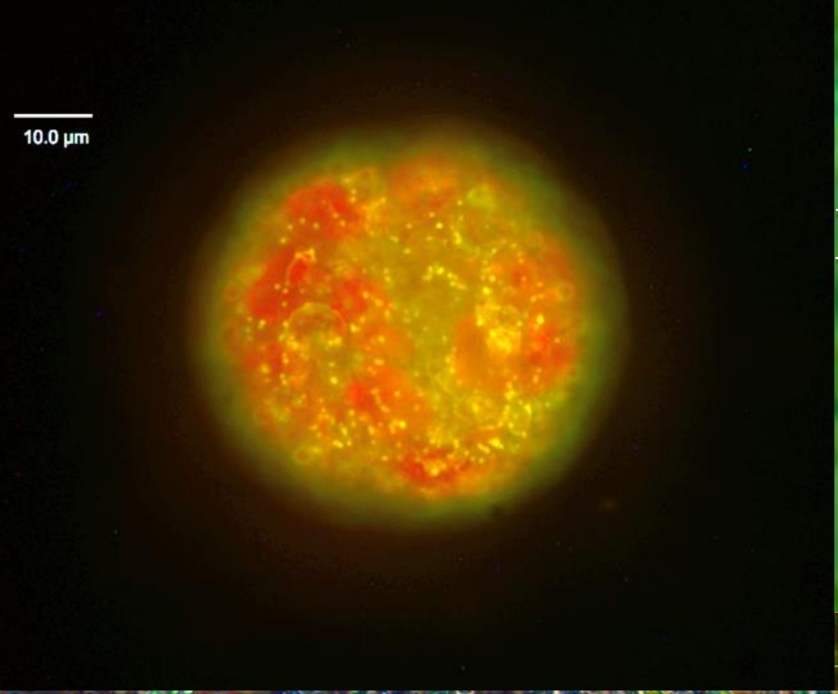


Algae for bioremediation and bioresources

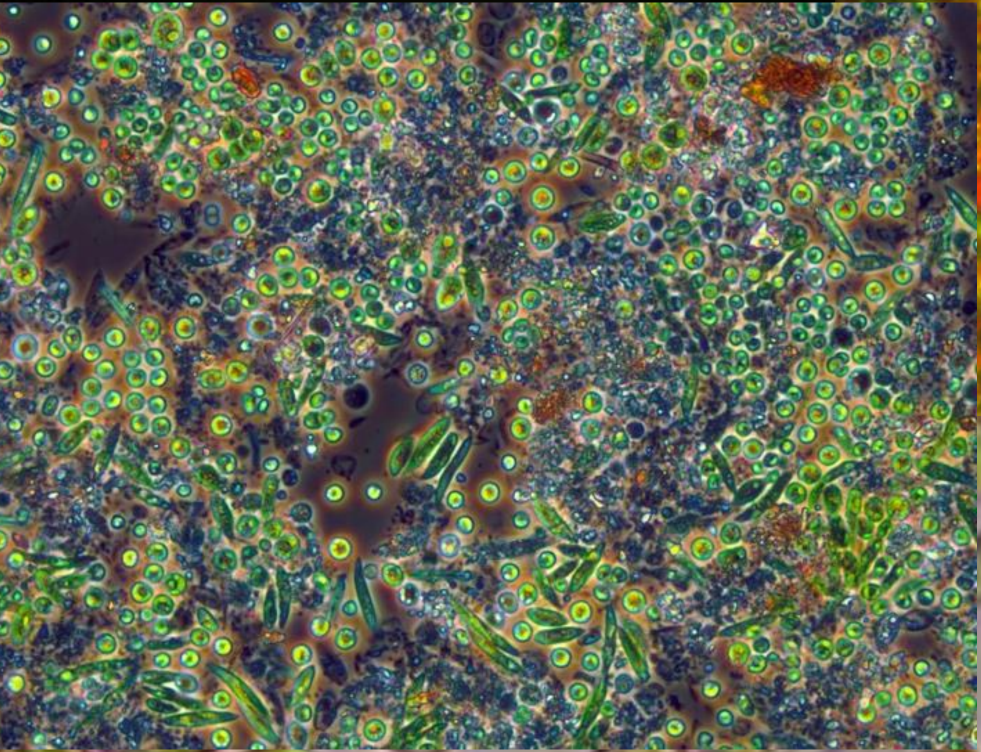
Problem Definition

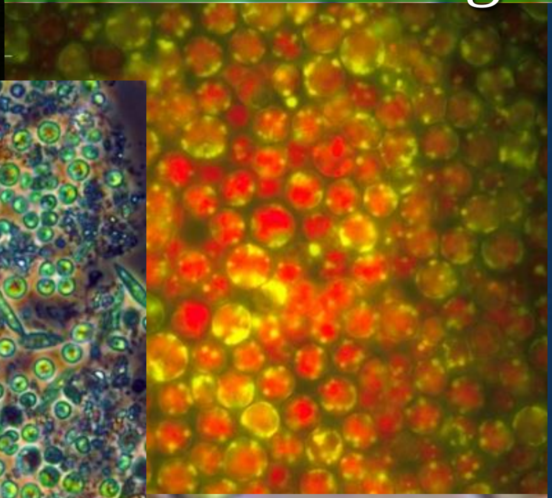
- The human impact upon our planet is steadily increasing. Communities of people around the world are consuming more energy than they are producing, relying almost entirely on nonrenewable resources for prosperity.

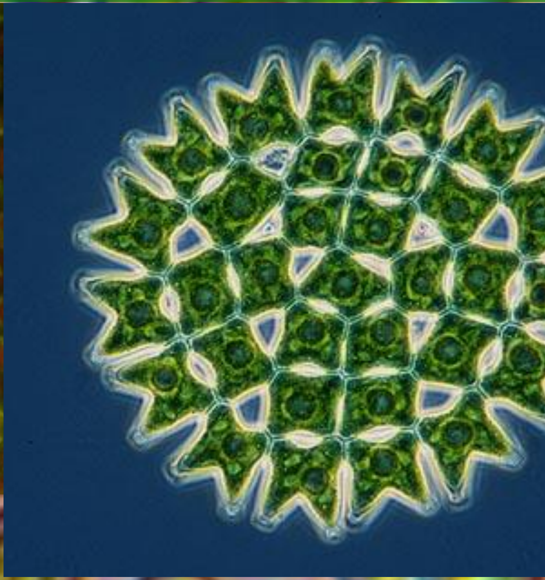
- Current dilemmas of our unsustainable society include:
  - Fugitive nutrient release causes cultural eutrophication
  - Unsustainable waste practices emit greenhouse gases



Algae : a catch-all phrase referring to any of the micro and macroscopic plants that lack true leaves, roots, an stems. Ranging in size from single-cells to giant kelps and including both prokaryotic and eukaryotic organisms.







Why Algae?

- Remediate Wastes
  - Municipal sewage, agricultural wastes, landfill leachates, industrial wastes.
- Biological Diversity
  - Immense natural genetic diversity can grow on fresh, brackish, or saline waters.
  - Produce a variety of secondary metabolites
- Efficient Photosynthesizers!
  - Can be grown anywhere light, moisture, and nutrients converge.
- Abundant growth
  - Algae form the trophic basis for many aquatic and terrestrial ecosystems

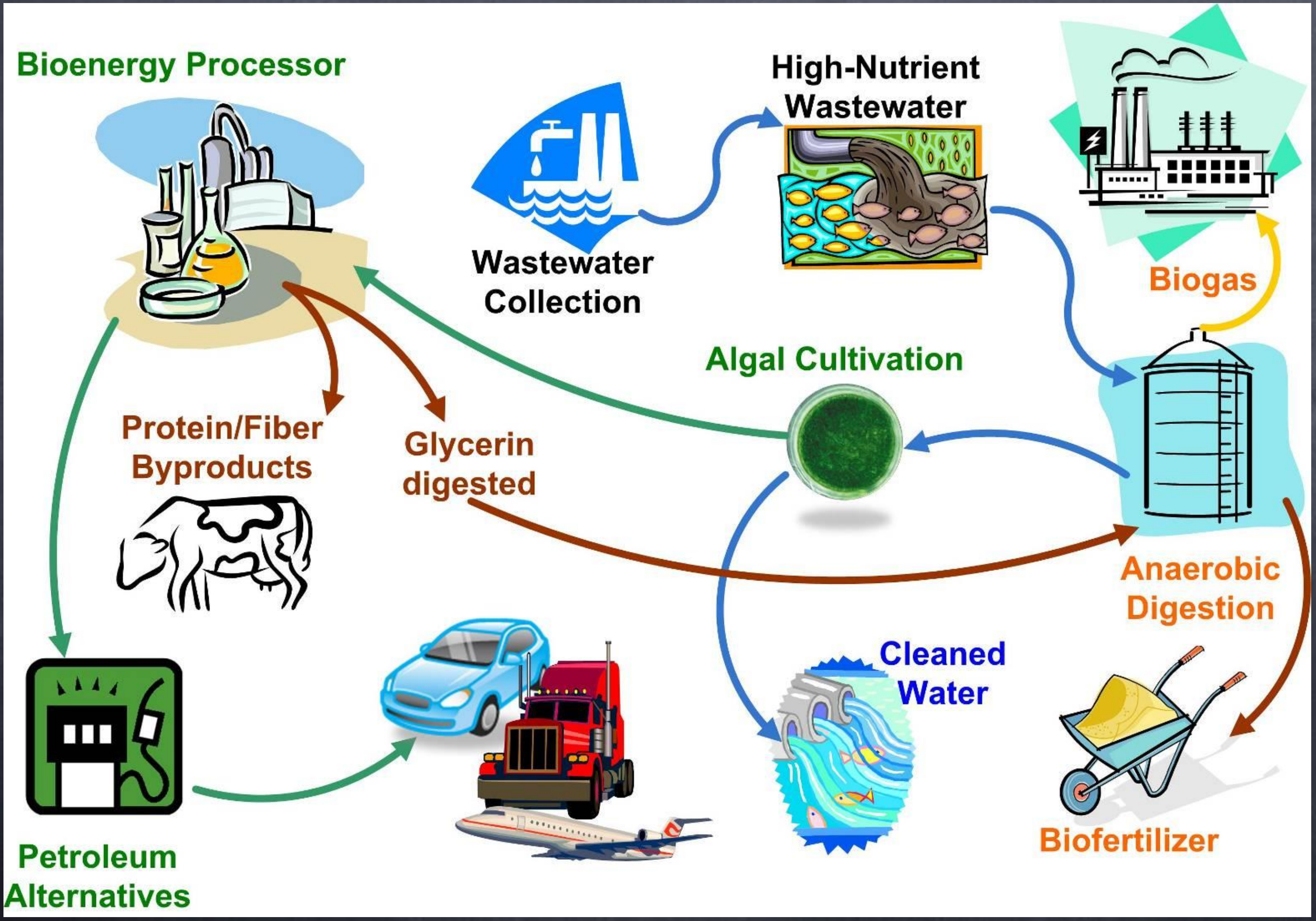
Algae can utilize wastes

- Algae have been used successfully to treat N and P excess of sewage/manure wastes generated by animals and human activities (Nurdogan and Oswald 1995, Lincoln *et al.* 1996, Wilkie and Mulbury 2002).
- Algae can significantly reduce the environmental impacts of wastes, while creating useful products
- May be able to grow on landfills

Ecological Energy

- Algae can thrive in high nutrient environments
- CO_2 emissions, from combustion, can supplement algae photosynthesis rates
- Algal biomass can provide the foods, feeds, fibers, fertilizers, and fuels of society
- Algae can help close the loop of wasteful human ecosystems

The Human Ecosystem



The Botanical Diversity of Algae

- **Algae are a diverse polyphyletic group of organisms**
  - **40,000 recognized species**
  - **~10,000,000 yet to be described**
  - **Nine major taxonomic Divisions**
- **Ubiquitous, found on every continent and in every ocean.**

Biochemistry of Algae

- Synthesize a wide range of organic compounds- 30,000+ natural compounds

Included are the major biochemical divisions of proteins, carbohydrates, lipids, and nucleic acids.

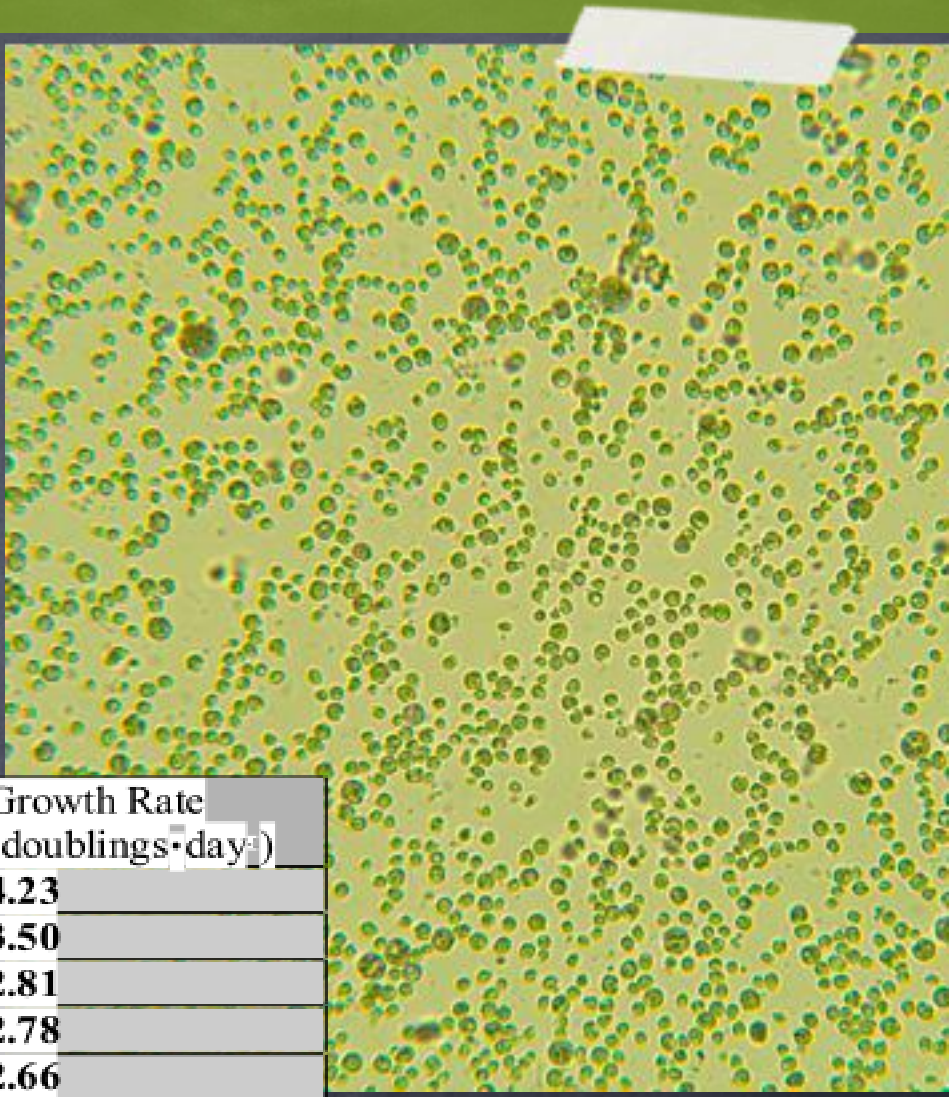
Also: Alkaloids, Sterols, Glycosides, Terpenoids, Anthocyanins, Flavanoids, Unusual starches, Glycogen, Fructans,....

Photosynthetic Efficiency

- Efficiency of converting light energy (photons) into biomass:
- Most terrestrial agricultural crops : ~0.1-2%
- Highly efficient plants, (e.g. Sugar cane): ~2-5%
- Aquatic algae, (*Spirulina maxima*): up to ~8.6%

Abundant Growth

- Aquatic Advantage
  - Efficient ionic exchange
  - No complex support structures
- Cellular Multiplicity
  - Daily doublings
- Biomass Production Potential
  - Daily Biomass Harvesting

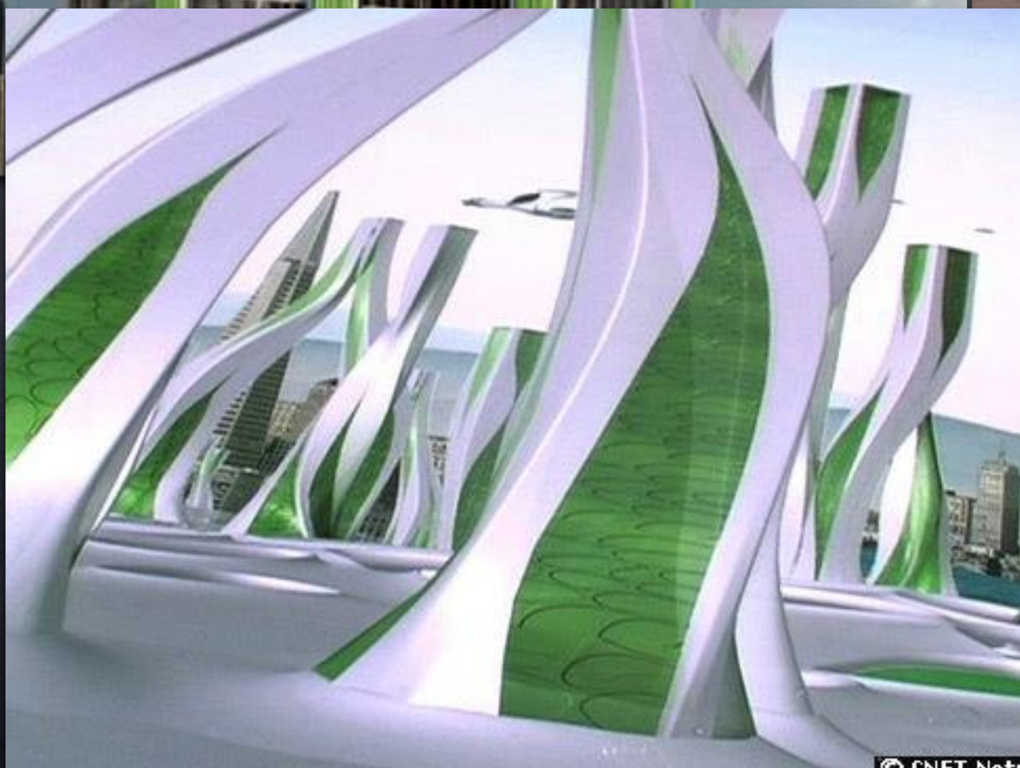


Strain	Genus	Family	Growth Rate (doublings·day^{-1})
OSCIL2	*Oscillatoria*	Cyanophyceae	**4.23**
OSCIL3	*Oscillatoria*	Cyanophyceae	**3.50**
AMPHO46	*Amphora*	Bacillariophyceae	**2.81**
NANNO13	*Nannochloris*	Chlorophyceae	**2.78**
CHLOR23	*Chlorella*	Chlorophyceae	**2.66**
SYNEC3	*Synechococcus*	Cyanophyceae	**2.51**

Adapted from: Sheehan J, Dunahay T, Benemann J, Roessler P (1998). A Look Back at the U.S. Department of Energy's Aquatic Species Program—Biodiesel from Algae. U.S. Department of Energy's Office of Fuels Development Prepared by: the National Renewable Energy Laboratory

Algae for Fuels

- Food crops such as corn and soy beans are increasingly being converted into ethanol and biodiesel, but...
- This raises global competition between fuels and foods- sustainable?
- Algae can be grown on non-arable land, where food crops simply cannot grow- rooftops, deserts, oceans, wastewater treatment plants, etc.
    - imagination is the limitation.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Where are we now?

Agronomy Vs. Algronomy

Agronomy

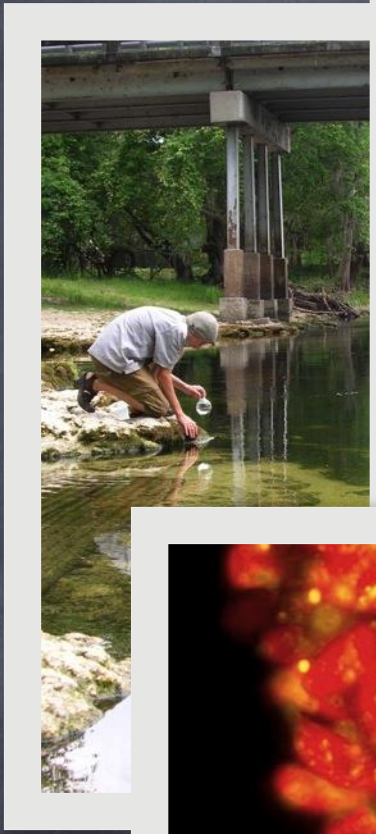
- The study of agriculture providing the foods, feeds, fibers, fertilizers, and fuels of society.
- Terrestrial crops (Angiosperms)
- Millennia of crop selection
- Millennia of cultural optimization
- Crops that feed the world

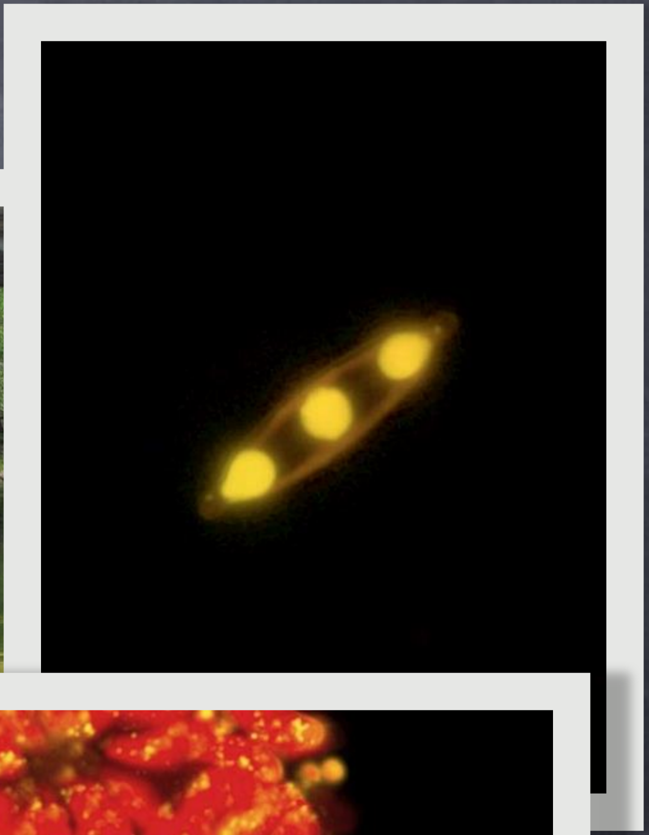
Algronomy

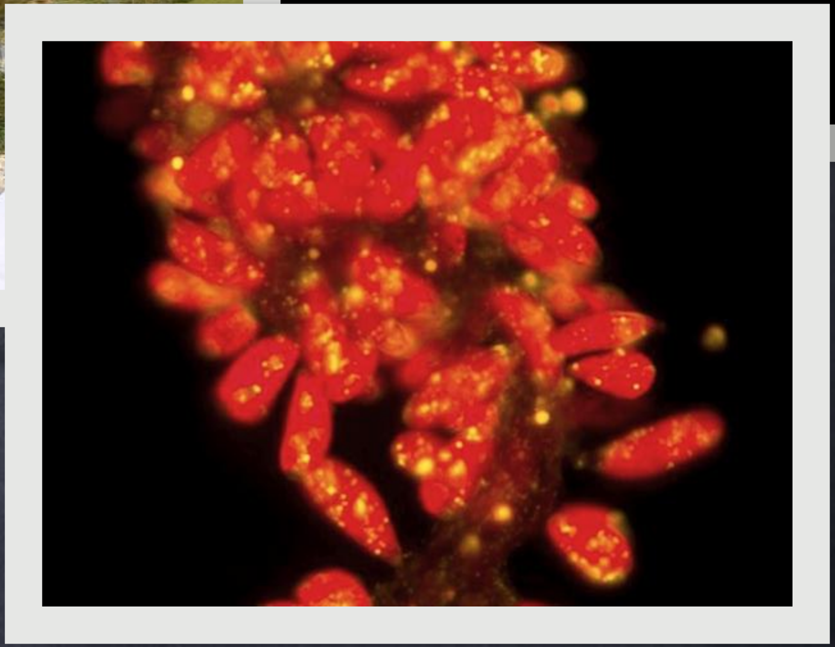
- The study of algaculture providing the foods, feeds, fibers, fuels, and fertilizers of society
- Aquatic algae (uni- and multicellular)
- Limited crop selection
- Limited cultural optimization
- Crops that (could) fuel the world

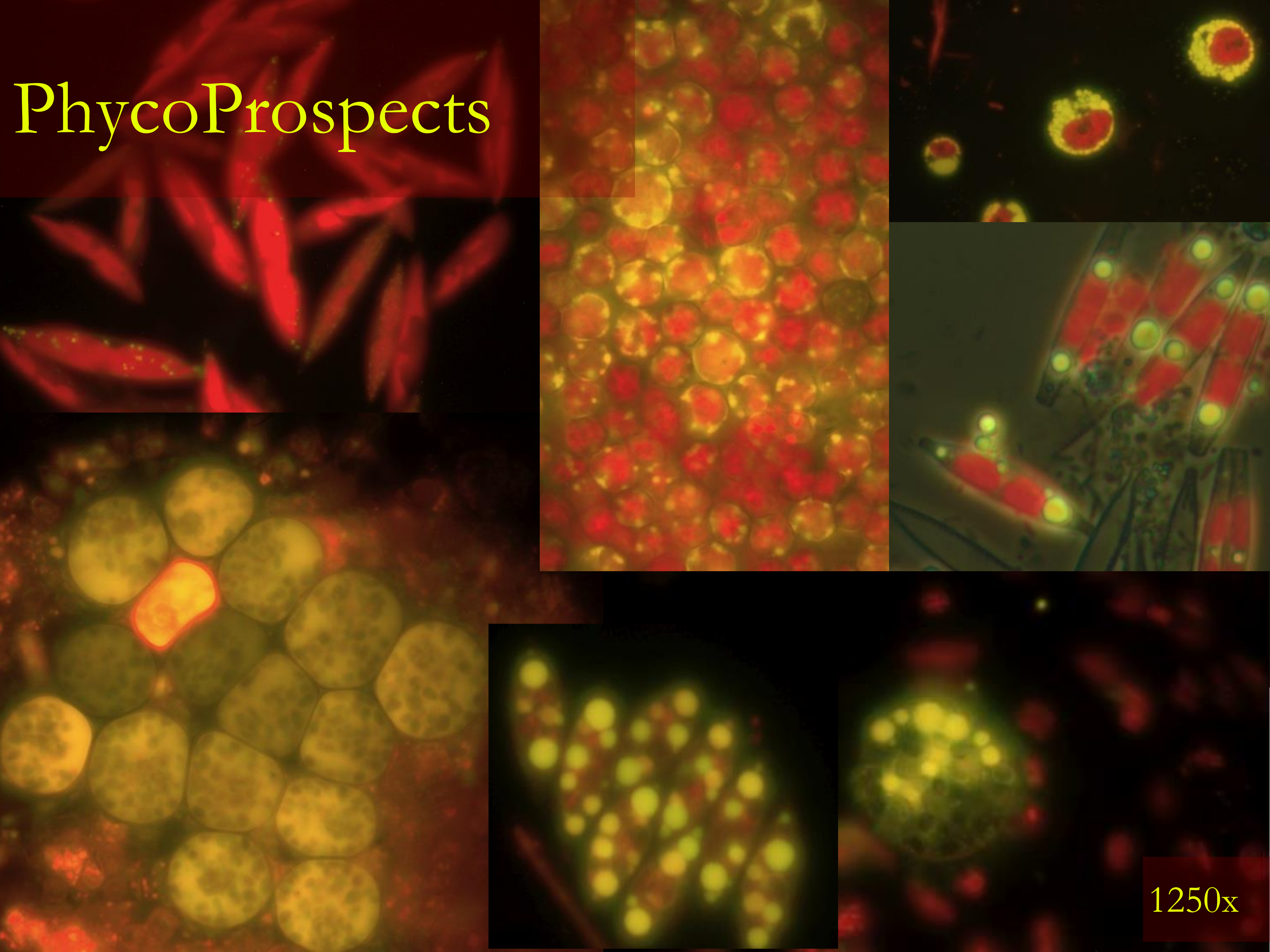
Phycoprospecting

- Find a biological base!
- Utilizing the lipo-fluorochrome Nile Red (9-diethylamino-5H-benzo[α]phenoxazine) for intracellular staining
- Local algae are collected and evaluated for the metabolic capacity to store photosynthetic energy in the form of energy-dense neutral lipids (oils)








PhycoProspects
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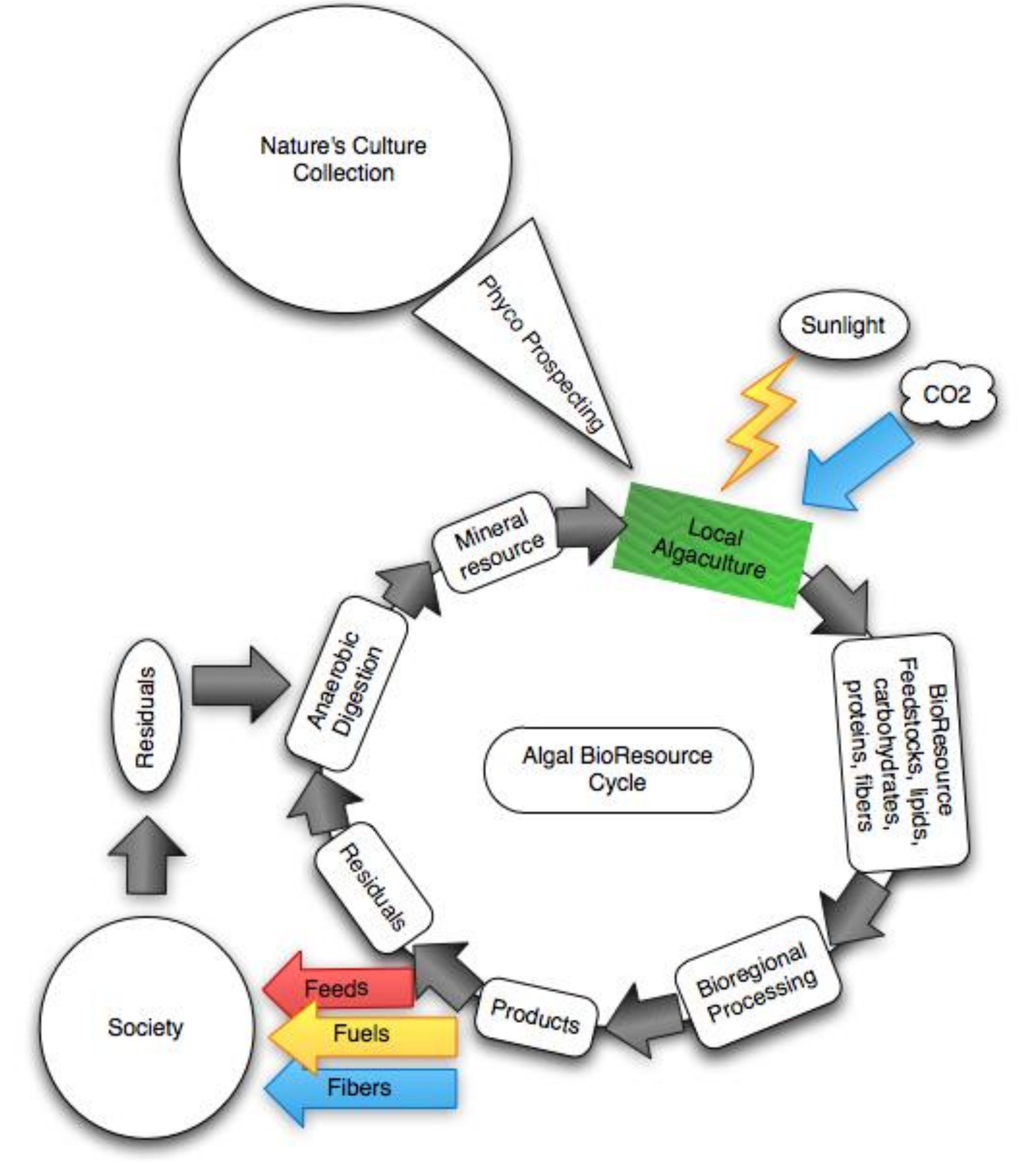

Nature's Culture Collection
Phyco Prospecting
Sunlight
CO2
Local Algaculture
Mineral resource
Anaerobic Digestion
Residuals
Algal BioResource Cycle
BioResource Feedstocks, lipids, carbohydrates, proteins, fibers
Bioregional Processing
Products
Residuals
Society
Feeds
Fuels
Fibers

Literature Cited-
Recommended Reading

- Andersen, R.A. (1992) Diversity of eukaryotic algae. Biodiversity and Conservation 1,267-292
- Chisti, Y. (2007) Biodiesel from microalgae. Biotechnol. Adv. 25, 294–306
- Lincoln, E.P., A.C. Wilkie, and B.T. French. 1996. Cyanobacterial process for renovating dairy wastewater. Biomass and Bioenergy. Vol. 10:1 pp. 63-68.
- Nurdogan Y., W.J. Oswald. 1995. Enhanced Nutrient Removal in High-rate ponds. Wat. Sci. Tech. Vol. 31:1 pp. 33-43.
- *Sheehan J, Dunahay T, Benemann J, Roessler P (1998). A Look Back at the U.S. Department of Energy's Aquatic Species Program—Biodiesel from Algae. U.S. Department of Energy's Office of Fuels Development, National Renewable Energy Laboratory www.nrel.gov/docs/legosti/fy98/24190.pdf
- Wilkie, A.C., W.W. Mulbury. 2002. Recovery of dairy manure nutrients by benthic freshwater algae. Bioresource Technology. Vol. 84:1 pp. 81-91.
- www.Oilgae.com - generic information

- *The most insightful report on the subject!


Chlorella sp. UF (high lipid strain)
Questions?
Comments?
125x