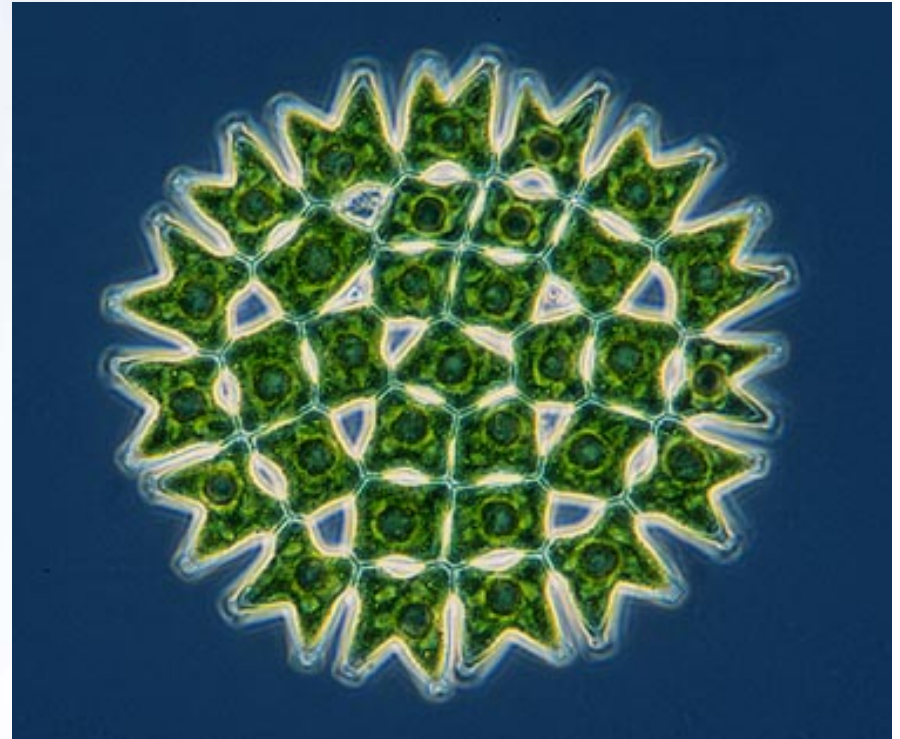
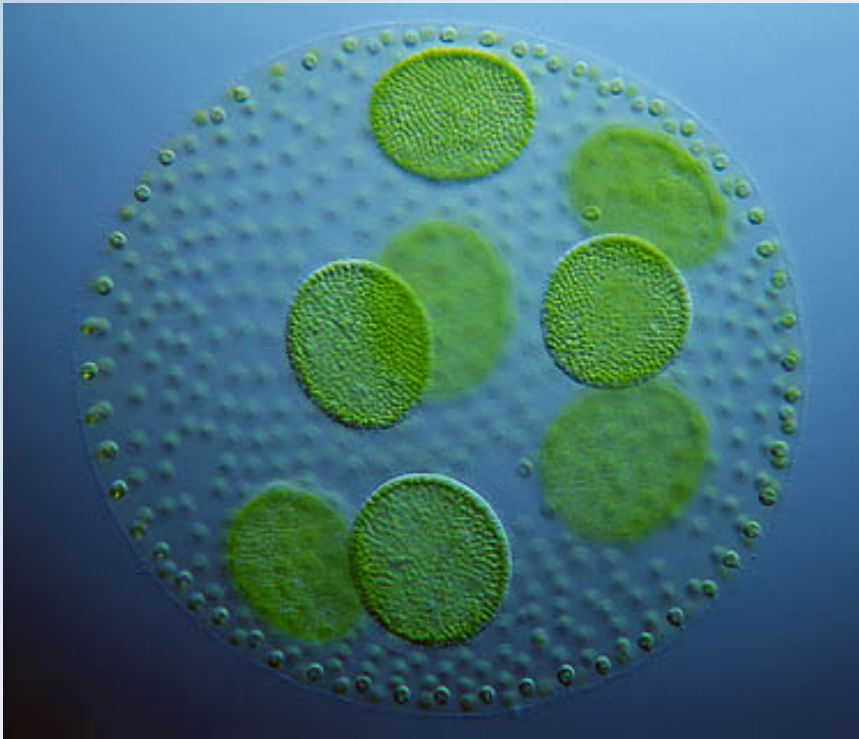


Carbon Dioxide Capture with Algae

Mark Rasmussen Ph.D.



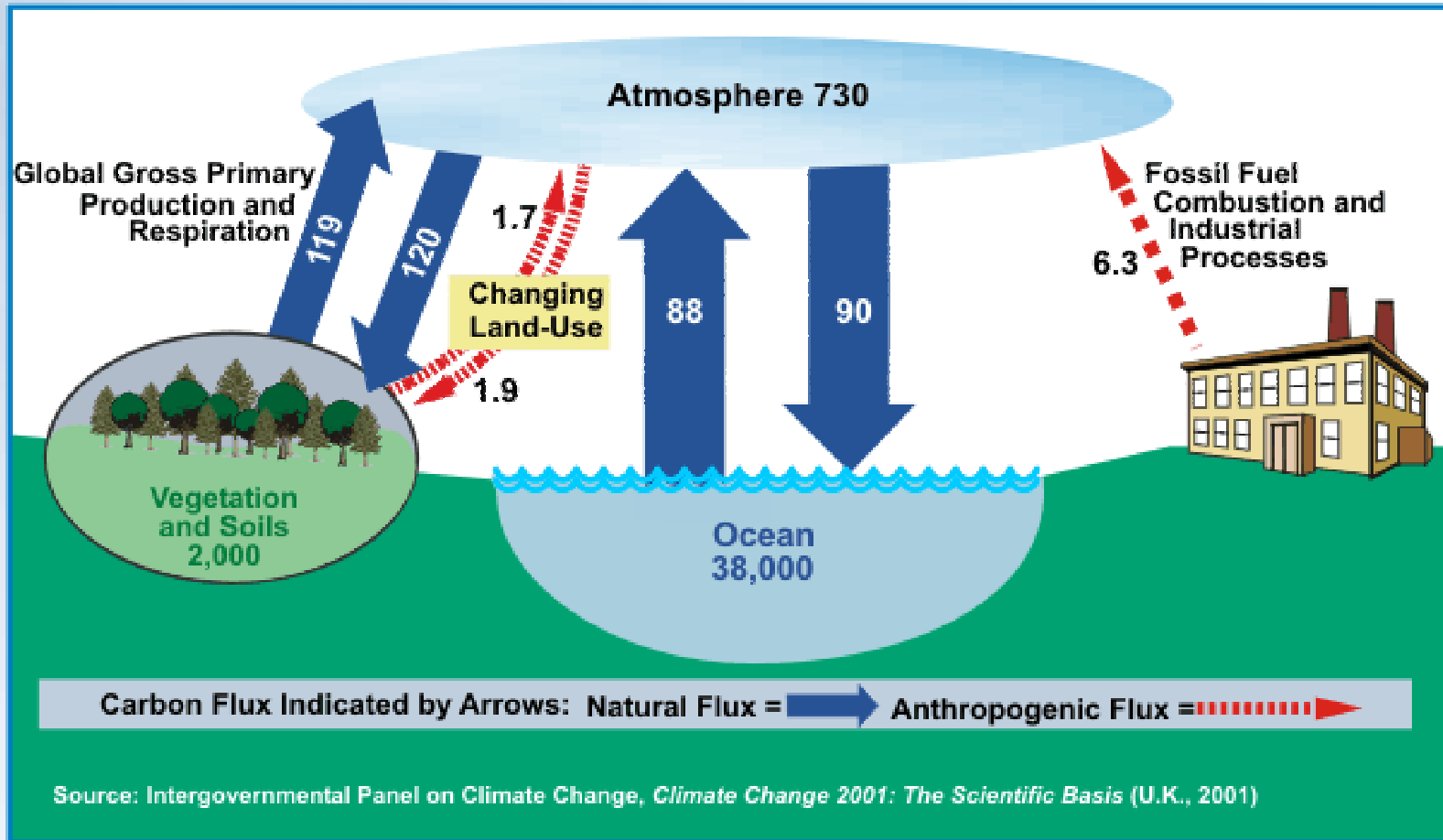
Global Carbon Cycle

Respiration + Combustion + Decay
(releases CO₂)

Versus

Photosynthesis (captures CO₂)

Global Carbon Cycle

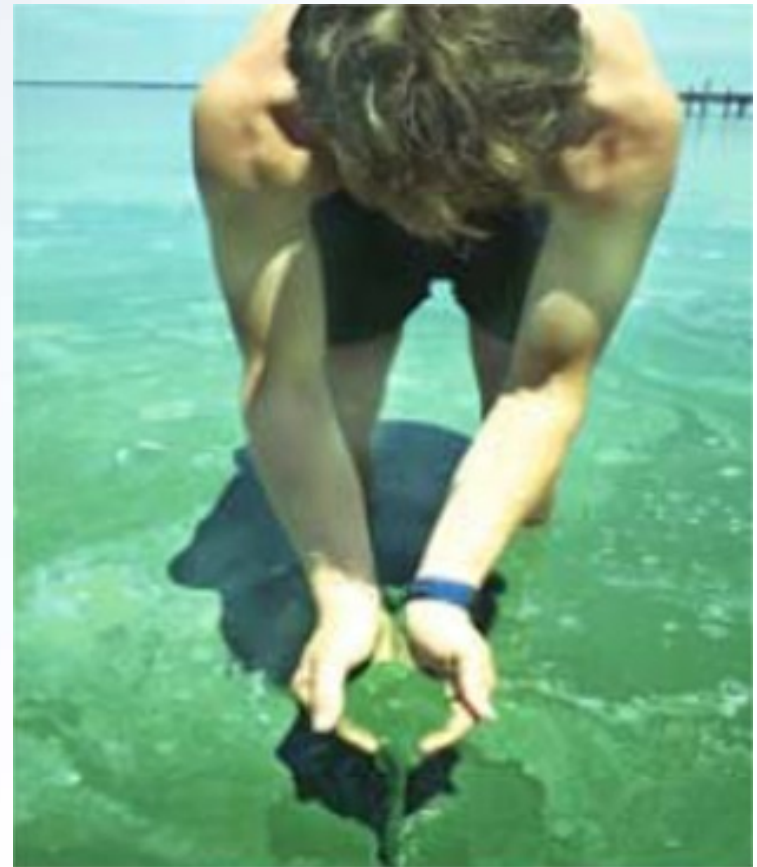
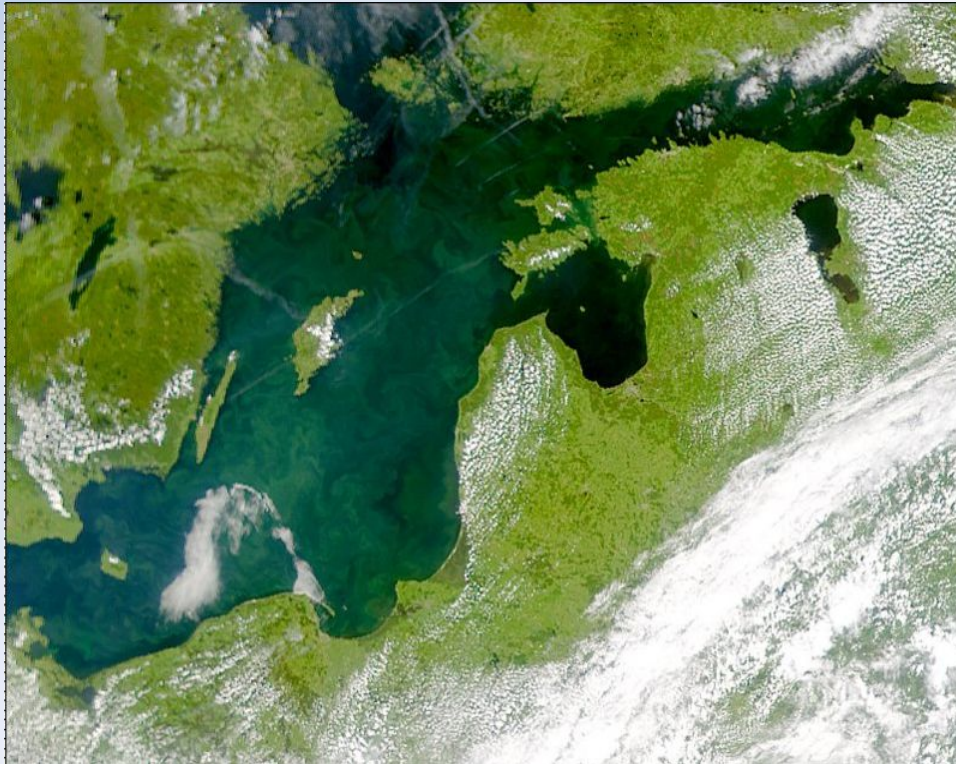


Algae: Basis of Food Chain



Algae bloom off of Newfoundland,
NASA “Visible Earth”

Algae Blooms



Algae: Nature's CO₂ Scrubber

- Earth's photosynthetic capacity is large.
- It is estimated that algae fix >65 Gt of carbon per year.
- Algae in nature fix carbon equal to the output of about **65,000, 500-MW generating plants**

The Potential of Algae Cultivation: Wastes to Resources

- Waste heat
- Waste carbon dioxide
- Plus Water & Sunlight

- Watershed nutrients
- Animal waste
- Sewage waste
- Marginal lands



Commercial Food Supplements

- Algae: *Dunaliella salina*
- Halophilic algae
- 20 tons/acre
- Nutra-Kol Pty Ltd
Australia
- High value beta
carotene



Algae Cultivation Methods

- Open Pond or Tank Methods
- Closed Bioreactor Systems

Open Culture Systems

Open systems

- Less expensive
- Temperature fluctuation
- Open to contamination
- Excess evaporation
- Types: open pond, center pivot, raceway



Closed Culture Systems

Closed bioreactors

- Controlled environment
- Less evaporation
- Capital costs
- Light issues
- Productivity
- Types: air lift, tubular, flat plate



Coal Plant Study: A Summary

- DOE study in 2002
- Calculations based upon a pond yield of 4g/l/day
- Assumption of 25% CO₂ capture from flue gas
- 2136 t/d algae biomass @ 26% lipid content
- Breakeven = \$97/ton of algae produced
- Or \$0.18/lb algae oil
- Current soybean oil prices >\$0.70/lb
- ✓ Productive algae: a competitive feedstock

Criteria for a Midwest Algae/CO₂ System

Open pond system

- Larger area requirements
- Native midwest algae
- Midwestern winters
- Less expensive

Closed photobioreactor

- More controlled biology, select species
- Greater productivity
- Greater facility requirements and costs

Algae Culture System Criteria

- **Fresh** water versus salt water
- **Moderate** versus high temperature
- **Natural** versus artificial light
- **Open** versus closed system
- **Native species** versus introduced species

Carbon Dioxide Solubility

- Increased solubility in fresh water
- Increased solubility at lower water temperatures
- ✓ Moderate temperature, fresh water system to maximize CO₂ solubility and exchange

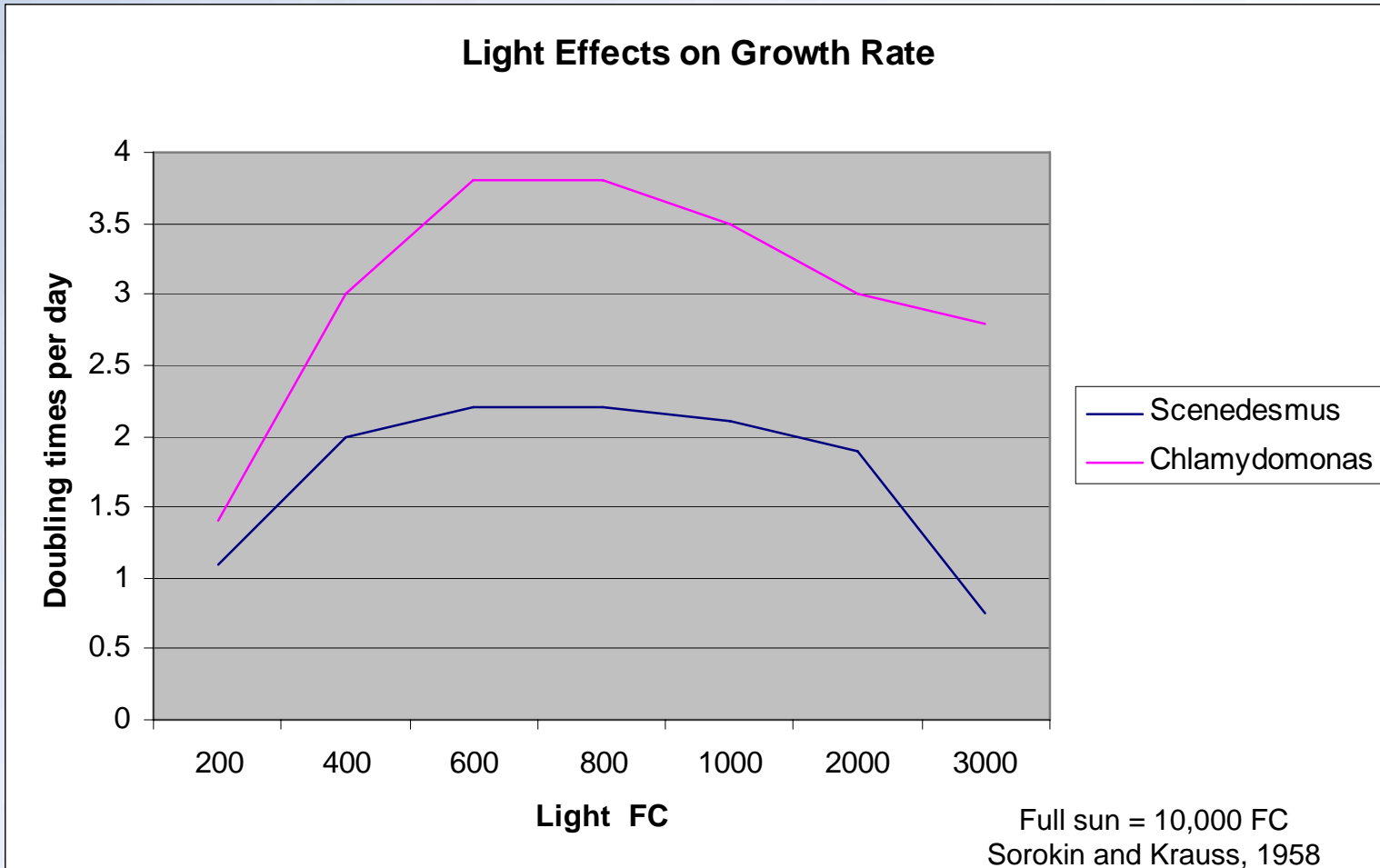
Light Intensity and Algal Growth

- Bright light: pigment degradation and heating effects
A metabolic burden and slower growth
 - Subdued light: pigment preservation
A metabolic benefit and faster growth
- ✓ Faster growth means greater CO₂ fixation

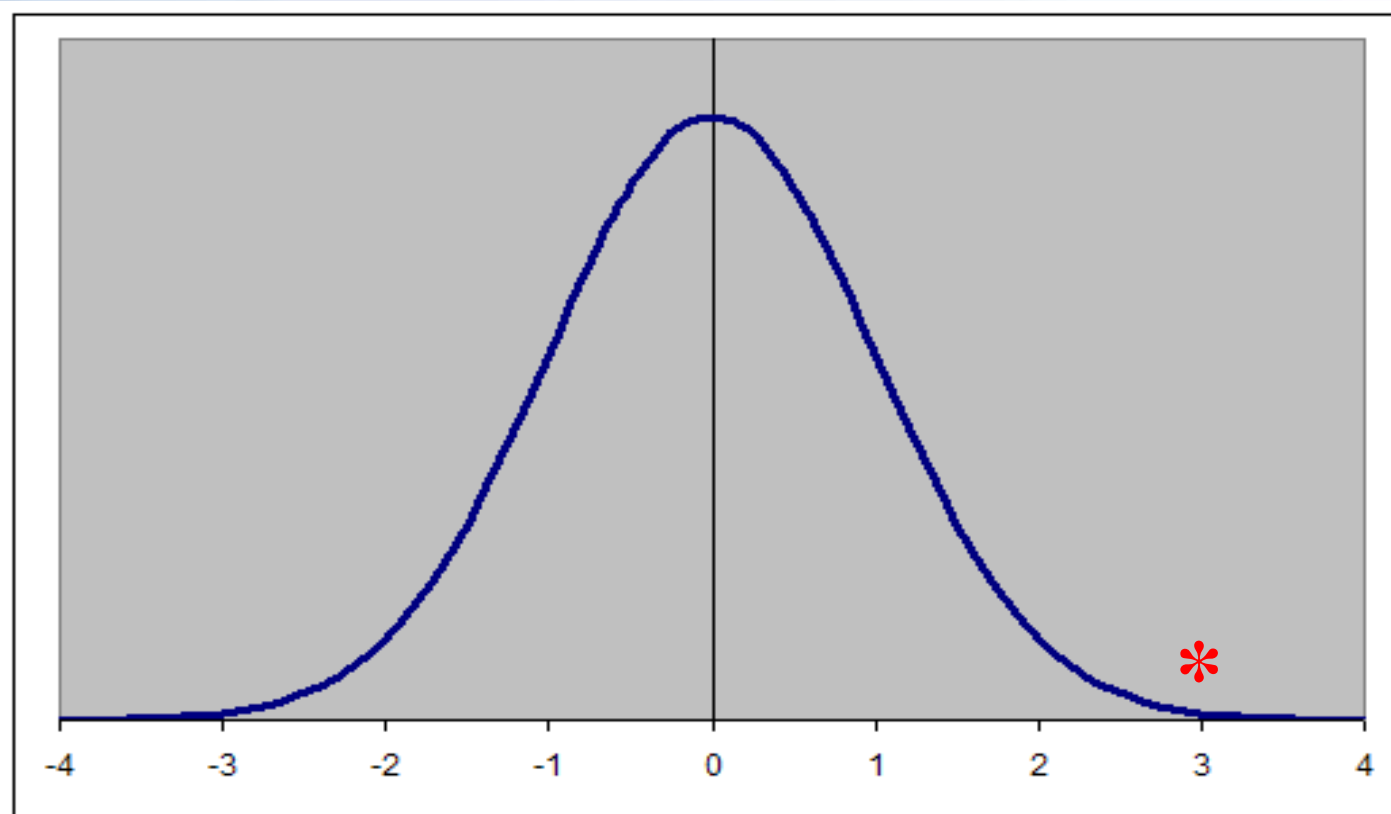
Lighting Effects on Algae Culture



Algae only need 5-20% full sunlight



Selecting algae with rapid growth and CO₂ fixation capacity



Determining Appropriate Growth Conditions with Lab Scale Photobioreactors

Photobioreactor



Research Areas: Algae Production

- Biomass productivity
- Lipid accumulation
- Cell harvest
- Cell disruption
- Conversion to biodiesel
- Scale up

The Future: Carbon Management and Biofuels using Algae



Scenedesmus opoliensis