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2nd Annual U.S.-China Advanced Biofuels Forum, Sept. 16, 2011; Idaho National Laboratory

National Alliance For Advanced Biofuels and Bio-products

Sponsored by the U.S. Department of Energy
Award # DE-EE0003046

Awarded to the Donald Danforth Plant Science Center
DUNS # 044193006

Presented by Babs Marrone
Team Leader, Harvesting and Extraction
Los Alamos National Laboratory
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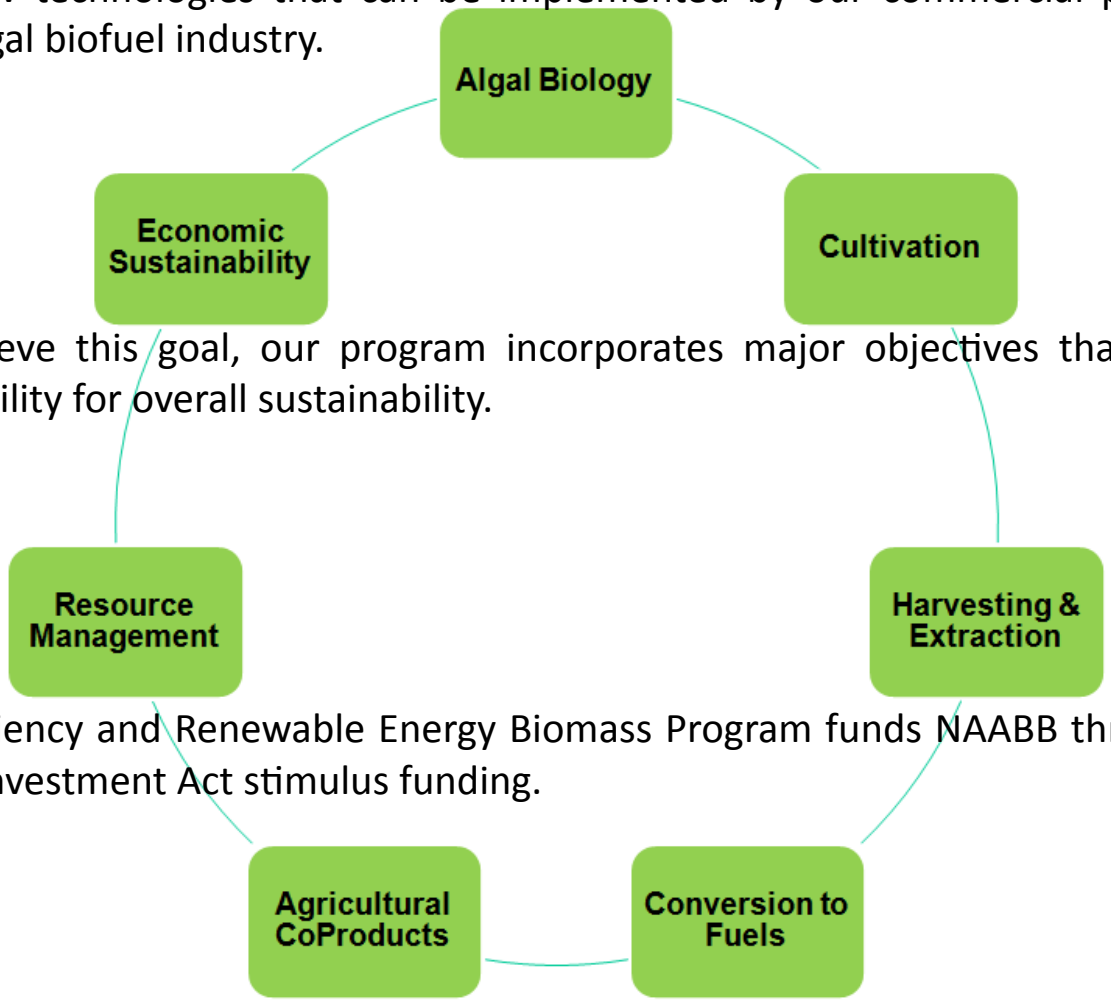
What is the NAABB?

•The overall goal of the National Alliance for Advanced Biofuels and Bioproducts (NAABB) consortium is to produce new technologies that can be implemented by our commercial partners and others developing the algal biofuel industry.



•In order to achieve this goal, our program incorporates major objectives that will establish the technologies' viability for overall sustainability.

•DOE Energy Efficiency and Renewable Energy Biomass Program funds NAABB through the American Recovery and Reinvestment Act stimulus funding.

National Alliance For Advanced Biofuels and Bio-products

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Vision

•The urgent need to develop renewable and sustainable, carbon-neutral sources of transportation fuels is now widely accepted. The correlation between carbon dioxide emissions and global warming, combined with the reality of globally-declining petroleum production is giving a new urgency to the search for ecologically sustainable and economically viable renewable fuel options. The NAABB is a powerful research collaborative that was funded in 2010 by the Department of Energy to further investigate and commercialize algal biofuels. The NAABB captures and integrates intellectual property, expertise, equipment, and facilities from a diverse set of companies, universities, and national laboratories in order to develop a systems approach for sustainable commercialization of biofuels and coproducts. The advantage of this alliance lies not only in the breadth and depth of knowledge represented by its members, but also in the dynamic network that it creates; ideas flow from the bench to the marketplace quickly to optimize real-world application.

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NAABB Consortium

Federal Sponsor:

US Department of Energy, Energy Efficiency and Renewable Energy, Office of Biomass Program

Lead:

The Donald Danforth Plant Science Center (Lead Organization)

National Laboratories:

Los Alamos National Laboratory
Pacific Northwest National Laboratory

Academia:

Brooklyn College (CUNY)
Clarkson University*
Colorado State University
Iowa State University*
Michigan State University
New Mexico State University
North Carolina State University*
Texas AgriLife Research – Texas A&M University System
University of Arizona
University of California, Davis**
University of California, Los Angeles
University of California, San Diego**
University of Pennsylvania
University of Texas, Austin **
University of Washington
Washington State University**
Washington University, St. Louis

Other Federal Agencies:

USDA/ARS

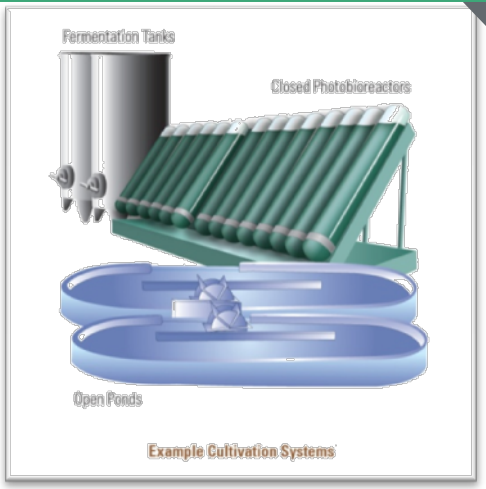
Industry:

Albemarle
Cellana
Diversified Energy
Eldorado Biofuels
Genifuel
Inventure
Kai Bioenergy***
Palmer Labs***
Phycal***
Pratt & Whitney***
Solix BioSystems
SRS Energy
Targeted Growth
Terrabon
UOP, Honeywell Company

* Subrecipients of Subawardees
** Services Provider
*** Industry Provider

Project Overview

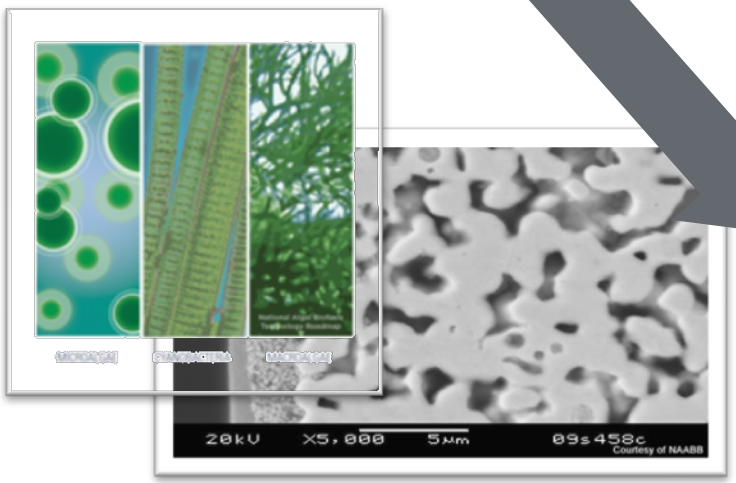
Biology and Cultivation



- Algal Strains - Growth, productivity, stability, and resilience
- Cultivation system design
- Temperature control
- Invasion and fouling
- Input requirements
- CO_2, H_2O sources, energy
- Nitrogen and phosphorous
- Siting and resources

Biomass Harvesting and Recovery

- Energy efficient harvesting and dewatering systems
- Biomass extraction and fractionation
- Product purification



A nano-membrane filter being developed by a NAABB partner.

A gasifier being used by a NAABB partner to convert algal biomass to fuels

Conversion and End-use

- Process optimization
  - Thermochemical
  - Biochemical
- Fuels characteristics
- Co-Products

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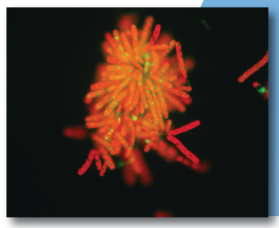
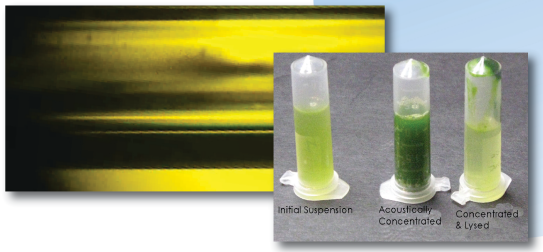
Algal Biology



Greater space-time lipid/algae yields

Cultivation

Harvesting and Extraction

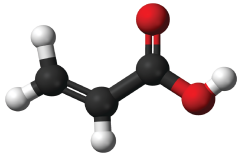


Novel techniques to reduce cost and environmental impact

Valuable Coproducts

Livestock feed

Direct energy production



Chemicals for industry use

Fuel Conversion

High energy-density fungible fuels

SUSTAINABILITY

CO_2

Water

Land

Nutrients

NAABB Goal Statement

The NAABB will develop technologies for cost-effective production of algal biomass and lipids, economically viable fuels and co-products, and provide a framework for a sustainable biofuels industry.

Productivity Targets

- >50% lipid content at harvest
- >20 g/m^2/day productivity (open system)
- 5g dw/l yield (closed system)

Harvesting and Extraction Targets

- 5,000 gal/day processing for harvesting unit
- 15 gal/day lipid extraction capacity per unit

Co-product Targets

- LEA feed value $250-1000 /ton

Sustainability

- Reduced CO_2 Emissions
- Water usage: less than 0.75 gal H_2O / gal fuel
- Nutrient recycle
  - LEA: 90% recycle nutrients
  - Energy required for conversion is 10% or less of energy in fuel
  - Energy Return on Investment (>> 1)

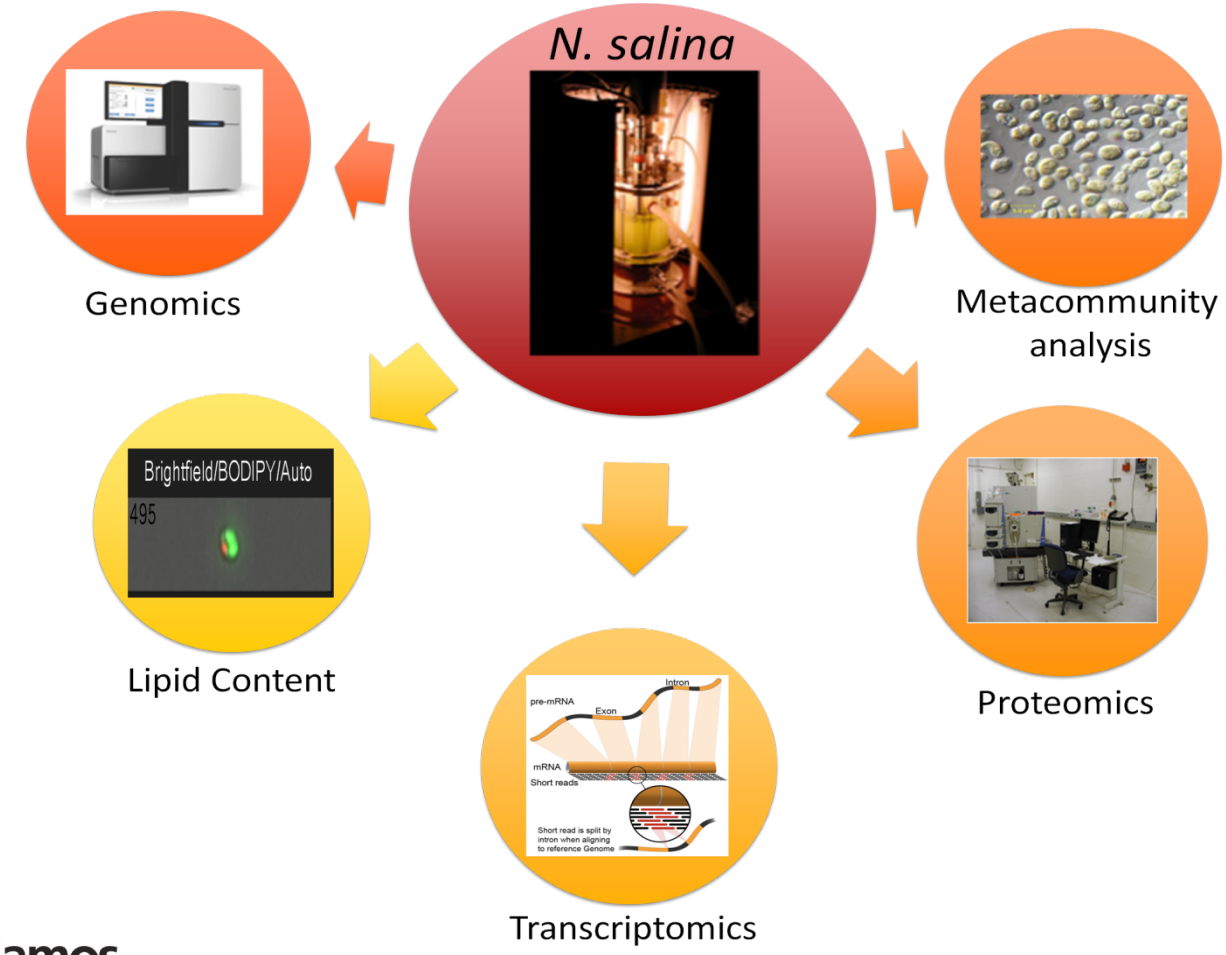
Process Economics

< $2.10 /gal of lipid

- Operating cost
  - $0.40/gal processing cost (oil)
- Capital Cost (Industry benchmarks for oil)
  - $1/annual gallon installed capacity (biodiesel)
  - $2/annual gallon installed capacity (green diesel)

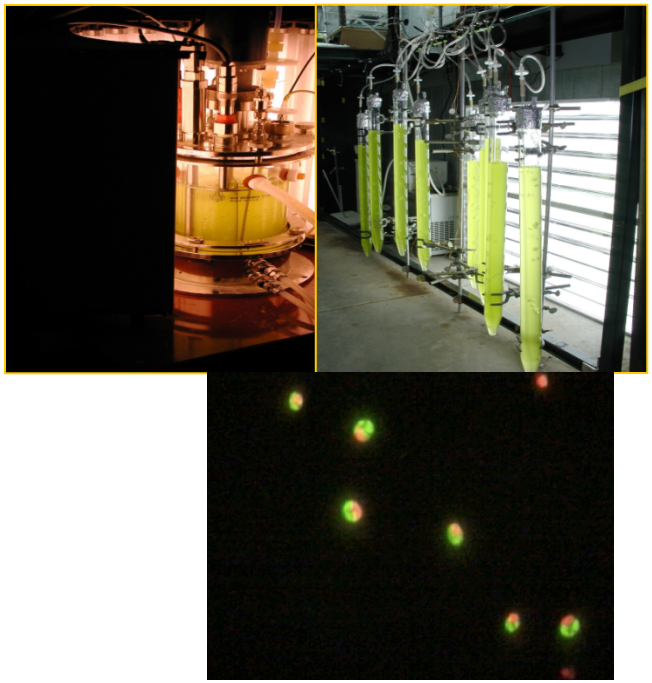
Current Collaborations between NAABB and QIBET/CHINA

Algal Genomics for Biofuels (LANL)



Algae Genome Sequencing

- Model & Production Organisms Sequenced:
- *Nanochloris*
  - Salt Water organism
  - Phototrophic growth; lipid producer
  - LANL Sequenced, Assembled and Finished
  - Transcriptome sequence data obtained
  - Analysis and annotation in process
- *Chlorella protothecoides*
  - Fresh water organism
  - Phototrophic and heterotrophic growth; lipid producer
  - LANL Sequenced, Assembled
  - Transcriptome data in process
  - Analysis and annotation in process
- *Chrysochromulina*
  - Fresh Water Growth
  - Phototrophic growth; lipid producer
  - LANL Sequencing in process
- *Nannochloropsis salina*
  - Salt water organism
  - Phototrophic growth, Lipid producer
  - Genome Sequencing underway in collaboration between QIBET and LANL



LANL Algae Genome Projects

Genome	Status	Size (Mb)	Scaffolds	Largest Contig	Total Contigs
Nannochloris sp.	Improved HQ Finishing	15.2	25	496,000	271
Chlorella protothecoides	Std. Draft	21.4	1940	101,658	4809
Chrysochromulina sp.	Std. Draft	52.2	N.D.	64,801	4904
Nannochloropsis salina	Sequence Data	N/A	N/A	N/A	N/A
Nannochloropsis salina data from QIBET assembled at LANL	Std. Draft	23	213	352,937	3496

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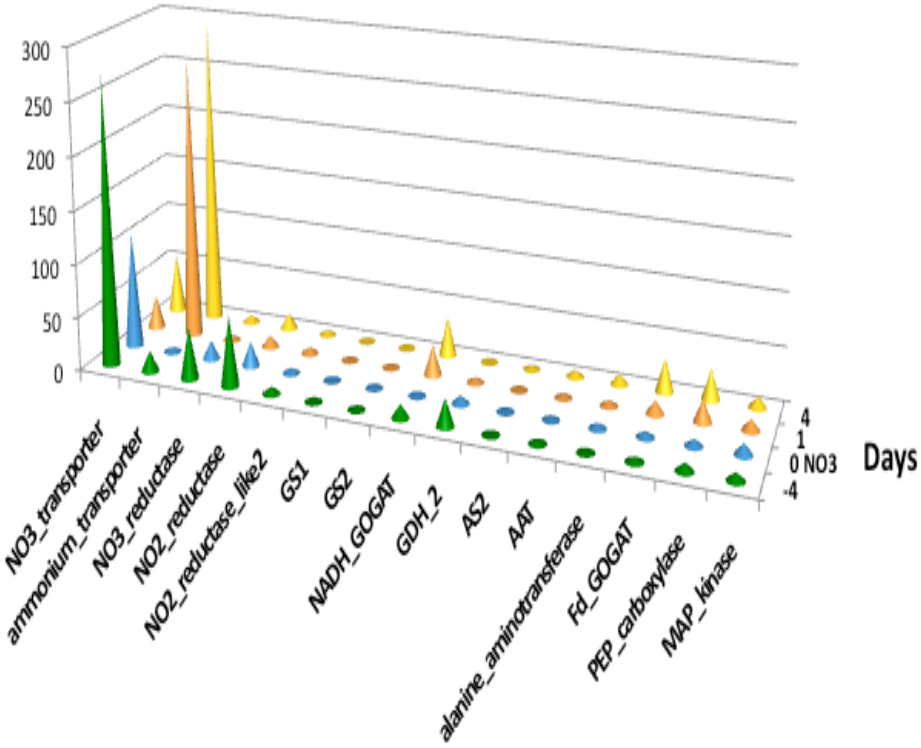
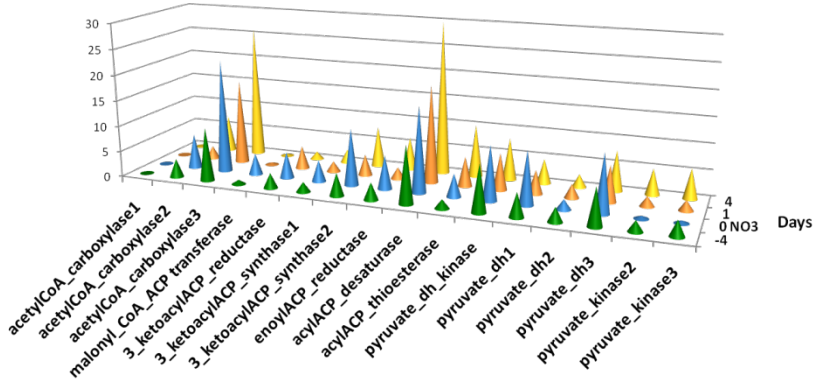
Transcriptome Dynamics

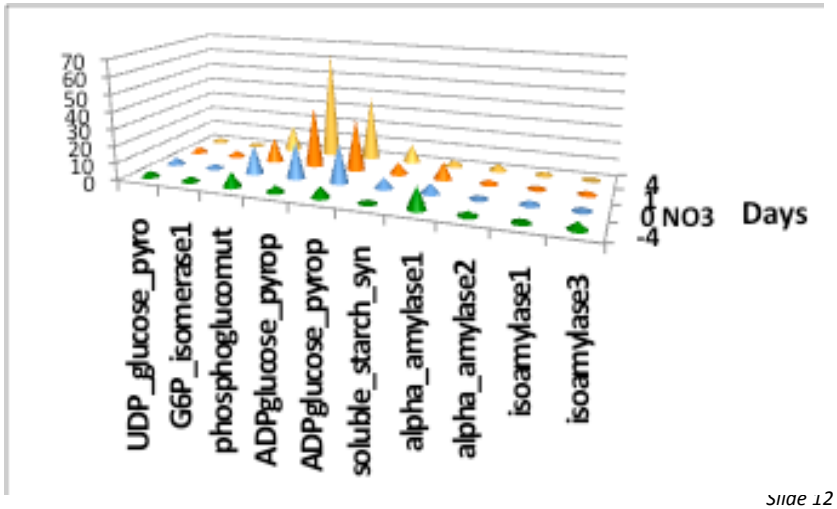
Nitrogen Assimilation



Enzymes of Fatty Acid Biosynthesis



Starch Synthesis and Degradation



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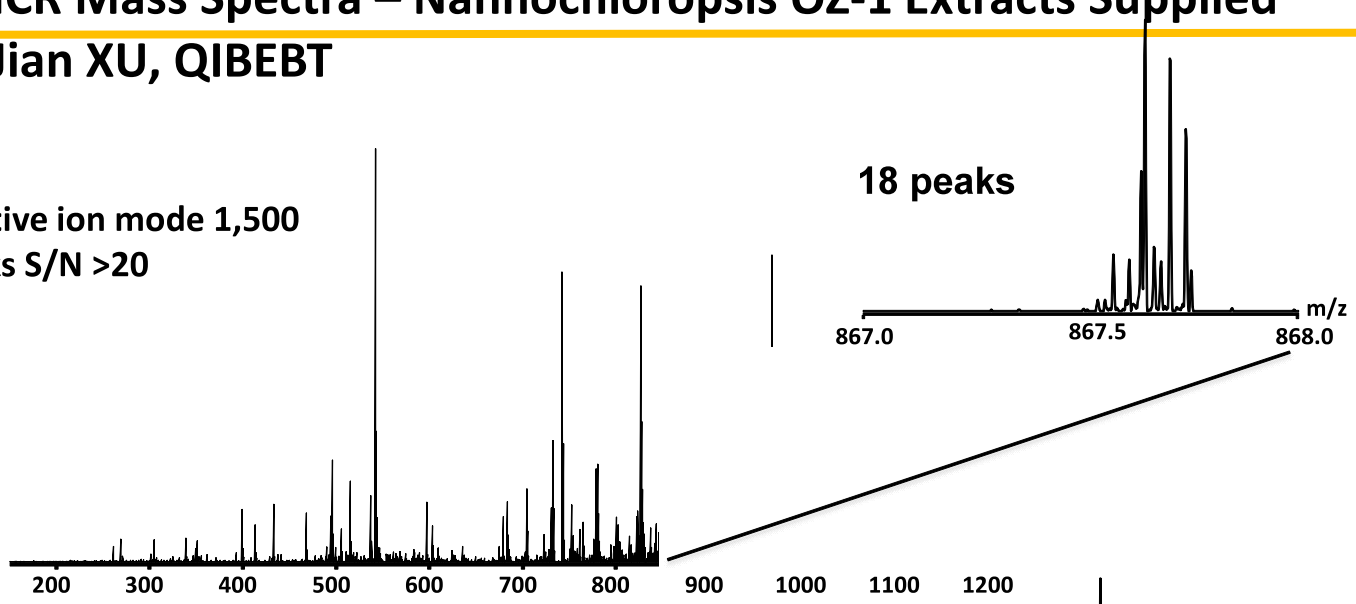
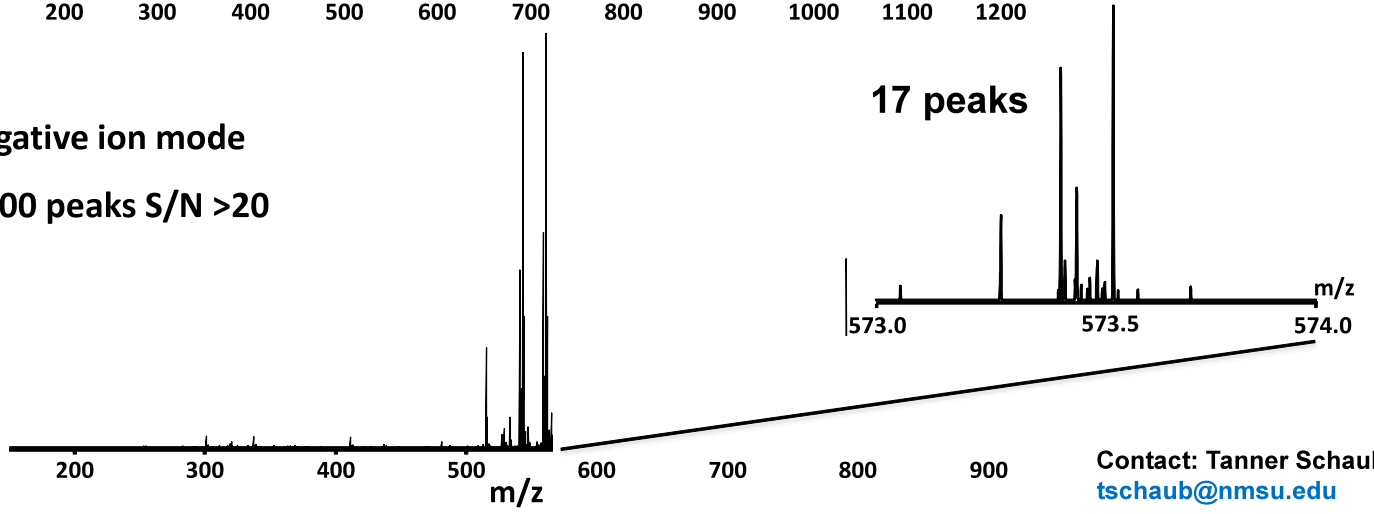
FT-ICR Mass Spectra – Nannochloropsis OZ-1 Extracts Supplied by Jian XU, QIBEBT

Positive ion mode 1,500 peaks S/N >20



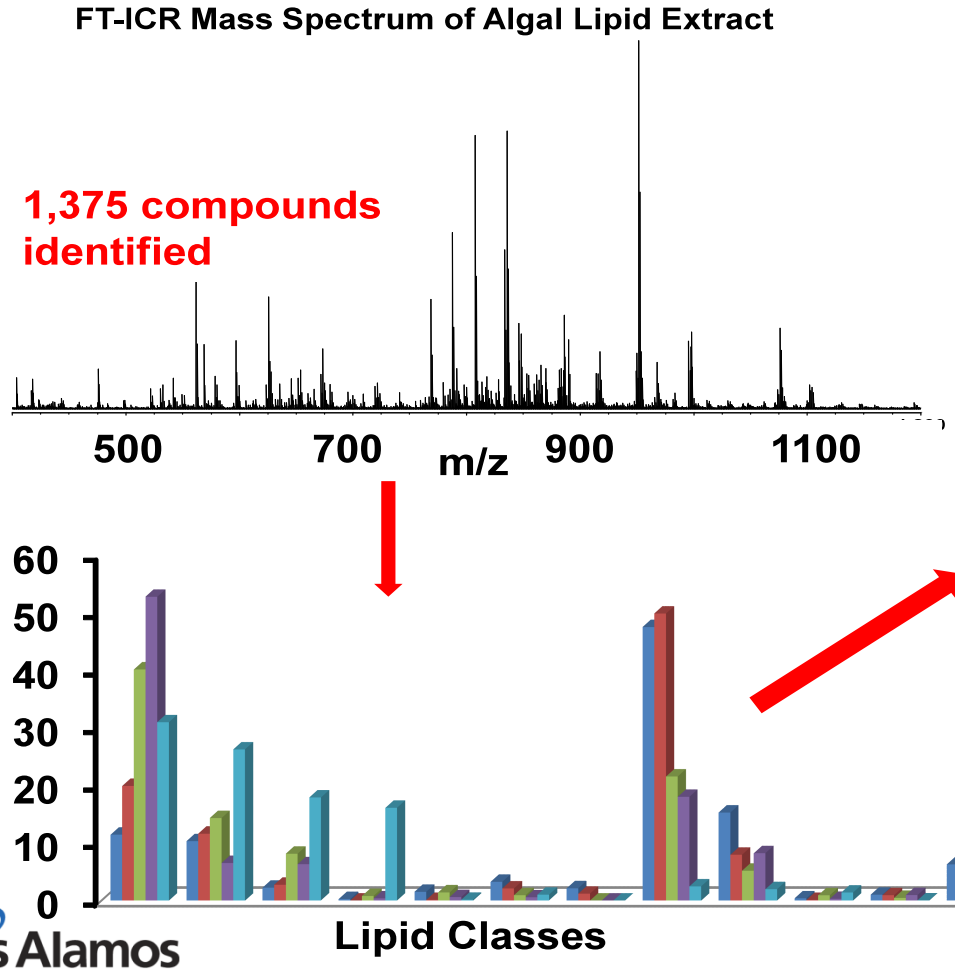
Negative ion mode

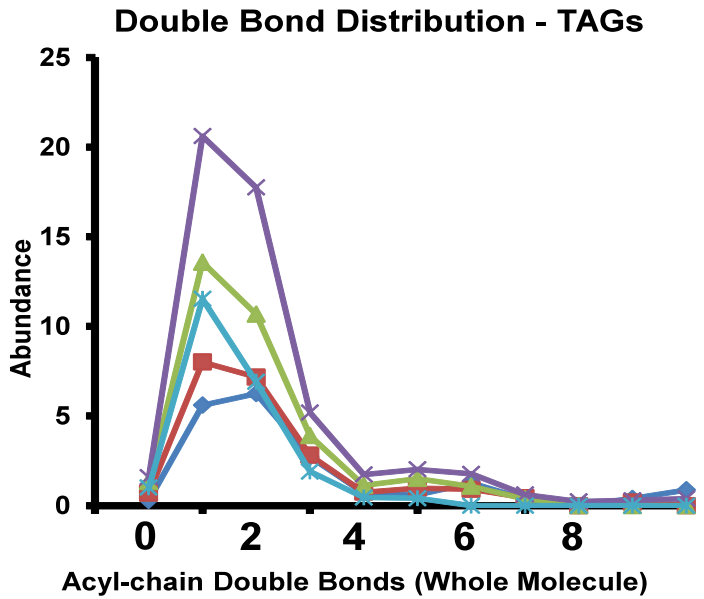
1,000 peaks S/N >20



Contact: Tanner Schaub
tschaub@nmsu.edu

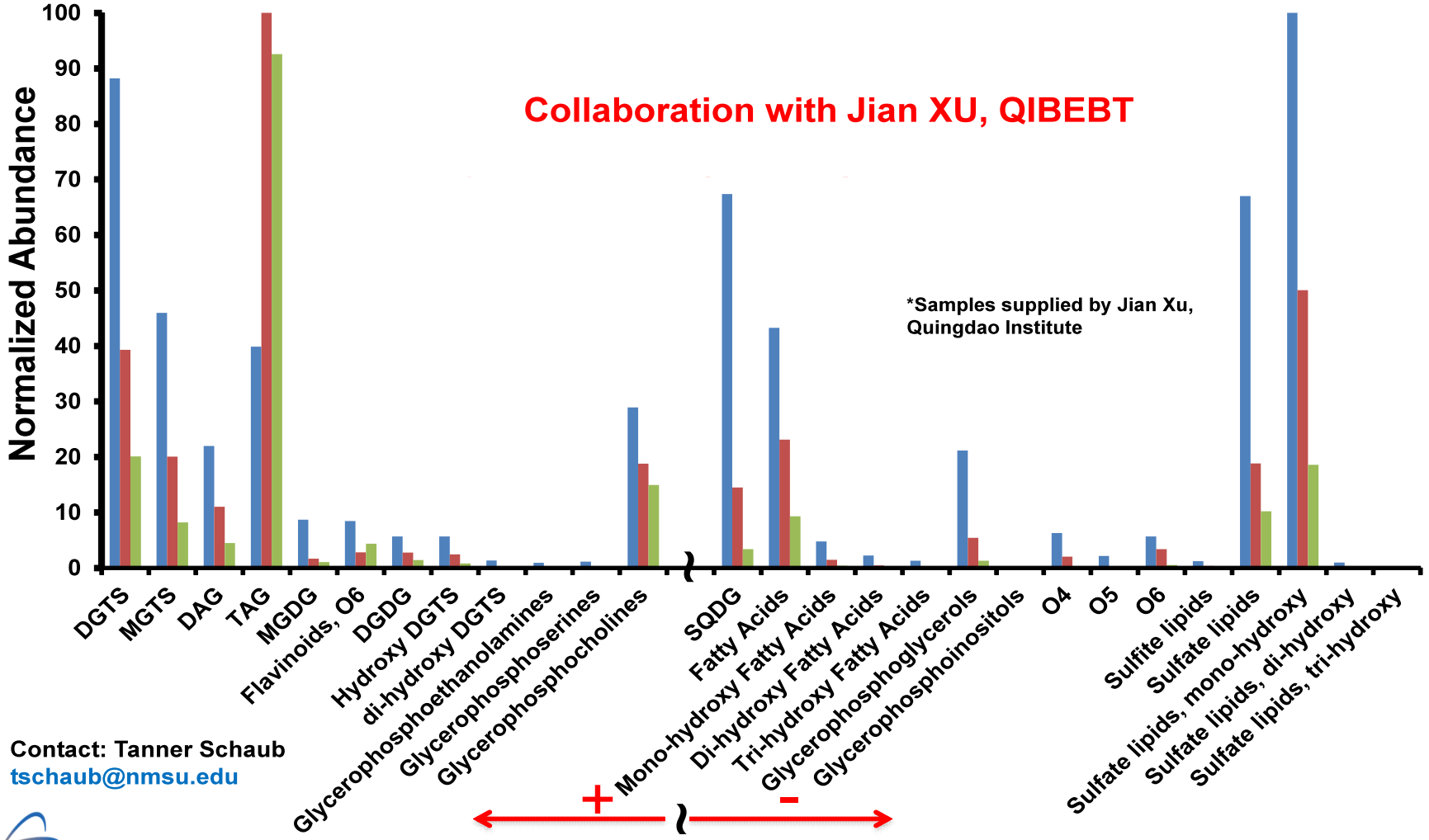
Ultra-high Resolution FT-ICR Mass Spectrometry for Detailed Algal Lipidomics





Contact: Tanner Schaub
tschaub@nmsu.edu

FT-ICR Mass Spectrometry Lipid Class Analysis for *Nannochloropsis* OZ1, 24 Hour Growth Period



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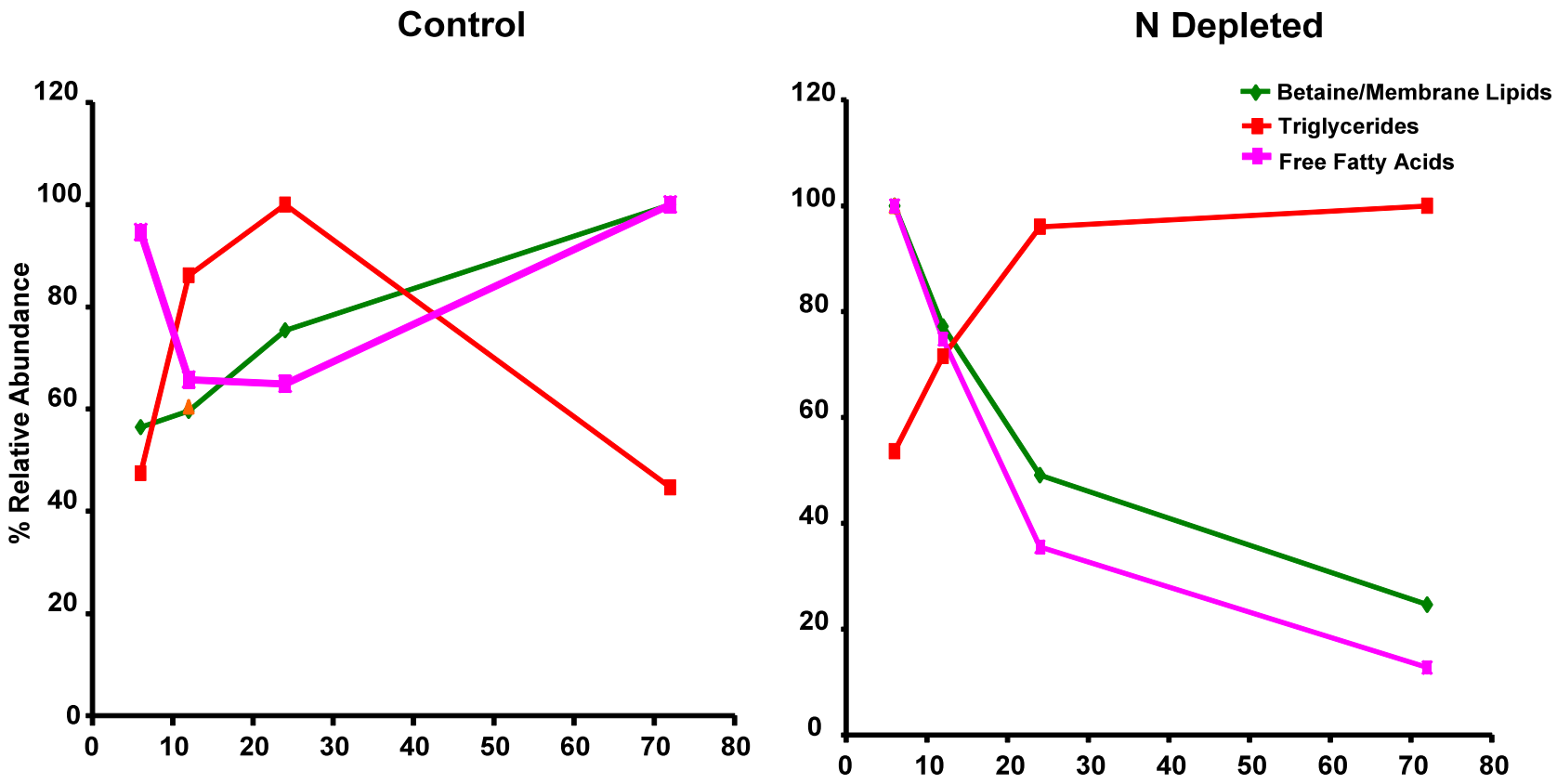
tschaub@nmsu.edu

Growth Period Lipid Compositional Change for N. OZ1



Thank you!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DISCOVERY
Feedstock Logistics
Targeted Growth
DEVELOPMENT
Harvesting
DEPLOYMENT
Fuel Conversion & CoProducts
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USDA
DONALD DANFORTH PLANT SCIENCE CENTER
Washington University in St. Louis
Los Alamos NATIONAL LABORATORY
THE UNIVERSITY OF ARIZONA
Brooklyn College
AgriLIFE RESEARCH Texas A&M System
DIVERSIFIED ENERGY
TEXAS
UNIVERSITY of WASHINGTON
UCDAVIS UNIVERSITY OF CALIFORNIA
Ucla
SOLIX ALGAE TO ENERGY
MICHIGAN STATE UNIVERSITY
Inventure
SOLIX ALGAE TO ENERGY
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Pratt & Whitney A United Technologies Company
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IOWA STATE UNIVERSITY
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AgriLIFE RESEARCH Texas A&M System
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