Biological Conversions

Lecture 17 – Photosynthetic Organisms and Animals

http://www.algaeindustrymagazine.com/blue-green-algae-being-engineered-for-nanocellulose/
http://www.extremetech.com/extreme/134910-nanocellulose-a-cheap-conductive-stronger-than-kevlar-wonder-material-made-from-wood-pulp

When you have an opportunity please visit the attached links and learn about algae that can be engineered to have high performance cellulose in their cell walls. Algae always have some cellulose, but this can be improved and because they have no lignin, they could potentially be an excellent source of tree-free cellulose. Algae have a lot of potential to improve a lot of industries and even though they are challenging and expensive to produce right now, they are certainly worth paying attention to.

Week 7 – Biological Conversions
-Learning Objectives-

- Explain the biological conversion of biomass.
- Identify things in your day to day life that use biological conversions of biomass.

Biomass Conversion Pathways

- Mechanical Conversions – normal everyday conditions
  - Crushing oil seeds and algae
  - Densification
  - Chipping and grinding
- Thermal Conversions – over 400 ˚C
  - Combustion (excess oxygen produces excess heat)
  - Gasification (heat with some oxygen)
  - Pyrolysis (heat with no oxygen)
- Chemical Conversions – under 400 ˚C
  - Biomass breakdown to components (acid, base, solvent, enzyme)
  - Biomass components to fuels & chemicals (endless possibilities)
  - Oil Conversions
- Biological Conversions – mild, wet conditions
  - Fermentations (microbes without oxygen)
  - Photosynthetic organisms and animals

3 BR350 - Lecture 2 – Common Denominators 4/12/2016

This week we are covering biological conversions, our fourth biomass conversion pathway type.

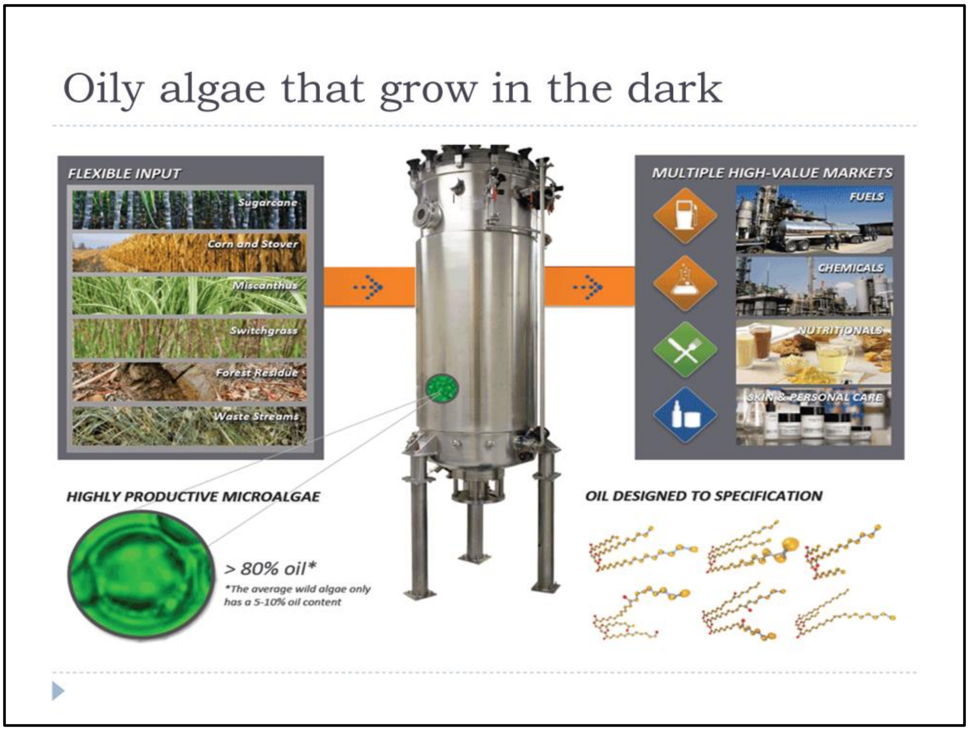
Photosynthetic organisms and animals

Certain microbes, plants, and animals are capable of producing oils and valuable chemicals. Considerable genetic engineering being done to create more/better options

Algae – oily algae, algae that secrete alcohols and oils
Plants – tapping trees for syrup or oils, oilseed crops
Animals – fat, shellac, tunicates, and insect oils

Photosynthetic organisms like algae and plants do not need to be fed sugar, or kept in a low O2 environments like fermentation microbes. They produce their own sugars using photosynthesis and they do not really need O2 as much as they need CO2. Photosynthetic organisms can be high tech like algae used for fuels/oil, or low tech like canola and peanut plants that are used to produce vegetable oils.

Likewise, animals are their own class because they require O2 and can be fed more complicated forms of biomass that haven’t yet been turned into sugar. Mammals tend to produce oils in the form of fats which are often converted into oils after harvesting. Insects have long been used to produce chemicals and are quickly gaining interest as a source of oils. The noble tunicate, a funky looking slimy filter feeder found in cold oceans, may also become a fascinating new source of cellulose sugars. Like grains, animals are often overlooked in all the bioenergy media. This is unfortunate because they currently play a role, and will likely continue to play an increasing role, in the biological conversion of biomass into useful chemicals and fuels.



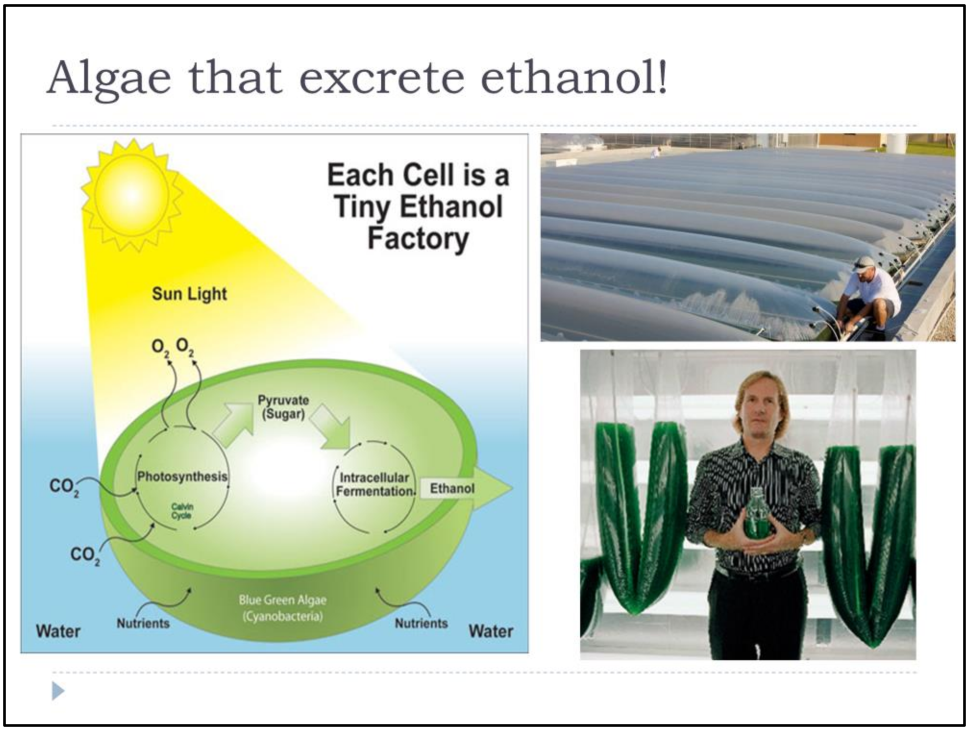
Martek and Solazyme
http://solazyme.com/technology

When we think about algae we always think about green ponds outside. This is ironic because some of the most valuable commercial algae products are generated by growing algae inside in the dark. Algae really need the sun to produce sugars that they then consume to grow. So, if you provide algae sugar they don't technically need the sun and then you can work on getting that algae to focus on making what you need. Free solar power is cheaper than sugar, so this isn't always economic, but for some things it really is. Two companies that have done this and done well are Martek founded in 1985 and Solazyme founded in 2010. They have both engineered algae that grow in the dark similar to yeast and must be fed sugar to grow. These algae can be 70-80% oil by weight when harvested.

Oily algae that grow in the light

http://allaboutalgae.com/all-algae-photos/
http://www.sapphireenergy.com/
http://www.syntheticgenomics.com/

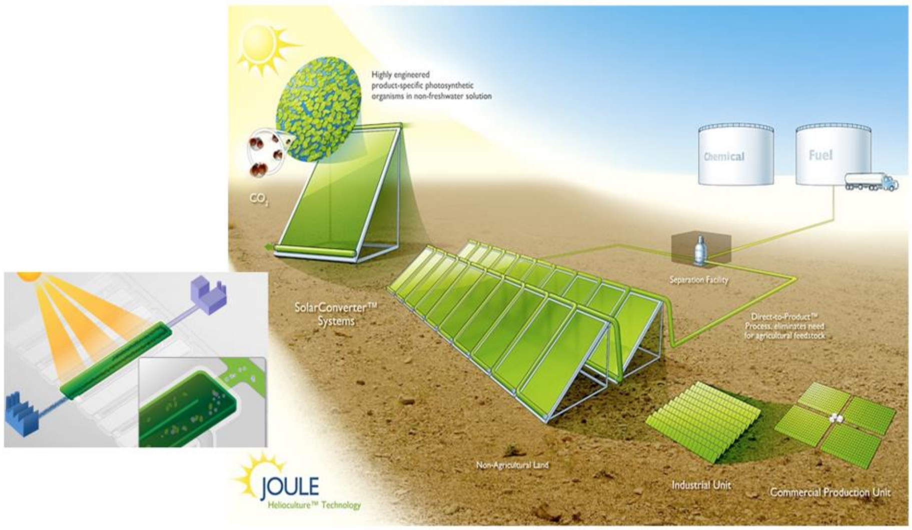
Even though growing algae in dark does some neat things, growing algae in the light is certainly the most popular way to use them. Right now the vast majority of algae grown in the light are used as food and for nutritional supplements like astaxanthin. There is also a growing algal pigment industry based on raceway ponds like the one shown in this picture. Two of the larger algal biofuels companies that use outside ponds are Sapphire and SG. Sapphire is working hard to produce algae cheaply enough that they can be converted into a crude oil that can be sent to a refinery. SG has a slightly different strategy and would like to produce algae rich in valuable oils and fuel chemicals. Hopefully they figure out how to make it economic as outside ponds take most advantage of algae’s natural strength at using sunlight instead of sugar.



http://www.algenolbiofuels.com/

One of the neater directions algae has taken lately is the production of chemicals by excreting them. A company called algenol uses an algae that actually excretes ethanol into the water around it. Their DIRECT TO ETHANOL Process was invented in 1984. It uses blue-green algae to make ethanol directly from intense CO2 and sunlight in saltwater. As a company, Algenol was founded 2006 and built a pilot plant in 2011. They use massive quantities of small bioreactors instead of open ponds and they hope to build a large commercial facility soon.

Algae that excrete oils too?!



http://www.jouleunlimited.com/

Like Algenol, but aimed in a different direction, Joule Unlimited aims to use cyanobacteria that excretes fatty acids and other diesel precursors into the water around them. They were founded in 2007 and built a pilot plant in 2010. They hope to build a commercial facility soon.

Conifers can be tapped to produce oils & chemicals

PETRO

Plants Engineered To Replace Oil

Back when we discussed history, we talked about tapping the pines and the naval stores industry. We have been tapping pines since the middle ages and Naval stores was massive U.S. industry from 1700's until the 1960's. These are perfect examples of plants and trees generating chemicals and fuels. However, that is old technology and it can be dramatically improved by using techniques available today. The DOE is funding a program called PETRO that aims to do just this and so far it has made some significant advances. The idea of growing crops that are a living part of an integrated biorefinery is a fascinating idea and this promises to be an exciting area of development.

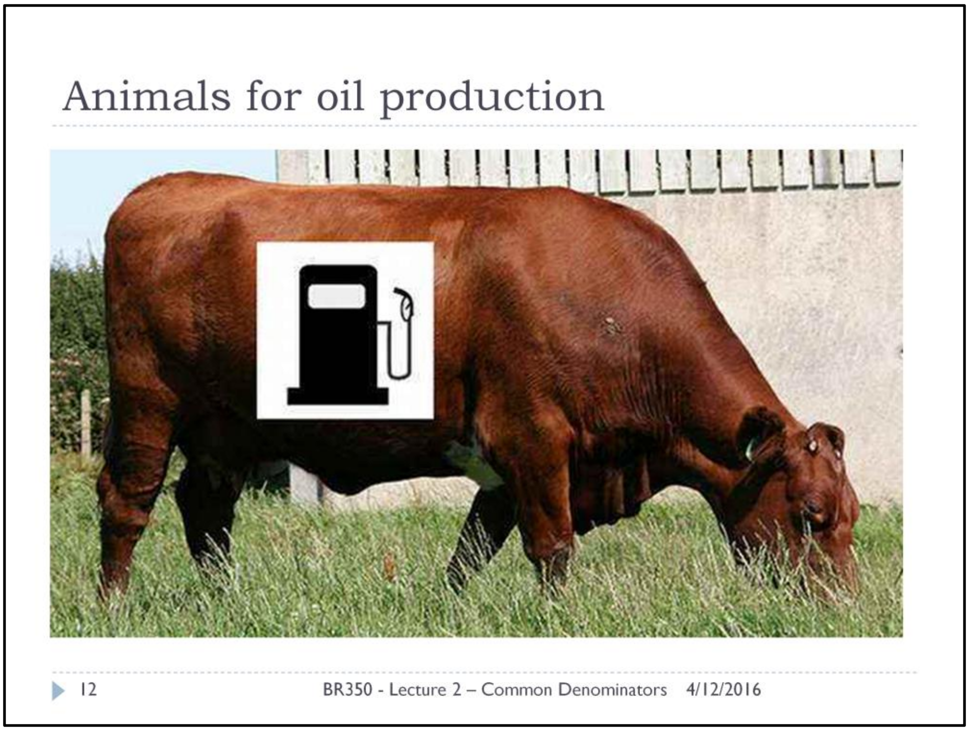
Oilseed crops are a major global business

http://en.wikipedia.org/wiki/Palm_oil
http://en.wikipedia.org/wiki/Vegetable_oil

Read slide

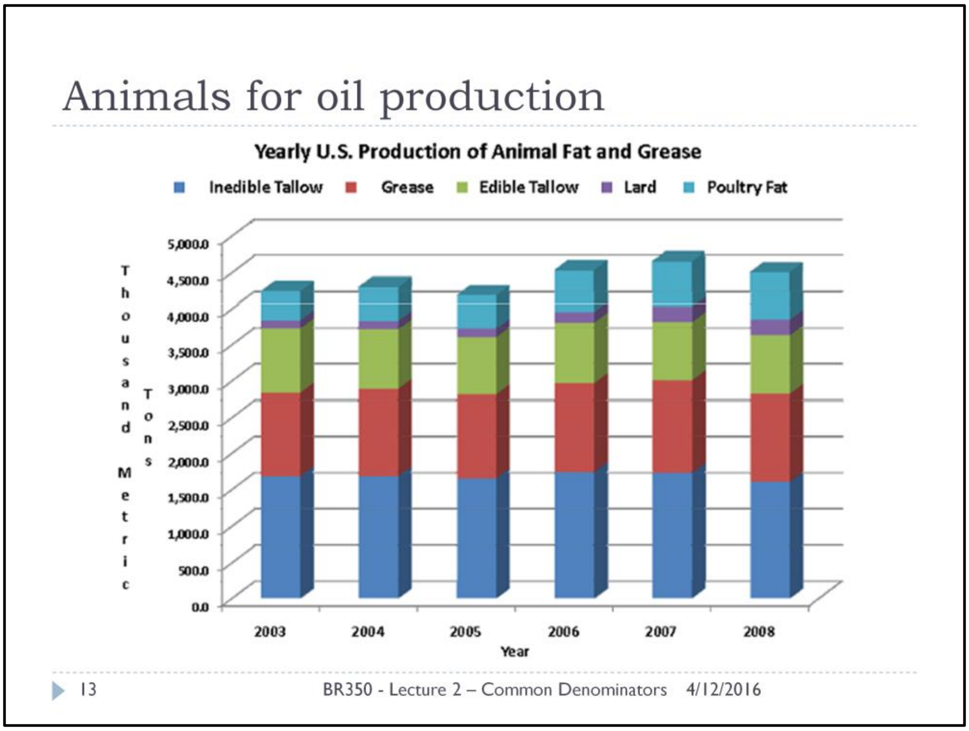
There is no better example of plants being used for biological conversions than oilseed crops. The production of those oils is a biological conversion and the extraction of those oils is a mechanical conversion, and combined these conversions generate a massive source of plant derived oils utilized by every nation in the world. Like any other major agricultural efforts this comes with its share of problems and challenges, but despite these it is important to consider the value that plants bring in being able to produce oils like this.

The noble tunicate will be mentioned twice because it is unique and it forces us to think outside the box. One of the most interesting new sources of biomass being considered is an ocean animal called a tunicate. It is one of the only known animals on earth that produces cellulose and, furthermore, it produces quite a bit. Tunicates are currently being investigated very closely as a new source of cellulose and protein. Like algae for cellulose, being able to farm tinucates for cellulose production could be a major paradigm changer.



http://www.nationalrenderers.org/economic/statistics/

We talked about the value of grain as a source of biomass and it is equally important to remember that animal fat is a major source of biologically available oils for bioenergy. We have been using animal fats for oils much longer than we have been using petroleum. It is not cheap and there is always a market for it somewhere. Ironically, the price of animal fat oil and petroleum has been pretty similar for the last 20 years or so. We don't usually look at a cow, pig or turkey and go, " Wow what an oil source!" Fat/oil are an important product generated by these animals, so its good to think about it.



http://lipidlibrary.aocs.org/processsing/animalfats/index.htm

This graph makes important statements about the quantity of fat produced and how stable that production has been for many years. 4-5 million metric tons of animal fat is quite a bit – about on the order of what a small-medium sized oil field produces every year. If you are curious you can look up a list of oilfield sizes online. This level of animal fat would be the equivalent of about 30 million barrels of oil/year which is about 0.1 million barrels/day

Insects have the potential to be an excellent source of oil

- Many insects have an oil content of 20-30% by weight
- Shellac is well known insect chemical product

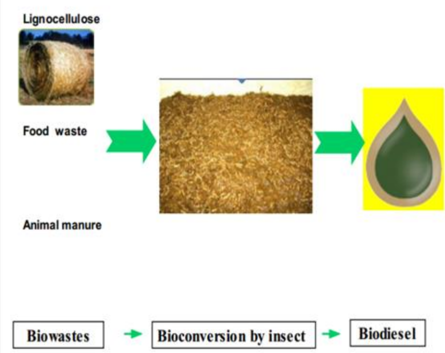


Figure 1: Technical process of bioconversion of organic wastes by insect.

Li, Q., et al. "Insect fat, a promising resource for biodiesel." J Pet Environ Biotechnol S 2 (2011): 2.
http://www.aocs.org/Membership/FreeCover.cfm?itemnumber=17016

From my perspective insects are one of the most interesting new sources of oil to come around in quite awhile. They eat a very wide variety of biomass and waste biomass sources, and they live in conditions that are easy for us to support. Many species are naturally high in oils and even more could be genetically engineered to produce either oils or chemicals of interest. There are many industries using insects chemicals today, so there is precedent for this kind of biological conversion. From the bioenergy perspective, it has the promise of being a very technologically simple biological conversion that could be done in a consolidated way in rural areas and that is always interesting.

Biological Conversion Summary

- Biological conversions often make chemicals difficult for humans to synthesize easily
- Living organisms "live" to grow and reproduce, not to make products for humans! MOST LIVE IN WATER
- These chemicals can be inside or outside of the organism and must be captured and concentrated
- Fermentations are well understood and can make a variety of liquid and gaseous fuels
- Genetic engineering is rapidly increasing the number or organisms that secrete/excrete valuable products

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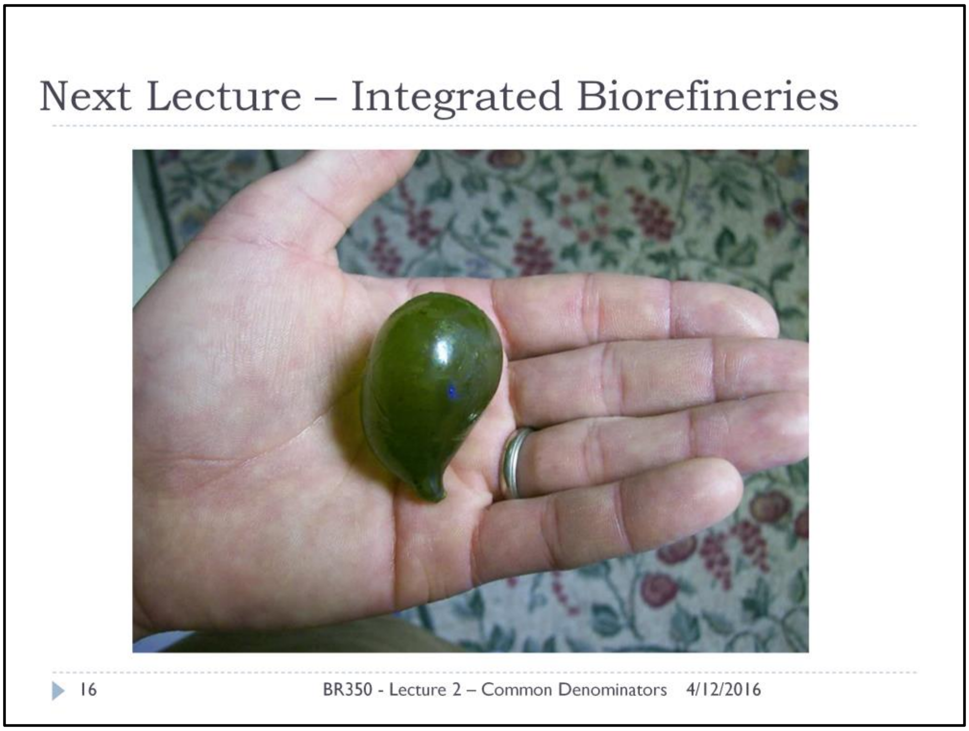

http://en.wikipedia.org/wiki/Valonia_ventricosa

This image shows someone holding one of the largest single celled organisms on earth. This organism is an algae called valonia ventricose and believe-it-or-not that entire green ball is technically just one cell. It is somewhat compartmentalized and has countless mobile nuclei giving instructions to keep things running, but it basically just one massive cell. Usually when we think of cells we think of something we have to look at through a microscope, so its fascinating that this type of algae makes us re-think what it really is to be a single celled organism.