BIOLOGICAL ENGINEERING

UtahState University

Augmenting anaerobic digestion of microalgal biomass

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SWBEC

Sustainable Waste-to-Bioproducts Engineering Center

CELLULAR ENGINEERING

What is anaerobic digestion and why to care?

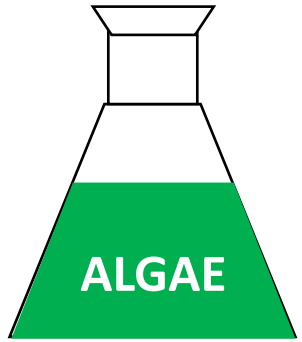
Organic waste
(plant/algae biomass, wastewater, animal manure)

Microbial buffet

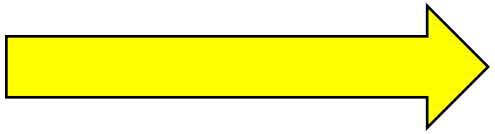
Biogas

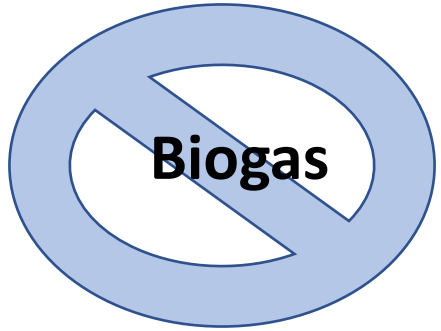
- Methane potential of USA – **7.9** million tones/year
- **5**% of natural gas in the electric power
- **56**% of natural gas in the transportation

Problem: how to efficiently digest algae?



Microbial buffet

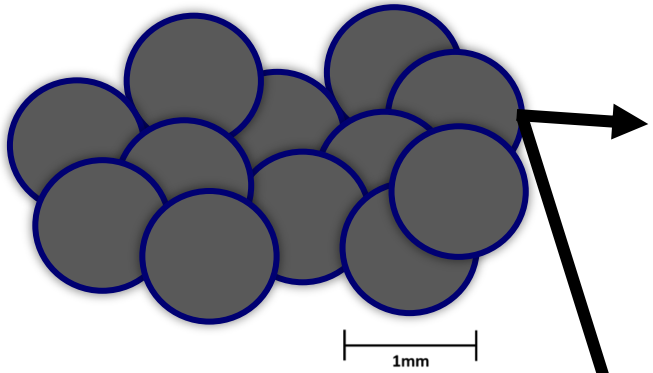


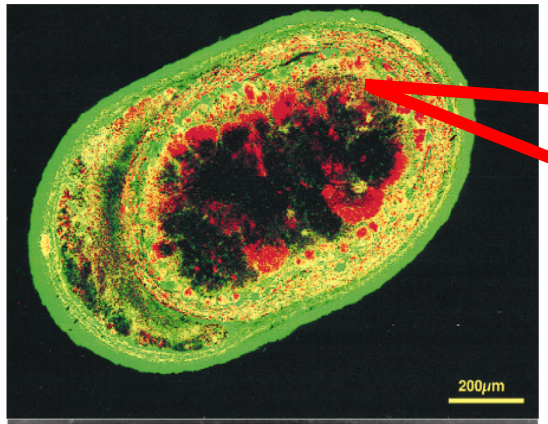


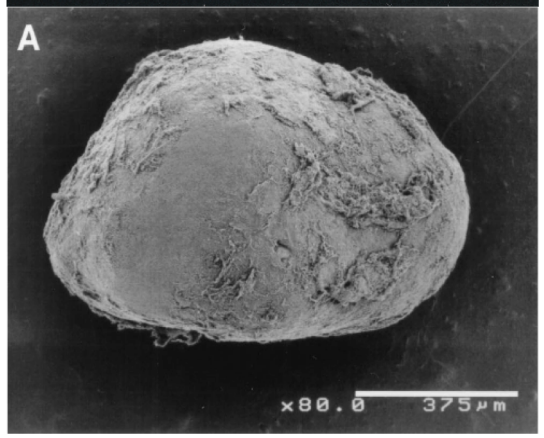
- “Good” algae that polish wastewater and needs to be processed afterwards;
- “Bad” algae that cover surface waters and needs to be processed.

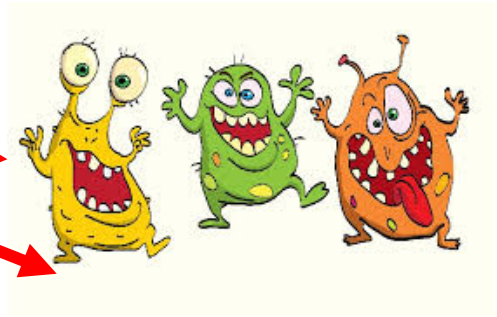
Augmentation is a solution

We have a very efficient anaerobic granular sludge









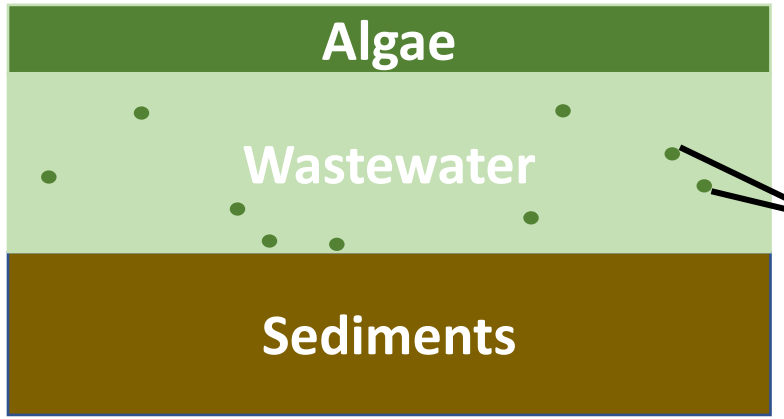
I LOVE algae!

from Sekiguchi Y. et al., 1999

Solving the problem: finding algae-loving bacteria

Logan City Wastewater Lagoons

sampled

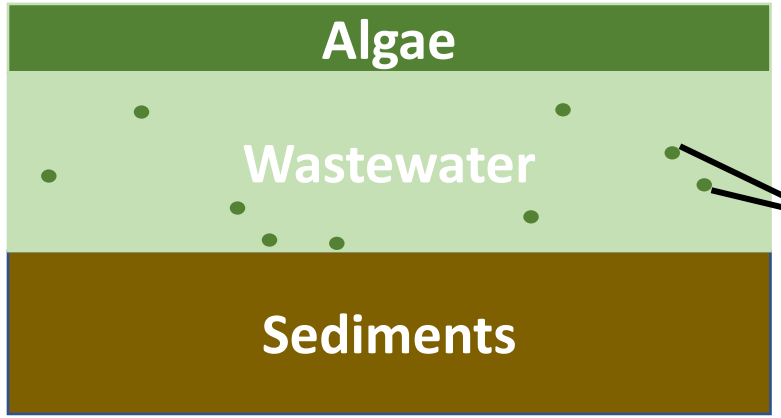


Algae biomass

Solving the problem: finding algae-loving bacteria

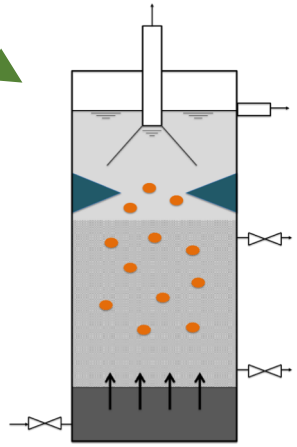
Logan City Wastewater Lagoons

sampled



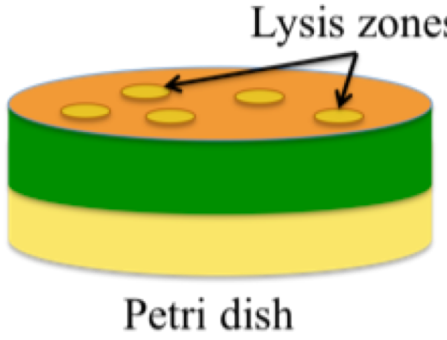
Algae biomass

inoculated



UASB

isolated



Anaerobic sludge lawn (hydrolytic phase)

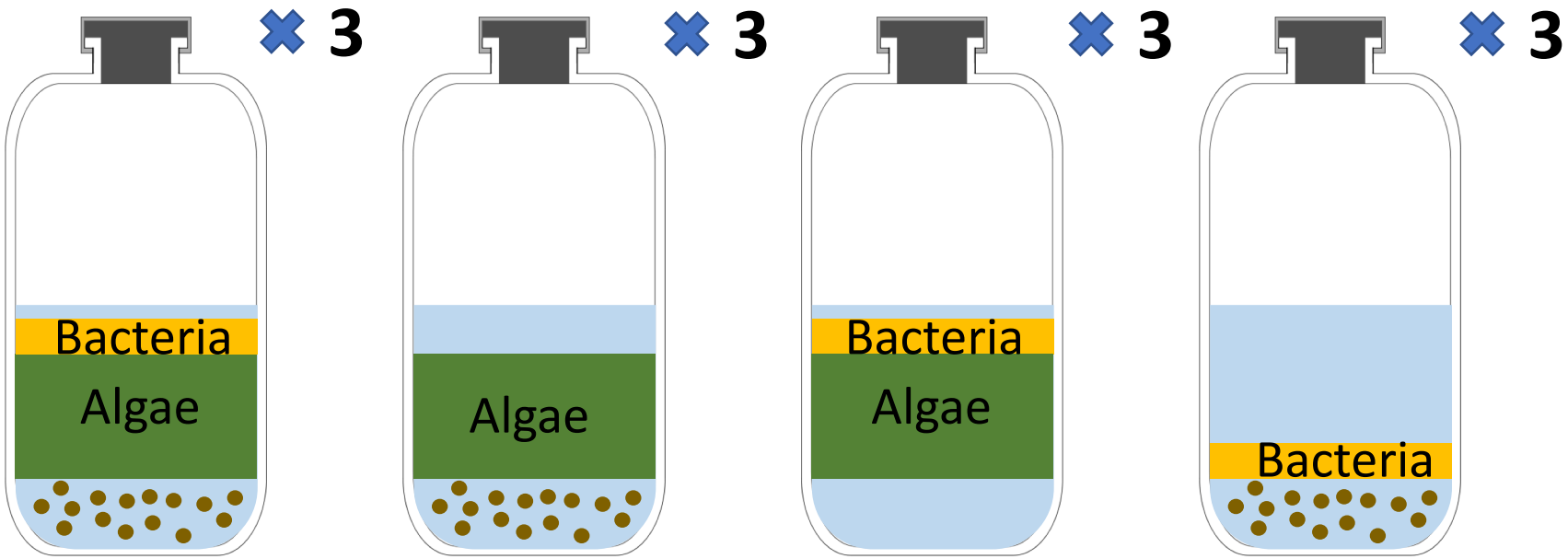
0.8 % Agar + Algae

1.5 % Agar

Isolated: *Citrobacter*, *Alcaligenes* and *Pseudomonas* spp..

Experimental set-up

Specific Methanogenic Activity (SMA) test



+ self-digestion controls

9.6 gVSS/L of algae

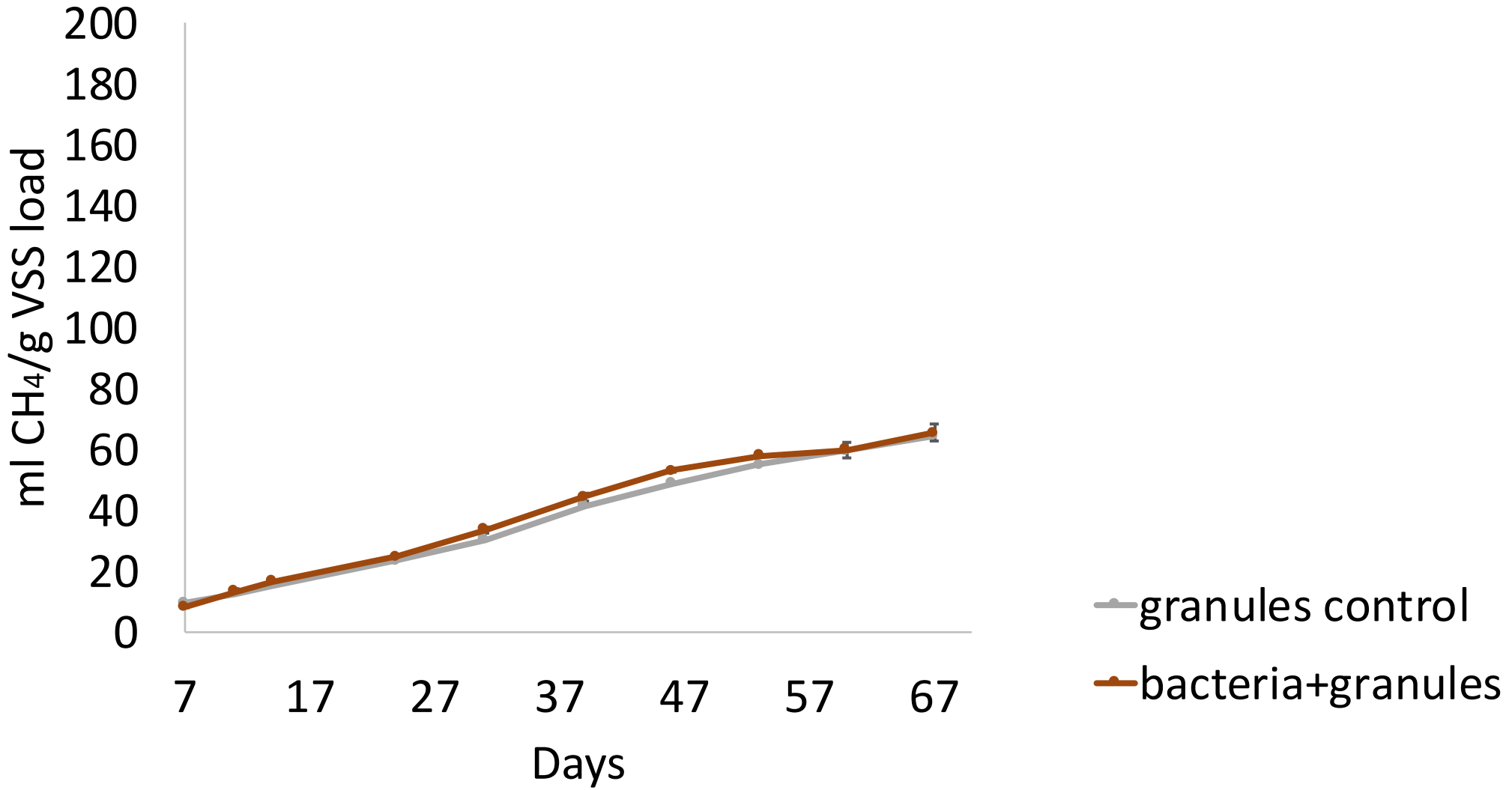
19 gVSS/L of granules

10% algalytic bacteria

1:2 substrate:inoculum

**Algae came from the surface of a trickling filter polishing municipal wastewater

Results: after 70 days, at 35±2°C, at 100 rpm…



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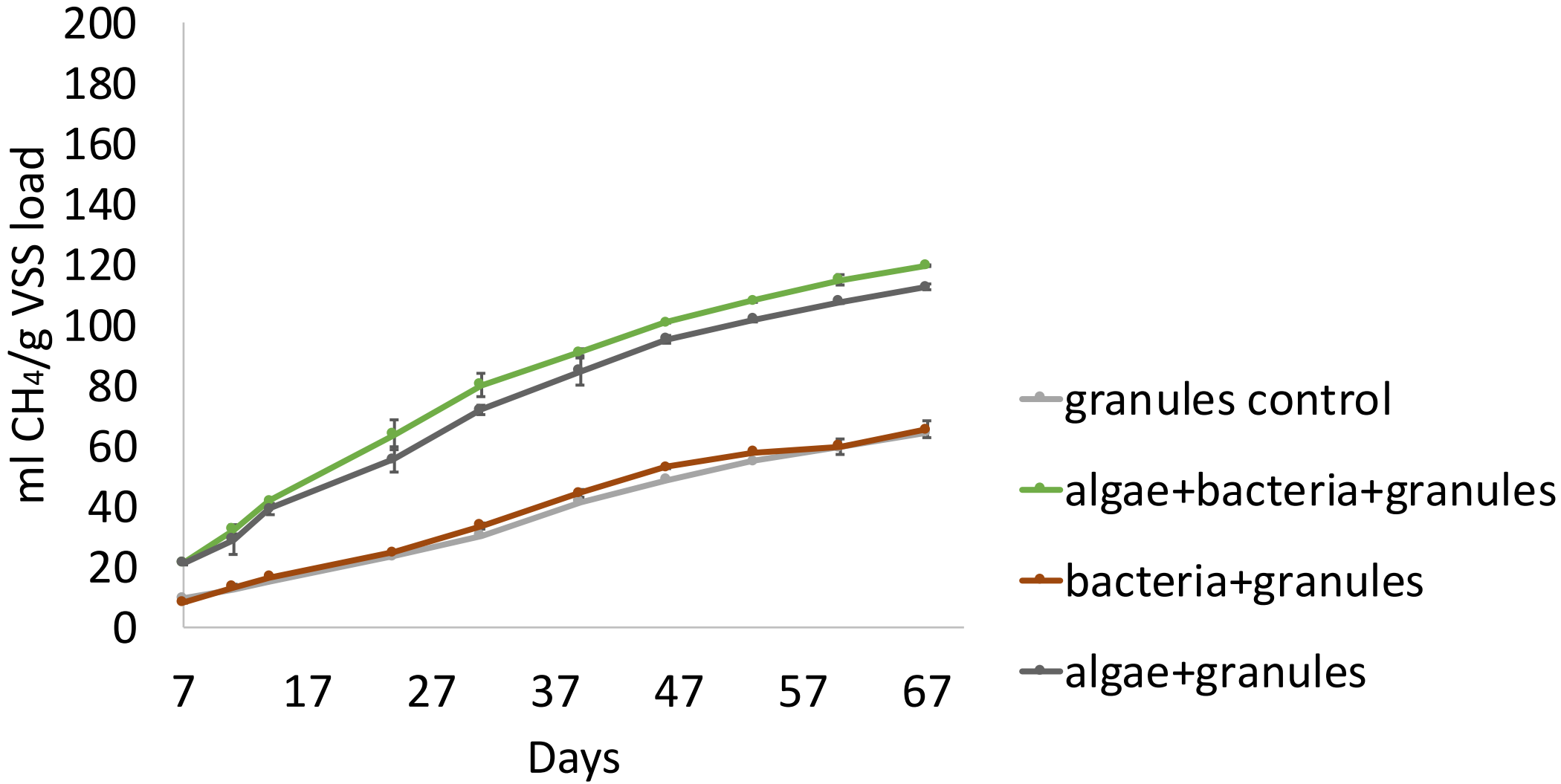

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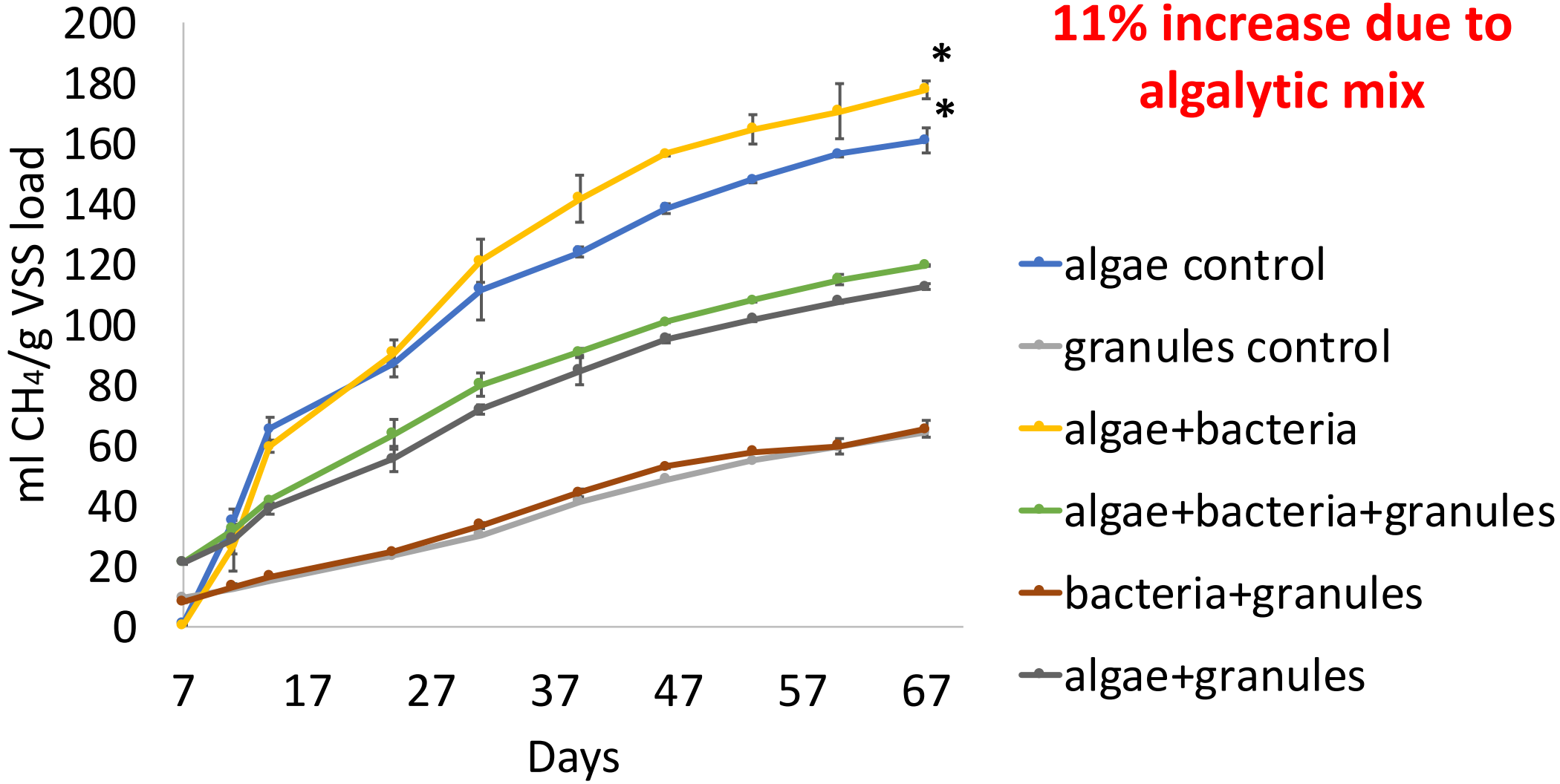
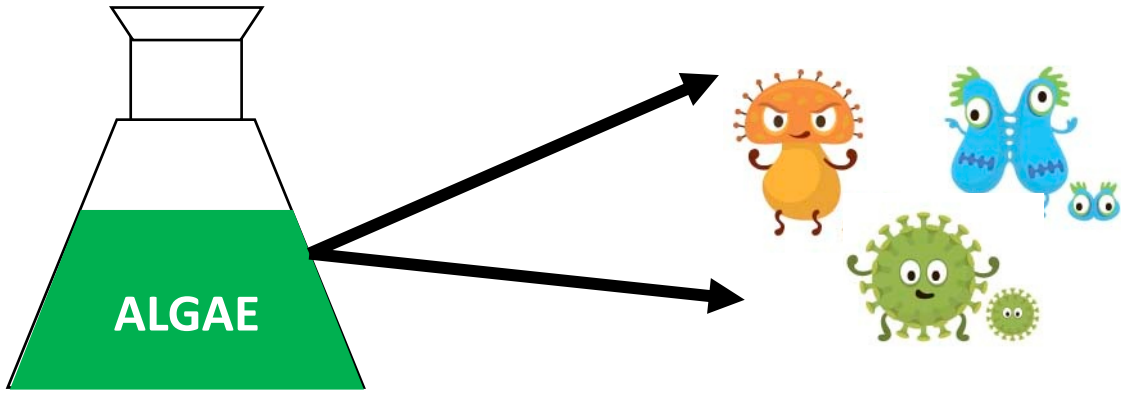


11% increase due to algalytic mix

Algae already figured things out…



A “clean” experiment on augmentation would be to use an axenic culture of algae

But large scale industries will never do it.
They deal with waste. Waste is contaminated.

How can we help those industries who need augmentation?

We can make a computer model to help predict the success of augmentation!

A computer model for augmenting anaerobic granules

iDynoMiCS individual-based Dynamics of Microbial Communities Simulator

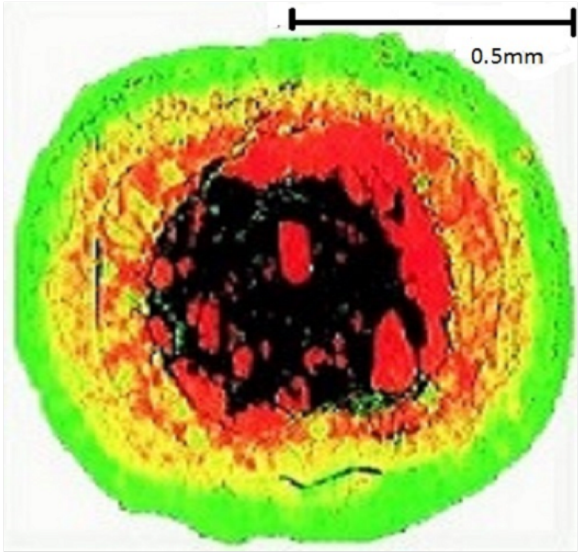
Model is based on:

- Kinetics of substrate consumption (Monod, Haldane, Simple inhibition)
- Bacterial attraction towards substrate

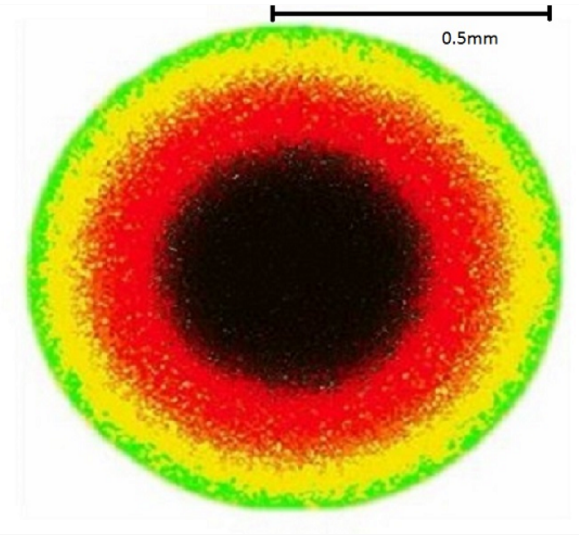
Input parameters:

- Growth characteristics (Ks, Ki, μ_{max}, μ_g)
- Diffusivity of substrates/products
- Strength of chemotactic attractance

Glucose -> **Acetate** -> Methane



Laboratory image (Sekiguchi, 1999)



Simulated image from our model (40 days)

*Doloman A., et al. (2017) Modeling *de novo* granulation of anaerobic sludge. *BMC Syst Biol*.

A computer model for augmenting anaerobic granules

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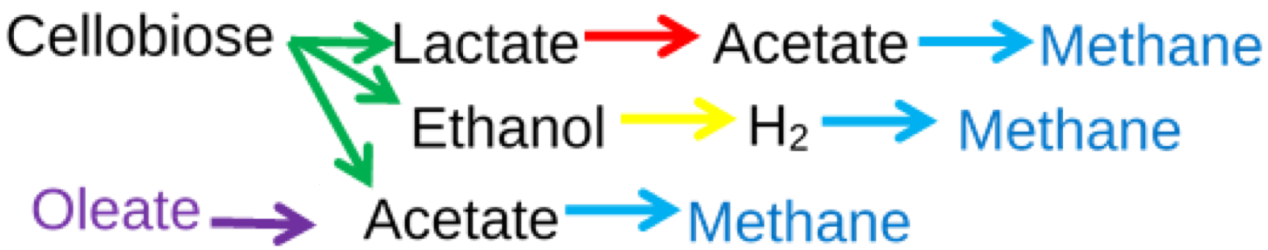


Day 0-17: cellobiose, 1.5 g/L

Day 17-60: cellobiose and oleate

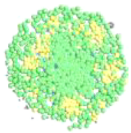
1) Cellobiose and oleate at 1.5 g/L
2) Cellobiose and oleate at 0.5 g/L
3) Oleate at 1.5 g/L

Cellobiose and oleate at 1.5 g/L, 40 days

OleateDegraders

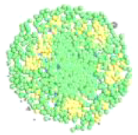
Cellobiose and oleate at 0.5 g/L, 60 days

OleateDegraders



Oleate at 0.5 g/L, 60 days

OleateDegraders



Conclusions and food for thoughts

- ✓ Algae digestion successfully augmented in batch conditions;
- ✓ Trial with axenic algal biomass is needed;
- ✓ When augmenting, remember to feed the existing bacteria, **BUT**, do not overfeed them!

Acknowledgements:

- SWBEC group @ BE (Profs. Ronald Sims and Charles Miller)
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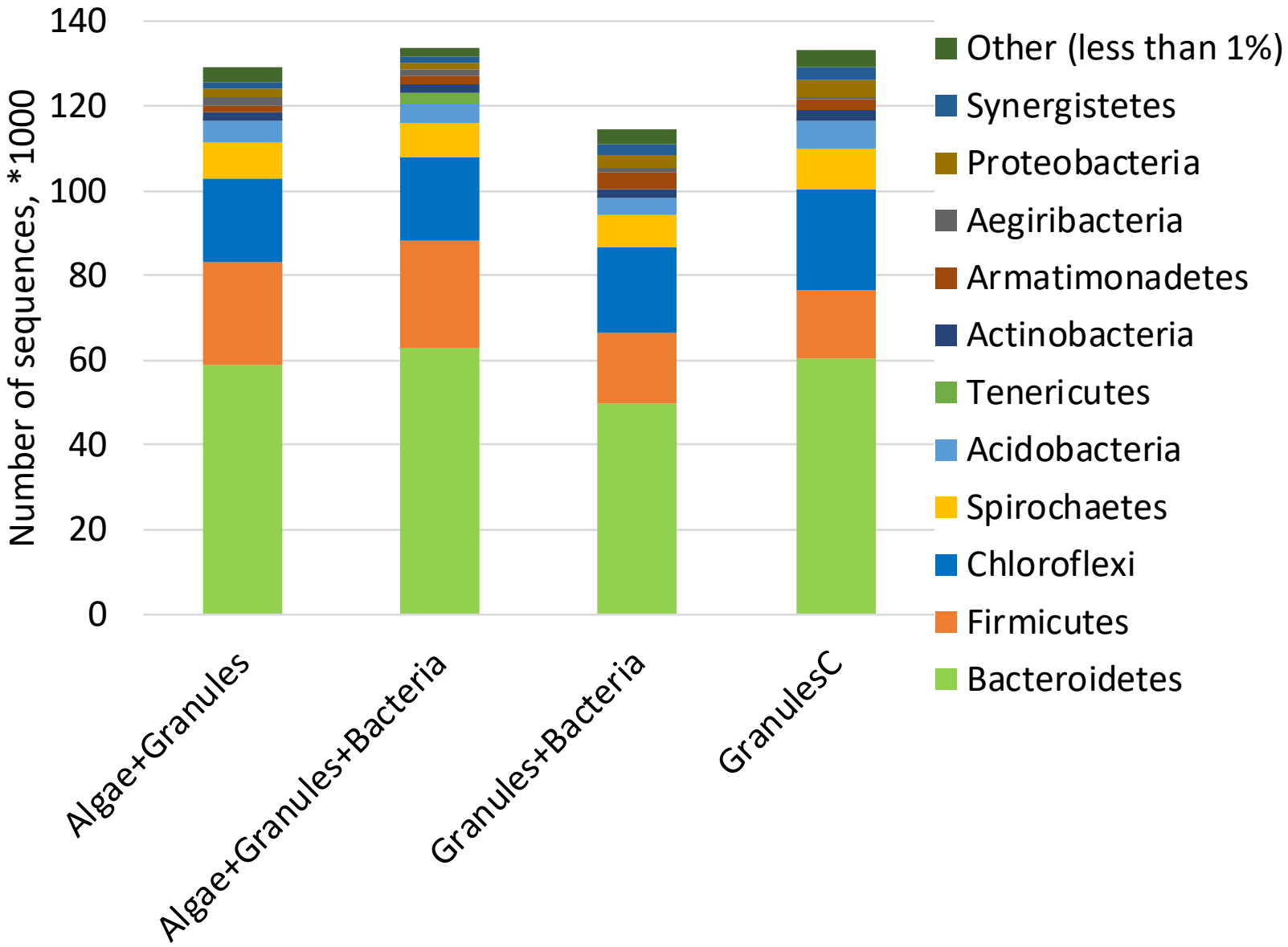
Results: what's up with the microorganisms?



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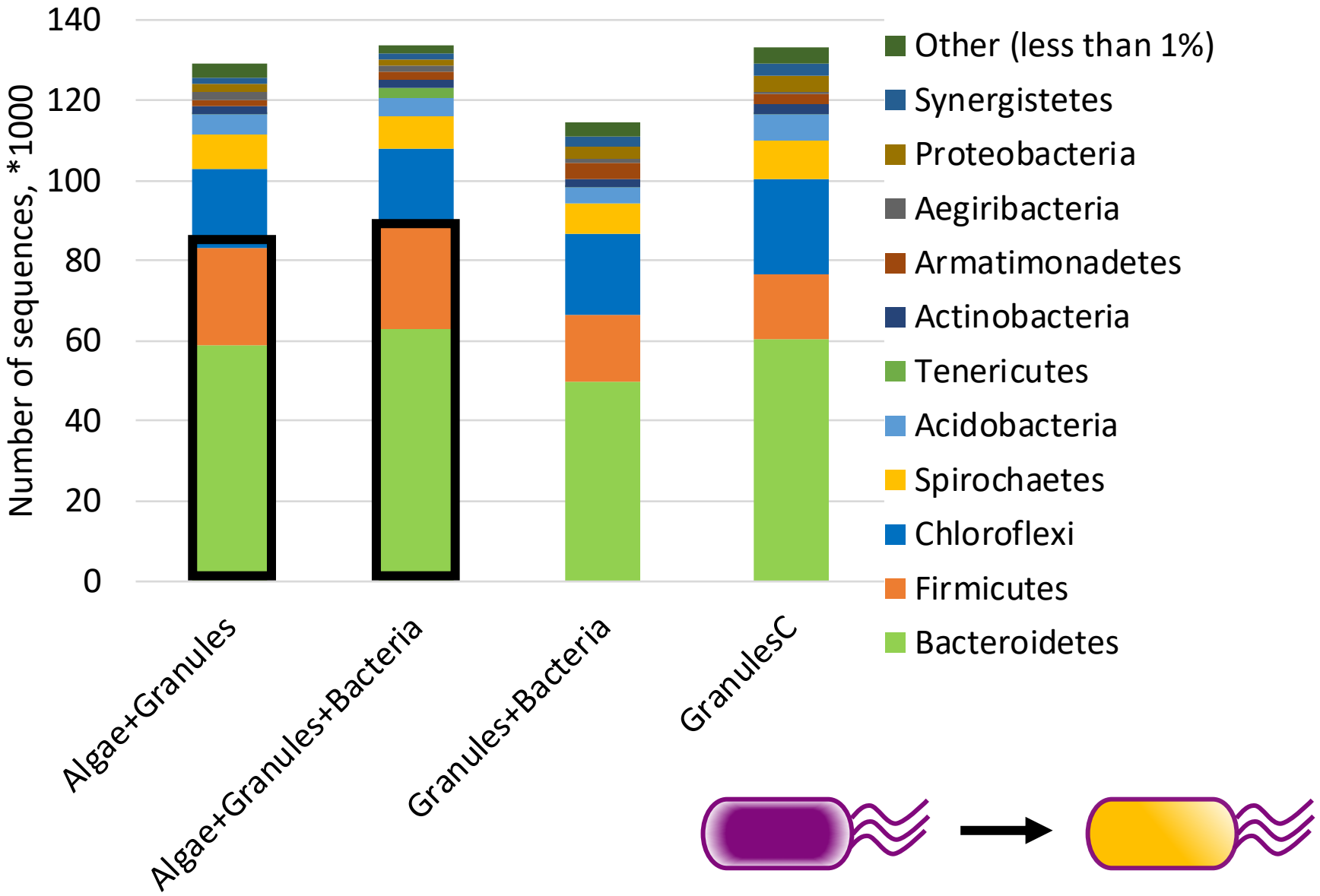

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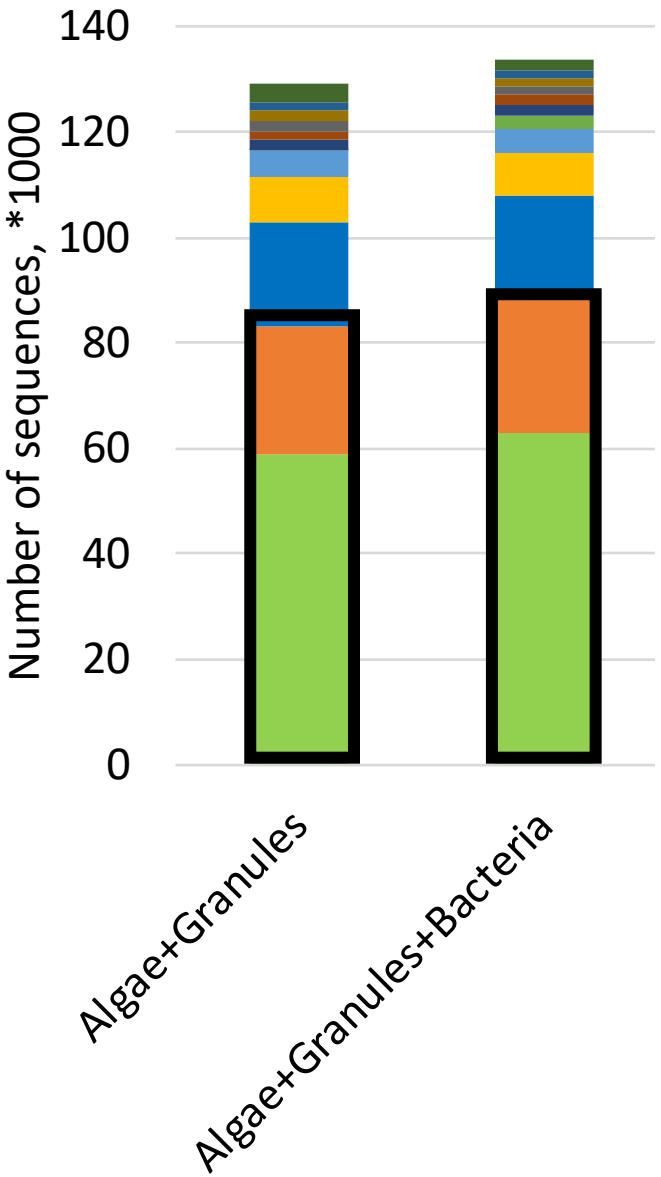

Augmented VS **Non-augmented**

- Increased number of polysaccharide and protein digesters (**Bacteroidetes**)

  More primary fermenters

- Number of Clostridia members shifted to those utilizing amino acids and sugars (**Firmicutes**)

  More secondary fermenters

Algae+Granules	Algae+Granules+Bacteria
Selenomonadales, Proteiniphilum (Firmicutes)	**Hydrogenispora, Lutispora** (Firmicutes)
Syntrophomonas, Syntrophorhabdus (Firmicutes)	Syntrophobacter (Firmicutes)
Aminobacterium (Firmicutes)	Veillonellaceae (Firmicutes)
Christensenellaceae (Firmicutes)	Peptococcaceae (Firmicutes)
Sedimentibacter (Firmicutes)	Gracilibacteraceae (Firmicutes)
Propionibacteriales (Actinobacteria)	Cellulosimicrobium (Actinobacteria)
Phycisphaerae (Planctomycetes)	
Geobacter (Proteobacteria)	
Desulfovibrio (Proteobacteria)	