Space Farming and Bioreactors: Growing Food and Recycling Waste for Sustainable Living in Space

BRYCE L. MEYER
St. Louis Space Frontier and NSS Space Ambassador

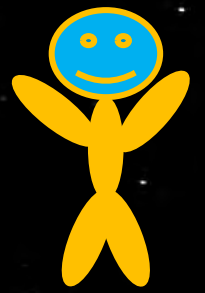
NSS ISDC 2022 Space Ambassadors Track 28 May 1500 EDT Regency C

NSS NATIONAL SPACE SOCIETY ISDC 2022 International Space Development Conference Arlington, VA May 27-29

ST. LOUIS SPACE FRONTIER

Outline

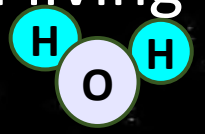
- Simplified Space Recycling and Chemistry of Life
- Closing the cycle ideally using space farms with bioreactors
- Presenting a simple cycle using bioreactors is a cool light up display
- Lessons Learned



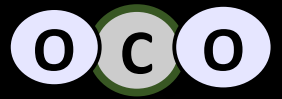
First Terms

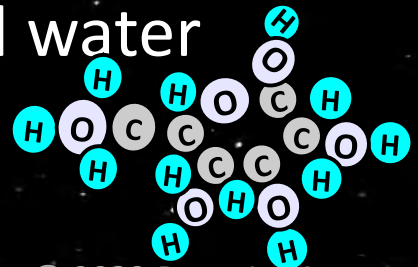
- **Mass:** The property of matter that gravity pulls on
- **Hydrogen:** The lightest element and the stuff that powers stars 

- **Oxygen:** The stuff in air we breathe 

- **Water:** the stuff we drink or is in foods and living things, made of two hydrogen atoms and an oxygen atom 

- **Carbon:** The stuff in pencils, charcoal, and diamonds, that is used in living things to make almost all their mass 

- **Carbon Dioxide:** The stuff you exhale, and that plants use. Made of a carbon atom and two oxygen atoms. 

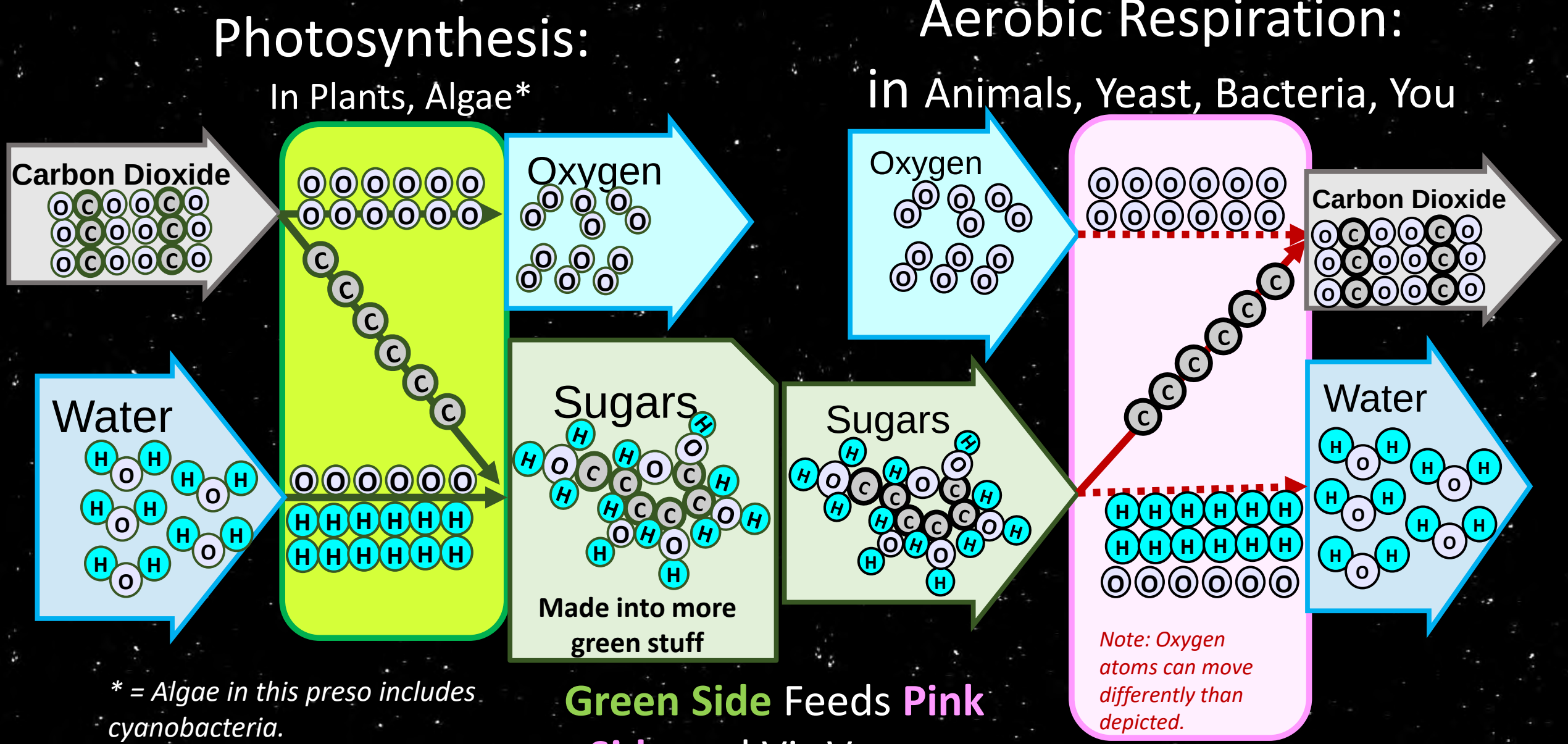
- **Sugars: Chemicals** Made by adding carbon dioxide and water together. The stuff that tastes sweet in candy! 

In Space…

- You must bring everything with you! There is no air, water, or food in space*
- It **costs** the value (**$$$**) of a nice new **pick-up truck** to:
  - Get a **bottle of soda and pizza** into **orbit**!
  - Get a **little can of soda** to the **moon**!
  - Get a **pack of gum** to Mars!
- So, we must recycle everything!

*=we could get carbon dioxide from Mars, and water and oxygen from rocks on the moon.

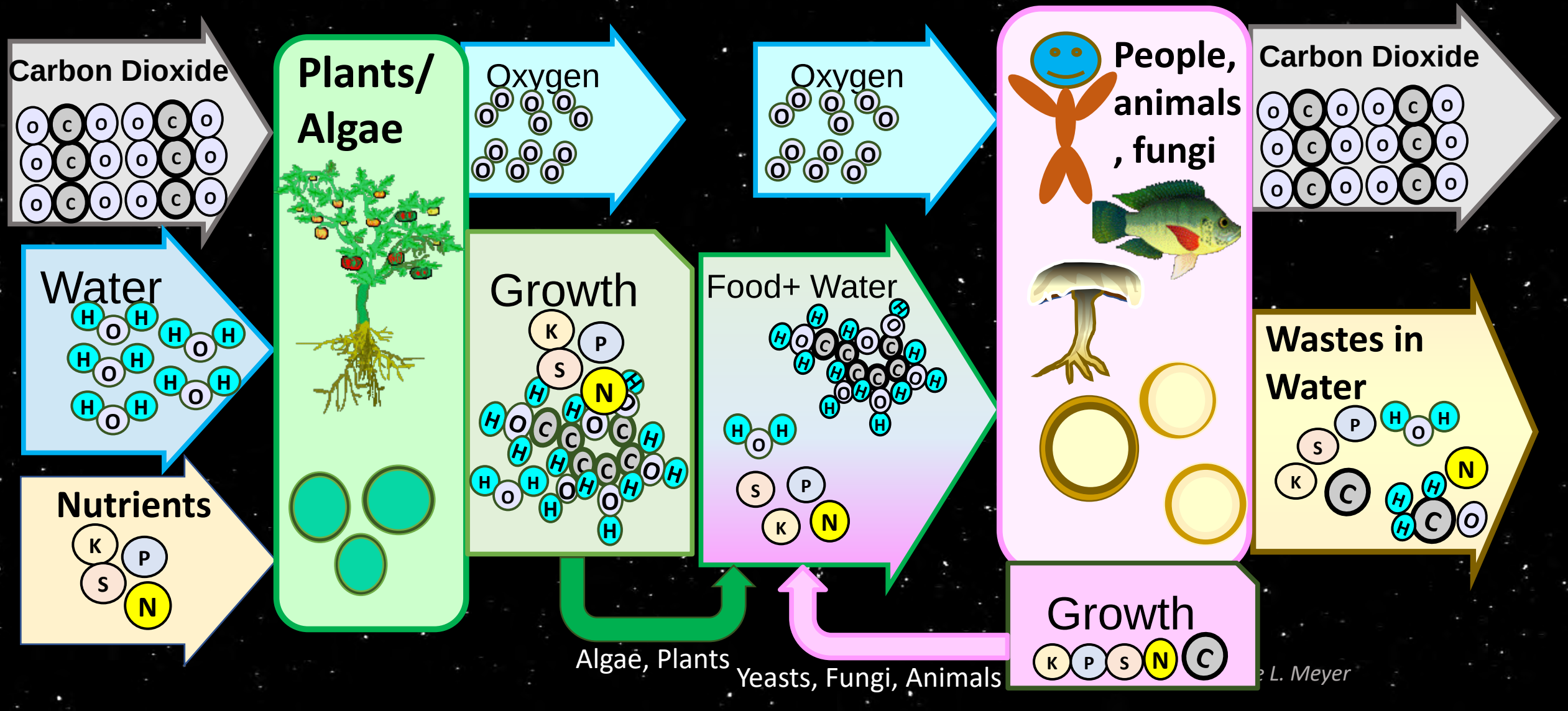
Aerobic and Photosynthetic Processes in Cells



* = Algae in this preso includes cyanobacteria.

Green Side Feeds **Pink Side** and Vis Versa…

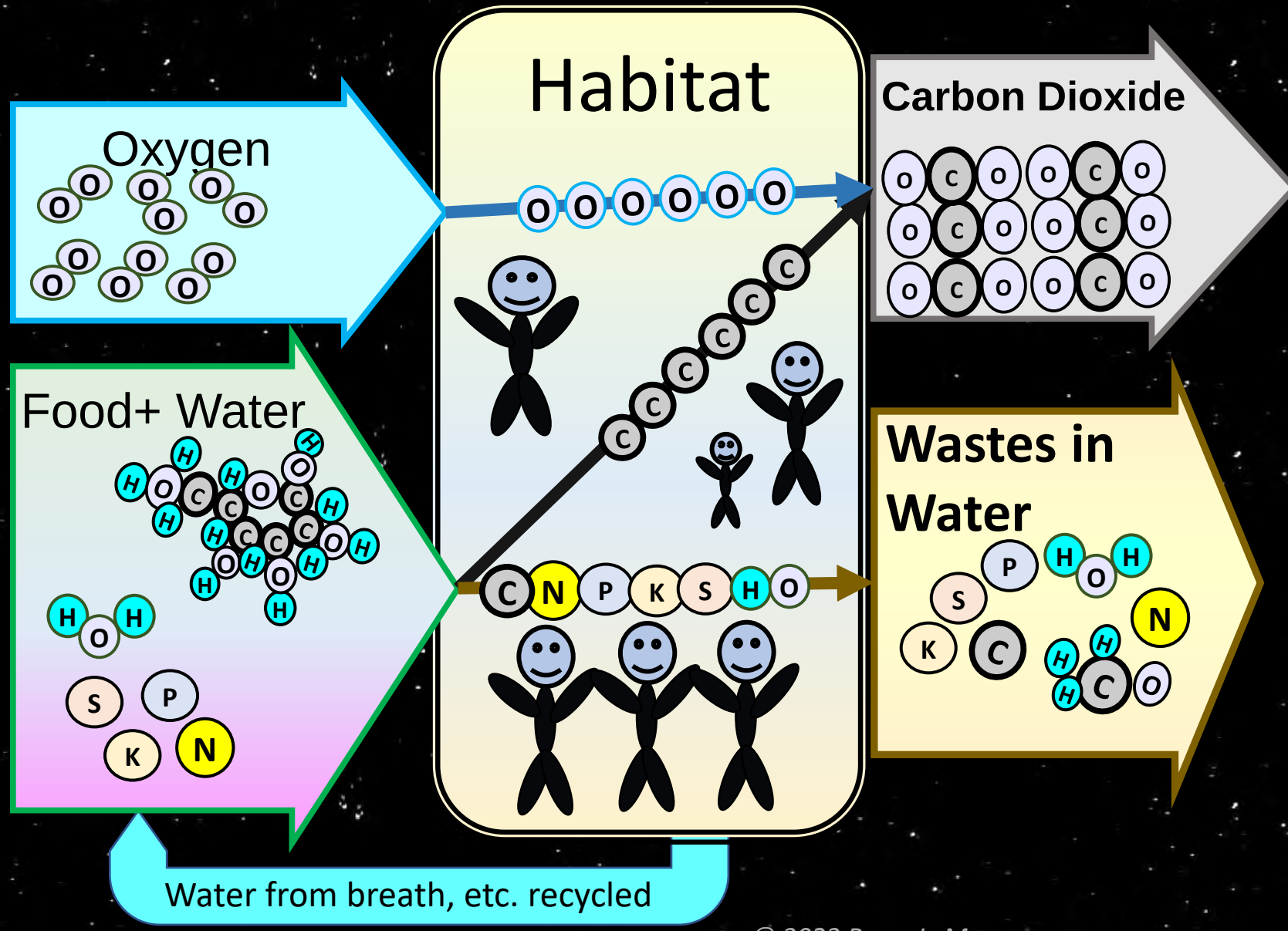
Photosynthesis and Aerobic Respiration in Organisms (plant, animals, etc.)



People Need…

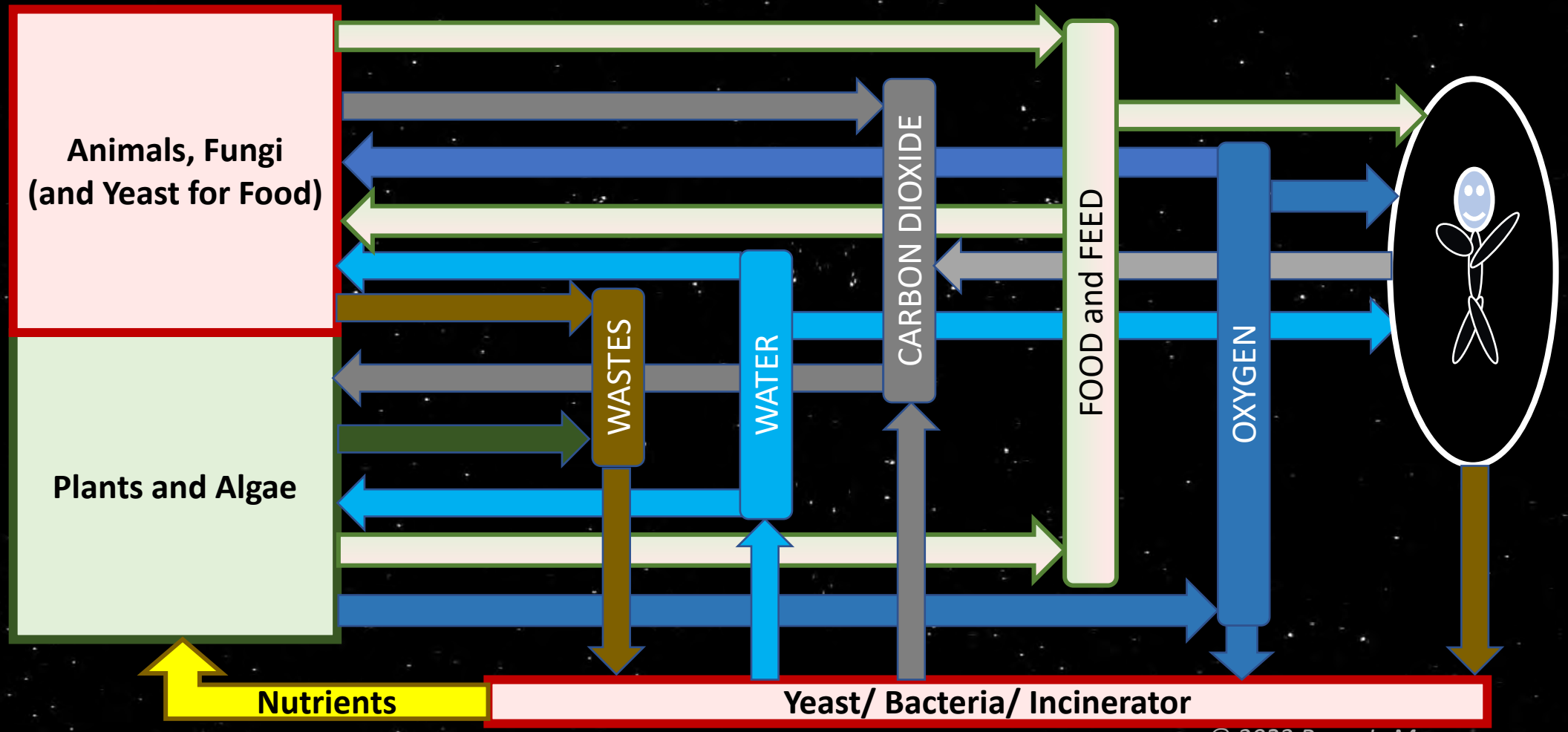
Roughly People need per day, per person:

- About 0.8 kg of oxygen per day
- About 4 liters of water (to drink and in food)
- About 1 kg food (half is water)

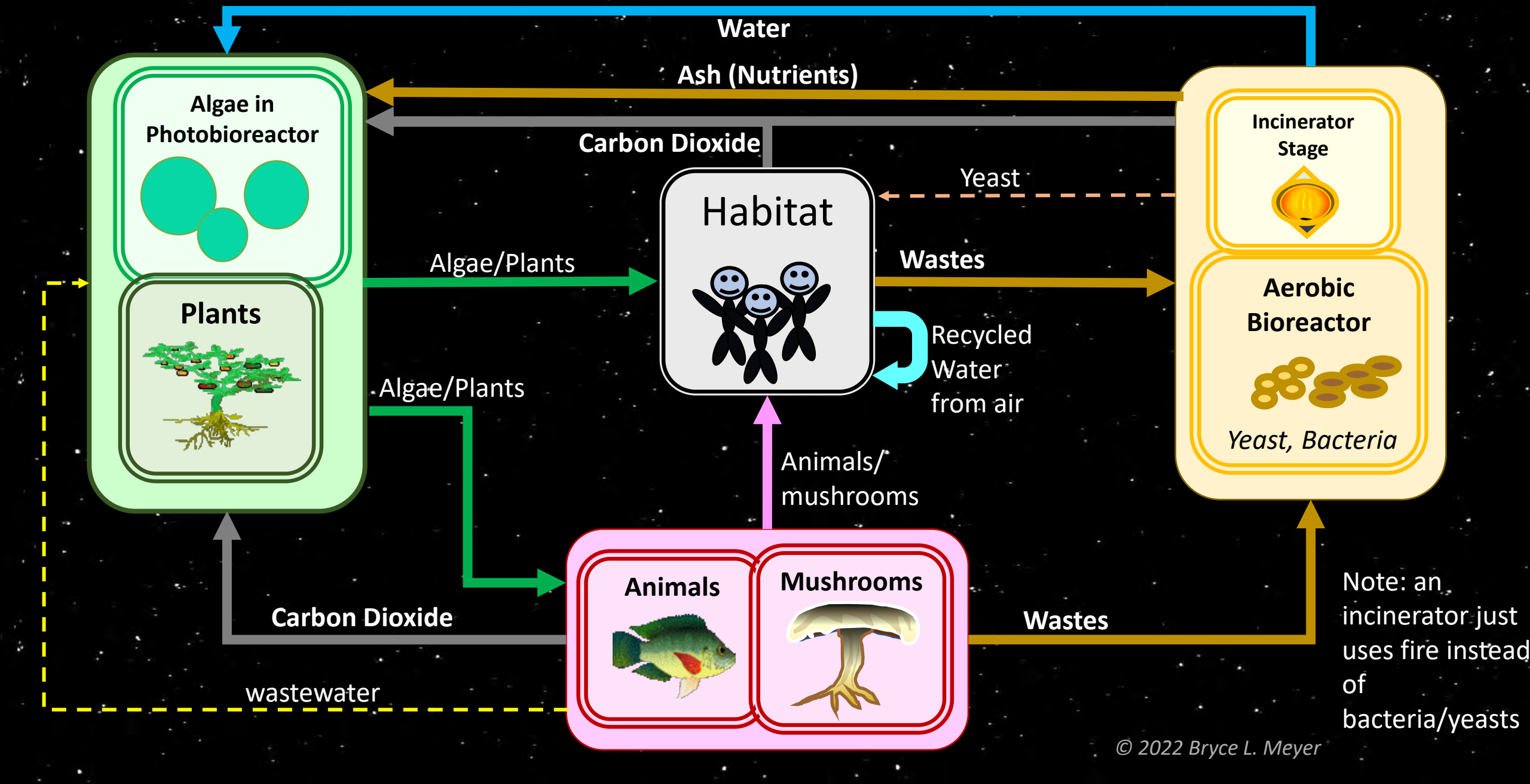


Space Farm Crops and Parts

- ‘Green Crops’: Plants and Photobioreactors(i.e. algae): Take in carbon dioxide, nutrients (from wastes), and water, and use light energy, to produce more plant/algae and release oxygen.
- Humans and ‘Pink Crops’: Animals, Fungi inc. Yeast, and Bacteria: Take in oxygen, water, and food, and release carbon dioxide, wastes, and water, with heat.

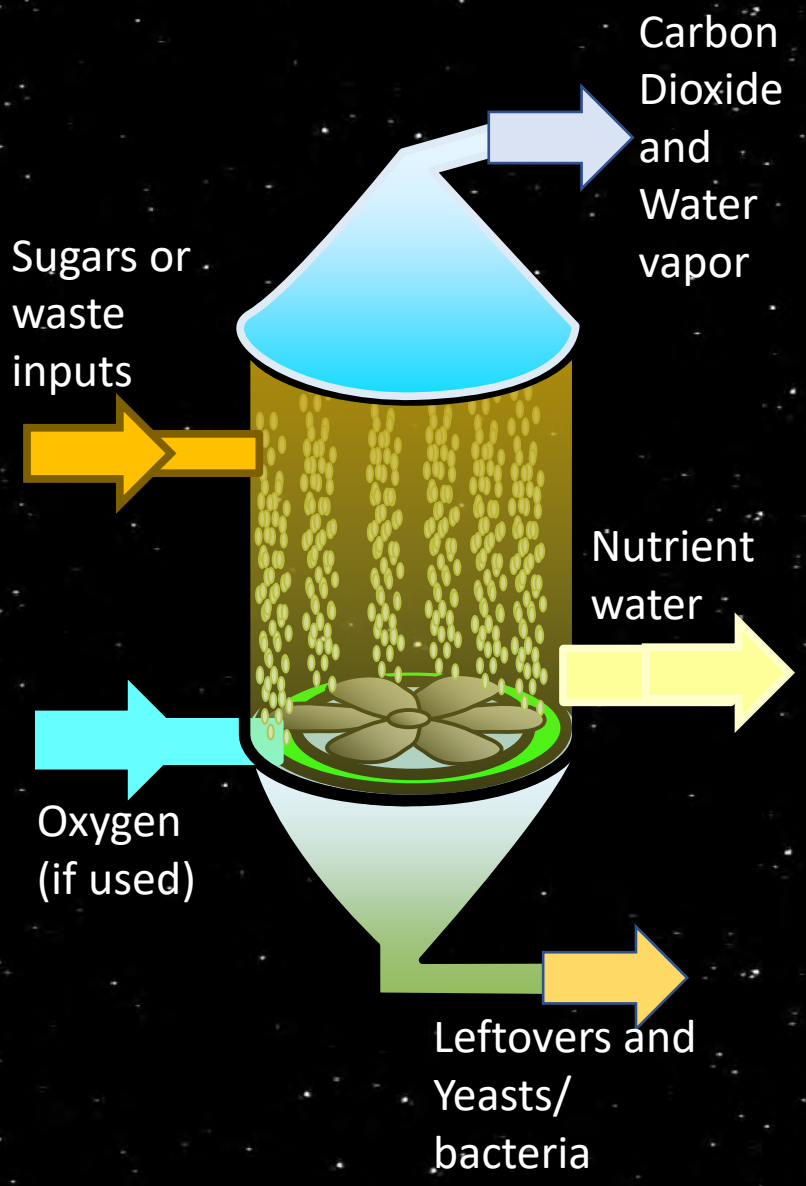


Closing the Cycle



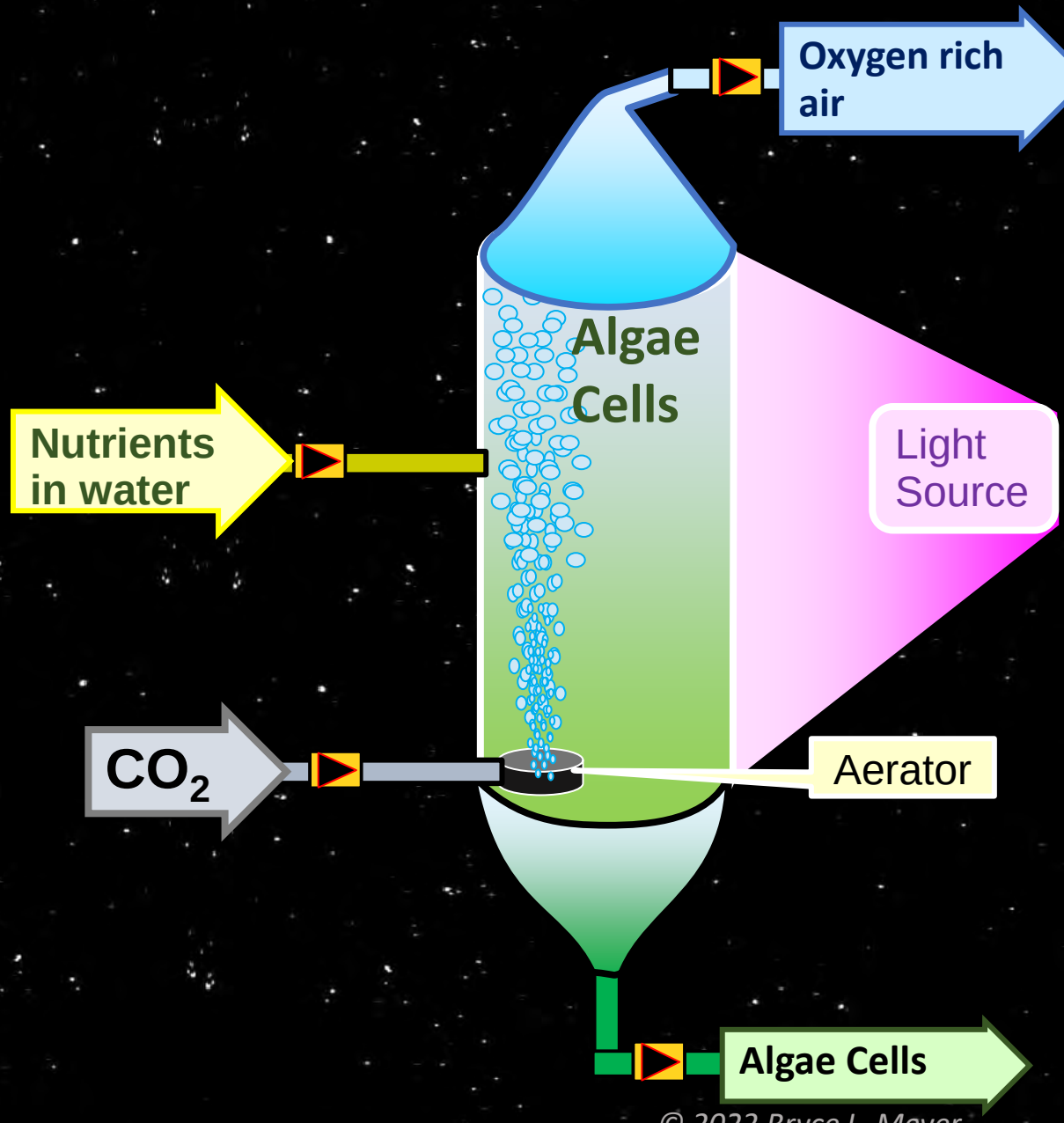
Bioreactors

- **Bioreactor: C**ombination of **machines** and **living things** to **covert chemicals**. Usually just a tank with valves (though not always).
- **Aerobic Bioreactor**: Uses yeast and/or bacteria to convert wastes/sugars ***and oxygen*** to carbon dioxide and water (and maybe more yeasts or nutrients)
  - Example: Your guts, cow stomach, cheese, soil
- **Anerobic Bioreactor**: Uses yeast and/or bacteria to convert wastes/sugars to carbon dioxide and water and alcohol (and maybe more yeasts or nutrients)
  - Example: Bread, Wine/Beer Vat



Photobioreactors

- **Photobioreactors**: Machines that use (green) living things like (plants or) algae and light to convert carbon dioxide and water (and some nutrients) to more plants or algae, and oxygen.
- Can have many shapes and designs.



How much green keeps me alive? (Super Rough)

Assume 0.8 kg O_2 **per day per person** (many very rough guesses follow):

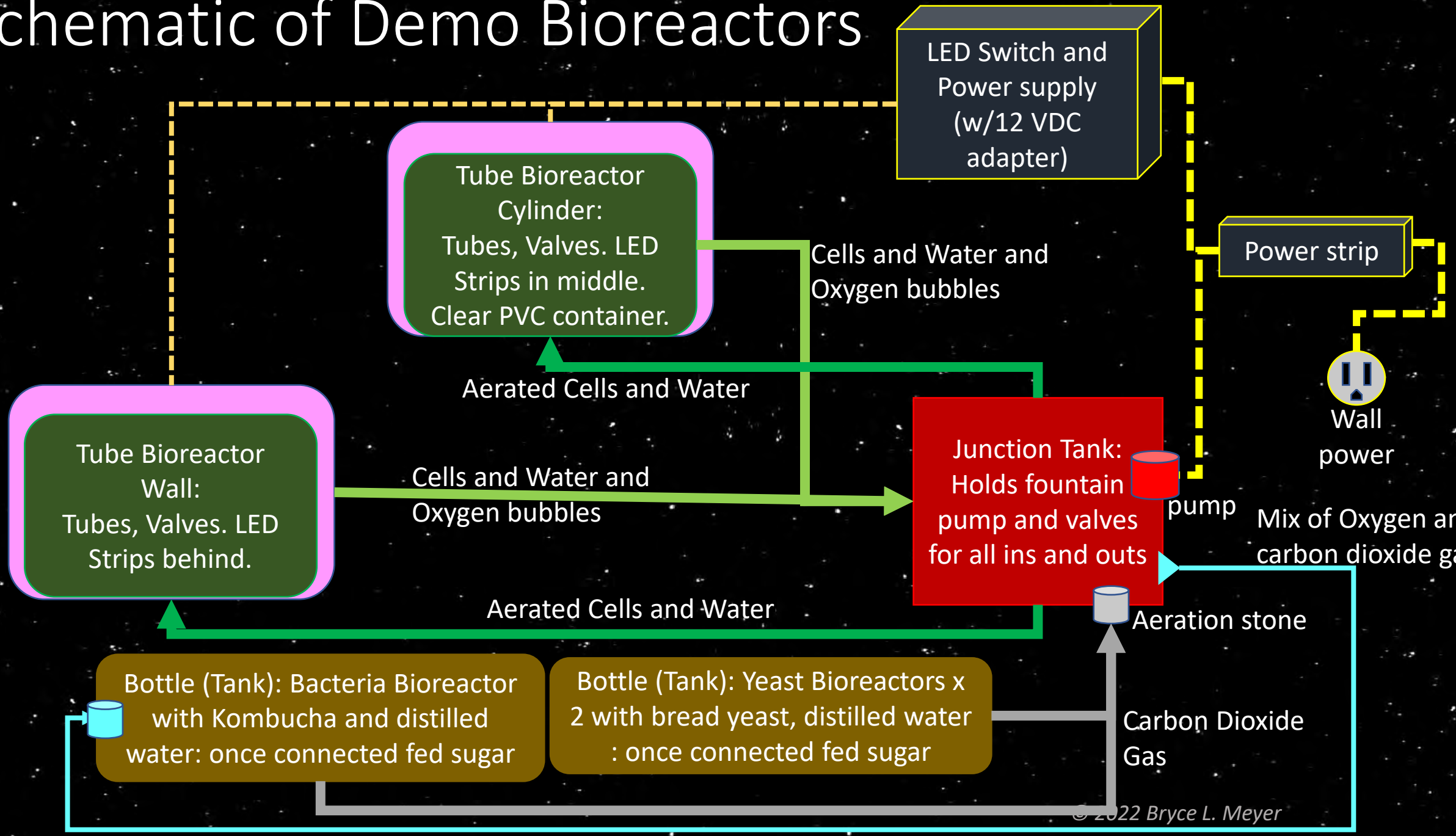
- 0.8 kg O_2 + 0.3 kg C from food → 1.1 kg CO_2
- Most Plants (Dry Mass) are around 40% Carbon.
- So, every day plants must add 0.3/40% = 0.75 kg of dry mass (roughly)
- How much plant/algae depends on the type, and how much water is in its living mass

Crop	Green Algae	Cyanobacteria	Lettuce	Tomato	Rice
% Water in wet mass (whole plant)	90% (100% edible)	90% (100% edible)	95% (99% edible)	85% (45% edible)	33% (50% edible)
Wet mass growth to get oxygen to breathe per day	7.5 kg	7.5 kg	15 kg	5 kg	1.2 kg
Kcal in growth/day in wet mass to get oxygen (need)	2,873 kcal	1,950 kcal	2,850 kcal	405 kcal	2,142 kcal* (at harvest)
Growth rate per day per kg live crop	8 kg/day	270 g/day	22 g/day	13 g/day	10 g/day
Starting wet mass (min) of living crop	2 kg	28 kg	682 kg	386 kg	121 kg

What can I demonstrate cheaply?

- **Yeast Bioreactors** (in this case anerobic): Tank (Plastic Bottle, Bread) : produces bubbles of carbon dioxide, can be fed sugars.
- **Bacteria Bioreactor** (in this case mostly anerobic): Tank (Plastic Bottle) : produces bubbles of carbon dioxide, can be fed sugars. Kombucha starter.
- **Photobioreactors**: Tube and Tank (Plastic Bottle): Easy to make with bottles, LED strips, and fish tank tube. Green algae from my home tanks etc.
- Linking: Tubes of fish tank hose, valves from fish tanks
- **Junction Tank** (plastic container from soup delivery) with very small **fountain pump** to circulate liquids and **aeration stone** for carbon dioxide intake.
- Note: used to also do hydroponics but that took too much prep and plants died quickly…

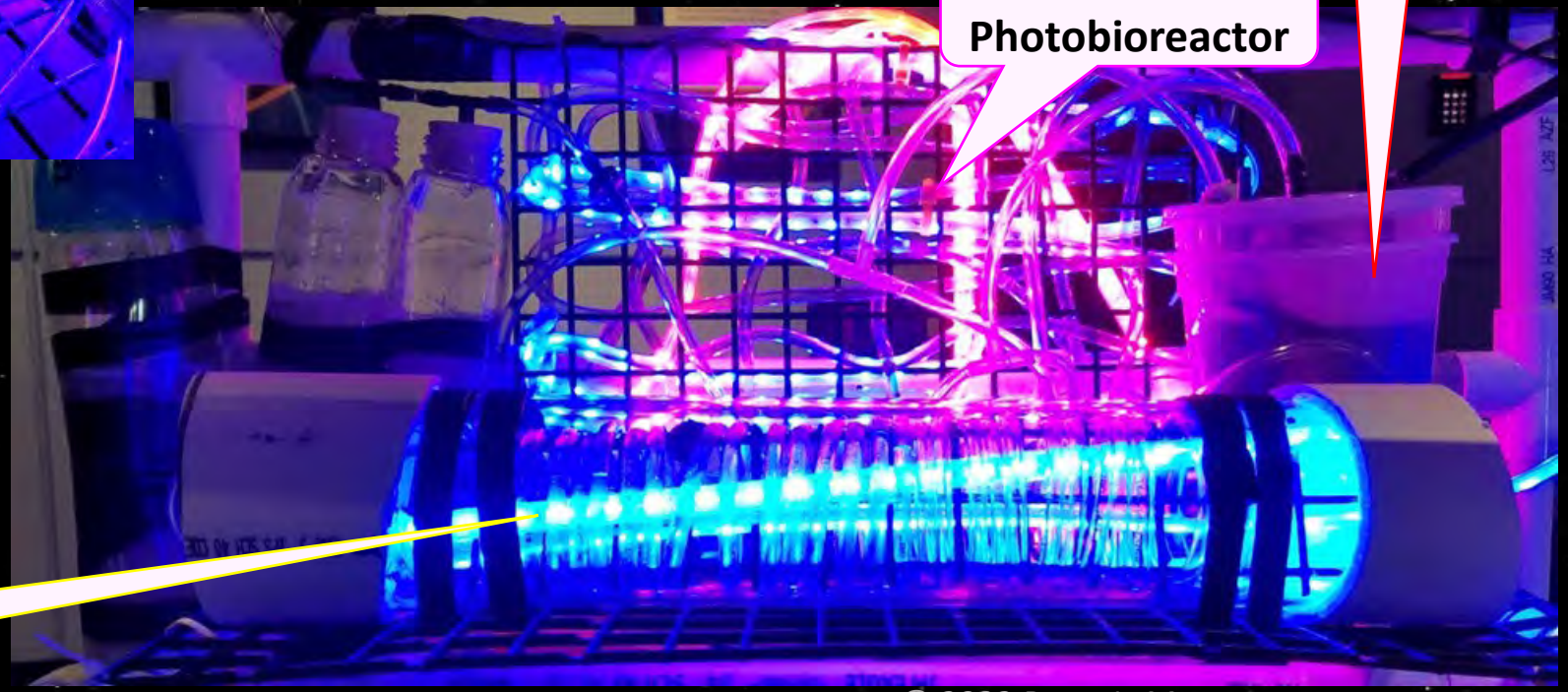
Schematic of Demo Bioreactors



Demo Bioreactors in use at
St. Louis Science Center
SciFest: Engineer Expo
26 Feb 2022

Junction Tank w/Pump

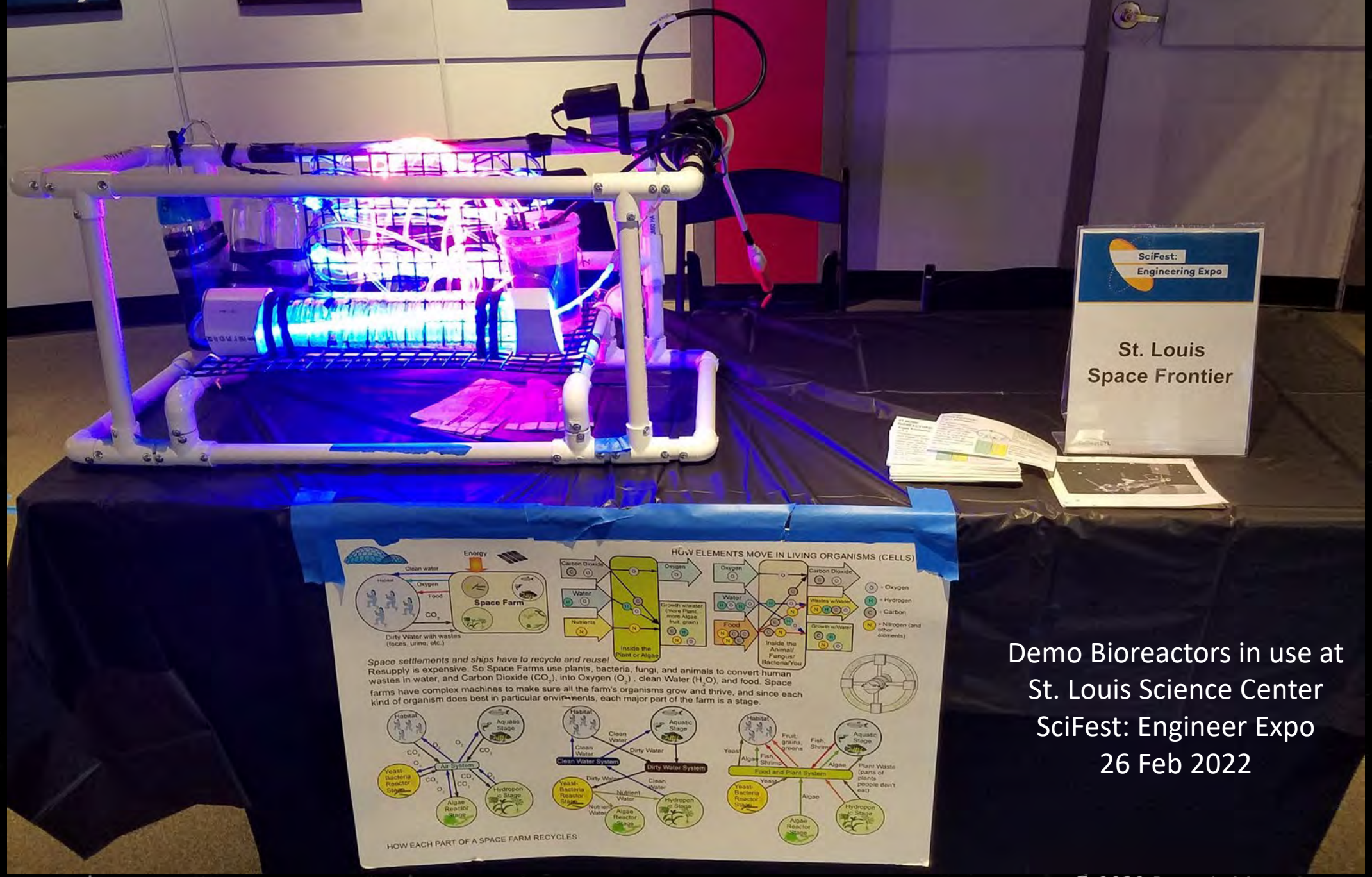
Wall Tube Photobioreactor



Bacteria Bioreactor

Yeast Bioreactors

Cylinder Tube Photobioreactor



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Lessons Learned

- Need to have a plan for how to present to many age groups!
  - Simple with hand motions for Pre-K to 3rd grade: show bubbles, blink lights
  - A bit more complex for 3rd-8th grade: inject some chemistry
  - More complex for HS, College, Adults (or extra inquisitive kids)…point to diagrams, have handouts
- The lights get this question set:
  - What is that?
  - Why do we want to go into space?
  - How can I do work with space?
    - What jobs or careers can do work with, and in space? **JUST ABOUT ANYTHING**…work into conversation!
  - What experiments can I do at home?

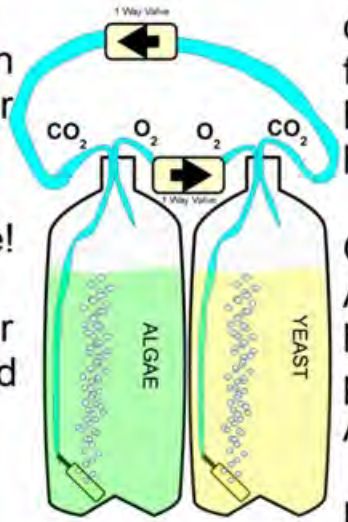
Point them to NSS and Chapter sites!

Handouts….

AT HOME BIOREACTORS!

Algae Bioreactor:
(a.k.a. Photobioreactor)
Add Algae + Solution Concentrate to 2 liter bottle with distilled water to ~3/4 full.
Put in a well lit place!
Optional: Add an Aquarium Aerator (or yeast bioreactor) and Air Stone

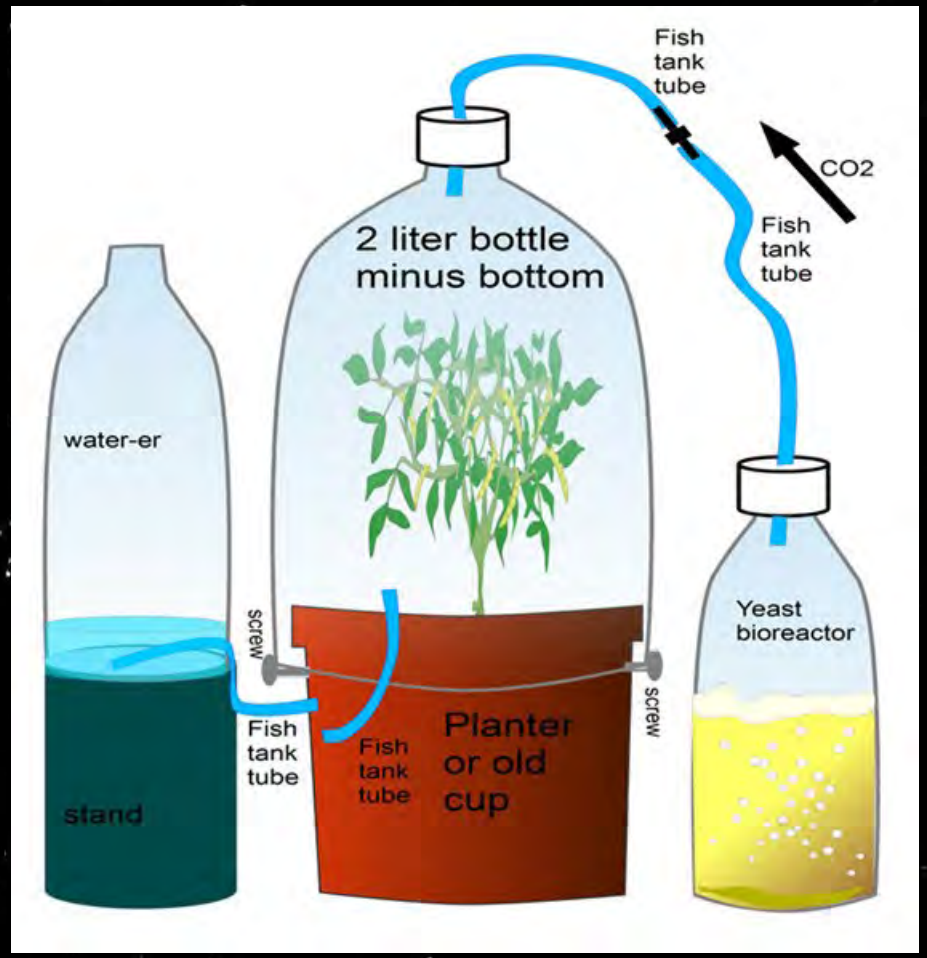
Put on a loose lid.



Yeast Bioreactor:
Add 1 tbsp Dry Yeast + 5 tbsp (or more) Sugar to 2 liter bottle with distilled water to ~3/4 full.
Make a paper cover to hid reactor from light!

Optional: Add an Aquarium Aerator (or hose from photobioreactor) and Air Stone

Put on a loose lid.



HAVE SOME AD ASTRA Magazines and Postcards with Websites!!!!

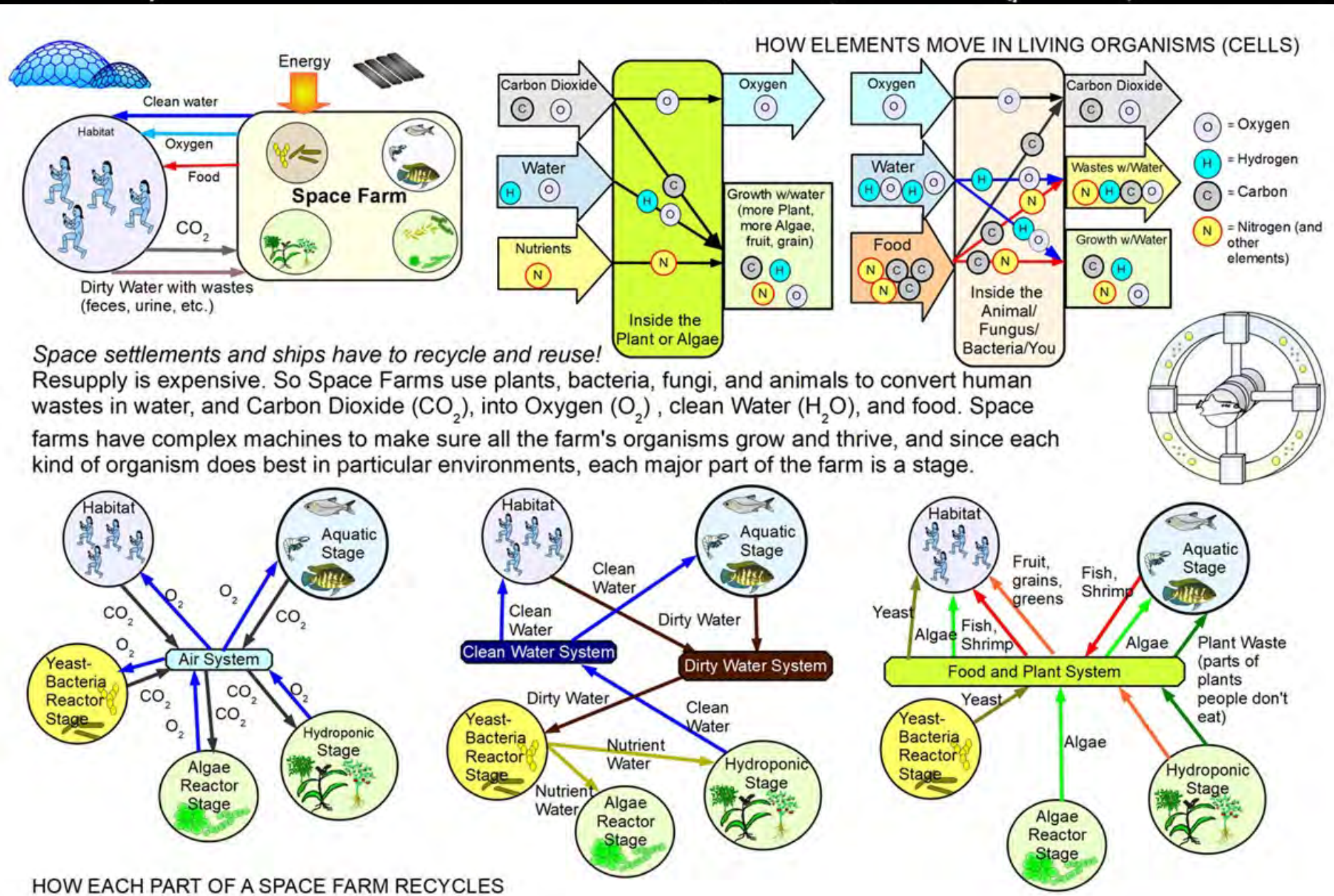


Diagram on Table

Conclusion

LOOK FOR MY SPACE FARM TEXTBOOK THIS FALL!!!

- Aerobic Biology is the reverse of Photosynthesis (loosely) so crops and algae can be part of closing the mass flow loop
- Bioreactors are one part of the space settlement recycling puzzle.
- Bioreactors are not exotic per se, but can be!
- Incinerators might be used in lieu of bioreactors
- Make cool light up displays to get people to ask questions about space settlement!
  - If they ask, you can tell them why space is a good thing and why they might want to do things with and in space!

BACKUP

Why do I do space? Trillions of Happy Smiling Babies!

Schedule

- Space Ambassadors Track Regency C 3:00-3:30 pm
- Space Farming and Bio Reactors: Growing Food and Recycling Waste for Sustainable Living in Space. Bryce Meyer (NSS Space Ambassador)Bryce Meyer Space Farming and Bio Reactors "Growing Food and Recycling Waste for Sustainable Living in Space. Presentation & Photos based on St. Louis Science Center Demonstration of Bio Reator Demonstrator.