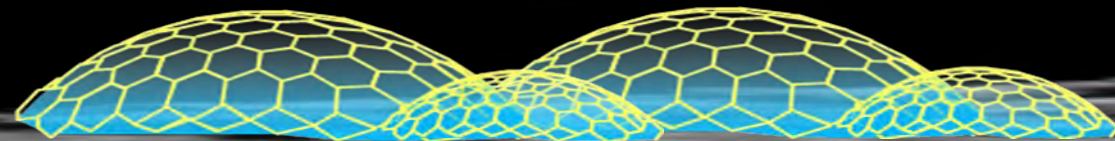


# The Basics of Farming in Space



Bryce L. Meyer  
NSS Space Ambassador  
<http://www.spacefarms.info>

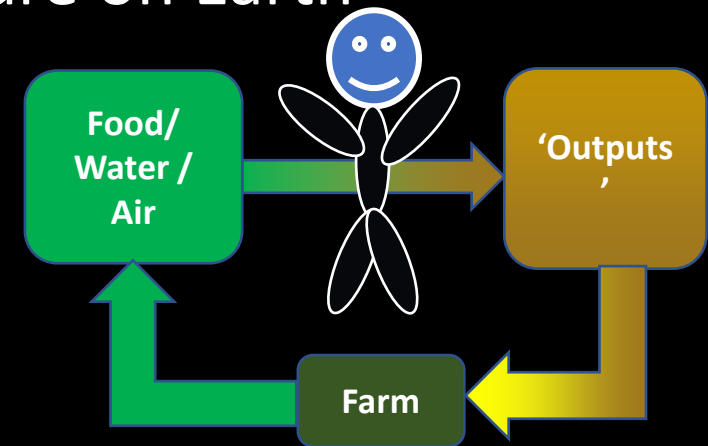


# Overview: Key Questions

- What is a Space Farm? Why would we need one? Is it like the farms here?
- How does my Space Farm change as I go from having a Space Outpost to having a permanent space settlement?
- What machines will I need? Do we have them now?
- How big is a space farm?
- What does a menu look like?

# What is a Space Farm? Why do I need one?

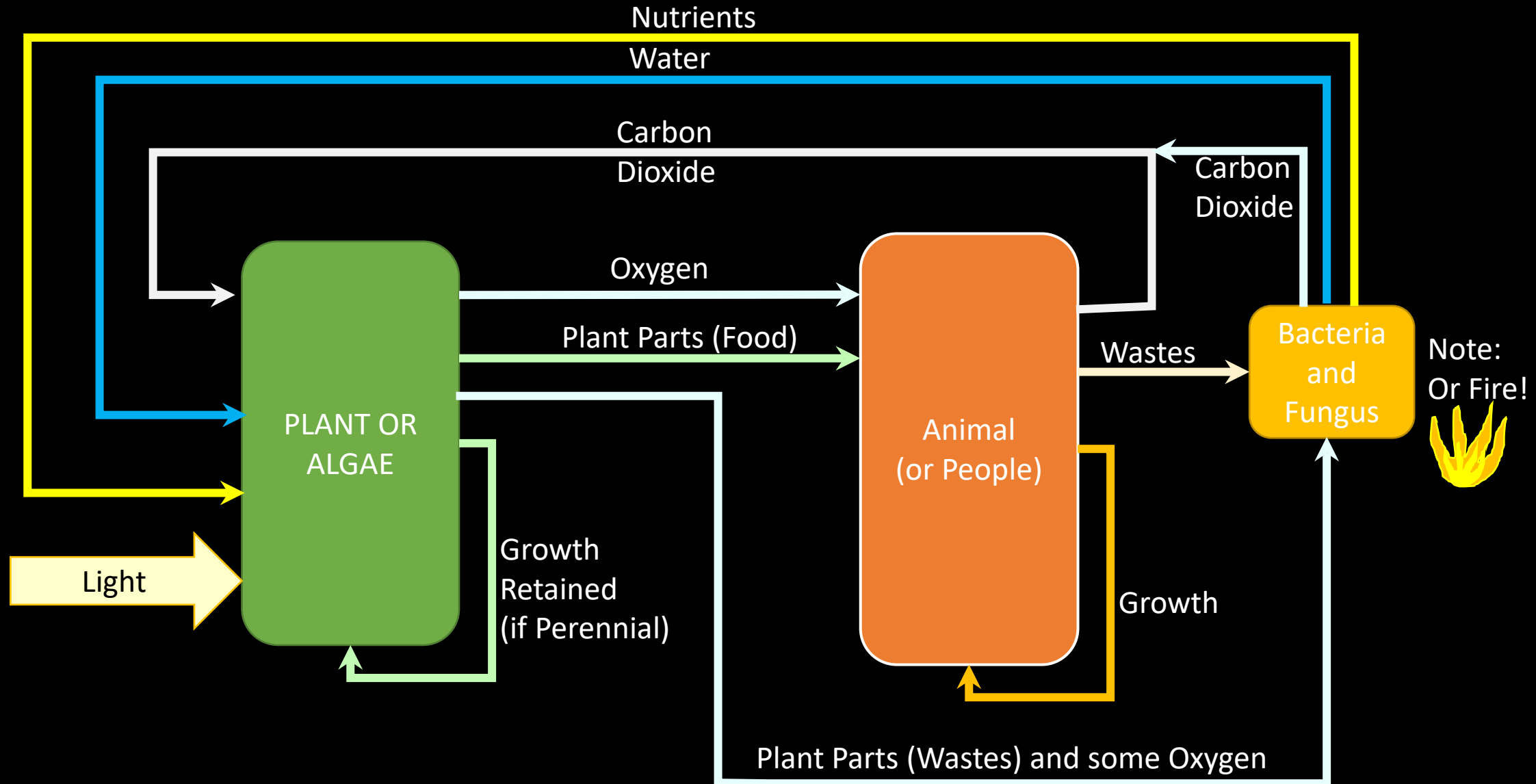
- Space Farm: the way food is grown by recycling air, wastes, and water.
- Space Farms use a combination of living things and machines to as efficiently as possible convert what comes out (of us) into the food, oxygen, and water we need.
- Why not just live off food sent from other places? In short, you could but then you are always paying to ship food in, and if the space settlement is far away you may not get food, even preserved food, quickly
- Why waste the wastes? A space farm works just like nature on Earth to recycle mass using energy.



# Wastes and Earth Farms?

- On Earth, plants (or algae) take in energy from the sun, and carbon dioxide from the air, and water and nutrients from the ground.
- We, or other animals, eat the plants, and the animals release carbon dioxide and water in breath, and water and materials from urine and feces
- Bacteria break down the wastes to release more carbon dioxide, water, and nutrient, which plants can then use.
- An Earth farm does something similar using the same mechanisms...

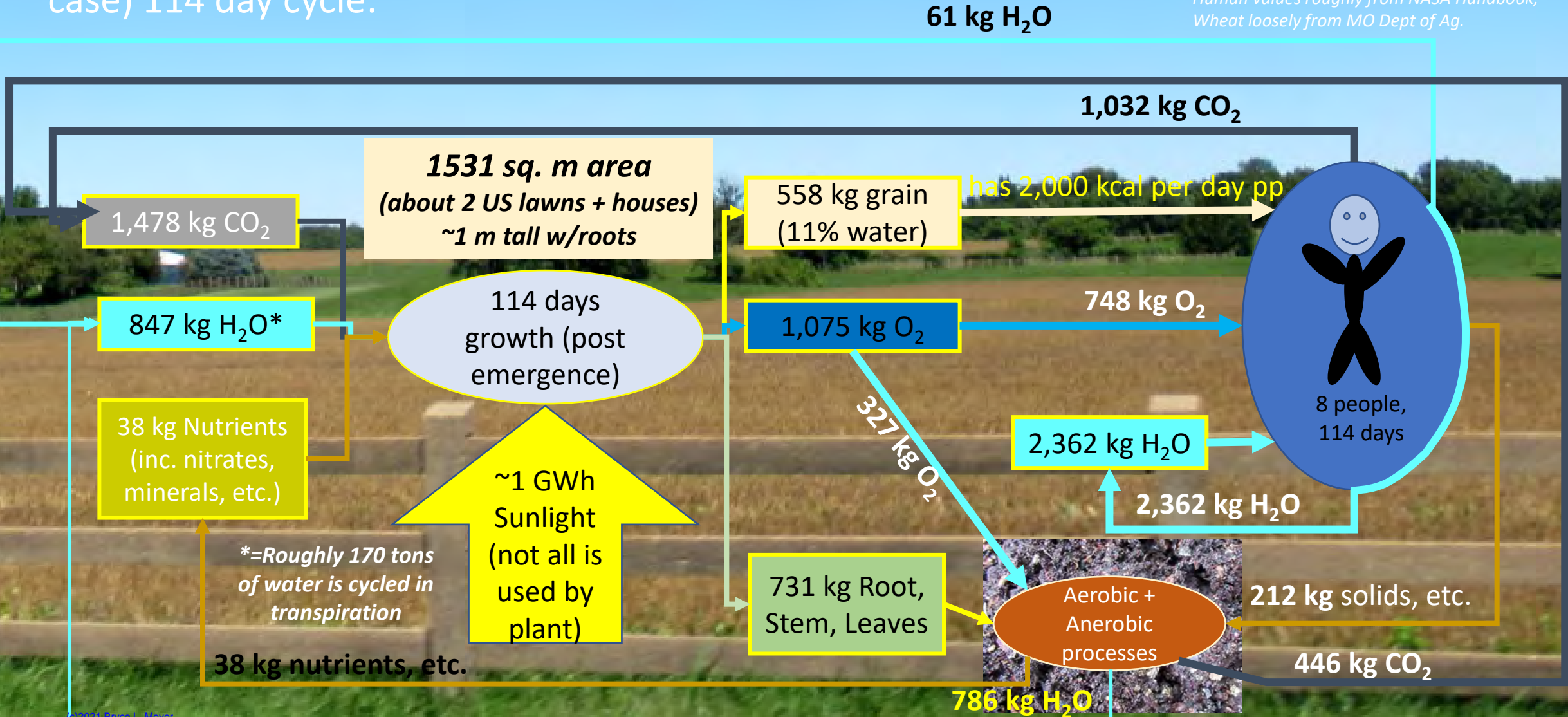
# A bit of simplified chemistry...



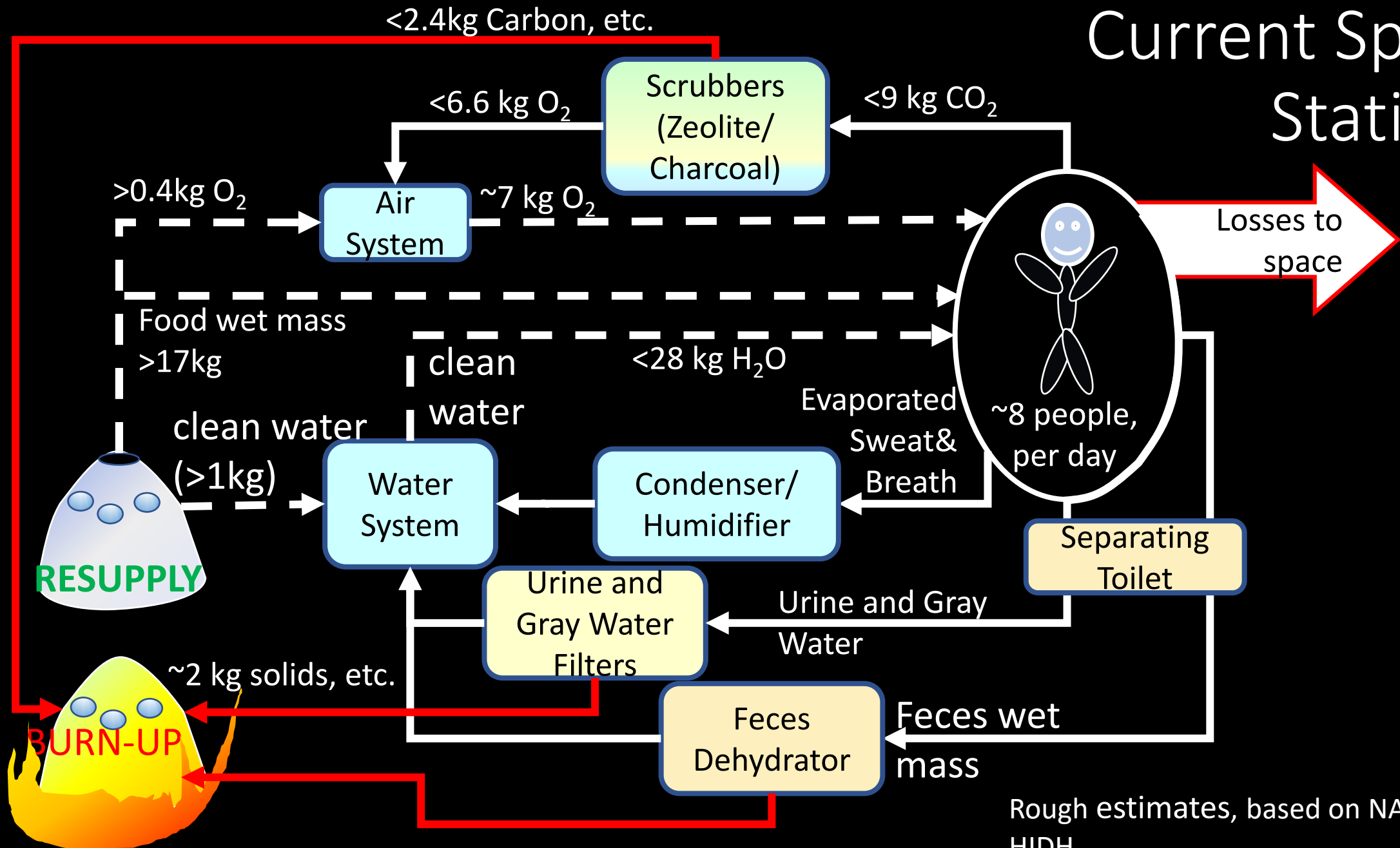
# Food for 8: Earth Analogy (A bit technical...)

- On Earth, Farms are soil based and take in things we take for granted:
  - Assume all 8 settlers just eat wheat (“man cannot live on bread alone...” literally in this case) 114 day cycle:

*Human values roughly from NASA Handbook, Wheat loosely from MO Dept of Ag.*



# Current Space Stations



Rough estimates, based on NASA  
HIDH

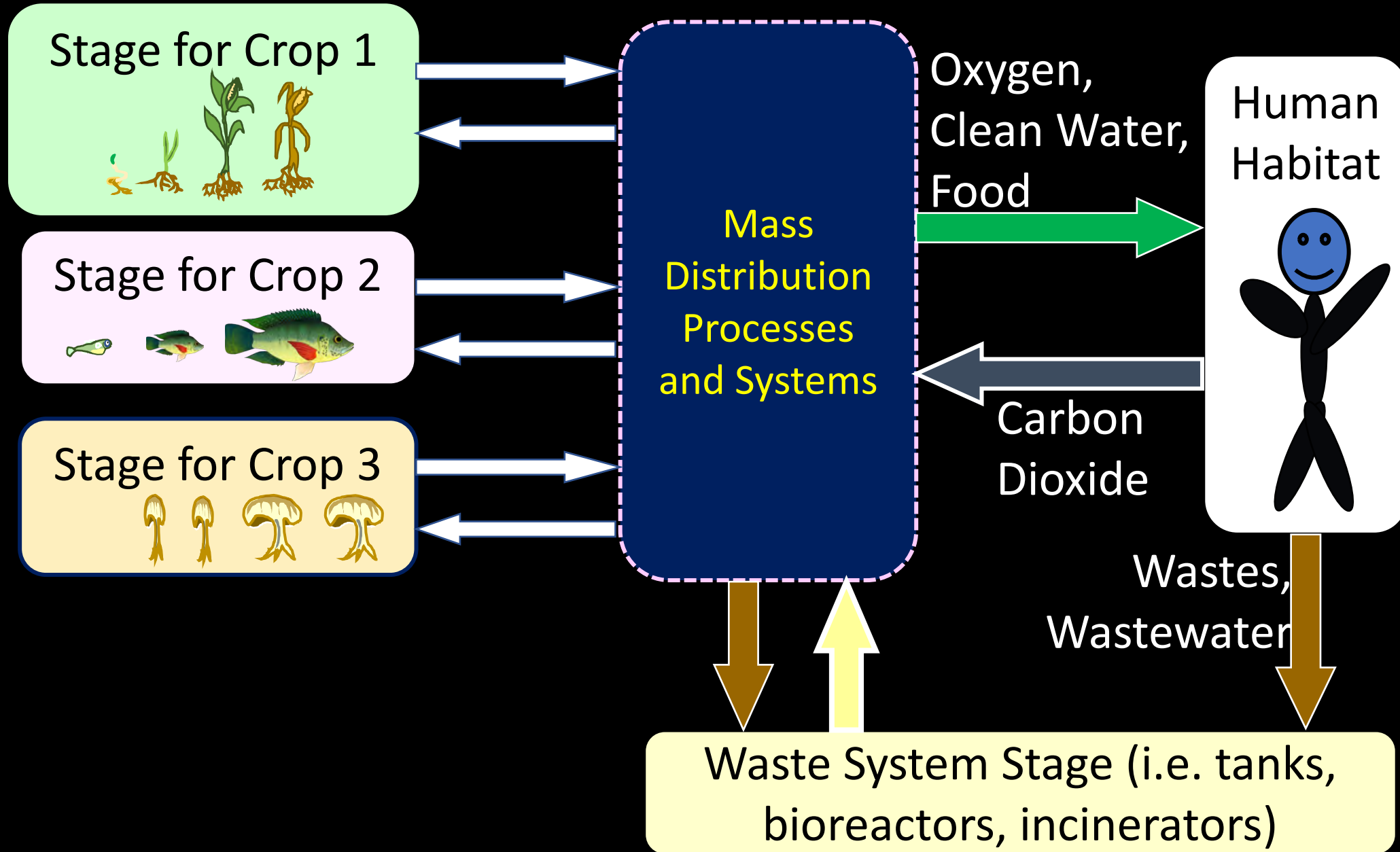
# Farm Concept: Stages

## Farm Living Components (Stages):

- Aquatic: Fish or shrimp in tanks
- 'Hydroponic': Hydroponic/Aeroponic/Aquaponic beds lit by LED lights or sun
- Photobioreactors (Algae Reactors): Machines with lights and algae to recycle air and water and grow food for people or animals
- Bioreactors: Machines that use Bacteria and Fungi to recycle wastes.  
**CONVERTS FIBER TO CARBON DIOXIDE!**
  - Replaces what soil does.
- Maybe Incinerators too.

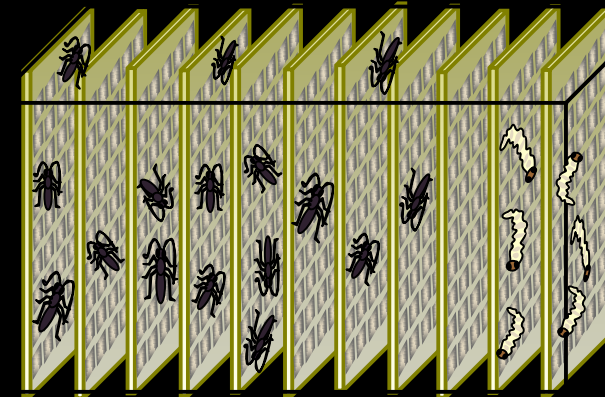
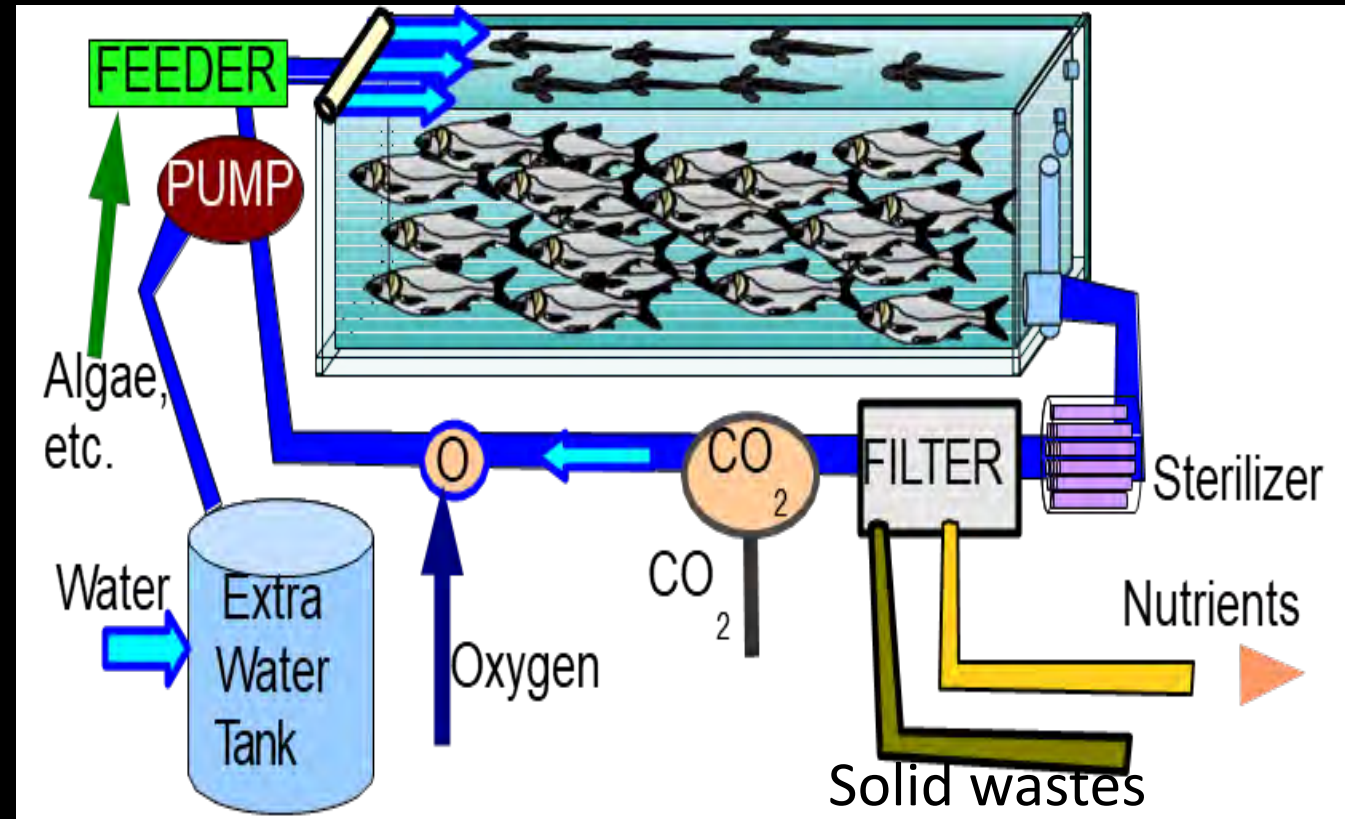
Farm Stages and the Human Habitat are linked to make an artificial ecosystem cycle.



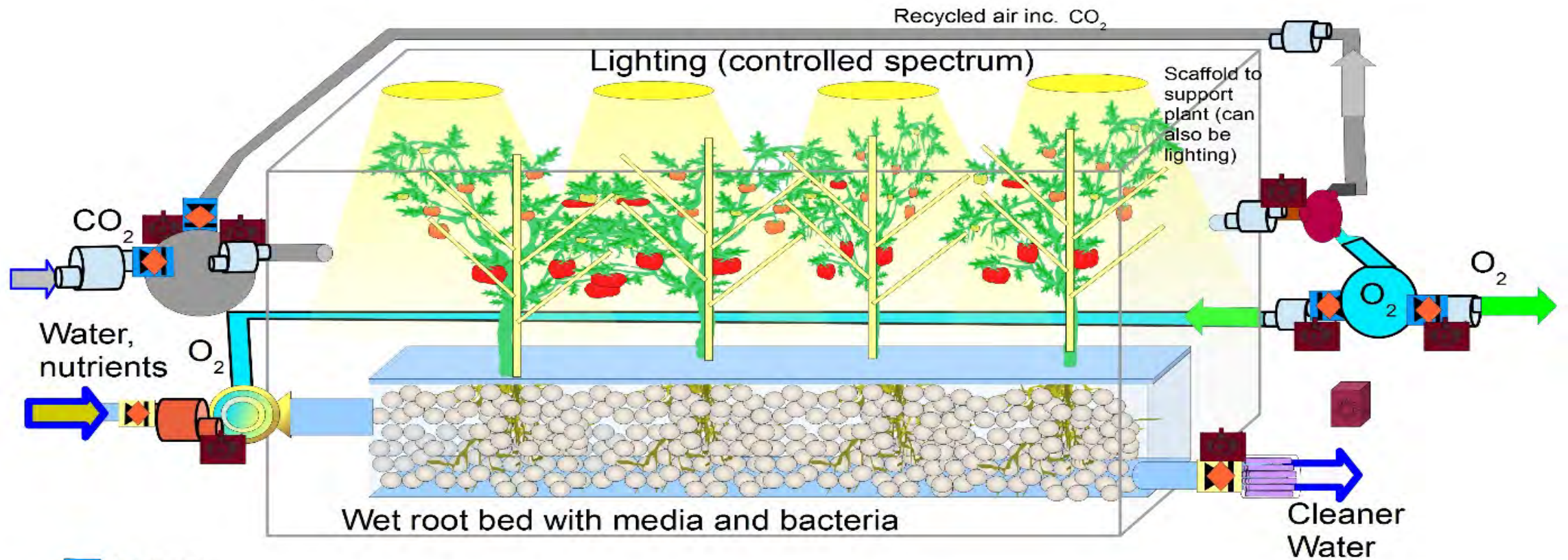


# Animal Stages: Fish, etc.

- Aquatic Organisms are very efficient at producing fresh protein...especially shrimp, and some fish
- They can be fed algae ideally
- Even if not eaten, can make the farm more efficient...fish wastes make good fertilizer: Aquaponics.



# Hydroponics and Aeroponics: One example

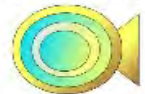


Intelligent valves gas

Intelligent valves liquid

UV Sterilizer

Gas Infuser w/manifold



Liquid Pump

Gas Pump

Controller w/sensors

Stage Control Processor

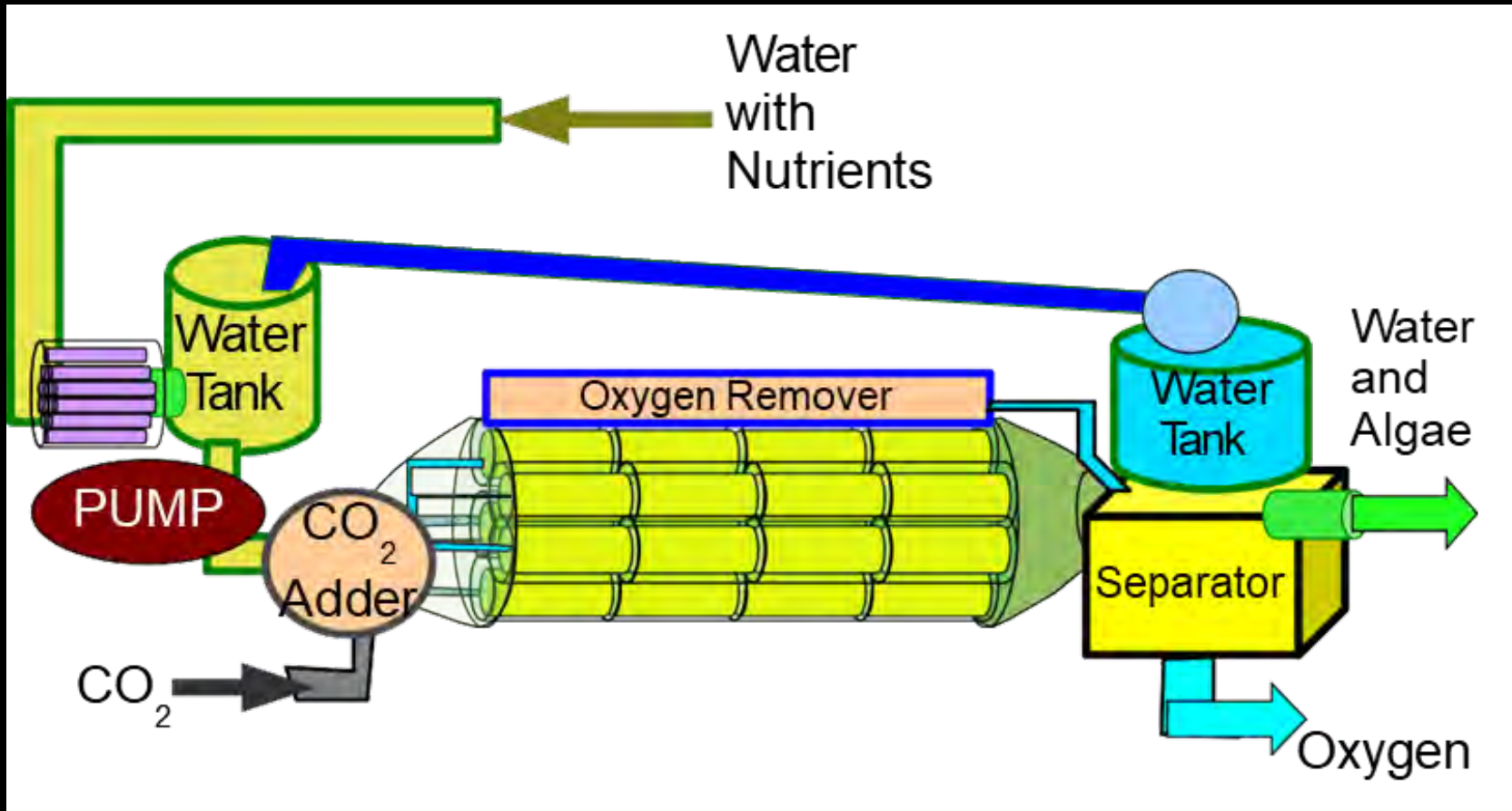
Gas Species Separator

Mass-Liquid Separator

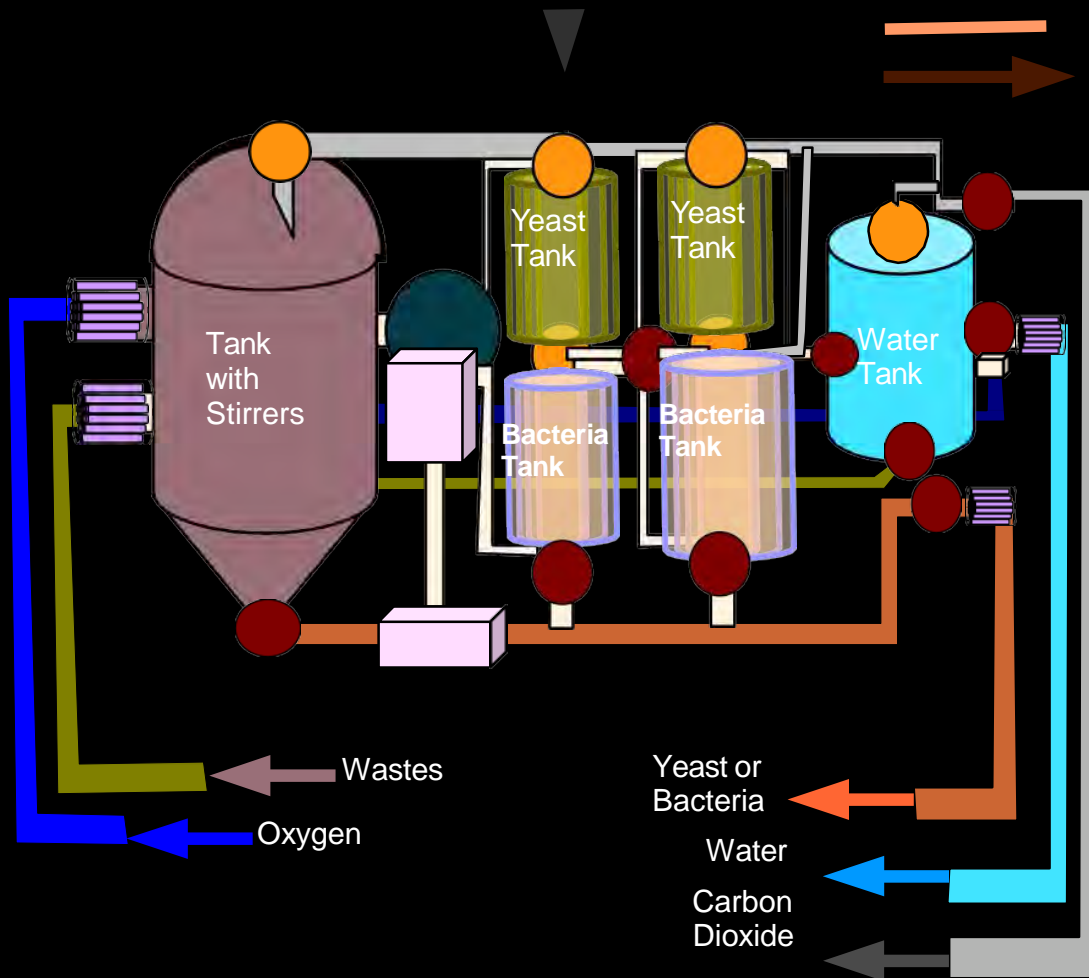


# Photobioreactors: Making a slime vat...

- Can be as simple as a vat with stirrers and lights, or as complex as you need...common on Earth for Biofuels and Food Production



# Bioreactors: For Food, Recycling and Beer...One example



- You are already familiar with Bioreactors:
  - Soil
  - Your Intestines
  - Wine and Beer fermenters
  - Sceptic and Waste Management systems
- Yeast Solids are very nutritious too!
- This is best an **AEROBIC** Reactor...

# Other Parts: Machinery to tie it together

- **Systems:**
  - **Dirty Water:** Moves liquid wastes from people and/or animals to the Bioreactor as needed.
  - **Clean Water:** Moves drinkable, fish-usable, and plant-usable water
  - **Solid Wastes System:** Moves solid waste to incinerator or bioreactor
  - **Food and Feedstock:** Moves human food and animal feed as needed
  - **Gas Management:** Moves Oxygen, Carbon Dioxide, and other gasses to animals, plants, photobioreactor, and bioreactor as required
  - **Energy System:** Takes energy from solar arrays, nuclear, or other sources to power machinery and lights.
  - **Heat Management:** Uses pipes, fins, pumps, and fans, to keep temperatures right where you need them
- **These include:** Tanks, Control Systems, valves, pumps, fans, generators, and batteries.

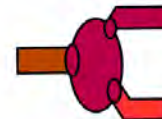
# A few of said machines...ALL ARE AVAILABLE NOW!



**Intelligent valves:**  
Combinations of variable valves and simple processors and sensors to control flow and direction



**Reverse Osmosis Purifier:** pushes liquid against a membrane to extract pure liquid (water) from a mixed liquid



**Gas Species Separator:**  
Pulls out one kind of gas from a mix of gasses.



**Gas Extractor (from Liquid):**  
extracts dissolved gasses from liquid.



**UV Sterilizer:** Similar to current Pond/Pool Ultraviolet filters with multiple loops and sensors to assure sterile liquid/gas



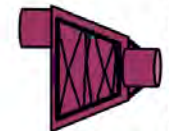
**Controller w/sensor array:**  
A complex set of routers, processors, and sensors that set conditions and control devices as directed by control software



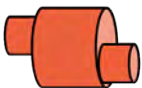
**Mass-Liquid Separator:**  
Pulls solids from a liquid mix.



**Condenser:**  
extracts liquid from a gas mix.



**Macerating pump:** takes coarse solids in liquid and mixes them into a fine mixed liquid



**Liquid Pump:** A self priming pump to push liquids (increase pressure)



**Agitator /Infuser:** A mixing blade and hose arrangement to stir thick liquids and add gasses and liquids while stirring.



**Gas Infuser w/Manifold:**  
mixes gases into a liquid solution, then distributes the result into multiple pipes.



**Complex Manifold Liquid Router:** shuts liquids based on chemical composition.



**Gas Pump:** A pump to push gases (increase pressure)



**Stage Control Processor:**  
A router-multi-processor computer programmed to optimize a stage (make and keep conditions ideal to convert inputs into outputs)

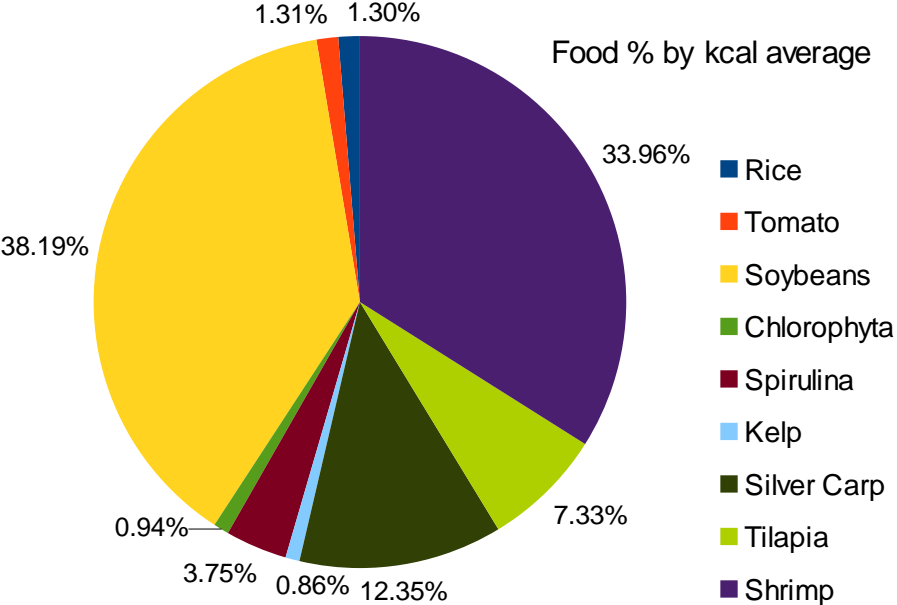
# The more complex the farm, the better the menu!

- Early Space Farms might just be a waste tank, an incinerator, a condenser, hydroponics or aeroponics, and a photobioreactor, with 3d printers: Menu is Glop, Printed Glop, and a very few fresh veggies.
- Adding even a few other parts makes a better menu...adding a larger hydroponic set gets more veggies, but requires more initial water, and carbon dioxide...
- Adding some animals like fish, shrimp, or insects, help balance carbon dioxide, and add more to the menu...
- The problem in all space farms is carbon dioxide, not oxygen.
  - Fiber is hard to break down, and plants need lots of CO<sub>2</sub> to grow.
  - YOU DO NOT EXHALE ENOUGH CO<sub>2</sub> TO GROW ENOUGH PLANTS TO FEED YOURSELF!



# A complicated farm = Diverse Menu

Scaled Layout (~3 hectares)



**KEY**

- 3@ Algae Bioreactor stages
- Yeast-Bacteria Bioreactor
- Nutrient+ Water Tank
- Waste Sludge Tank
- Food processing + storage
- Septic Tanks /Black Water
- Food Fermentation: Saki, Beer, Fish Sauce, Tofu
- Shrimp Aquatic Stage
- Silver Carp Aquatic Stage
- Tilapia Aquatic Stage
- Tomato Hydroponic Stage
- Soybean Hydroponic Stage
- Rice Hydroponic Stage
- Oxygen Gas Tanks
- Carbon Dioxide Gas Tanks
- Clean Water Tanks
- Mixed Inert Gases Tanks

Adding a mushroom garden would aid in menus too...

# Herbs and Spices?

Most spice plants are great plants to grow in the habitat with people! They clean the air, can clean some water (i.e. wash water, not flushable water/wastes) Fit into corners, hallways, offices, etc.

Spice	Time to First Harvest (wiki)
Basil	75 days
Cilantro	30 days
Dill	90 days
Fennel	100 days
Mustard	95 days
Chives	60 days
Marigold (Candula)	70 days
Mint	90 days
Tarragon	60 days
Oregano	120 days
Cumin	120 days
Ginger	200 days
Serrano Peppers*	120 days
Paprika*	150 days
Saffron	180 days
Chili Peppers*	120 days
Coriander	100 days
Garlic	180 days
Turmeric	300 days
Thyme	1 year
Rosemary	1 year
Hops	2-3 Years
Coffee**	2-3 Years
Tea**	2-3 Years

\* = Same species as bell peppers, \*\* = large enough to require space and possibly a hydroponic stage, good for export!

# Today's Space Menu

- Fried Shrimp with algae strip salad, spiced with a mix of turmeric, thyme, etc.
- pseudo-Curry Shrimp and soy noodles
- Baked Fish with fennel and sage, and tomato/kelp salad with yeast flavoring.
- Tofu soup with algae power
- Other Sides: Spiced Soy-Rice Noodles, Edamame, Steamed Rice, Soy-Cheese Analog
- Drinks: Water, tomato juice, saki, beer, rice pseudo-Mexican horchata (no cinnamon :0( )), algae juice.
- Dessert: Rice Flour Ginger Muffins

*Will Improve as I add species!*

# Chicken, Eggs, Others?

As the settlement gets bigger: More plants get grown in soil versus hydroponics...More animals can be added, eventually chickens, insects, rodents...

Settlement Size	Chemical Processors	Photobioreactors	Anerobic/Aerobic Bioreactors	Hydroponic (substrate-less)	Hydroponic (w/substrates)	Soil Farm	Insect Farm	Aquatic Animal	Land Animal
8	X	X		X			X	(pets/grow-out only)	(Pets are a portion of a person...)
20	X	X	X	X	X		X	X	(pets only)
50		X	X	X	X		X	X	(pets only)
100		X	X	X	X		X	X	(pets only)
500		X	X	X	X		X	X	Rodents, maybe chickens
1,000		X	X	X	X	X	X	X	Rodents, Goats, Chickens
10,000		X	X	X	X	X	X	X	Large Animals

# Conclusion

- Space Farms are adaptations of farms on Earth, so that I don't have to ship up everything I need to live
- Space Farms are mass recyclers!
- Space Farms can also provide a better diet too!
- The bigger the settlement, the more complex the menu can become.
- All the machinery and species exist on Earth now.
- They are not much bigger than farms here.