

Farming in Space for Future Space Settlements: Not just Glop and Salad!

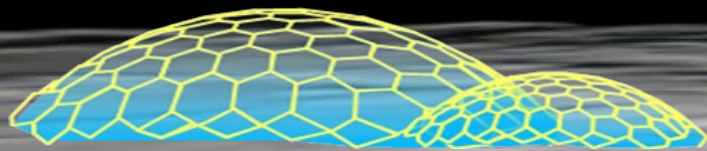
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NSS Board of Directors Region IV

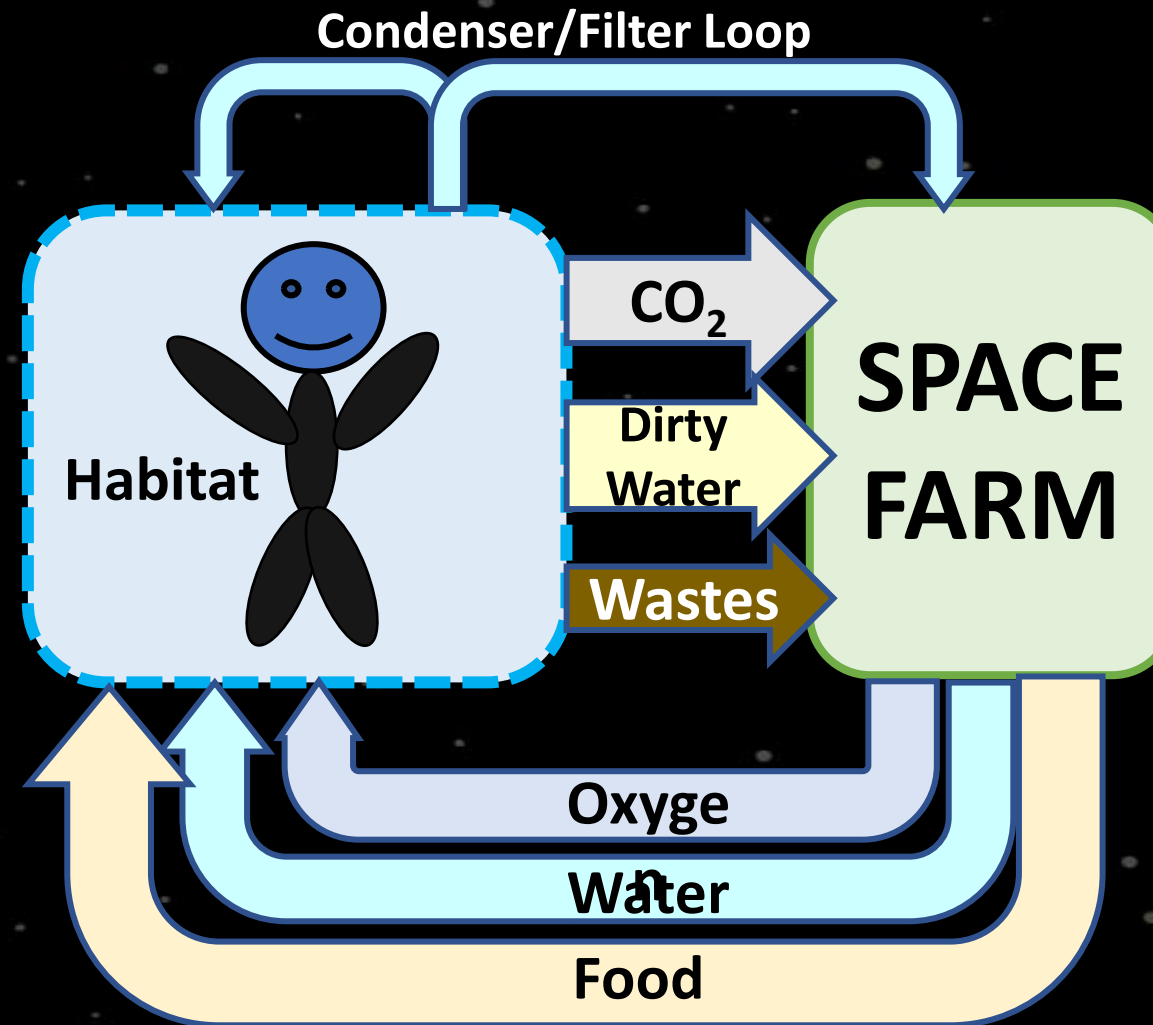
AIAA Space Settlement Technical Committee

28 Oct 2021



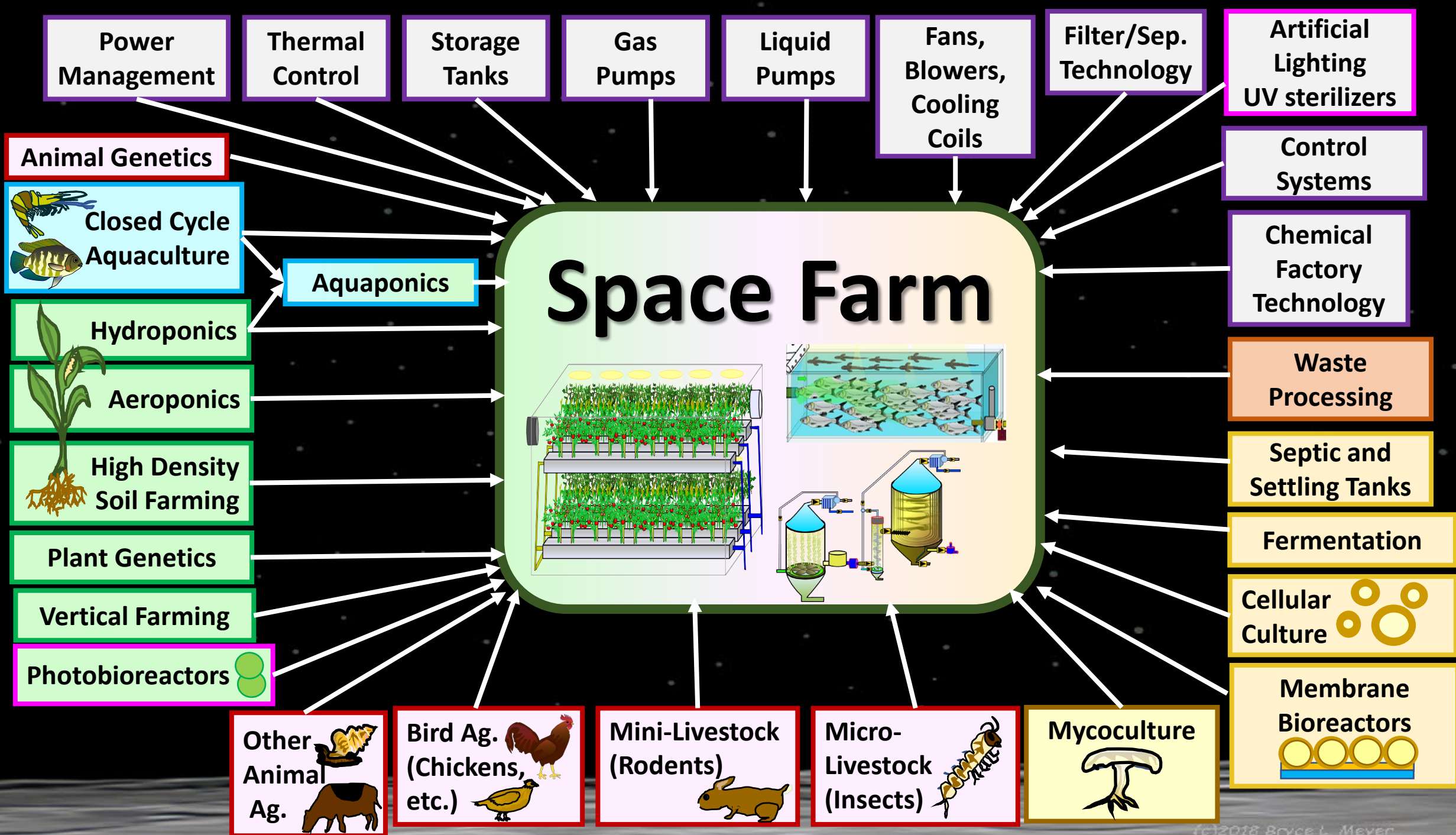
What is a Space Farm?

Space Farms are combinations of machinery and biology that recycle the air, water, and wastes from the human habitat to produce oxygenated air, clean water, and food.



What drives a space farm design?

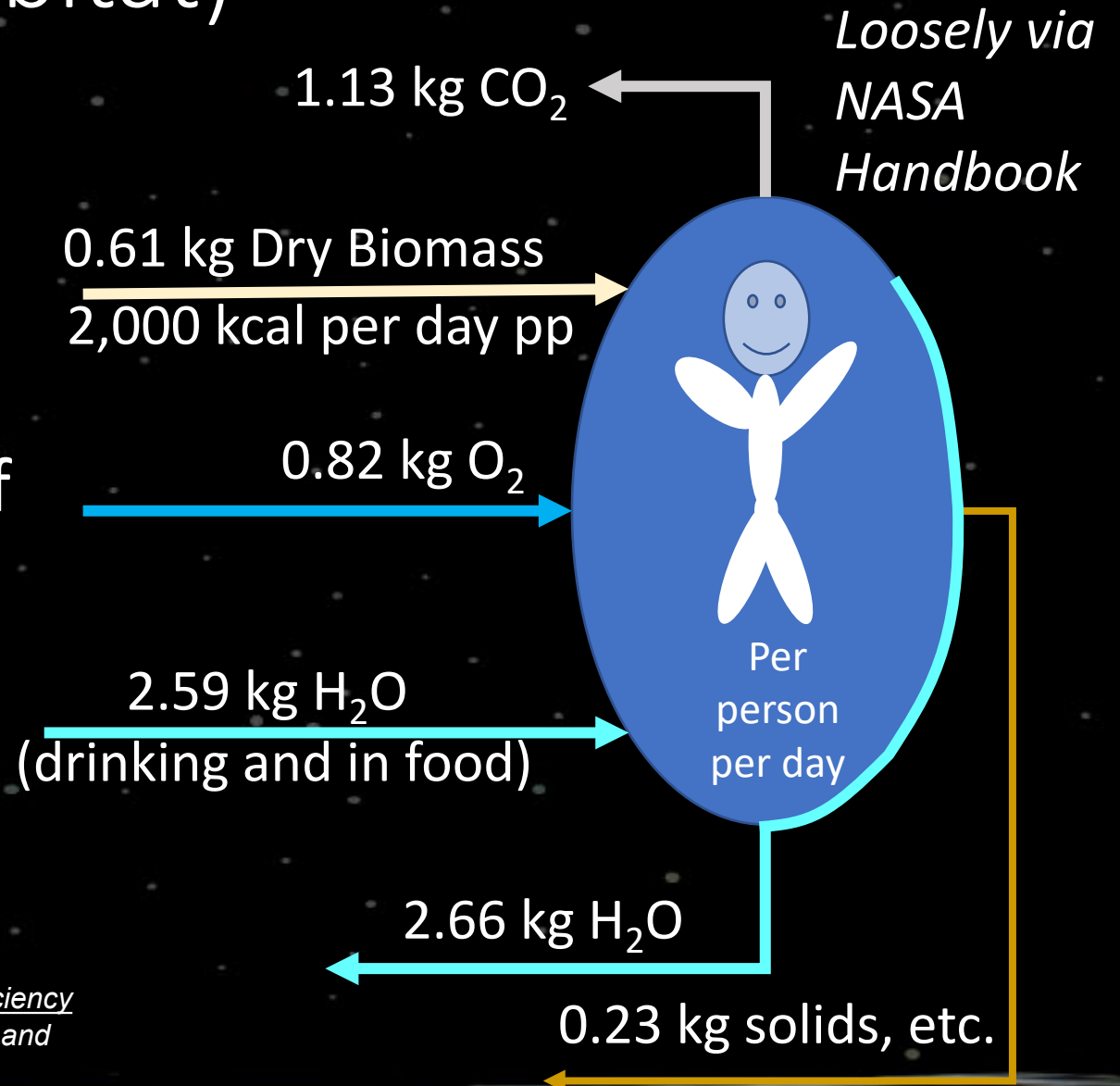
- Human Population in Settlement
- Enclosed Volume and Area
- Availability of useable C,H,O,N compounds and water
- Energy Available
- Time to Build and Improve
- Menu Diversity, Dietary Requirements
 - More Crops=More Menu Options



Human Settlement (Habitat)

- Space Farms are the core element in a self-sustaining (mass-wise) long term settlement.
- Space Farm takes the outputs of the Human Habitat and outputs food, clean water, and oxygen. “Poop to Plate”
- Dietary Diversity is Key to Psychological Health

NSS Space Settlement MILESTONE 9: Technology for Adequate Self-Sufficiency
People leaving Earth with the technology and tools needed to settle, survive and prosper without needing constant resupply of survival essentials from Earth.



Some Recycling Can Happen in the Habitat

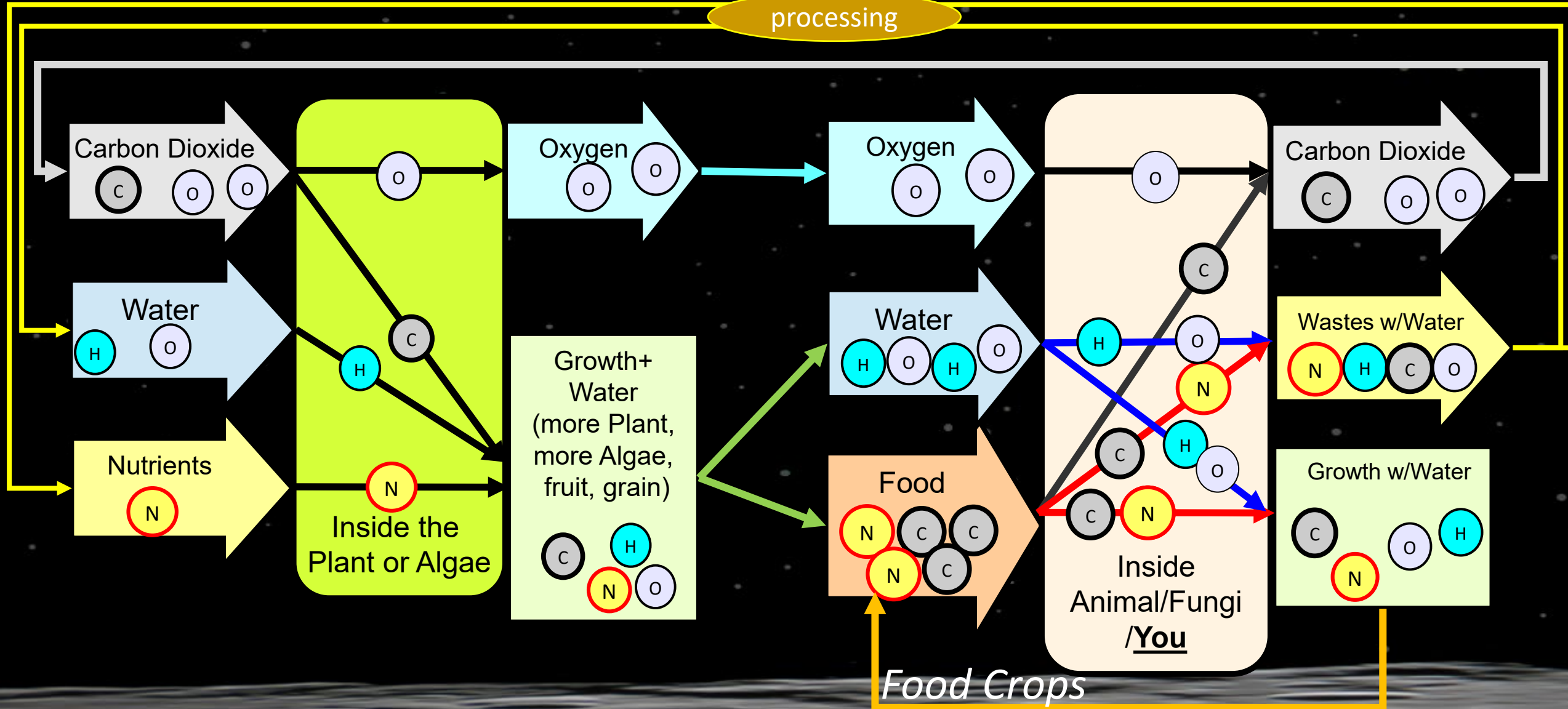
- Most human water output is in breath and sweat
 - Can be condensed using dehumidifiers, then sterilized using UV, and returned directly as potable water
- Water from hand washing, showers, food prep can be coarse filtered, sterilized, then reused:
 - Flushing Toilets
 - **In Habitat Plants: Spices +** Vines which transpire, thus cleaning water for recapture by dehumidifiers. MAKE AIR SMELL BETTER!!!!!!
 - **Spices become the houseplants in every corner of habitat**
 - Note: Assumes organic soaps and shampoo

Some Recycling Can Happen in the Habitat (2)

- **Black water** = anything with human wastes, urine, or other organic contamination goes to waste treatment and farm!
- Since humans generate extra water, then some condensed water goes to the farm too.
- Carbon Dioxide from air goes to the farm (if not used by in-habitat plants).
 - Can be concentrated using cryopumps or other gas separators.

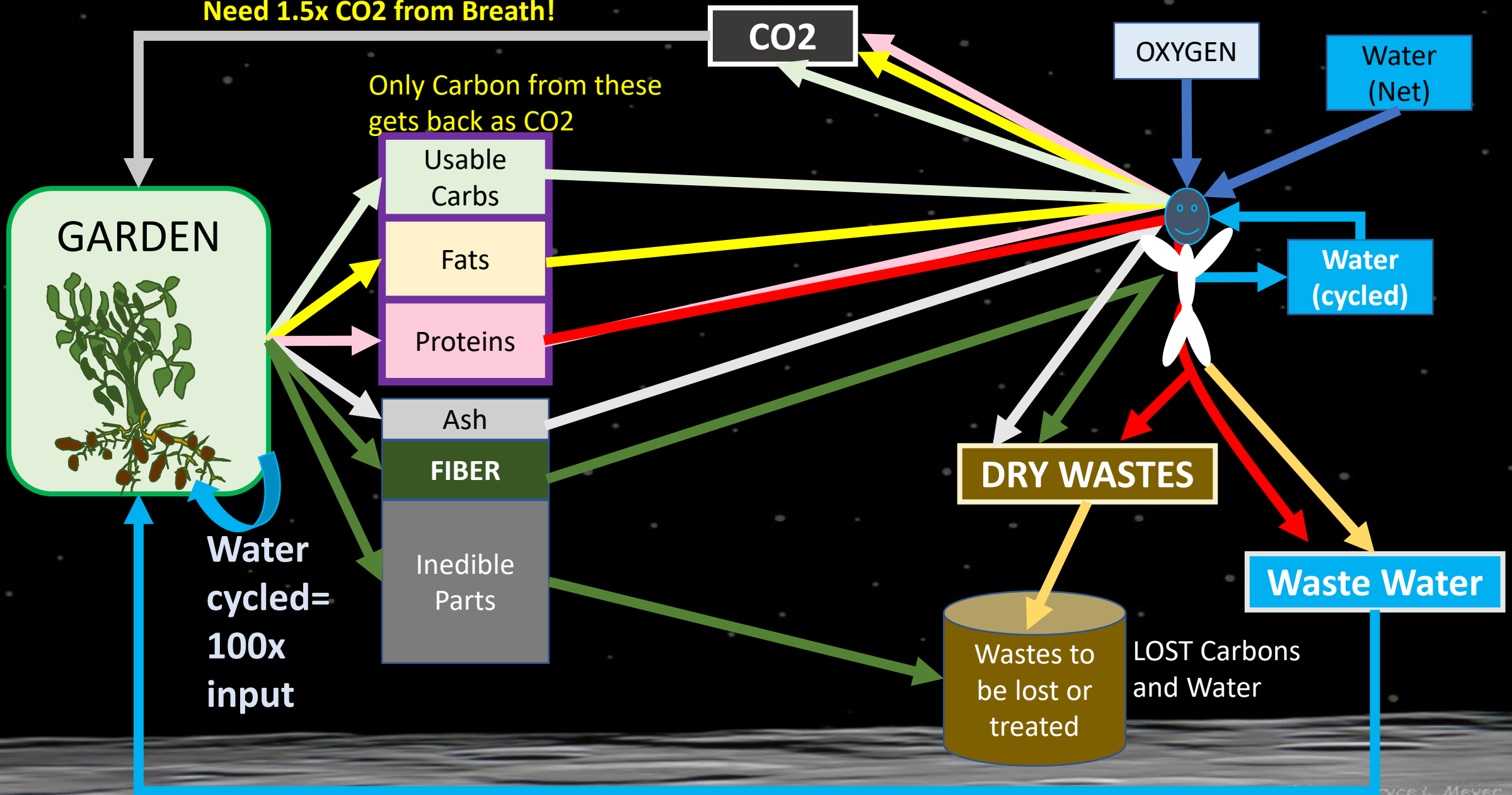
Simplified Biochemistry

processing

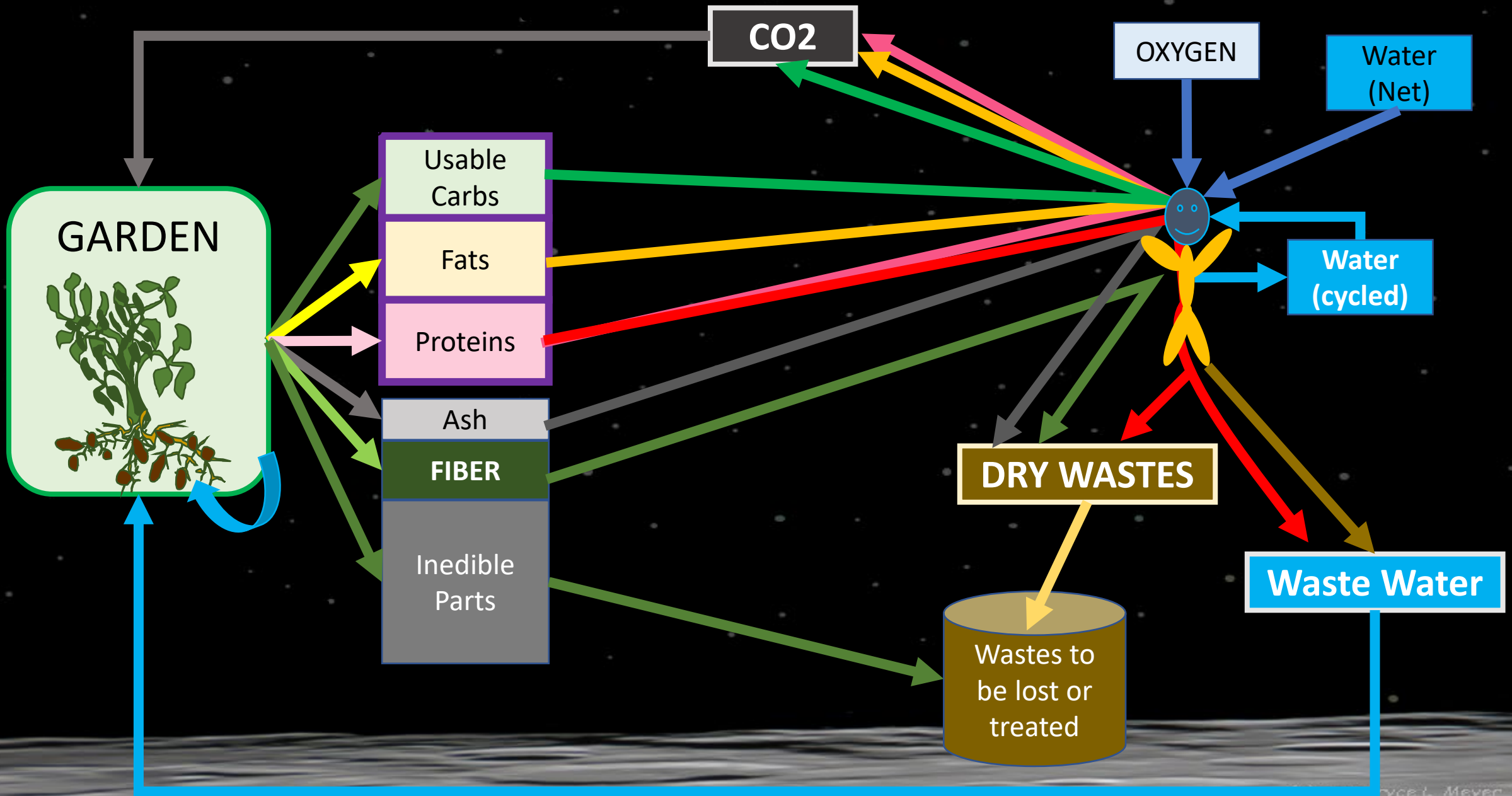


Carbon Cycle Problem

Need 1.5x CO₂ from Breath!



Carbon Cycle Problem

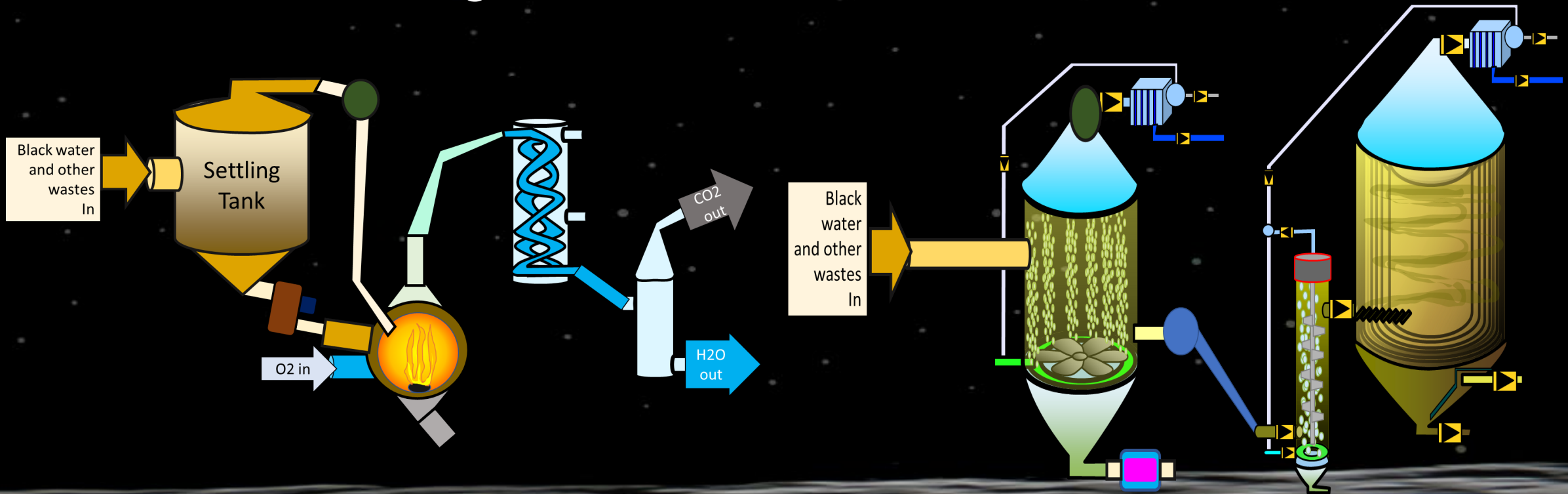


Bioreactors Can Close the Loop....

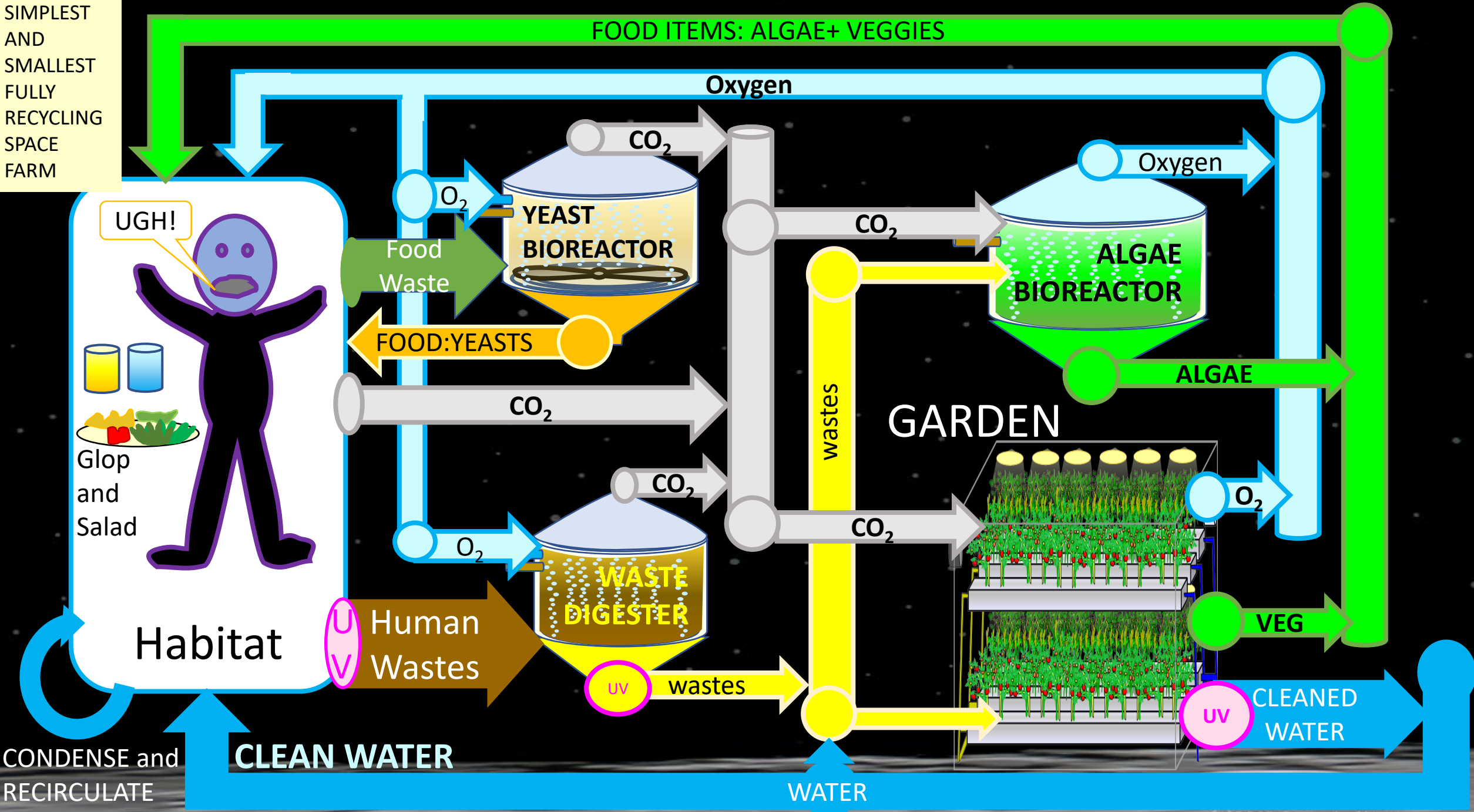
- **Bioreactor: Living Cells + Machines:** designed to make chemical or biological products from algae, bacteria, cyanobacteria, or yeasts.
- **Aerobic Bioreactors:** Can be simple digesters, to complex membrane-based bioreactors.
 - Primary reaction: Inputs (C,H,O,N,etc.) + Oxygen \rightarrow CO₂ + Water
 - Secondary: Inputs (C,H,O,N,etc.) + Oxygen + Water \rightarrow CO₂ + Water + biomass
 - Can make Yeast Solids
- Initial settling tanks should be aerobic bioreactors...digestors
- **Photobioreactors:** use lights, tanks, aerators, controls and valves
 - Primary Reaction: CO₂ + Water + nutrients (N,etc.) \rightarrow Biomass + Oxygen

Initial Waste Management from Habitat and Farm: Incinerator or no

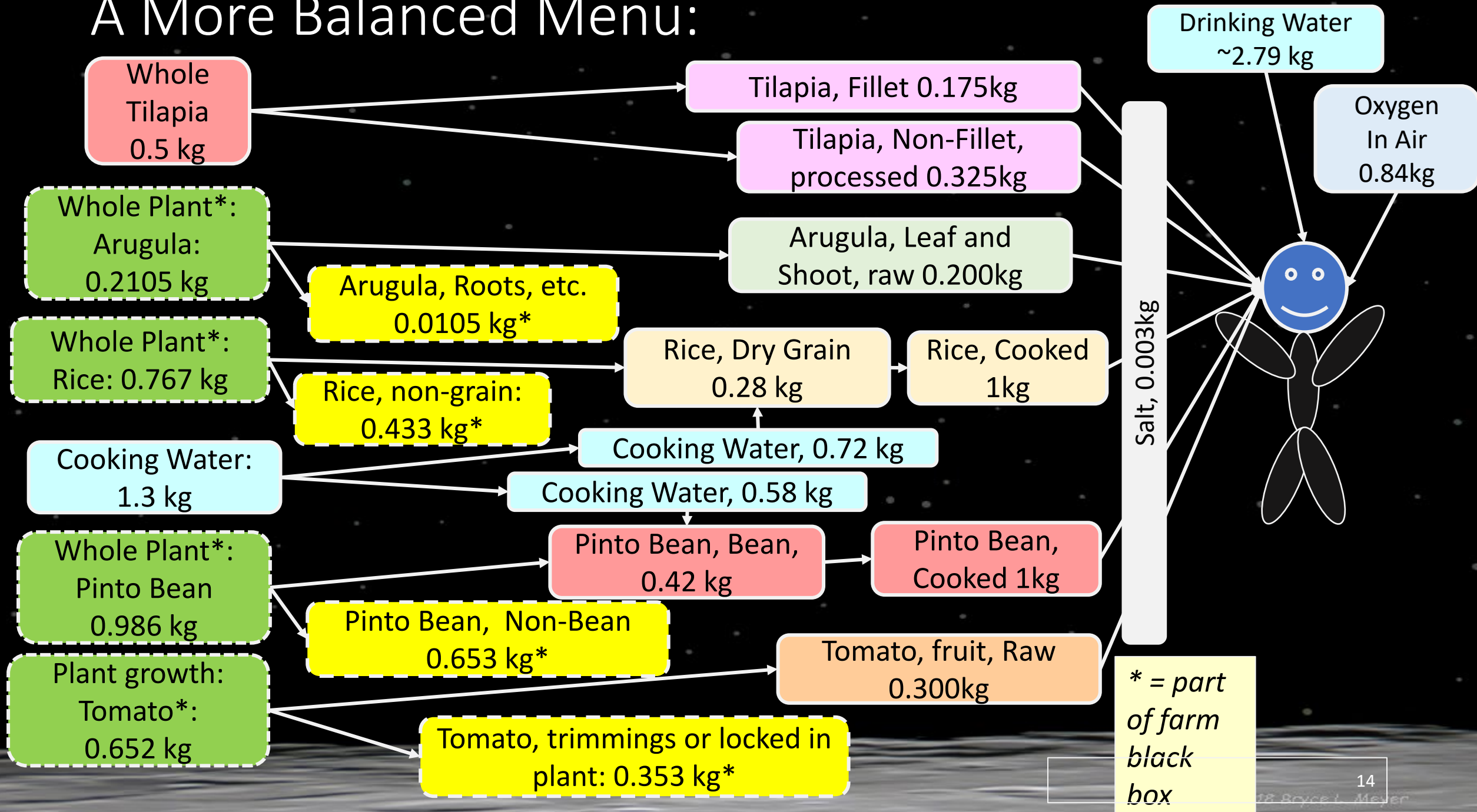
- Incinerators are usually $\frac{1}{4}$ the size of an efficient aerobic bioreactor
- Still need settling tanks!



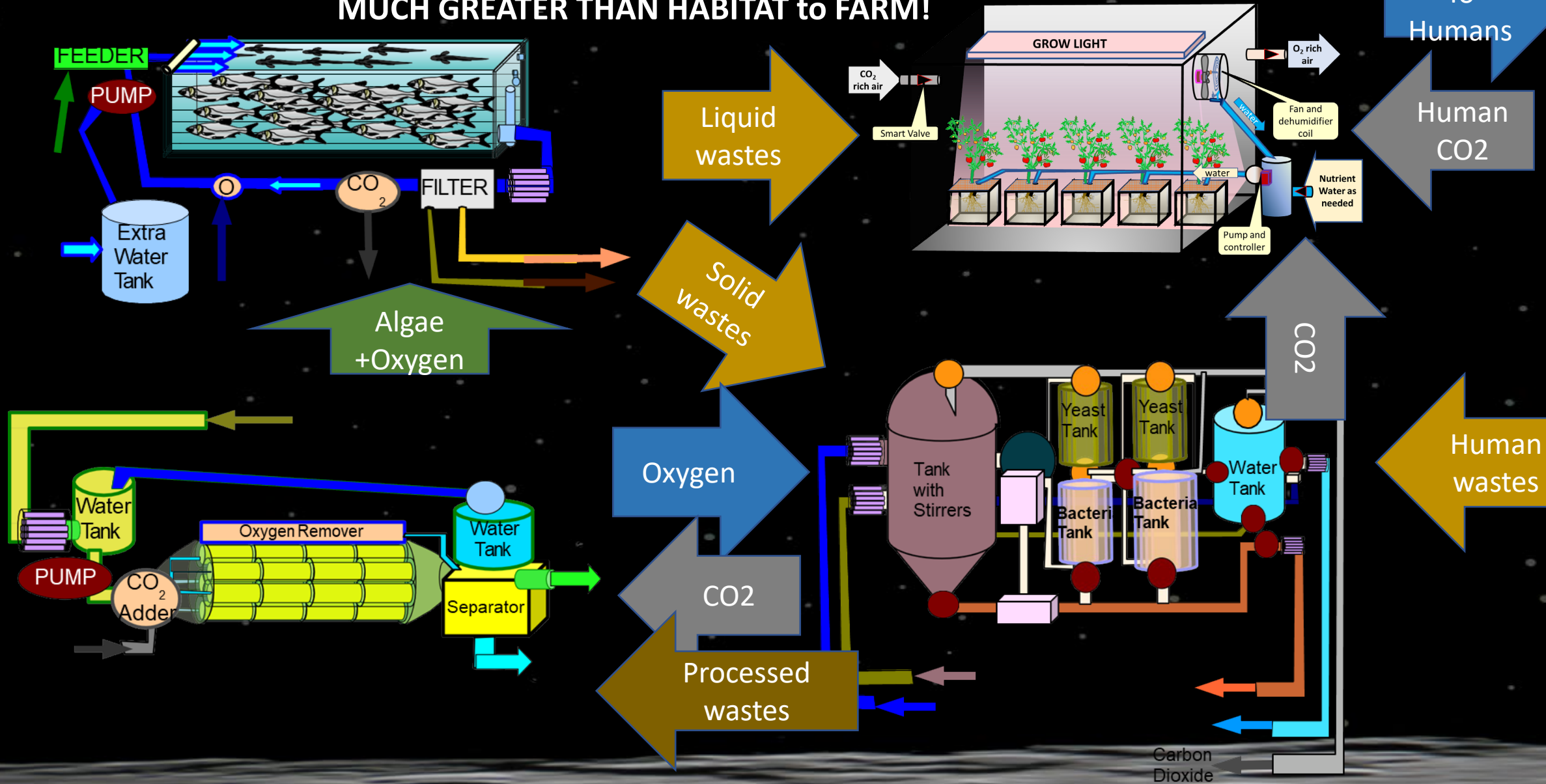
SIMPLEST
AND
SMALLEST
FULLY
RECYCLING
SPACE
FARM



A More Balanced Menu:

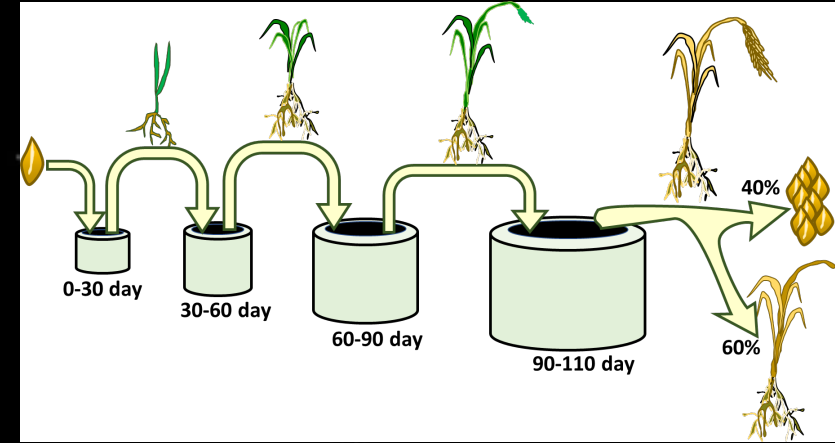


MASS FLOWS INSIDE A COMPLEX FARM MUCH GREATER THAN HABITAT to FARM!

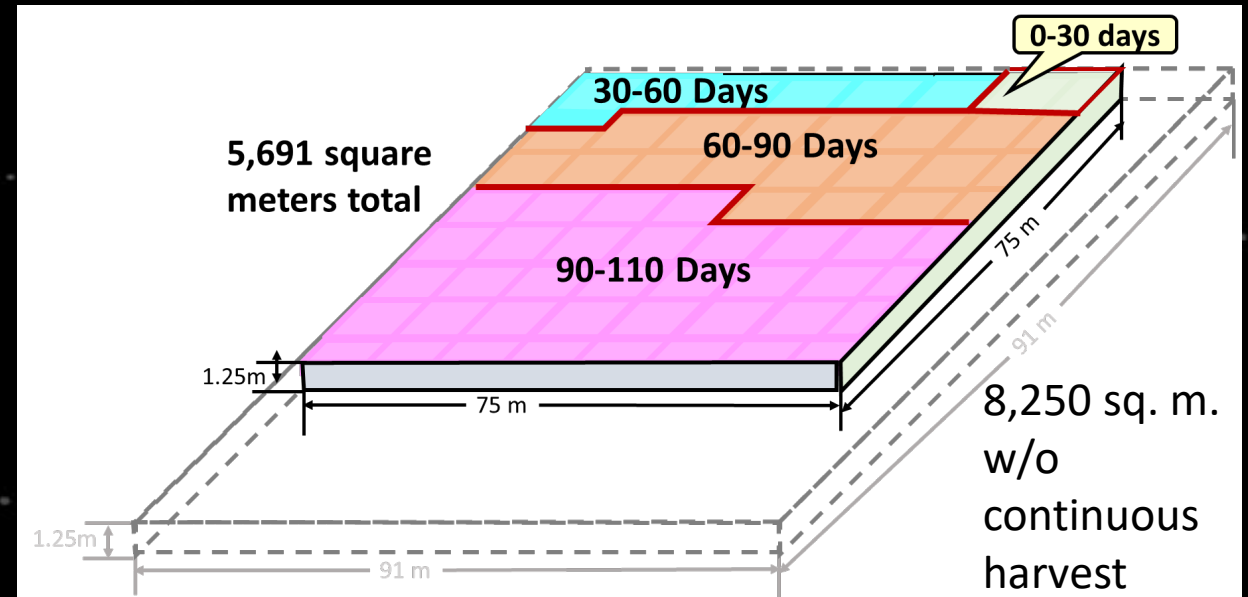
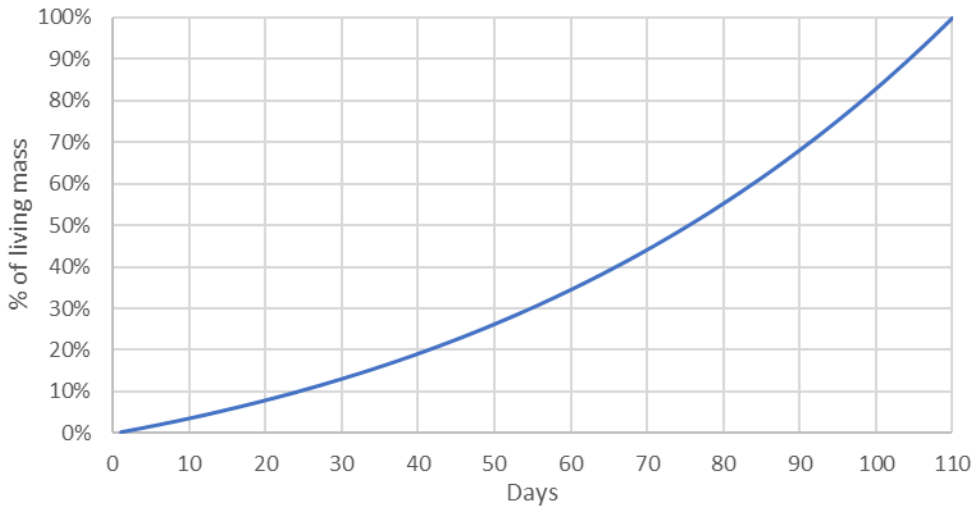


Continuous Harvest!

- **Continuous Harvest Concept:** Fresh Food Every Day, makes for a smaller farm too (by at least 30% for grains)



Wheat Growth 110 day harvest



Plants

- Soil v. soilless trade: Soil takes more room and time (1-2 years) to build but may be more productive for some crops.
- Soilless: Need greater chemical control

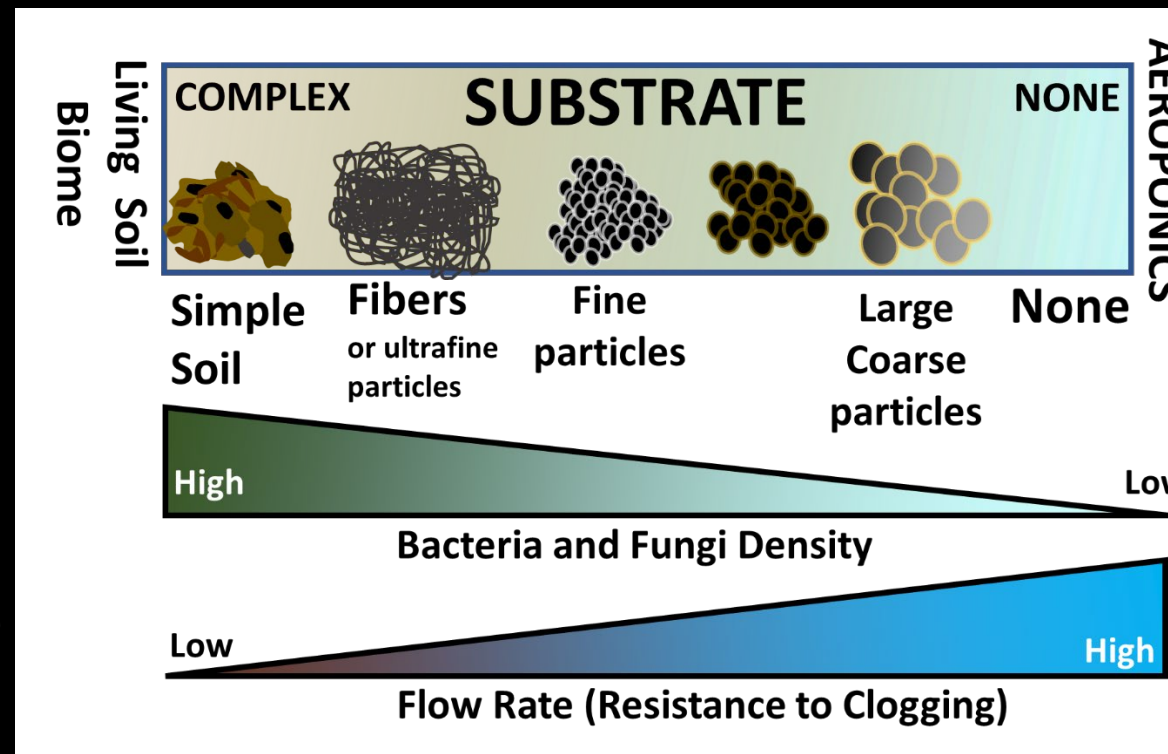
Regardless There are considerations for plants:

Early settlement favors perennial cultivars of tomatoes, peppers.

Veggies are easiest and quickest, but low in calories and proteins

Legumes, inc. Soybeans, Peanuts, Pinto is good oil and protein source, and pinto beans or early beans are fast growing and tough

Potatoes and other root crops may need for root volume, Grains: Takes Lots of room but high calories



Menus Determine Farm Structure and hence Mass Flow part 2:

- Animal Proteins: Aquatic Organisms: esp. Shrimp and fish like blue tilapia and silver carp
 - Take room and much initial water, but accumulate proteins, can process algae in a virtuous loop, and provide processed nutrients for plants n liquid wastes
 - NOTE FROM CALCULATIONS: Algae → (Fish or Shrimp) → Hydroponics is a very energy efficient cycle
 - Shrimp are more delicate to biochemistry than fish
 - Insects: volume efficient and good at processing other products inc. materials.

Overall Herbs and Spices

Herbs and Spices can also be grown in habitat as ornamental plants, because they smell good, recycle carbon dioxide, and can use grey water. In Habitat grown potted plants, or as hydroponic

crops:

- Sage
- Basil
- Mint
- Oregano
- Garlic
- Saffron
- Ginger
- Turmeric
- Coriander
- Thyme
- Chive
- Rosemary
- Cumin
- Paprika
- Fennel
- Mustard
- Hops (need 2 years)

FYI..given time (2-3 years) you could grow COFFEE and TEA as potted or hydroponic crops

- Unfortunately some common items are more difficult, requiring recipe adaptation:

- Olives
- Cinnamon
- Black Pepper
- Nutmeg
- Cocoa

Menus Determine Farm Structure and hence Mass Flow: Animals

- Animal Proteins: Birds:
 - Chickens: Eggs are more mass efficient than just broiler/frier production
 - Can be shipped as eggs
 - Drawbacks: volume needed, feathers, temperature control
- Animal Proteins Mammals:
 - Takes a VERY LARGE and MATURE settlement for animals, even rodents
 - Rodents before big animals
 - Big animals: Milk before meat

MENU/EXPORT DIVERSITY

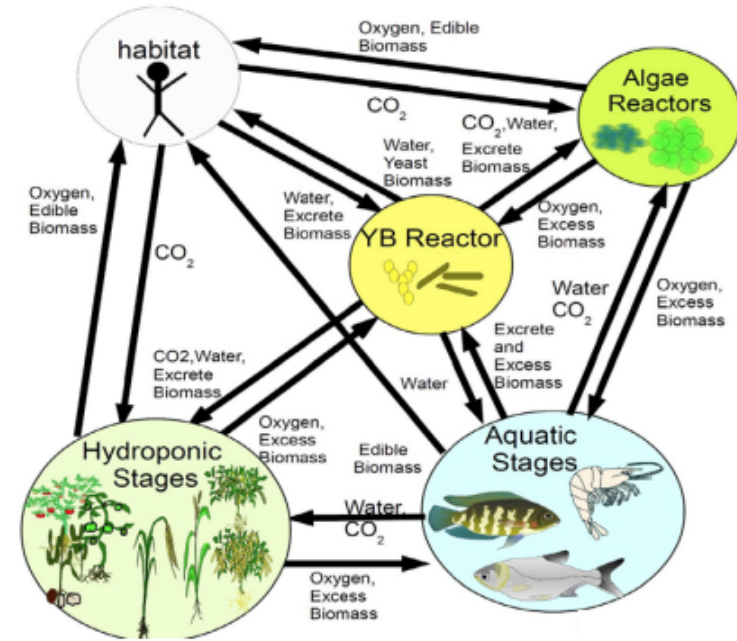


SETTLEMENT/FARM SIZE/TIME

3 Year Old Settlement Farm
266 kg live mass in farm per
settler, for 100 people:7 Hectares

Vascular Plants Animals

- Soybeans
 - Rice
 - Potatoes
 - Barley
 - Tomatoes
 - Coffee
 - Spices:
 - Ginger
 - Mustard
 - Silver Carp or tilapia
- Algae
Yeasts + Bacteria
- Fermented Products:
• Malt, Soy Sauce,
Liquor/Beer
- Concentrates: Rice Sugars



Species	Stage Type	Per person		For 100 Settlers	
		L _{tot}	L _{crop}	L _{tot}	L _{crop}
Barley	Hydroponic	50	0.67	5000	67
Bell Peppers	Hydroponic	23	1.11	2300	111
Chlorella	Algae Reactor	5	3.67	500	367
Pinto Beans	Hydroponic	20	0.85	2000	85
Potatoes	Hydroponic	14	1.06	1400	106
Rice	Hydroponic	7	0.23	700	23
Shrimp	Aquatic	34	2.58	3400	258
Silver Carp	Aquatic	30	0.75	3000	75
Soybeans	Hydroponic	54	1.44	5400	144
Spirulina	Algae Reactor	5	1.25	500	125
Tilapia	Aquatic	10	0.61	1000	61
Tomato	Hydroponic	14	12.73	1400	1273
		Live kg	Live kg	Live kg	Live kg

Space Menus (assume 3 year old settlement)

Drink options: Soymilk, Barley Malt, Ginger tea, and some coffee (as an upgrade), horchata, bloody mary.

Puffed Malted cereal, puffed rice cereal, barley porridge with beans, steamed sweet rice w/ginger.

Soy egg substitute, soy-cheese, fried tilapia or carp, refried beans.

Rice or potato pancakes with rice/potato syrup, mustard sauce, catsup, and/or soy margarine.

Rice flour muffins, potato bread.

Fried potatoes. Fresh tomatoes.

Space Menus (assume 3 year old settlement)

Drink options: as for breakfast, plus full vodka bar, wines (algae, potato, rice), beer, kombacha. Fried, baked, steamed, breaded or not, fish or shrimp. With or without beans, rice, and tortillas.

- Fish or soy sausages.

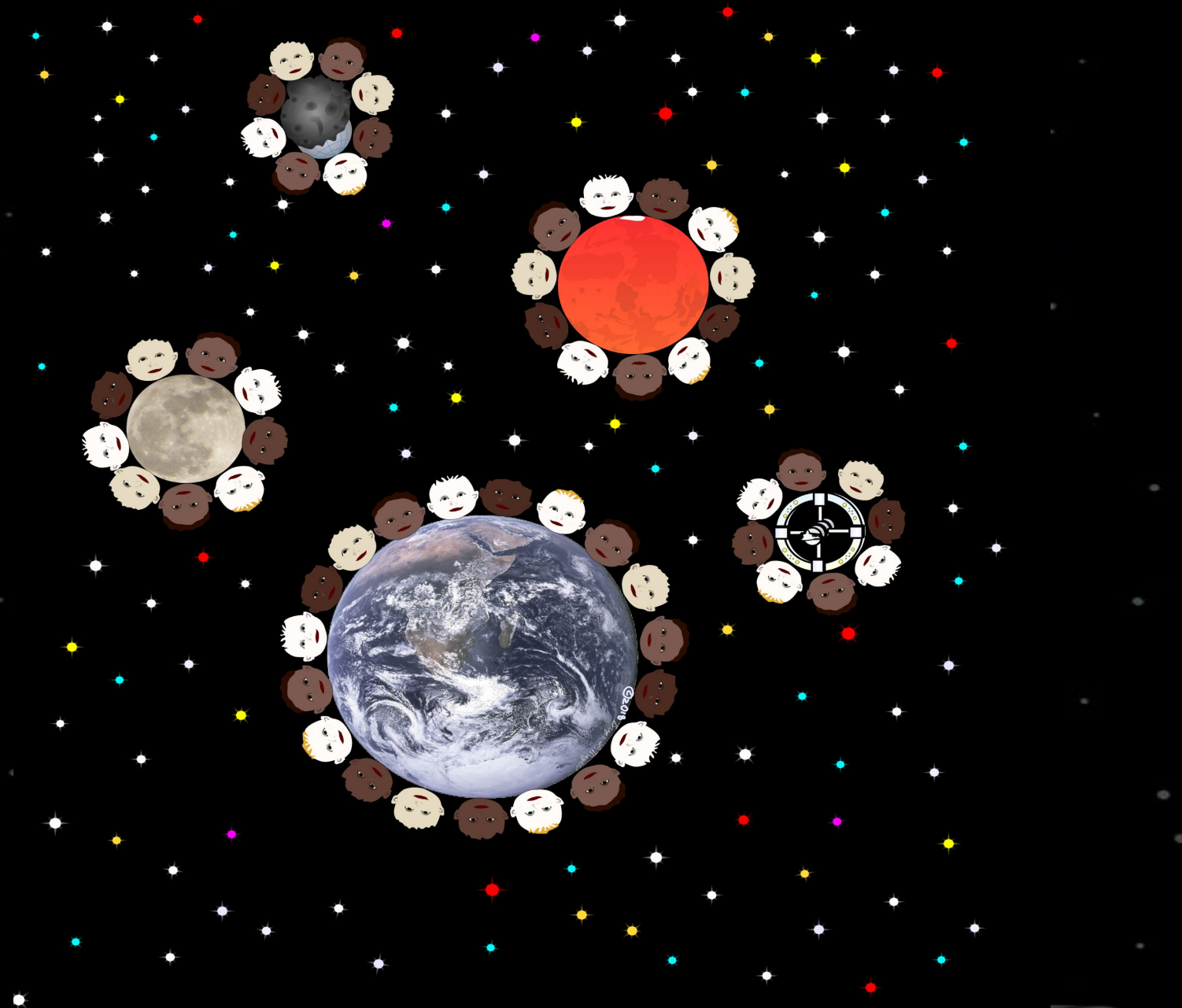
Bean Burritos w/soy-cheese, rice, peppers.

Noodle bowls: pick vegetables and proteins.

Spaghetti with soy or fish 'meatballs'. Fettuccine with shrimp and soy-alfredo.

Sushi and Sashimi plate of tilapia, cooked shrimp rolls, carp rolls.

THANK YOU!



BACKUPS