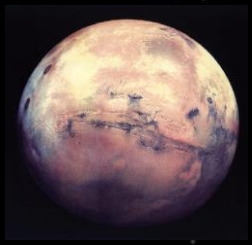
Biomimetic devices and their application in space exploration

Michael Flynn
NASA Ames Research Center



Advanced Life Support

Objective:

Keep Astronaut alive

Provide habitable environment

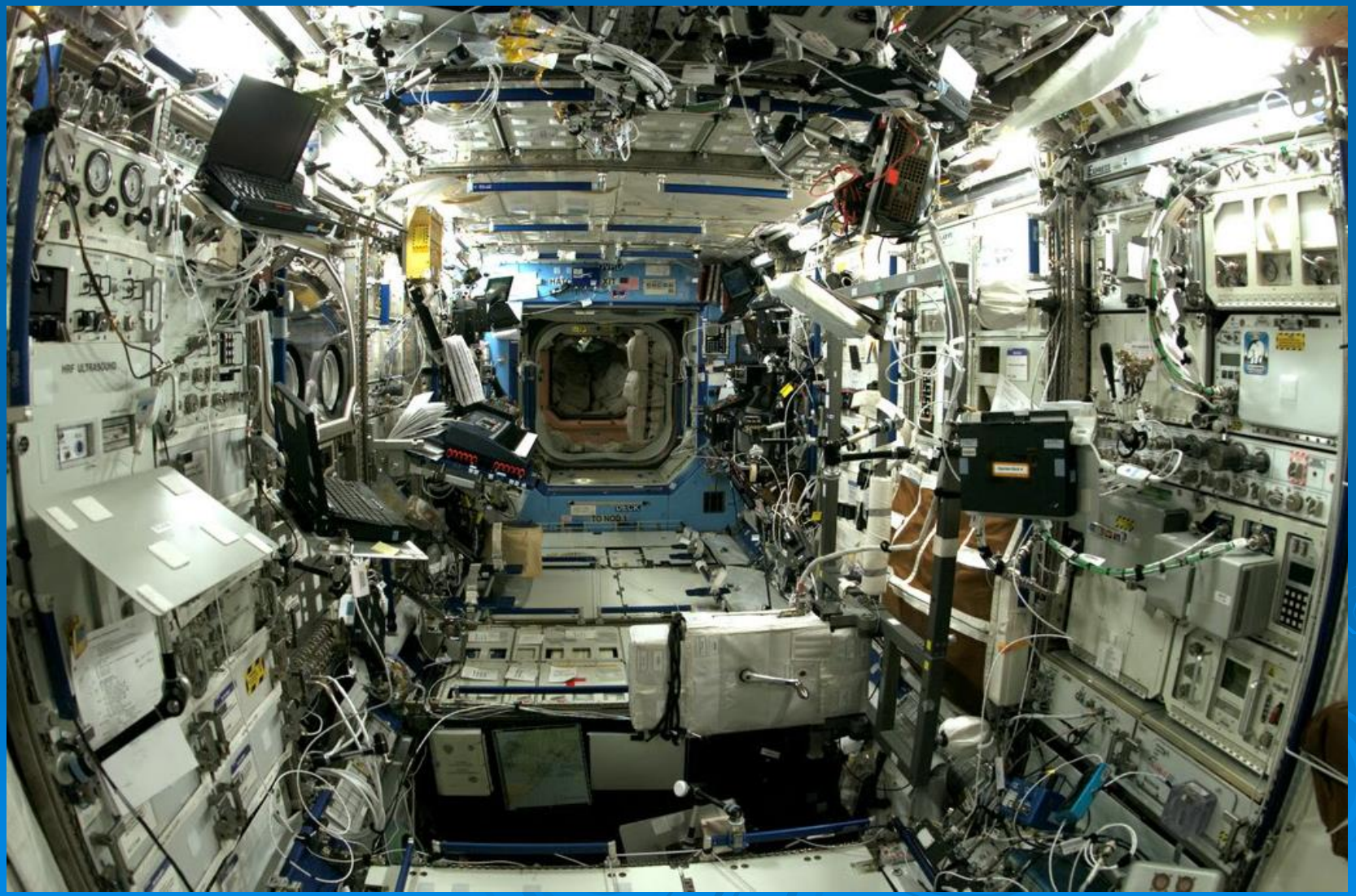
Reduce Cost

International Space Station

ISS Water Recycling System

Concept to Practice

It is one thing to talk about what could be done but entirely another to make it work



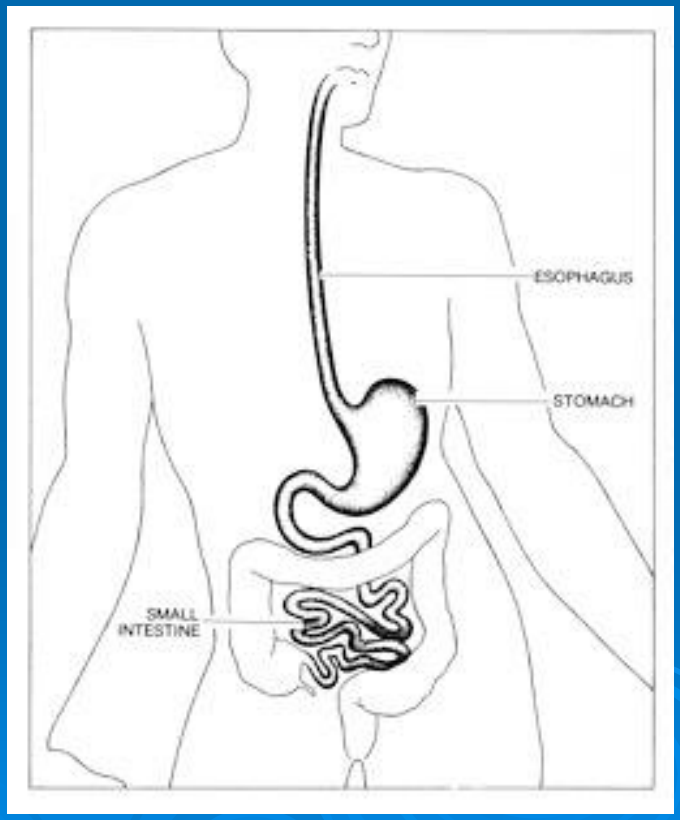
Mars

Reliability – A new Direction

Plant Root Zone Model

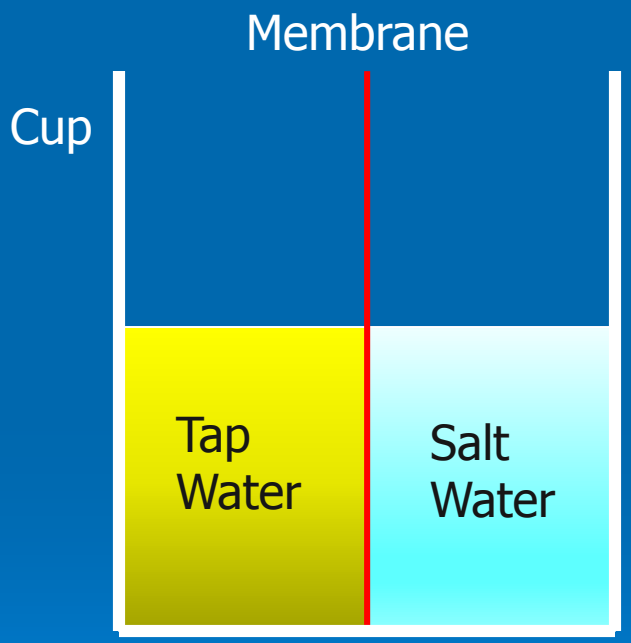
https://commons.wikimedia.org

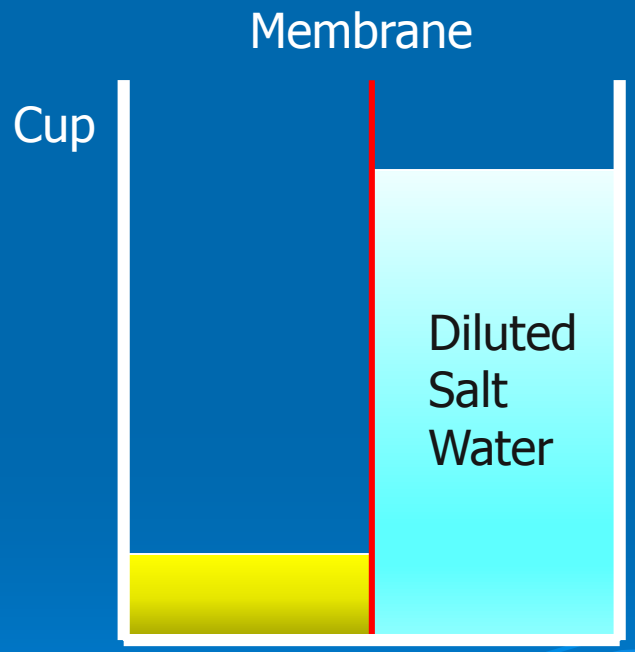
Human Intestine Model



https://commons.wikimedia.org

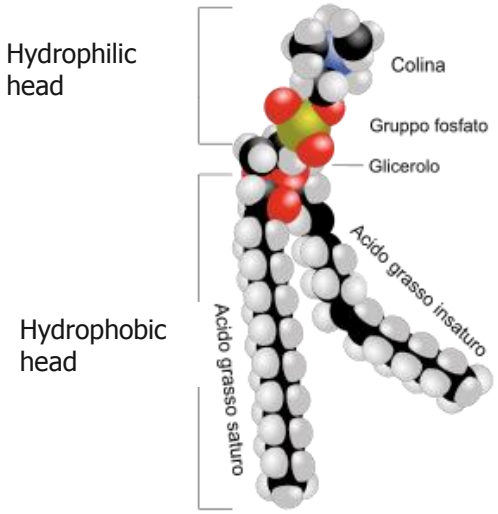
Forward Osmosis



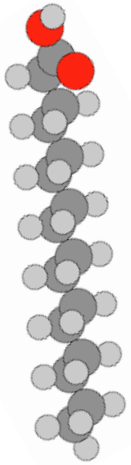


Lipid and Fatty Acids Membranes

Phospholipid

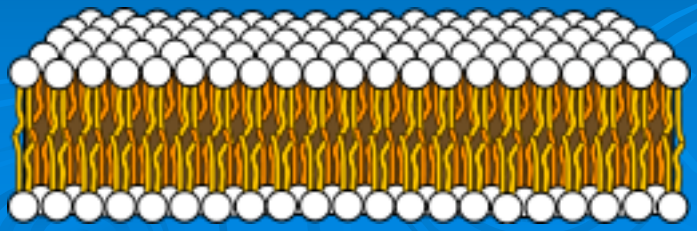


Fatty Acid - Palmitic



https://commons.wikimedia.org

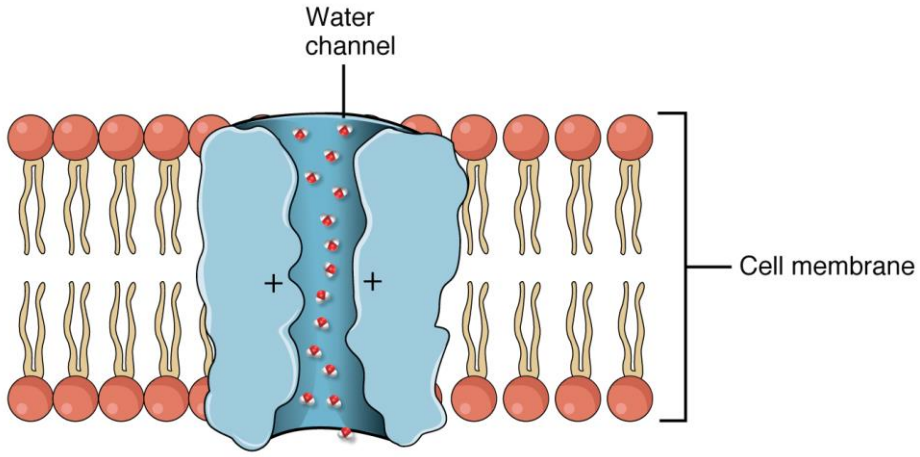
Lipid Bilayer



https://commons.wikimedia.org

Aquaporin Membranes

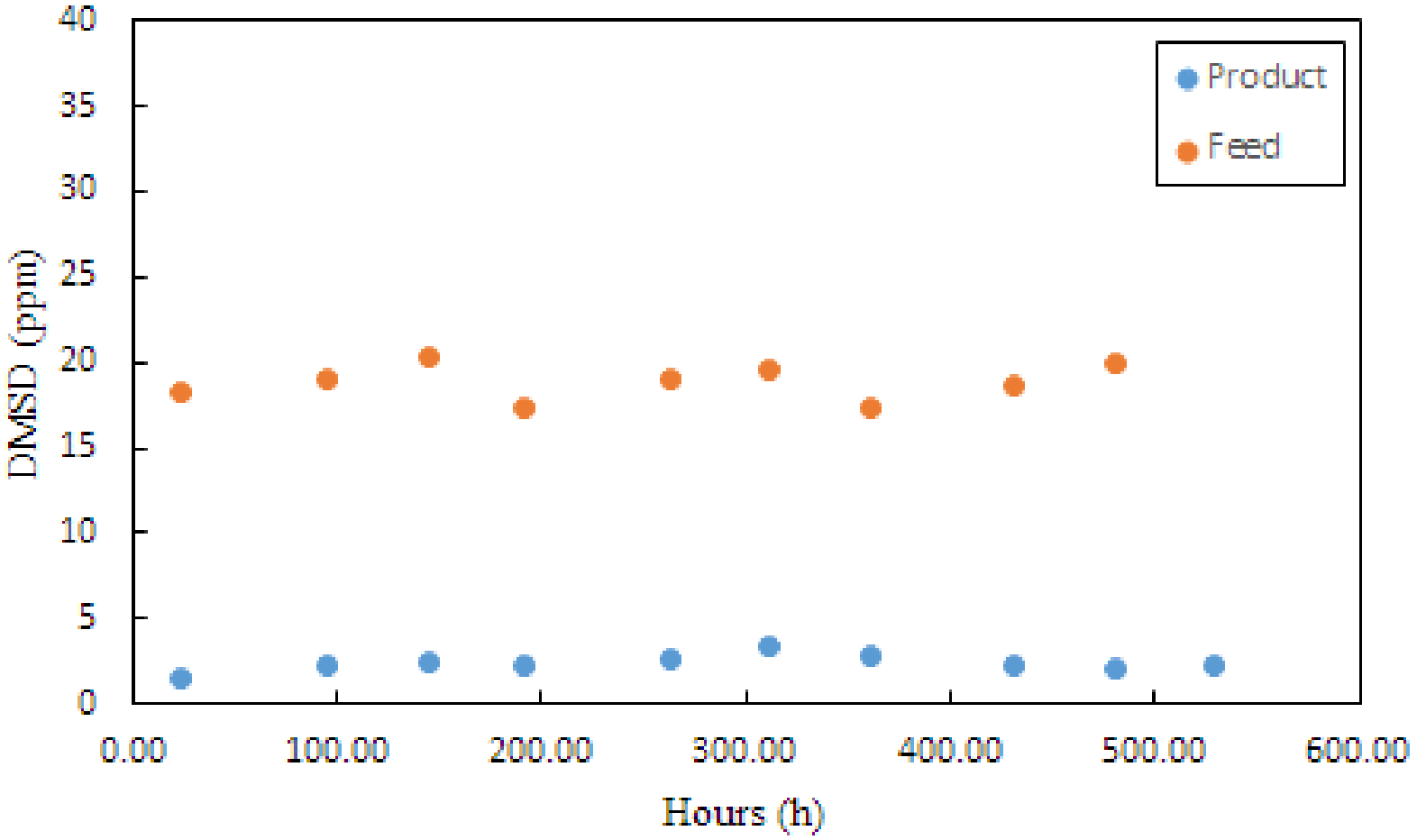
- Aquaporins are integral cell membrane proteins that serve as channels in the transfer of water.
- This protein provides a structured inner pore that has a internal + charge.
- In mammalian cells, more than 10 variations have been identified.
- Aquaporins can be embedded into lipid membranes and used in water purification modules.



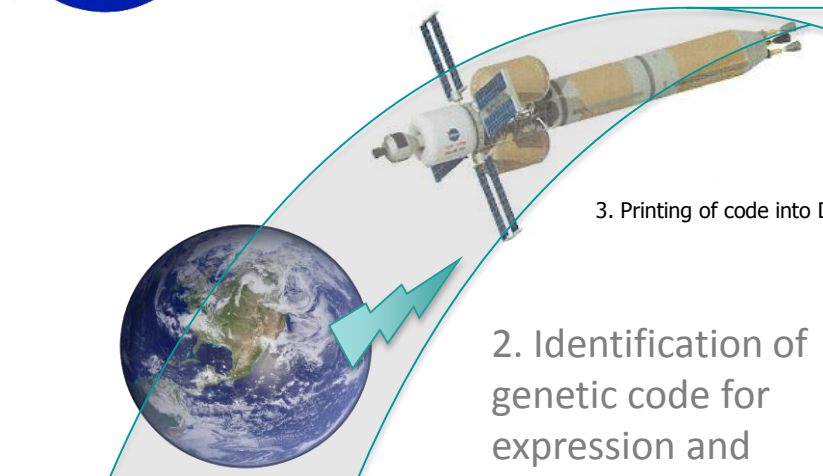
Structure of aquaporin membrane protein

Commercially available Aquaporin LLC. membrane module

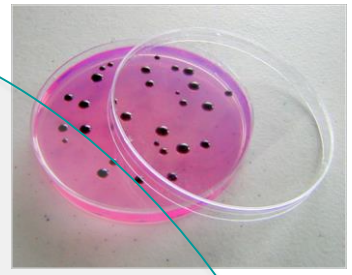
Dimethylsilanediol (DMSD) Analysis



Synthetic Drug Delivery



3. Printing of code into DNA in flight.



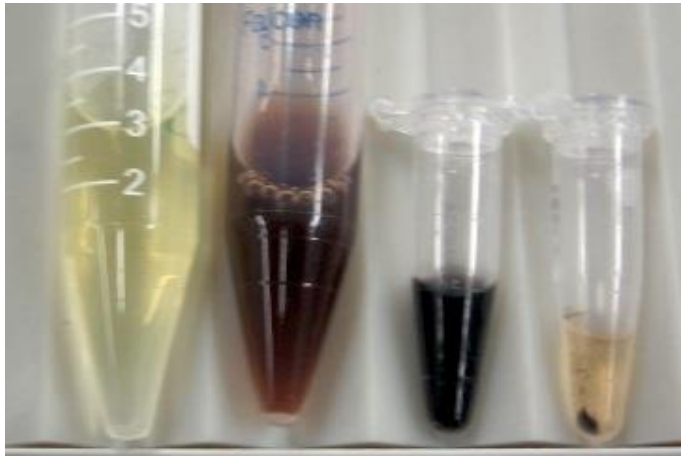
2. Identification of genetic code for expression and transmission of code from Earth to space.

5. Growth of engineered organism, production of target compound and purification of drug.

1. Diagnosis from Earth using telemedicine

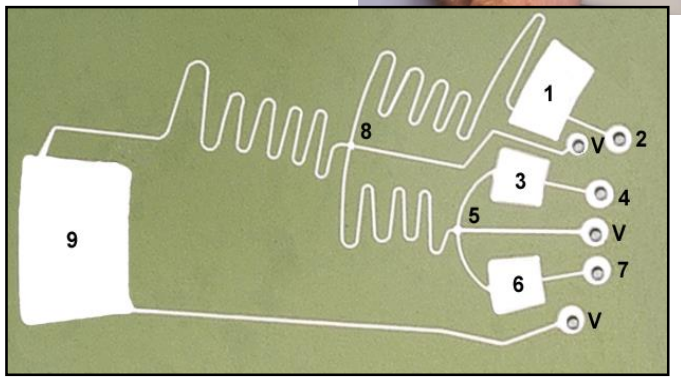
6. Therapeutic use of synthetic drug during flight.

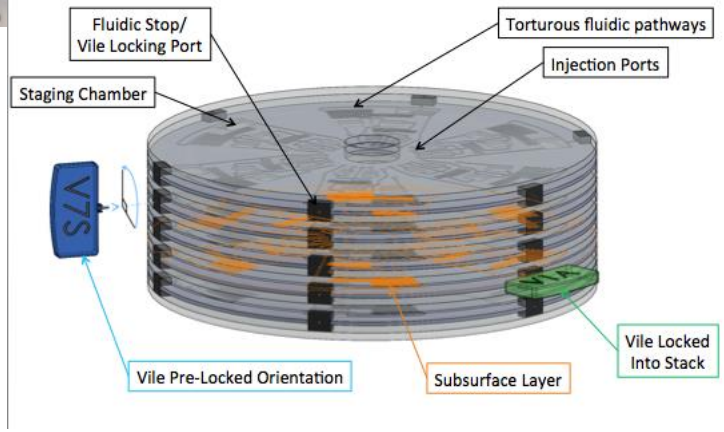
Synthetic Drug Synthesis



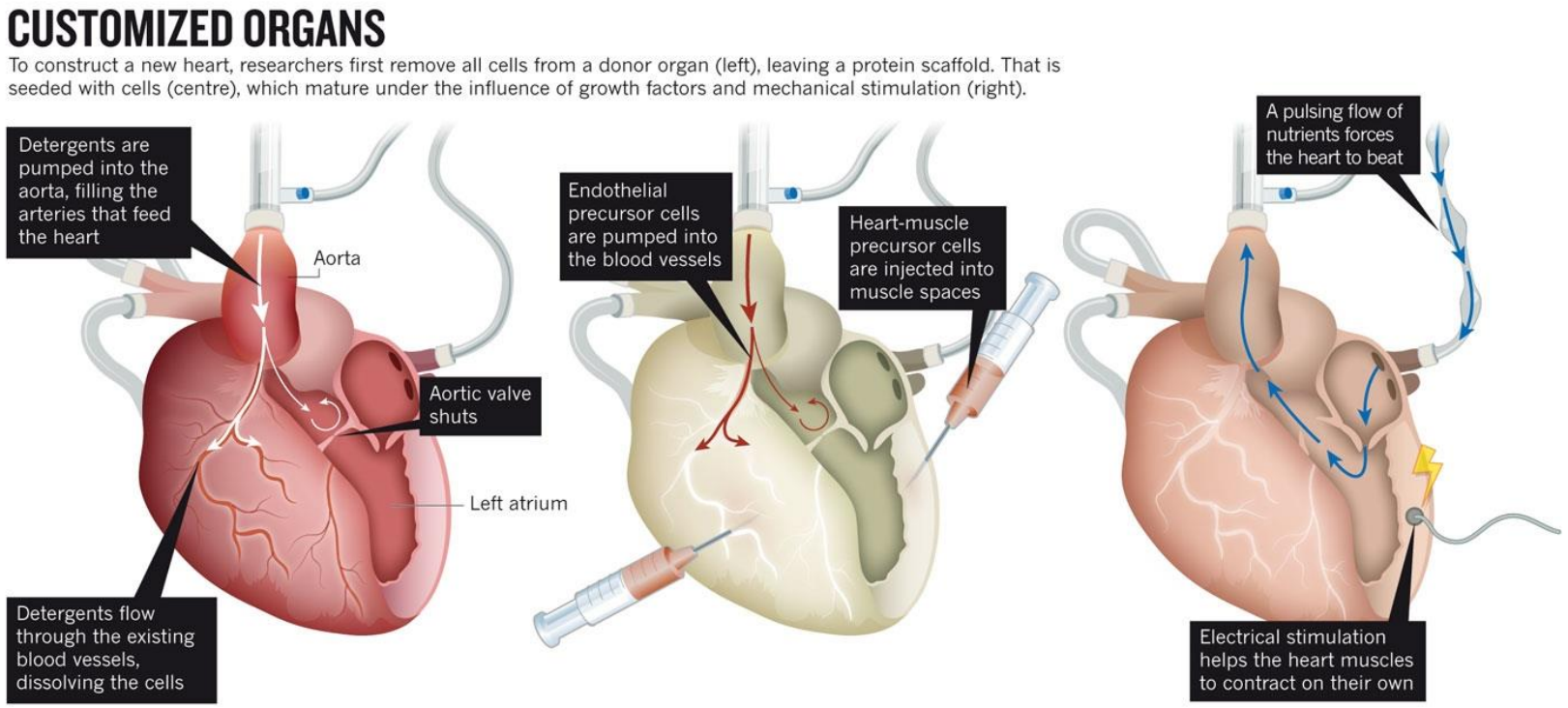
melanin purification

rotating disk analytical system (RDAS)

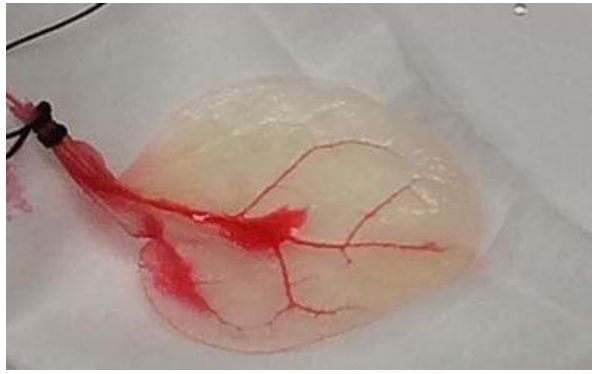




Bio Pumps



- Doris A. Taylor - Texas Heart Institute



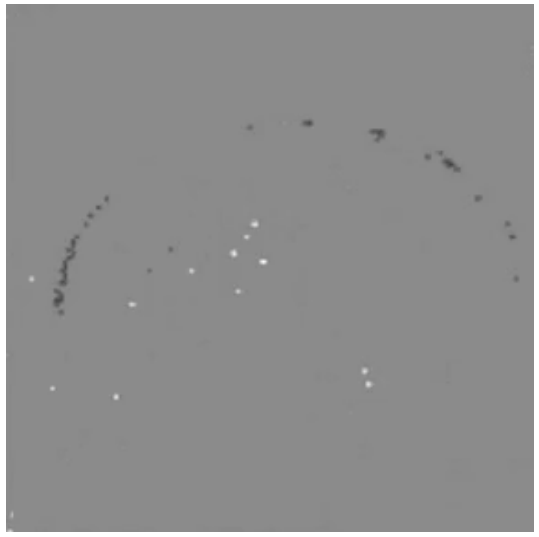
Glenn Gaudette, Worcester Polytechnic Institute uses the same process to convert spinach leafs into cardiac scaffolds.

In the future 3 D printed scaffolds could provide bases for fully artificial structures.

Bio Imaging

Chris Voigt, University of California in San Francisco

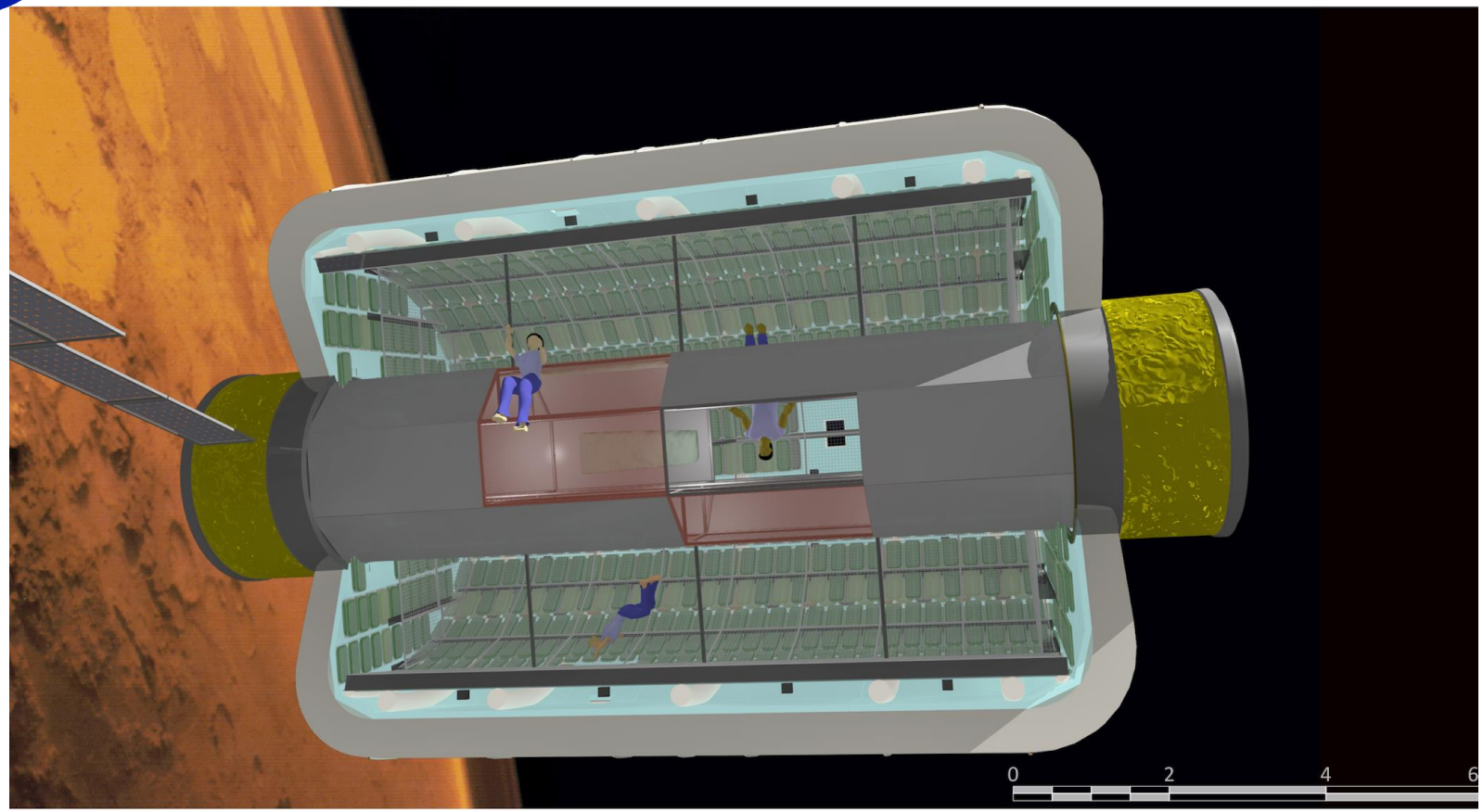
Uses inserted genes from blue-green algae into the cell membrane of the *E. coli*. One gene codes for a protein that reacts to red light. Once activated, that protein acts to shut down the action of a second gene. This switch-off turns an added indicator solution black. Delivers a resolution of 100 megapixels per square inch.

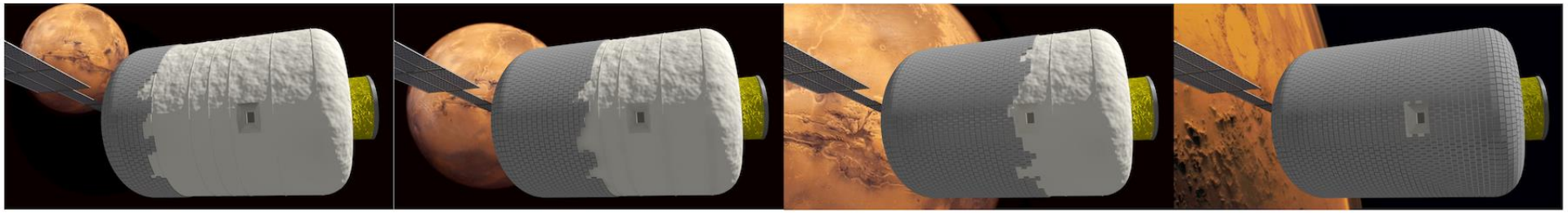


Tobi Delbruck, iniLabs

Uses traditional software approach to simulate function of retina.

The Living Habitat





STANDARD W.W. BAG UNIT
POLYETHYLENE BAG WITH ONE OR MORE SPECIALIZED MEMBRANES

BAG: 25 CM x 50 CM
POUCH: 22.5 CM x 45 CM

INDIVIDUAL W.W. BAGS ARRAYED IN POCKETED MESH PANEL
MESH ALLOWS AIR + LIGHT TO REACH BAGS

IN/OUT PORTS W/TUBES

SEWN SEAM SEPARATING POCKETS

W.W. BAGS SECURED IN INDIVIDUAL MESH POCKET AFFIXED TO OPEN MESH BACK PANEL

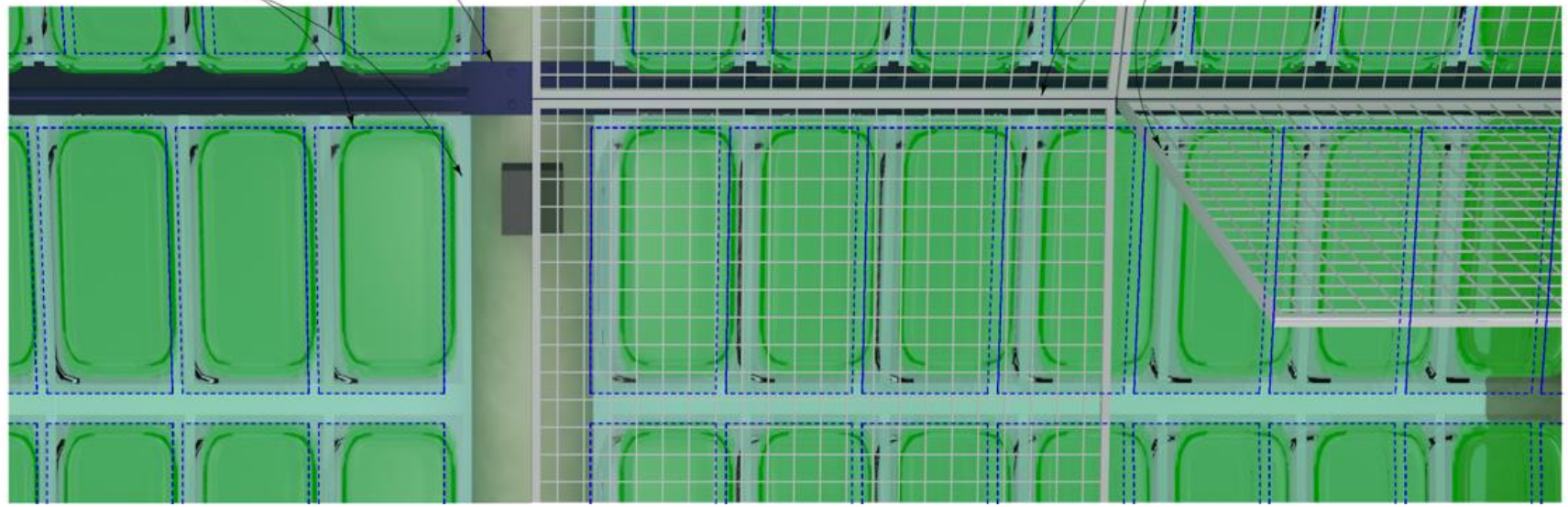
SNAPPED CLOSURES AT TOP AND BOTTOM OF EACH POCKET FOR SECURE ACCESS

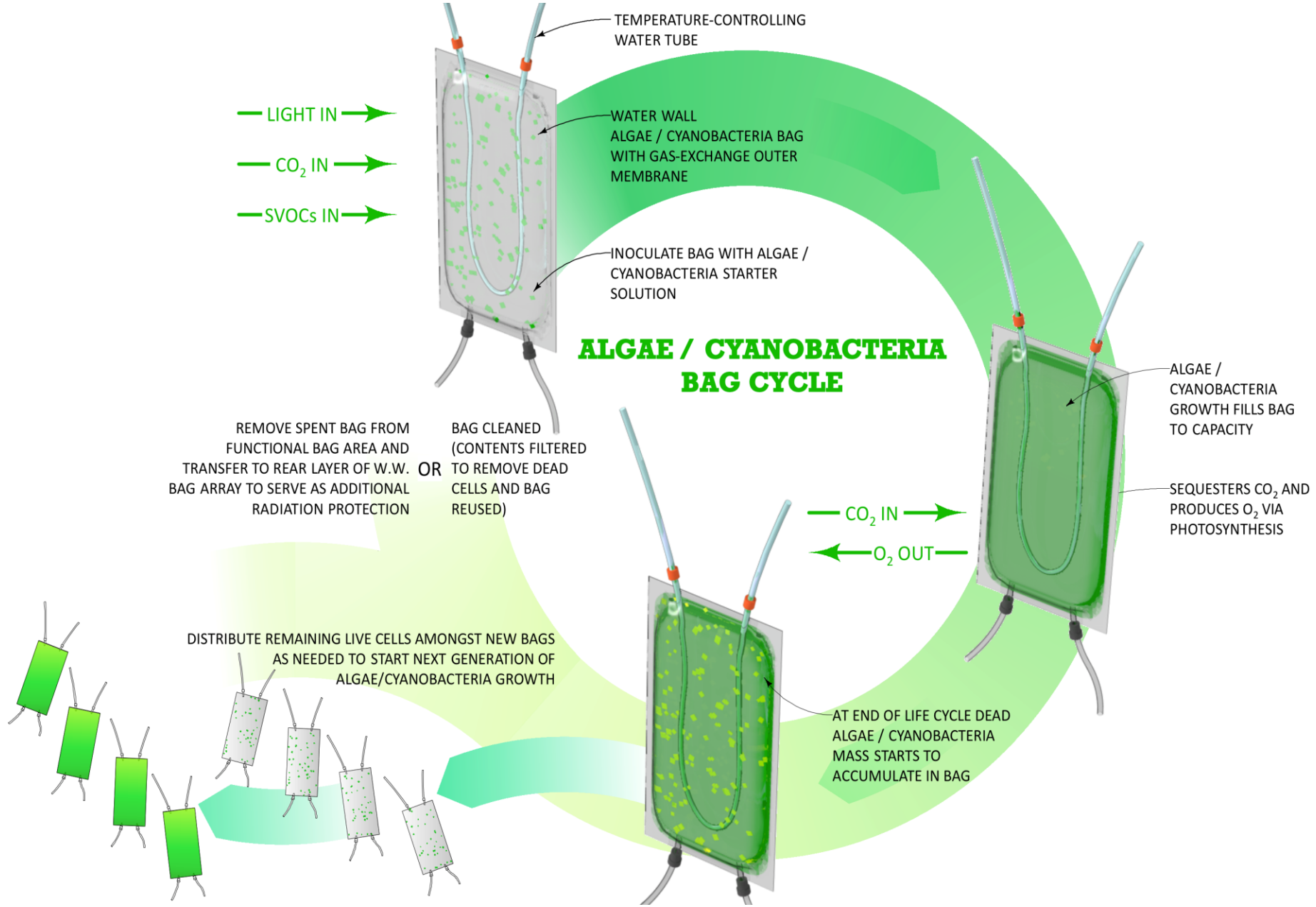
T-BEAMS SPAN BETWEEN INNER CURVATURE OF RIGIDIZED HOOP STRUCTURE. T-BEAM FLANGES ABUT, WHILE STANDOFF WEB IS INTERRUPTED FOR TUBE AND LIGHTING RACEWAY

FRONT AND BACK LAYERS OF ARRAYED BAGS OFFSET TO PROVIDE OVERLAP AT EDGES + PROVIDE CONTINUOUS RADIATION PROTECTION

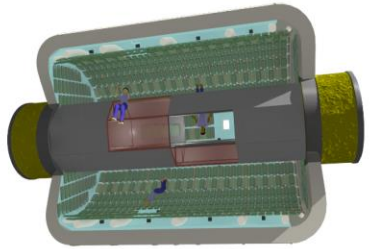
HARD OPEN-GRID PANELS PROTECT ARRAY OF W.W. BAGS. PANEL HINGED AT T-BEAM STANDOFF WEB FOR ACCESS

WATER WALLS BAG INSTALLATION




TEMPERATURE-CONTROLLING WATER TUBE
LIGHT IN
CO_2 IN
SVOCs IN
WATER WALL ALGAE / CYANOBACTERIA BAG WITH GAS-EXCHANGE OUTER MEMBRANE
INOCULATE BAG WITH ALGAE / CYANOBACTERIA STARTER SOLUTION
ALGAE / CYANOBACTERIA BAG CYCLE
ALGAE / CYANOBACTERIA GROWTH FILLS BAG TO CAPACITY
SEQUESTERS CO_2 AND PRODUCES O_2 VIA PHOTOSYNTHESIS
CO_2 IN
O_2 OUT
AT END OF LIFE CYCLE DEAD ALGAE / CYANOBACTERIA MASS STARTS TO ACCUMULATE IN BAG
REMOVE SPENT BAG FROM FUNCTIONAL BAG AREA AND TRANSFER TO REAR LAYER OF W.W. BAG ARRAY TO SERVE AS ADDITIONAL RADIATION PROTECTION
OR
BAG CLEANED (CONTENTS FILTERED TO REMOVE DEAD CELLS AND BAG REUSED)
DISTRIBUTE REMAINING LIVE CELLS AMONGST NEW BAGS AS NEEDED TO START NEXT GENERATION OF ALGAE/CYANOBACTERIA GROWTH

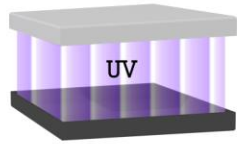
WASTEWATER BAG CYCLE



GRAYWATER
FROM CREW + SYSTEMS

FRESH WATER RETURNED
FOR HABITAT USE

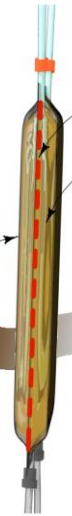
WATER UNDERGOES
UV TREATMENT



SALINE WATER
DESALINATED AT
REVERSE OSMOSIS
(R.O.) PUMP

SALINE SOLUTION IS
DILUTED AS WATER IS
PULLED ACROSS
MEMBRANE

SALT RETURNED TO REPLENISH
SALINE DRAW

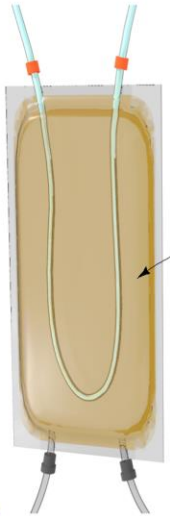


F.O. MEMBRANE

HIGHLY CONCENTRATED
SALINE SOLUTION AT DRAW
SIDE PULLS WATER ACROSS

WASTEWATER

WATER MOVES
ACROSS MEMBRANE;
CONCENTRATED
SALT BRINE
LEFT BEHIND



DIRECTED TO WASTEWATER
BAG WITH FORWARD
OSMOSIS (F.O.) MEMBRANE

SOLID DRIED MASS IN W.W. BAG
CAN BE PLACED, OUT OF SIGHT, IN
CABIN TO PROVIDE ADDITIONAL
MASS FOR RADIATION PROTECTION

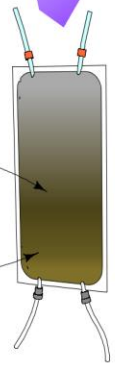
BAG PASSED THROUGH VACUUM
CHAMBER W/ODOR CONTROL TO
COMPLETELY DRY WASTE

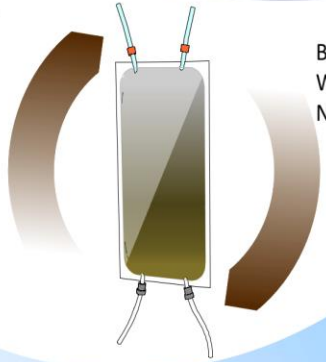
BAG CONTENTS LEFT TO
DECOMPOSE UNTIL
NON-BIOLOGICALLY ACTIVE

BLACKWATER
FROM CREW
SOLID WASTE

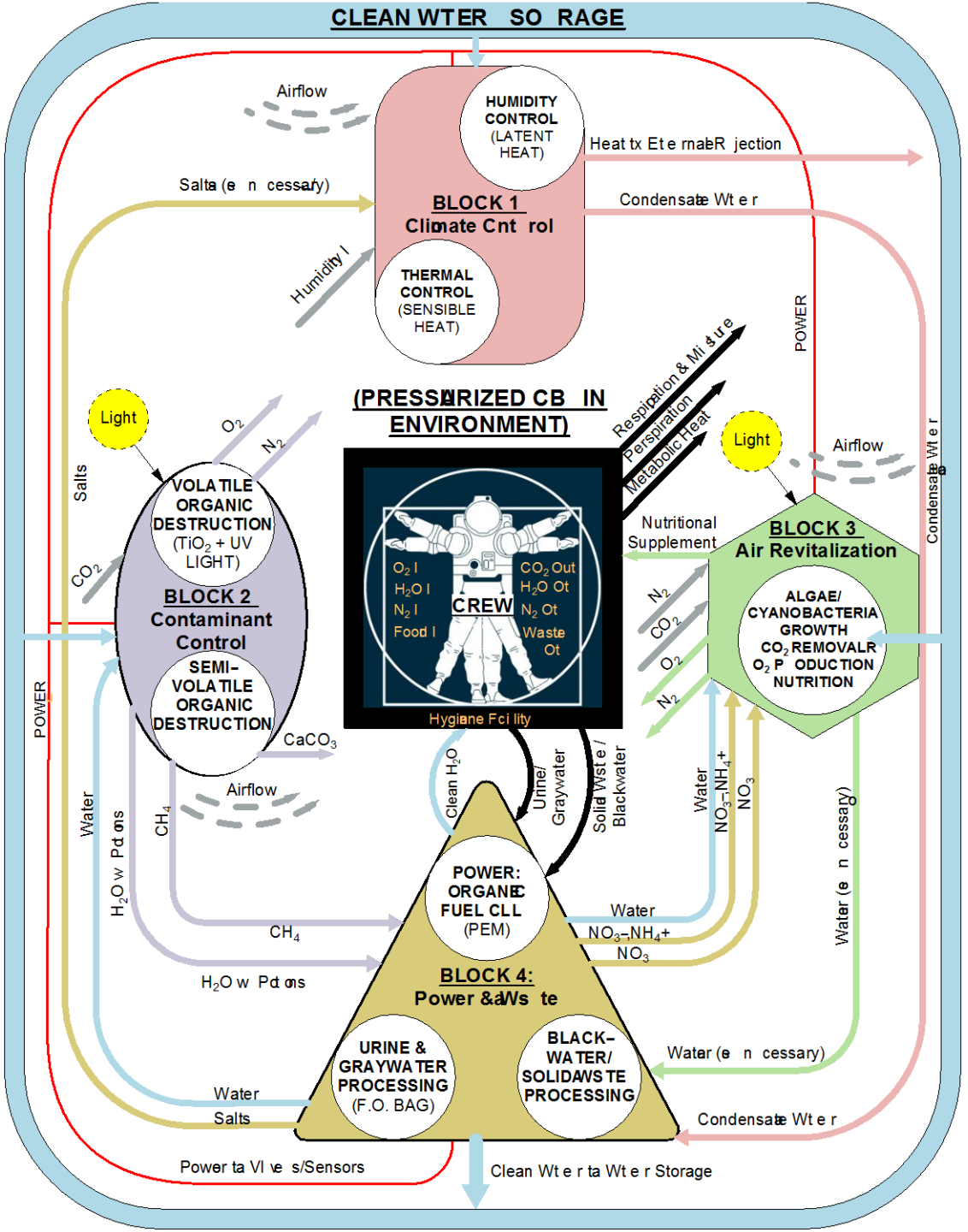
SPENT BAG FILLED WITH
BLACKWATER + CONCENTRATED
SALT BRINE SLURRY

SALINE SOLUTION AT DRAW SIDE
PULLS WATER OUT OF WASTE





BAG REFILLED
W/WASTE + REUSED
NUMEROUS TIMES



Water Wall integration Diagram