UNIT 1

: SEED

ISAAC M. WILHELM

Submitted in partial fulfilment of the requirements for the degree of Masters in Biodesign 2020/21 Central Saint Martins UAL

Tutors:
Nancy Diniz, Course Leader MA Biodesign CSM UAL
Alice Taylor, Lecturer Biology and Living Systems, CSM UAL

CONTENTS

DESIGN PROJECTS

1a: Dissecting Biological Machines // Dissection, Observation + Documentation

Dissection Documentation: African Sharptooh Catfish 6

Microscopic Observation: African Sharptooth Catfish 10

1b: Dissecting Biological Machines // Digital Image Analysis + Interpretation

Digital Image Analysis: Skeletonized Leaves 18

Interpretation: Microscope Slides 22

Observation: Noble False Widow 26

Bacteria Cultures: Pigeon Sh!t 28

2: Artificial Biological Machines // Design Translation

Speculative Design: The Know-It-All 34

Designing with Kudahuvadhoo // Coastline Remediation

Design Solution: aquaFandita 46

Experiment: Cranbrook Mangrove Nursery 58

Experiment: Young Coconut Filament 62

Experiment: Introductory Biomaterials Exploration 63

Experiment: Biocement 64

Experiment: Copal Resin Coating 67

Experiment: *S. pasteurii* Calcification 68

Experiment: Calcium Carbonate Crystallization 70

EXPERIMENTS

Grow Lab: *Vibrio fischeri* // Bioluminescent Bacteria

Documentation + Observation: Simulated Squid Light Organ 82

Grow Lab: *Physarum polycephalum* // Slime Mold

Documentation + Observation: Group Thinking + Networking 86

Home Lab: Algae Bioremediation

Documentation + Observation: What's Eating Grandma? 90

Home Lab: Bacterial Growth Plates

Documentation + Observation: Search for the Wrinkly Bacteria 98

Home Lab: *Agaricus bisporus* // Baby Button Mushroom Mycelium Plates

Documentation + Observation: My My Mycelium Failures 104

Home Lab: *Trametes versicolor* // Turkey Tail Mushrooms

Documentation + Observation: Highland Hanger + Fungi Friends 108

Home Lab: *Bacillariophyceae* // Diatoms

Documentation + Observation: Comparative Bog Diatom Analysis - Incomplete 112

WORKSHOPS

GANs // Generative Adversarial Networks

Documentation 117

Grasshopper // Parametric Design Scripting

Documentation 119

Physical Computing - DIY Incubator // Audrino Hardwiring + Scripting

Documentation 121

Biomimicry // Biological Brainstorming

Documentation 123

BIBLIOGRAPHY

Comprehensive References 124

In dedications to my forefathers and name bearers, St. Isaac Jogues and Isaac Newton. Your tenacity to convert the nonbelievers and push the boundaries of fundamental reality to Enlightenment are an inspiration. Sir Newton, I squirmed as a child when playground bullies teased your name, proclaiming “I’m not named after him!” St. Isaac, although I am now agnostic, I will forever be inspired by your courage to civilize barbaric Native American war-tribes through Christian generosity. Now proud to share a forename, may my life’s journey in Biodesign prove but at least a fractional exponent of your global impacts towards a better future.

DESIGN PRO

JECTS

1a: DISSECTING BIOLOGICAL MACHINES

DISSECTION, OBSERVATION + DOCUMENTATION

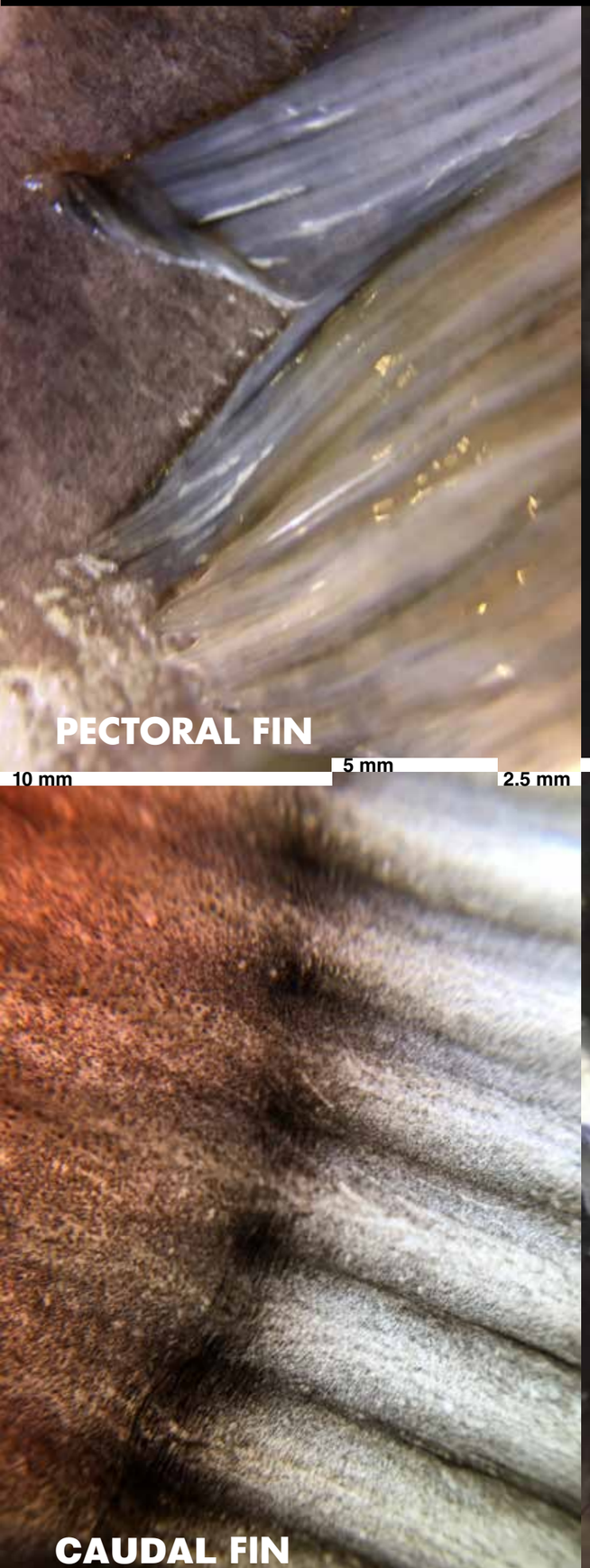
CLARIAS GARIEPINUS // AFRICAN SHARPTOOTH CATFISH

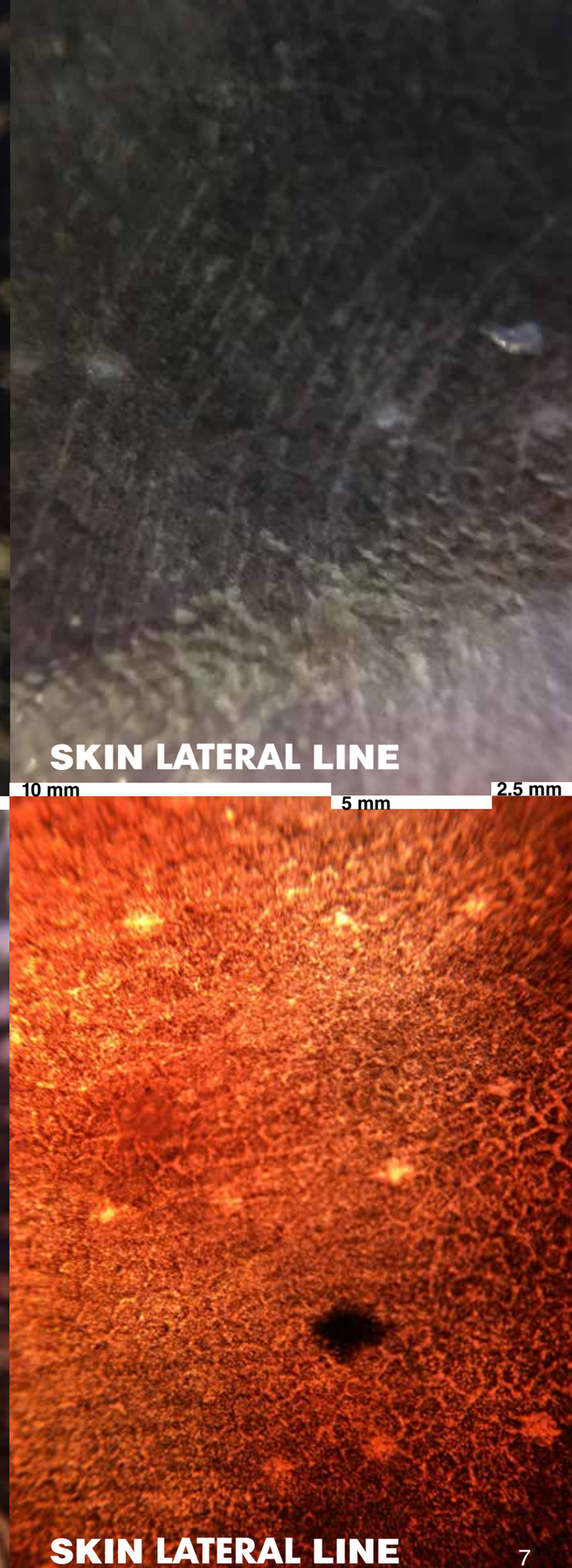
BIOLOGICAL BATTERIES: CATFISH ELECTRIC CELLS

Raised on a fish farm in the Netherlands before laying on ice at London's Billingsgate Fish Market, my specimen was haphazardly purchased shortly before dawn while wadding in fresh fish-juice water. The African Sharptooth Catfish (*Clarias Gariepinus*) is of particular interest for its ability to produce electrical currents. Native to Africa and the Middle East, the species generates an irregular discharge for a notably longer duration than other freshwater electric fish, at a range of 10-30 Hz for 5-260 ms; furthermore, electric pulses only occur during agitated states with multiple *Clarias Gariepinus* (Baron, 1994). Possessing tastebuds on its tongue, head, and lateral line, Dr. John Caprio of Louisiana State University states, "You can't touch any place on a catfish without touching thousands of taste buds…it's as if the tip of your tongue grew out and covered your body," (Freebeekeeper, 2012). How the fish produces this electric discharge is uncertain; however, there seems to be an electrical importance to ampullary organs located on the head and lateral lines of this catfish's skin. Supporting this belief, electrorecptor organs in the skin of certain fish species detect potential electrical differences (Peters, 2009).

In conclusion my interest in *Clarias Gariepinus*, and electric fish in general, is a curiosity in the structural efficiency of the physiological system responsible for electrical discharge. Specifically, could further research on catfish ultimately lead to biomimicking infrastructural systems that generate and transmit electricity more sustainably?

EXTERNAL ANATOMY: MACRO PHOTOS

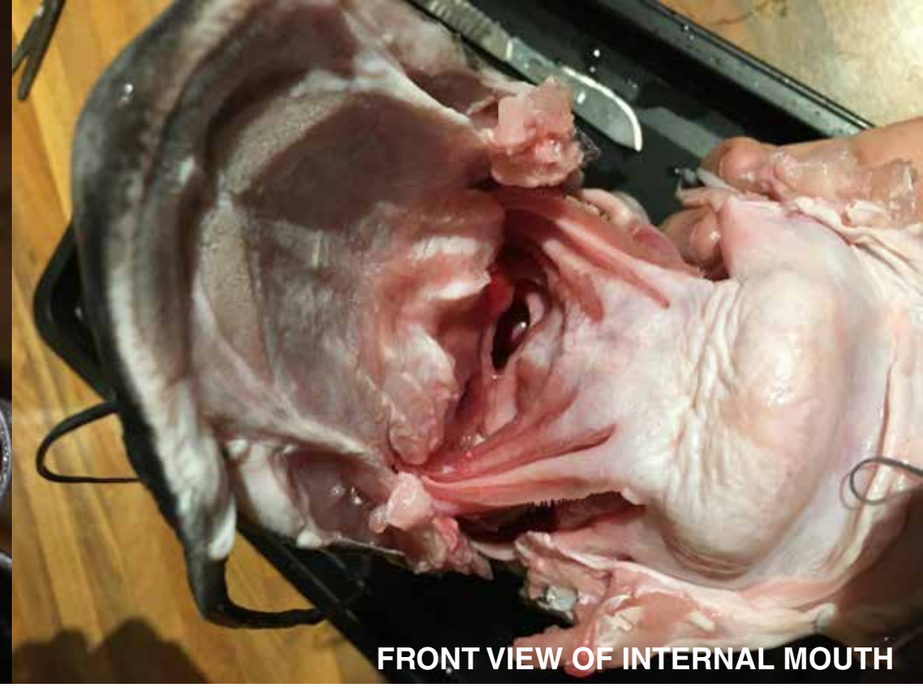




EXTERNAL ANATOMY

TOP VIEW OF EXTERNAL SKULL

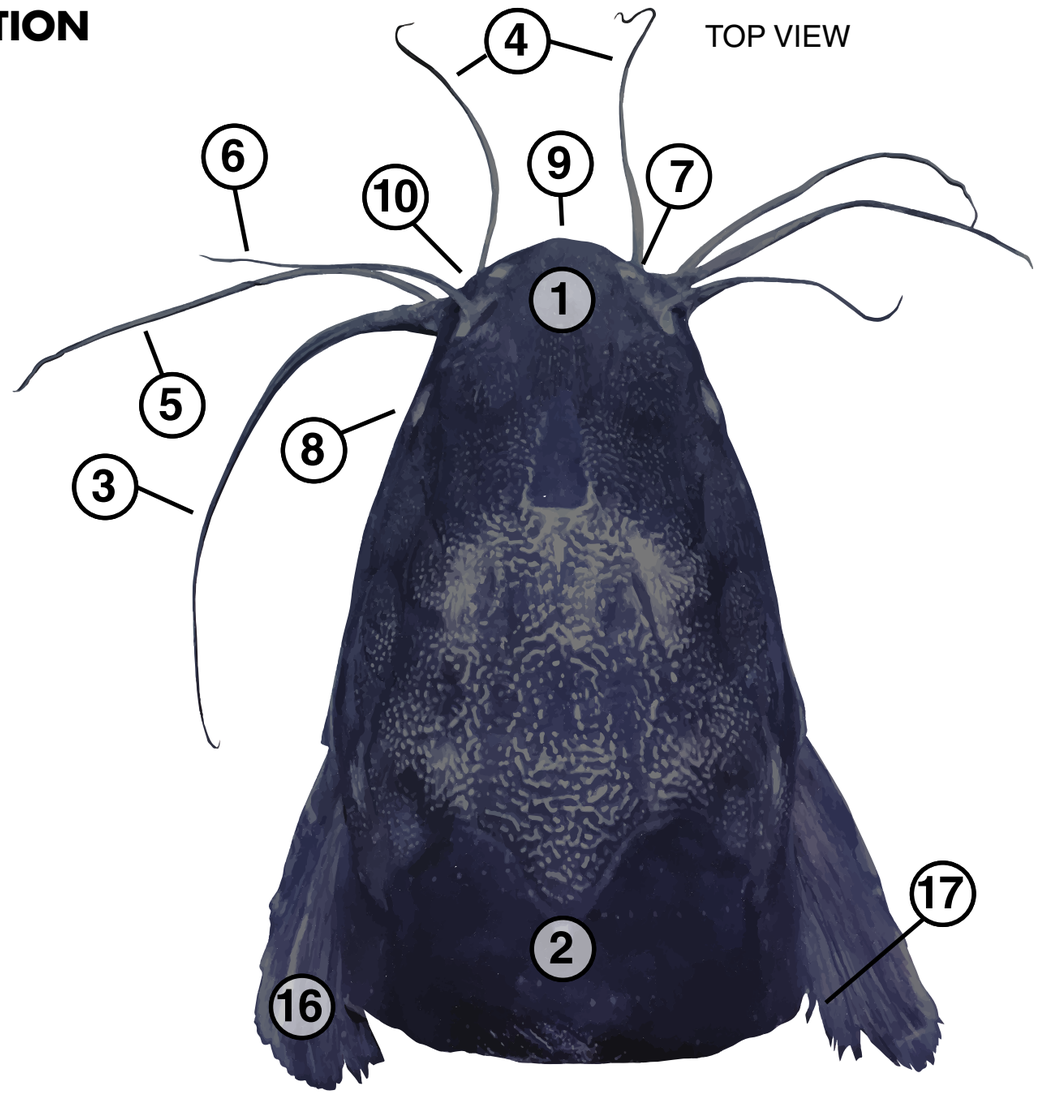
FRONT VIEW OF EXTERNAL MOUTH

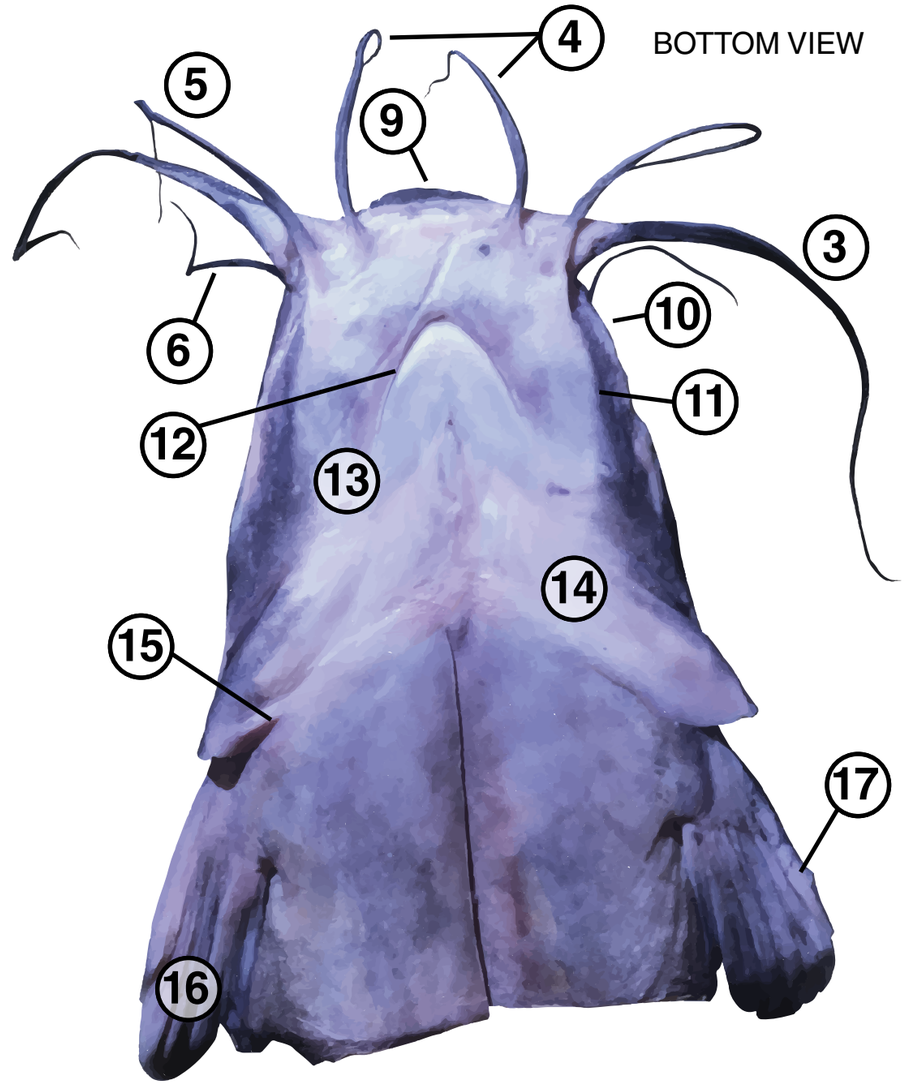


FRONT VIEW OF INTERNAL MOUTH

EXTERNAL IDENTIFICATION

1. Rostral Tip of Skull Roof
2. Claudal Tip of Skull Roof
3. Maxillary Barbel
4. Inner Mandibular Barbel
5. Outer Mandibular Barbel
6. Nasal Barbel
7. Olfactory Organs (Nostrils)
8. Eye
9. Premaxilla
10. Maxilla (Upper Jaw)
11. Mandible (Lower Jaw)
12. Hyoid
13. Preoperculum
14. Operculum (Gill Flap-Cover)
15. Branchiostegal Membrane
16. Pectoral Fins
17. Pectoral Spine

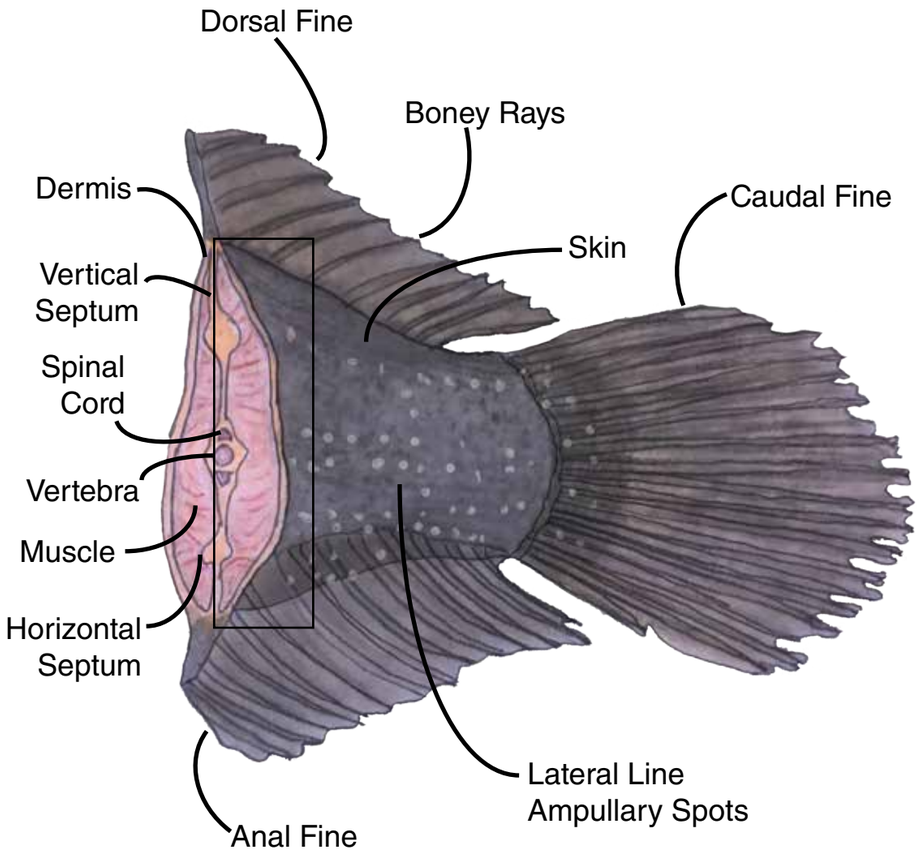




2cm 1 cm

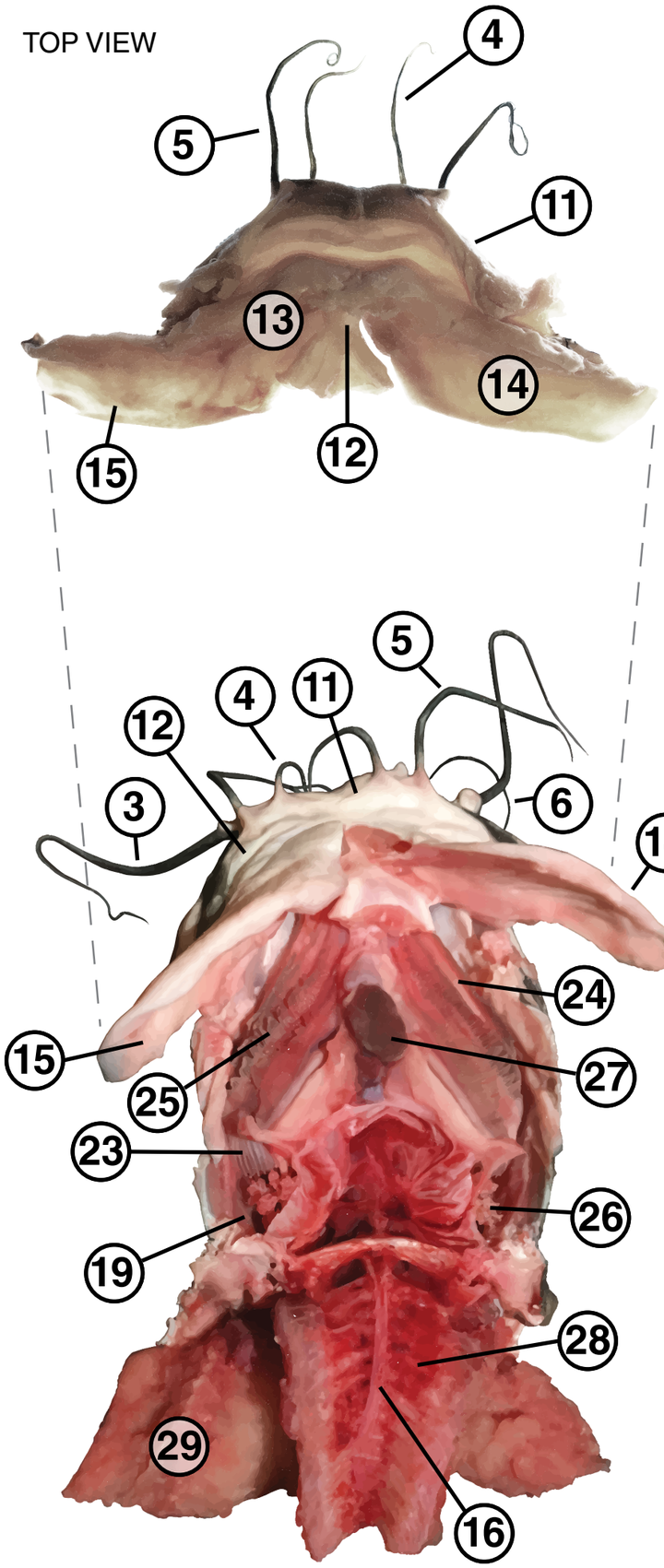
INTERNAL IDENTIFICATION

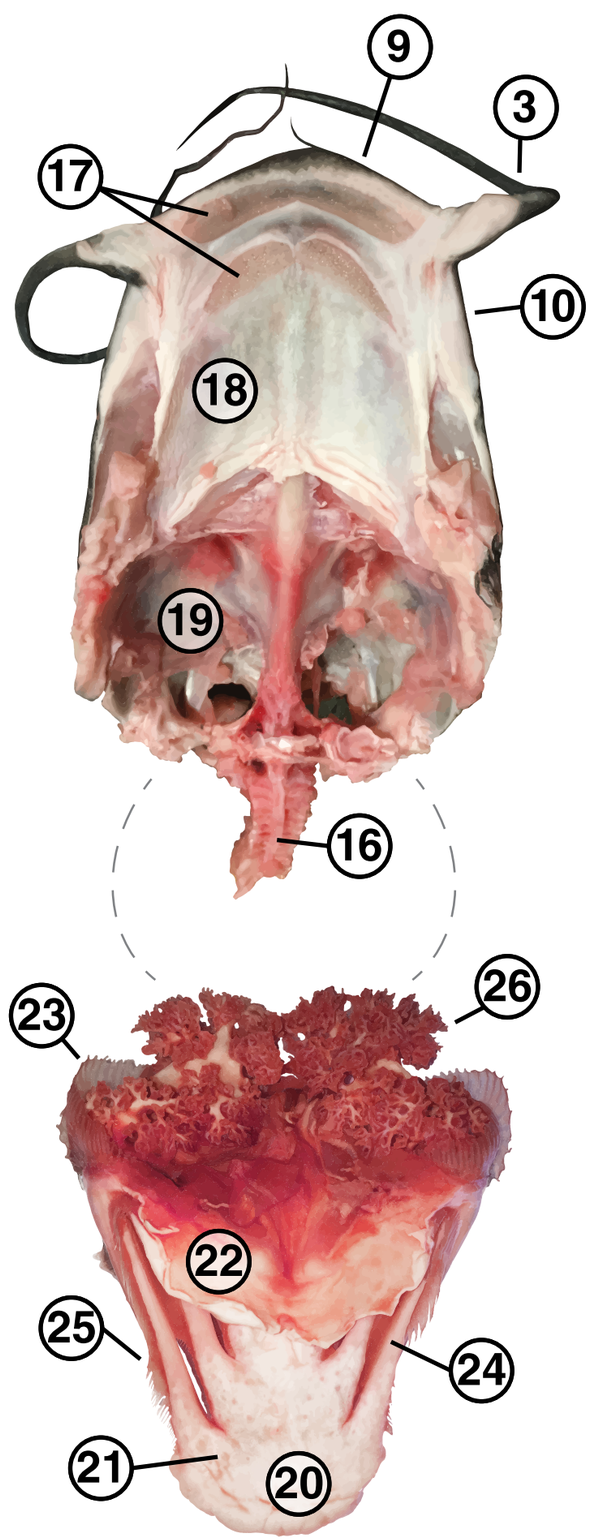
1. Rostral Tip of Skull Roof
2. Claudal Tip of Skull Roof
3. Maxillary Barbel
4. Inner Mandibular Barbel
5. Outer Mandibular Barbel
6. Nasal Barbel
7. Olfactory Organs (Nostrils)
8. Eye
9. Premaxilla
10. Maxilla (Upper Jaw)
11. Mandible (Lower Jaw)
12. Hyoid
13. Preoperculum
14. Operculum (Gill Flap-Cover)
15. Branchiostegal Membrane
16. Vertebral Column
17. Dentry (Teeth)
18. Roof of Oropharyngeal Chamber
19. Suprabranchial Cavity
20. Tongue
21. Tastebuds
22. Interbranchial Septum
23. Gill Fan
24. Gill Rakers
25. Gill Filaments
26. Arborescent Organs
27. Heart
28. Ribs
29. Muscle



VERTICAL SECTION SKETCH

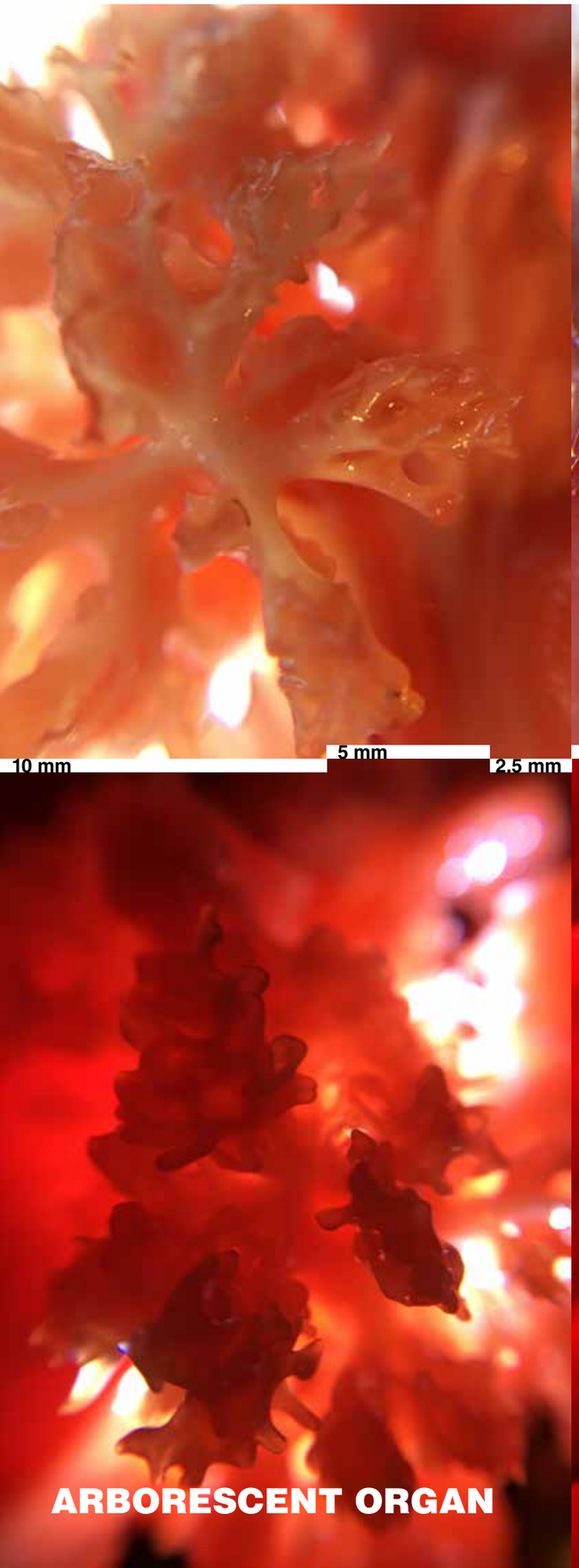
INTERNAL ANATOMY

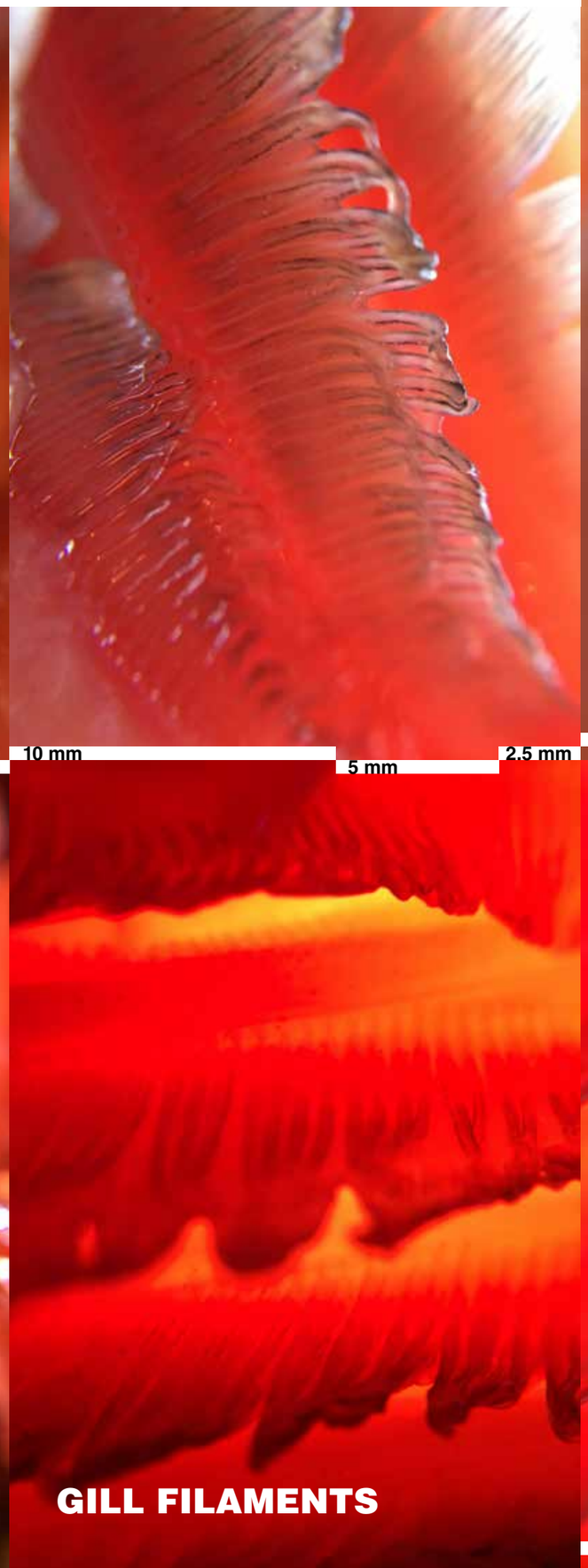


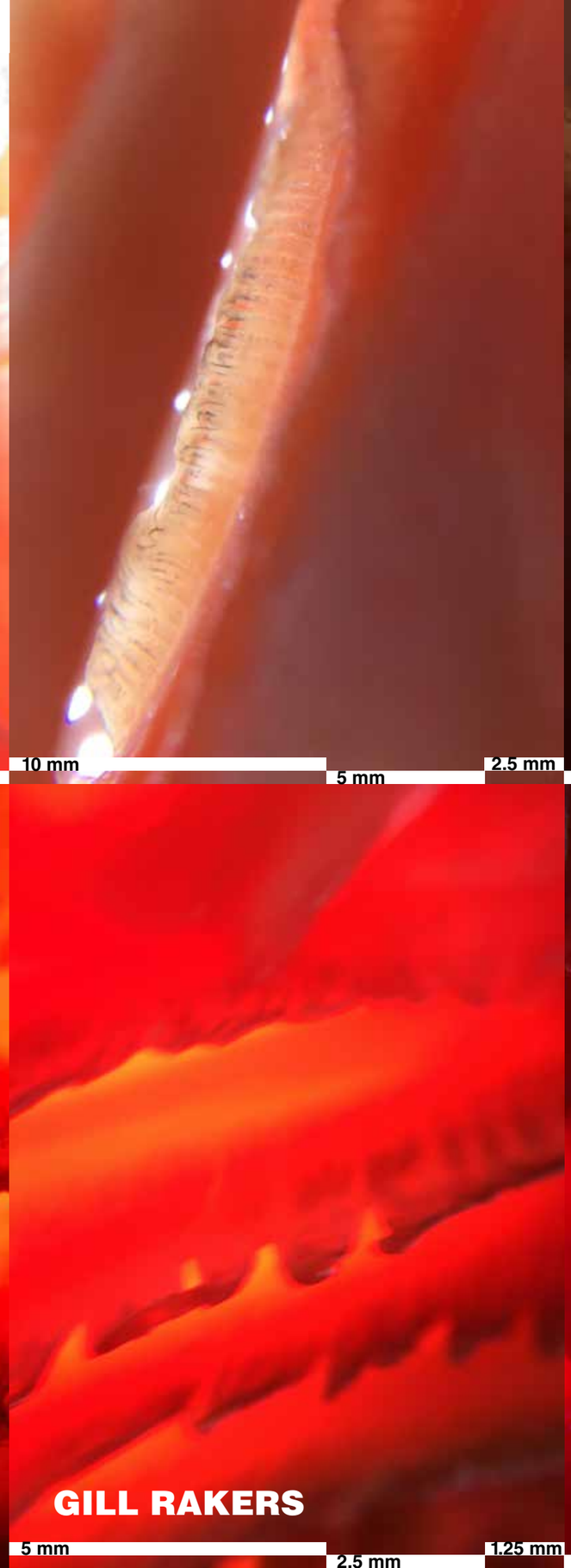


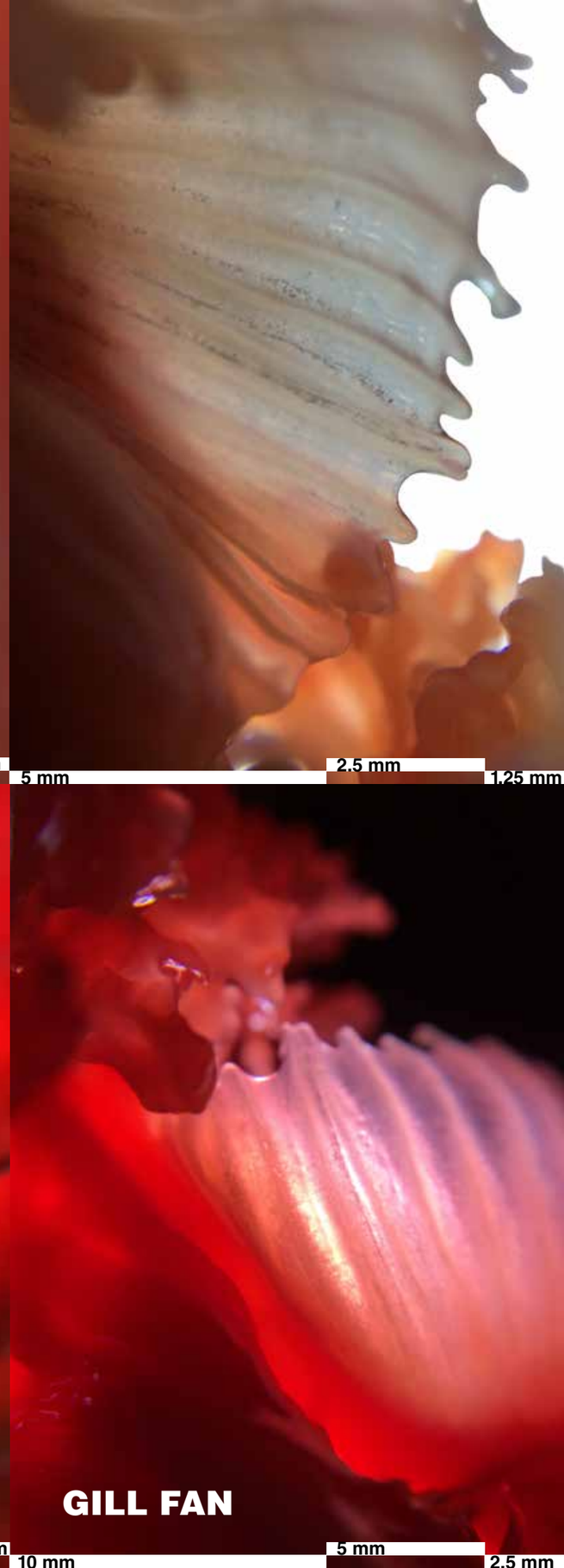
2cm 1 cm

RESPIRATORY ORGANS: MACRO PHOTOS



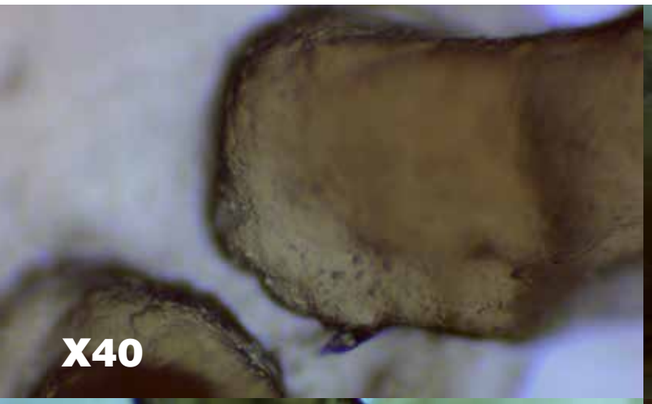


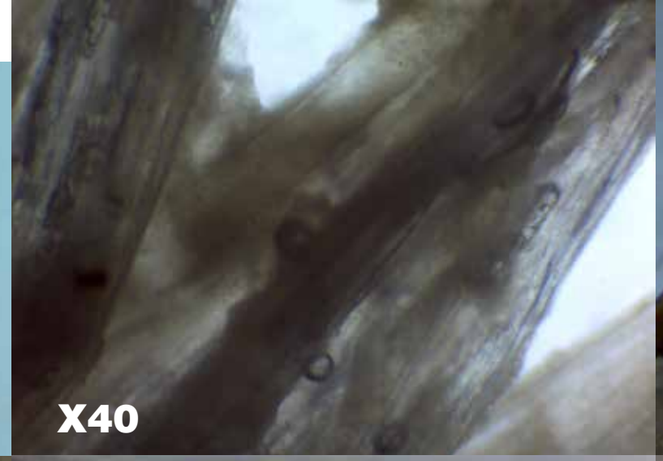


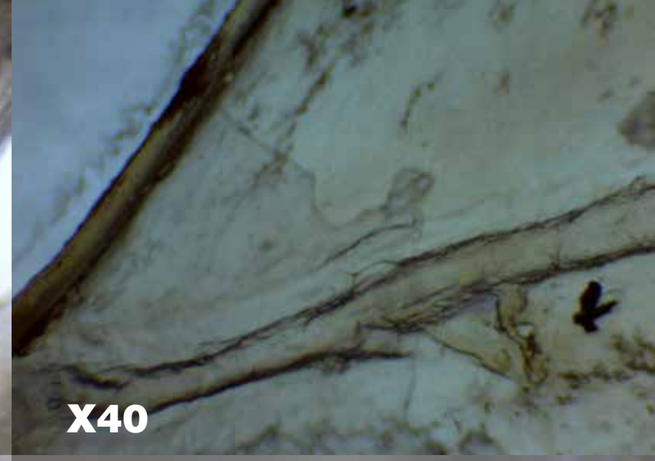


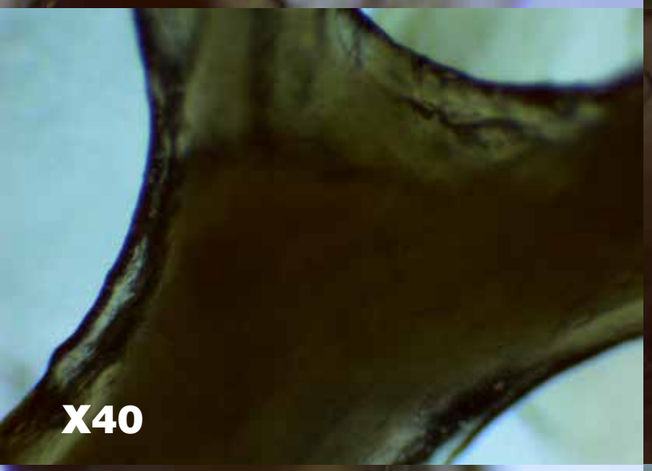
X40

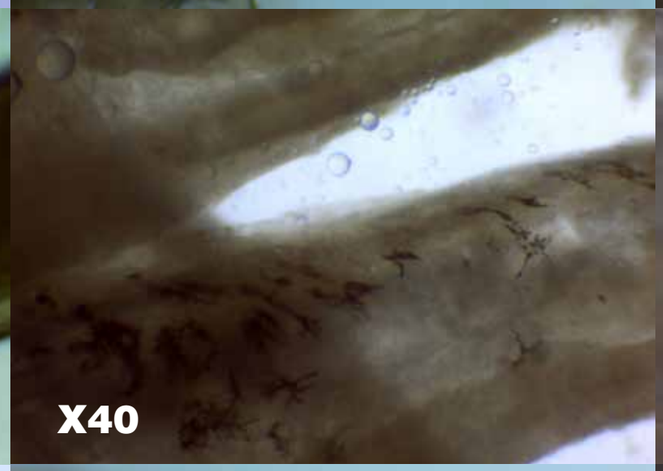
RESPIRATORY ORGANS: MICRO PHOTOS

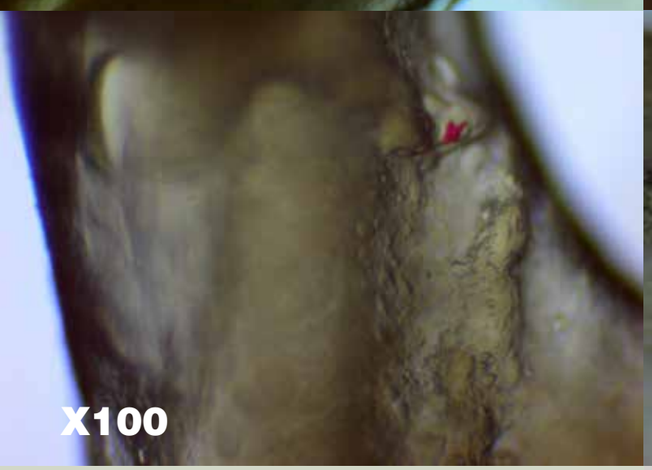


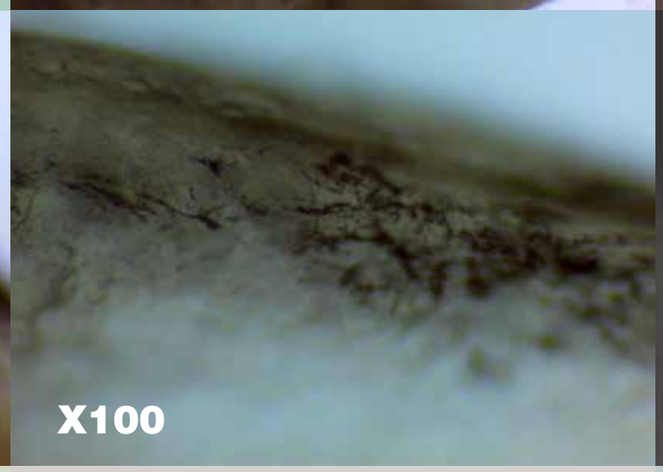












ARBORESCENT ORGAN

A pair of tree-shaped clusters structured with cartilage are located behind the gill rakers. Valcularised tissue on its surface has the ability to absorb oxygen directly from the atmosphere (de Graaf, 1996).

GILL FILAMENTS

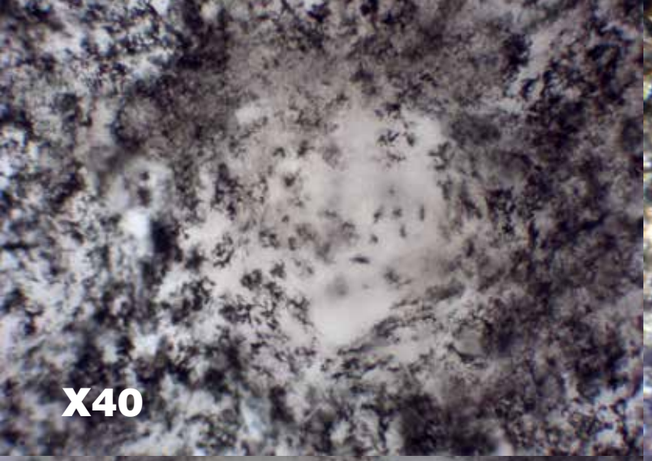
Filaments run along both sides of the gill arches. Each side is called a hemibranch; together a holobranch. Spiracles enlarge to allow water flow over the filaments. Ionoregulatory cells contained in its epithelium support the basic respiratory unit, lamellae (Wilson, 2002).

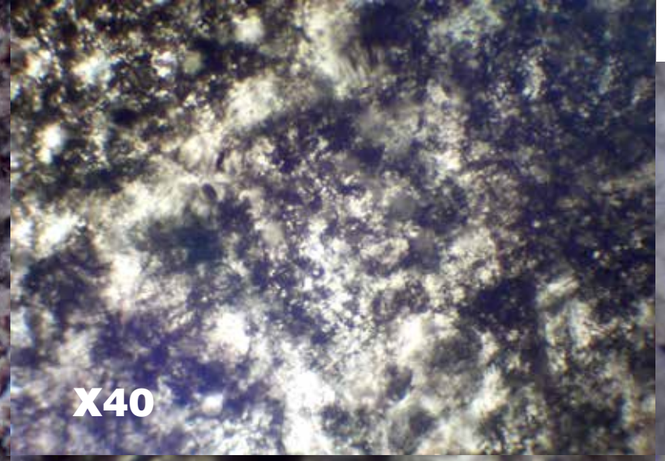
GILL RAKERS

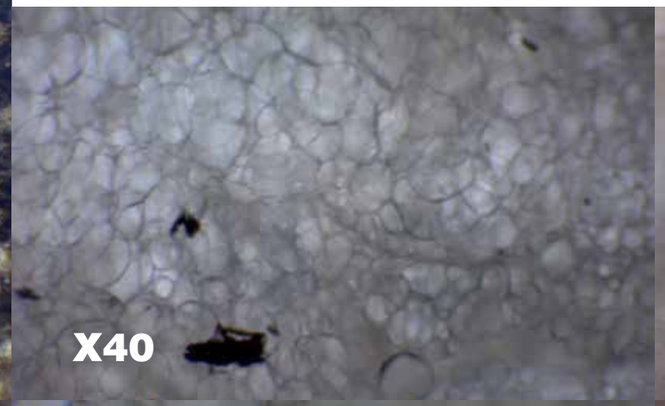
Clarias Gariepinus gill rakers are tightly compacted and long. There are a large amount of tastebuds on the rakers. The epithelial layer contains lymphocytes, immune fighting white blood cells, and several alarm substance cells (Zayed, 2004).

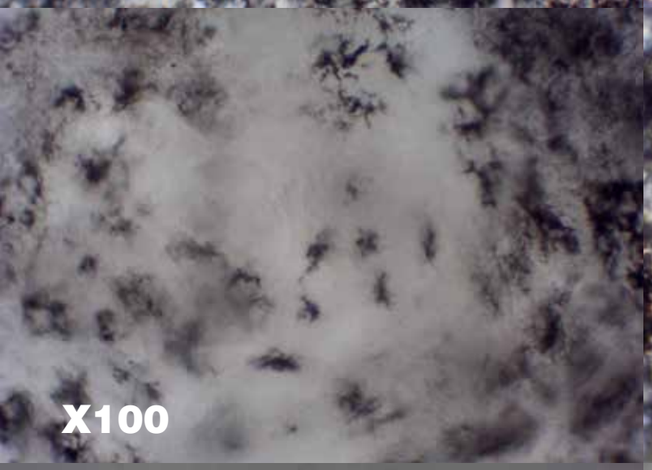
GILL FAN

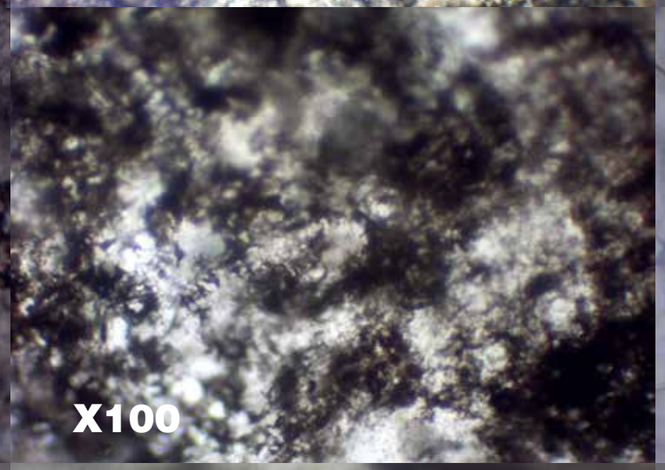
Located behind the arborescent organs in the suprabranchial chamber, gill fans assist in the absorption process of oxygen when breathing from the atmosphere. They consists of double rows of paired lamellae. Microvilli and microridges project across the epithelial cells (Lewis, 1979).

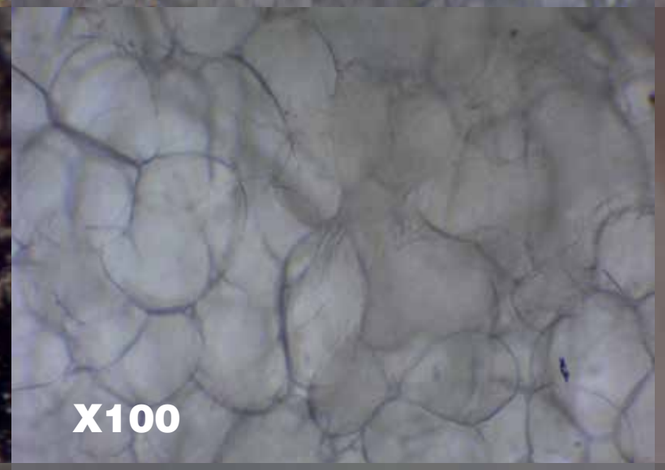


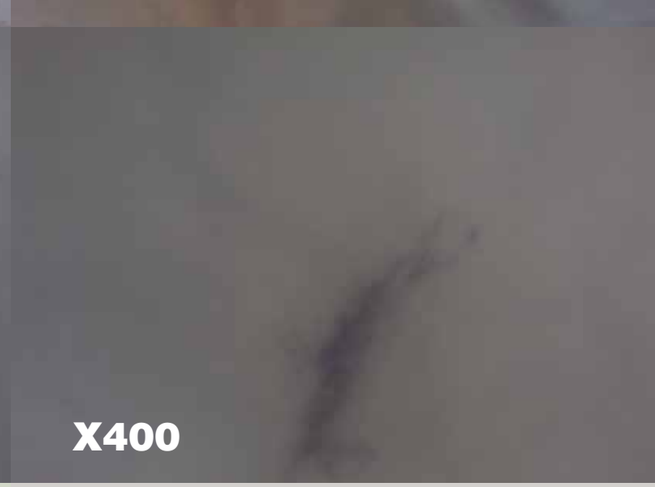












AMPULLARY SPOT LATERAL LINE - EXTERNAL

Lateral lines contain low frequency sensors that can detect seismic activity. Electroreceptors are also found grouped together in small pits along the lateral line ampullary spots (Ferrebeekeeper, 2012).

AMPULLARY SPOT DORSAL FIN - EXTERNAL

During adolescence these ampullary spots develop as free neuromasts. Examined closely, these free neuromasts contain sensory cells of opposing polarities (Mukai, 2008).

AMPULLARY SPOT LATERAL LINE - INTERNAL

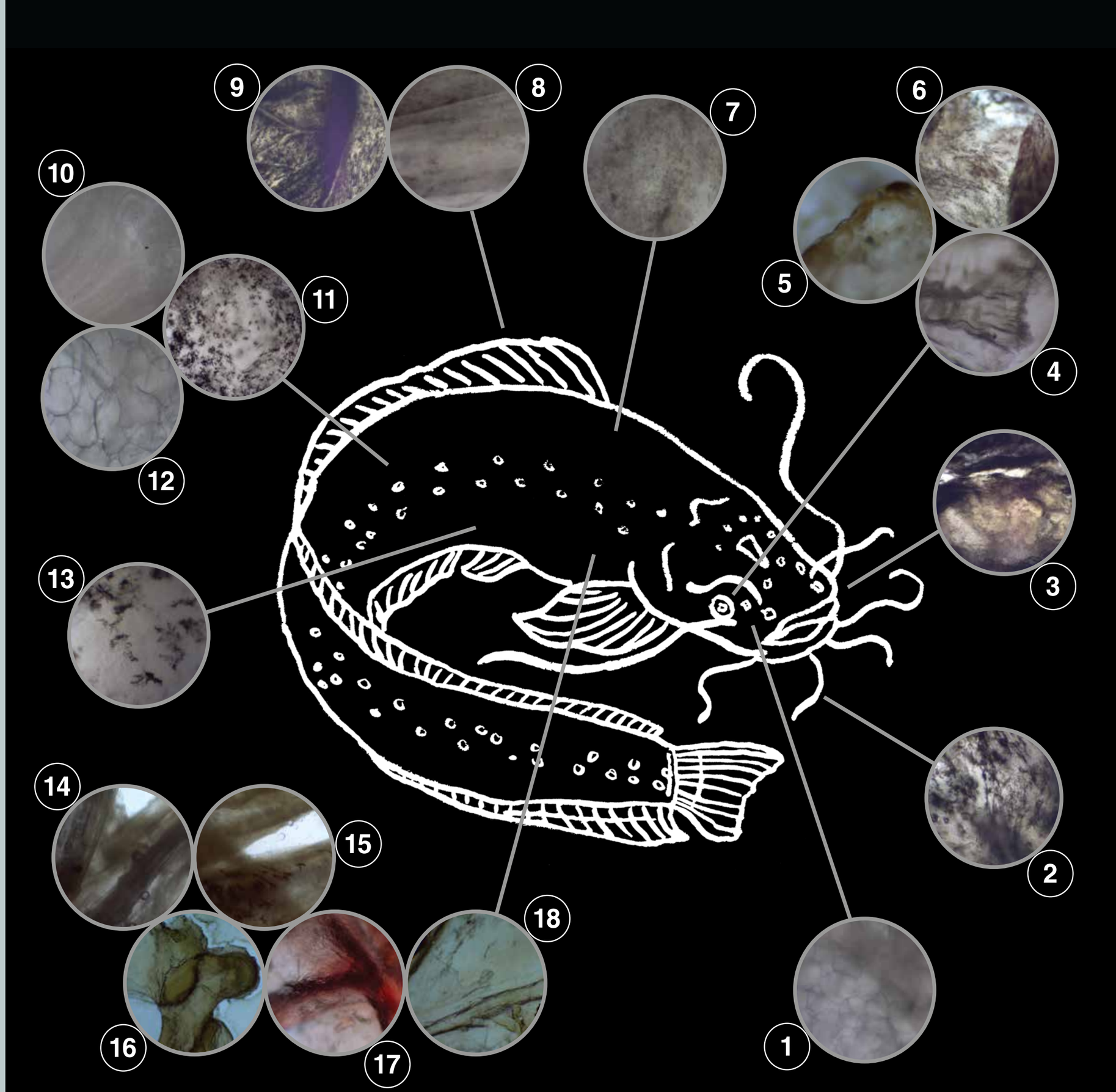
“Catfish, unlike us, are not limited to tasting things with their tongues. Their entire bodies are covered with tastebuds,” (Ferrebeekeeper, 2012). The cellular morphology underneath the dermis of the ampullary spots is similar to the tastebuds on the tongue.

TASTEBUD TONGUE - INTERNAL

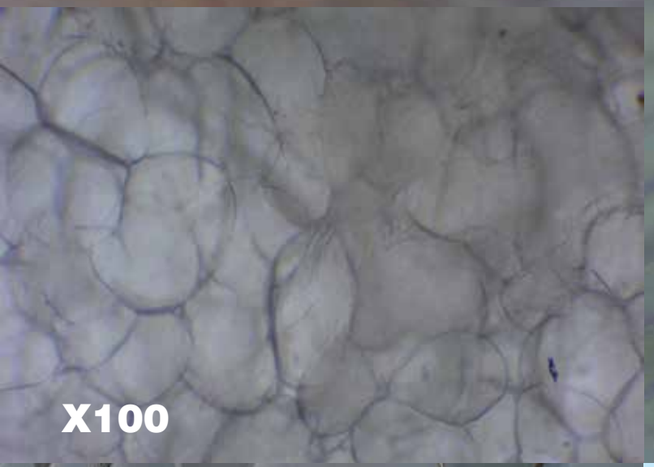
Tastebuds in the oral cavity protrude from the epithelia, contrary to sunken external skin tastebuds (Ohkubo, 2005). Here the vagal taste system manages the swallowing reflex; the skin tastebuds locate potential food sources (Atema, 1971).

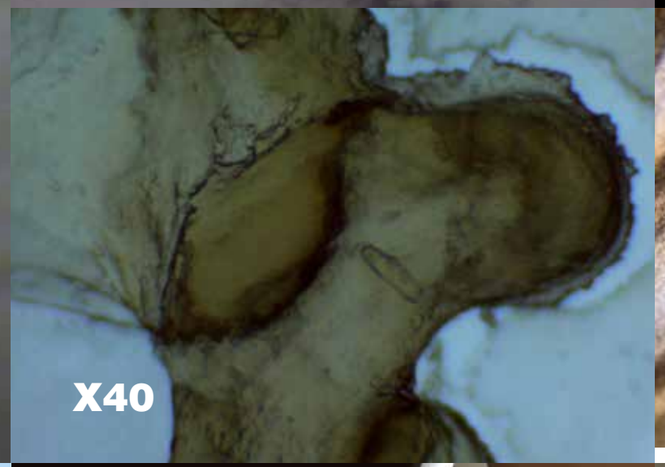
CELLULAR ANATOMICAL DIAGRAM

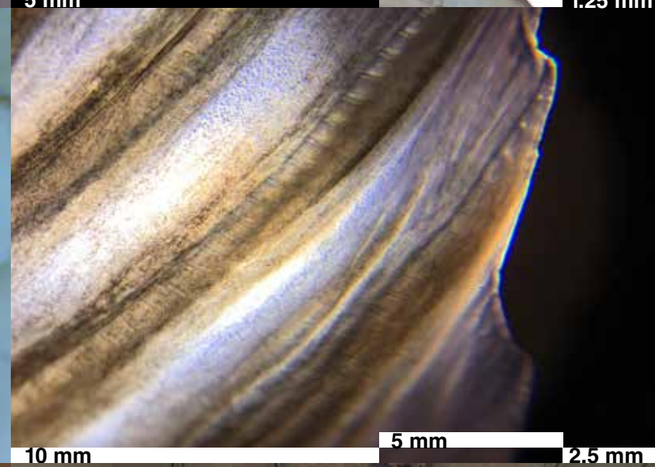
1. x100_Tongue: Internal Tastebud
2. x100_Inner Barbel: External Skin
3. x040_Premaxilla: External Skin
4. x100_Eye: Internal Optic Lens
5. x100_Eye: Internal Optic Nerve
6. x100_Eye: Internal Optic Fluid
7. x400_Claudal Tip Skull: External Ampullary Spot
8. x40_Dorsal Fin: Internal Spine
9. x40_Dorsal Fin: External Skin
10. x40_Lateral Line: Internal Horizontal Septum
11. x40_Lateral Line: External Ampullary Spot
12. x40_Lateral Line: Internal Ampullary Spot
13. x100_Belly: External Skin
14. x40_Respiratory Organs: Internal Gill Rakers
15. x40_Respiratory Organs: Internal Gill Filaments
16. x40_Respiratory Organs: Internal Arborescent Organ
17. x40_Respiratory Organs: Internal Valcularised Tissue
18. x40_Respiratory Organs: Internal Gill Fan



MORPHOLOGICAL STRUCTURES: BUILT ENVIRONMENT







SENSORY CELLS

The structure of the internal tongue tastebuds and ampullary spot have a morphological structure similar to soap bubbles. These cells are used to autonomously convey information. Watercube by PTW Architects uses its bubble facade to circulate air and transmit light.

OPTIC LENS

The crystal like cellular structure of the optic lens allows light to pass through its rods. The patterning of the rods resembles channel glass, like Steven Holl's Nelson-Atikins Museum of Art.

SKIN PIGMENT / ARBORESCENT ORGAN

Branching clusters of the pigment cells and arborescent organ expand surface area, enhancing efficiency. Similarly, Galaxy Soho by Zaha Hadid utilizes the same branching technique to generate fluid circulation, breaking the rigidity of the corporate paradigm.

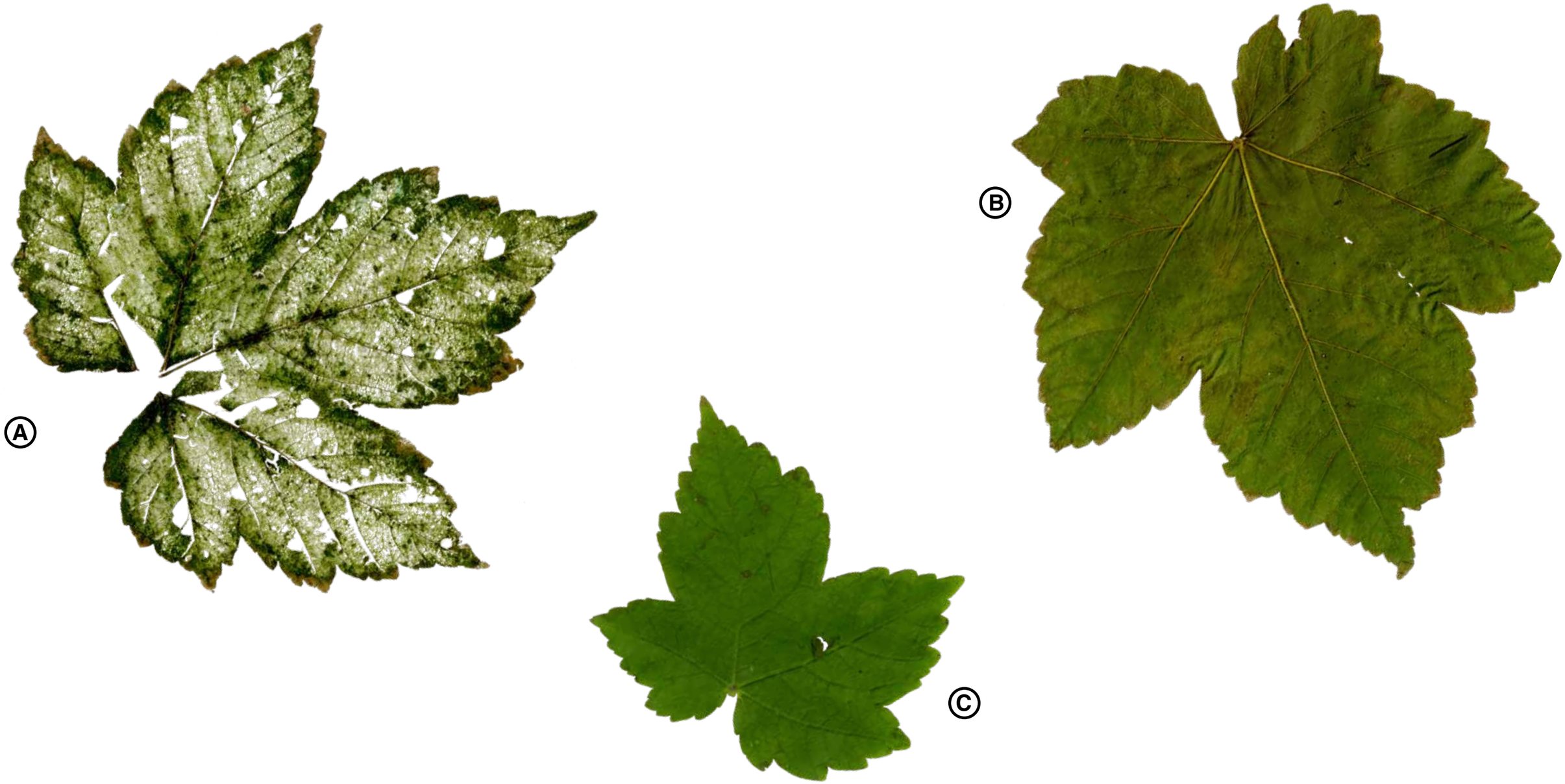
GILL FAN / PECTORAL FIN

Spiny cartilage structures provide rigidity and stability during movement of gill fans and fins spanning tissue. Gothic ribbed vaultings in Salisbury Cathedral maximize the structural tension following a similar logic to the fins and gill fans.

1b: DISSECTING BIOLOGICAL MACHINES

DIGITAL IMAGE ANALYSIS + INTERPRETATION

SKELETONIZED LEAVES // SLIDE PREP // NOBLE FALSE WIDOW // BACTERIA CULTURES: PIGEON SH!T



ACER PSEUDOPLANTUS SYCAMORE

Sycamore trees, *Acer pseudoplantus*, are native to Europe, and were likely introduced to Britain by Romans. Their wing-shaped seeds (samara) are very fertile, allowing the plant to aggressively spread. Case in point, these particular leaf specimens were found growing on a sapling under an established shrub. Leaves transform from dark green to bright yellow as photosynthesis stops in Autumn. Sycamore leaves tend to be a thriving environment and food source for aphids and corresponding predators (Woodland Trust, 2020b). The toothed symmetrical palmate leaves have five lobes; some leaves appear to have an abnormality of four lobes (see above, Specimen C). Furthermore, the back of this juvenile leaf was soft to touch, compared to the smooth top surface. New sycamore leaves are covered in trichomes on their underside to protect photosynthetic cells. These trichomes shed from the leaf once the photosynthetic cells are fully operational. Trichomes can be found in many forms throughout various parts of trees (Coder, 2004).

Ⓐ Skeletonized Sycamore Leaf

Ⓑ Mature Regular Sycamore Leaf

Ⓒ Juvenile Sycamore Leaf (Abnormal)

FIJI IMAGEJ: *ACER PSEUDOPLANTUS*

Distance Map Process

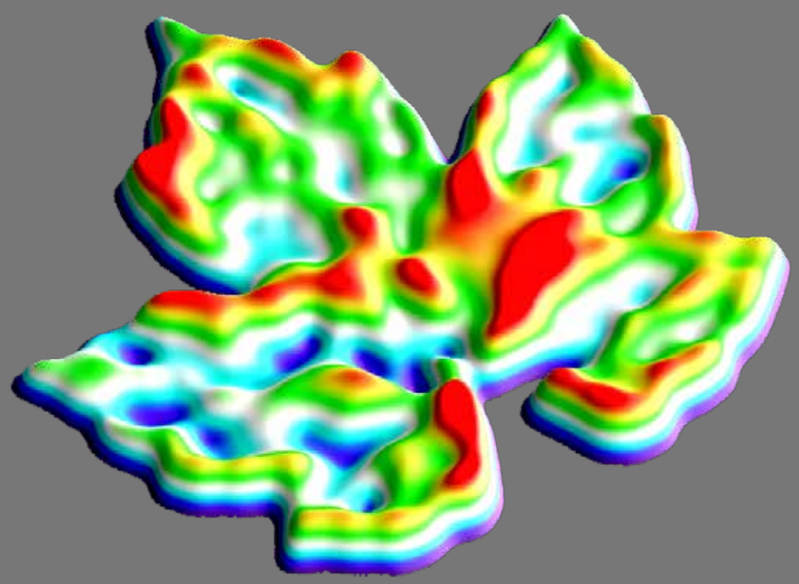
Distance mapping process shows the sycamore leaf has a tight vascular structure. The process shows area-edges of the leaf's surface farther away from one another in darker shades. The only areas in gray/black are the cuticle and epidermis which were not easily removed.

Outline Process

Outline process depicts the defined surface edges of the leaf. It clearly identifies some areas along the outer edge of the leaf that were not physically skeletonized. However, the process does not allow for one to tell easily which areas are unskeletonized surfaces verses torn sections.

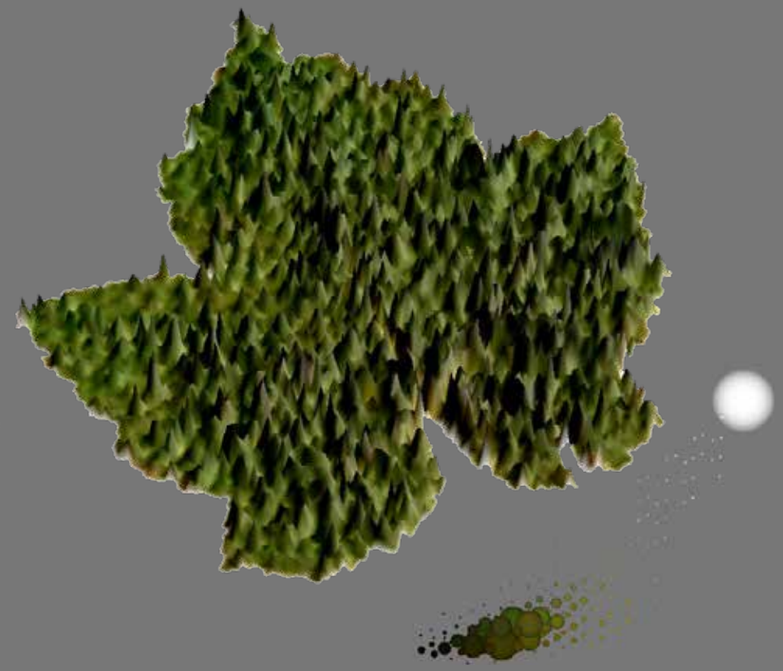
Skeletonize Process

Skeletonize process is great for showing how expansive the vascular system of the sycamore leaf is. It clearly extends all the way to edges of the leaf and is organ system responsible for maintaining the leaf's morphological shape.



3D Surface Plot Analyze

Surface Plot Analyze shows the most durable areas remaining after physical skeletonization process. Red and yellow represents the membranes that could not be removed; whereas blue and purple are the areas where the vascular structures broke off during the skeletonization.

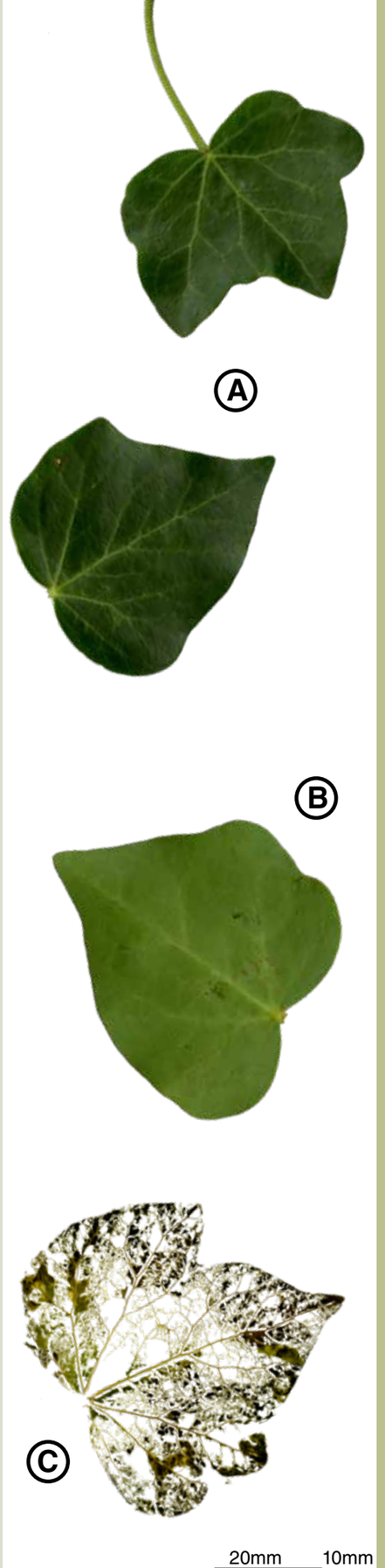


Color Surface Plot / Color Counter / Color Inspector 3D Plug-in

By surface plotting a color image of the whole sycamore leaf, the locations on the leaf that has a greater pigment concentration depicted with higher bumps. Then with the Color Inspector 3D plug-in a digital graph is generated showing which colors are most abundant. Lastly using the Color Counter plug-in, 102,949 unique colors are identified on the leaf. This helps understand the dark green pigmentation concentration.

HEDERA HELLIX
ENGLISH IVY

English Ivy, *Hedera helix*, is a herbaceous vine native to Europe, Asia, and Africa. It is amensalistic, using established trees and plants to grow on and subsequently killing its living scaffolding through shade. The variously shaped, smooth waxy palmate leaves of the vine typically have three to five lobes. English ivy is an evergreen, and its berries and pollen provided a food source for many insects and birds in sparse times. Furthermore, it is critical to some insect species diet before hibernation (Woodland Trust, 2020a). Herbalists use the leaves to remedy respiratory illness. According to English Heritage, the vine plant can occasionally offer assistance in architectural preservation (Goldman, 2016).



Ⓐ Top English Ivy Leaf

Ⓑ Rear English Ivy Leaf

Ⓒ Skeletonized English Ivy Leaf

CLETIS AUSTRALIS
EUROPEAN HACKBERRY

European hackberry, *Cletis australis*, is native to Europe and is believed to be the ancient lotus fruit of Greek mythology. The bark of the tree can be cultivated to create a natural yellow dye. European hackberry trees are hermaphrodites, using pollinators to transfer pollen between their male and female sex organs (PFAF, 2020). Asymmetrical, the toothed elongated leaves come to a singular tip. This leaf morphology is known as lanceolate. Leaves transform from a grey-green to pale yellow as they stop photosynthesis in Autumn. Their violet fruit are a source of nutrients to a variety of wildlife (Gilman, 1993).

Ⓓ Top European Hackberry Leaf

Ⓔ Skeletonized European Hackberry Leaf

ACER RUBRUM
RED MAPLE

Red Maple, *Acer rubrum*, is native to North America, and is the most copious native tree species in the continent's eastern forests. This species is what's known as a generalist, meaning it can thrive a wide range of conditions of soil, sunlight, environments, and elevations. Red maples have winged-seeds, samaras, like the sycamore, Acer pseudoplantus. The sap of red maples can be used to make maples syrup, and its leaves are a dietary delight of moose. The symmetrical palmate leaves are serrated with three to five lobes. Leaves change from a green to red, yellow, and orange as they stop photosynthesis in Autumn (NWF, 2020).

Ⓕ Top Red Maple Leaf

Ⓖ Rear Red Maple Leaf

Ⓗ Skeletonized Red Maple Leaf

Distance Map Process

Distance Mapping Process shows the variating density of the vascular systems of the different leaf species. The filter shows the area-edges of the leaf's surface that are farther away from one another in darker shades. The only areas that are showing in gray/black are the areas that the cuticle and epidermis were not easily removed.

Skeletonize Process

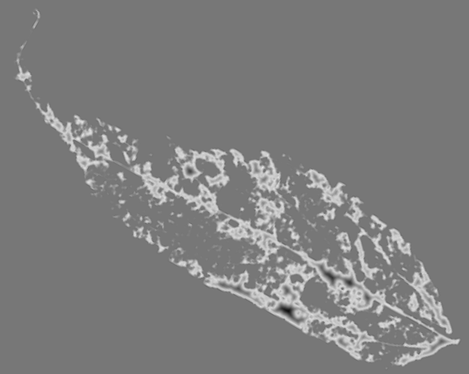
Skeletonize Process maps the vascular skeleton system of the leaves. It is easy to observe how the different morphological shapes are dictated by the vascular structural hierarchy. The middle lanceolate leaf has a vascular hierarchy that is organized differently from the other two palmate leaves.

Color Surface Plot / Color Counter / Color Inspector 3D Plug-in

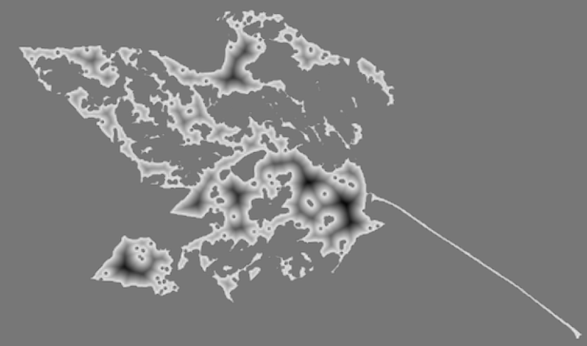
Locations on the leaves that have a greater pigment concentration are depicted with higher bumps using Color Surface Plot analyze. Then using the Color Inspector 3D plug-in a digital graph is generated that shows which colors are most abundant on the leaf's surface. Lastly with the Color Counter plug-in, the total number of unique colors are identified on each leaf (English Ivy 19,244; European Hackberry 92,353; Red Maple 43,652). This information allows for interpretation of pigment distribution.

HEDERA HELLIX

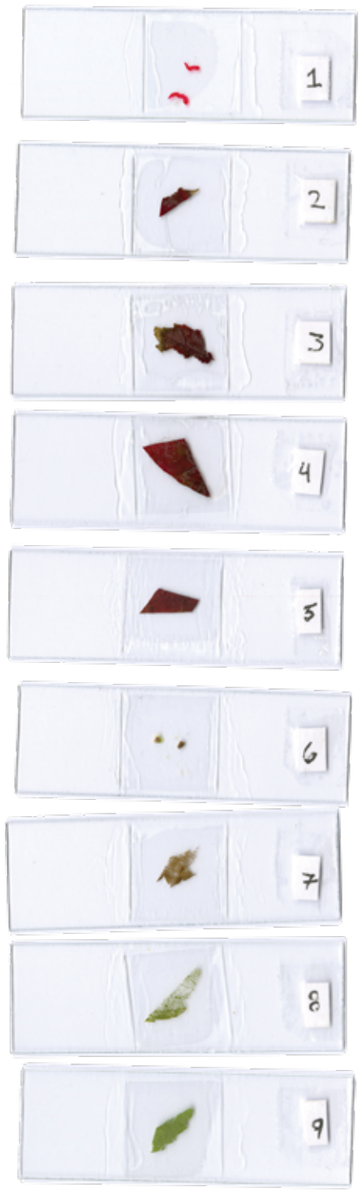
CLETIS AUSTRALIS

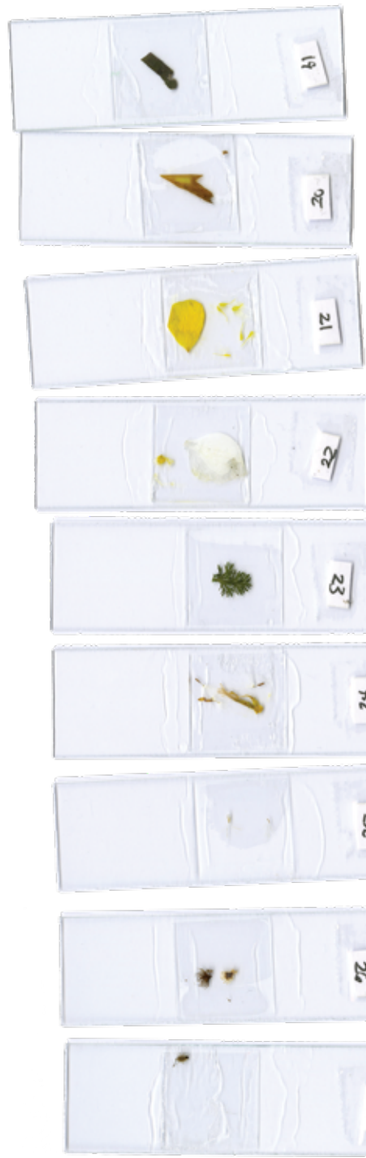


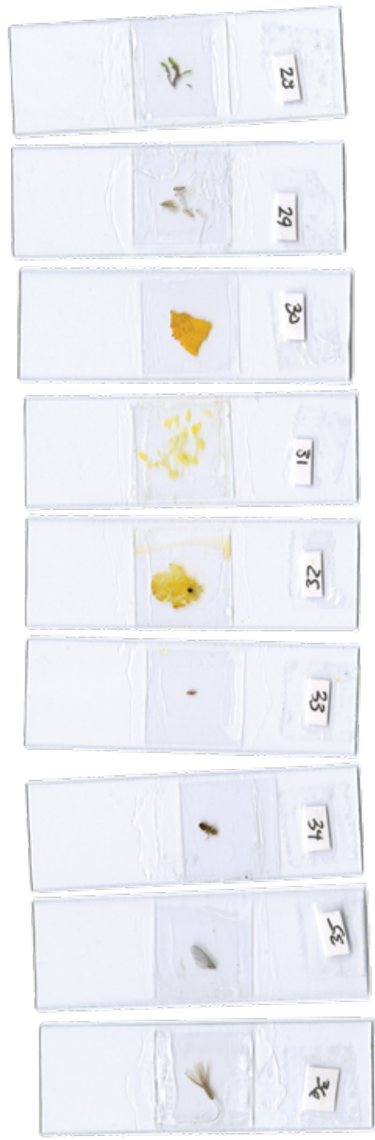
ACER RUBRUM



10mm 20mm







MICROSCOPE SLIDES

1. Unknown Aphid
2. Red Maple Leaf, Back (Pressed)
3. Red Maple Leaf, Front (Pressed)
4. Red Maple Leaf, Back
5. Red Maple Leaf, Front
6. Red Maple Bud
7. Red Maple Leaf, Skeletonized
8. Sycamore Leaf, Skeletonized
9. Sycamore Leaf
10. English Ivy Leaf, Skeletonized
11. English Ivy Leaf, Inner Membrane
12. Bald Cypress Pine Needle
13. White Alder Seed
14. Red Bistort Leaf
15. Red Bistort Flower Petal
16. Feijoa Leaf Fuzz
17. Paper Plant Flower Petal & Stamen
18. Paper Plant Flower Carpel Section
19. Common Dogwood Leaf
20. Guelder-Rose Leaf
21. Meadow Buttercup Flower Petal
22. Unknown Fruit Tree Flower Petal
23. Common Yarrow Leaf
24. Bristly Oxtongue Flower Petal & Seed
25. Guernsey Fleabane Seed
26. Greater Knapweed Bur-Seed
27. Queen Anne's Lace Bur-Seed
28. Silvergreen Bryum Moss
29. Orchard Grass Seed
30. Pumpkin Outer Skin
31. Pumpkin Pulp
32. Pumpkin Pulp with Mold
33. Slender Springtail
34. Unknown Ant
35. Common House Fly Wing
36. Prairie Ironwood Seed

40mm 20mm

x40 *Photoshop HDR Merge*

x100

x100

ACER PSEUDOPLANTUS
SYCAMORE LEAF

Carrying nutrients to and from the mesophyll, vascular bundles create a network. The middle image shows air cavities of spongy mesophyll. However, the lack of green mesophyll cells in the right image of a skeletonized leaf indicates the importance of the remaining vascular bundles.

x40

x100

x400 *Photoshop Focus Stack*

ACER RUBRUM
RED MAPLE LEAF

When observing the red maple leaves under the microscope it was very evident that they contained a higher amount of glucose than other leaf species observed. The cellular formations where blurred by layers of irregular cubic volumetric shapes, which notable of sugar crystals.

x40

x100

x400 *Photoshop Focus Stack*

HEDERA HELLIX
ENGLISH IVY

The green, black, and brown circles are the palisade mesophyll layer which was once attached to the cuticle and upper epidermis. Furthermore, the black dots are the chloroplasts within the mesophyll cells (Carlson, 2017). Chloroplasts are the organelles that conduct photosynthesis.

x40

x100 *Photoshop Focus Stack*

x400 *Photoshop Focus Stack*

ACER RUBRUM
RED MAPLE BUD

Red Maples shoots grow rapidly in the summer, and as a result buds sprout on these new twigs in autumn. However, they do not open as flowers and leaves until the proceeding warmer spring (Duffy, 2020).

ORCHESELLA CINCTA
SLENDER SPRINGTAIL

Springtails get their common name from their furcula, an appendage on their rear-end under the abdomen, which is tension released when threatened (Hardie, 2020). This specimen was found hoping on a sycamore leaf.

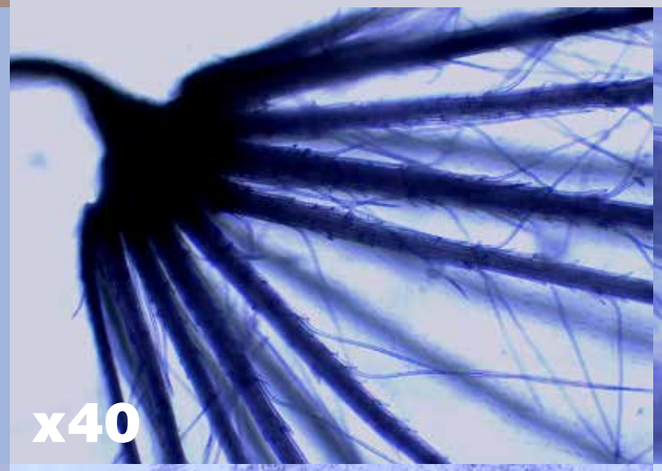
x40

x100

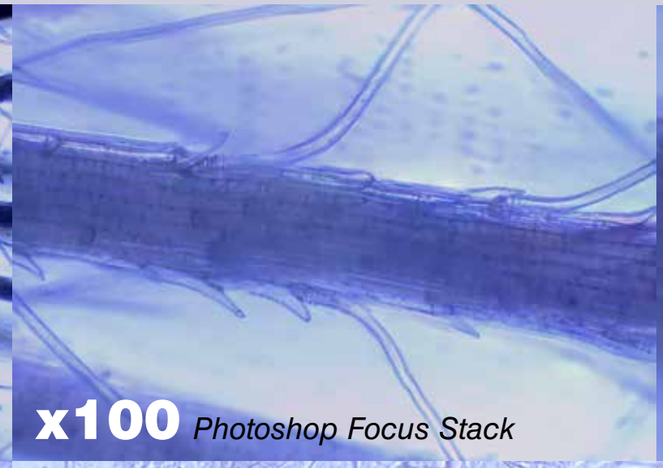
Photoshop Photomerge

HELMINTHOTHECA ECHIOIDES
BRISTLY OXTONGUE SEED

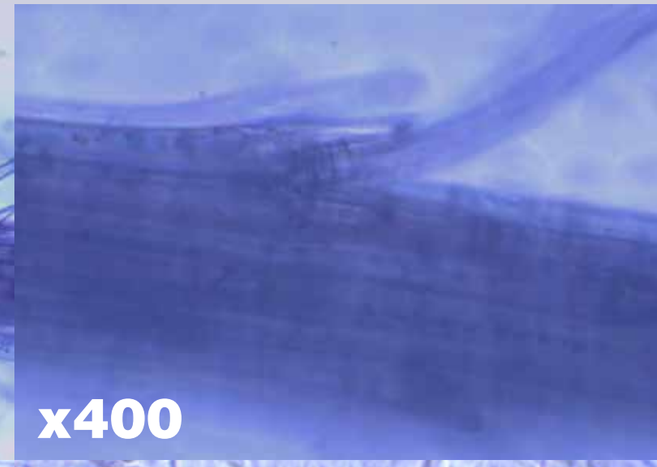
The pappus of Asteraceae family are hairlike structures radiating around an achene, which holds the seed and serves as a parachute for wind dispersal (Conrad, 2012). It consists of smaller fibrous hairlike strands.



x40



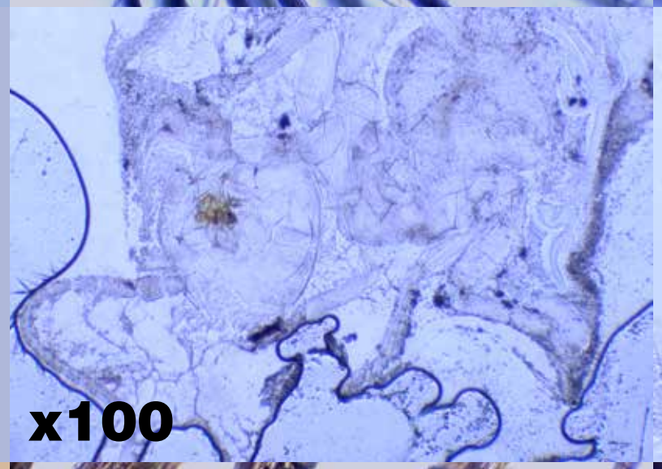
x100 *Photoshop Focus Stack*



x400

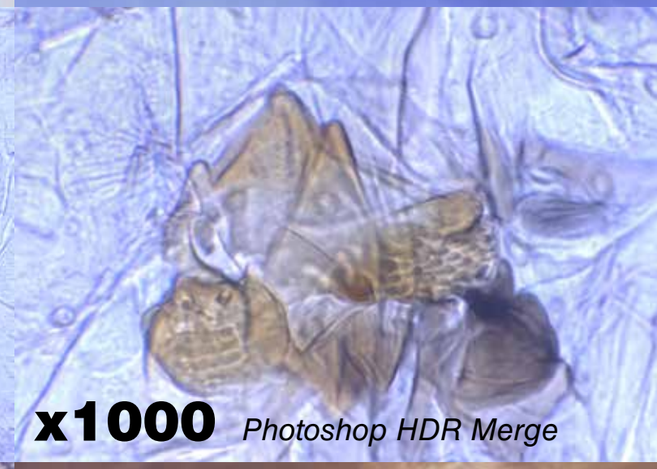
APHIDOIDEA
UNKNOWN APHID

This micro-insect was identifiable by its morphological attributes of a large abdomen, short thorax, and long antennas. Aphids are viviparous, and their eggs develop at ovulation inside parthenogenetic females (Hadley, 2019).



x100

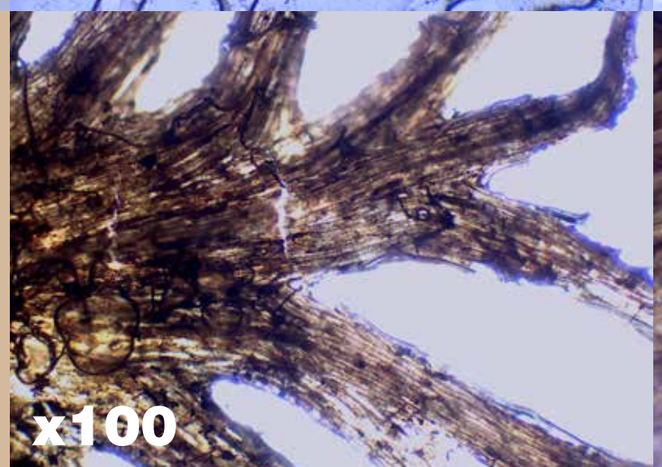
x400



x1000 *Photoshop HDR Merge*

CENTAUREA SCABIOSA
GREATER KNAPWEED BUR

Despite having an evolutionary advantage of latching onto animal fur, Knapweed is most easily spread by wind and water. Because their seeds versatility for spreading, they are often found growing along roadside and new development sites (F.S. USDA, 2014).

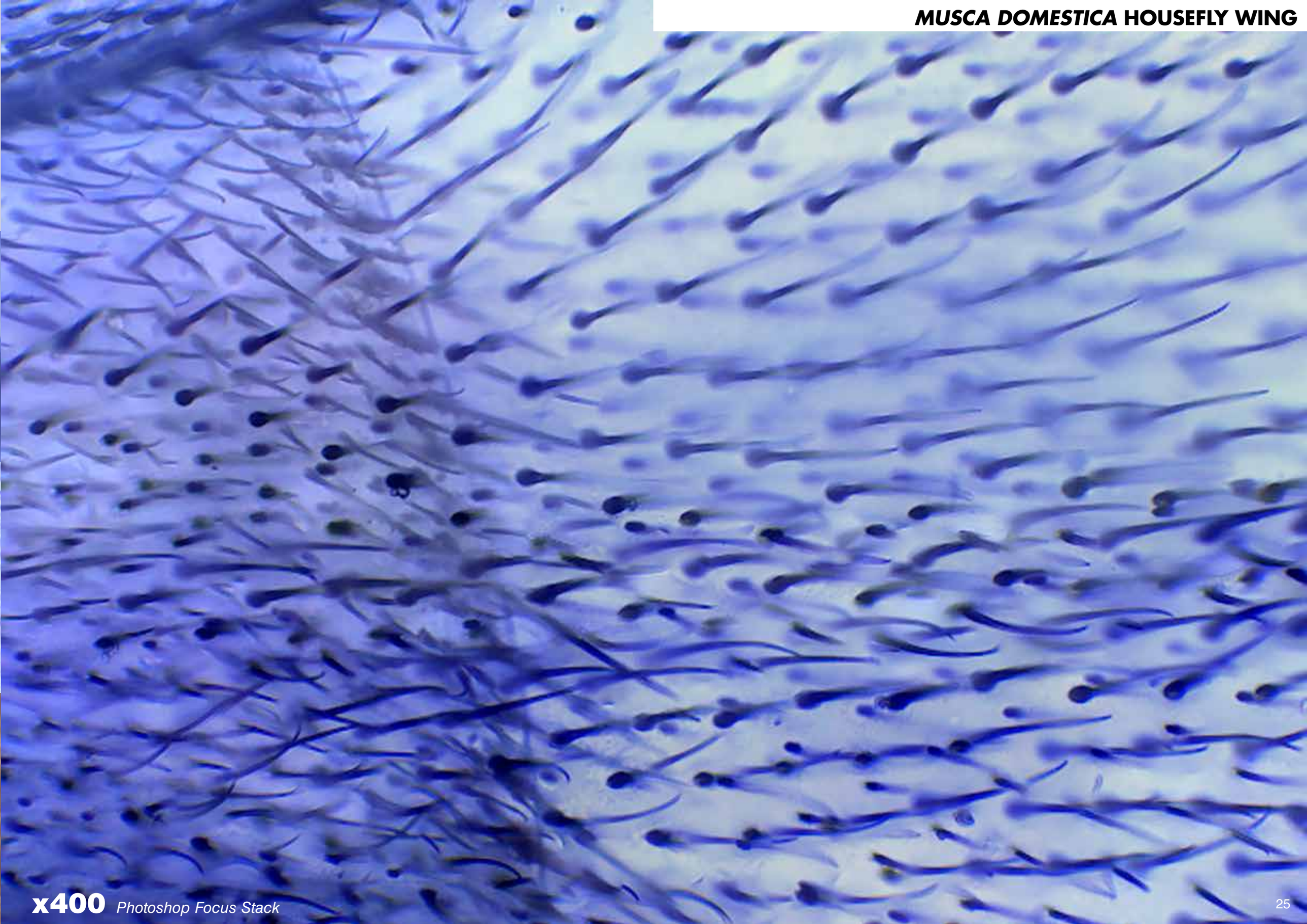


x100

x400 *Photoshop Focus Stack*

x1000 *Photoshop Focus Stack*

MUSCA DOMESTICA HOUSEFLY WING



x400 *Photoshop Focus Stack*

STEATODA NOBILIS
NOBLE FALSE WIDOW

Observed with the Grow Lab Stereoscope, the Noble False Spider abdomen pulsated. After several minutes confined in a small Petri dish, it became evident that the pulsating was due to the spider using its spinnerets. Amazingly the spider spun a small web in response to stress. This image was generated using Focus Stack features in Adobe Photoshop with a multitude of digital images at various focus depths.

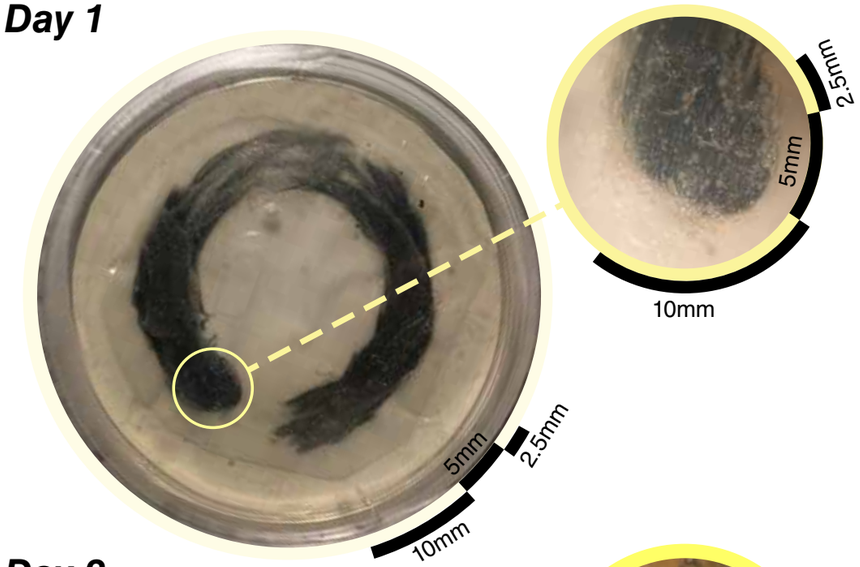
BACTERIA CULTURES: PIGEON SH!T

Background:
Open public space is a plethora of activity in urban environments. They are used as for social gather, exercise, artistic expression, cultural monuments, and curated naturescapes. Several times a week, I bike past a public space that serves all of urban functions and more at the intersection of Camden High Street and Crowndale Road. I regularly notice the towering statue of Richard Cobden looking towards Napoleon III's France and away from London's beggars sitting outside Sainsbury's. Most days a seemingly kindhearted person or two can be found feeding crumbs and seeds to feral pigeons, Columba livia domestica; however, in my point of view pigeons are vial creatures carrying disease that terrorize lunchtime citizens. The statue of Richard Cobden is covered in many feces droppings from Camden feral pigeons and I want to know what kinds of bacterial disease these monsters might be harboring.

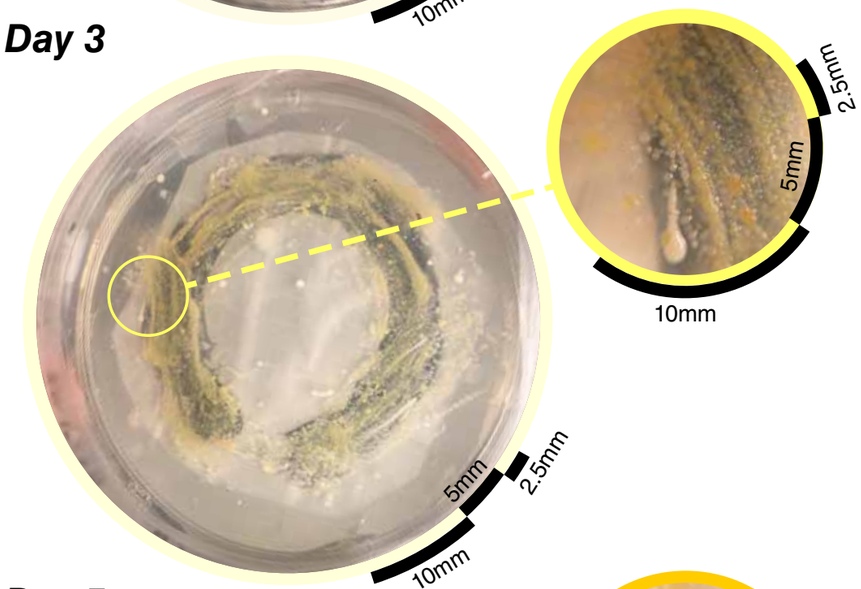
Hypothesis:
The feral pigeon feces contain many bacteria that are dangerous to human health. Cultures of *Salmonella* will most likely be the dominate bacteria grown in plates; *Histoplasma capsulatum* fungus will also be present in small quantities.

Swab Collection Site
Culture Growth Site

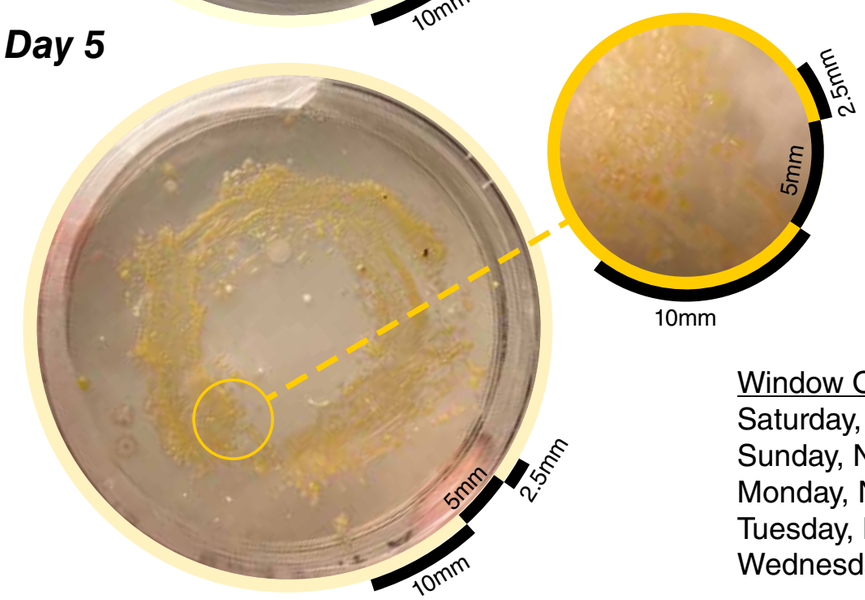
Day 1



Day 3



Day 5



Ingredients + Materials:
2x - Petri Dishes Prepared w/ Agar Medium
6x - Essential Waitrose100% Cotton Tip Swabs
59.2 mL Bottle of Assured Instant Hand Sanitizer (70% Ethyl Alcohol)
2x - 4cm Length of Parafilm Laboratory Film
Scotch Tape from Poundland
4x - M&S Resealable Small 1 L Plastic Freezer Bag
Eddie Bauer Green Backpack, Synthetic Material
Small Amazon Box
Huggies Natural Care Extra Care Baby Wipe with Aloe Vera, 56 Count Box

Equipment:
iPhone
GoPro Hero6
Clip-on Macro Lens for iPhone
Headlamp 12000 Lumen 5 LED Bulbs

Protocol:
The Petri dishes were prepared prior by CSM Grow Lab staff. The medium used for growth was agar. Dishes were left out overnight to remove pre-existing condensation on inside of lid.
The experiment started by sterilizing six cotton swabs with hand sanitizer at approximately 2:00 PM Friday, November 13, 2020. I allowed the swabs to dry in a plastic freezer bag until procurement.
Prior to collecting swab samples, I traced the outline of the Petri dishes onto Crawford & Black tracing paper and then drew two images onto the paper with makers. For Plate 1, I drew the circular Japanese symbol Enso which is a Zen Buddhist symbol representing the beginning and end of all things, or the connection of existence. For Plate 2, I drew my personal design studio logo “IMW,” a series of orthogonal lines. I carefully cut out the images and tapped them onto the underside of the Petri dishes with scotch tape. Thus creating a tracing template for methodically and artistically plating my bacterial swabs.
At 12:15 AM on Saturday November 14, 2020 I began my bicycle journey towards Richard Cobden. Wearing my safari-grade headlamp, I began taking samples from the statue of Richard Cobden at 12:20 AM. I initially noticed that there were no pigeons currently present on site, but their numerous feces dropping of various ages. Furthermore, the droppings were often matted by traffic from other pigeons, and often mixed with soft white pigeon down feathers. The colors of the droppings ranged in shades of white, black, brown, and green. I did not target feces droppings to swab based on their “freshness,” but rather focused on sample from areas that looked heavily trafficked. After swabbing I spent several minutes documenting the site with my iPhone. Furthermore, videos of the swabbing was shot live with a GoPro. The samples were placed in a new / unused small freezer bag. I transported the plated swabs in my backpack. At 12:35 AM I arrived at my flat room and promptly sealed the Petri dishes each with a 4cm long strip of Parafilm. Then I wrote the date, my name, contents, and specimen number on the Parafilm. I took several photos of the plated specimens on my desk. Afterwards I placed Feces 1 on my 4th building story northwestern facing windowsill. Feces 2 was placed inside a small box under my bed, removed from all source of natural and artificial light. Before going to bed I opened the window at 1:30 AM. The operable window opening is approximately 30 cm above the window sill. Whenever I opened the window at night during this experiment I also rolled down the blackout shade.

<u>Window Opening & Closing Schedule</u>
Saturday, November 14 – Open @ 1:30 AM; Close @ 1:45 PM
Sunday, November 15 – Open @ 2:30 AM; Close @ 1:15 PM
Monday, November 16 – Open @ 4:00 AM; Close @ 1:14PM
Tuesday, November 17 – Open @ 3:05 AM; Close @ 11:00 AM
Wednesday, November 18 – Open @ 12:52 AM; Close @ 2:05 PM

<u>Recorded Outdoor Temperatures</u>
Saturday, November 14 – 50 Degrees F / 10 Degree C
Sunday, November 15 – 54 Degrees F / 12 Degrees C
Monday, November 16 – 48 Degrees F / 9 Degrees C
Tuesday, November 17 – 55 Degrees F / 13 Degrees C
Wednesday, November 18 – 57 Degrees F / 14 Degrees C

Observations + Results:
Saturday, November 14, 2020
Feces 1 – Lid was clear of condensation. Transparent murky creamy colored colonies appeared to form along brush strokes from swab. Several white transparent singular colonies formed in random locations away from the swab contact area. They varied in sizes and opacity.
Feces 2 – Lid is very condensed. Shook dish back-and-forth gently to move droplets of water to allow a visual into plate, without breaking the parafilm seal for the controlled Petri dish environment. Similar transparent colonies grew on swab strokes. However more yellow-tan-brown creamy color. Several locations had more adamant clusters of light brown formations.
Sunday, November 15, 2020
Feces 1 – Clusters of colonies started to appear yellow while some major singular colonies and edges of swab stroke colonies remained white. Growth exceeded that of Feces 2.
Feces 2 – Clusters mostly remain same as yesterday. Condensation inside lid seemed to increase, but it was easier to motion droplets off. Remained a murky tan color to colonies that were hard to distinguish.
Monday, November 16, 2020
Feces 1 – Almost all colonies turned yellow, some turned a bright yellow. Most However, most of the colonies stayed at a deep yellow ochre color. Some large singular peripheral white colonies remained. Two white colonies at the very edge of plate medium appeared to be growing a fuzzy texture at their spherical outers with a dark brown / light black central node.
Feces 2 – Growth remained mostly unchanged and as a translucent creamy tan color throughout the entire plated medium. There were several white opaque spots that appeared to be a slimy texture. One of them had branches/arteries extending out from its central node. Condensed water leaked from side of dish through the tape. Used a different box at this point because original box was needed for an Amazon return.
Tuesday, November 17, 2020
Feces 1 – White fuzzy colonies increased in size. There were two of them. One large singular colony on inside edge of swab stroke remains opaque with some disc rings inside it. Several clusters of golden orange-yellow colonies started to randomly appear in swab stroke clusters. A bright fluorescent yellow cluster has become noticeably dominate on the edge of the plate. Approximately 12 opaque white slimy colonies.
Feces 2 – Was able to observe several medium sized opaque white colonies forming around the peripheral edges of the plate. Entire plated agar has turned a murky translucent tan color.
Wednesday, November 18, 2020
Feces 1 – One of the two fuzzy white colonies began devouring a white opaque colony. Disced white colony remained. Golden orange-yellow colonies became more frequent within swab stroke clusters. Bright fluorescent yellow cluster on the edge of the plate increased in size and grew more spherical. Approximately 14 bright yellow colonies. Approximately 20 opaque white slimy colonies. Removed lid to take final photographs with iPhone for presentation package. Smells like soft French cheese, approaching Limburger.
Feces 2 – Opened lid inside a new/unused plastic freezer bag. Cleaned surface w/ tissue, proceeded by a wipe-down with a baby wipe, then lastly wiped down again with a tissue and hand sanitizer. Replaced lid and removed from bag. Promptly threw bag in communal kitchen rubbish bin. Observed approximately seven opaque white colonies. There is a strange tan brown slim that seems to be randomly growing underneath the agar. Smells more earthy, but still equally rancid.

Conclusion:
There are several types of bacteria living inside feral pigeon feces.

1 – White Fuzzy with Black Central Node, Abnormalities
2 – Opaque White Circular Slimy, Occasional Singulars
3 – Opaque White Flat Filamentous, Occasional Singulars
4 – Yellow Ochre Course, Dominate Colonies
5 – Bright Fluorescent Yellow Slimy Circular, Occasional Singulars
6 – Gold, Orange-Yellow Course Circular, Secondary Colonies
7 – Brown-Tan Translucent Murky Irregular, Dominate Colonies

Possible Plate Interpretation
1 – *Alternaria*, Fungi Mold
2 – *Salmonella*
3 – Fungi
4 – Bacteria, yeast
5 – Bacteria, Staphylococcus aureus (best guess)
6 – Bacteria, yeast
7 – Unsure

I would not advise anyone to touch a feral pigeon; however, based on the results it seems that maybe they are not as disgusting as I perceived. The bacteria and fungi found in their feces seem to be very ordinary and similar to most common environmental bacteria.


2.5 mm
5 mm
10 mm

2: ARTIFICIAL BIOLOGICAL MACHINES

DESIGN TRANSLATION

THE KNOW-IT-ALL // *RA 8h 52m 36s | Dec +28° 19′ 51″*

GROUP 6: *ISAAC M. WILHELM, ISABEL TUGGEY, JIAYU YANG, SAUMYA SINGH*

ABSTRACT: HRM 2022 INTERGALACTIC EXPLORATORY MISSION

Isaac Wilhelm

Thanks to tremendous scientific advancements in space travel during the Great Lockdown, a new element, Wilhelmite, was discovered 40 light years away on 55 Cancri e. Our team went through a great ordeal to procure a specimen of the element during Her Royal Majesty's 2022 Intergalactic Exploratory Mission.

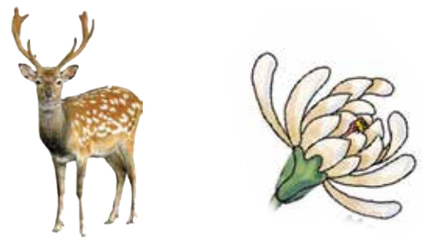
Shortly after presenting the specimen to the Royal Court the elemental gemstone began showing signs of life. Immediately we began observing and documenting the alien lifeform, the Know-It-All.

The Know-It-All is made up of the Wilhelmite at its foundational EcoCore. The EcoCore is radioactive and releases energy used by the Know-it-all to exhibit unearthly abilities. For instance, its ability to replicate and mutate the DNA of consumed creatures. Miraculously, these DNA traits are exhibited through different morphological abnormalities on the flower bud. Furthermore, the Know-It-All reproduces mutant hybrids once the flower buds have reached their end-of-life. We believe the species to have an intergalactic collective consciousness with an overwhelming desire for universal immanence.

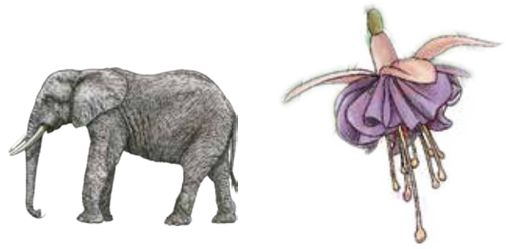
The new element, Wilhelmite, has similar properties to carbon. Like Carbon-14, this isotope is radioactive. The instability of the 6 protons and 8 neutrons creates a heavy nucleus in the isotope identified at the EcoCore. We have observed the element bonding with carbon to generate a negative ion. The radioactivity of the element results in some seemingly impossible lifeform function.

The organism taps into the Wilhelmite's radioactive energy, allowing it to create its own energy field, or Aura. This Aura allows for the Know-It-All to sense, analyze, respond, and manipulate its micro-environment.

Hummingbird + Petunia
(5 Years + 3 Years) / 20 = 4.8 Months

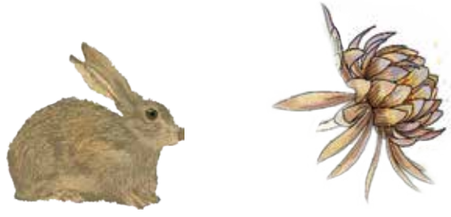


Sika Deer + Chrysanthemum
(18 Years + 4 Yers) / 20 = 1.1 Years



Elephant + *Fuchsia hybrida*
(70 Years + 2 Years) / 20 = 3.6 Years

Spider + *Gomphrena celosiodes*
(8 Years + 5 Years) / 20 = 7.8 Months



Rabbit + Sacred Lotus
(10 Years + 1,000 Years) / 20 = 50.5 Years

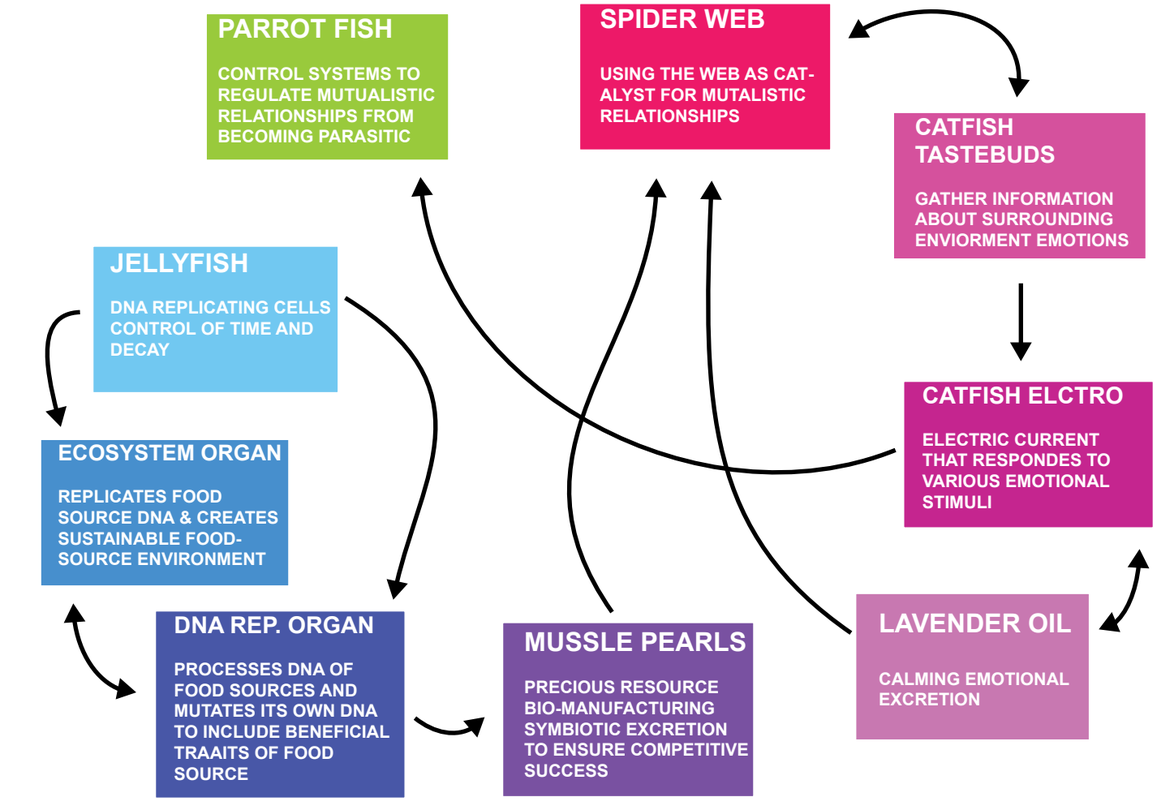
Butterfly + *Papaver rhoeas*
(2 Years + 5 Years) / 20 = 4.2 Months

THE KNOW-IT-ALL HOLISTIC ILLUSTRATION

Jiayu Yang, Isabel Tuggey, Isaac Wilhelm

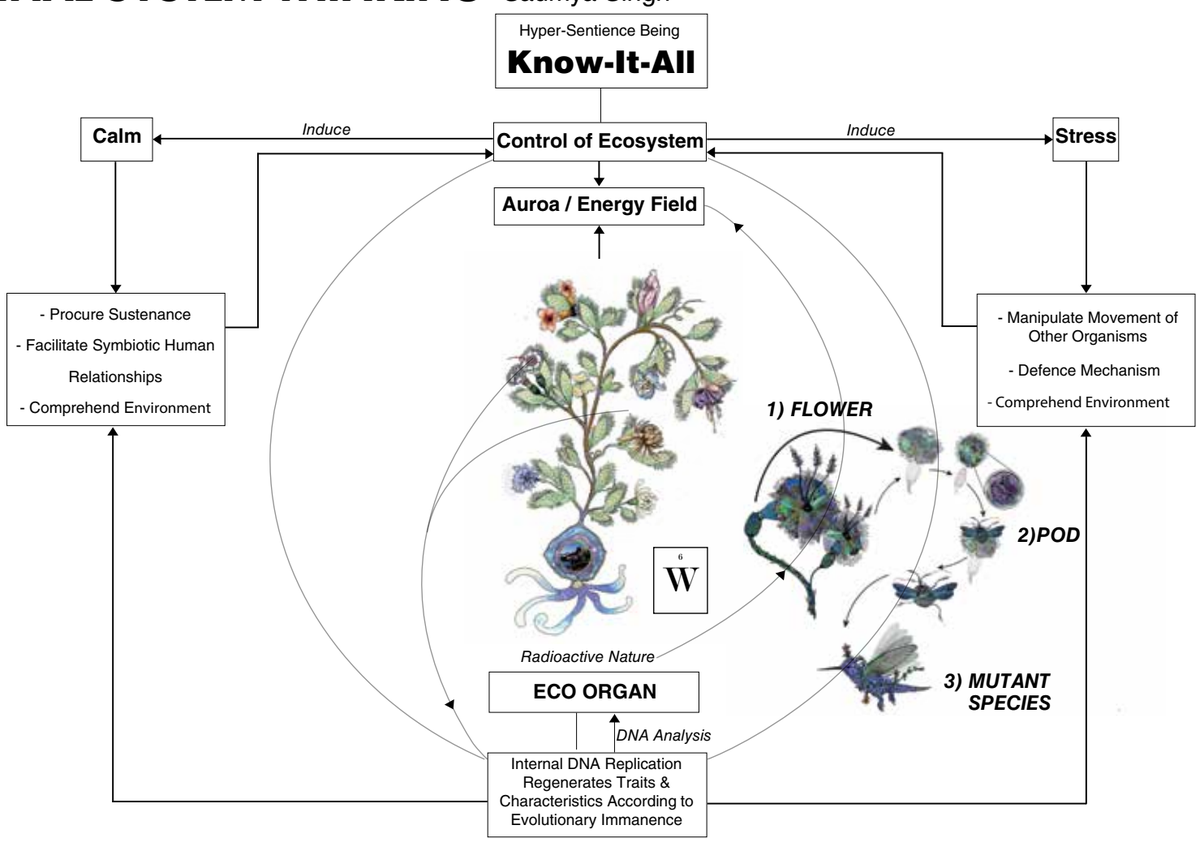
PRELIMINARY SYSTEM THINKING

Isaac Wilhelm



FINAL SYSTEM THINKING

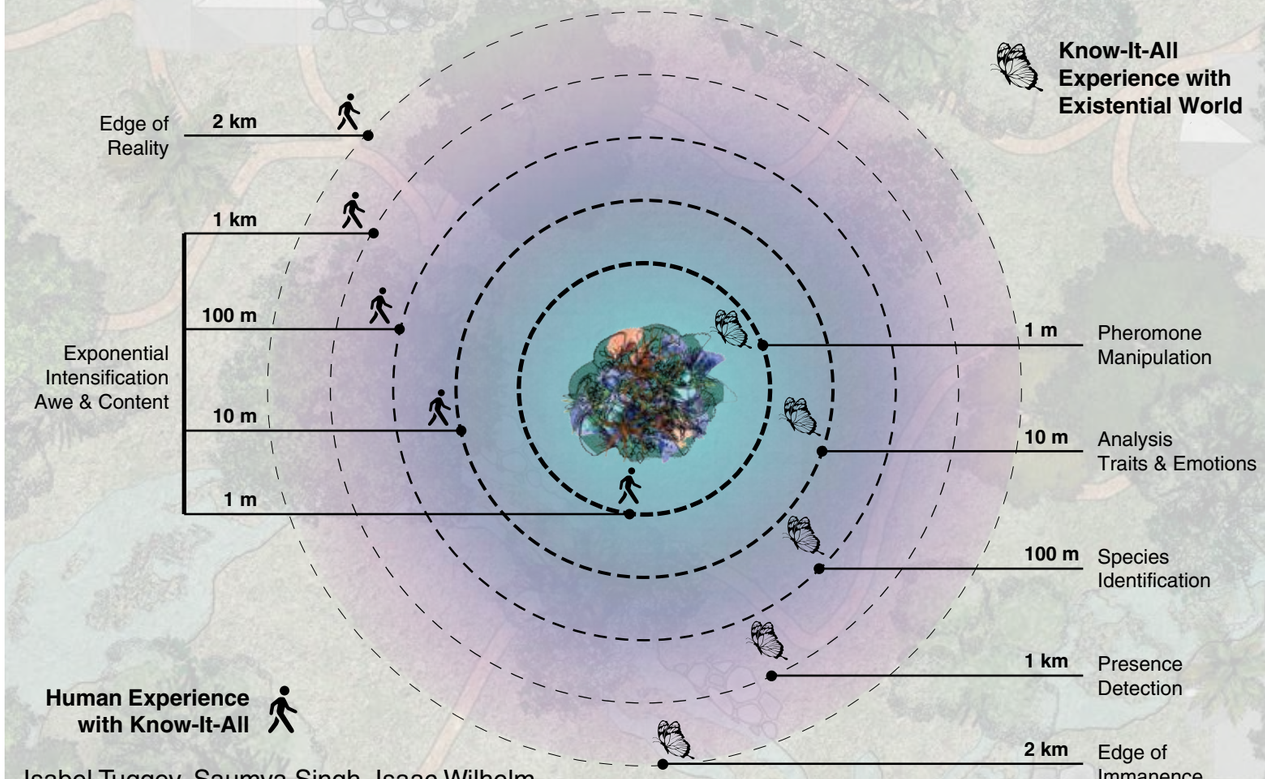
Saumya Singh



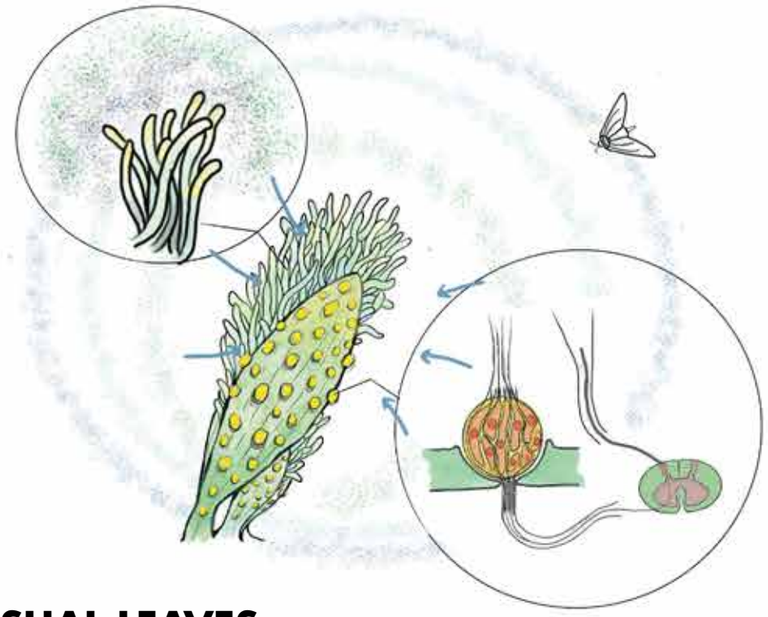
INTERGALACTIC JOURNEY

Isaac Wilhelm, Jiayu Yang

AURA OF IMMANENCE



Isabel Tuggey, Saumya Singh, Isaac Wilhelm



SENSUAL LEAVES Jiayu Yang

Isaac Wilhelm

Life Span of Flower Bud

$$\frac{L1 + (L2 + L3 + L4 + L5 + L6 + L7 + L8)}{nL \times 10} = LS$$

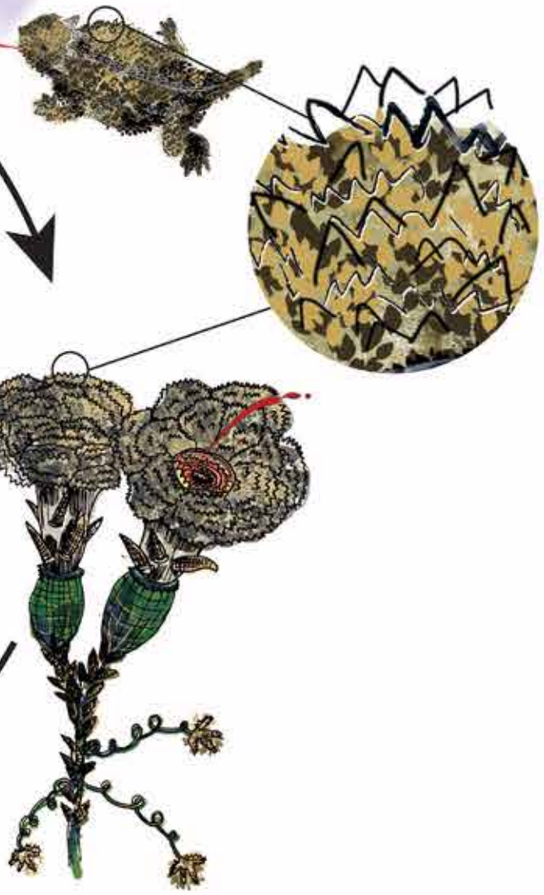
Life Span of Pod

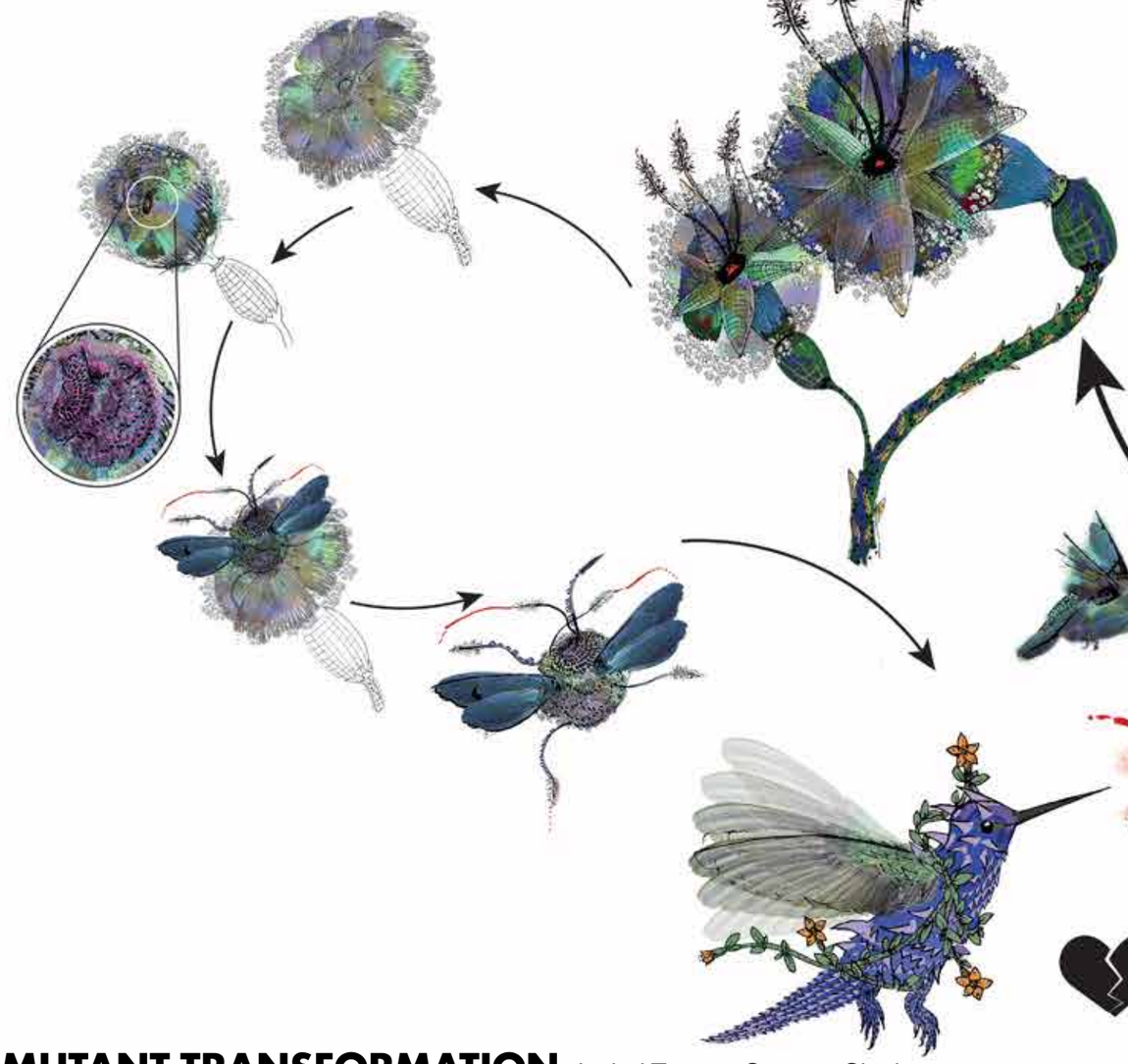
$$\frac{L1 + (L2 + L3 + L4 + L5 + L6 + L7 + L8)}{nL \times 2.5} = LS$$

Life Span of Mutant

$$\frac{L1 + (L2 + L3 + L4 + L5 + L6 + L7 + L8)}{nL \times 5} = LS$$

L*x* = Life Span of Organism DNA Processed
nL = Total Number of Organisms Processed (max 8)
LS = Final Life Span (years)





MUTANT TRANSFORMATION Isabel Tuggey, Saumya Singh

Isabel Tuggey **IMMANENT EVOLUTION**

WILHELMITE CHEMISTRY Isaac Wilhelm

6 — Atomic Number (Number of Protons)

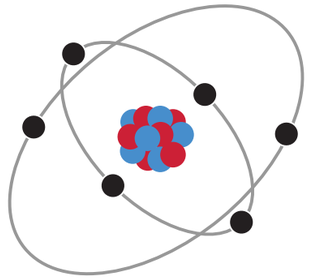
Wm — Symbol

Wilhelmite — Name

12.333 — Atomic Weight

4 - 2 — Electrons Per Shell

Inner Shell — Outer Shell



6 — Atomic Number (Number of Protons)

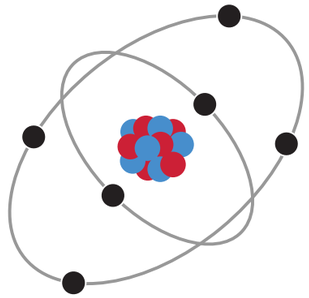
C — Symbol

Carbon — Name

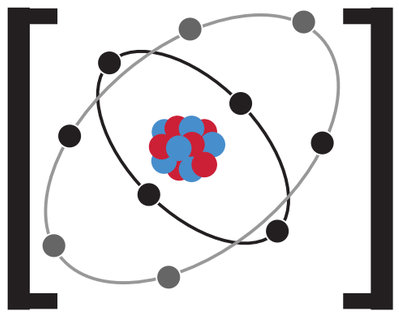
12.011 — Atomic Weight

2 - 4 — Electrons Per Shell

Inner Shell — Outer Shell



Wm^{4-} Ion

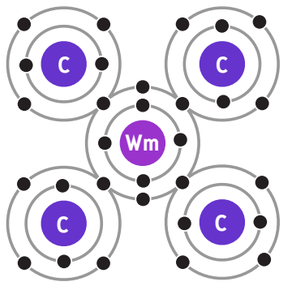


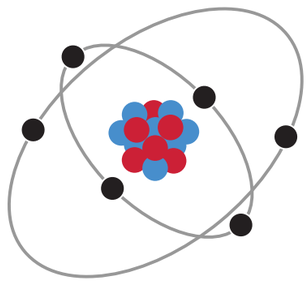
$^{14}_{6}Wm$

Wilhelmite - 14

**6 Protons

8 Nuetrons



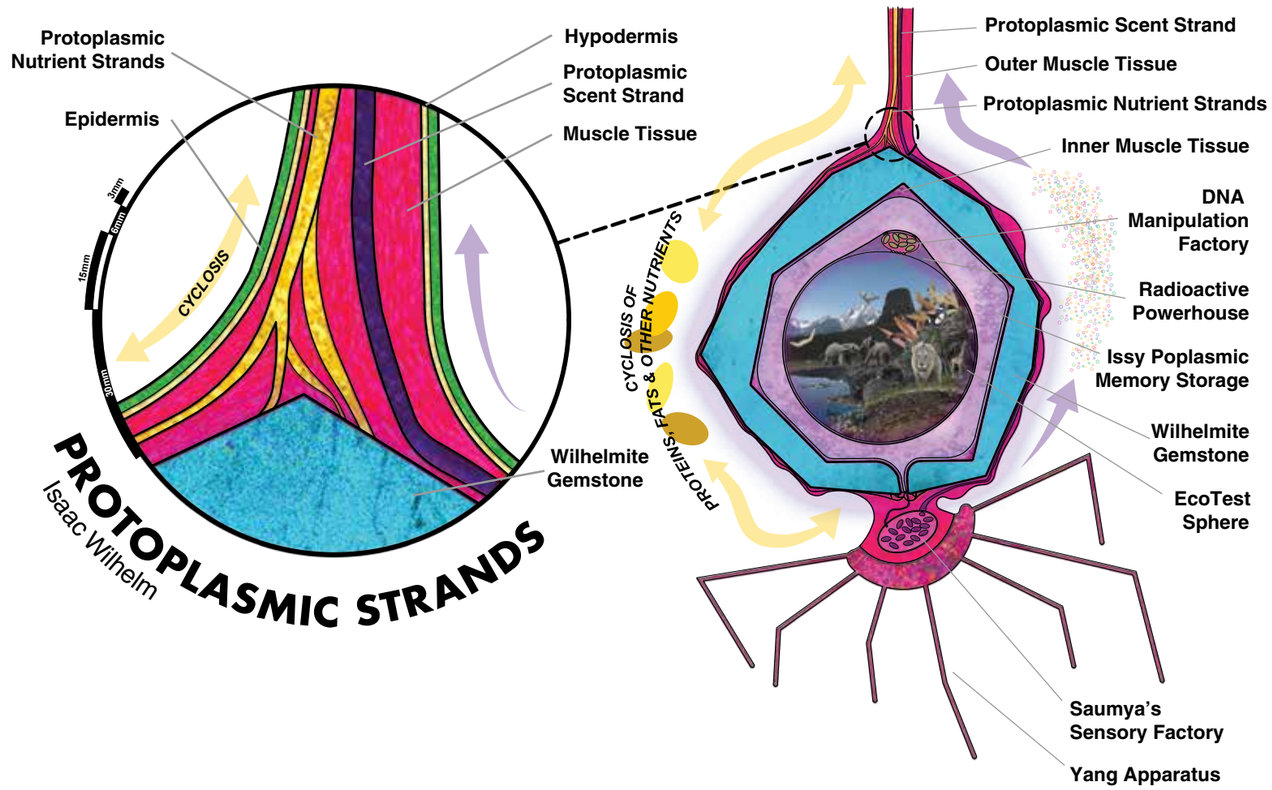


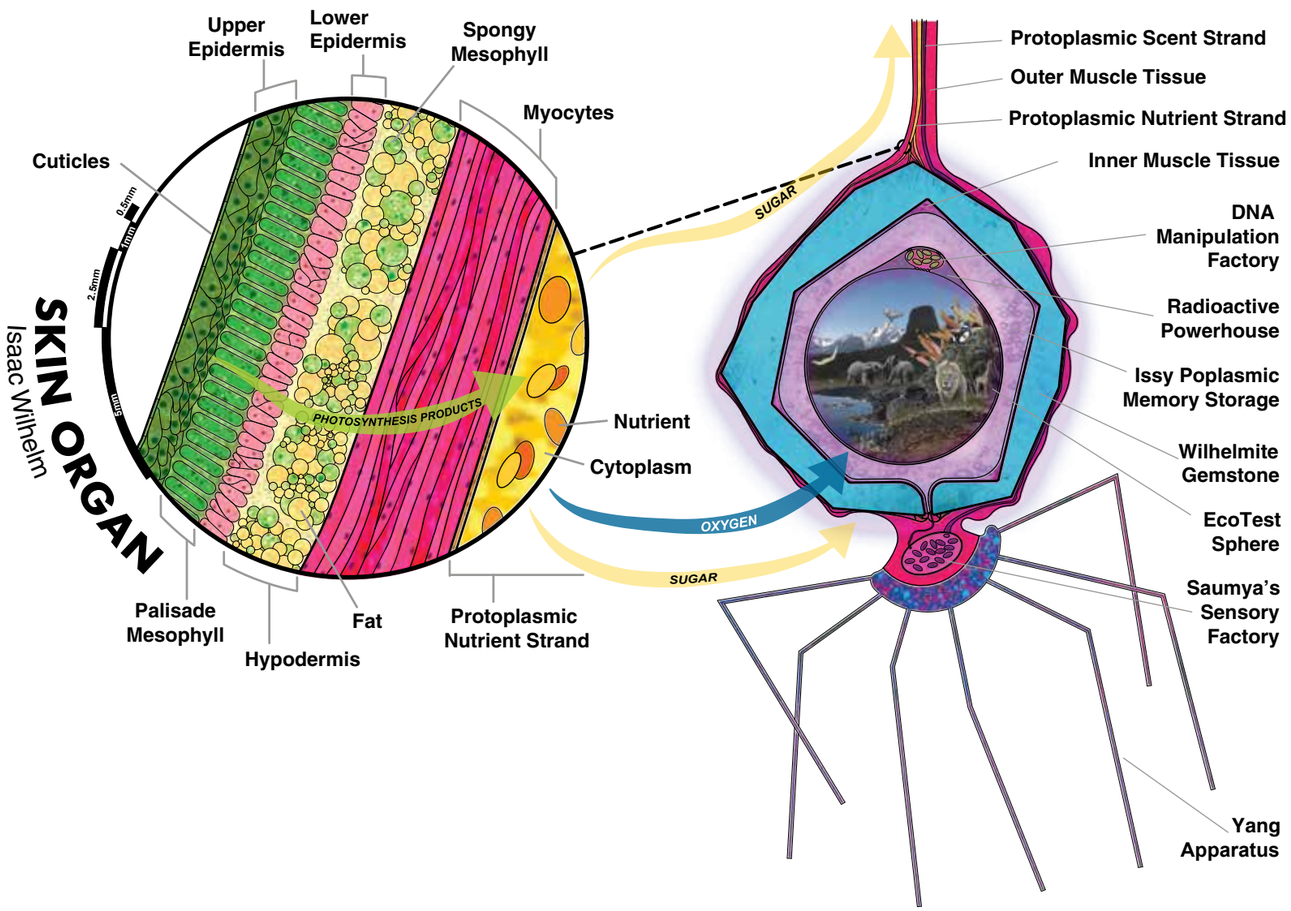
Electrons (-)

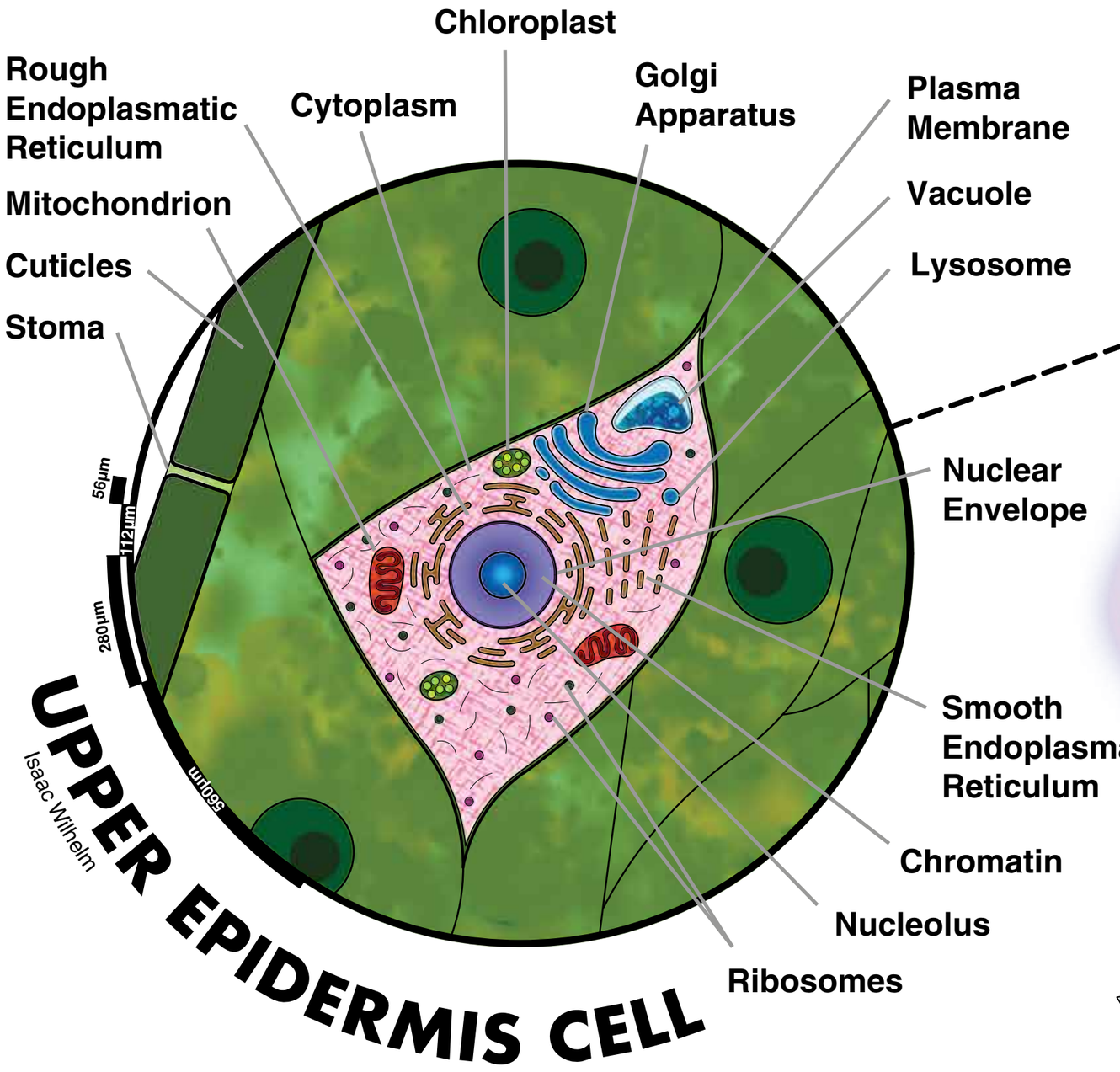
Protons (+)

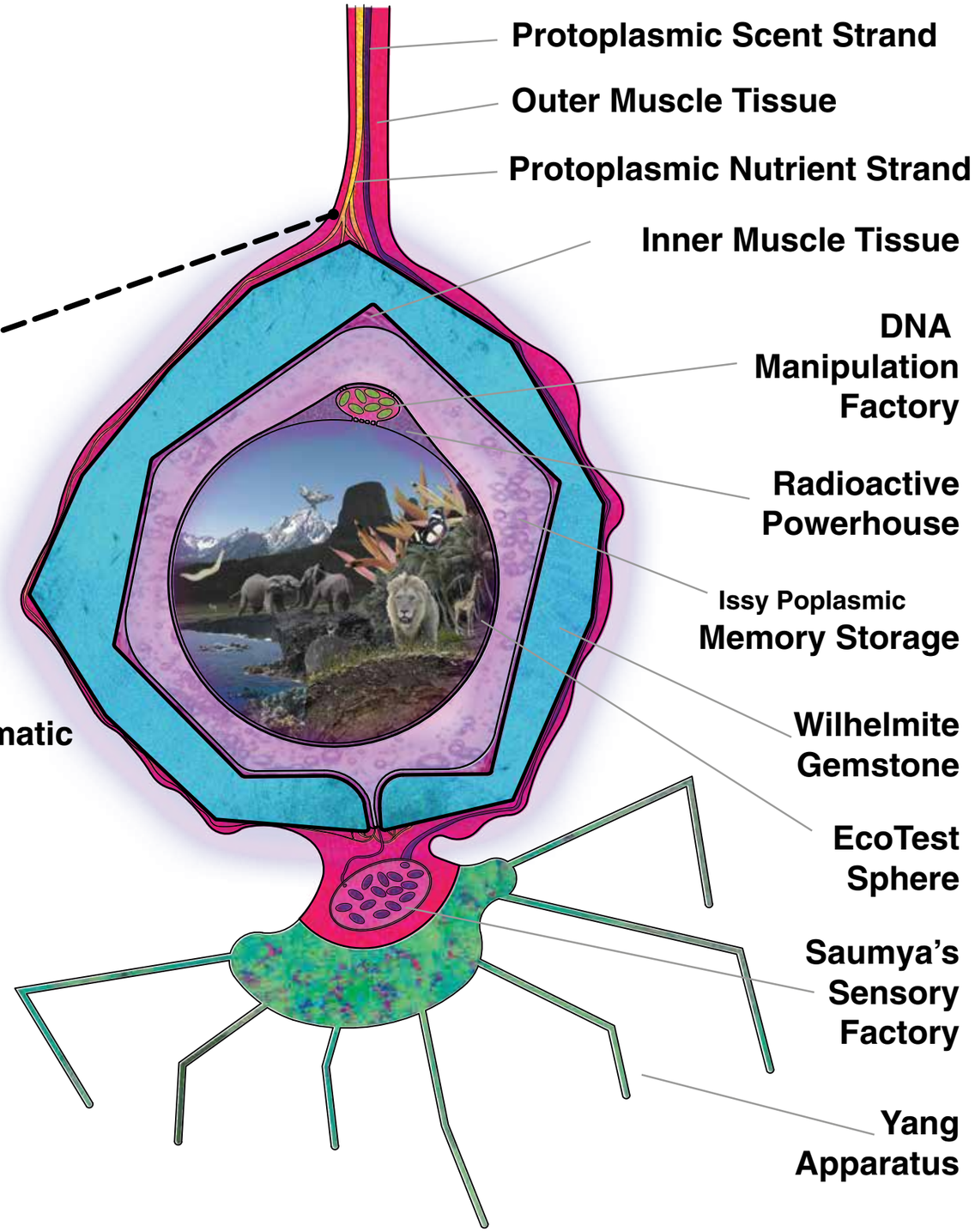
Nuetrons

Nucleus

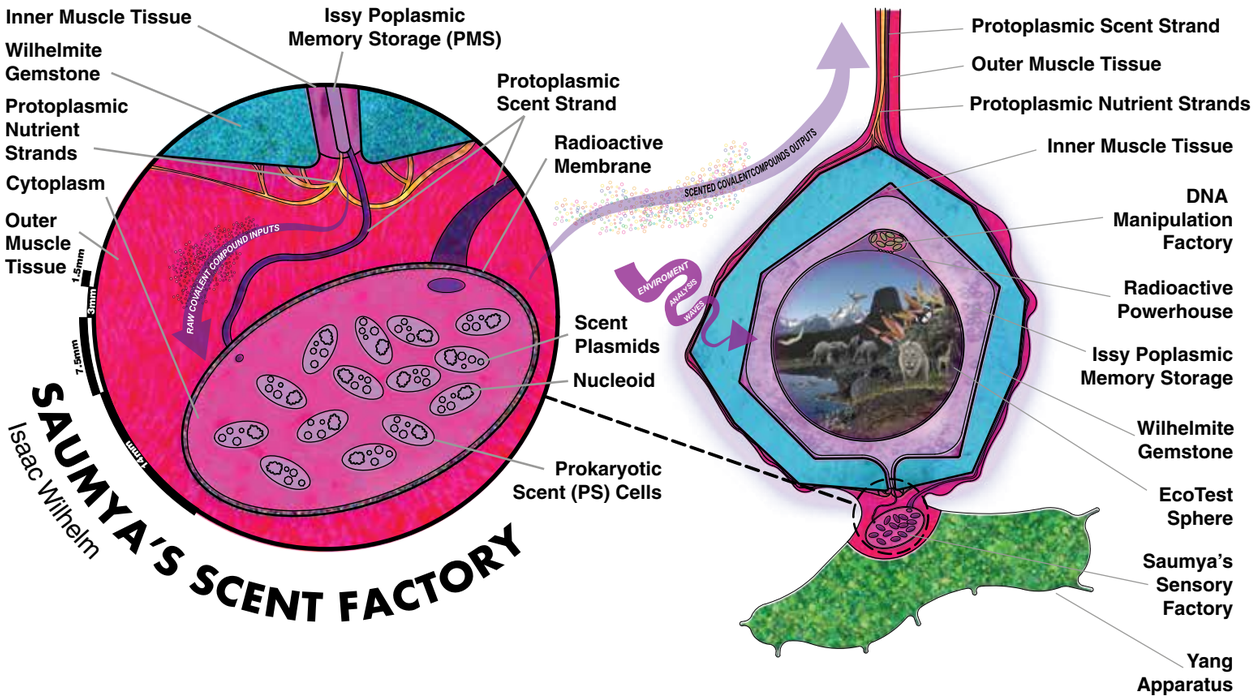




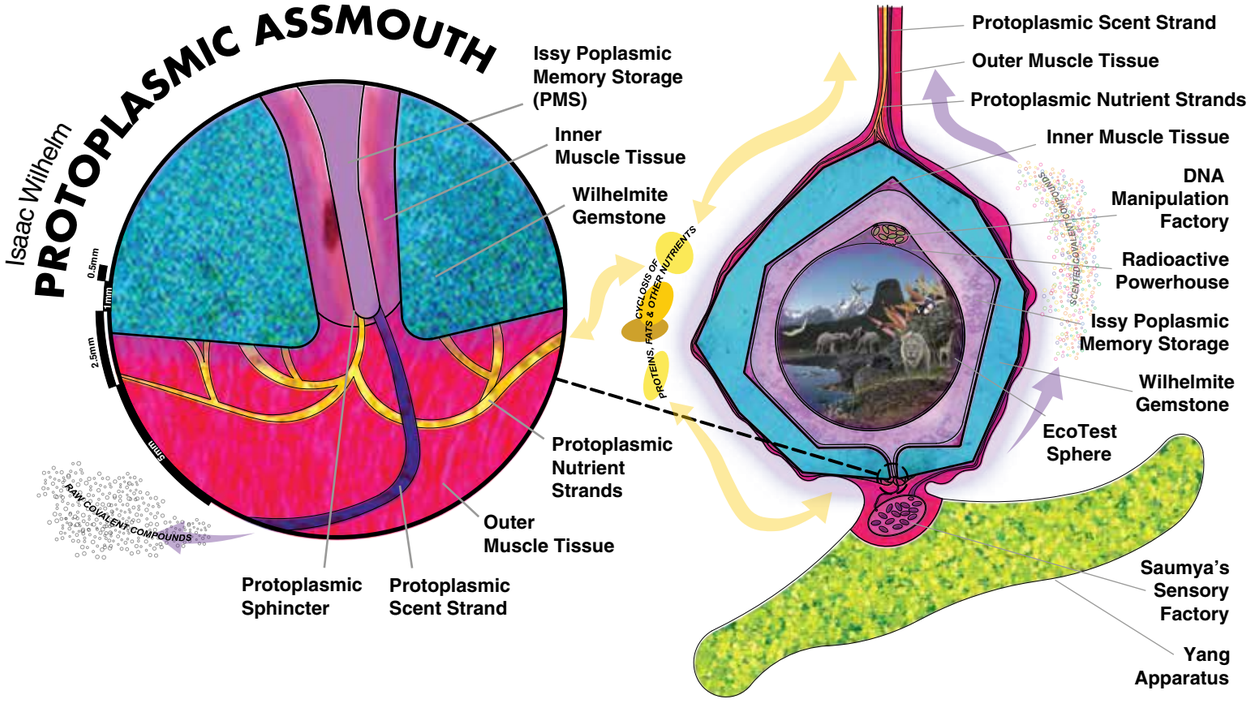

Chloroplast
Rough Endoplasmatic Reticulum
Cytoplasm
Golgi Apparatus
Plasma Membrane
Mitochondrion
Vacuole
Cuticles
Lysosome
Stoma
Nuclear Envelope
Smooth Endoplasmatic Reticulum
Chromatin
Nucleolus
Ribosomes
56µm
112µm
280µm
560µm
UPPER EPIDERMIS CELL
Isaac Wilhelm


Protoplasmic Scent Strand
Outer Muscle Tissue
Protoplasmic Nutrient Strand
Inner Muscle Tissue
DNA Manipulation Factory
Radioactive Powerhouse
Issy Poplasmic Memory Storage
Wilhelmite Gemstone
EcoTest Sphere
Saumya's Sensory Factory
Yang Apparatus

4 cm
3 cm
2 cm



SAUMYA'S SCENT FACTORY
Isaac Wilhelm

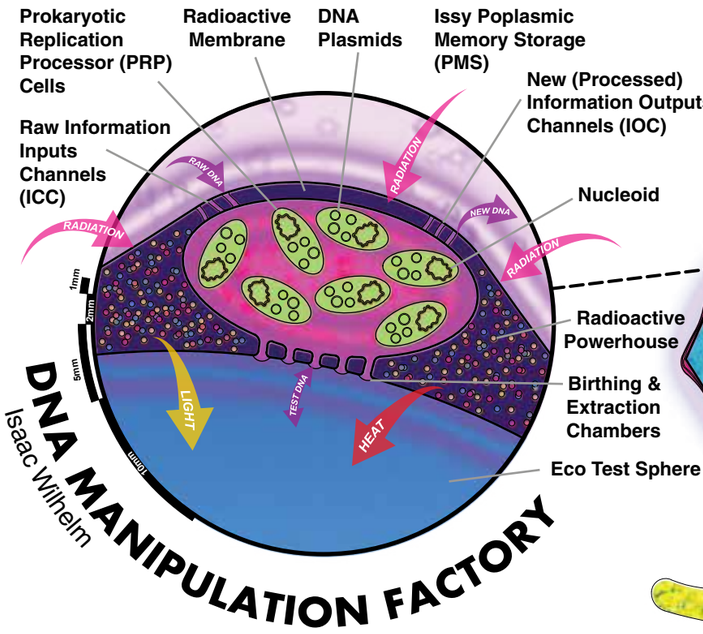


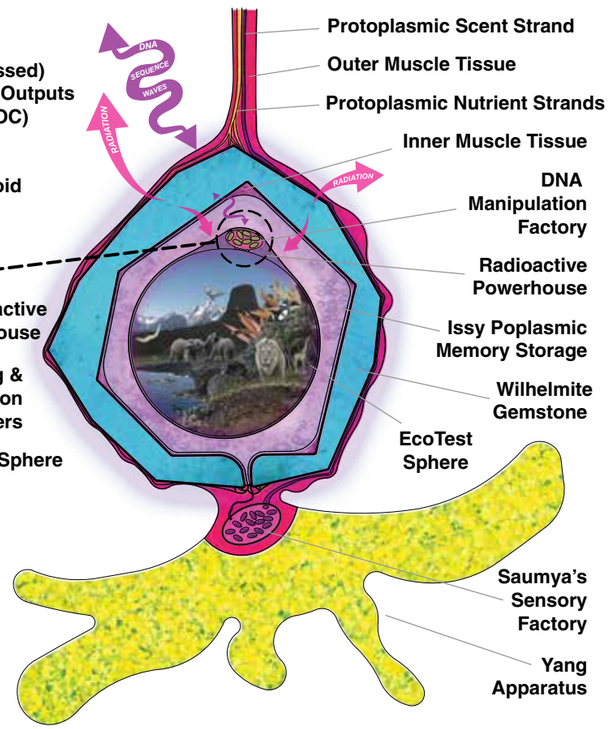
PROTOPLASMIC ASSMOUTH
Isaac Wilhelm

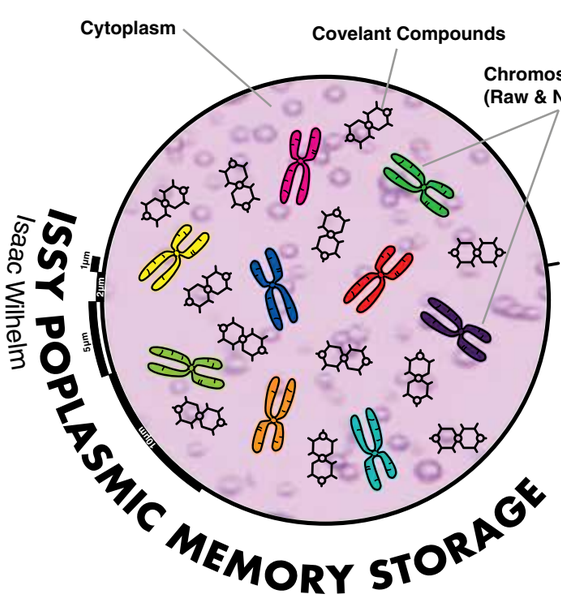
4 cm 3 cm 2 cm

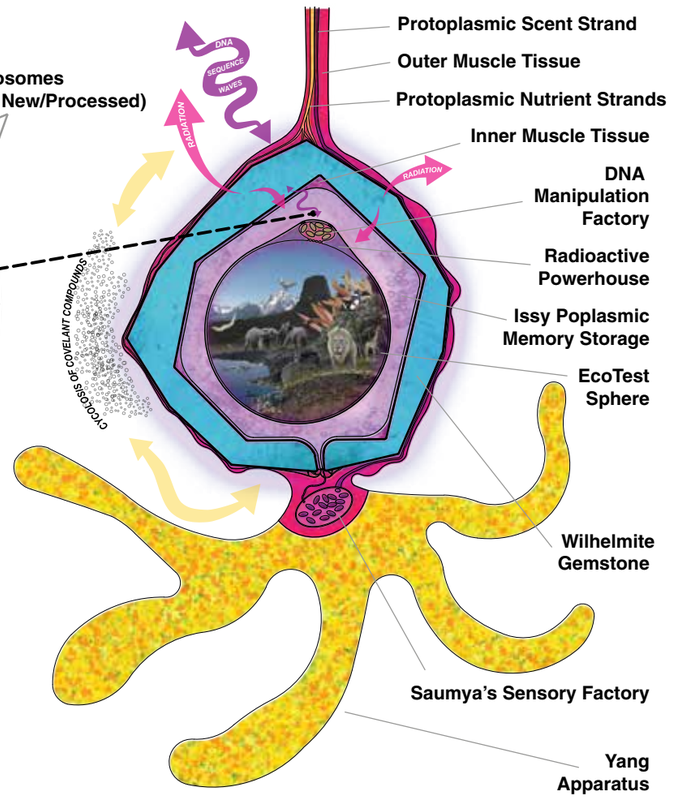
CONCEPTUAL SKETCHES Isaac Wilhelm

CONCEPTUAL VIGNETTE Isaac Wilhelm



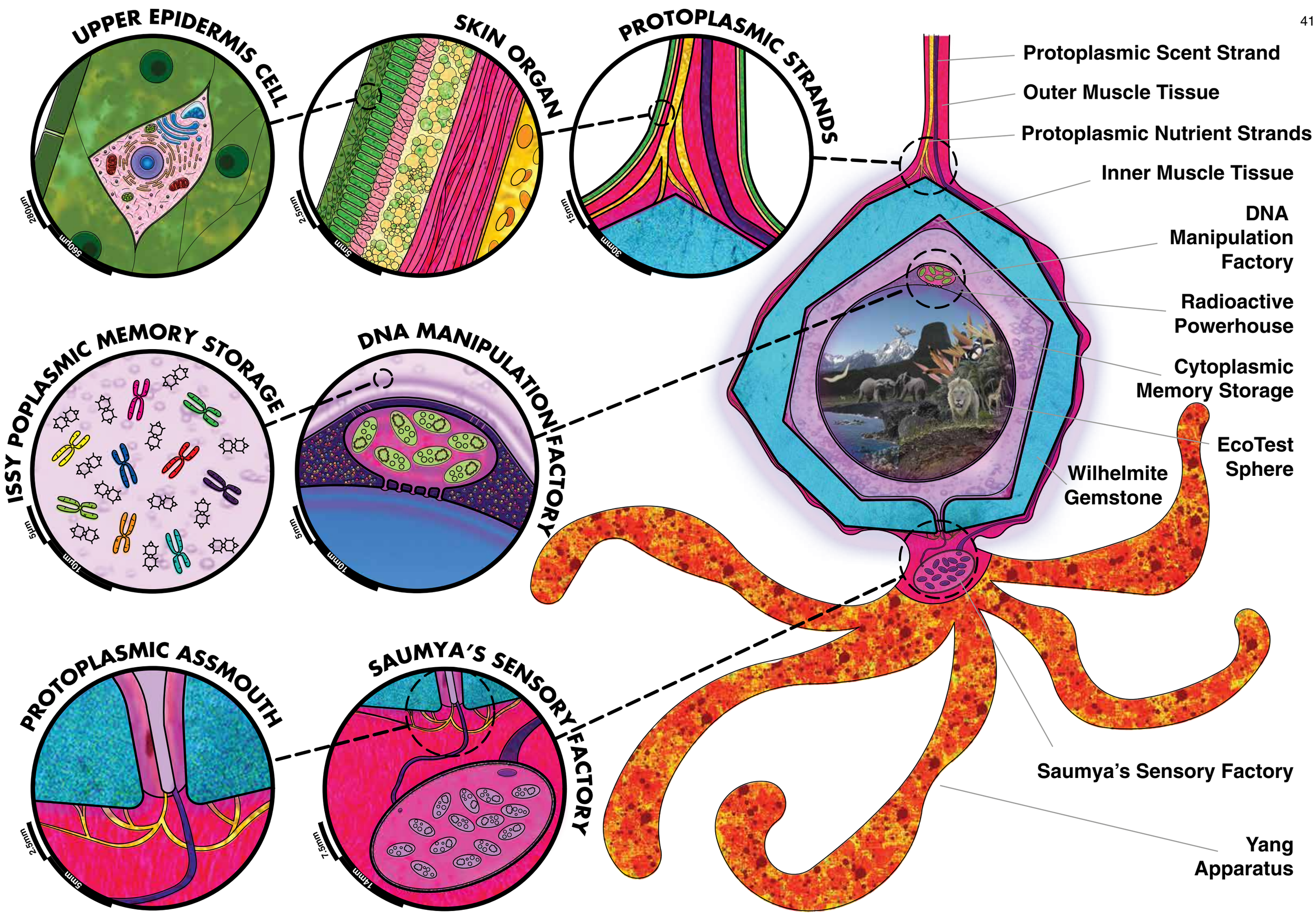






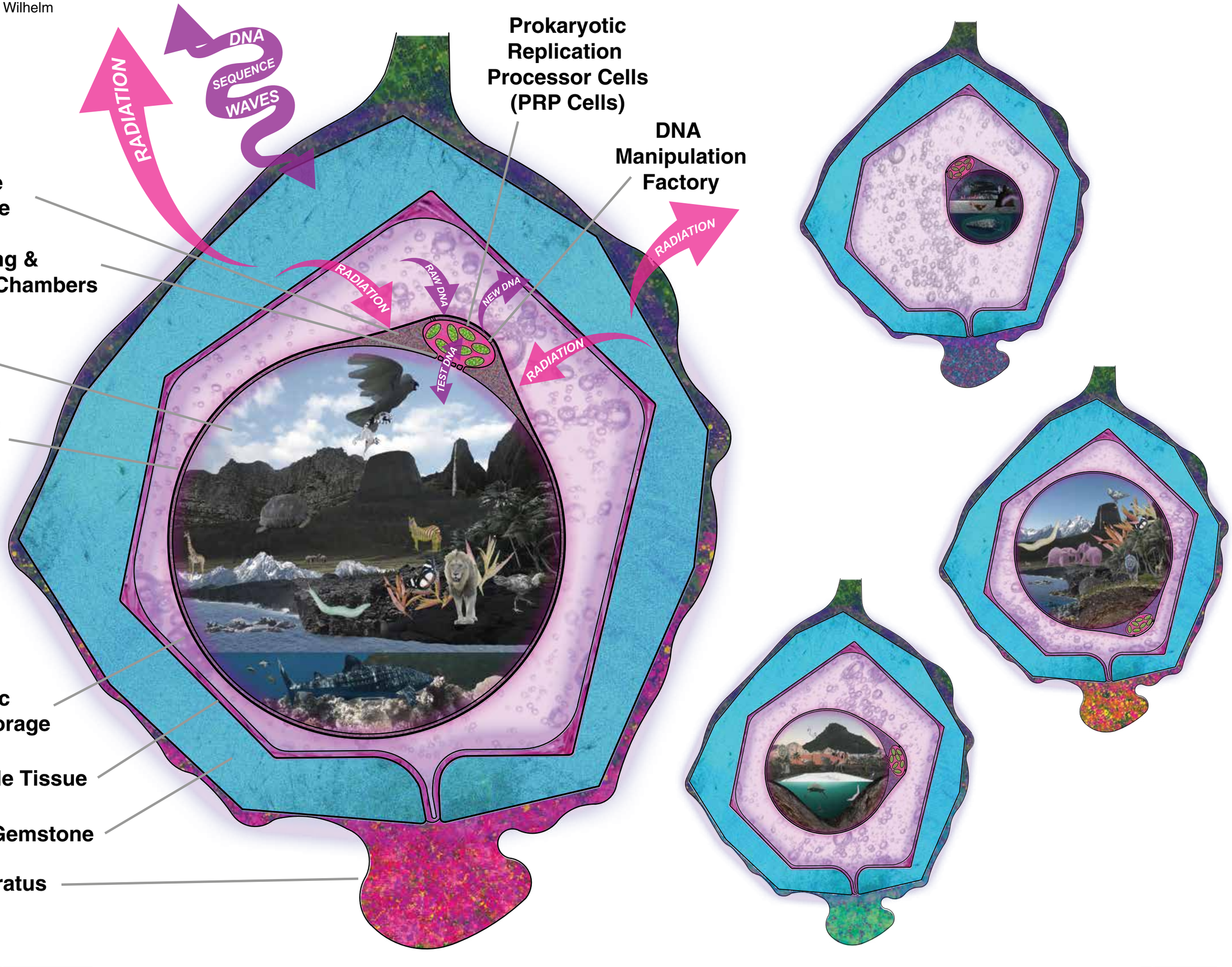
CONCEPTUAL COLLAGE Isaac Wilhelm, Isabel Tuggey, Saumya Singh

4 cm 3 cm 2 cm



Isaac Wilhelm

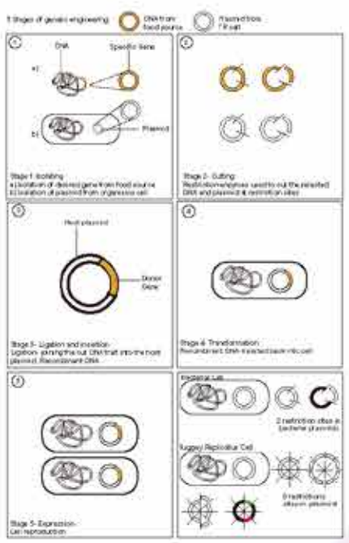
EcoCore Isaac Wilhelm

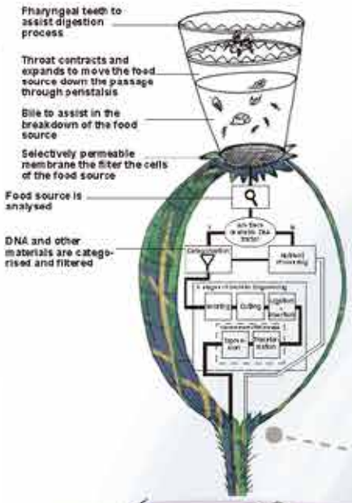


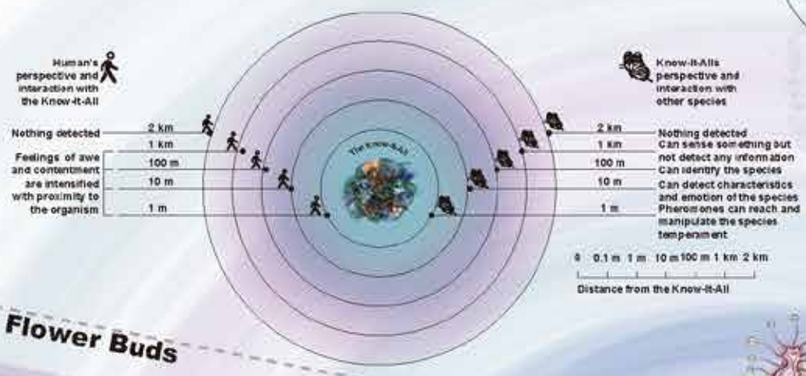
The Know-It-All

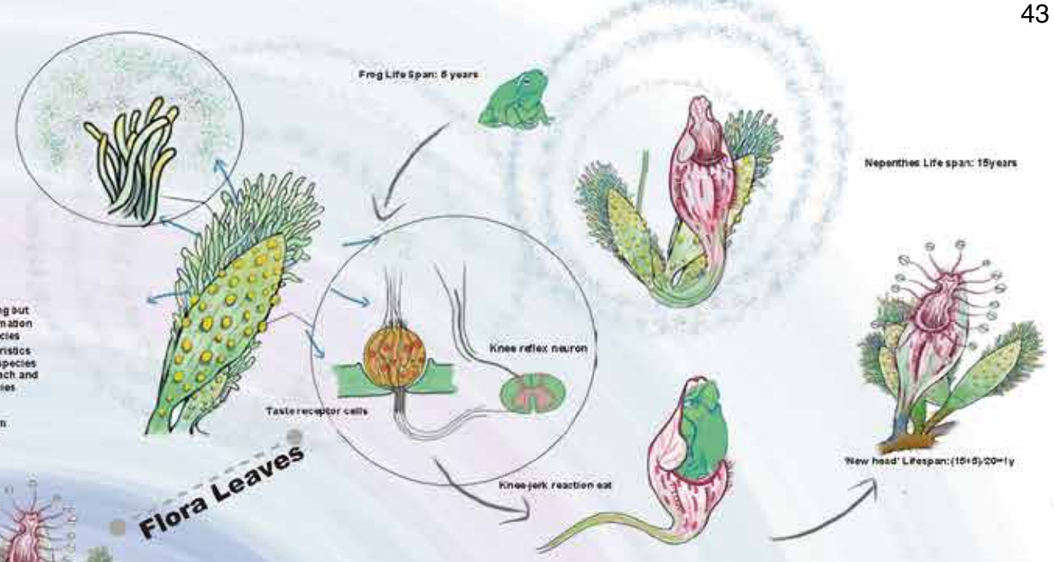
RA 8h 52m 36s I Dec + 28° 19' 51"

The Tuggey Replicatus Organ



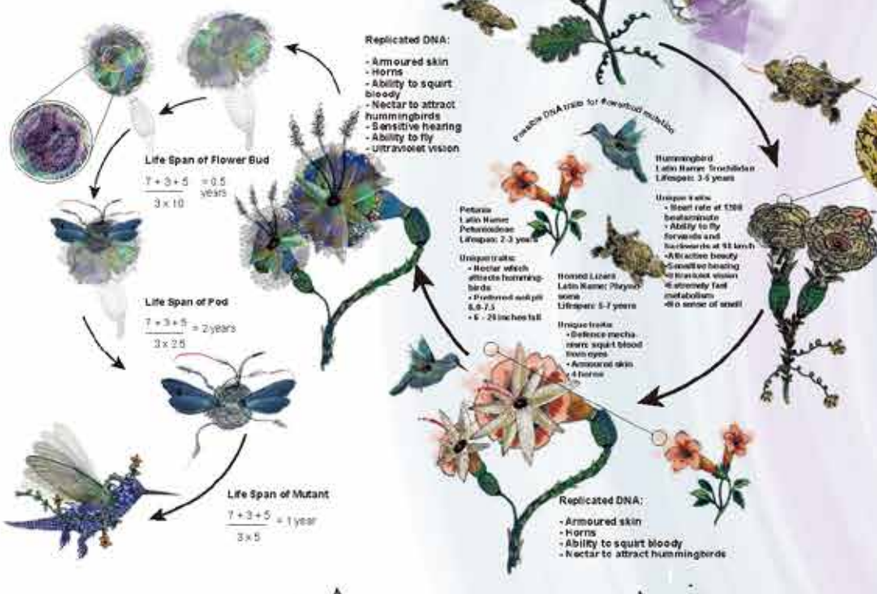


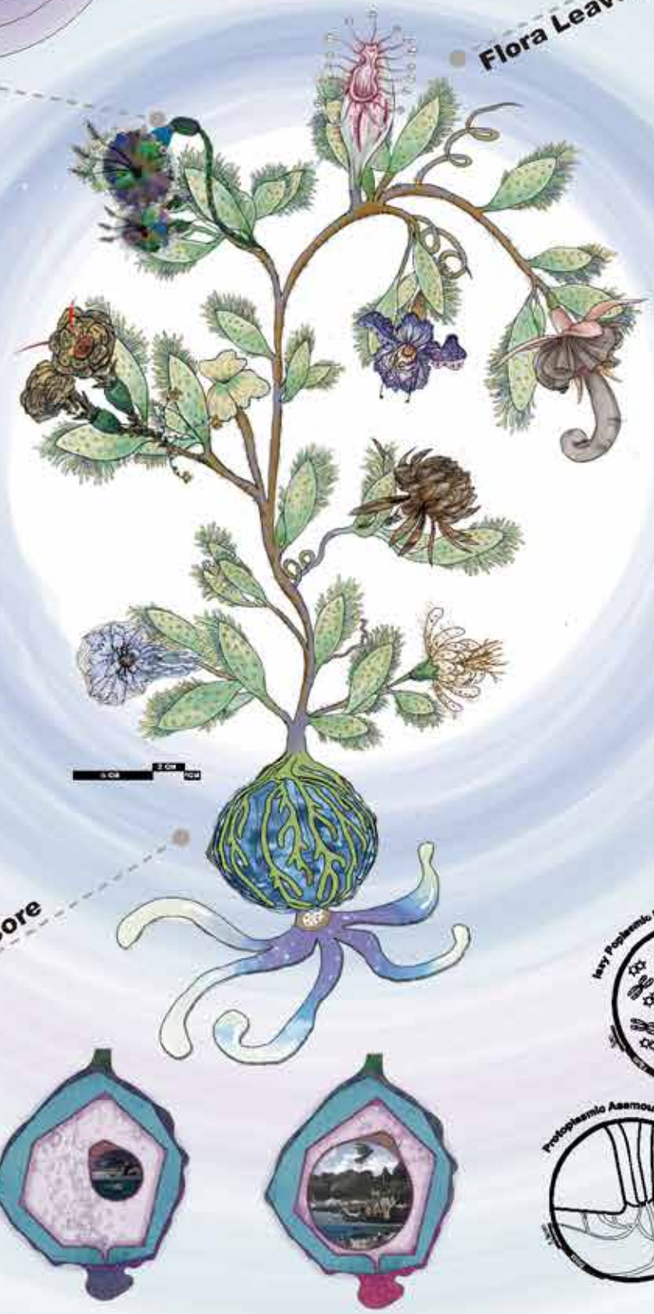


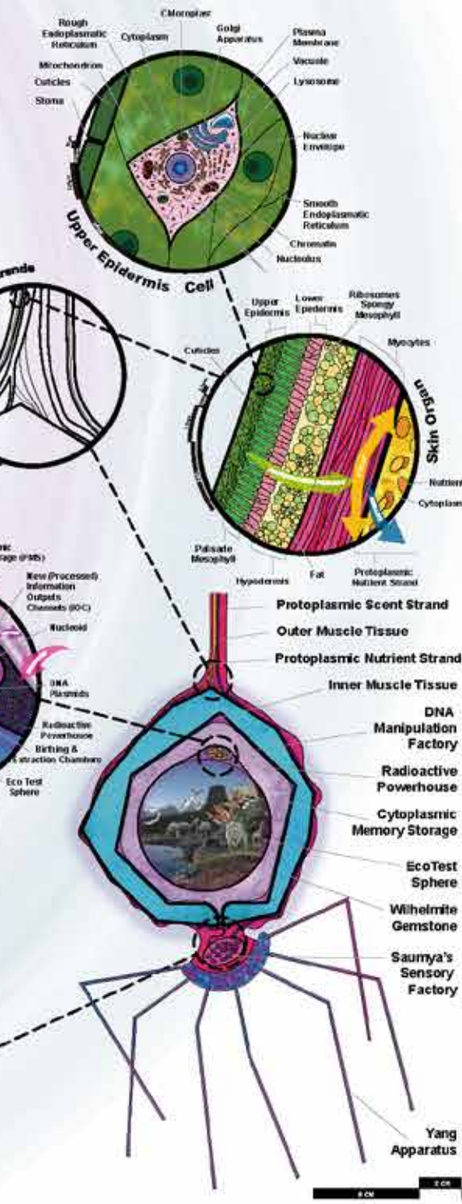


Flower Buds

Flora Leaves







Loveless Mutants

Group 6: Isabel Tuggey, Isaac Wilhelm, Jiayu Yang, Saumya Singh
MA Biodesign Central Saint Martins Alice Taylor & Nancy Diniz

DESIGNING WITH KUDAHUVADHOO

COASTLINE REMEDIATION

aquaFaṇḍitas // *REROOTING OUR COASTLINES*

IN PARTNERSHIP WITH: *THE ECO ORG*
IN COLLABORATION WITH: *CINZIA FERRARI, NICHOLE CHRYSIKOU, SHEM JOHNSON, JULIAN RODRIGUEZ*
HATHAREH GROUP 4: *ISAAC M. WILHELM, ANA BEATRIZ ALVES, MARTHE FRENOD, VINCENT DISSAUX, YIHENG GU*

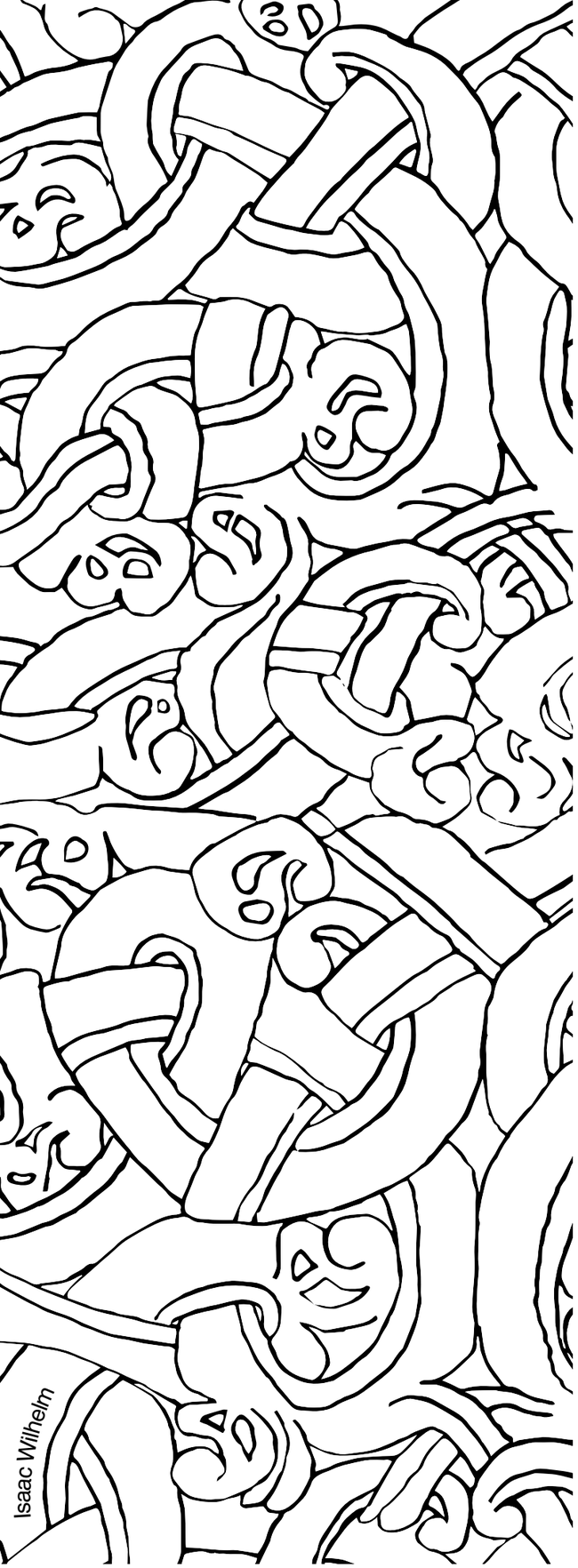
aquaFaṇḍitas REROOTING OUR COASTLINES

Constructed out of local coir rope, aquaFanditas provides protection to freshly planted mangroves, assuring a higher success rate. Inspired by the negative space functionalities of the mangrove roots, it is approximately 1 meter wide by ½ meter high (size varies depending on each community maker). Using a simple looping technique with lashings, a simple rhythmic pattern can easily be crafted by anyone, young or old. Calcified through a process using a common soil bacterium (S. pasteurii), the biomateriality provides a hospitable micro-surface for natural algae propagation. Additionally, the rope's flexibility prior to calcification means community members can implement a personal identity into their design form, ideally prolonging community interest in mangrove conservation and stewardship.

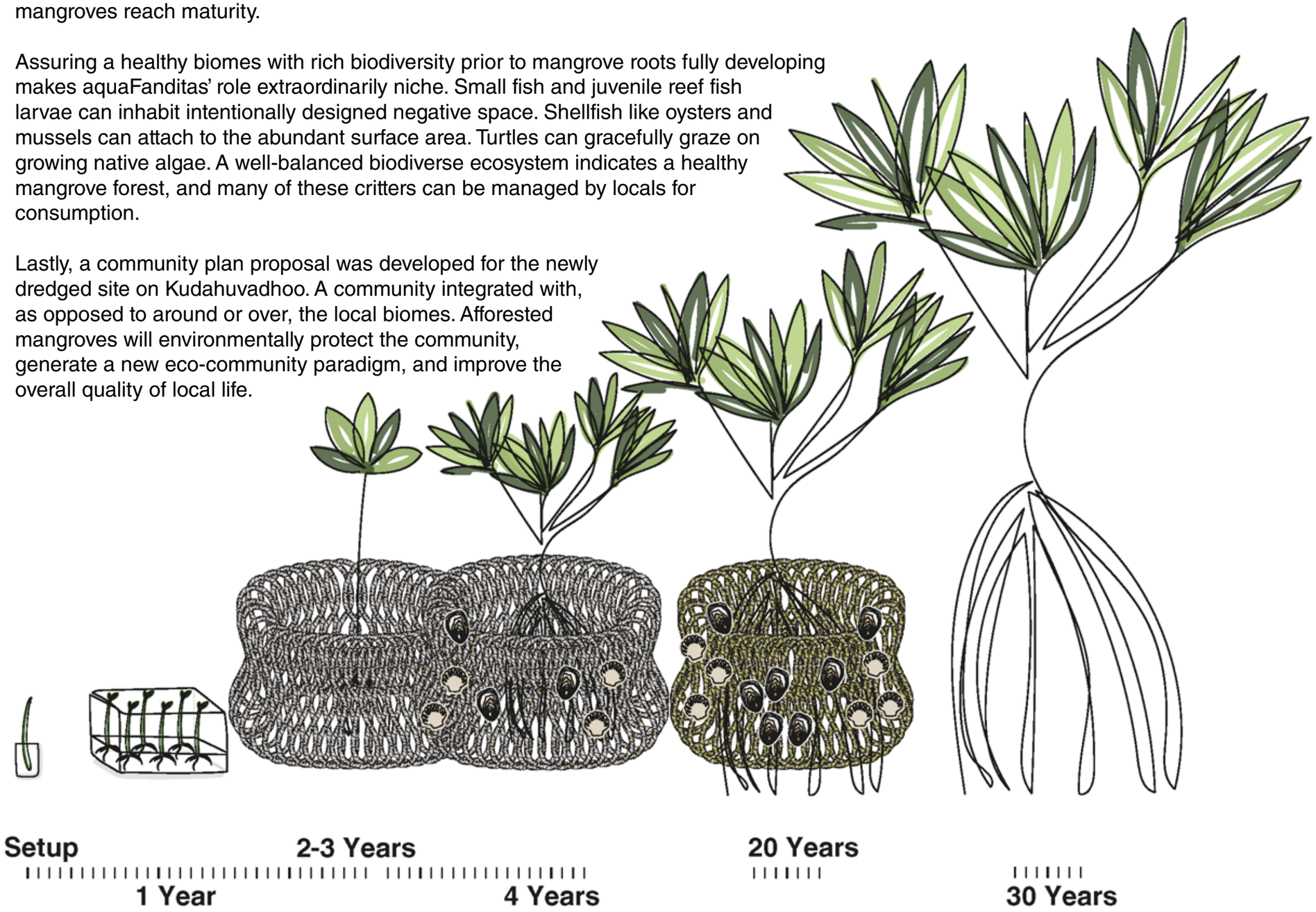
Corresponding to mangrove root development, aquaFanditas biodegrades with an inherent lifespan. As the roots expand between the calcified loops, the biomaterial cracks and allows the mangrove to harvest nutrients. Since mangroves play a vital role in erosion control and the habitation of reef fish larvae, aquaFanditas is intentionally designed to temporarily fulfilling these roles intermediately until the mangroves reach maturity.

Assuring a healthy biomes with rich biodiversity prior to mangrove roots fully developing makes aquaFanditas' role extraordinarily niche. Small fish and juvenile reef fish larvae can inhabit intentionally designed negative space. Shellfish like oysters and mussels can attach to the abundant surface area. Turtles can gracefully graze on growing native algae. A well-balanced biodiverse ecosystem indicates a healthy mangrove forest, and many of these critters can be managed by locals for consumption.

Lastly, a community plan proposal was developed for the newly dredged site on Kudahuvadhoo. A community integrated with, as opposed to around or over, the local biomes. Afforested mangroves will environmentally protect the community, generate a new eco-community paradigm, and improve the overall quality of local life.



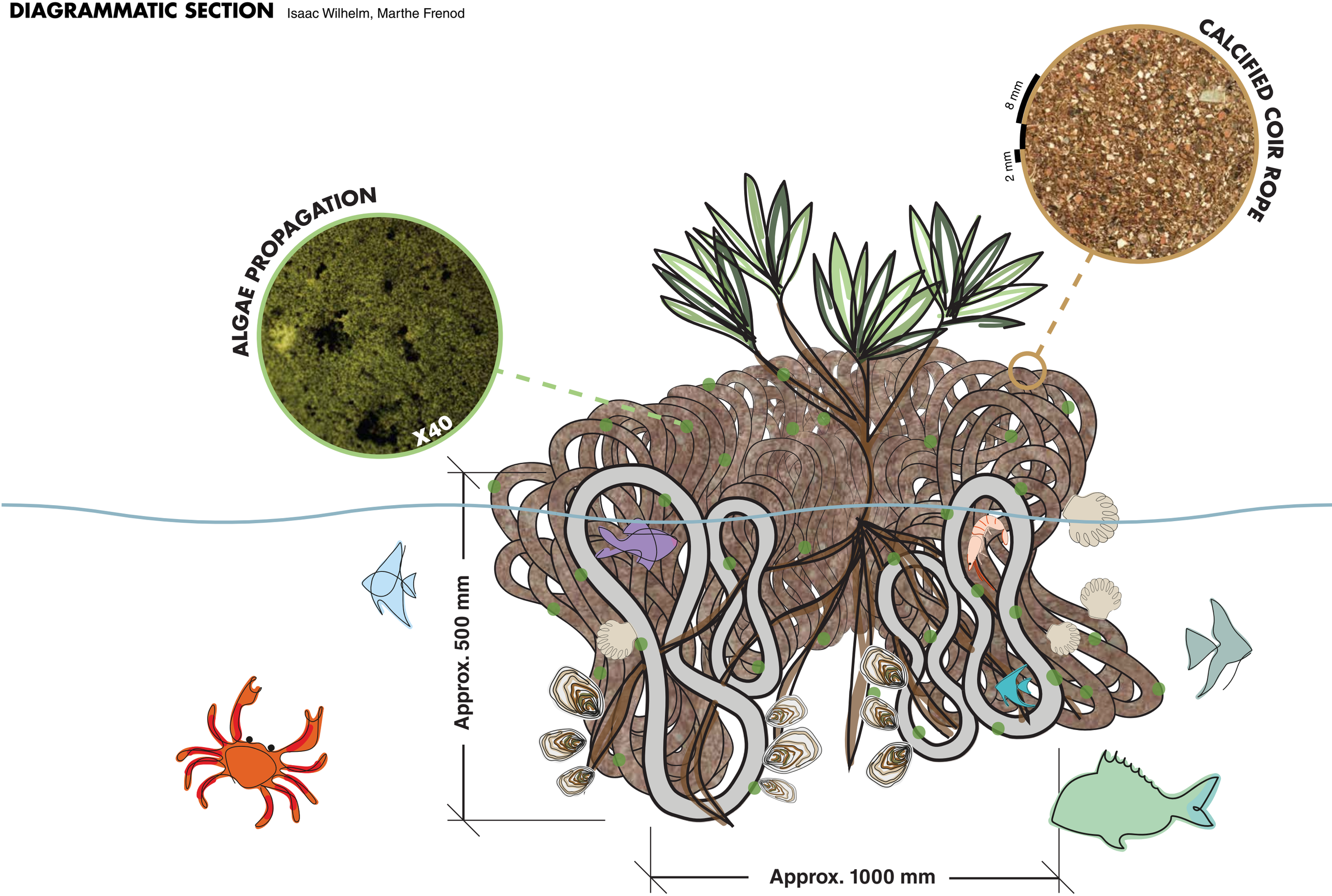
CORAL CARVING SKETCH



Marthe Frenod INHERENT LIFESPAN DIAGRAM

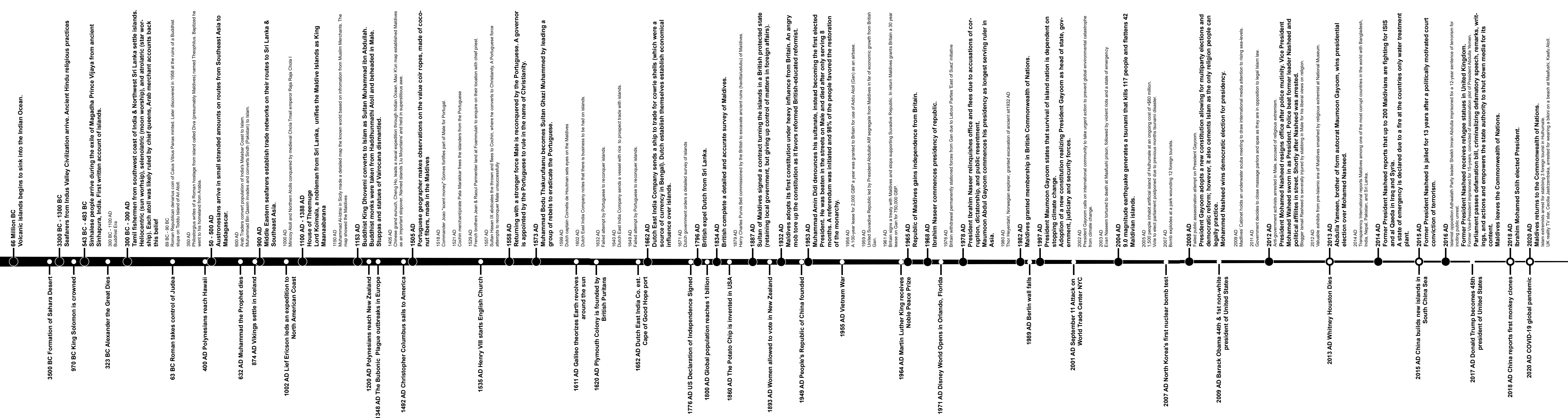
DIAGRAMMATIC SECTION

Isaac Wilhelm, Marthe Frenod



MALDIVES HISTORICAL TIMELINE

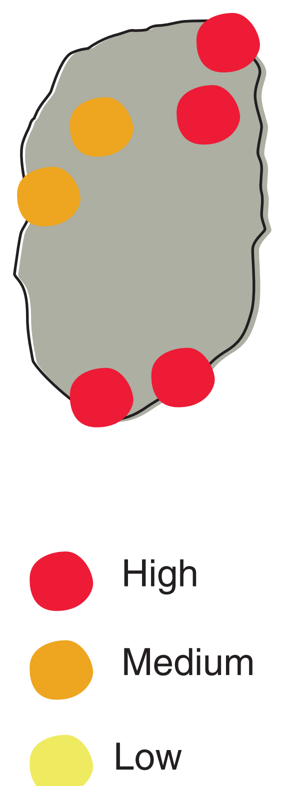
Isaac Wilhelm



CLIMATE IMPACT ANALYSIS

Marthe Frenod

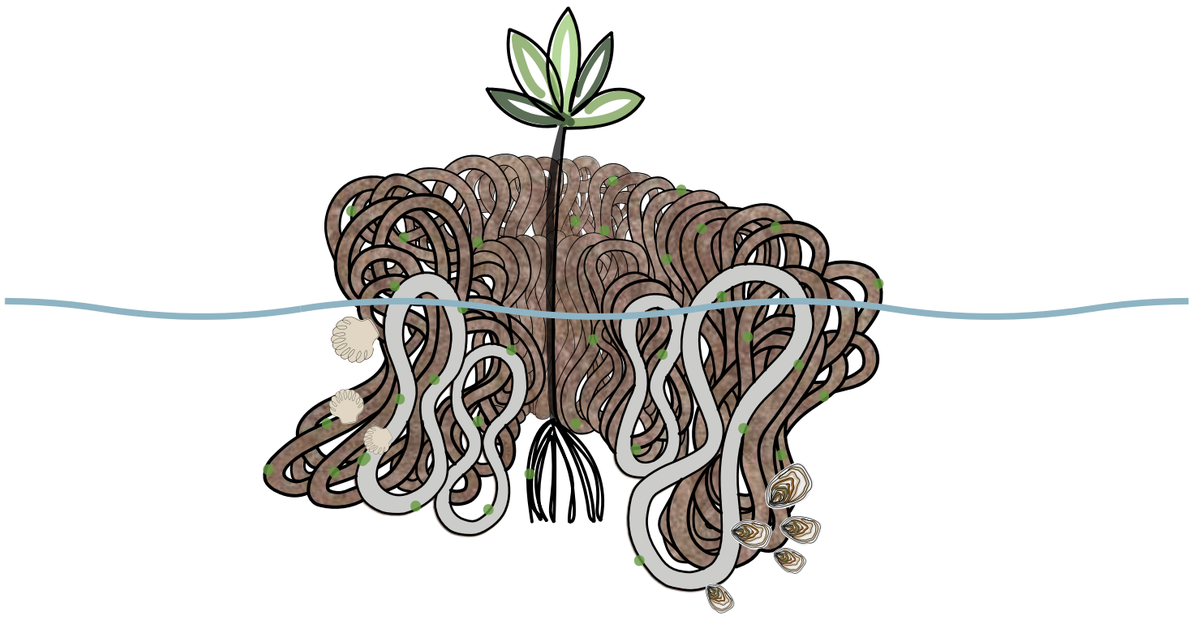
Hydrometeorological Multihazard

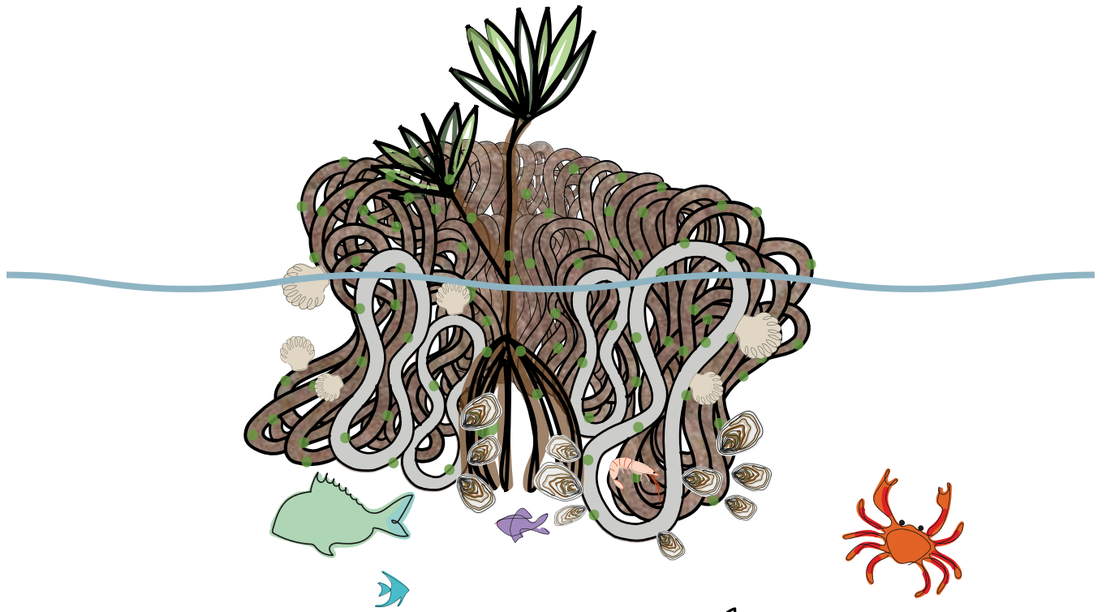


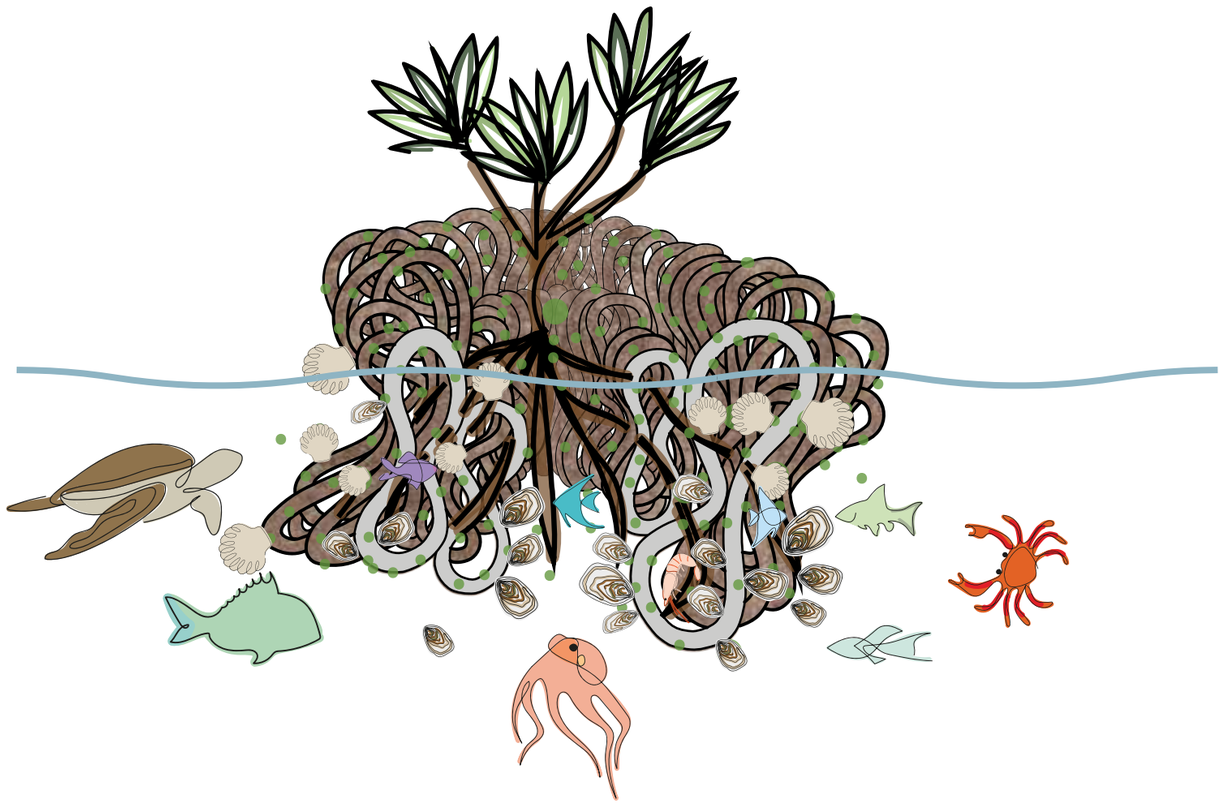
Tsunami Hazard Rank

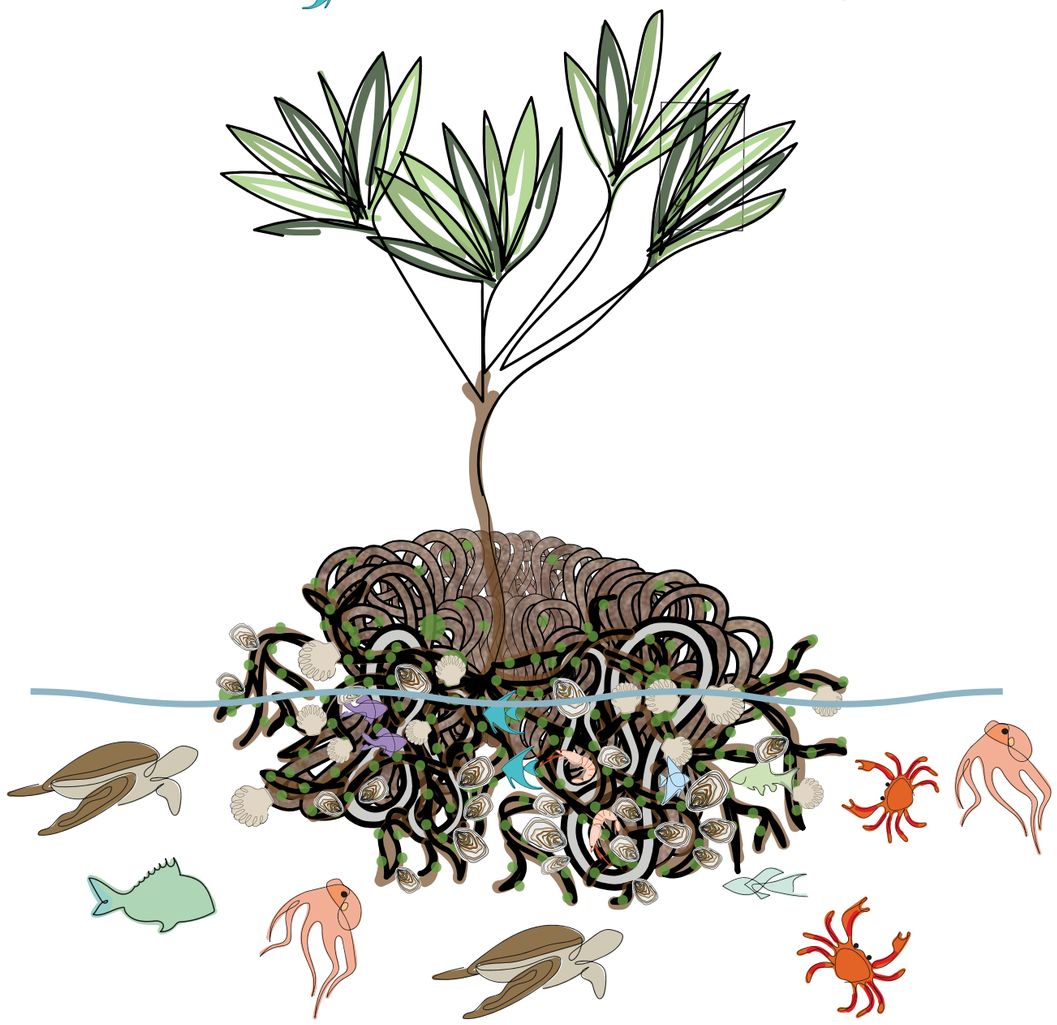
REROOTING OUR COASTLINES

Isaac Wilhelm









Residental
Produce/Retail
Commercial/Business
Community Centre
Education Centre
Agricultural
Wastewater Bioremediation
Mangrove Forest
Coral Gardens
Seagrass Meadows
Alage Farm
Mosque
Coconut Grove
Agriculture Veyo
Eco Centre

COMMUNITY PLAN PROPOSAL

Isaac Wilhelm

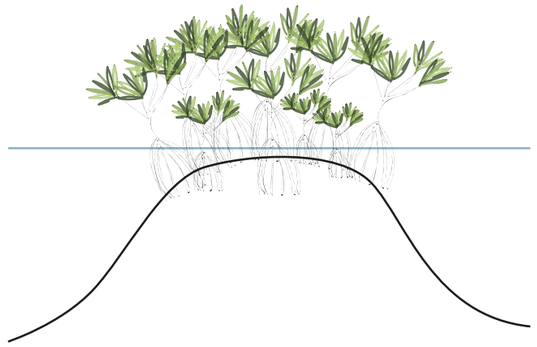
600 m
300 m

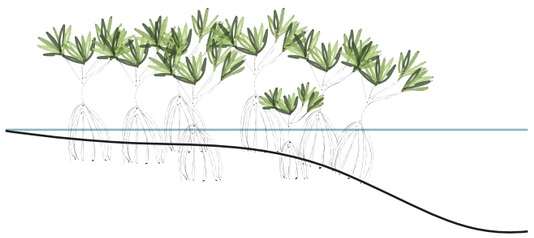
Overwashed Mangrove Forests

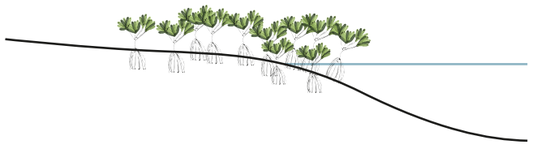
Fringe Mangrove Forests

Dwarf Mangrove Forests

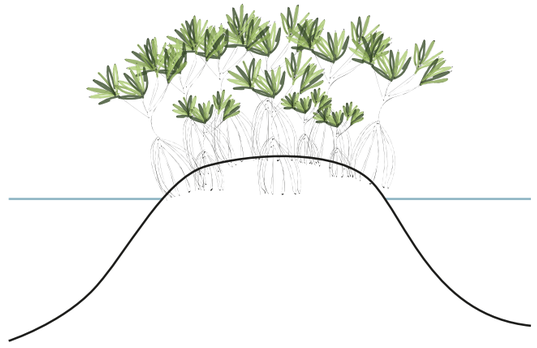
High Tide

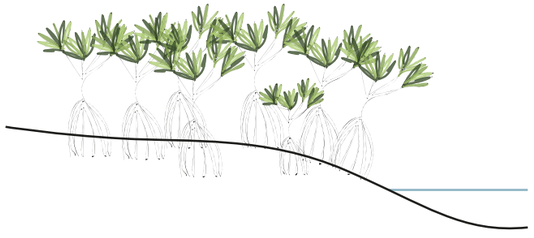






Low Tide

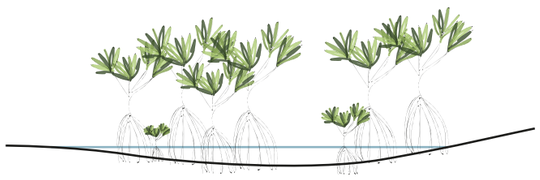


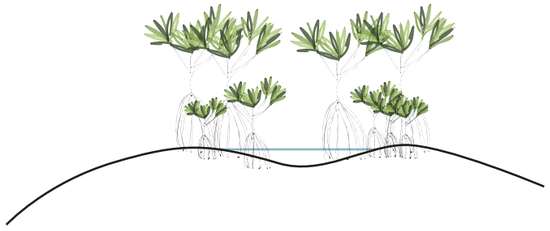


Basin Mangrove Forests

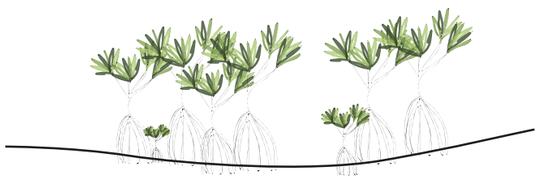
Hammock Mangrove Forests

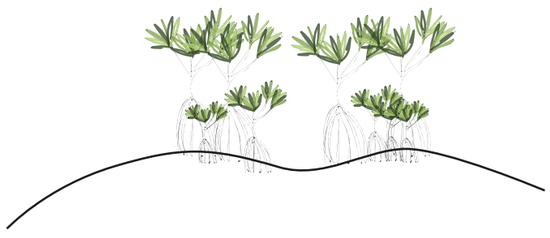
Wet Season



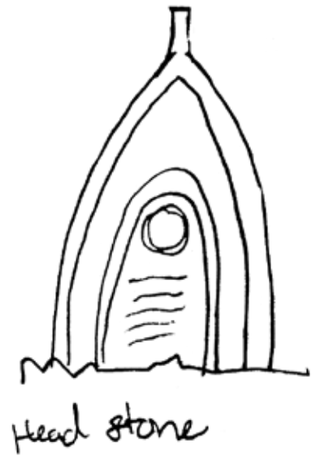


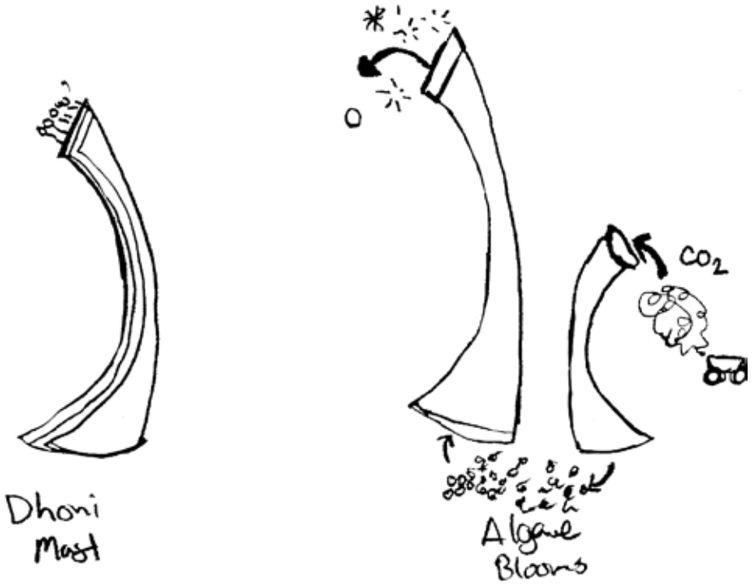
Dry Season





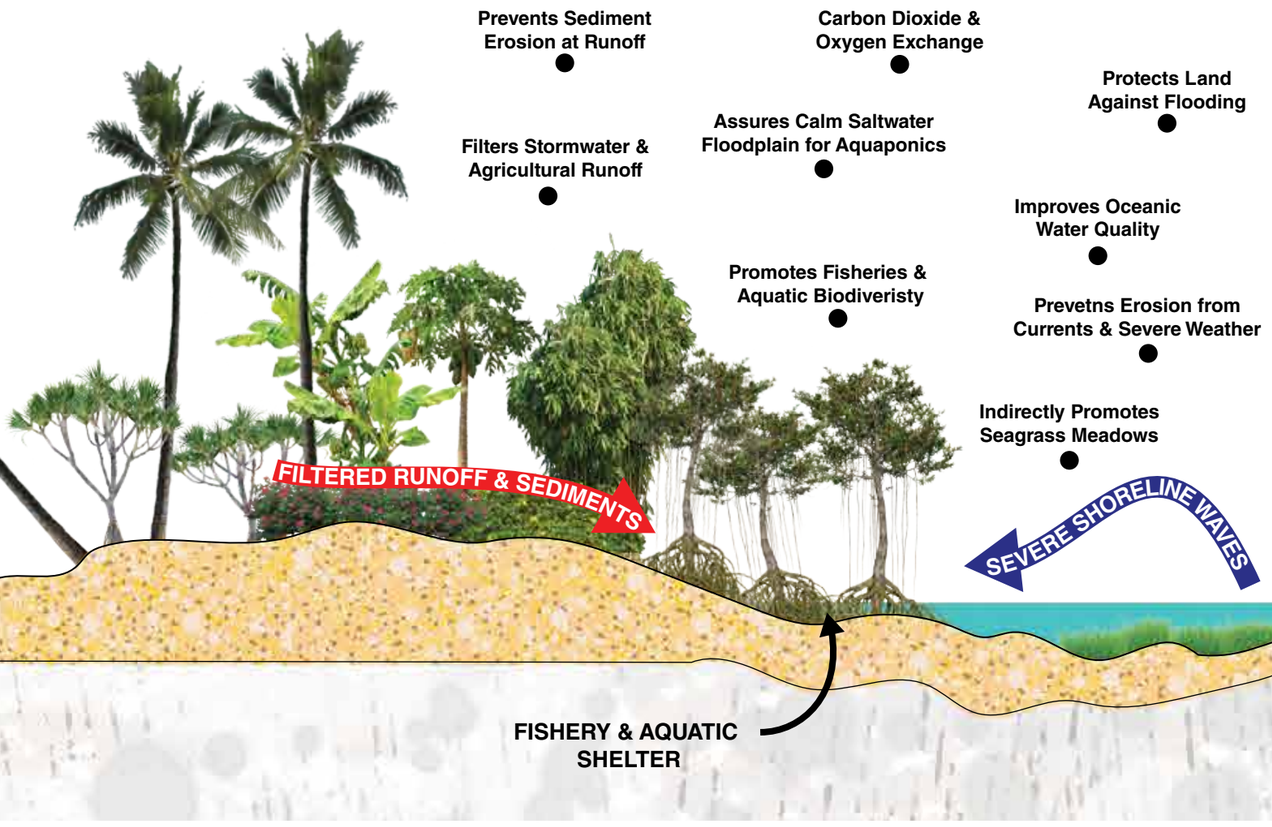
MANGROVE TYPOLOGIES Marthe Frenod



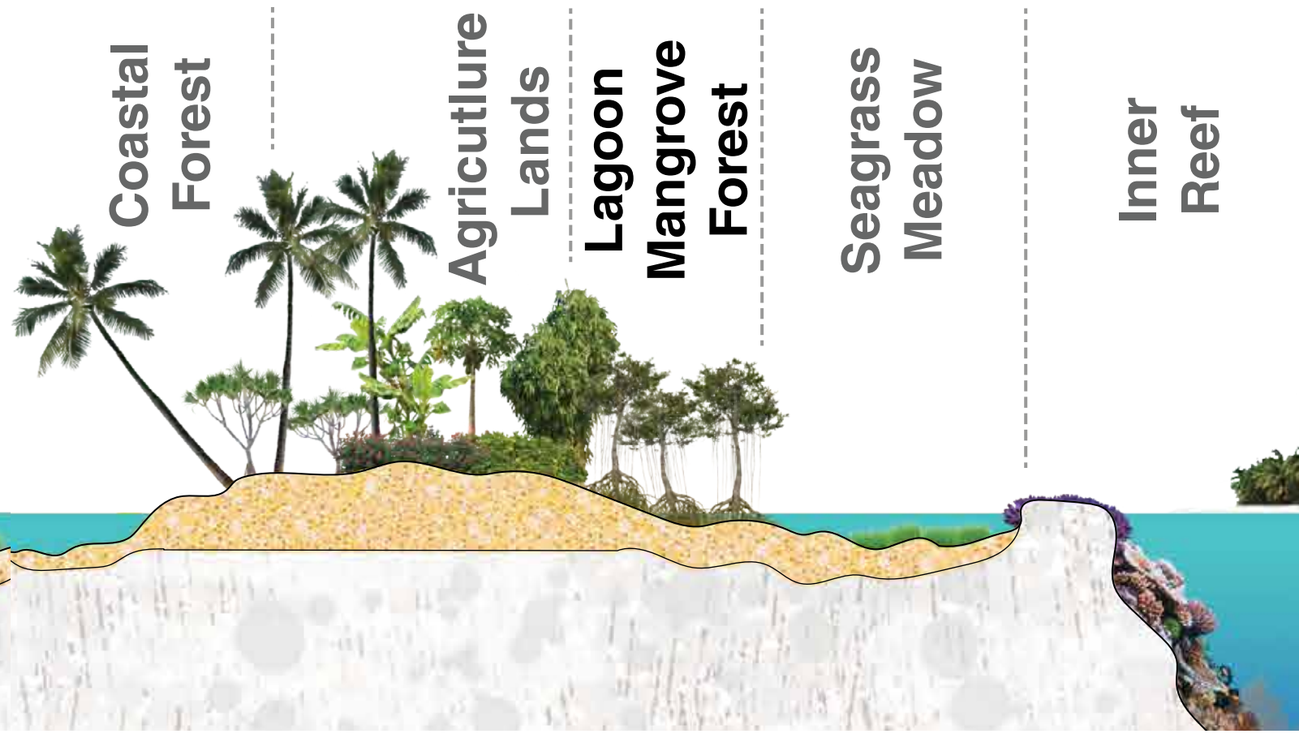


CONCEPTUAL SKETCHES Isaac Wilhelm

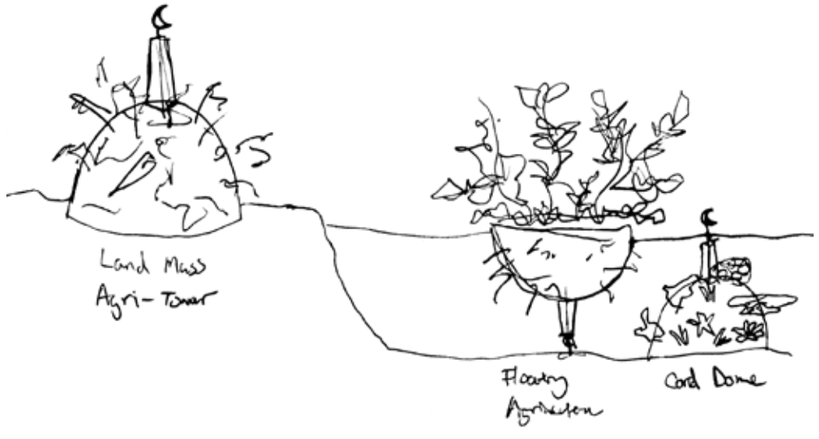
MANGROVE ECO-FUNCTIONS Isaac Wilhelm



ATOLL BIOMES Isaac Wilhelm

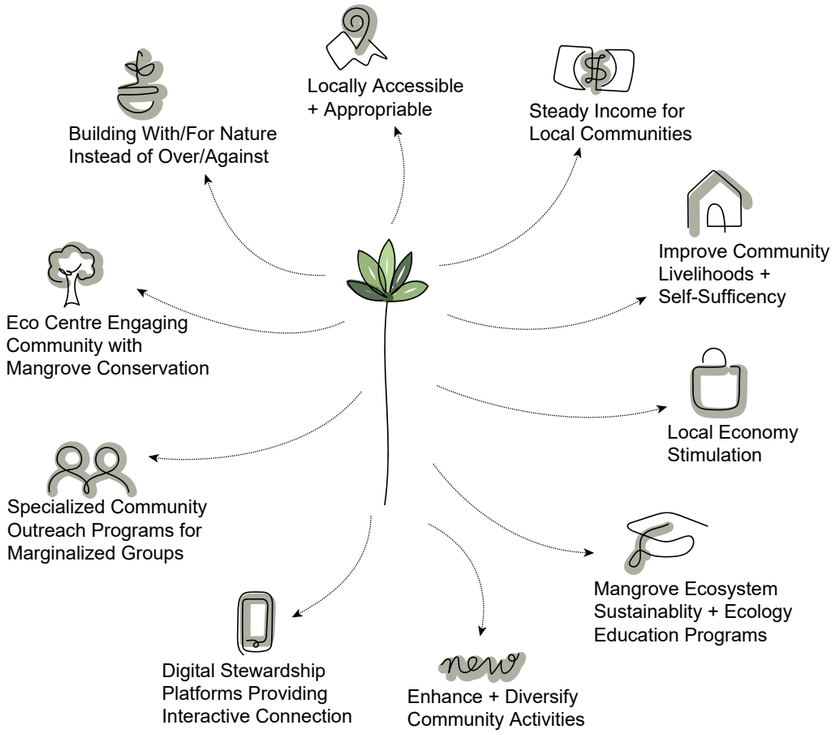


CONCEPTUAL SKETCHES Isaac Wilhelm



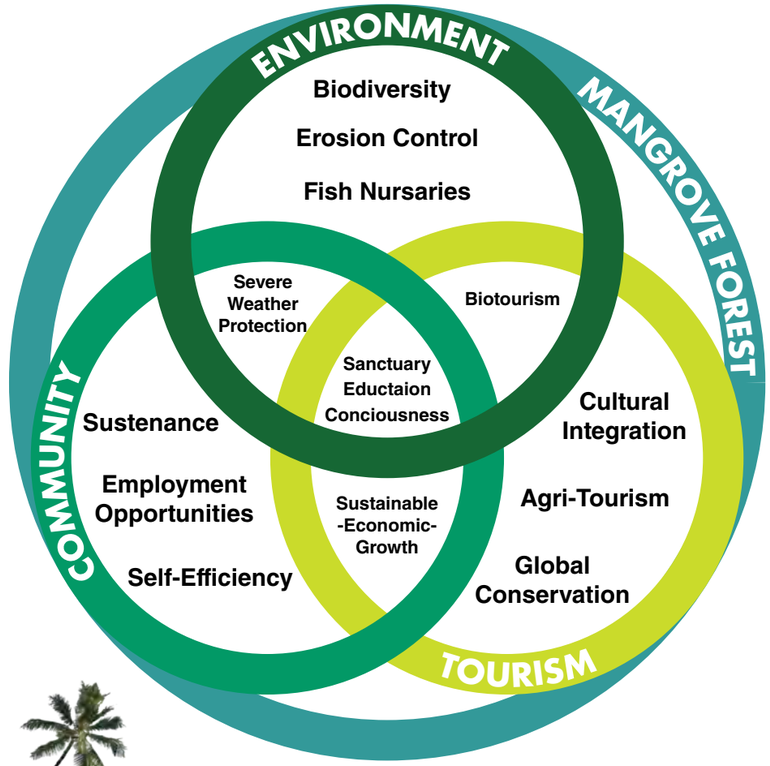
VALUE PROPOSITIONS

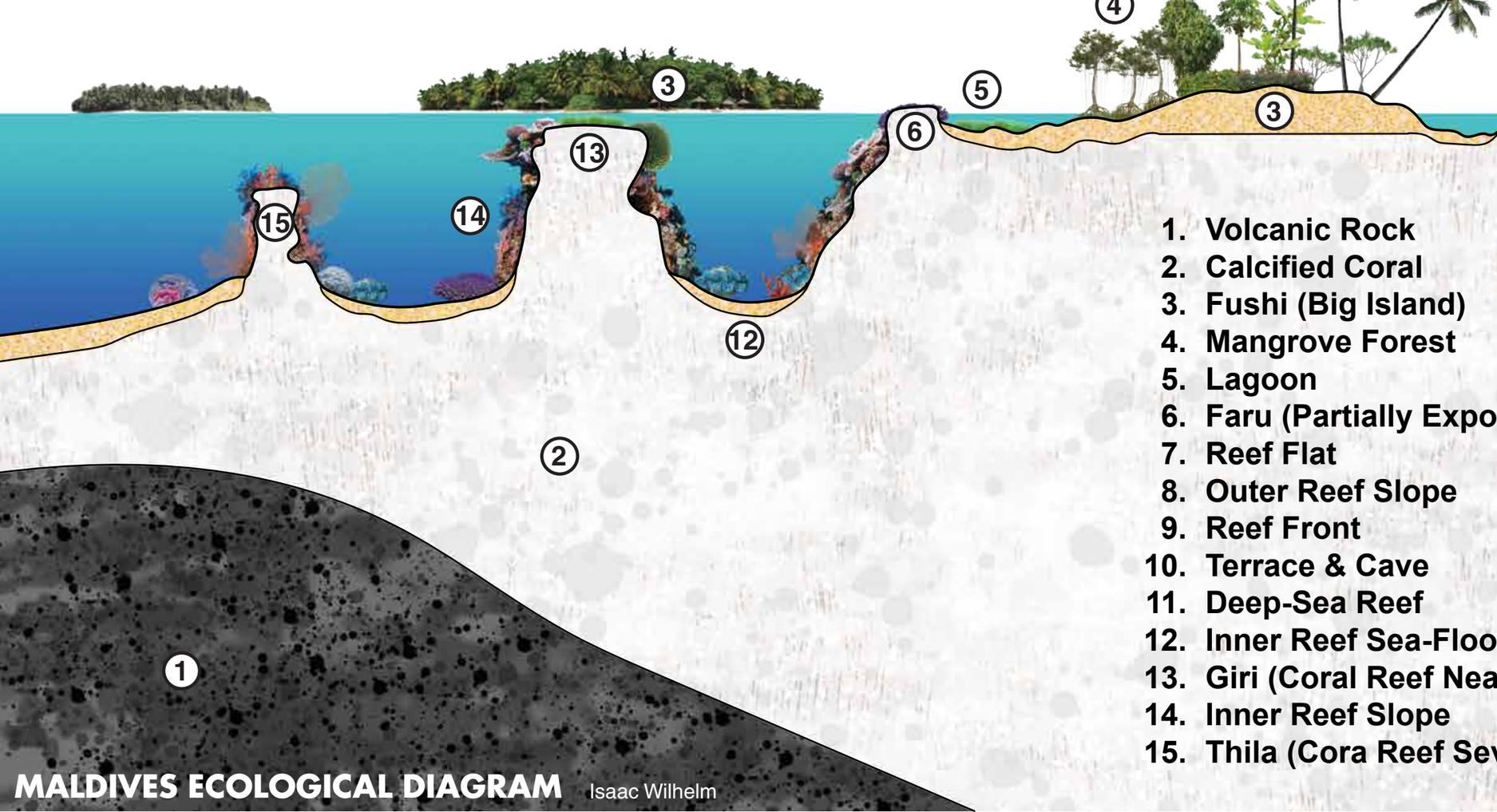
Marthe Frenod, Isaac Wilhelm



VALUE VENN DIAGRAM

Isaac Wilhelm





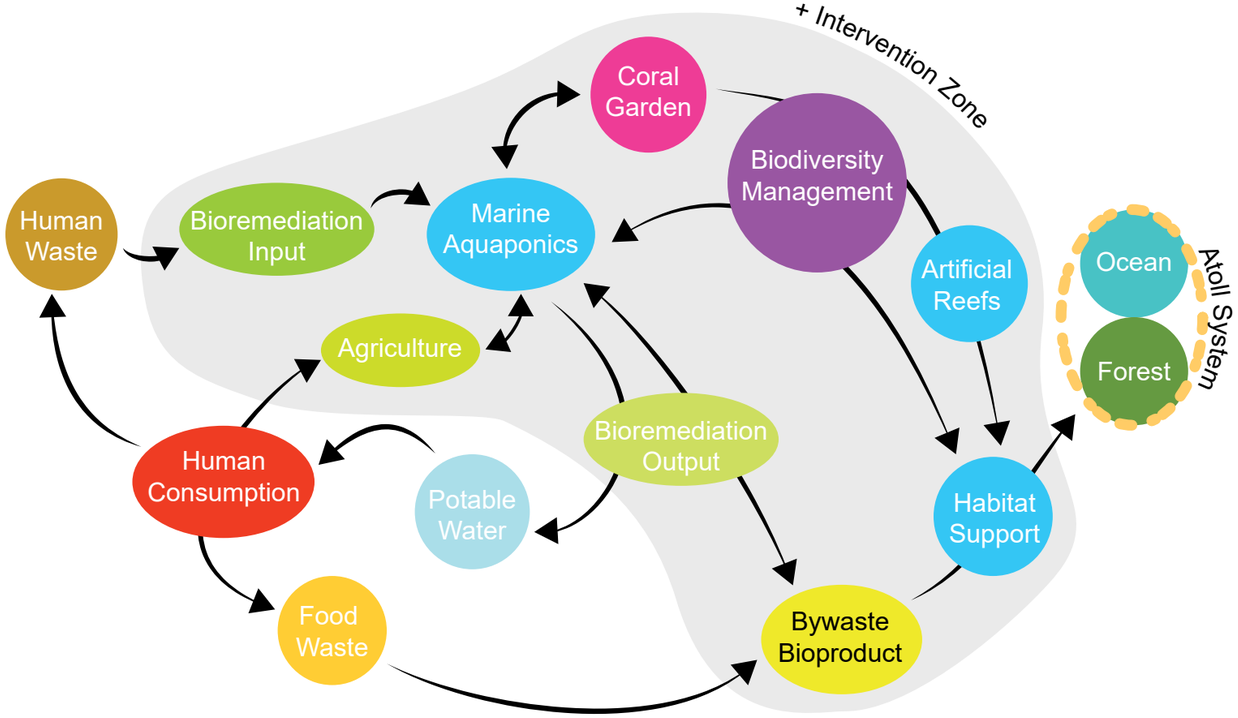
1. Volcanic Rock
2. Calcified Coral
3. Fushi (Big Island)
4. Mangrove Forest
5. Lagoon
6. Faru (Partially Exposed Reef)
7. Reef Flat
8. Outer Reef Slope
9. Reef Front
10. Terrace & Cave
11. Deep-Sea Reef
12. Inner Reef Sea-Floor
13. Giri (Coral Reef Near Surface)
14. Inner Reef Slope
15. Thila (Cora Reef Several Meters Below)

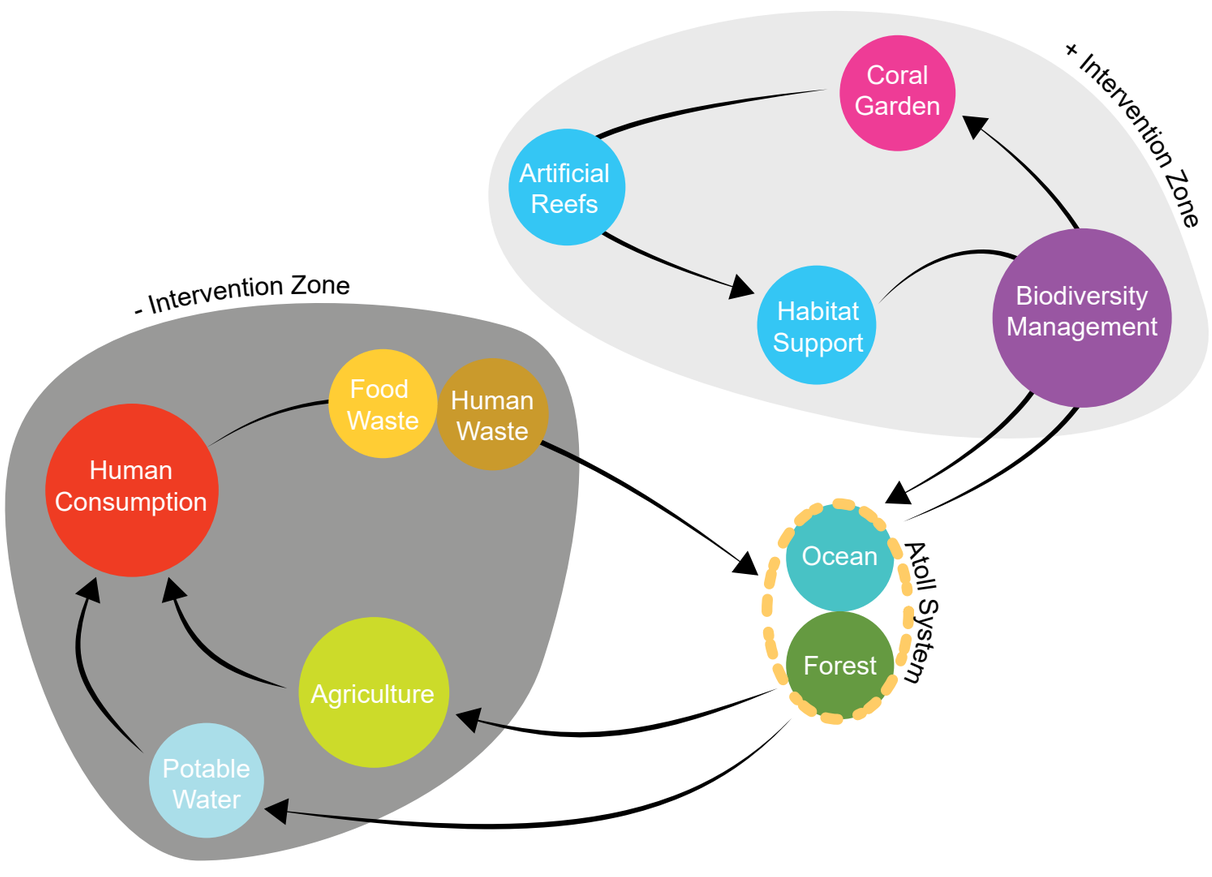
MALDIVES ECOLOGICAL DIAGRAM

Isaac Wilhelm

PRELIMINARY SYSTEM THINKING

Isaac Wilhelm





MANGROVE ACTIVATION

Marthe Frenod, Isaac Wilhelm

Aesthetics

Community Landscaping
Artistic Inspiration
Vista Framing

Education

Public Education
Indicator Species
Environmental Legislation

Research

Living Laboratories
Ecological Significance
Medicinal Qualities
Water Desalination
Silvology

Ecotourism

Guided Tours
Eco Centre
Protected Parks
Birdwatching

Community

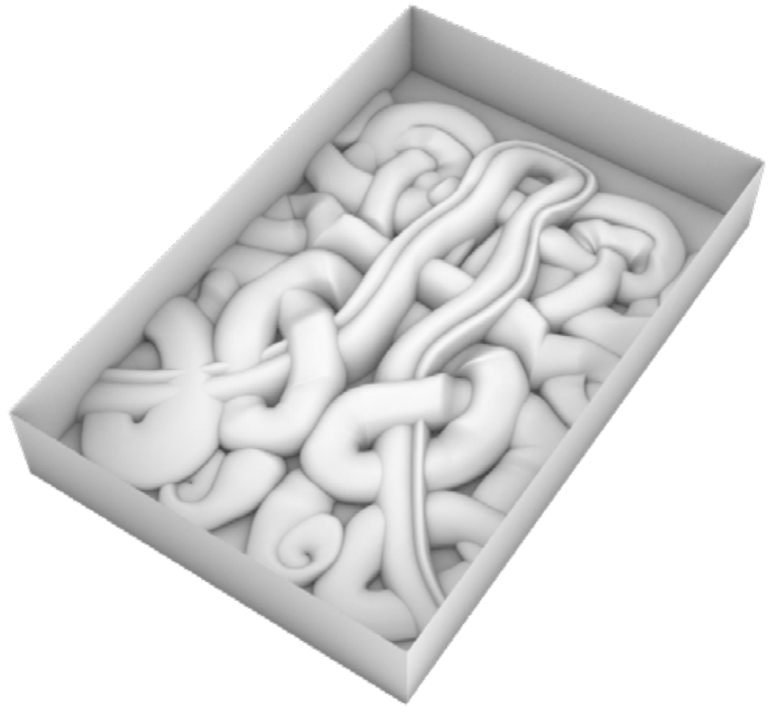
Habitat Stewardship
Cultural Heritage
National Identity
Folklore & Crafts

Spiritualism

Cultural Ceremony
Festivals
Religious Rites
Taboos

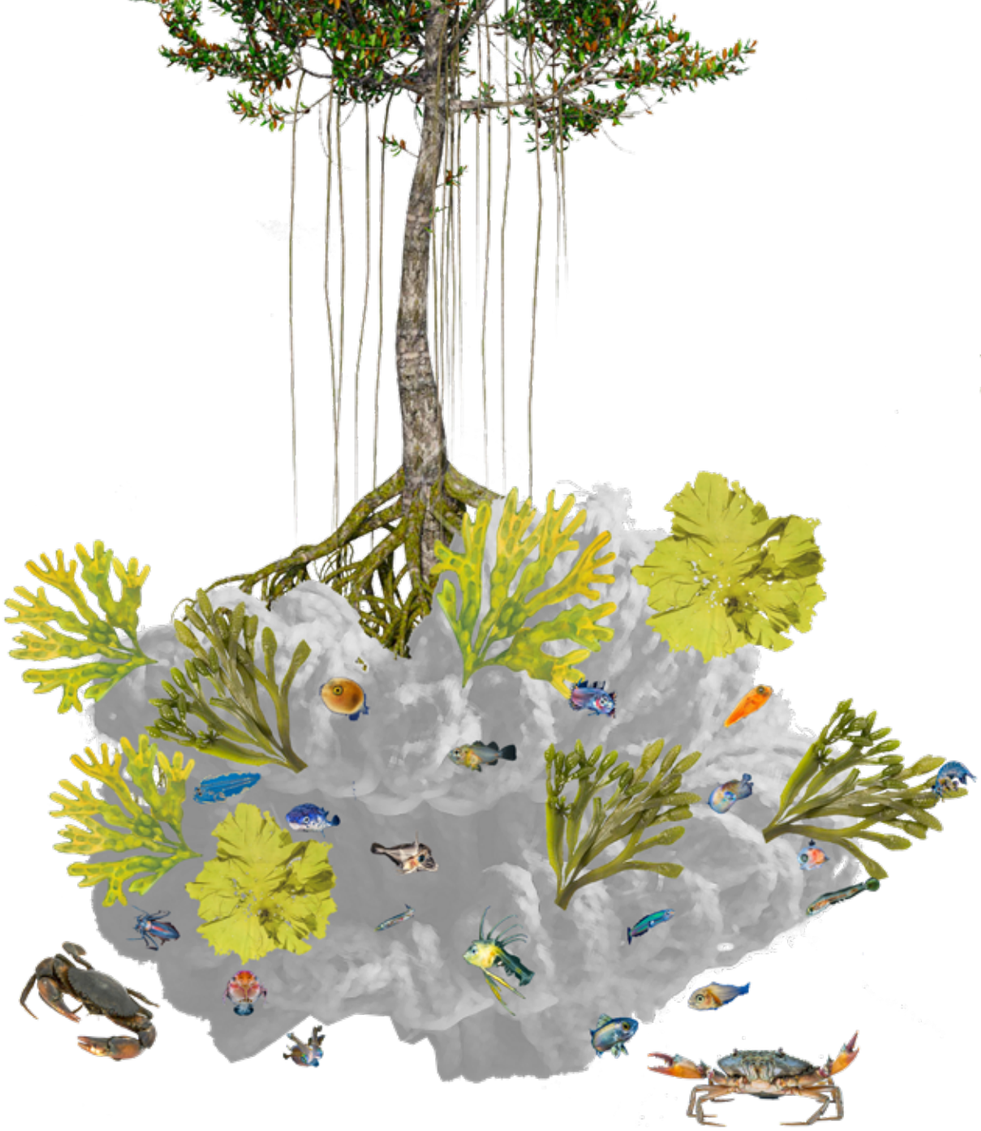
Recreation

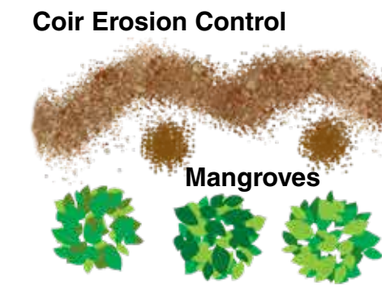
Aquatic Activites
Hiking Tails
Bbqs & Picnicing
Outdoor Yoga
Sanctuaries



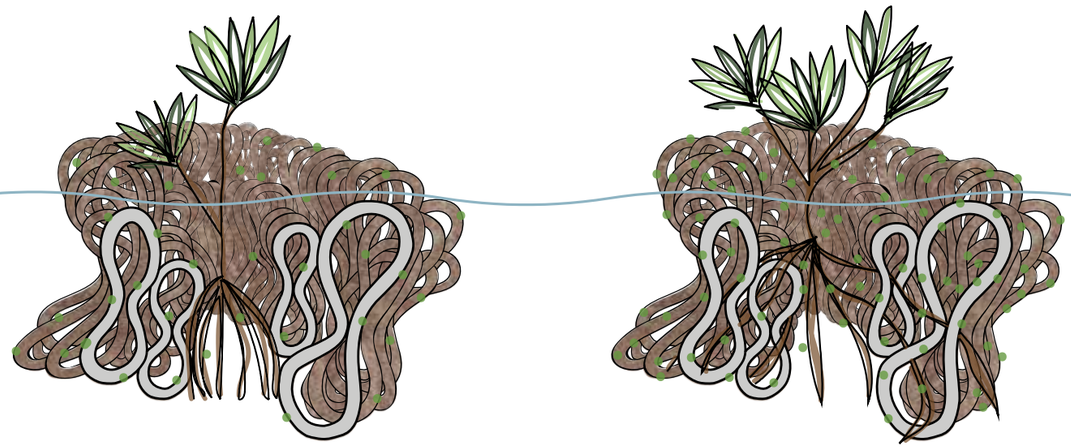
DIGITAL STUDY MODEL

Isaac Wilhelm





PARTI COLLAGES + SKETCHES Isaac Wilhelm



Isaac Wilhelm, Marthe Frenod **ALGAE PROPAGATION DIAGRAM**

AERIAL DEPLOYMENT VIGNETTE

Isaac Wilhelm

CRANBROOK MANGROVE NURSERY

Isaac Wilhelm

Ingredients + Materials:
Tap Water
Miracle Gro (Water Soluble)
Sainsbury's Sea Salt
Potting Soil
Aquarium Grade Sand
Pea Gravel
3x - Red Mangrove Seeds

Equipment:
3x - Used Plastic Soup Containers
4L Large Transparent Plastic Container
LED Grow Lamp
Permanent Marker
100 mL Glass Beaker
1 L Glass Beaker
Measuring Spoons
Digital Thermometer + pH Meter
Tape Measure
Metal Stirrer
Pocket Knife
iPhone

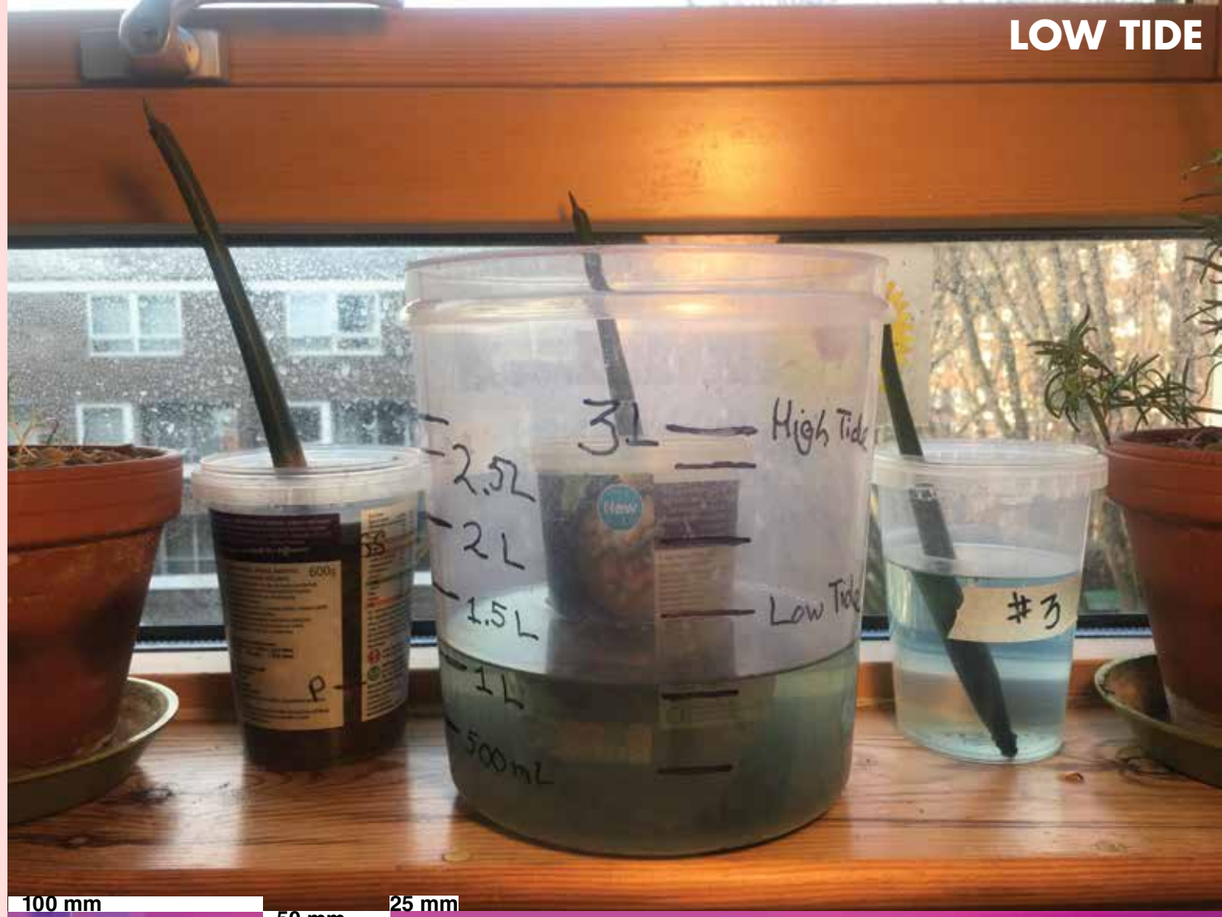
Hypothesis:
Seedling No. 1 will have the best growth rate in the two container tidal simulation method.

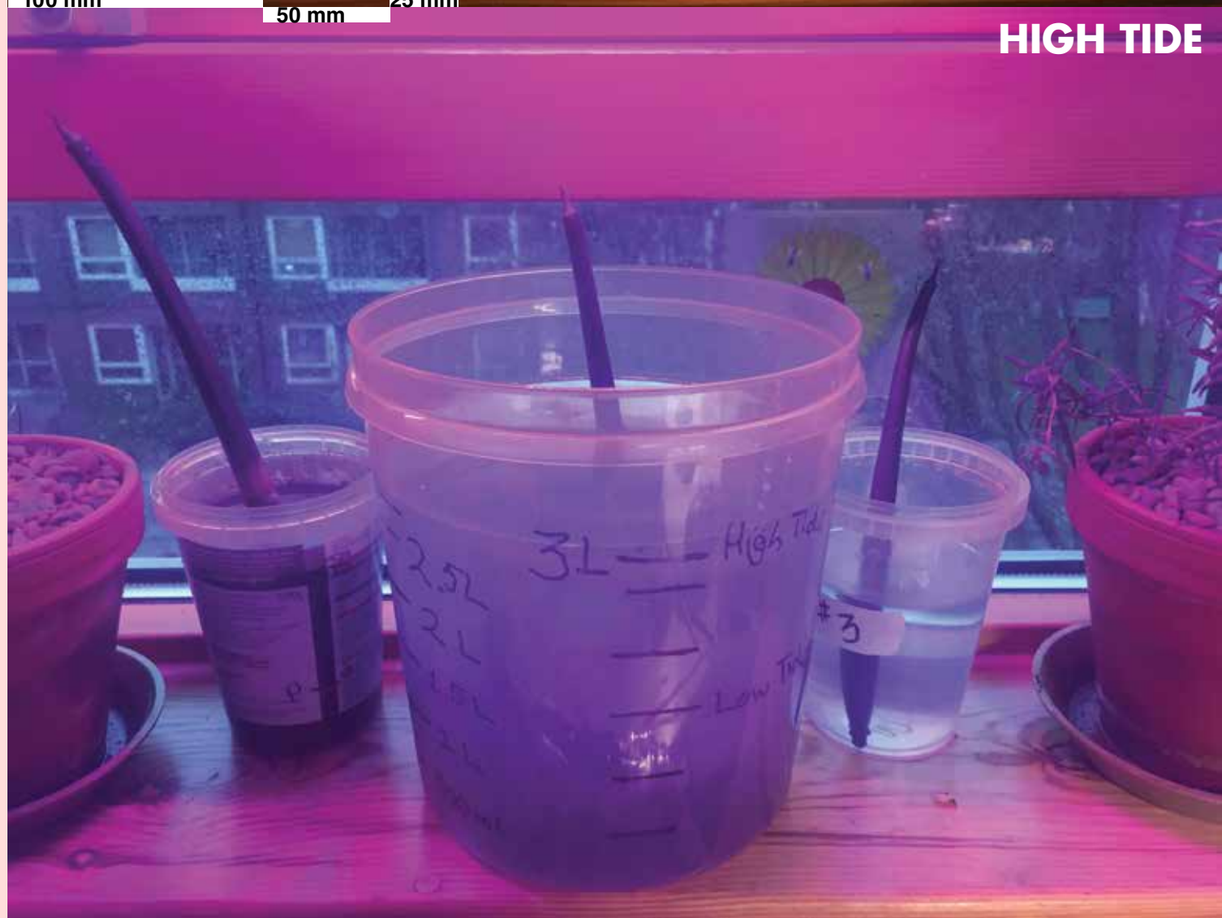
Seedling No. 1: Two Container System Protocol
Mark soup container 1 1/2 inches from bottom and four inches from bottom. Pierce bottom of container, creating four drainage holes. Fill container with pea gravel up to 1 1/2 mark. Mix equal parts sand and soil and fill container up to remaining 4 inch line.
Plant mangrove seedling pod into 1.5-2 inch hole n soil mix made with index finger. Then place within secondary 4 L plastic container.
Fill container with 3 L of water to fully flood seedling. Day 1-6 7.14% saline water; day 7-10 14.28% saline water; day 11-14 28.57% saline water; day 15-beyond 50% saline water. Simulate tidal changes by removing/adding 2 L of 20° C water approx. Every 12 hours. Occasionally add 2 small spoons of Miracle Grow to saline solution. Place under grow lamp with approx. 12-18 hrs of light a day.

Seedling No. 2: One Container System Protocol
Mark soup container 1 1/2 inches from bottom and four inches from bottom. Fill container with pea gravel up to 1 1/2 mark. Mix equal parts sand and soil and fill container up to remaining 4 inch line.
Plant mangrove seedling pod into 1.5-2 inch hole n soil mix made with index finger. Then flood container to brim line, with water mixture of 1L to 2 small spoons of Miracle Grow, with 1 teaspoon of sea salt per 500mL of water mixture. Place on window sill under grow lamp.

Seedling No. 3: Water Only Protocol
Double existing tap water in container w/ the 500ml miracle gro water mixture + 1 tsp sea salt. Place on window sill under grow lamp.

Conclusion:
The mangroves did not have any observational growth. However Seedling No. 3 did look the unhealthiest. More time and better growing conditions (more daylight and warmer climate) required to get conclusive results.





Miracle Gro Added
Full Water Clean

Mangrove Seedling No. 1: Two Container System

Solution	Day	Date	UV Lights		Room		Tide		High Tide Water		High Tide Soil		Low Tide Water		Low Tide Soil	
			On	Off	Temp C	Humidity	High	Low	Temp C	pH	Temp C	pH	Temp C	pH	Temp C	pH
7.14% Saline Solution	1	21.02.23	1:30 PM	12:15 AM	21.30	53%	12:00 PM	10:12 PM	18.40	7.24	18.60	6.83	18.20	7.27	18.40	6.86
	2	21.02.24	9:50 AM	2:52 AM	22.80	59%	9:23 AM	7:02 PM	19.30	7.33	19.30	6.90	19.10	7.28	19.00	6.98
	3	21.02.25	10:55 AM	3:45 AM	19.90	59%	11:07 AM	1:07 AM	19.40	7.48	19.50	7.02	19.30	7.55	19.20	7.17
	4	21.02.26	12:15 PM	9:00 PM	22.90	49%	2:20 PM	12:05 PM	19.30	7.66	19.40	7.00	18.40	7.61	19.00	6.85
	5	21.02.27	3:23 PM	2:00 AM	21.40	54%	3:28 PM	1:50 AM	19.00	7.53	19.10	6.89	18.90	7.54	19.10	7.33
	6	21.02.28	3:00 PM	1:42 AM	18.80	62%	10:25 AM	6:23 PM	17.60	7.44	17.70	6.78	18.30	7.51	18.80	7.21
14.28% Saline Solution	7	21.03.01	1:20 PM	3:43 AM	19.80	61%	5:32 PM	3:43 AM	19.00	7.10	19.00	6.91	18.40	7.48	18.90	6.91
	8	21.03.02	12:30 PM	12:33 AM	20.20	60%	4:20 PM	12:35 AM	18.90	7.49	19.10	6.84	18.60	7.04	18.80	6.90
	9	21.03.03	1:56 PM	2:11 AM	18.60	66%	2:19 PM	2:19 AM	19.30	7.54	19.30	7.07	17.70	7.30	17.70	7.00
	10	21.03.04	10:15 AM	3:20 AM	20.30	59%	3:05 PM	3:40 AM	19.60	7.51	19.80	7.11	19.00	7.11	19.10	6.95
28.57% Saline Solution	11	21.03.05	9:55 AM	12:44 AM	18.90	73%	3:37 PM	12:32 AM	16.70	7.58	16.60	7.12	17.60	7.87	17.80	7.00
	12	21.03.06	11:33 AM	1:05 AM	18.20	67%	11:48 AM	12:55 AM	20.60	7.56	20.40	7.01	16.80	7.49	16.90	7.07
	13	21.03.07	2:10 PM	12:09 AM	18.40	50%	12:30 PM	11:58 PM	17.40	7.64	17.40	7.18	20.20	7.53	20.00	7.28
	14	21.03.08	1:12 PM	1:15 AM	22.30	52%	2:15 PM	11:42 PM	20.30	7.86	20.60	7.51	20.80	7.75	21.00	7.30
50% Saline Solution	15	21.03.09	11:24 AM	11:35 PM	21.30	53%	11:30 AM	11:33 PM	20.40	7.72	20.40	7.27	19.30	7.71	19.80	7.48
	16	21.03.10	10:15 AM	12:55 AM	21.20	59%	11:53 AM	1:04 AM	18.70	7.72	18.80	7.17	19.50	7.73	19.90	7.58
	17	21.03.11	11:46 AM	2:58 AM	21.30	53%	12:02 PM	12:30 PM	17.90	7.80	18.20	7.19	20.30	7.81	20.50	7.35
	18	21.03.12	1:26 PM	6:15 PM	22.10	51%	1:27 PM	2:09 AM	19.60	7.71	19.70	7.25	20.40	7.70	20.60	7.21
	19	21.03.13	11:11 AM	3:00 AM	21.60	51%	12:05 PM	3:00 AM	19.20	7.77	19.20	7.47	20.20	7.76	20.30	7.25
	20	21.03.14	3:05 PM	12:35 AM	20.20	51%	4:54 PM	12:41 AM	20.10	7.73	20.20	7.33	19.30	7.81	19.20	7.59

Mangrove Seedling No. 2: One Container System

Day	Date	UV Lights		Room		Water		Soil		Waterline Above Soil
		On	Off	Temp C	Humidity	Temp C	pH	Temp C	pH	
1	21.02.23	1:30 PM	12:15 AM	21.30	53%	18.60	7.09	18.50	6.49	18 mm
2	21.02.24	9:50 AM	2:52 AM	22.80	59%	19.30	7.08	19.40	6.54	17 mm
3	21.02.25	10:55 AM	3:45 AM	19.90	59%	19.50	7.15	19.60	6.65	16 mm
4	21.02.26	12:15 PM	9:00 PM	22.90	49%	19.40	7.13	19.40	6.58	14 mm
5	21.02.27	3:23 PM	2:00 AM	21.40	54%	19.80	7.44	19.50	6.71	14 mm
6	21.02.28	3:00 PM	1:42 AM	18.80	62%	17.20	7.17	17.20	6.95	12 mm
7	21.03.01	1:20 PM	3:43 AM	19.80	61%	18.30	7.12	18.30	7.01	12 mm
8	21.03.02	12:30 PM	12:33 AM	20.20	60%	18.70	7.53	18.60	6.94	11 mm
9	21.03.03	1:56 PM	2:11 AM	18.60	66%	17.90	7.59	18.10	7.12	10 mm
10	21.03.04	10:15 AM	3:20 AM	20.30	59%	19.20	7.66	19.10	7.19	9 mm
11	21.03.05	9:55 AM	3:45 AM	18.90	73%	17.70	7.71	17.50	7.35	7 mm
12	21.03.06	11:33 AM	1:05 AM	18.20	67%	16.70	7.75	16.60	7.38	6 mm
13	21.03.07	2:10 PM	12:09 AM	18.40	50%	16.80	7.79	17.00	7.21	6 mm
14	21.03.08	1:12 PM	1:15 AM	22.30	52%	21.20	7.55	21.10	7.12	4 mm
15	21.03.09	11:24 AM	11:35 PM	21.30	53%	19.60	7.65	19.60	7.09	2 mm
16	21.03.10	10:15 AM	12:55 AM	21.20	59%	-	-	19.40	7.59	0 mm
17	21.03.11	11:46 AM	2:58 AM	21.30	53%	-	-	20.90	7.19	0 mm
18	21.03.12	1:26 PM	6:15 PM	22.10	51%	-	-	18.90	7.65	0 mm
19	21.03.13	11:11 AM	3:00 AM	21.60	51%	-	-	20.70	7.54	0 mm
20	21.03.14	3:05 PM	12:35 AM	20.20	51%	-	-	19.00	7.71	0 mm

Mangrove Seedling No. 3: Water Only

Day	Date	UV Lights		Room		Water	
		On	Off	Temp C	Humidity	Temp C	pH
1	21.02.23	1:30 PM	12:15 AM	21.30	53%	17.80	7.99
2	21.02.24	9:50 AM	2:52 AM	22.80	59%	18.70	8.07
3	21.02.25	10:55 AM	3:45 AM	19.90	59%	18.50	8.03
4	21.02.26	12:15 PM	9:00 PM	22.90	49%	17.90	8.05
5	21.02.27	3:23 PM	2:00 AM	21.40	54%	18.80	8.01
6	21.02.28	3:00 PM	1:42 AM	18.80	62%	16.90	8.06
7	21.03.01	1:20 PM	3:43 AM	19.80	61%	17.90	8.02
8	21.03.02	12:30 PM	12:33 AM	20.20	60%	18.20	8.02
9	21.03.03	1:56 PM	2:11 AM	18.60	66%	17.20	8.06
10	21.03.04	10:15AM	3:20 AM	20.30	59%	18.70	8.09
11	21.03.05	9:55 AM	3:45 AM	18.90	73%	17.20	8.13
12	21.03.06	11:33 AM	1:05 AM	18.20	67%	15.90	8.15
13	21.03.07	2:10 PM	12:09 AM	18.40	50%	16.40	8.18
14	21.03.08	1:12 PM	1:15 AM	22.30	52%	20.40	8.19
15	21.03.09	11:24 AM	11:35 PM	21.30	53%	18.60	8.25
16	21.03.10	10:15 AM	12:55 AM	21.20	59%	18.40	8.30
17	21.03.11	11:46 AM	2:58 AM	21.30	53%	20.20	8.29
18	21.03.12	1:26 PM	6:15 PM	22.10	51%	18.40	8.36
19	21.03.13	11:11 AM	3:00 AM	21.60	51%	19.80	8.39
20	21.03.14	3:05 PM	12:35 AM	20.20	51%	18.90	8.35

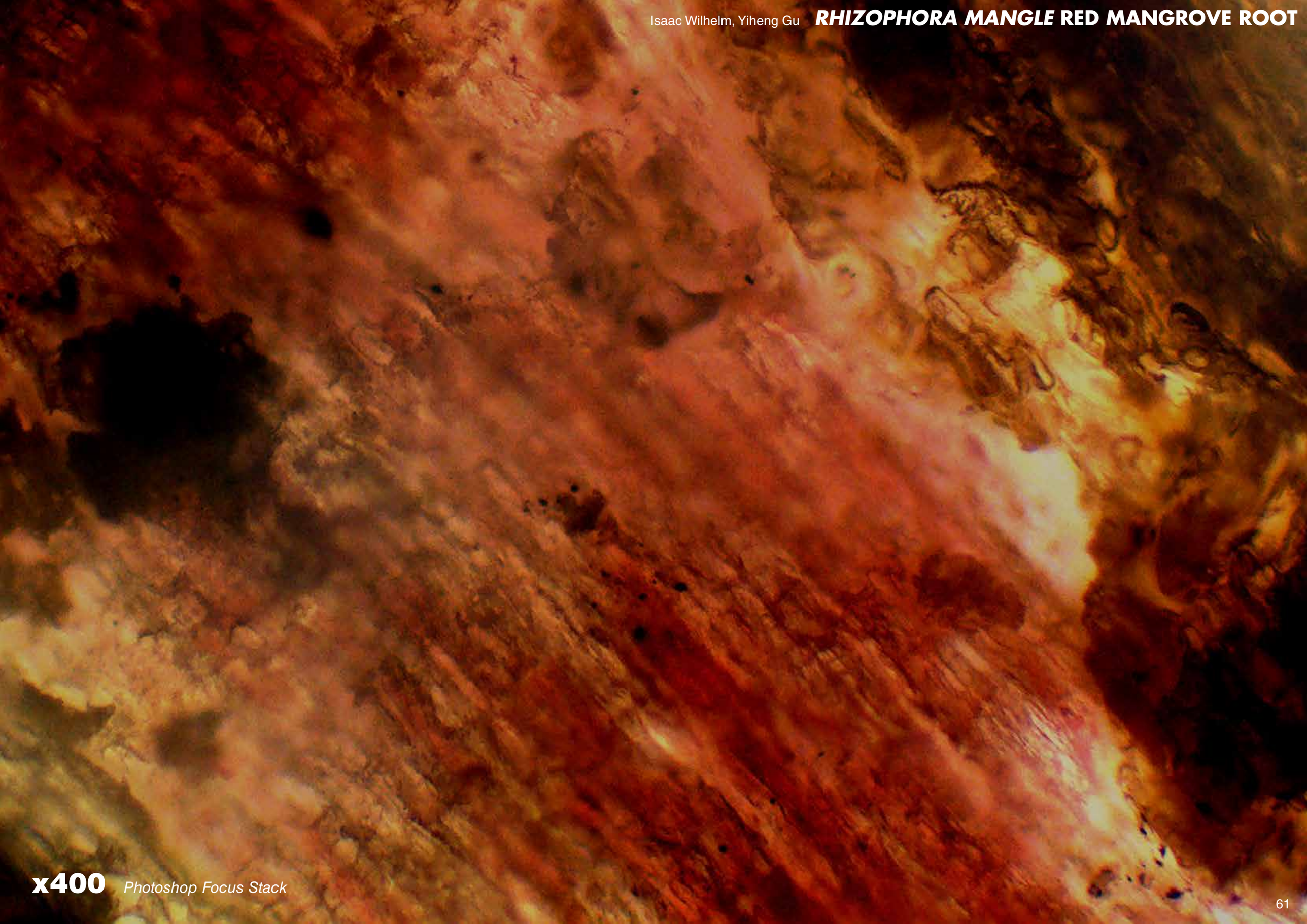
4 mm 2 mm 1 mm

***RHIZOPHORA MANGLE* RED MANGROVE ROOT**

Isaac Wilhelm, Yiheng Gu

Isaac Wilhelm, Yiheng Gu

RHIZOPHORA MANGLE RED MANGROVE ROOT



x400 *Photoshop Focus Stack*

YOUNG COCONUT FILAMENT EXTRACTION

Isaac Wilhelm

Ingredients + Materials:
4x - Young Coconuts

Equipment:

Knife	Chisel	Bowls
Metal Spoon	Herb Drying Net	Glass Jars
Wooden Spoon	Electric Blender	iPhone
Hammer	Strainer	

Hypothesis:
Young Coconut Husks can be dried and processed int a filament substance to use for biomaterialization.

Protocol:
With chisel and hammer split coconut apart and remove flesh/meat with metal spoon. With knife and/or fingers peel fibrous outer husk from hard inner shell. Pull husk clumps into narrow strands for faster drying in herb drying net. After approximately 48 hours material should be dry enough to process.

Place small portions of dried husk into blender and oscillate until most of the husk has turned to dust. Shift dust through strainer into bowl. Repeat process until all husk has been processed to a fine filament. Two grades should be the final outcome, one a fine filament dust and another a fine fiber strand.

Conclusion:
Processing is possible, however it was more labor intensive than initially believed.

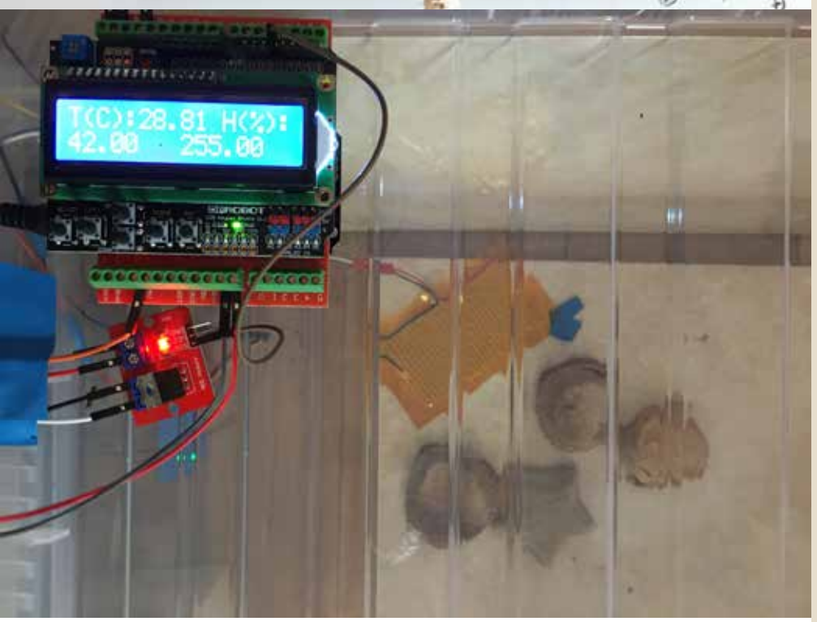
YOUNG COCONUT FILAMENT

EXTRACTION PROCESS

INTRODUCTORY BIOMATERIALS EXPLORATION

Isaac Wilhelm, Shem Johnson

CURING PROCESS



COATED COIR ROPE

Material 1 Ingredients:
4 Tbsp. Calcium Carbonate Powder
5 Tbsp. Young Coconut Filament
12 g Glycerol
100 mL Elmer's Glue
240 mL Cold Water

Material 2 Ingredients:
4 Tbsp. Calcium Carbonate Powder
6 g Glycerol
50 mL Elmer's Glue
120 mL Cold Water

Material 3 Ingredients:
5 Tbsp. Young Coconut Filament
6 g Glycerol
50 mL Elmer's Glue
120 mL Cold Water

Materials:
7mm Diameter Coir Rope

Equipment:
Stove, Measuring Spoons, Beaker, Stove, Pot, Silicon Molds, Wooden Clothes Pins, iPhone

Hypothesis:
Combining calcium carbon/coconut filament with Elmer's glue will result in a biomaterial that is water resistant and durable.

Protocol:
Mix cold water & glue in pot before heating, until paste substance forms. Continuously stir over heat source. After homogeneity, add glycerol and calcium carbonate and/or coconut filament/fiber. Continue stirring over heat until a white deposit appears on surface. Pour into mold (or dip rope into solution), place in incubator for faster drying times. Can take up to two weeks to cure.

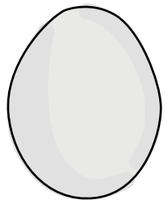
Conclusion:
Neither water resistance or durable, these biomaterial explorations were brittle, dissolved in water, and started cultivating mold while they were curing.

FINAL PROTOTYPES

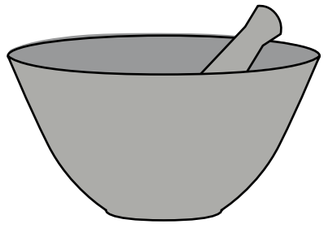
BIOCEMENT: PROTOCOL

Isaac Wilhelm, Yiheng Gu, Vincent Dissaux, Marthe Frenod

① Crushing Eggshells



1 - Eggshells



2 - Crushing

3 - Egg Shell Powder

② Biocement Mixture (for 1 L)

167 g Calcium Carbonate

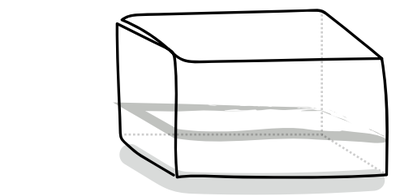
133 g Sodium Alginate

500 g Local Coarse Sand

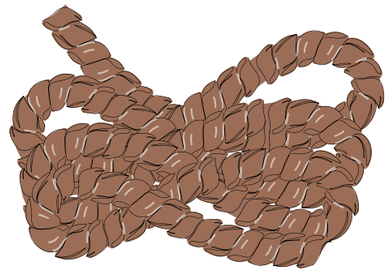
267 g Eggshell Powder

100 g Coconut Filament

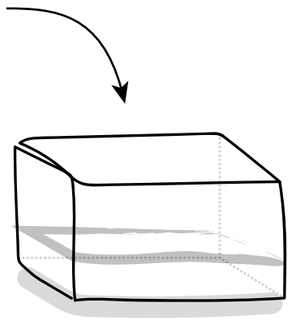
1L water



③ Coating



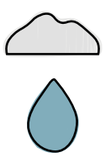
Coir Rope

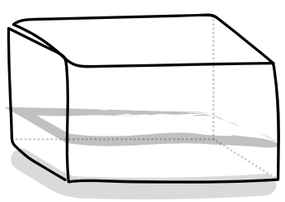


④ Solidifying Solution

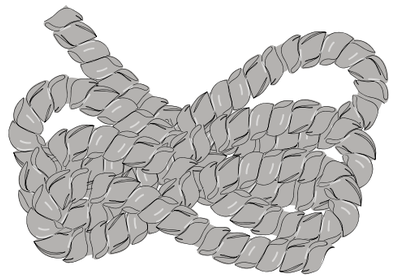
333 g Calcium Chloride

1 L Water

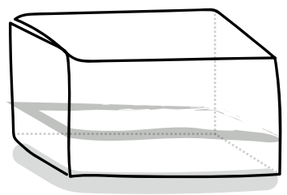




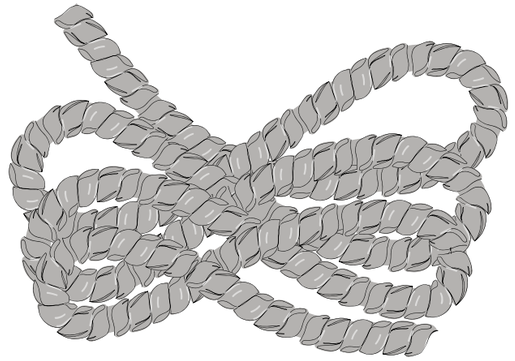
⑤ Dipping



Coir Rope



⑥ Drying



BIOCEMENT: COATED COIR ROPE

Isaac Wilhelm, Yiheng Gu

Hypothesis:
Calcium carbonate-sodium alginate biocement will be durable, but it will not be water resistant. Other materials can be added to change the aesthetic quality of the material.

Conclusion:
The material remain durable with all tested aggregate recipes. However, recipe 2 was the strongest. All samples were not water resistant as hypothesized.

RECIPES

1. 0.25 g Sodium Alginate
   25 g Calcium Carbonate
   15 mL Reverse Osmosis Water

2. 0.25 g Sodium Alginate
   25 g Calcium Carbonate
   2.5 g Coconut Filament
   15 mL Reverse Osmosis Water

3. 4 g Sodium Alginate
   15 g Crushed Eggshells
   30 mL Reverse Osmosis Water

4. 4 g Sodium Alginate
   15 g Crushed Eggshells
   3 g Coconut Filament
   30 mL Reverse Osmosis Water

5. 4 g Sodium Alginate
   10 g Calcium Carbonate
   3 g Coconut Filament
   30 mL Reverse Osmosis Water

6. 4 g Sodium Alginate
   10 g Calcium Carbonate
   30 mL English Channel Seawater

7. 4 g Sodium Alginate
   10 g Calcium Carbonate
   3 g Coconut Filament
   30 mL English Channel Seawater

8. 4 g Sodium Alginate
   5 g Calcium Carbonate
   14 g English Channel Sand
   30 mL Reverse Osmosis Water

9. 4g Sodium Alginate
   5g Calcium Carbonate
   3g Coconut Filament
   14g English Channel Sand
   30 mL Reverse Osmosis Water

10. 4 g Sodium Alginate
    15 g Crushed Eggshells
    3 g Coconut Filament
    15 g English Channel Sand
    30 mL Reverse Osmosis Water


①


②

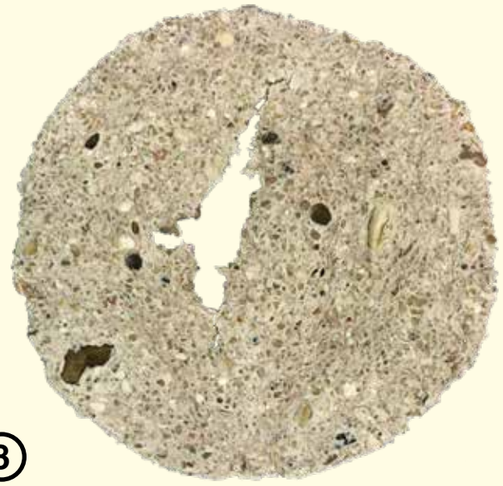

③


④


⑤


⑥


⑦


⑧


⑨


⑩

BIOCEMENT: PLATE MOLD 10

Isaac Wilhelm, Yiheng Gu

A BAD IDEA Julian Rodriguez

HEATING PROCESS

Day 1

Day 6

Isaac Wilhelm

COPAL RESIN COATING

Ingredients + Materials:

100g Copal Gum
300 mL Seawater
Aluminum Pan
Wooden Kebab Stick
Biocement Coated Coir Rope
Used Plastic Jar with Lid

Equipment:

Oven
Oven Mitten
iPhone

Hypothesis:

Due to the fact that calcium carbonate-sodium alginate biocement alone is not water resistant,the natural resin from trees can be used to create a coating on the biomaterial to provide semi-water resistances.

Protocol:

Preheat own to 250 C. Measure out approximately 100g of copal gum and place in aluminum pan. Once preheated, set pan with copal gum on center rack of oven.

Leave in oven for 5 minutes. Check to see that copal gum is bubbling, if not leave in for 5 minute intervolves to assure in does not over heat. Once bubbling, remove pan from oven.

Carefully dip one end of biocement coated coir rope into the bubbling copal gum (keep your fingers as far away from the hot substance as possible) and twirl it to assure the copal gum resin wraps and adheres to the surface. Hold the resin coated biocement coir rope in the air for a minute or two while it cools to room temperature.

Place the aluminum pan with the copal gum back in the still heated oven for several minutes while it reheats. Once bubbling again, repeat the process on the other side of the biocement coir rope so that the sample is fully covered in resin. Don't forget to turn the oven off knuckle-head, and place the aluminum tray with unused copal gum resin in the recycle bin.

Once the resin has cooled down to room temperature, fill a clean used jar with 300 mL of seawater. Close lid on jar and set aside to watch if resin coating degrades with time.

Do not attempt to do this process in a microwave, as the resin will overheat uncontrollably.

Observations + Results:

After a few days the resin coated sample was unchanged. After 4 days I noted some slight degradation in the resin coating. On day 6 the coating had severally cracked and seawater was reaching the underlying biocement coating. The resin coating has continued to degrade and break off in small and large chunks.

Conclusion:

Copal gum resin is not a sufficient material to create a semi-water resistant natural coating. In a still sample of seawater the sample only lasted 4 days before showing signs of degradation. In a living ocean with currents and critters process would be highly ineffective and meaningless. However, this does not mean that lignin derived from coconut husk fiber would have the same results. Further experimentation of other species gum/resin and lignin is required.

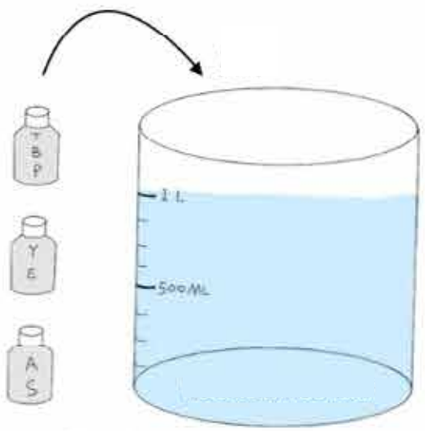
S. PASTEURII CALCIFICATION: PROTOCOL

Yiheng Gu, Isaac Wilhelm, Marthe Frenod

Hypothesis:
After soaking in the liquid medium of *S. pasteurii*, the coir rope will easily calcify. By repeating the process several times the rope will be sufficiently calcified to withstand tidal ocean stresses.

Mix Liquid Medium Solution

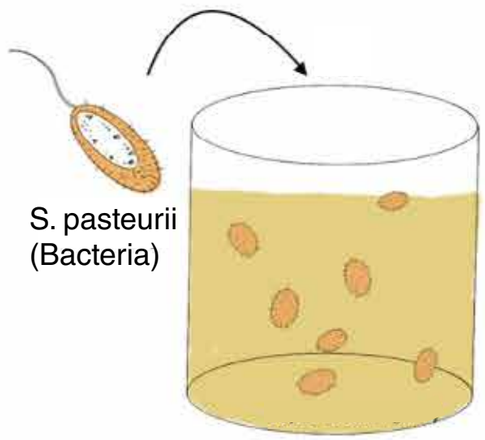
①



1 L Reverse Osmosis Water
15 g Trizma Base Powder
15 g Yeast Extract
8 g Ammonia Sulphate

Add S. pasteurii

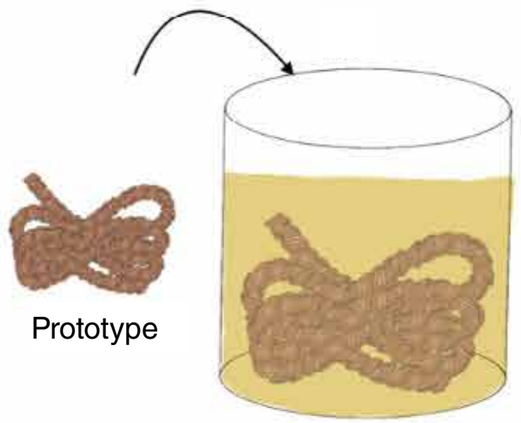
②



S. pasteurii
(Bacteria)

Add Coir Rope

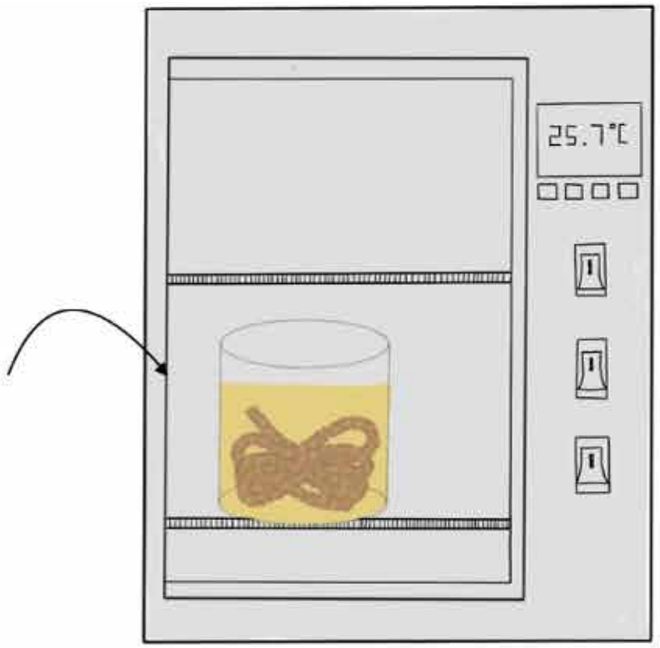
③



Prototype

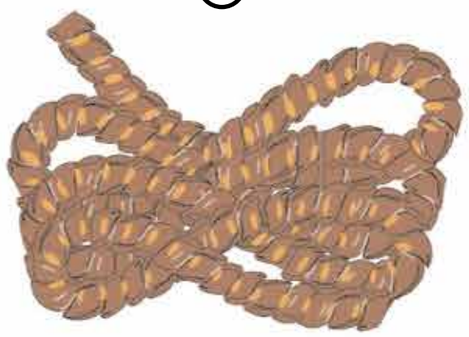
Incubate 3-5 Days

④



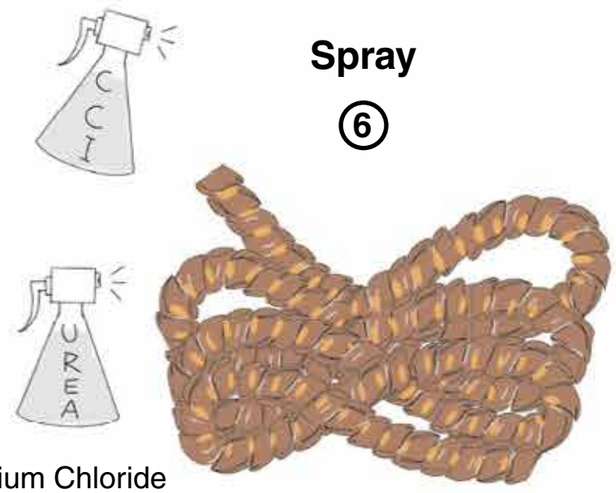
Remove from Liquid Medium

⑤



Spray

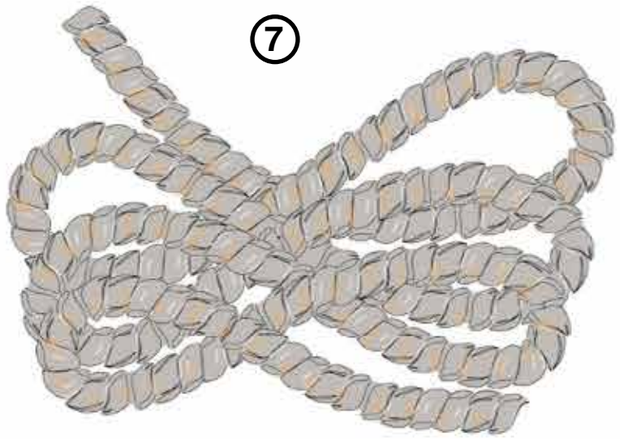
⑥



Calcium Chloride
+ Urea

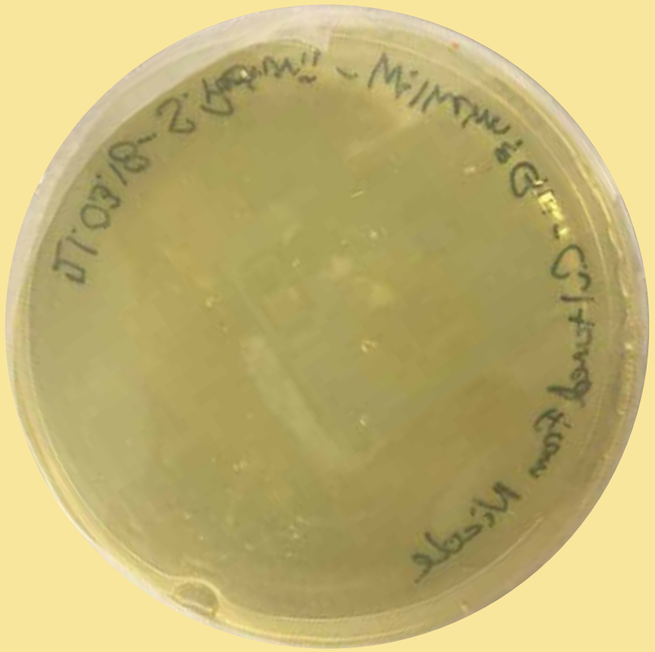
S. pasteurii Calcified Rope

⑦

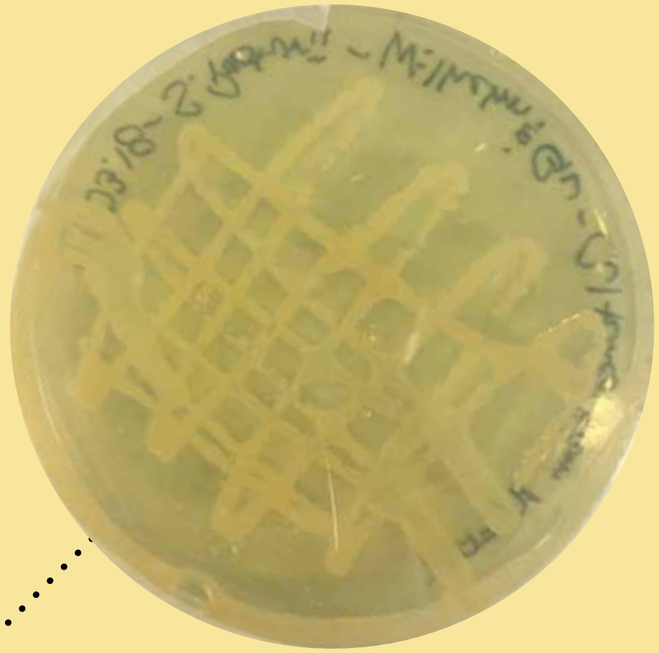


S. PASTEURII: PLATE COLONIZATION

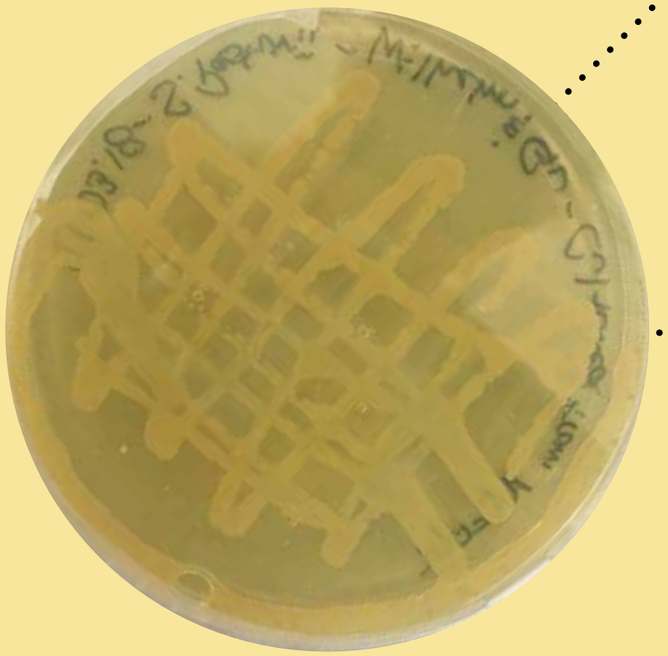
Isaac Wilhelm, Yiheng Gu, Nicole Chrysikou



Day 2



Day 5



Day 8

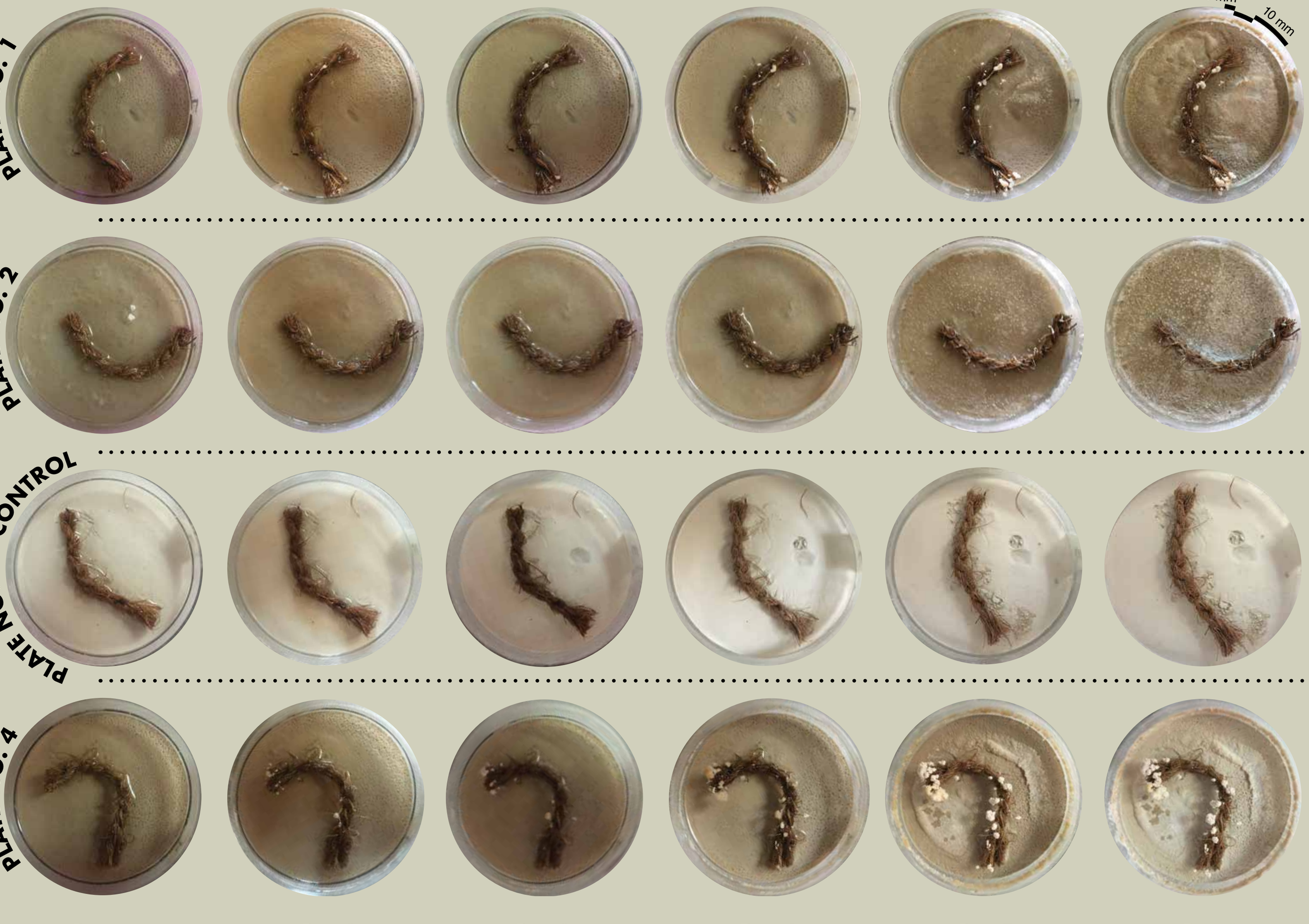
Day 12

PLATE TRANSFER PROCESS

LIQUID MEDIUM PROCESS

CALCIUM CARBONATE CRYSTALLIZATION 1

Isaac Wilhelm



Day 1 ***Day 2*** ***Day 3*** ***Day 4*** ***Day 5*** ***Day 6***

Materials:
9x - 7mm Dia. Coir Rope 8mm Length

Equipment:
3x - 90mm Glass Petri Dishes
Measuring Spoons
Metal Stirrer
iPhone

Hypothesis:
Calcium carbonate (aragonite) crystals will form on the surface of coir rope through a chemical process using vinegar. The strongest crystallization will happen with Dolomite lime and the Dolomite rock.

Procedure:
Using 2-3 glass petri dishes, the lid and the dish are separated and used for separate solution growth containment, providing 4-5 variations per trial.
First fill the petri dish with desired dry ingredients, then add wet ingredients. Stir solution until homogeneous. Place a piece of coir rope in each petri dish.

Observations + Results:
Round 1: Plate No. 3 Control did not grow any crystals. Plate No. 2 grew very few tiny crystals. Plates No. 1 + 4 where successful.
Round 2: Plates No. 2 + 3 + 5 were all unsuccessful. Plates No. 1 + 4 continued to flourish.
Round 3: Plate No. 3 had very little crystallization. Plate No. 5 had a lot of crystallization on the Dolomite rock, however very little on the actual rope. Plate No. 1 + 4 continued to grow adequately; however the already formed crystals dissolved in the new solution. Plate No. 2 grew with greater color clarity, quality, and quantity.

Conclusion:
Crystals grew in all scenarios that involved any form of calcium carbonate with a vinegar. However, the Dolomite Lime was not as successful has predicted and although many crystals grew on the Dolomite rock, not many grew on the rope. The best results occurred with calcium carbonate and distilled malt vinegar.

CALCIUM CARBONATE CRYSTALLIZATION 2

Isaac Wilhelm

PLATE NO. 1

Remaining CaCO
6 tsp. White Wine Vinegar

PLATE NO. 2

1/2 Tbsp. Vitax Granular -
Garden Lime
6 tsp. White Wine Vinegar

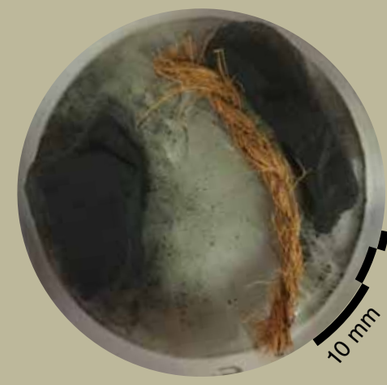
PLATE NO. 3 - CONTROL

1Tbsp. Kelkay -
White Chipping Stone
6 tsp. White Wine Vinegar

PLATE NO. 4

Remaining CaCO
6 Drops 5% Iodine
6 tsp. White Wine Vinegar

PLATE NO. 5 - CONTROL



2x 40 mm Blue Slate Stones
6 tsp. White Wine Vinegar

Day 1

Day 2

Day 3

Day 4

PLATE NO. 1

PLATE NO. 4

12 mm

9 mm

6 mm

Day 1

Day 2

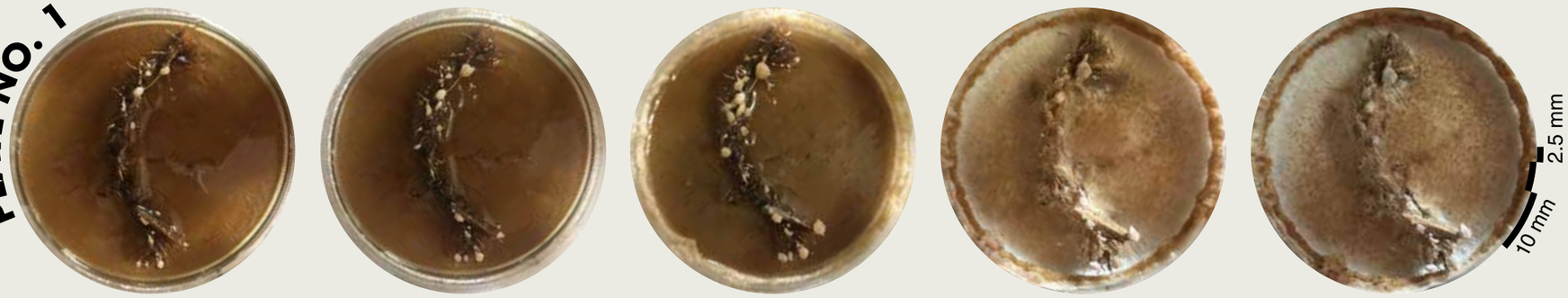
Day 3

Day 4

Isaac Wilhelm

CALCIUM CARBONATE CRYSTALLIZATION 3

PLATE NO. 1



Remaining CaCO
6 tsp. White Wine Vinegar

PLATE NO. 2

1/2 Tbsp. CaCO
6 tsp. Distilled Malt Vinegar

PLATE NO. 3

1/2 Tbsp. Elixir Gardens -
Dolomite Lime Powder, Magnesium Limestone
6 tsp. Distilled Malt Vinegar

PLATE NO. 4

Remaining CaCO
6 Drops 5% Iodine
6 tsp. White Wine Vinegar

PLATE NO. 5

1x 50mm Dolomite Rock
6 tsp. Distilled Malt Vinegar

Day 1 ***Day 2*** ***Day 3*** ***Day 4*** ***Day 5***

PLATE NO. 1

PLATE NO. 2

PLATE NO. 4

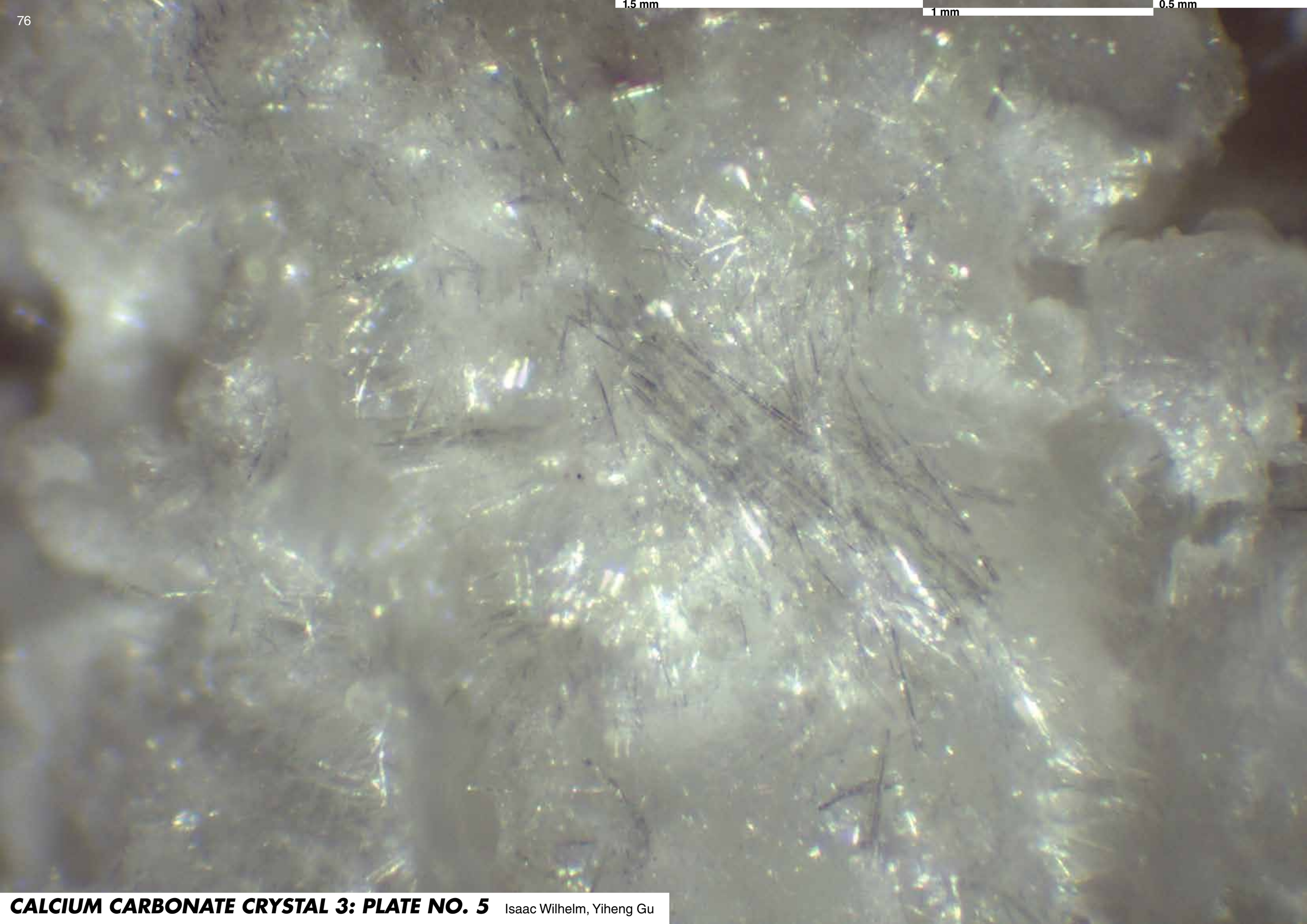
PLATE NO. 5

10 mm

7.5 mm

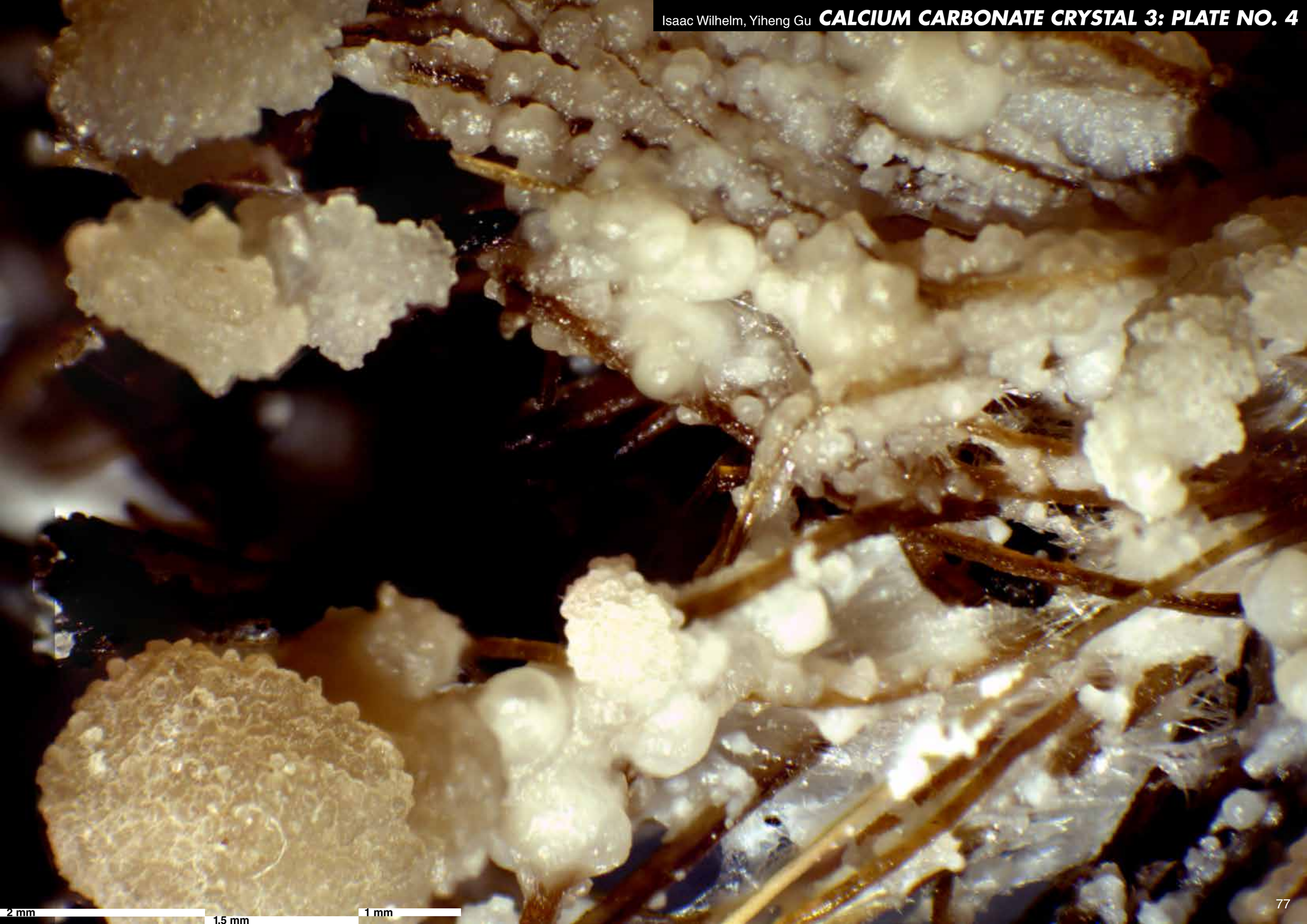
5 mm

Day 1 *Day 2* *Day 3* *Day 4* *Day 5*



CALCIUM CARBONATE CRYSTAL 3: PLATE NO. 5 Isaac Wilhelm, Yiheng Gu

Isaac Wilhelm, Yiheng Gu **CALCIUM CARBONATE CRYSTAL 3: PLATE NO. 4**



EXPER

IMENTS

GROW LAB:

VIBRIO FISCHERI // BIOLUMINESCENT BACTERIA

SIMULATED SQUID LIGHT ORGAN

TUTORS: *NANCY DINIZ + ALICE TAYLOR*
LAB TECHS: *SHEM JOHNSON + JULIAN RODRIGUEZ*

VIBRIO FISCHERI: PLATE COLONIZATION

Ingredients + Materials:
Plastic Petri Dish with Pre-Poured Agar Medium
V. fischeri Colonized Liquid Medium Source
Sterilized Cotton Swab
Parafilm
Latex Gloves

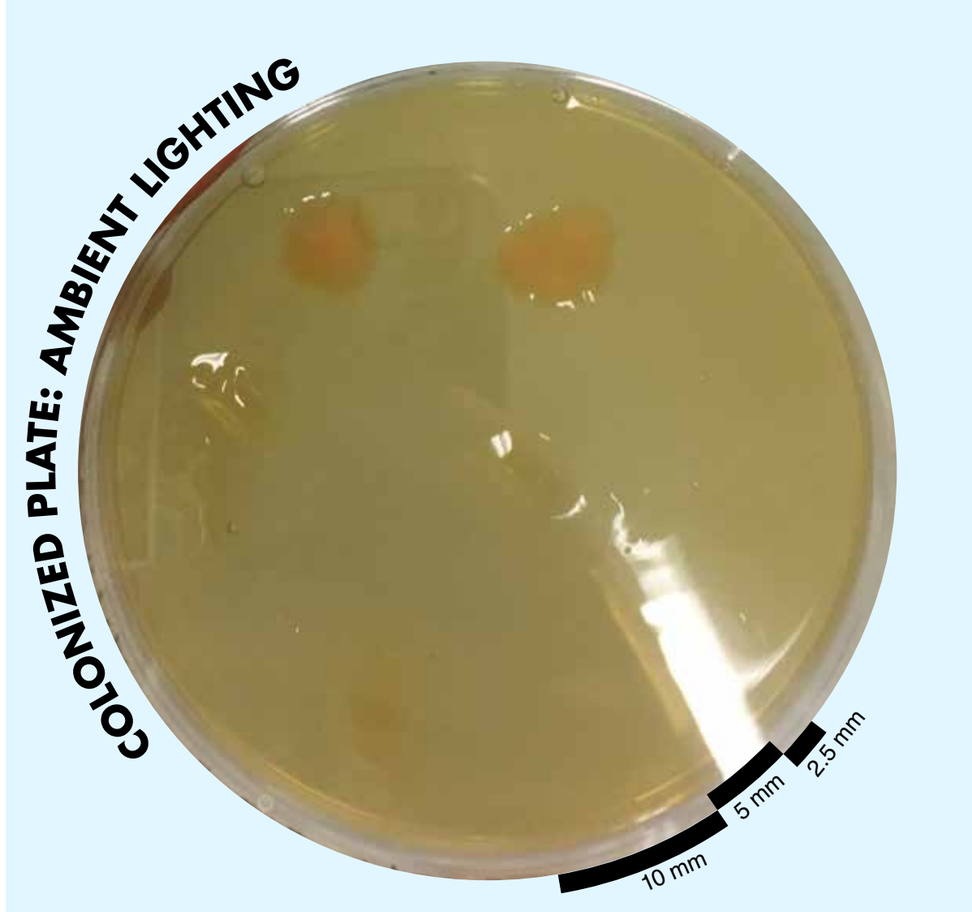
Equipment:
Lab Hood
Incubator
Electric Stir Plate
Scissors
Permanent Marker
iPhone

Hypothesis:
V. fischeri will colonize the agar plate and display bioluminescent qualities when observed in pitch-black darkness.

Protocol:
Complete all of the steps for plate colonization under the sterilization of the lab hood while wearing latex gloves. Place the *V. fischeri* pre-colonized liquid medium on the electric stir plate. Dip a sterile cotton swab into the liquid medium. Open the petri dish with pre-poured agar and stipple a smiley face on the medium with the dipped side of the cotton swab. Promptly re-lid the petri dish, and throw away the cotton swab in biohazard bin.
With a permanent marker write the date, contents, and your name on the side of the plastic petri dish lid. With the scissors cut an appropriately sized piece of parafilm and wrap it around the side of the petri dish lid. Place the petri dish in the incubator.

Observations + Results:
Approximately 2 weeks later the *V. fischeri* colonized the agar plate. Five colonies developed, and were visible under pitch-black darkness. However, the colonies were not as bioluminescent as anticipated.

Conclusion:
Although the plate did colonize, the density of the colonies was not favorable. It was concluded that the liquid medium should have had a magnetic stir bar in it to maintain a homogeneous density of the bacteria during the swab culturing process.



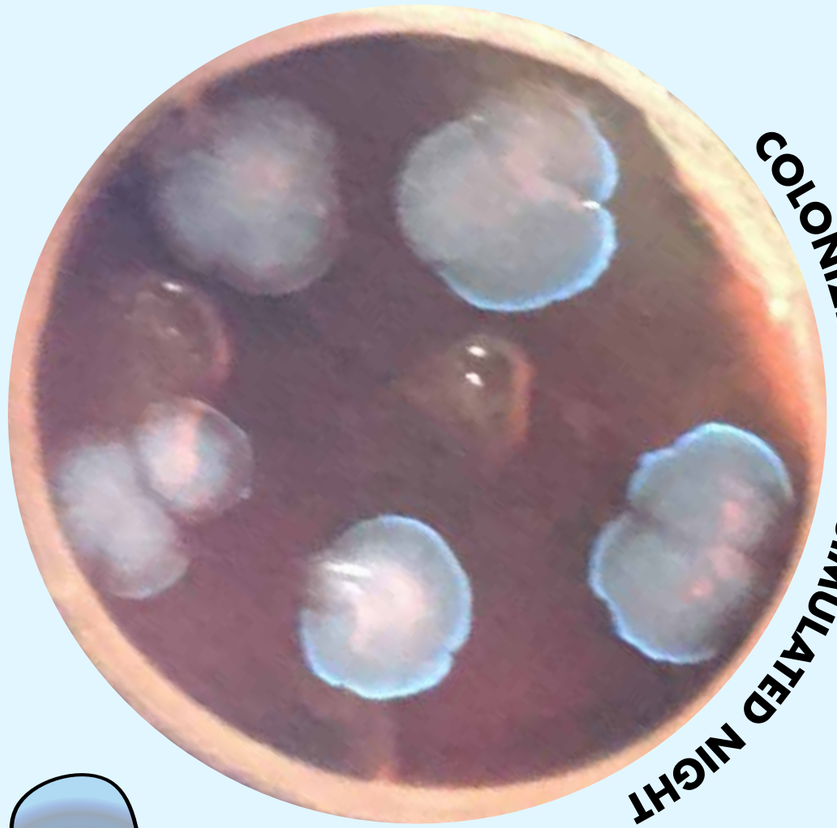


PLATE TRANSFER PROCESS

GROW LAB:

PHYSARUM POLYCEPHALUM // SLIME MOLD

GROUP THINKING + NETWORKING

TUTORS: *NANCY DINIZ + ALICE TAYLOR*
LAB TECH: *SHEM JOHNSON + JULIAN RODRIGUEZ*

PHYSARUM POLYCEPHALUM: PLATE GROWTH

Ingredients + Materials:
Existing *P. polycephalum* Colony Plate Source
Petri Dish Pre-Poured with Agar Medium
Raw Rolled Oats
Parafilm
Plastic Sandwich Bag
Small Box

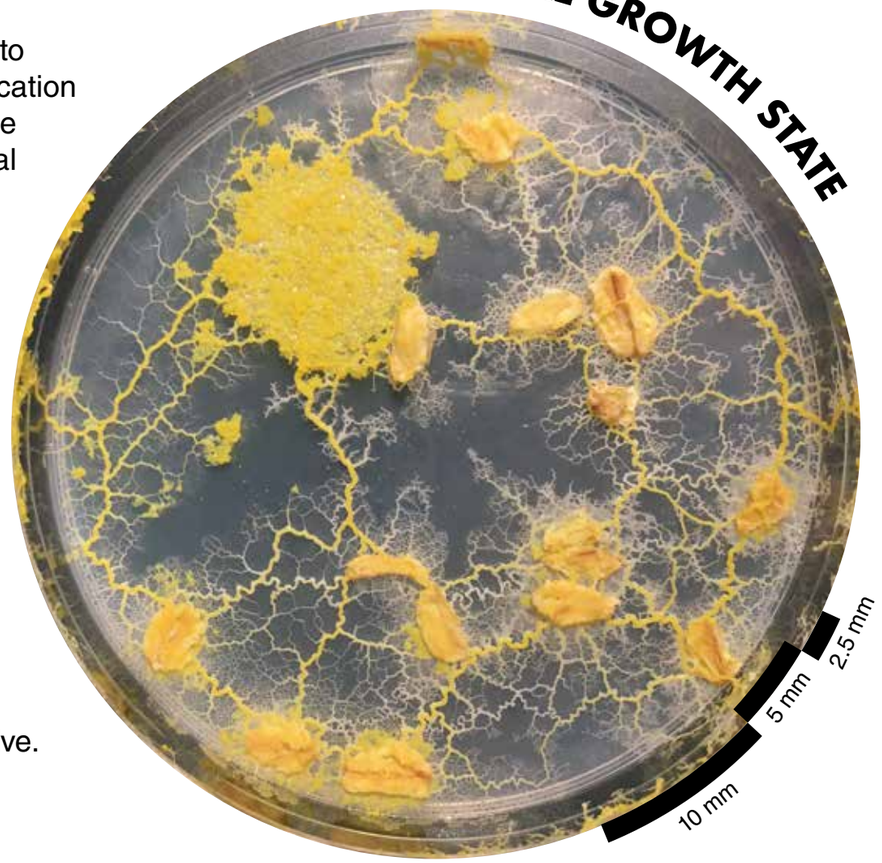
Equipment:
Sterile Scalpel
Permanent Marker
Scissors
Microscope
iPhone

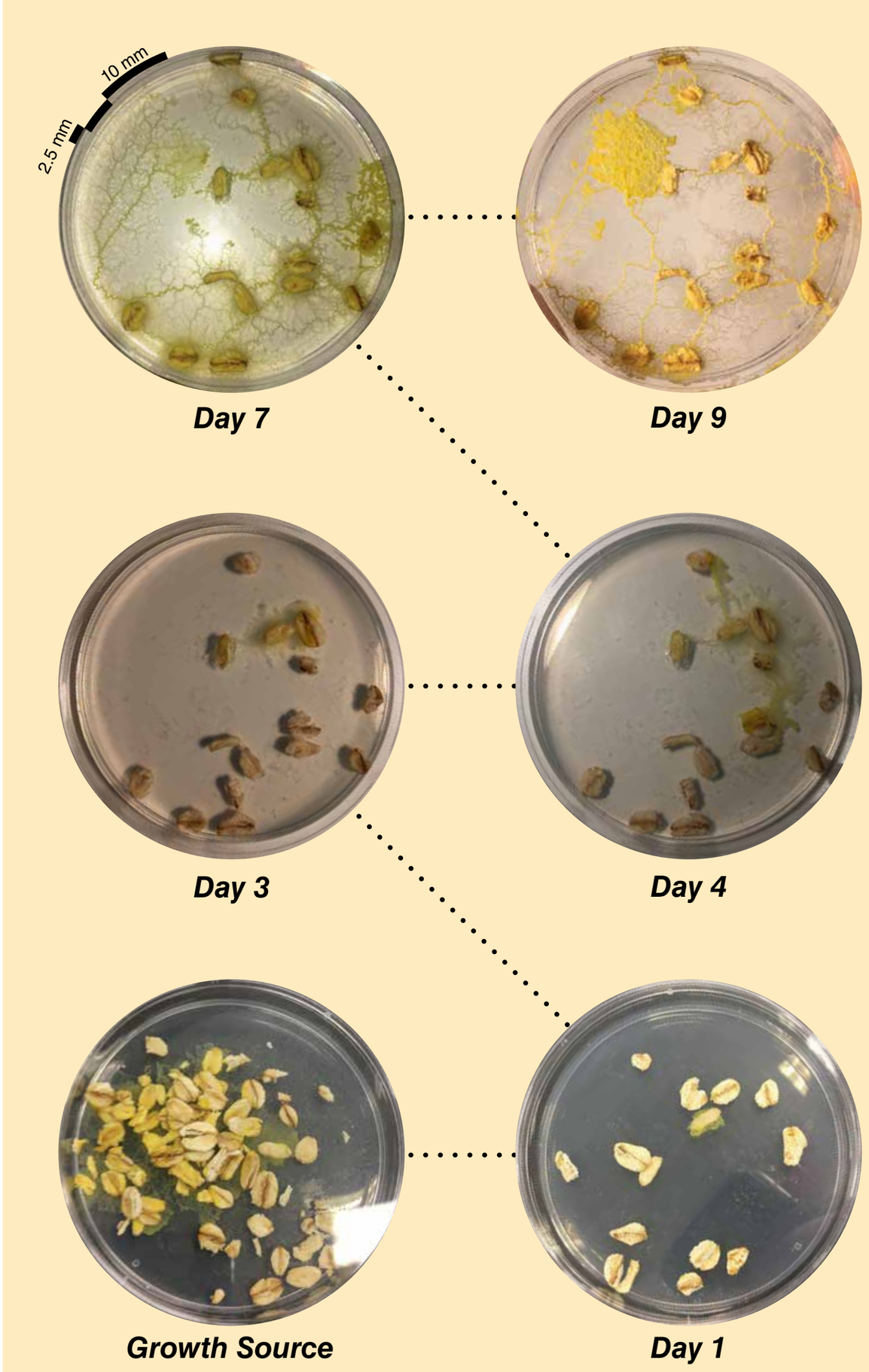
Hypothesis:
A network of slime mold will grow and colonize the agar plate in a method correlating to the fungi locating the individual rolled oat food sources.

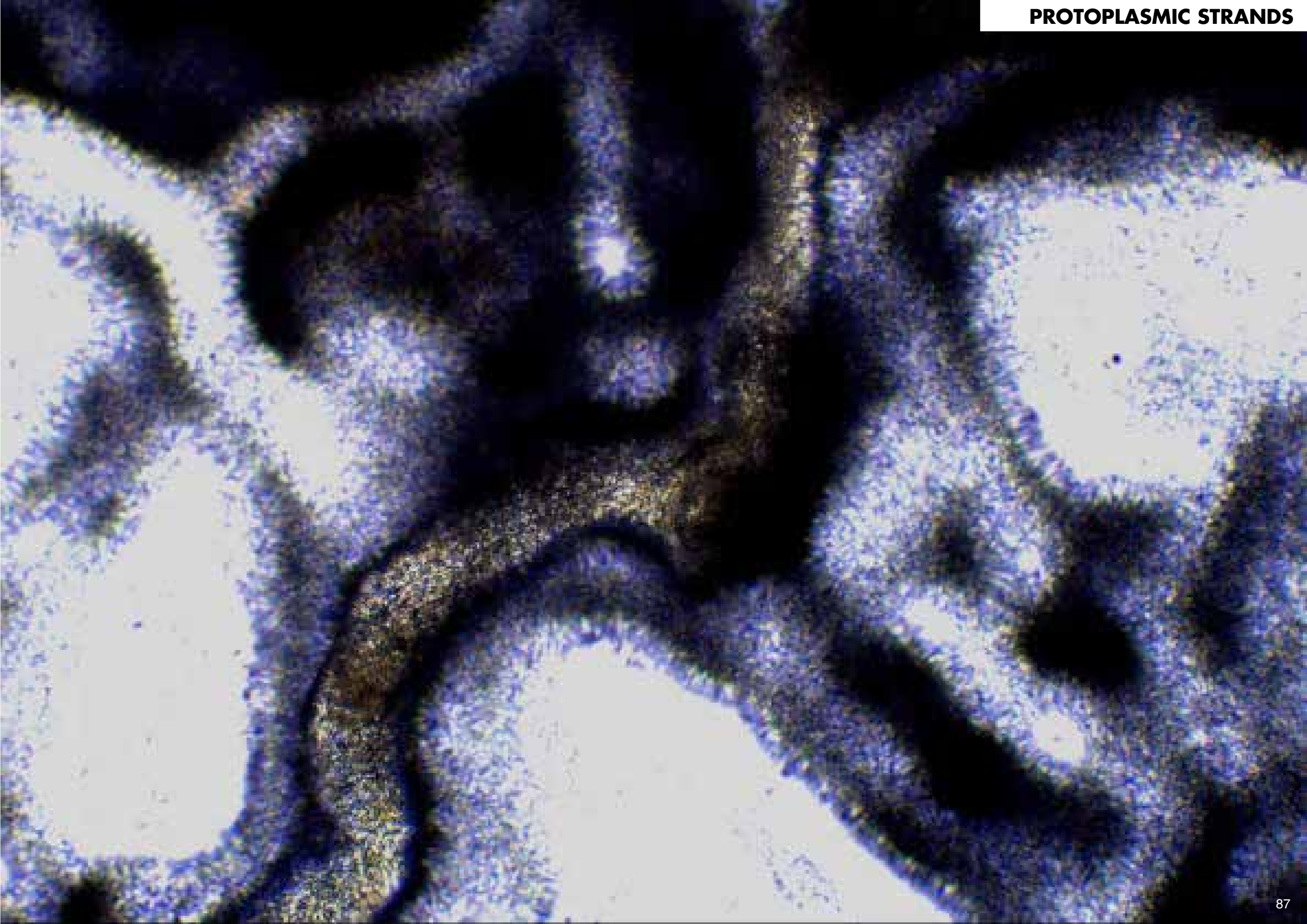
Protocol:
Use a sterile scalpel to collect small piece of the *P. polycephalum* from the existing colony plate, place it onto the petri dish with pre-poured agar medium, and promptly close the lid.
Momentarily open the plate to sprinkle a few raw rolled oats over the medium.
Using a permanent marker note the date, organism, and your name on the side of the petri dish lid. With the scissor cut a piece of parafilm and wrap it around the side of the plate lid.
Place the sealed plate in a plastic sandwich bag and transport it to your home lab.
In your home lab, take the sealed plate out of the sandwich bag and enclose it in a solid close box. Keep the box in a place where it is not too hot and out of direct sunlight, to avoid internal overheating with the micro-environment.

Observations + Results:
After 3 days the fungi began to expand out from it original location in search of more food. By the next day the fungi had several rolled oat food sources in all different direction around the original specimen. By day 7 an expansive network of fungi had reached all of the rolled oat food sources on the plate.
Under a microscope, cyclosis was observed in network protoplasmic strands sending nutrients between the fungi colonies on day 7.

Conclusion:
The hypothesis was conclusive.







HOME LAB:

ALGAE BIOREMEDIATION

WHAT'S EATING GRANDMA?

TUTORS: ***NANCY DINIZ + ALICE TAYLOR***

PART 1: SOIL COLLECTION

Ingredients + Materials:
100 mL London Tap Water
50 mL Top Soil
Ceramic Bowl
Wooden Kebab Stick
Miracle Gro (Water Soluble)
Small Box
Sodium Bicarbonate

Equipment:
4x - 50 mL Plastic Falcon Tubes
5 mL Plastic Pipette
Digital Thermometer + Ph Meter
Digital Thermometer + Hydrometer
Digital Scale
Microwave
LED Grow Lamps
Pocket Knife

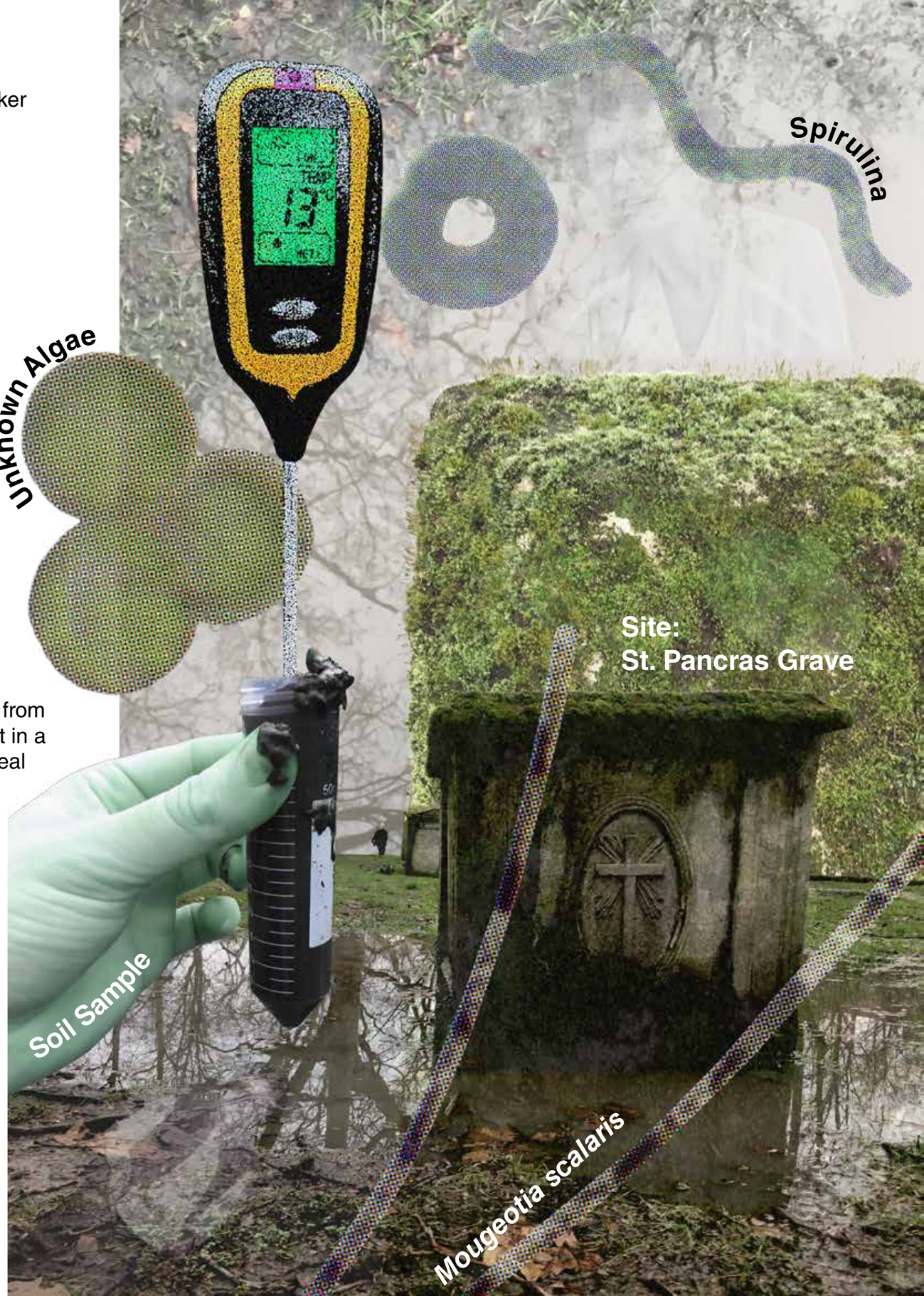
Permanent Marker
iPhone

Hypothesis:
Micro-algae living in the soil could be used to breakdown waste and human remains to generate a sustainable bioremediation strategy for waste management. Potentially this algae could in turn be used as a food source, agricultural nutrient, or biofuel.

Protocol:
The field procurement site was a bog puddle over a grave at St. Pancras Cemetery Park, London. Concluded with the wet finger method the wind in was blowing from the northwest. According to my thermometer/hydrometer at eye level it was 20.6 C with 55% humidity, while at the base of the bog puddle it was 19.5 C with 55% humidity. Soil temperature at extraction was 12 C, while the water 11 C.
Collect a soil sample by pressing a tube upside down into the soil as far as possible (within reason). While pulling the tube out, wiggle it sideways to make sure the deepest part of the soil stays in the tube. Place the on lid firmly. Collect 50 mL of surface water from the puddle in another tube.
Microwave tap water 3 minutes in a ceramic bowl with a wooden kebab stick, to keep water from boiling over. Measure 1g of soil from top of procurement tube (the deepest soil) and place it in a new tube, remember to label it. Using a pipette dispense 10 ml of water into the tube and seal it. Repeat process with a second tube. Place approximately .05g of Miracle Grow in each of the 3 water filled tubes. Measure the tubes' water temperature and pH level daily.
Tube 1: Soil Sample under Grow Lamp
Tube 2: Soil Sample in Darkness of a Box
Tube 3: Top Water Sample

Observations + Results:
Day 5 small quantities of algae observed in Tube 3. Day 7 growth in Tube 3 appeared to be a brown algae, added a small quantity of sodium bicarbonate to encourage propagation by increasing water pH level. Day 11 new pH Meter purchased due to insufficient data from previous device. Also, there was a population boom in Tube 3. Day 14 Tube 1 + 2 began to smell of ammonia, and Tube 3 was 25% transparent due to algae propagation. Day 25 Tube 3 had a clump of brown algae floating. While water samples from Tube 1 + 2 observed under microscope had zero algae present.

Conclusion:
The density and tenacity of algae present in the average soil is not sufficient to naturally bioremediating the decease for an algae-based food source or biofuel.



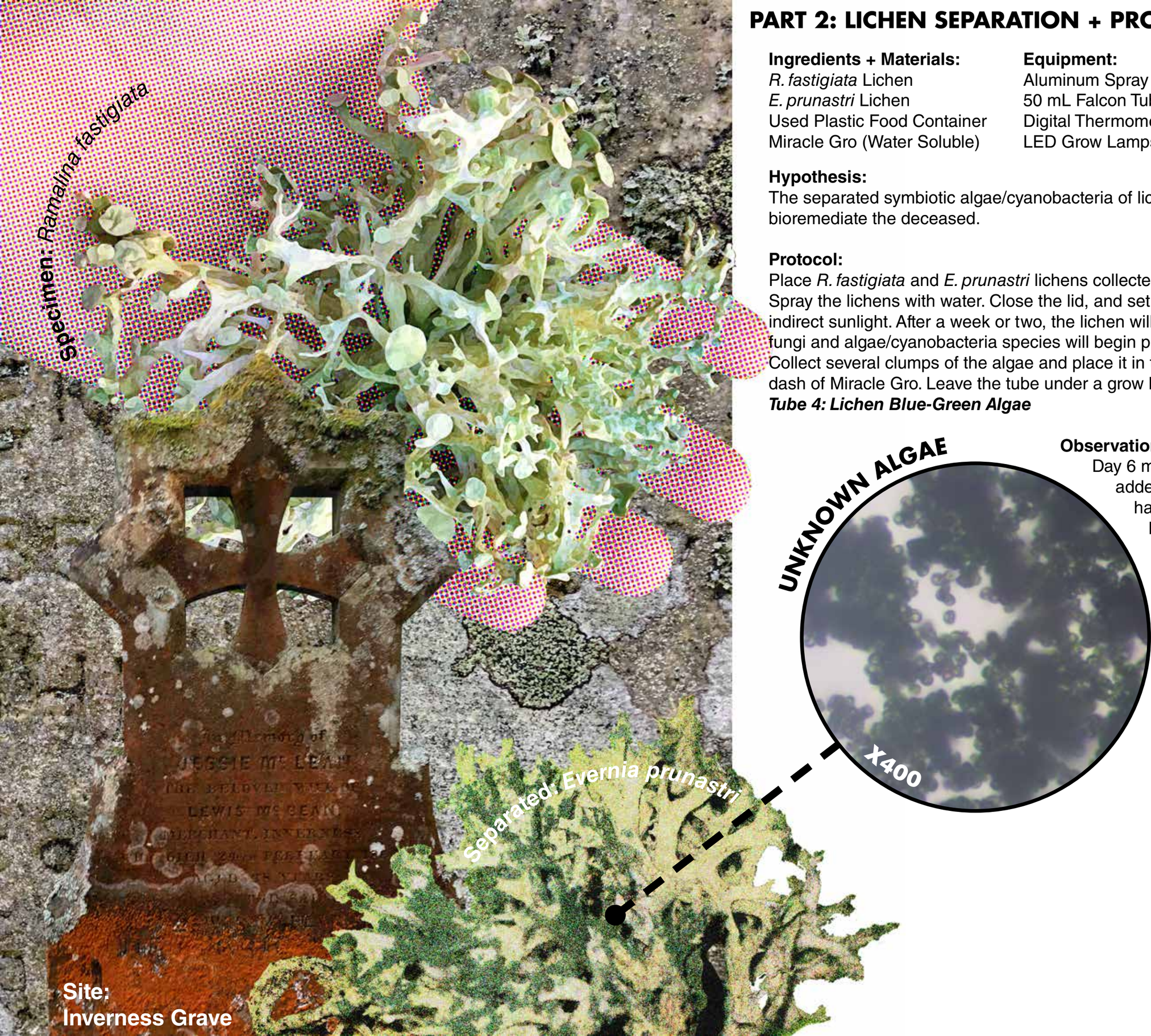
PART 2: LICHEN SEPARATION + PROPAGATION

Ingredients + Materials:
R. fastigiata Lichen
E. prunastri Lichen
Used Plastic Food Container
Miracle Gro (Water Soluble)

Equipment:
Aluminum Spray Bottle
50 mL Falcon Tube
Digital Thermometer + Ph Meter
LED Grow Lamps
Permanent Marker
iPhone

Hypothesis:
The separated symbiotic algae/cyanobacteria of lichen can be easily propagated to bioremediate the deceased.

Protocol:
Place *R. fastigiata* and *E. prunastri* lichens collected from nature in a plastic container. Spray the lichens with water. Close the lid, and set aside somewhere cool with low indirect sunlight. After a week or two, the lichen will break its symbiotic state, thus the fungi and algae/cyanobacteria species will begin propagating independently. Collect several clumps of the algae and place it in tube with 50 mL of tap water with a dash of Miracle Gro. Leave the tube under a grow lamp at room temperature.
Tube 4: Lichen Blue-Green Algae



Observations + Results:
Day 6 more blue-green algae clumps were added. Day 15 the population seems to have increased. Day 25 the population has fully deceased.

Conclusion:
There was a small moment of success in the experiment, however likely due to insufficient aeration and nutrients the blue-green algae deceased. More iterations needed to be conclusive.

PART 3: FALCON TUBE PROPAGATION

Ingredients + Materials:
Procured Unknown Spirulina
Procured *M. scalaris*
Miracle Gro (Water Soluble)
Sodium Bicarbonate
Empty Used Tissue Box

Equipment:
2x - Plastic Falcon Tubes
LED Grow Lamps
Permanent Marker
Digital Thermometer + Ph Meter
Scissors
iPhone

Hypothesis:
Spirulina could bioremediate the deceased as long as a hospitable pH level of 9 is maintained. The commonness of *M. scalaris* requires low maintenance and a valid deceased bioremediator.

Protocol:
20 mL samples of spirulina and *M. scalaris* were procured in an algae swap with coursemate Célina Camboni in falcon tubes. A dash of Miracle Gro was added.
Using a permanent marker, trace 6 circles from the circumference of a falcon tube onto the side of an empty tissue box. With a pair of scissors carefully cut an x across the diameters of each circle. Next cut as much of the surface area of the bottom and top of the box without compromising the structural integrity.
Place all 6 tubes of algae propagation (excluding Tube 2) into a hole of the box and under a LED grow lamp.
Tube 5: Spirulina
Tube 6: M. scalaris

Observations:
Day 14 density of Tube 5 decreased, while density of Tube 6 increased. Day 16 Tube 5 size of algae propagation increased, while color of Tube 6 diminished. Day 25 density of Tube 5 increased, while Tube 6 appeared constant. Both appeared healthy under microscope.

Conclusion:
Spirulina grew well in controlled environment; however, *M. scalaris* was not so easygoing despite is commonness.

PART 4: FLASK PROPAGATION

Ingredients + Materials:
Contents of Tube 1, Tube 4, Tube 5, Tube 6
Masking Tape
Miracle Gro (Water Soluble)
Sodium Bicarbonate
Billington's Demerara Sugar
Sainsbury's Coarse Sea Salt

Equipment:
4x - 250 mL Glass Büchner Flask
4x -Rubber Top Plugs
2x - Wooden Clothes Pins
Cordless Power Drill
Drill Bits
Boyu CJY-3500 Air Pump
Tubing + Plastic Tube Splits
LED Grow Lamps
Digital Thermometer + Ph Meter
Measuring Spoons
Permanent Marker
Wooden Trays

Hypothesis:
Using an automatic aeration system will increase the propagation time of the algae and result in denser cultivation, after all wasn't grandma 99% hot air.

Protocol:
Assemble the air pump with appropriate number of plastic splits and tubing lengths. Using cordless power drill with a bit fasten a hole through the center of all 4 rubber top plugs large enough to feed the air tube through.
Dump the contents of Tube 1, Tube 4, Tube 5, and Tube 6 into separate flasks, labeling with marker and masking tape. Add approximately 220 mL of tap water to each flask. Place rubber top plugs firm on and feed air tube through holes. Plug air pump in and place flask under grow lamp on wooden trays to prevent vibration shifting. Grow Lamp and air pump were switched off before going to bed and on when awoken due to adjacency to bed.

Observations + Results:
Day 2 of flask propagation added 1/2 tsp. sodium bicarbonate to Flask 4 + Flask 5, raising pH levels from 7 to 8. Day 3 1/4 tsp. demerara sugar added to all the flask, and 1/4 tsp. calcium carbonate + 1/4 tsp. sea salt added Flask 5. After 2 weeks there were zero changes to the any of the flasks. Furthermore, when observed under the microscope there was zero life present.

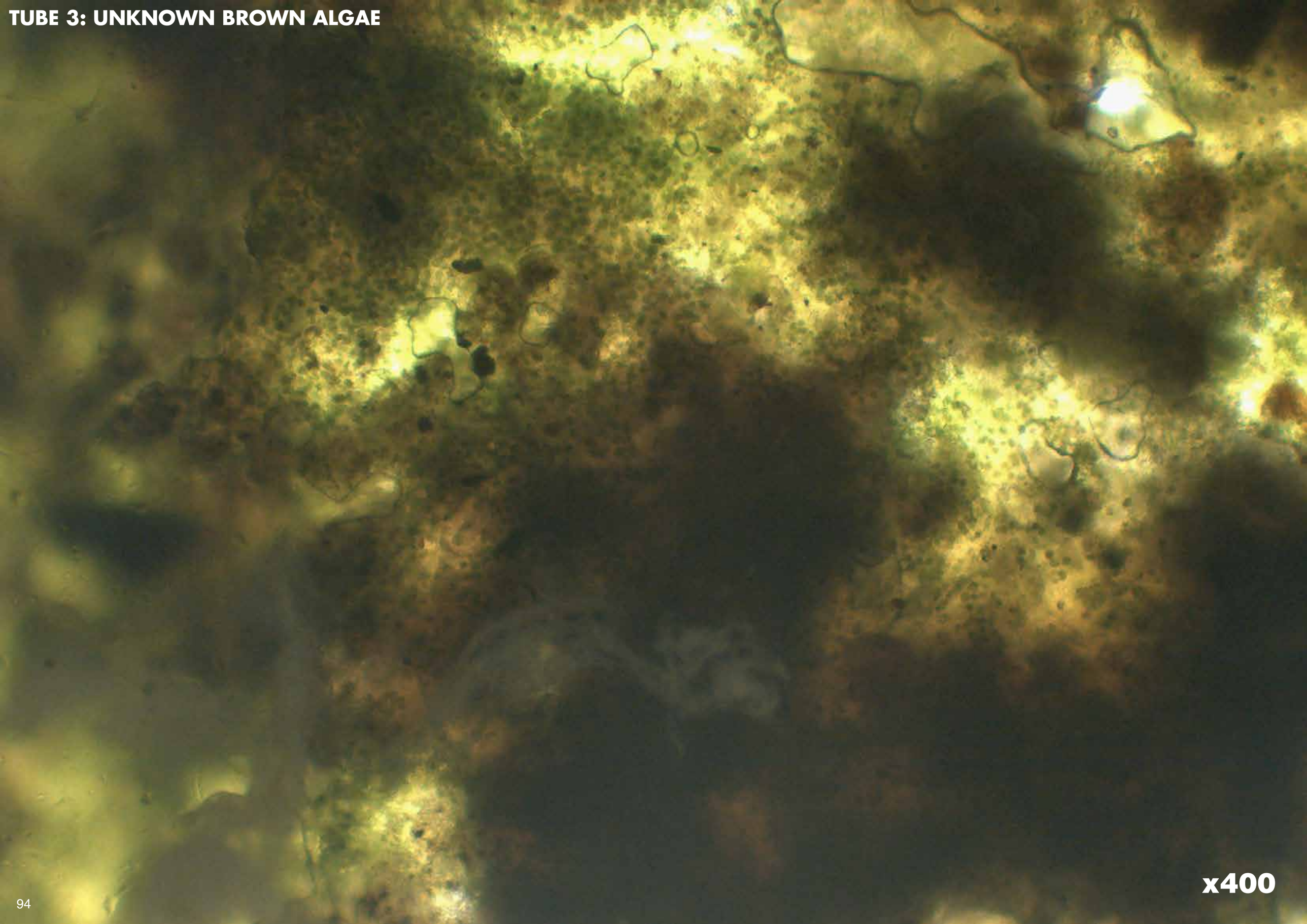
Conclusion:
Perhaps the 8 - 10 hours per day that the grow lamps and air pump were turned off crippled the growth of the algae. More likely the sodium bicarbonate killed the contents of Flask 1 + Flask 4 + Flask 6, while the sea salt killed Flask 5.

Algae Bioremediation: Part 1-3

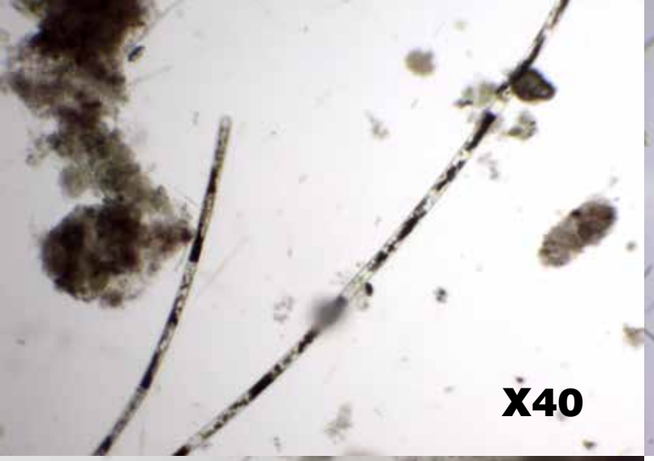
Day	Date	UV Lights		Room		Tube 1		Tube 3		Tube 4		Tube 5		Tube 6		Box		Tube 2	
		On	Off	Temp C	Humidity	Temp C	pH	Temp C	pH	Temp C	pH	Temp C	pH	Temp C	pH	Temp C	Humidity	Temp C	pH
1	21.01.29	-	11:37 PM	23.00	54%	22.00	5.5	25.00	2.50	-	-	-	-	-	-	-	-	24.00	5.50
2	21.01.30	1:48 PM	2:55 AM	21.90	51%	20.00	6.00	19.00	6.00	-	-	-	-	-	-	18.80	61%	22.00	6.00
3	21.01.31	2:03 PM	1:08 AM	17.00	55%	20.00	6.50	18.00	6.50	-	-	-	-	-	-	21.20	50%	19.00	6.50
4	21.02.01	4:10 PM	1:48 AM	18.50	58%	19.00	6.50	20.00	6.50	23.00	7.00	-	-	-	-	21.60	50%	22.00	6.00
5	21.02.02	3:10 PM	1:21 AM	18.80	54%	19.00	7.00	19.00	7.00	21.00	7.00	-	-	-	-	23.30	47%	22.00	6.50
6	21.02.03	11:00 AM	1:00 AM	19.00	58%	21.00	7.00	22.00	7.00	22.00	7.00	-	-	-	-	22.60	47%	23.00	7.00
7	21.02.04	10:11	1:10 AM	16.50	62%	21.00	7.00	19.00	7.00	23.00	7.00	-	-	-	-	22.40	50%	22.00	7.00
8	21.02.05	1:25 PM	12:25 AM	20.90	63%	20.00	6.50	18.00	6.50	18.00	7.00	-	-	-	-	23.90	52%	21.00	6.50
9	21.02.06	11:22 AM	1:06 AM	19.70	64%	23.00	7.00	23.00	7.00	23.00	7.00	23.00	7.00	22.00	7.00	23.60	51%	24.00	7.00
10	21.02.07	2:37 PM	12:35 AM	17.70	60%	21.00	6.50	19.00	6.50	20.00	7.00	20.00	7.00	20.00	7.00	21.00	50%	22.00	6.50
11	21.02.08	10:15 AM	1:41 AM	18.40	49%	22.40	8.60	21.60	8.24	21.70	7.50	20.80	9.44	21.30	8.09	20.30	49%	22.80	8.78
12	21.02.09	1:37 PM	2:40 AM	18.30	58%	21.10	8.67	18.30	8.27	19.30	7.58	19.50	9.44	19.80	8.11	20.80	50%	21.60	8.81
13	21.02.10	2:01 PM	10:00 PM	18.90	51%	20.10	8.72	18.30	8.32	18.90	7.66	22.90	9.36	22.90	9.36	20.80	48%	23.10	8.85
14	21.02.11	1:18 PM	3:57 AM	19.40	45%	20.30	8.75	18.20	8.36	19.50	7.58	20.40	9.40	20.70	8.00	21.10	46%	22.00	8.86
15	21.02.12	11:05 AM	3:58 AM	20.10	50%	22.10	8.69	21.80	8.32	20.50	7.63	19.70	9.43	21.20	8.10	20.60	46%	22.30	8.85
16	21.02.13	3:05 PM	2:50 AM	18.60	52%	23.40	8.76	23.70	8.35	24.10	7.40	23.90	9.29	24.10	8.22	20.10	46%	21.70	8.88
17	21.02.14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18	21.02.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19	21.02.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20	21.02.17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21	21.02.18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22	21.02.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23	21.02.20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	21.02.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25	21.02.22	12:10 PM	2:20 AM	22.50	57%	23.90	8.89	23.80	8.41	23.40	7.48	23.30	9.80	23.80	8.40	22.40	55%	24.00	8.86

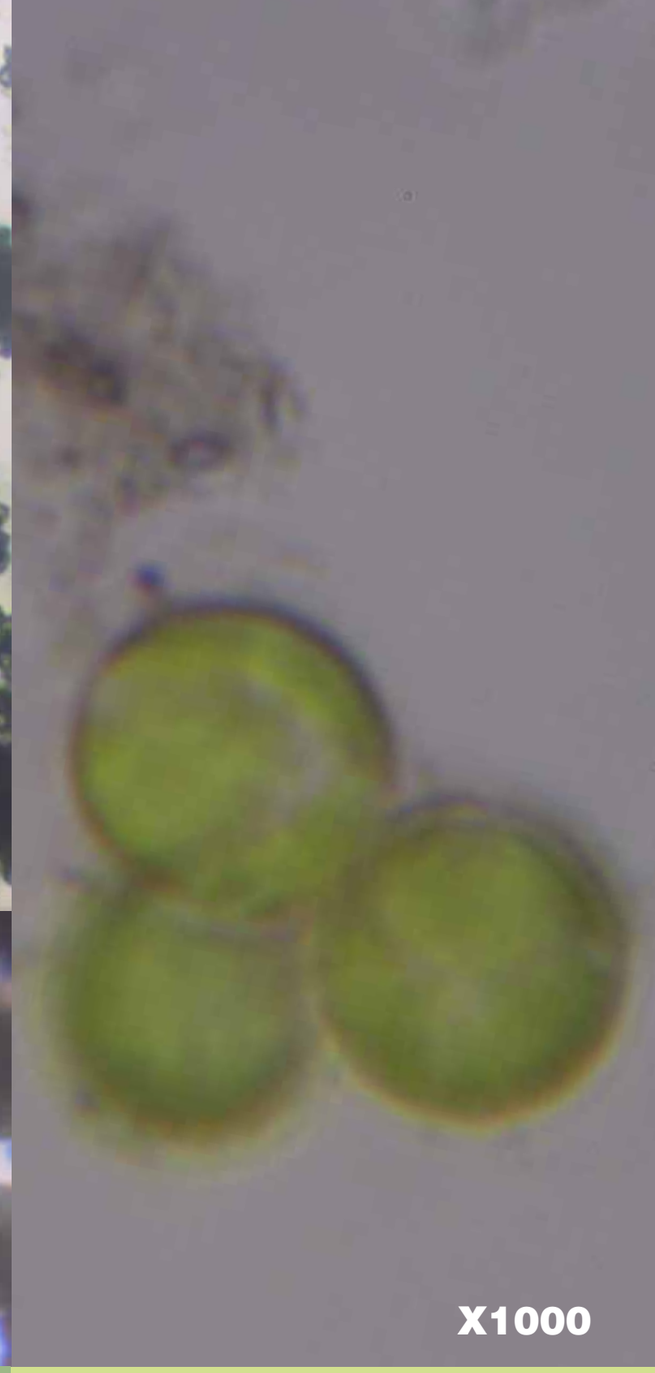
Nutrients Added / pH Adjusted
Manual Microorganism Introduction
Positive Algae Observation
Ammonia Smell Observation
Negative Algae Observation
Negative Algae Observation

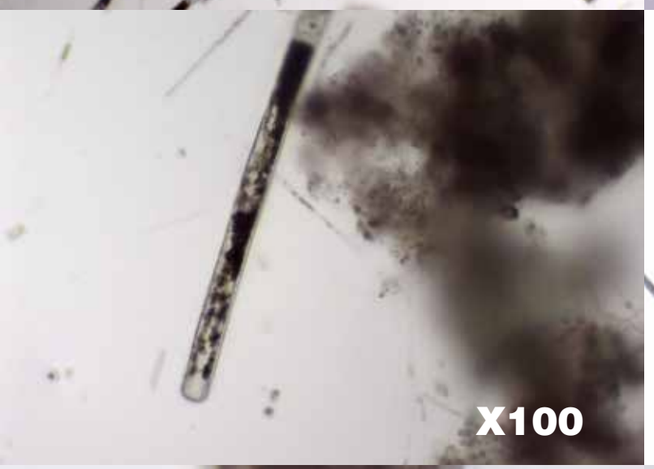
TUBE 3: UNKNOWN BROWN ALGAE

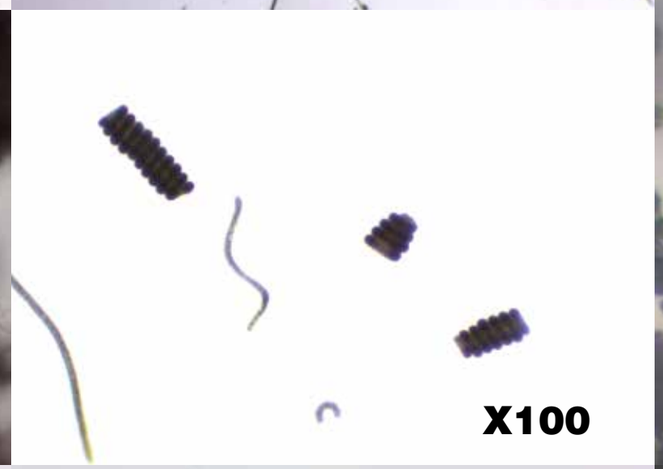


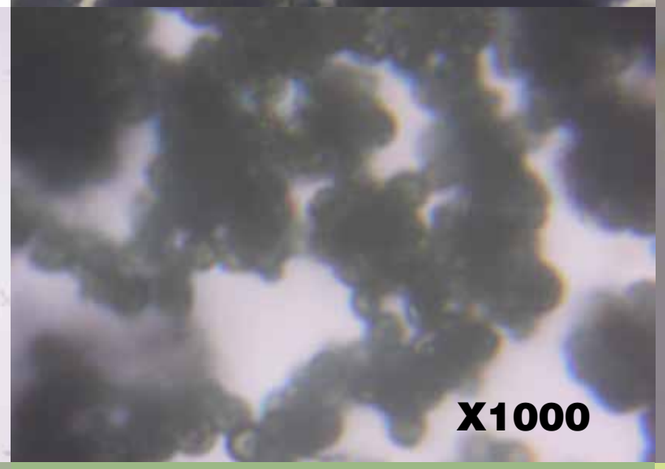
x400











HAIR ALGAE
MOUGEOTIA SCALARIS

Sourced from Célina Camboni's family pond in southern France. *Mougeotia* grows into dark-green long visible string clumps that resemble lost mermaid weaves.

SPIRULINA
UNKNOWN

Sourced from a friend of a friend, the exact species of spirulina is unknown. Spirulina is a highly dense cyanobacteria, and is often misconceived as a blue-green algae. It resembles metal springs, although it appears also to take a linear form.

OAKMOSS LICHEN ALGAE
UNKNOWN

Sourced by breaking *Evernia prunastri*, oakmoss lichen, fungi and algae symbiosis, the algae appears to be a blue-green algae. This particular lichen was procured in the Scottish Highlands.

BOG SOIL ALGAE
UNKNOWN

Propagated from a procured water bog sample from the St. Pancras soil collection site, the exact species of this green algae is unknown. The density of the propagation was not strong.

HOME LAB:

BACTERIAL GROWTH PLATES

SEARCH FOR THE WRINKLY BACTERIA

LAB TECH: ***SHEM JOHNSON***

BACTERIAL GROWTH PLATES 1

Ingredients + Materials:
1 tsp. Table Sugar
1 1/2 tsp. Agar
230 mL Tap Water
1 tsp. Marmite
Sterile Cotton Swabs
Masking Tape

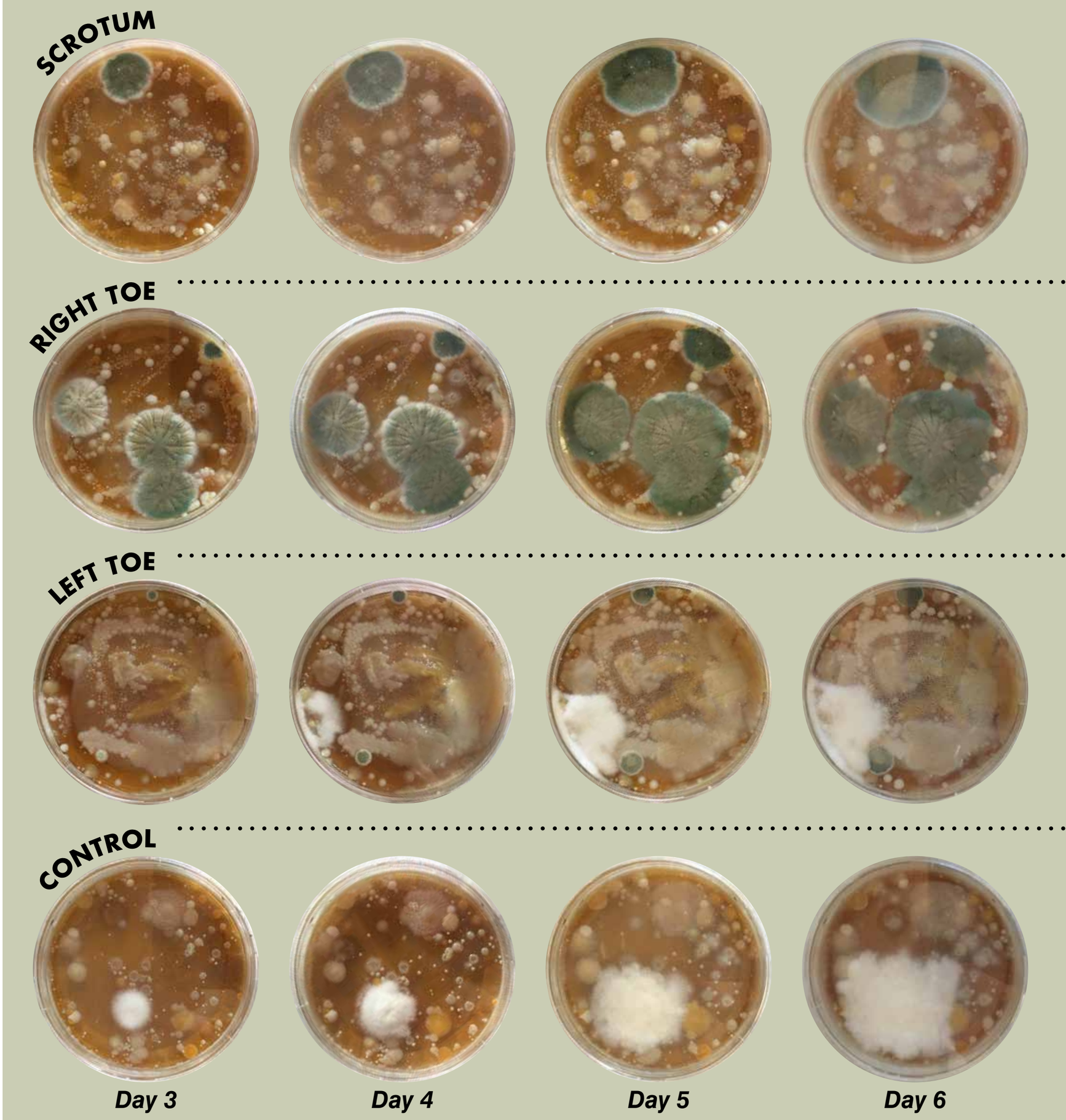
Equipment:
4x - 90 mm Petri Dish
Measuring Spoon
500 mL Glass Beaker
Large Metal Spoon
Stove
Small Pot
Permanent Marker
iPhone

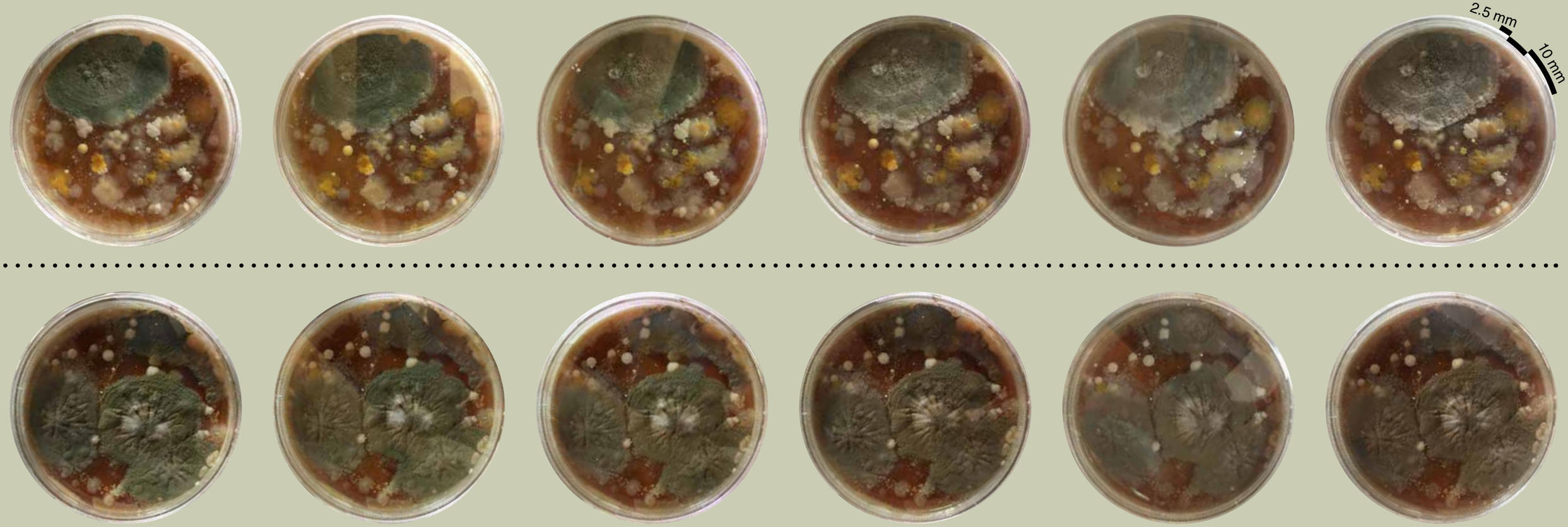
Hypothesis:
There is a greater variety of bacteria + fungi on human toes than the scrotum. The scrotum is a hospitable environment for bacteria + fungi with warmer body temperatures and higher perspiration humidity.

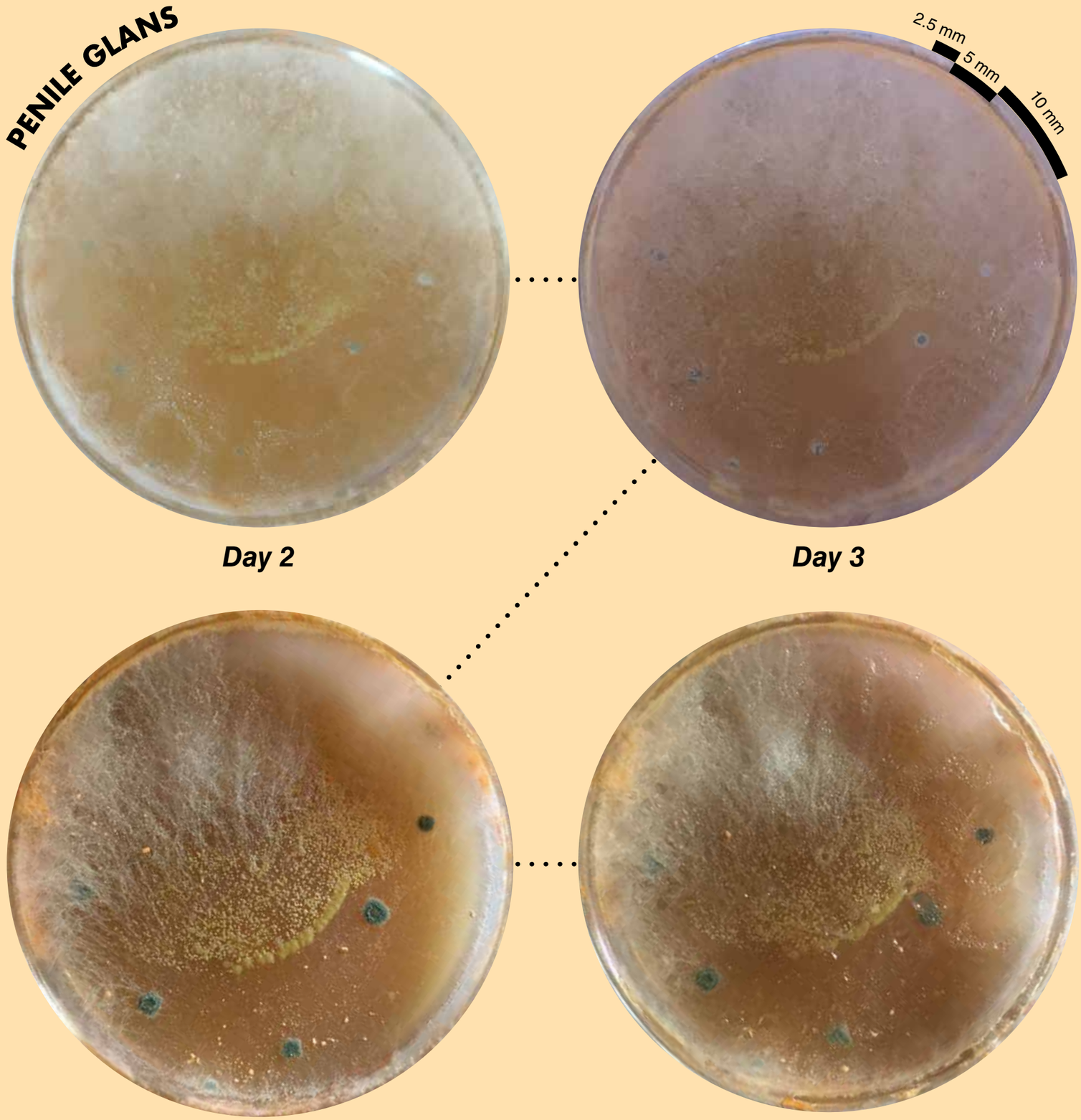
Protocol:
Add ingredients to pot, mixing over medium stove heat until homogeneous. Allow agar to cool for several minutes, without solidifying. Pour into the 4 petri dishes, filling halfway. Assure medium is level and even. Promptly cover plates to prevent contamination. Using a fresh sterile cotton swab for each culture plate, swab right big toe, left big toe, and posterior scrotum. Wipe swabs across plates, close, seal edges with masking tape, and notate. Place 3 culture plates and Control Plate in room temperature with indirect daylight.

Observations + Results:
Day 2 evident all the plates contaminated, Control Plate growing bacteria + fungi at same rate as cultured plates. Day 3 documented colony resembling wrinkly bacteria on Control Plate. Day 4 observed both Big Toe Plates had stronger growths of *A. fumigatus*, common fungus found in household dust and soil. Scrotum Plate appearing mostly populated by different specimens of *Staphylococcus* bacteria which lives harmlessly across human body. Day 5 large filamentous fungi colonies dominating on both Left Big Toe Plate and Control Plate, potentially *Basidiomycota*.

Conclusion:
Kitchen pot method was not a sterile procedure for uncontaminated plate cultures. The human growth plates contained abundant colonies of microbiome common bacteria, including *Bacillus, Micrococcus, Corynebacterium, and Staphylococcus*.




2.5 mm
10 mm
Day 7
Day 8
Day 9
Day 10
Day 11
Day 12



BACTERIAL GROWTH PLATES 2

Ingredients + Materials:

1 tsp. Table Sugar
1 1/2 tsp. Agar
230 mL Tap Water
1 tsp. Marmite
Masking Tape

Equipment:

90 mm Glass Petri Dish
Used Glass Jar with Lid
Measuring Spoon
500 mL Glass Beaker
Large Metal Spoon
Stove
11 L Pressure Cooker
Permanent Marker
Audrino Incubator
iPhone

Hypothesis:

Pressure cooker sterilization of glass petri dish and agar medium results in uncontaminated human bacteria cultures.

Protocol:

Add ingredients in glass jar, place lid loosely on top. Fill pressure cooker with water just below rack stand height. Place pressure cooker on stove, and set petri dish and jar with agar mixture on rack stand. Close pressure cooker and heat on low-medium. Once steam starts comes out of vent, set timer for 20 minutes.
Turn off stove, waiting 15 minutes before opening cooker. Allow agar to cool several minutes, without solidifying. Pour into petri dish, filling level halfway. Close plate and allow to solidify. After 10 minutes, open plate and wipe both sides of penile glans across medium. Close plate, seal with making tape, label, and incubate at 30 C.

Observations + Results:

Day 2 bacteria + fungi colonies present. 6 small *A. fumigatus* colonies identified, and many colonies of *Micrococcus*. 75% of the plate is covered in orange fuzzy fungi, possibly *C. sitophila*. Day 3 *C. sitophila* color transforms to pale orange. Day 4 *C. sitophila* regressed to only covering 50% of surface, but growing down edges of lid and more vibrant orange. *A. fumigatus* and *Micrococcus* colonies tripled. Day 5 *C. sitophila* covers 25% of surface and color desaturated. *Micrococcus* colonies continue to grow approximately 125%.

Conclusion:

Less contamination occurred sterilizing with the pressure cooker; the plate was still contaminated by *C. sitophila* and *A. fumigatus*. Perhaps a longer steam time is required for full sterilization.

BACTERIAL GROWTH PLATES 3

Day 2

Day 5

Ingredients + Materials:

Nutrient Rich Agar	Parafilm
Reverse Osmosis Water	

Equipment:

90 mm Plastic Petri Dish	Autoclave
500 mL Glass Bottle	Permanent Marker
Digital Scale	Audrino Incubator
Metal Stirrer	iPhone

Hypothesis:

Autoclaving equals zero contamination and penile glans culture will solely be common microbiome bacteria.

Protocol:

Follow directions on agar container. Mix agar + water in bottle, autoclave with lid loosely on. Once sterilized, allow agar to cool, and pour into petri dish. AT HOME wipe penile glans across medium, close, seal, and label. Incubate at 30 C.

Observations + Results:

Day 2 colonies of *Bacillus, Staphylococcus,* and *Micrococcus* present. Day 5 colonies 2x size, some areas of high density.

Conclusion:

Sterile environment for plate cultures is only achievable with an autoclave.

HOME LAB:

AGARICUS BISPORUS // BABY BUTTON MUSHROOM MYCELIUM PLATES

MY MY MYCELIUM FAILURES

LAB TECH: *SHEM JOHNSON*

MARMITE AGAR MYCELIUM PLATES

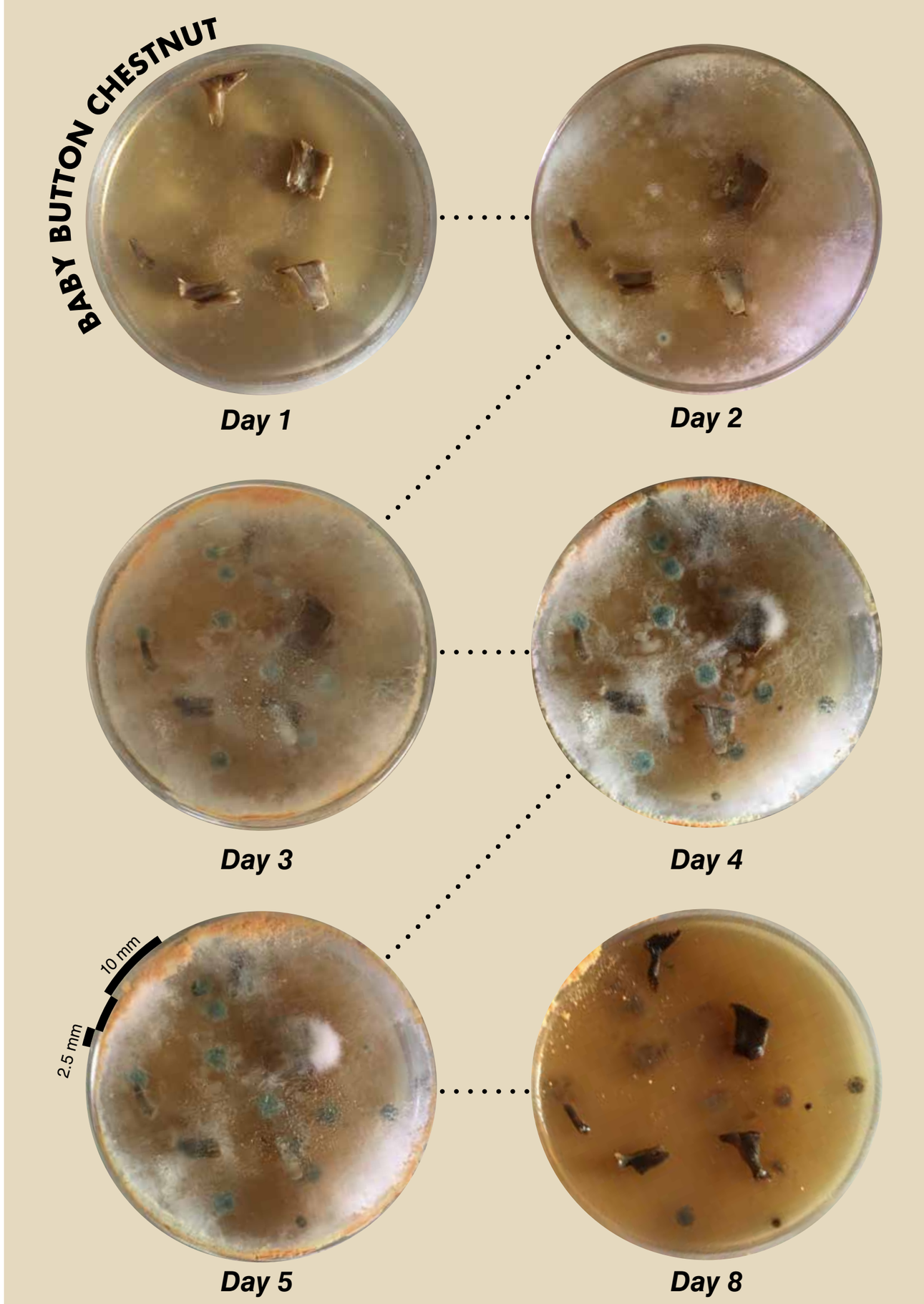
Ingredients + Materials:
1 tsp. Table Sugar
1 1/2 tsp. Agar
230 mL Water
1 tsp. Marmite
Baby Button Mushroom Stem
Baby Chestnut Mushroom Stem
Masking Tape
Sterilized Toothpicks

Equipment:
2x - 90 mm Glass Petri Dish
Used Glass Jar with Lid
Measuring Spoon
500 mL Glass Beaker
Large Metal Spoon
Stove
11 L Aluminum Pressure Cooker
Permanent Marker
iPhone

Hypothesis:
Marmite agar will encourage mushroom mycelium to grow rapidly.

Protocol:
Add ingredients in glass jar, place lid loosely on top. Fill pressure cooker with water just below rack stand height. Place pressure cooker on stove, and set petri dishes and jar with agar mixture on rack stand. Close pressure cooker and heat on low-medium. Once steam starts comes out of vent, set timer for 20 minutes.
Turn off stove, waiting 15 minutes before opening cooker. Allow agar to cool several minutes, without solidifying. Pour into petri dishes, filling level halfway. Close plates and allow to solidify. Carefully prey a baby button stem into several small pieces, and after 10 minutes open a plate to place stem pieces on medium. Repeat process with baby chestnut stem and other plate. Place plates on floor on enclosed closet, out of daylight in darkness.
Observations + Results:
Day 2 contamination from bacteria *A. fumigatus* and fungi *C. sitophila* is noticeable on both plates. Day 4 50% of the plates' surface is covered by *C. sitophila* and is growing prolifically on stems; *A. fumigatus* colonies are 4x larger. Day 5 *C. sitophila* covers 75% of surface and is growing significantly at lid edges. Lid is opened to inspect plate closer. Day 8 All of the bacteria + fungi have died, including the host stems.

Conclusion:
Marmite encourages fungi growth, just not *A. bisporus* as intended. Pressure cooker method was contaminant again. For some unknown reason, briefly exposing the plate cultures to open air terminated their lives.



Day 5

Day 8

2.5 mm

10 mm

Day 3

Day 4

Day 1

Day 2

BABY BUTTON

Specimen: Agaricus bisporus

Pressure Cooker

HOME LAB:

TRAMETES VERSICOLOR // TURKEY TAIL MUSHROOMS

HIGHLAND HANGERS + FUNGI FRIENDS

SELF-DIRECTED: ***ISAAC M. WILHELM***

HIGHLAND BRANCH FUNGI PROPAGATION

Ingredients + Materials:
Coniferous Branch Existing *T. Virsicolor*
Large Plastic Freezer Bag
Miracle Gro (Water Soluble)
Tap Water

Equipment:
Swiss Army Knife with Saw Blade
Large Transparent Plastic Container
Macro Camera Lens
Spray Bottle
iPhone

Hypothesis:
Procured wild fungi, *T. Virsicolor*, growing on a dead coniferous tree branch can be propagated in a DIY terrarium.

Protocol:
Using a Swiss army pocket knife cut a segment of a fallen coniferous branch with fungi growing on it. Enclose branch in plastic bag. At home place the branch in a large plastic container and spray it with Miracle Gro enriched water. Store container one a shelve with low indirect light.

Observations + Results:
After 1 week open container for a day to allow some air exchange and spray with tap water before reclosing, no changes observed. After 1 month opened to observe original *T. virsicolor* mostly decayed; however new fungi colonies were growing in small white and tan clusters all over branch. Sprayed with water before reclosing. After 3 months opened to observe many dead fungus gnats on bottom and side of container, and several flew out as well. The original *T. virsicolor* were completely dead, and many of the past new colonies had died as well. There were some new clusters of fungi forming though, and an unidentified species of slime mold.

Conclusion:
Procured wild fungi can indeed be propagated in a DIY terrarium; however, more experimentation and research required to determine proper air exchange and nutrient needs.

1 MONTH: *T. VERSICOLOR*

PROCUREMENT SITE

3 MONTHS: UNKNOWN SLIME MOLD

3 MONTHS: *T. VERSICOLOR* MYCELIUM

3 MONTHS: *T. VERSICOLOR* MYCELIUM

3 MONTHS: *T. VERSICOLOR* MYCELIUM

HOME LAB:

BACILLARIOPHYCEAE // DIATOMS

COMPARATIVE BOG DIATOM ANALYSIS - INCOMPLETE

SELF-DIRECTED: *ISAAC M. WILHELM*

BACILLARIOPHYCEAE
UNKNOWN DIATOMS

Ingredients + Materials:
Snow-Covered Frozen Bog Water Sample
Bog Water Sample
Microscope Slide + Cover Slip

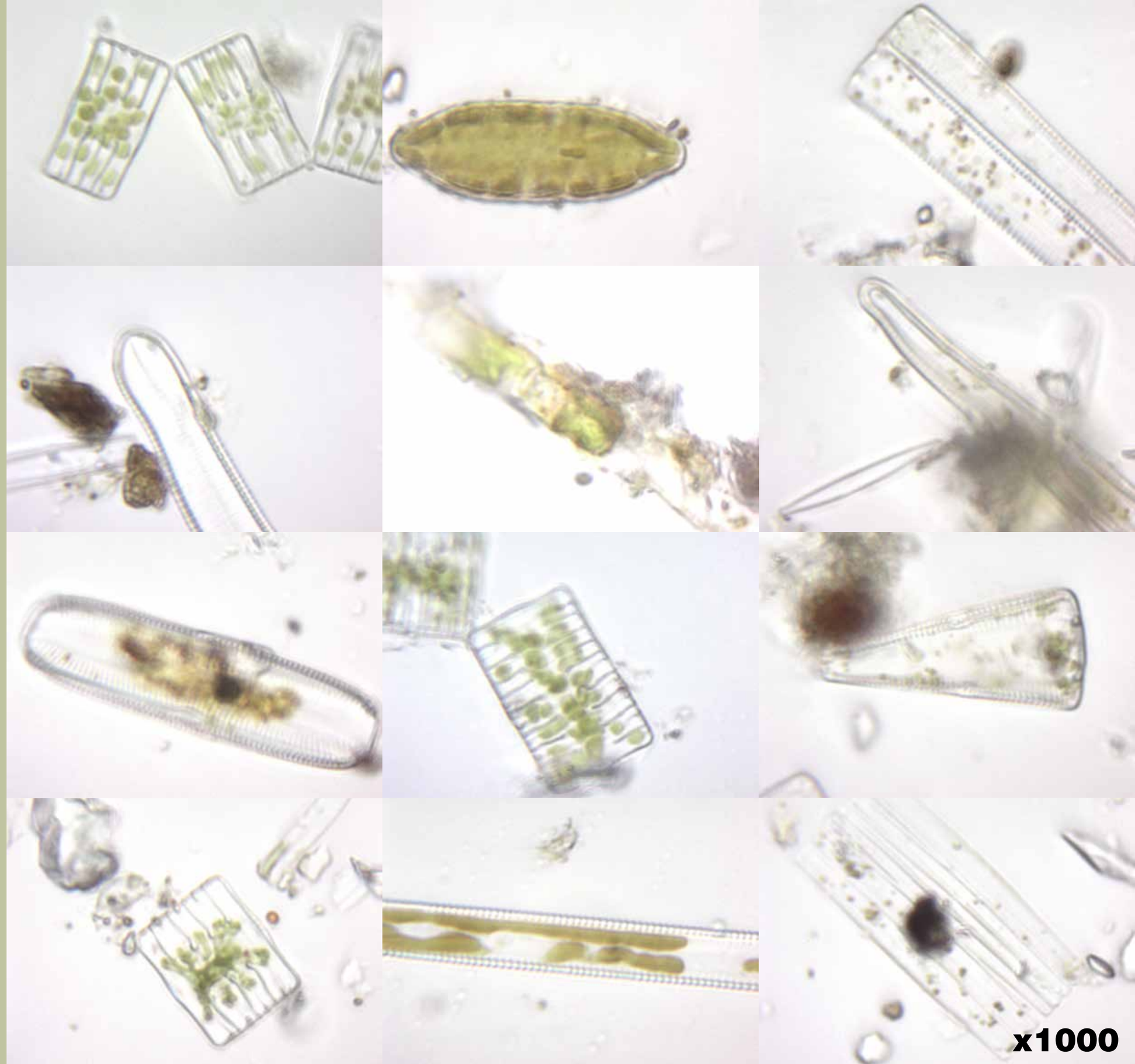
Equipment:
2x - 750 mL Used Plastic Bottles
Microscope
5 mL Glass Pipette

Hypothesis:
According to Andrew Bramburger, a Great Lakes ecologist, diatoms are more productive under snow-covered ice providing protection from solar radiation (Folger, 2020). This same observation can be seen in Highland bogs where the upper open portions of a bog system are frozen with snow, and lower canopy covered areas aren't.

Protocol:
Collect two samples of bog water from the same bog system in Scottish Highlands. Sample 1 from knoll top open meadow bog that is frozen and snow covered. Sample 2 from knoll base canopy covered bog that was unfrozen with no snow.

Observations + Results:
Under microscope observed many diatoms in Sample 1. Was unable to complete observations of Sample 2. However I observed a clump of brown algae growing in Sample 1 after about 1 month; while Sample 2 was unchanged (unfortunately I did not photograph before throwing out samples).

Conclusion:
Experiment was not completed, but potential brown algae growth was an optimistic sign mistakenly ignored.



WORK

SHOPS

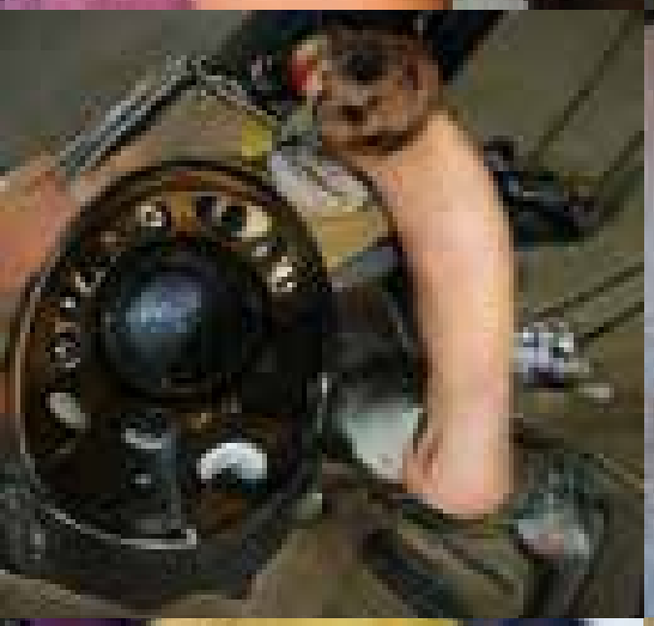
GANs

GENERATIVE ADVERSARIAL NETWORKS

TUTOR: ***JOSH MURR***







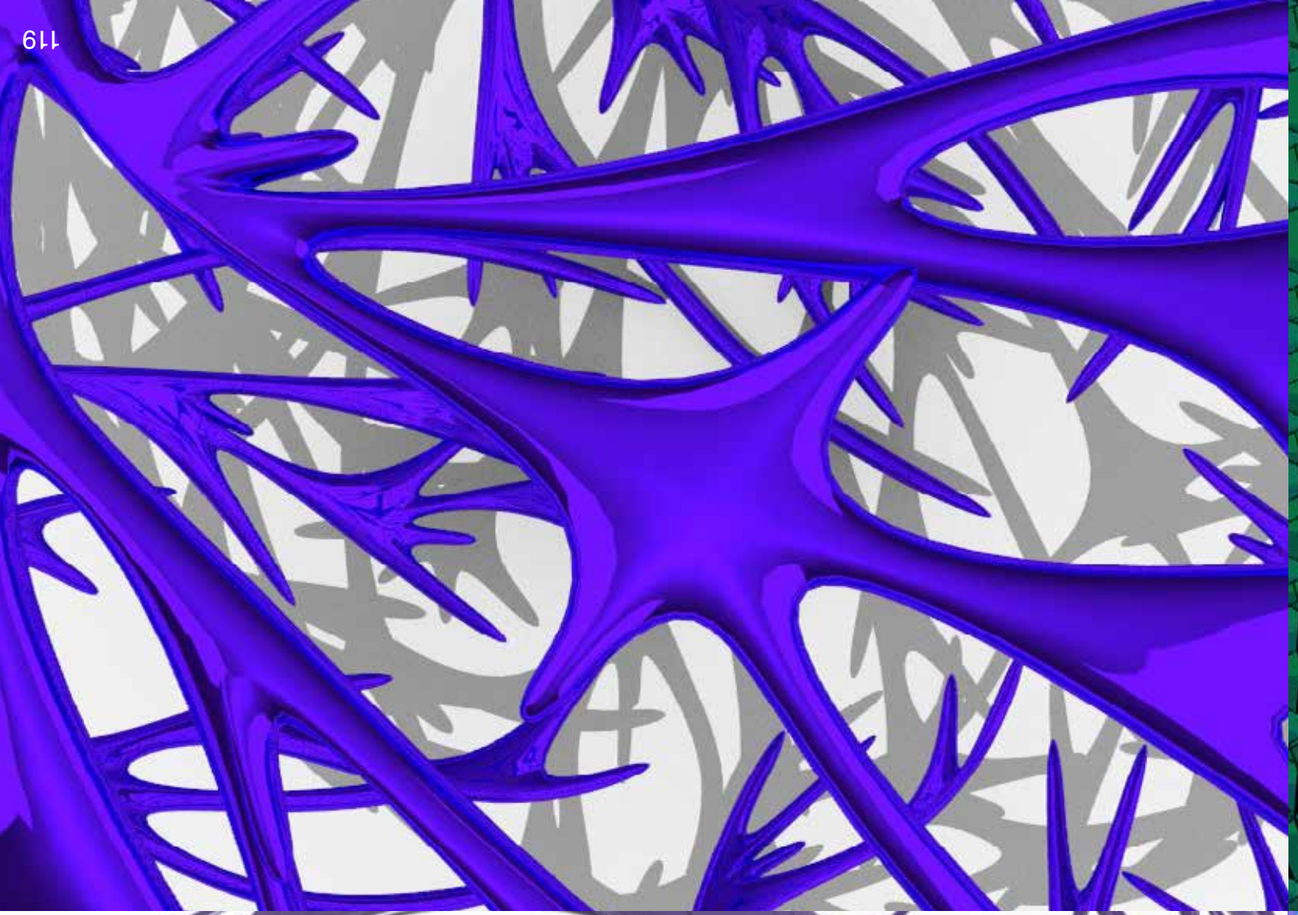


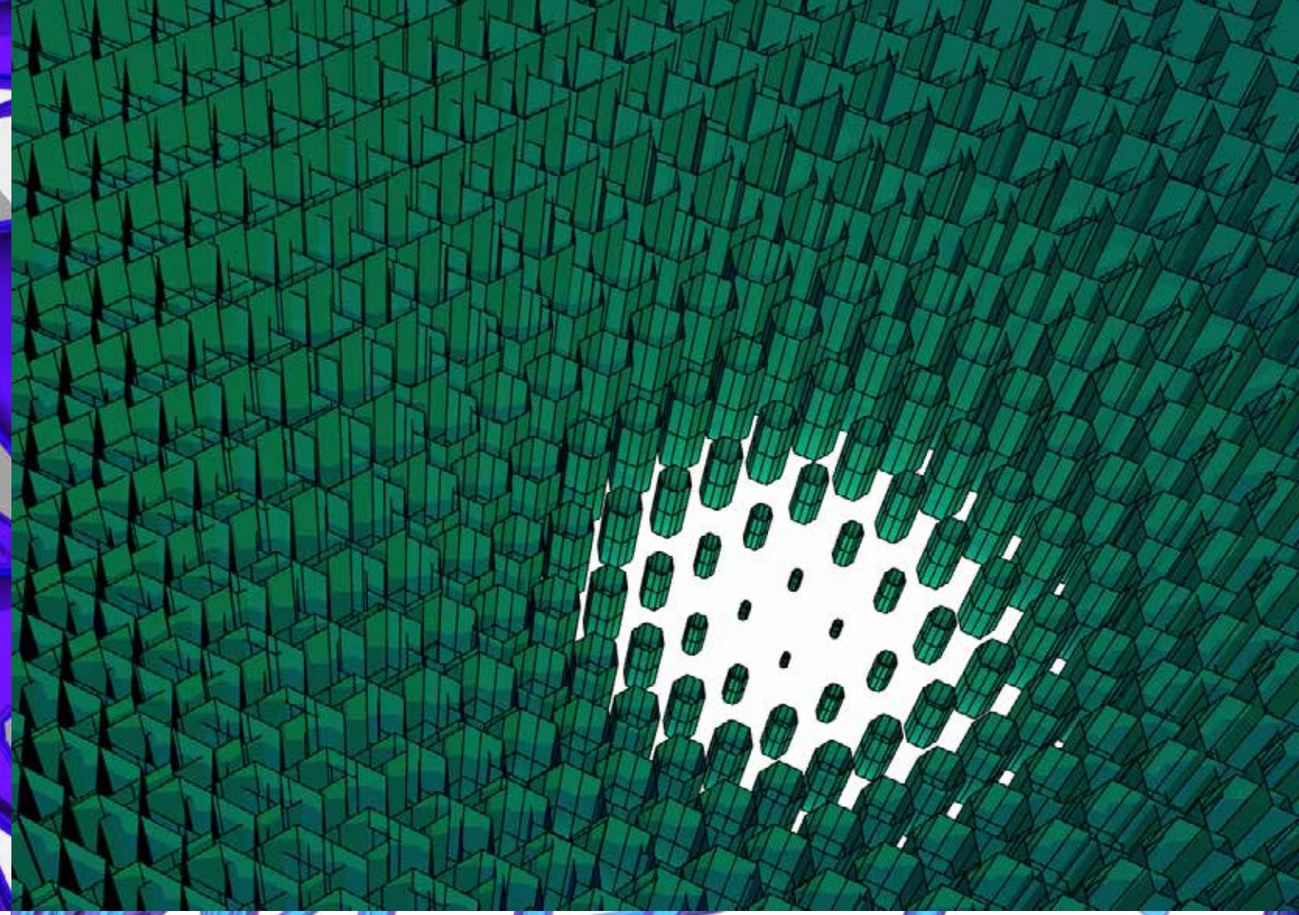


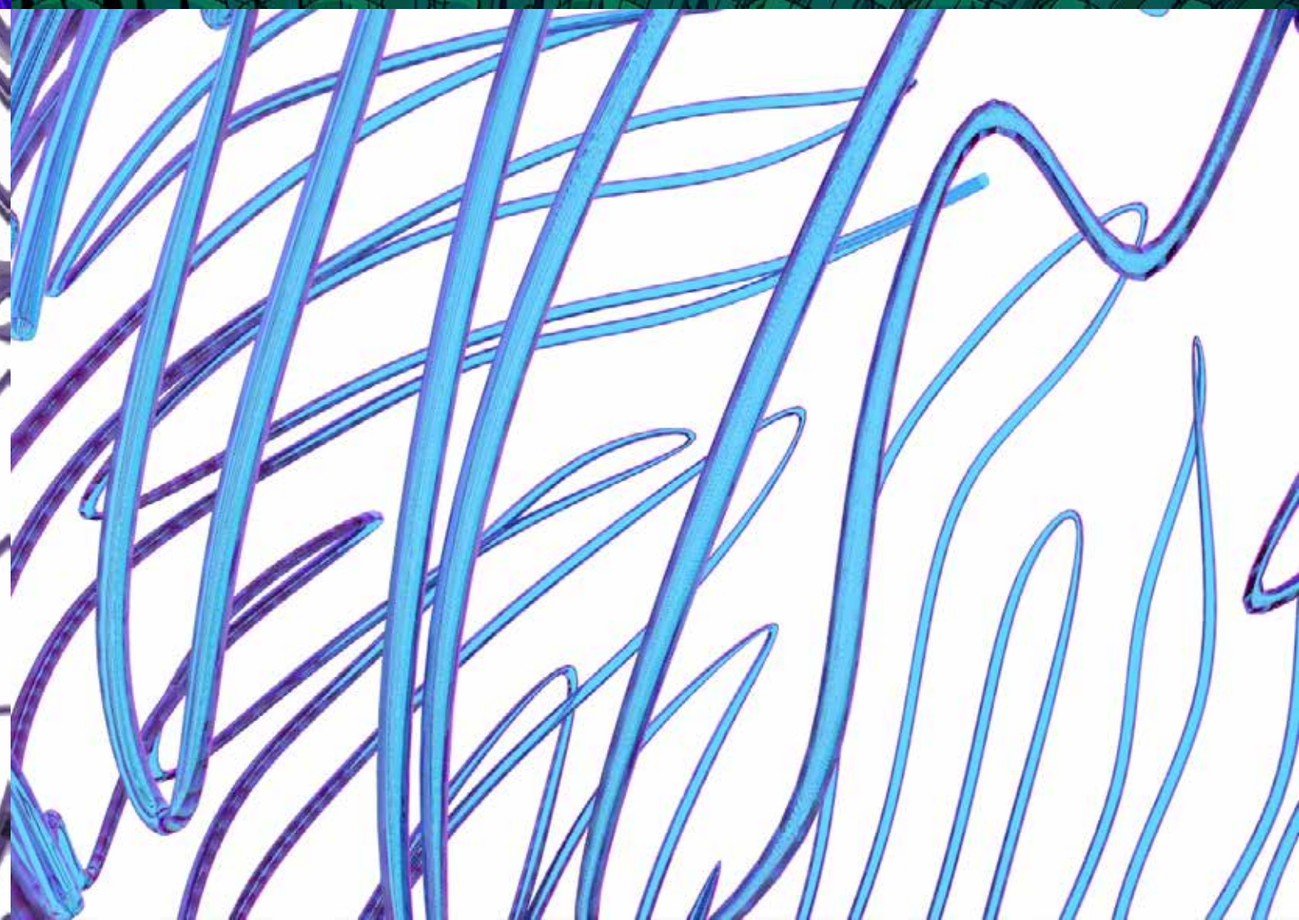

GRASSHOPPER

PARAMETRIC DESIGN SCRIPTING

TUTOR: *IGOR PANTIC*





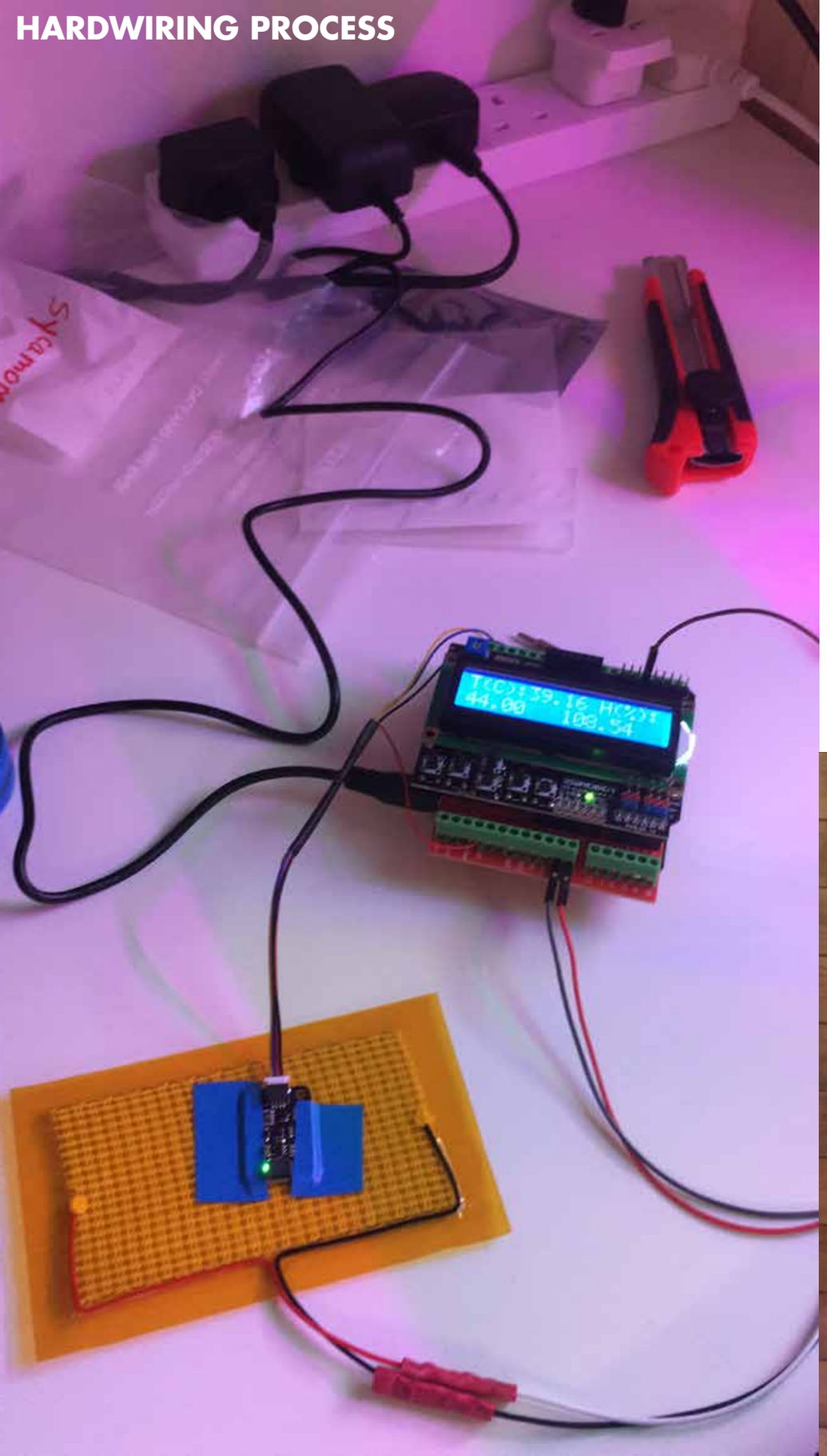


PHYSICAL COMPUTING - DIY INCUBATOR

AUDRINO HARDWIRING + SCRIPTING

TUTOR: ***RALPH MOORS***

HARDWIRING PROCESS




```
/*****************************************************

Implementing basic example from the PID library

https://playground.arduino.cc/Code/PIDLibaryBasicExample/

Making the buttons work better

https://github.com/rlogiacco/AnalogButtons/blob/master/examples/AnalogButtons/AnalogButtons.ino


*****************************************************/

#include <LiquidCrystal.h>
#include <Adafruit_AHTX0.h>
#include <Adafruit_HTS221.h>

#include <PID_v1.h>
#include <AnalogButtons.h>


//Define Variables we'll be connecting  for the PID.
double Setpoint, Input, Output;

//Specify the links and initial tuning parameters
PID myPID(&Input, &Output, &Setpoint,9,0.4,11, DIRECT);

LiquidCrystal lcd(8, 9, 4, 5, 6, 7);        // select the pins used on the LCD panel
```

PROTOTYPE 1

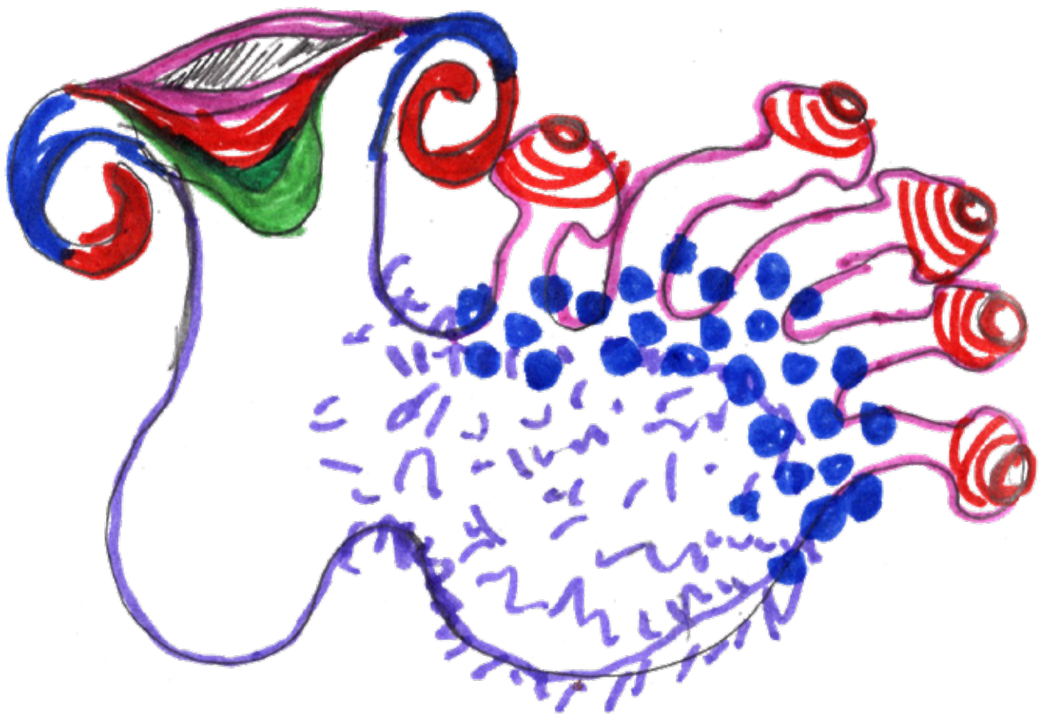
PROTOTYPE 2

BIOMIMICRY

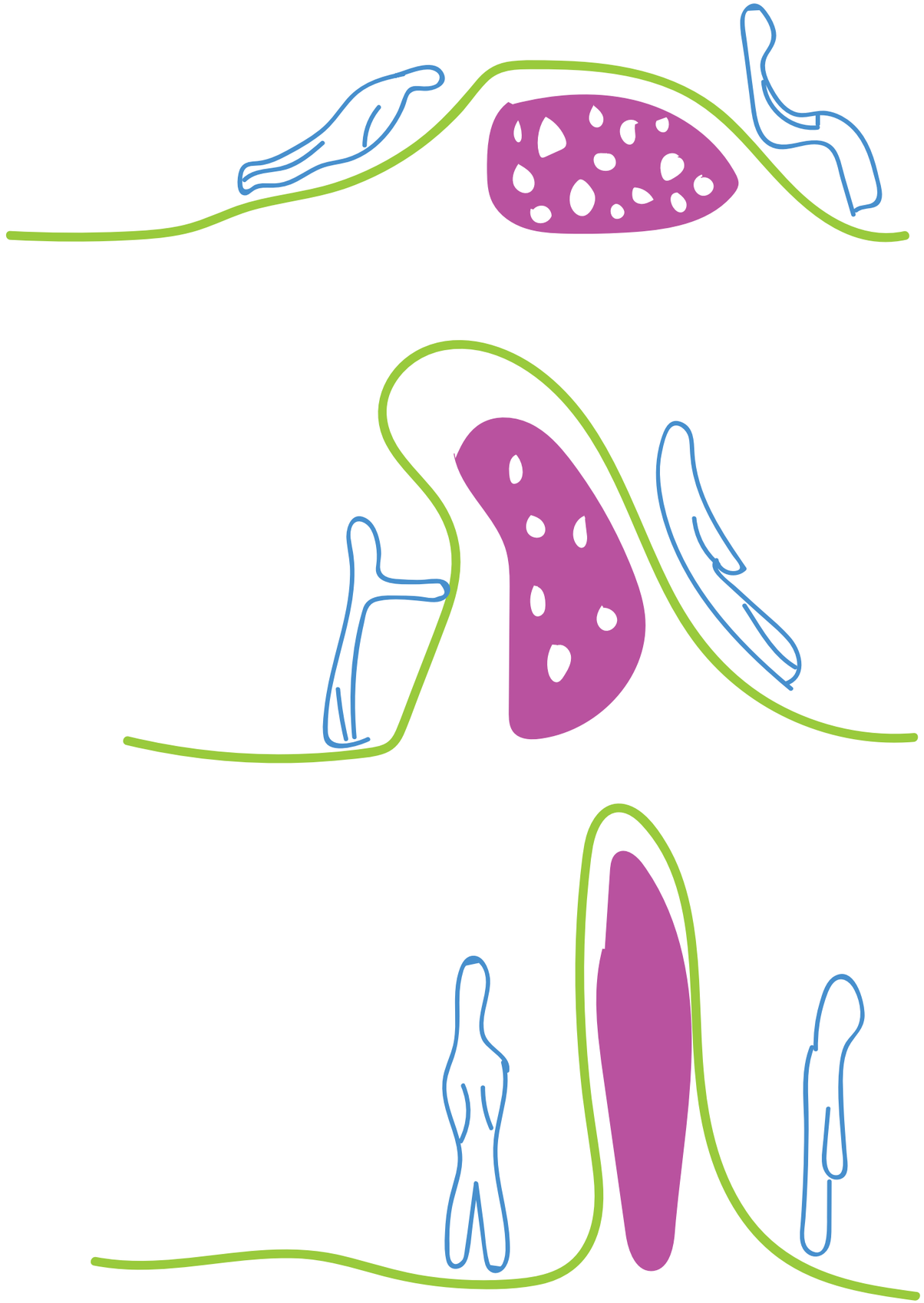
BIOLOGICAL BRAINSTORMING

TUTOR: *CAROLE COLLET*

AUTOPHILOUS STUBBY EARMUFFS



LYRATE SEXUAL SOCK



ASKNATURE.ORG: LEOPARD SEA CUCUMBER PLASTICITY

BIBLIOGRAPHY

Atema, J. (1971). Structures and Functions of the Sense of Taste in the Catfish (Ictalurus natalis). Brain, Behavior and Evolution, 4(4), pp.273–294.

Baron, V.D., Orlov, A.A. and Golubtsov, A.S. (1994). AfricanClarias catfish elicits long-lasting weak electric pulses. Experientia, 50(7), pp.644–647.

Carlson, D. (2017). Leaf Structure. [online] Carlson Stock Art. Available at: http://www.carlsonstockart.com/photo/leaf-structure-anatomy-illustration [Accessed 13 Nov. 2020].

Coder, K. and Warnell, D. (2004). Tree Trichomes: Big Hairy Tree? [online] . Available at: http://urbanforestrysouth.org/resources/library/citations/Citation.2004-07-16.2805/fss_get/file [Accessed 13 Nov. 2020].

Conrad, J. (2012). Composite Flowers. [online] Backyard Nature. Available at: http://www.backyardnature.net/fl_comps.htm [Accessed 13 Nov. 2020].

de Graaf, G. and Janssen, H. eds., (1996). Artificial reproduction and pond rearing of the African catfish Claris gariepinus in Sub-Saharan Africa. Rome: Fao.

Duffy, C. (2020). When Do Maple Trees Bud? | Hunker. Hunker. [online] Available at: http://www.hunker.com/13428987/when-do-maple-trees-bud [Accessed 13 Nov. 2020].

ferrebeekeeper. (2012). Sensitive Siluriformes–How Catfish Perceive the World. [online] Available at: http://ferrebeekeeper.wordpress.com/2012/01/20/sensitive-siluriformes-how-catfish-perceive-the-world [Accessed 28 Oct. 2020].

Folger, T. (2020). The Great Lakes, North America's greatest resource, faces many threats. National Geographic, 17 Nov., pp.40–81.

Forest Service USDA. (2014). Field Guide for Managing Diffuse, Meadow, Spotted, and Squarrose Knapweeds in the Southwest. [online] Available at: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5410116.pdf [Accessed 13 Nov. 2020].

Goldman, R. (2014). 5 Fast Facts About English Ivy. [online] Healthline. Available at: http://www.healthline.com/health/5-fast-facts-english-ivy [Accessed 13 Nov. 2020].

Gilman, E. and Watson, D. (1993). Celtis australis Figure 1. Middle-aged Mediterranean Hackberry. [online] Environmental Horticulture, University of Florida. USDA Forest Service. Available at: http://hort.ufl.edu/database/documents/pdf/tree_fact_sheets/celausa.pdf [Accessed 13 Nov. 2020].

Hadley, D. (2018). Why Are There So Many Aphids in My Garden? [online] ThoughtCo. Available at: https://www.thoughtco.com/why-are-there-so-many-aphids-1968631 [Accessed 13 Nov. 2020].

Hardie, J. (2020). RE: London. [Email].

Lewis, S.V. (1979). The morphology of the accessory air-breathing organs of the catfish, Clarias batrachus: A SEM Study. Journal of Fish Biology, 14(2), pp.187–191.

Mukai, Y., Tuzan, A.D., Lim, L.S., Wahid, N., Sitti Raehanah, M.S. and Senoo, S. (2008). Development of sensory organs in larvae of African catfish Clarias gariepinus. Journal of Fish Biology, 73, pp.1648–1661.

National Wildlife Federation. (2020). Red Maple. [online] Available at: http://www.nwf.org/Educational-Resources/Wildlife-Guide/Plants-and-Fungi/Red-Maple. [Accessed 13 Nov. 2020].

Ohkubo, Y., Masubuchi, M., Fujioka, K., Tomita, Y., Matsushita, T., Ohsuga, K. and Marui, T. (2005). Distribution and Morphological Features of Taste Buds in the Zebrafish, Danio rerio. Journal of Oral Biosciences, 47(1), pp.77–82.

Peters, R.C. (2009). Electroreceptor Organs. Encyclopedia of Neuroscience, pp.1078–1083.
PFAF. (2020). Celtis australis Nettle Tree, European hackberry PFAF Plant Database. [online] Available at: http://pfaf.org/user/Plant.aspx?LatinName=Celtis+australis [Accessed 13 Nov. 2020].

Woodland Trust. (2020a). Ivy (Hedera helix) - British Wildflowers. [online] Available at: http://www.woodlandtrust.org.uk/trees-woods-and-wildlife/plants/wild-flowers/ivy [Accessed 13 Nov. 2020].

Woodland Trust. (2020b). Sycamore (Acer pseudoplatanus). [online] Available at: http://www.woodlandtrust.org.uk/trees-woods-and-wildlife/british-trees/a-z-of-british-trees/sycamore/. [Accessed 11 Apr. 2021].

Wilson, J.M. and Laurent, P. (2002). Fish gill morphology: inside out. Journal of Experimental Zoology, [online] 293(3), pp.192–213. Available at: https://www.webpages.uidaho.edu/fish511/Readings/Gill%20morphology.pdf.

Zayed, A.E. and Mohamed, S.A. (2004). Morphological study on the gills of two species of fresh water fishes: Oreochromis niloticus and Clarias gariepinus. Annals of Anatomy - Anatomischer Anzeiger, 186(4), pp.295–304.

Isaac M. Wilhelm
MA Biodesign, 2022
i.wilhelm0720191@arts.ac.uk
+44 07387296711
@imwhatever_designs

ual: central saint martins