

BIODIVURBANIZATION

// FoF [FERNS of FUTURES]

by Isaac M. Wilhelm



UNIT 3: HARVEST

// FINAL PORTFOLIO

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Variated Hart's-Tongue Fern
Watercolor

"Above all, as I have implied, the man who goes alone can start today; but he who travels with another must wait till that other is ready, and it may be a long time before they get off."

- Henry David Thoreau, Walden



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Swirls // England, UK



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INTRO- DUCTION



Argyll Forest // Scotland, UK

ABSTRACT

For 360 million years ferns continue to transcend time. Vessels of evolution, how can fostering stewardship with indigenous ferns encourage healthier endemic urban biodiversity?

The first exploratory installment of biodiversity's relationship to the urbansphere, i.e. 'biodivurbanization'. Sensory experiences catalyze cognitive connections between UK urbanites and indigenous ferns on an evolutionary timescale. Ferns have survived three mass extinction. What can we learn through their persistence and resilience?

As urbanscapes expand multi-dimensionally in a speeding digitized global metropolis, urbanites not only lose sense of self, but also their endemic biomes. Before the current sixth mass extinction (Holocene) and agricultural civilization reached the British Isles 6,000 years ago, tribes of people existed as hunter-gatherers. Sourcing sustenance from nature, humans played beneficial roles to planetary biological systems. Navigating the forest requires deep sensory awareness. Conversely, in today's technological world we have evolved to primarily engage visually.

Distinct fern scents help UK urbanites build memory retention with present indigenous, past prehistoric, and future genetically modified ferns. Three scent vessels explore the biomorphologies of ferns and restoring ecological balance by sourcing materials from agricultural byproducts and remediated invasive species biomass.

Pucks Glen, Scotland, UK



3x L1 m

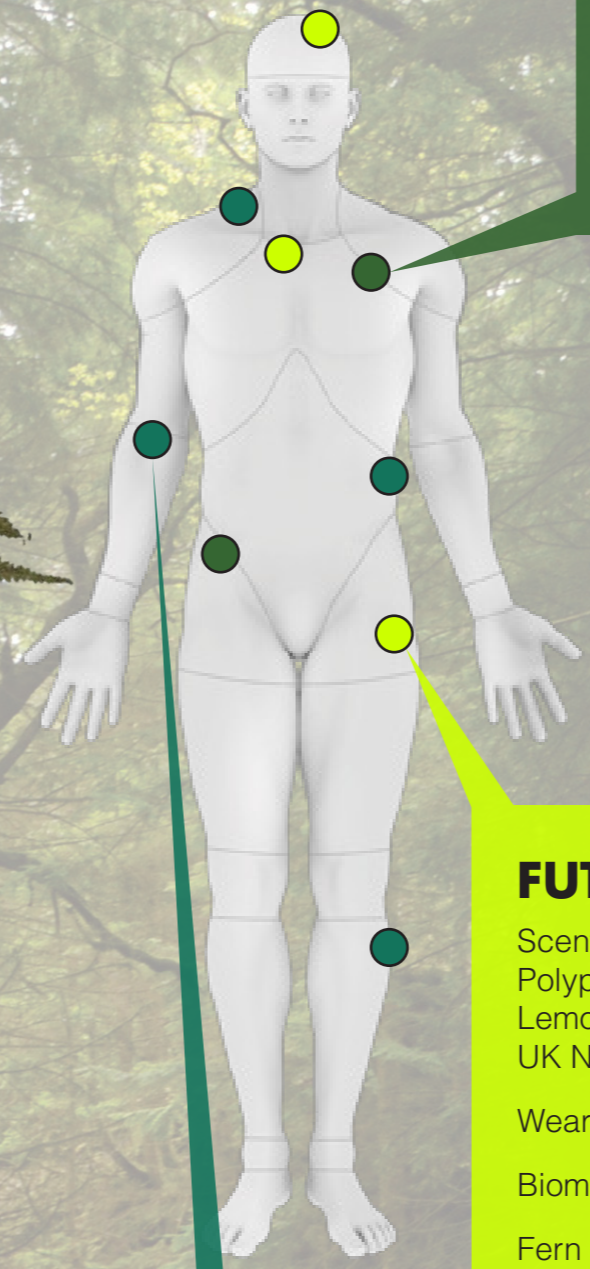
PAST: FF//FIRST FERN

Three Roll-On Liquid Scents
Royal Fern (*Osmunda regalis*), 180 Million Year Old Genus
Grey-Cushioned Grimmia Moss, Ancestor to Pteridophytes
Flat Wrack (*Fucus spiralis*), Ancestor to Bryophytes

Wearable: Arms / Upper Torso, Waist / Legs

Biomimics Frond

Fern Spore Embedded Paper from Invasive Rhododendron



PRESENT: CMF//COMMON [MALE] FERN

Scented Alginate Balls Room Fragrance
Common Male Fern (*Dryopteris filix-mas*), Present Every 10km² in UK

Wearable: Shoulder-Strap, Belt-Loop

Biomimics Sporangium

Reassembles into Miniature Fern Terrarium

ø 15 cm



FUTURE: FEE//FERN EVOLUTION EVENTUALITY

Scented Alcohol Gels for Sanitation
Polypody (*Polypodium vulgare*), Most Recent Evolved + Diverse Genus
Lemon-Scented Fern (*Oreopteris limbosperma*), Citrus Oil Glands
UK Native Floral Scents Speculate Fern Gland Mimicry Evolution

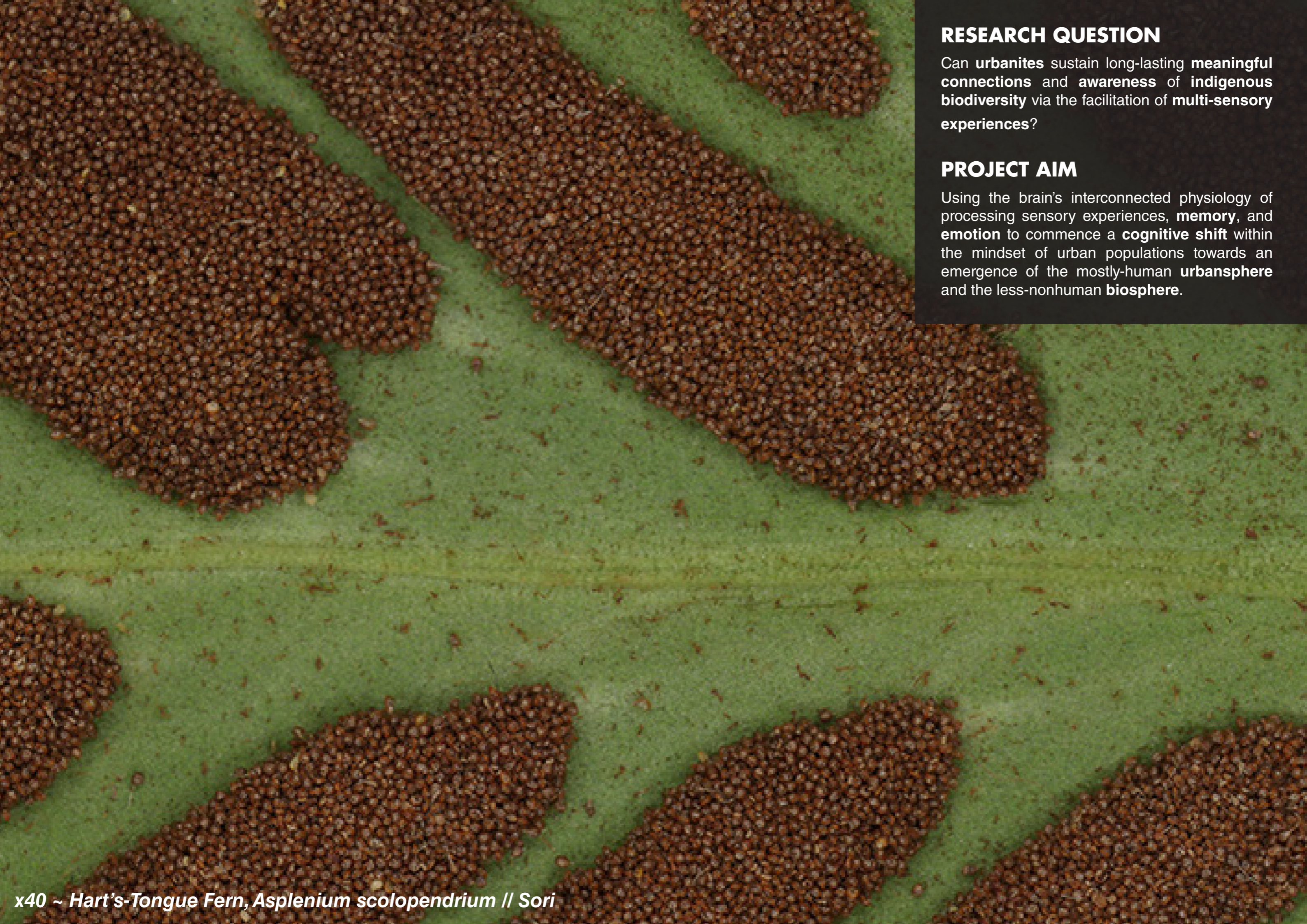
Wearable: Waist, Collar, Head

Biomimics Gametophyte

Fern Spore Propagation Media + Materials

L 32 cm x
W 30 cm





RESEARCH QUESTION

Can **urbanites** sustain long-lasting **meaningful connections** and **awareness** of **indigenous biodiversity** via the facilitation of **multi-sensory experiences**?

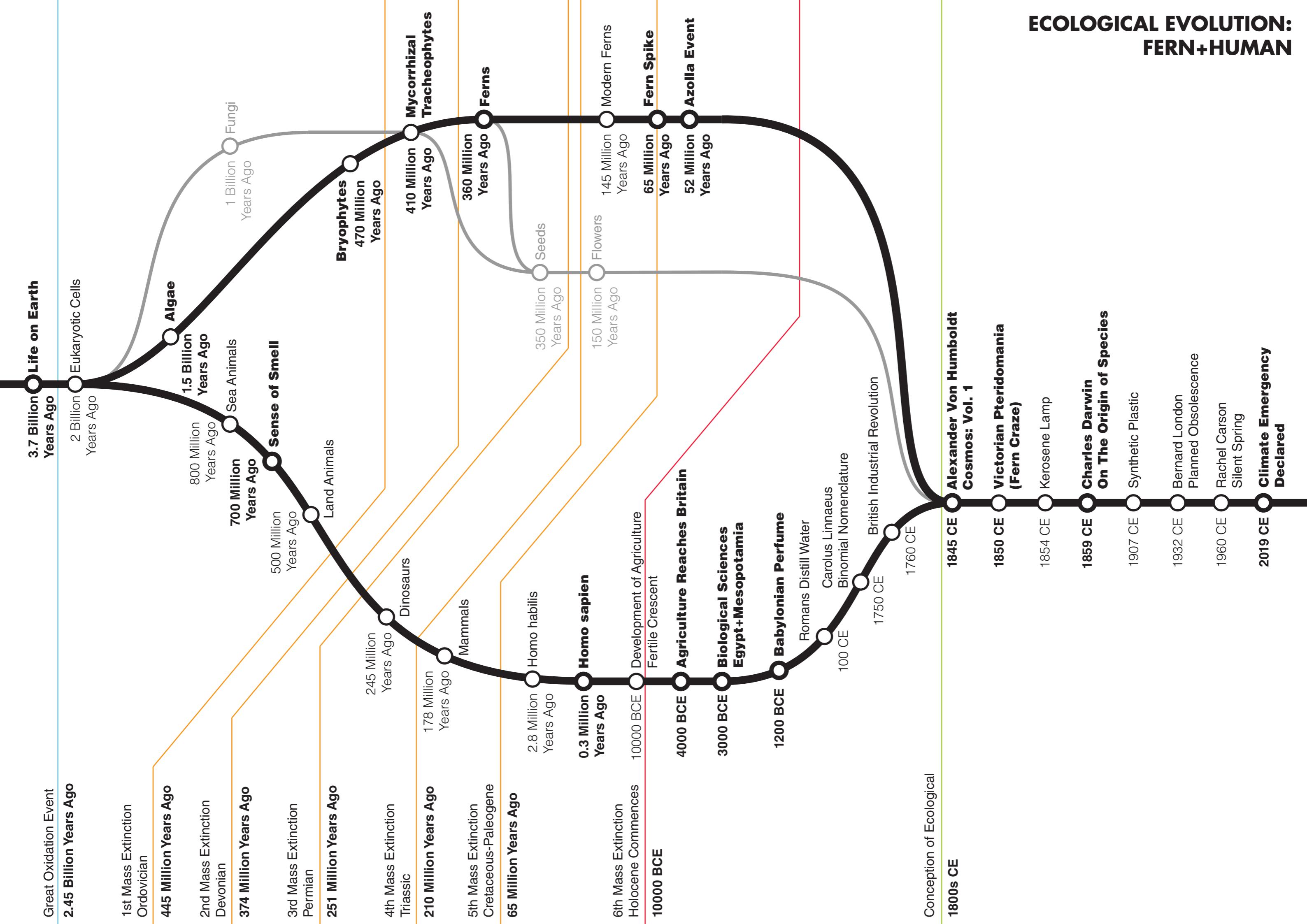
PROJECT AIM

Using the brain's interconnected physiology of processing sensory experiences, **memory**, and **emotion** to commence a **cognitive shift** within the mindset of urban populations towards an emergence of the mostly-human **urbansphere** and the less-nonhuman **biosphere**.

MANIFESTO

1. Biodivurbanization: Reintroducing indigenous biodiversity into the urbansphere.
2. Designed facilitation of experiential interactions between humans and non-humans; encouraging increased stewardship of humans for non-humans.
3. Closing waste streams, transformation towards regenerative systems with integrated bio-byproducts.
4. Assisting in the reversal of Holocene's 12,000 years of human toxicity.
5. Moving the urbansphere towards a beneficial Earth system contributing to a healthy biosphere, cryosphere, geosphere, atmosphere, hydrosphere.
6. Working towards a 100-year future of infrastructure evolving towards fully autonomous living organisms.

ECOLOGICAL EVOLUTION: FERN+HUMAN



HUMAN EXPERIENCE: SENSORY+ECOLOGICAL DEVELOPMENT

Past Man: Hunter-Gatherer

- Pre-Holocene
- Coexisted with Biodiversity
- Lived in Nature
- Ferns as Wild Resource








Present Man: Urbanite

- Holocene
- Disregards Biodiversity
- Lives on Nature
- Ferns as Domestic Decoration



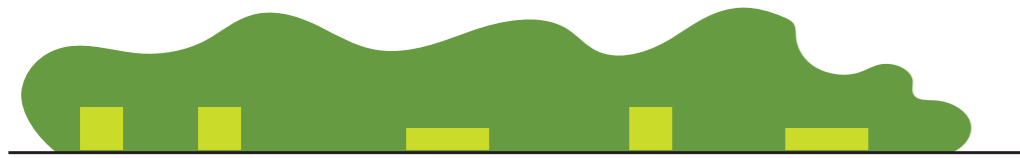
Future Man: Space Propagator

- Post-Holocene
- Encourages Biodiversity
- Lives with Nature
- Ferns as Terraforming Tools

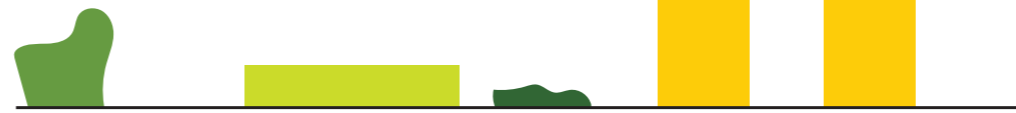
-  **Taste:** Gustatory Cortex (Parietal Lobe)
Gestation Week 9
-  **Smell:** Olfactory Cortex (Frontal Lobe)
Gestation Week 10
-  **Touch:** Parietal Lobe
Gestation Week 11
-  **Movement:** Motor Cortex (Frontal Lobe)
Gestation Week 12
-  **Sight:** Occipital Lobe
Gestation Week 27
-  **Hearing:** Auditory Cortex (Temporal Lobe)
Gestation Week 35
-  **Emotion:** Temporal Lobe / Amygdala
6-12 Months Old
-  **Memory:** Temporal Lobe / Amygdala / Hippocampus / Cerebellum
2 Years Old



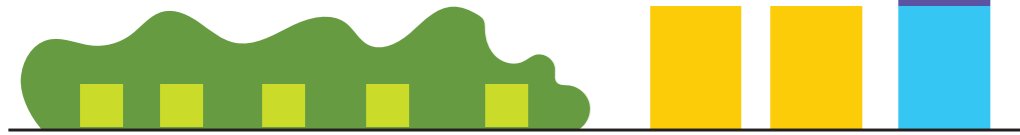
**BIODIVURBANIZATION:
BIODIVERSITY+URBANIZATION**



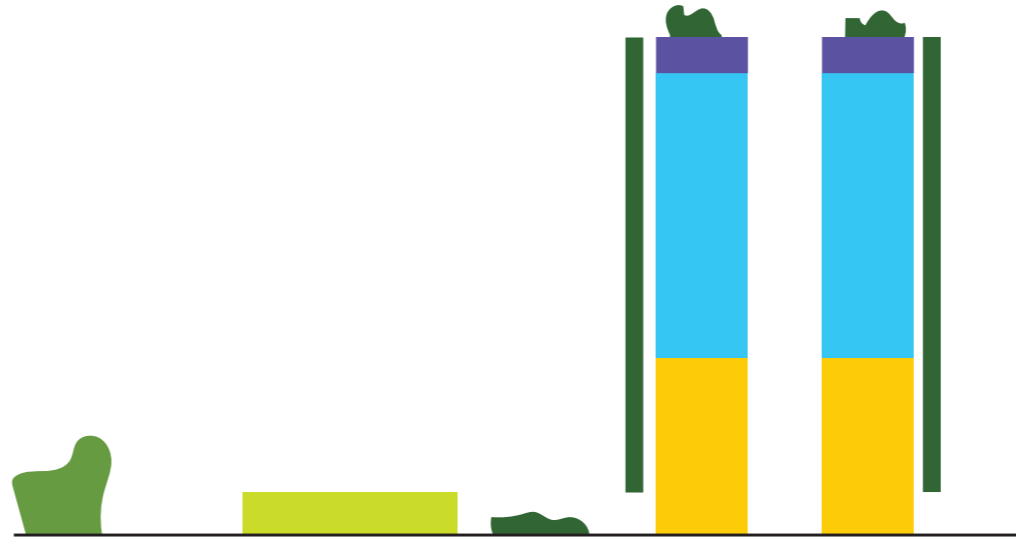
Once Upon A Time: Indigenous Planet



Yesterday: Global Urbanization



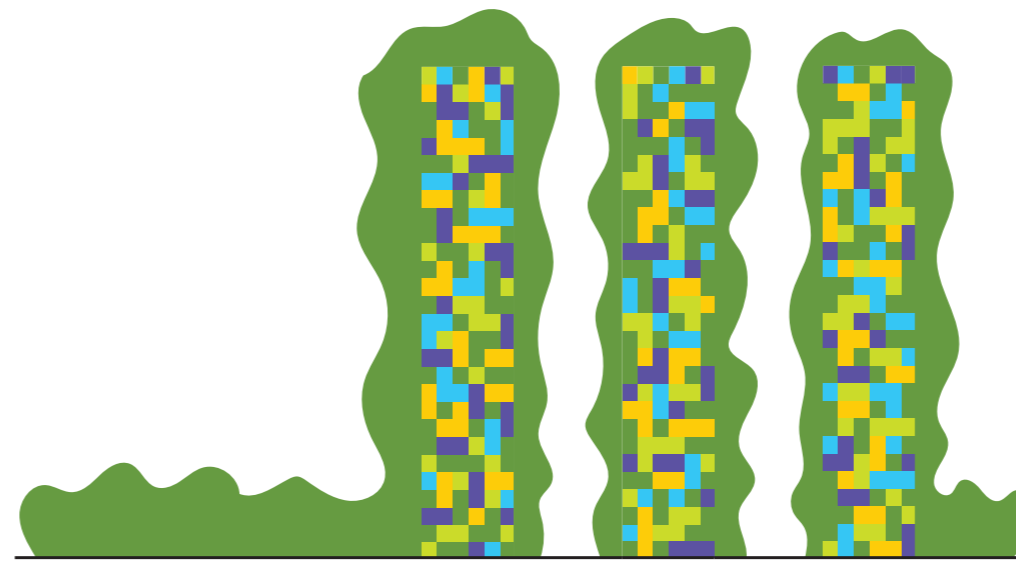
Long Ago: Birth of Agriculture



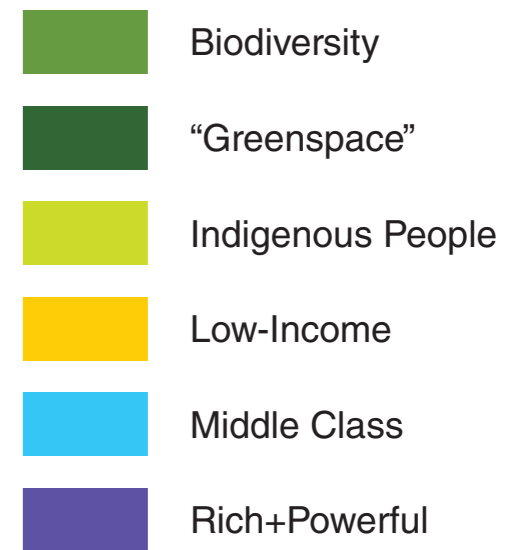
Today: Benign Urban Greenspace



Awhile Back: Commercial Industrialization



Tomorrow: Symbiotic Urbansphere/Biosphere



TEMPERATE RAINFORESTS: WHY DO THEY MATTER?

Temperate rainforests are more rare than subtropical+tropical rainforests (Woodland Trust, 2021). Many of the same reasons are responsible for the continued deforestation of temperate rainforests as tropical rainforests. Although temperate rainforests do not have as much biodiversity as tropical rainforests, they do possess a greater biomass (Freeman, 2021).

The temperate Celtic Rainforest exists in small, fragmented patches along the western coast of the UK. These small islands of rainforests were once a large, unified ecosystem. About 6,000 years ago agriculture arrived in Britain (Davis, 2019a). Since then, rainforest have been replaced by grazelands, crop fields, and timberlands.

British Celtic Rainforest

- Existing Fragments
- Climatic Zones



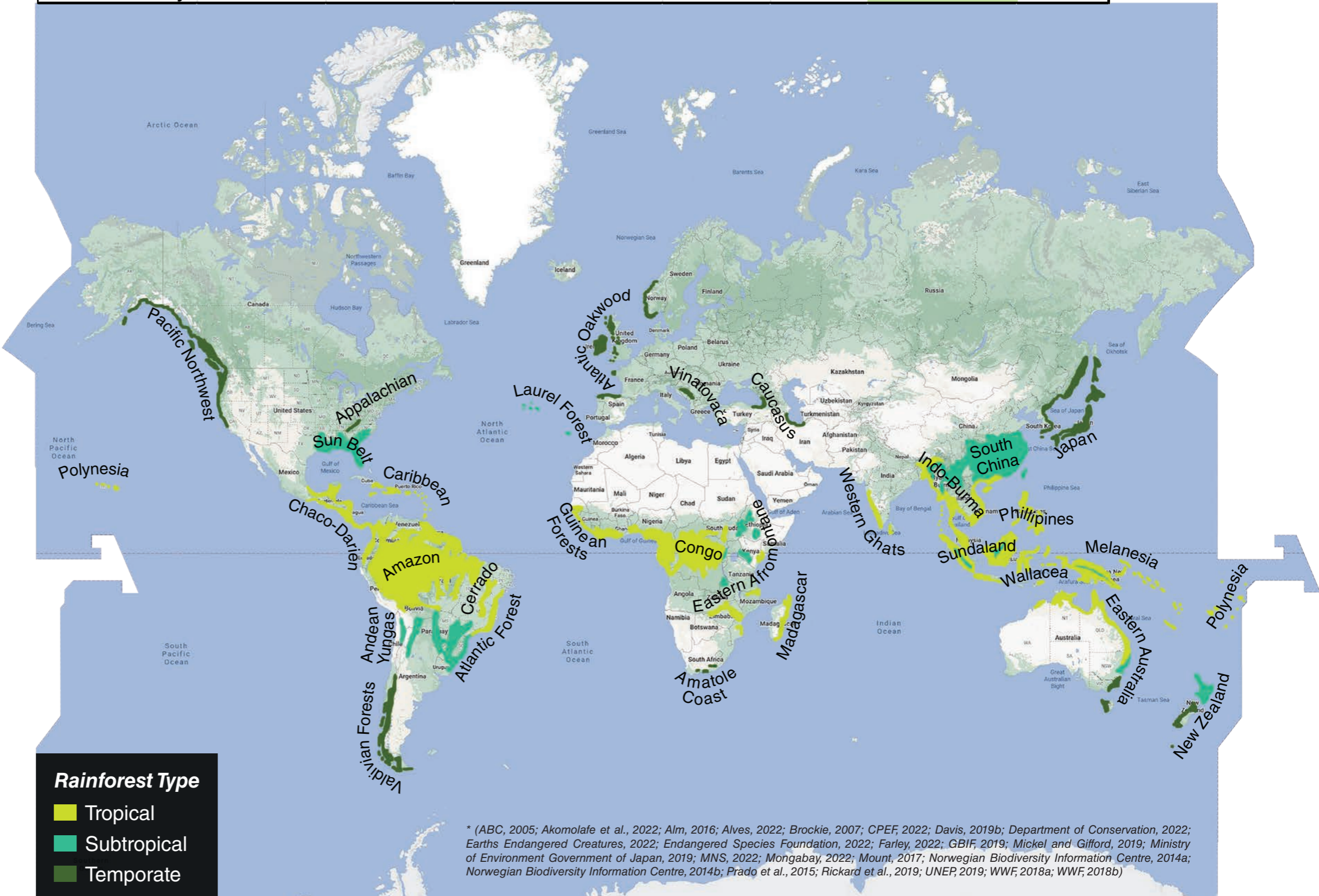
(Shrubsole, 2022)

Well-Being of Global Rainforest Countires*

	Population Growth	Urban Population	Annual Average Deforestation Rate	Native Species	Alien Species	Endangered Species	Native Ferns
UK	0.50%	83.00%	0.65%	70,000	2,566	7,000	63
Japan	-0.30%	92.00%	0.14%	94,500	2,243	2,042	600
Brazil	0.70%	88.00%	0.58%	133,000	1,080	1,172	1,111
New Zealand	0.80%	87.00%	0.57%	70,000	851	7,500	200
Costa Rica	0.90%	80.00%	0.32%	500,000	396	351	800
Malaysia	1.30%	78.00%	1.43%	200,000	317	1,476	1,165
Australia	1.20%	86.00%	1.00%	300,000	2,799	1,700	450
Norway	0.80%	83.00%	0.33%	43,705	1,096	2,752	53

Category Leaders

- Highest
- Secondary
- Tertiary



Rainforest Type

- Tropical
- Subtropical
- Temporante

* (ABC, 2005; Akomolafe et al., 2022; Alm, 2016; Alves, 2022; Brockie, 2007; CPEF, 2022; Davis, 2019b; Department of Conservation, 2022; Earths Endangered Creatures, 2022; Endangered Species Foundation, 2022; Farley, 2022; GBIF, 2019; Mickel and Gifford, 2019; Ministry of Environment Government of Japan, 2019; MNS, 2022; Mongabay, 2022; Mount, 2017; Norwegian Biodiversity Information Centre, 2014a; Norwegian Biodiversity Information Centre, 2014b; Prado et al., 2015; Rickard et al., 2019; UNEP, 2019; WWF, 2018a; WWF, 2018b)

Crinan Wood // Scotland, UK



Indigenous Species

1. Sessile Oak, *Quercus petraea*
2. +1,000 Bryophytes
3. 63 Ferns
4. 3 Quillworts
5. 8 Clubmosses
6. 9 Horsetails
7. +/- 500 Lichens
8. +15,000 Fungi

Invasive Species

9. Rhododendron
10. 3 Water Ferns

CELTIC RAINFOREST: BIODIVERSITY+ANTHROPOLOGICAL ID

Myths

Wearing Ferns Provided Invisibility; Ferns Granted Perpetual Youth
 Fairies+Trolls+Changelings Lived in Ferns; Wall Rue Kept Witches Away
 Male Fern Roots Used as Aphrodisiac + in Love Potions
 Uprooting Ferns Caused Rainstorms + Mental Insanity

Medicinal Uses

Chewing First Bracken of Year Soothed Toothaches
 Maidenhair Prevented Baldness + Made Cold & Cough Syrup
 Male Ferns Remedied Congestion+Worms; Wall Rue Remedied Rickets

Industrial Uses

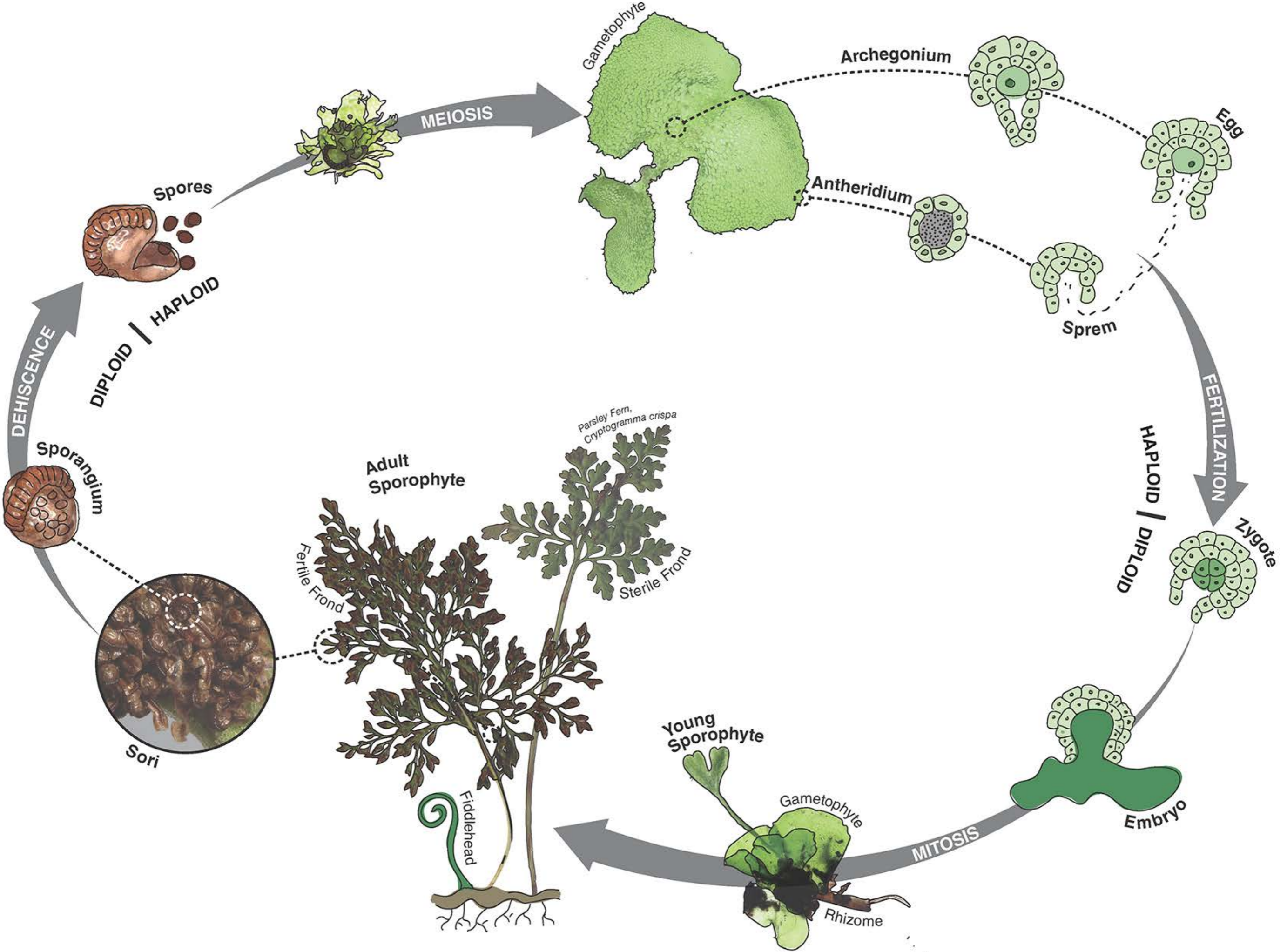
Fuel; Thatching; Bedding; Compost+Mulch; Potash Glass+Soap
 (Brown, 2020)



Pucks Glen // Scotland, UK

Coed Cwm Elan // Wales, UK

FERN REPRODUCTION CYCLE

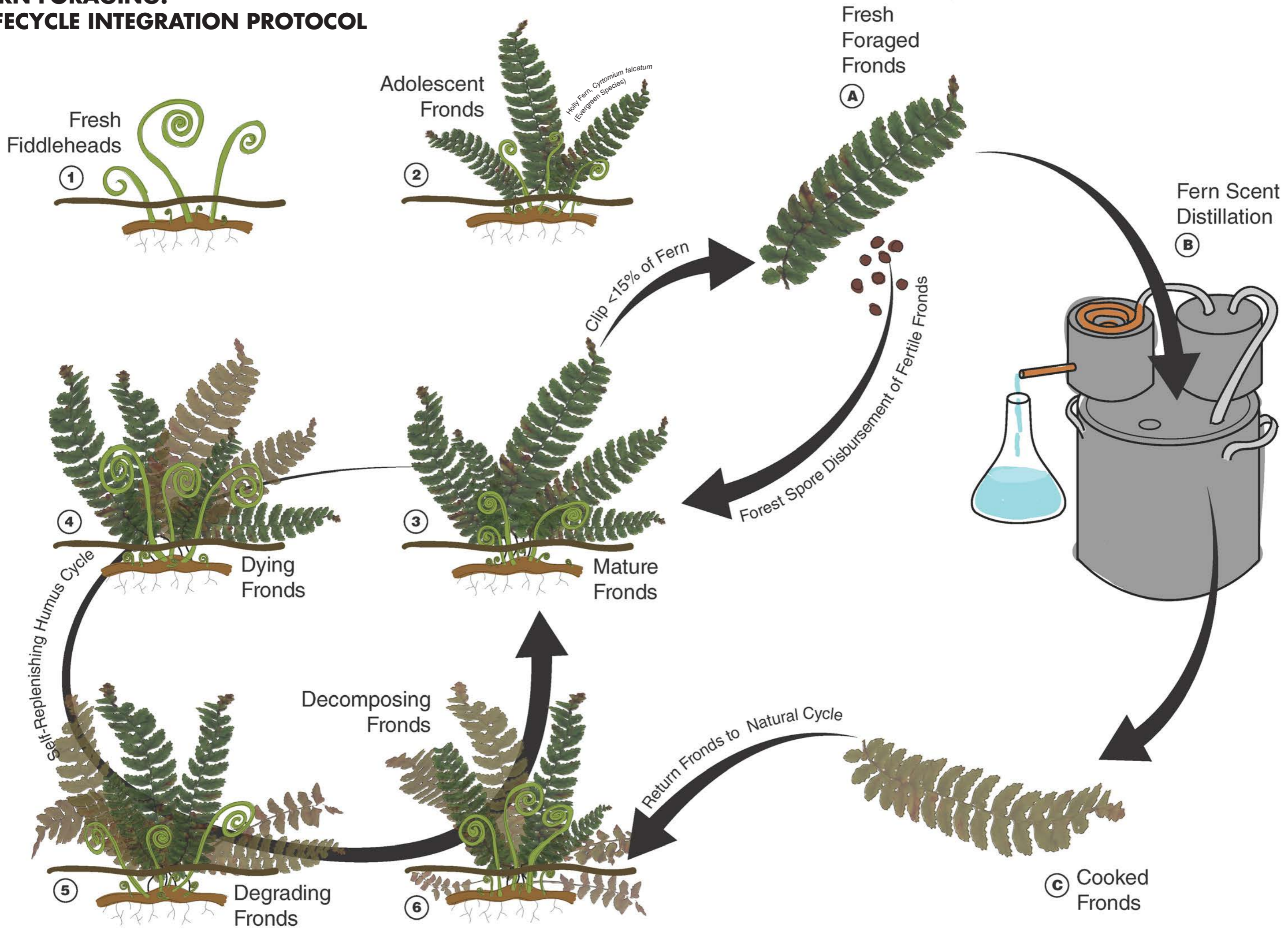


SCENT PROTOCOOLS



x40 ~ Tunbridge Filmy-Fern, *Hymenophyllum tunbrigense* // Sori

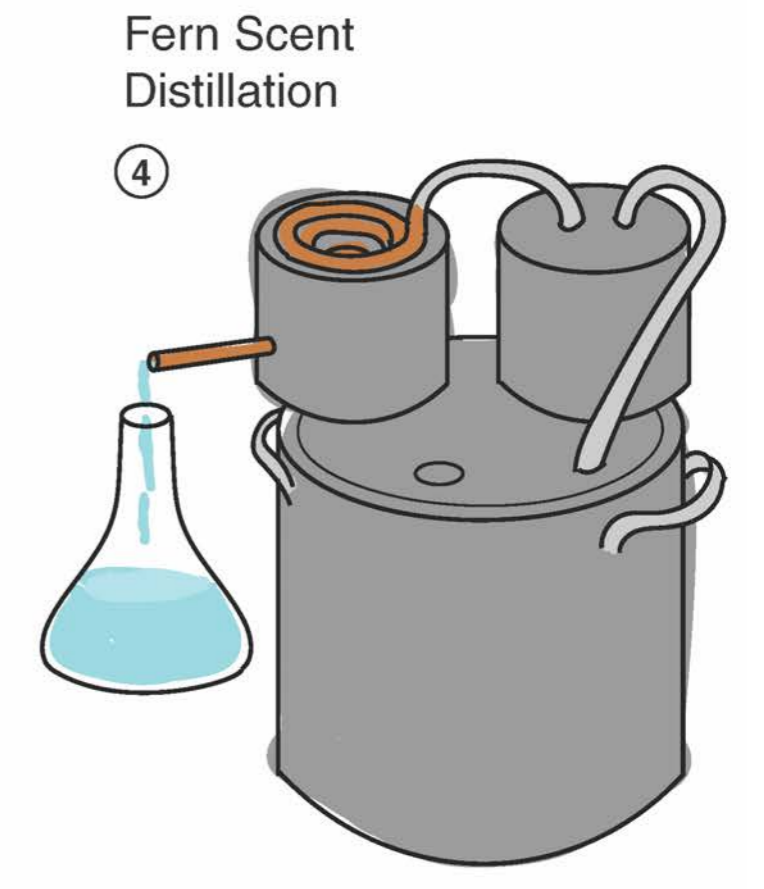
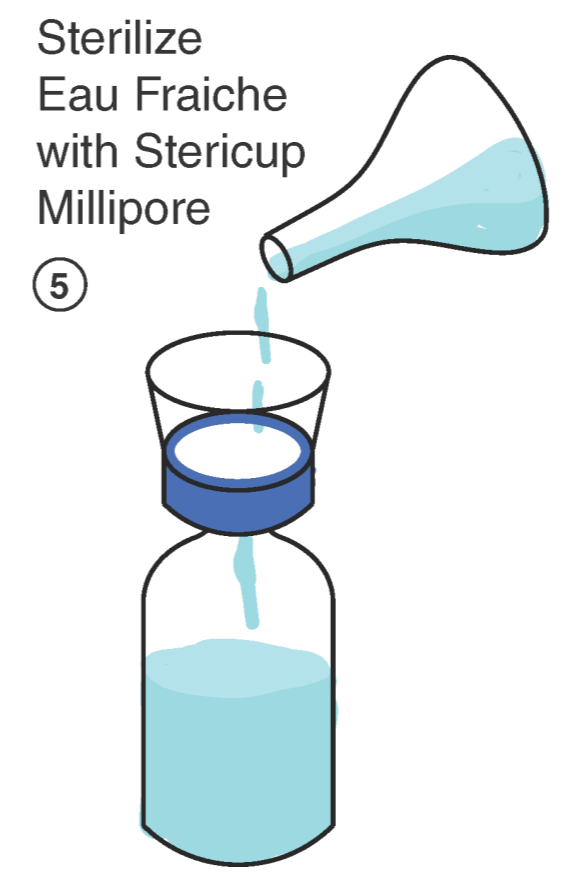
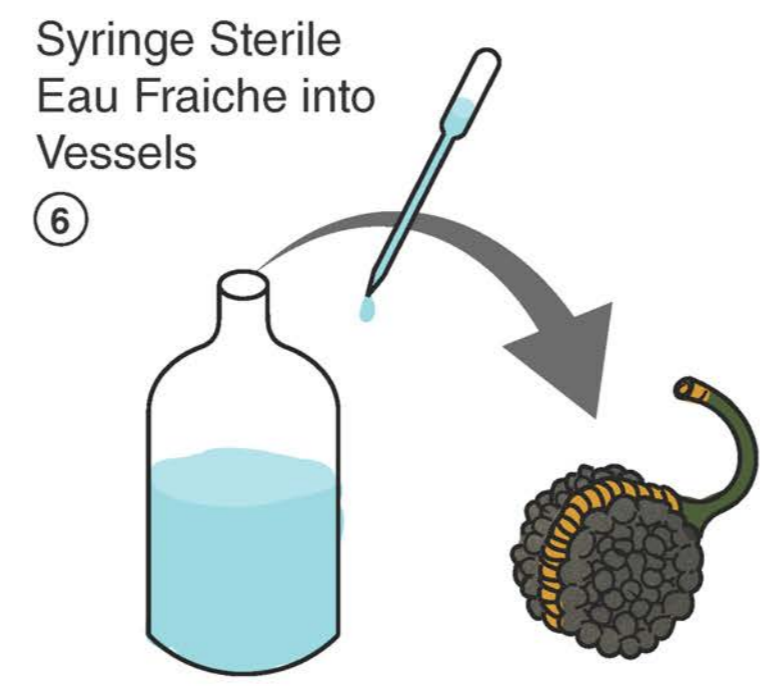
FERN FORAGING: LIFECYCLE INTEGRATION PROTOCOL



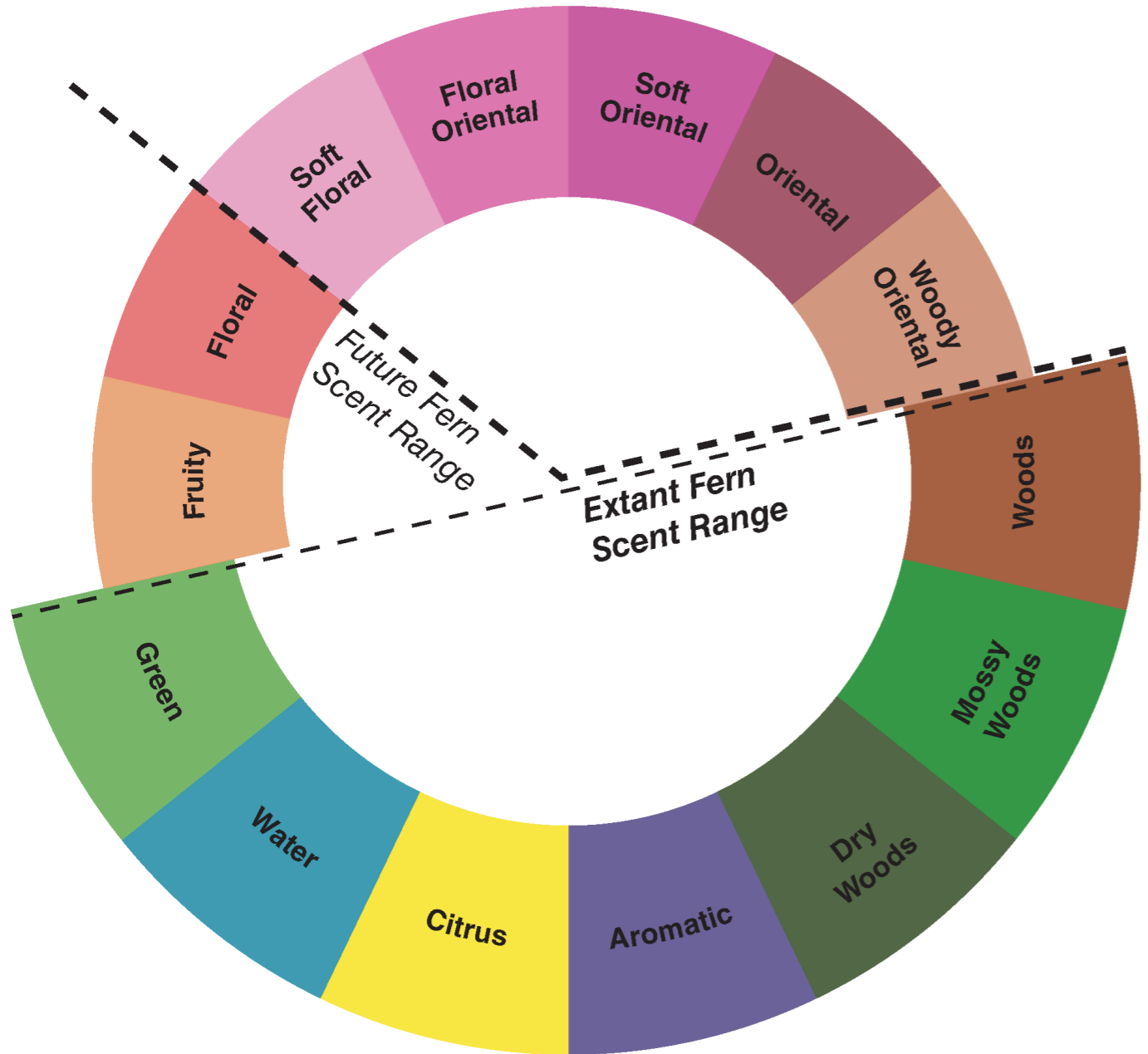
Common Male Fern // Distillation



**SCENT PRODUCTION:
DISTILLATION+STERILIZATION PROTOCOL**



SCENT WHEEL+SPECIES SCENT KEY



Hypothesis:
Each species of fern foraged will have a unique scent profile after distillation, despite most species exhibiting very low aromatic properties during their lifecycle.

Conclusion:
Each species has a unique scent profile after distillation. Although some species have similar notes, their full scent profile is unique and identifiable.

		Scent Key: FoF Scents + Other Indigenous Ferns									
		Fruity	Floral	Green	Water	Citrus	Aromatic	Dry Woods	Mossy Woods	Woods	
FF	Flat Wrack <i>Fucus spiralis</i>			●	●						
	Grey-Cushioned Grimmia Moss <i>Grimmia pulvinata</i>				●				●		
	Royal Fern <i>Osmunda regalis</i>			●					●		
CMF	Common Male Fern <i>Dryopteris filix-mas</i>						●	●			
FEE	Lemon-Scented Fern <i>Oreopteris limbosperma</i>					●				●	
	Lavender Polypody <i>x Polypolavandula (Polypodium x Lavandula)</i>		●	●	●						
	Apple Blossom Polypody <i>x Polypomalus (Polypodium x Malus)</i>	●		●	●						
OTHER INDIGENOUS FERNS	Lady Fern <i>Athyrium filix-femina</i>			●							
	Hart's-Tongue <i>Asplenium scolopendrium</i>			●	●						
	Maidenhair Spleenwort <i>Asplenium trichomanes</i>				●		●				
	Parsley Fern <i>Cryptogramma crispera</i>								●	●	
	Golden Scaly Male Fern <i>Dryopteris affinis</i>								●	●	
	Narrow Buckler-Fern <i>Dryopteris carthusiana</i>										
	Broad Buckler-Fern <i>Dryopteris dilatata</i>						●		●		
	Common Polypody <i>Polypodium vulgare</i>			●	●						
	Bracken <i>Pteridium aquilinum</i>						●				
	Hard Fern <i>Struthiopteris spicant</i>			●					●		

SCENT VESSEL TYPOLOGY

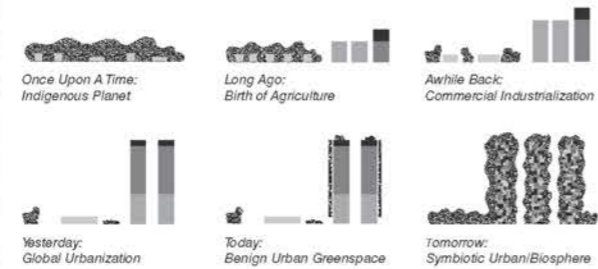
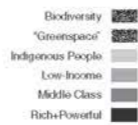


Great Woods // England, UK

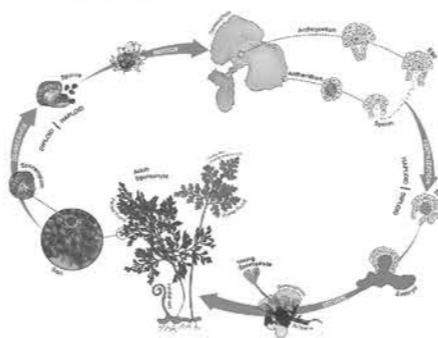
HOW TO BIODIVURBANIZE: FERNS

WHAT IS BIODIVURBANIZATION?

Biodivurbanization is defined as reintroducing indigenous biodiversity into the urbansphere. Encouraging increased stewardship of humans for non-humans, it involves designed facilitation of positive experiential interactions between the two. A major long-term goal of the movement is to assist in the reversal of Holocene's 12,000 years of human toxicity. Another desired outcome is moving the urbansphere towards a beneficial Earth system contributing to a healthy biosphere, cryosphere, geosphere, atmosphere, and hydrosphere. This is the lift-off-point of working towards a 100-year future when infrastructure evolves toward functioning as fully autonomous living organisms. Past Man coexisted with biodiversity as a hunter-gatherer and used ferns as a medicinal wild resource. Present Man disregards biodiversity and typically relates to ferns as a domestic decoration. Future Man must encourage biodiversity and can potentially utilize ferns as an intergalactic terraforming agent.

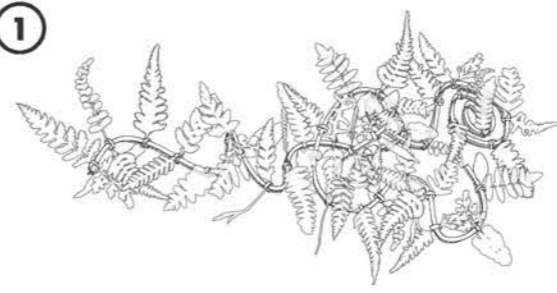


FERN LIFE CYCLE



Ferns are unique plants in that they do not have seeds, but instead propagate through spores. They are not sexually active in their easily identifiable mature state, instead they are sexually active as microscopic gametophytes. There are two separate life stages, haploid and diploid. Fertile fronds on mature sporophytes contain patches of sori. These sori consist of clusters of sporangia. Spores are released from sporangium through dehiscence. Through meiosis the spores grow into gametophytes. These gametophytes are typically unseen growing under the forest floor. The antheridium releases free swimming sperm which is dependent on wet soil conditions to reach the egg of the archegonium on the gametophyte. The sperm and chemically attracted to the egg by a hormone. After fertilization, and embryo begins to grow, eventually developing rhizomes and a young sporophyte. Soon the young sporophyte matures, and the cycle begins again. When the fronds of the fern die, they decay and contribute to the humus of the plants soil. Some species of ferns live in separate habitats as gametophytes and sporophytes.

1



PAST: FIRST FERN

The scent profile for this vessel consists of three evolutionary scents contained within pliable silicone tubing. First tube Royal Fern (*Osmunda regalis*), from an ancient 180 million old genus. Second tube containing a Gray-Cushioned Grimmiid Moss (*Grimmia pulvinata*) scent. Third tube containing an algae scent of Flat Wrack (*Fucus spiralis*). Each of the tubes is decorated with a pinnae design made of rhododendron paper embedded with spores of the fern morphology represented. Currently, non-native rhododendron is choking out the little sunlight forest floor plants like ferns need to survive in the Celtic Rainforest. The mid-height rhododendron shrubs were

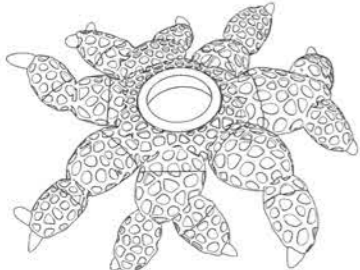
originally planted in Victorian gardens for their vibrant flowers. Every year the shrubs are mitigated from wild forest; however, the plant fiber is incinerated. As a result, the stored carbon on the shrubs is released into the atmosphere. Alternatively, the fiber can be pulped for paper, and the spores of native ferns embedded. This process offers a circular solution to restoring balance natural environments, managing both invasive and native species simultaneously. Each rachis piece of the vessel is numbered. By referring to the adjacent Spore Paper Species Legend identification of individual paper pinnae allows for the cultivation of any of the 66 indigenous species of UK ferns.

SPORE PAPER SPECIES LEGEND

- Adder's-Tongue, *O. vulgatum*
- Small Adder's-Tongue, *O. azoricum*
- Least Adder's-Tongue, *O. lusitanicum*
- Moonwort, *B. lunaria*
- Nordic Moonwort, *B. nordicum*
- Royal Fern, *O. regalis*
- Pillwort, *P. globulifera*
- Kilmasney Fern, *V. speciosa*
- Wilson's filmy-fern, *H. wilsonii*
- Tunbridge filmy-fern, *H. tunbrigense*
- Kerry Mouse-tail Fern, *S. myosuroides*
- Southern Polypody, *P. caubricum*
- Intermediate Polypody, *P. interjectum*
- Polypody, *P. vulgare*
- Manton's Polypody, *P. x mantoniae*
- Maidenhair Fern, *A. capillus-veneris*
- Jersey Fern, *A. leptophylla*
- Parsley Fern, *G. crispus*
- Bracken, *P. aquilinum*
- Pinewood Bracken, *P. pinetorum*
- Oak Fern, *G. dryopteris*
- Limestone Fern, *G. robertianus*
- Brittle Bladder-Fern, *C. fragilis*
- Diaphanous Bladder-Fern, *C. diaphana*
- Dickie's Bladder-Fern, *C. dickiana*
- Mountain Bladder-Fern, *C. montana*
- Hart's-Tongue, *A. scolopendrium*
- Maidenhair Spleenwort, *A. trichomanes*
- Green Spleenwort, *A. viride*
- Sea Spleenwort, *A. marinum*
- Rustyback, *A. ceterach*
- Forked Spleenwort, *A. septentrionale*
- Delicate Maidenhair Spleenwort, *A. trichomanes subsp. trichomanes*
- Lobed Maidenhair Spleenwort, *A. trichomanes subsp. pachyrachis*
- Wall-Rue, *A. ruta-muraria*
- Lanceolate Spleenwort, *A. obovatum*
- Black Spleenwort, *A. adiantum-nigrum*
- Irish Spleenwort, *A. onopteris*
- Alpine Woodsia, *W. alpina*
- Oblong Woodsia, *W. livens*
- Hard-Fern, *S. spicata*
- Lady-Fern, *A. filix-ferna*
- Alpine Lady-Fern, *P. distentifolium*
- Flexile Lady-Fern, *P. distentifolium var. flexile*
- Lemon-Scented Fern, *O. limbosperma*
- Beech Fern, *P. connectivis*
- Marsh Fern, *T. palustris*
- Holly Fern, *P. lonchitis*
- Soft Shield-Fern, *P. setiferum*
- Hard Shield-Fern, *P. aculeatum*
- Mountain Male-Fern, *D. oreades*
- Common Male-Fern, *D. filix-mas*
- Golden Scaly Male-Fern, *D. affinis*
- Borne's Scaly Male-Fern, *D. bornei*
- Narrow Scaly Male-Fern, *D. cambrensis*
- Elegant Male-Fern, *D. pseudodisjuncta*
- Alpine Male-Fern, *D. lacunosa*
- Robust Male-Fern, *D. x complexa*
- Braun's Wood Fern, *D. x uliginosa*
- Crested Buckler-Fern, *D. cristata*
- Rigid Buckler-Fern, *D. submontana*
- Scaly Buckler-Fern, *D. remota*
- Broad Buckler-Fern, *D. dilatata*
- Northern Buckler-Fern, *D. expansa*
- Narrow Buckler-Fern, *D. carthusiana*
- Hay-Scented Buckler-Fern, *D. aemula*

FoF

2



GAMETOPHYTE CULTURE PLATES

- Ingredients:**
- 0.2g Murashige + Skoog Medium (Provided)
 - 0.4g Agar (Provided)
 - 50 mL Water
 - FF Rhododendron Fern Spore Paper (Provided)
- Equipment + Materials:**
- Digital Scale
 - Pressure Cooker
 - Stovetop
 - Glass Jar with Metal Lid
 - 45 mm Glass Petri Dish (Provided)
 - Parafilm (Provided)
 - Hand Sanitizer (Provided)
 - 70% Isopropyl Alcohol
 - Sterile Latex Gloves
 - Two Large Candles
 - Lighter/Matches
- Directions:**
- Unscrew from FEE large bulb (labelled 1 and 2) to pour scented hand sanitizer on hands.
 - Unscrew from FEE small bulb tip of agar powder (labelled A) and Murashige + Skoog (labelled B). Measure appropriate amounts of each using digital scale.
 - Pour both powders in clean glass jar and add 50 mL of water. Stir contents until homogenous. Screw jar lid on approximately half.
 - Place jar and glass petri dish in pressure cooker and set to medium heat on stovetop. Once cooker is steaming set timer for 20 minutes. Turn off stovetop, and then wait another 20-30 minutes to open pressure cooker.
 - Spray work area with alcohol. Set two candles about 20 cm apart on work surface and light them. The area between two candles will be your sterile work area.
 - Remove jar and petri dish from pressure cooker and set in sterile work area.
 - Open jar and pour thin layer of liquid medium into petri dish. Wear glove as the jar may be too hot to handle. Allow medium to cool until it has become consistency of jelly.
 - Ripe desired piece of Rhododendron Fern Spore Paper from FF and place on top of cooled medium in petri dish. Place lid on petri dish and wrap side with parafilm.
 - Label with date and species name before finally placing into centre of FEE.
 - Over next 2-5 weeks watch as paper begins to grow fern gametophytes. Once gametophytes have grown, transfer into CMF terrarium for sporophyte growth.

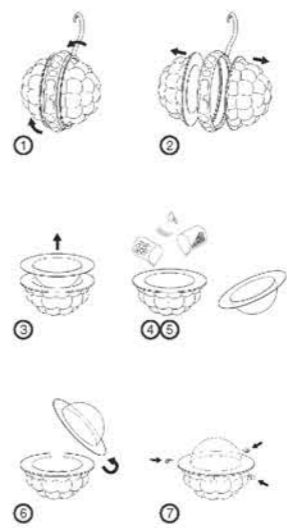
PRESENT: COMMON [MALE] FERN

The form of this vessel biomimics the morphology of sporangium. The vessel stores a room scent derived from Common Male-Fern (*Dryopteris filix-mas*), a fern that is present approximately every 10 km² in the UK. The room fragrance is locked into sustainable alginate ball beads, which are refillable and biodegradable. These sodium alginate-based beads replace non-recyclable polypropylene (PP) and polyethylene (PE) plastic aroma beads. Like FEE vessel, the concentric domes are casted in bioresin using pigment from non-native invasive water ferns. Able to double biomass in several days, water ferns have amazing propagation qualities; however, this can be problematic regarding native aquatic biodiversity. Furthermore, at one point in Earth's past, water ferns were responsible for reoxidizing the atmosphere. After use is complete the vessel can be reassembled into two fern terrariums. The sides of the centre ring unscrew, releasing the translucent green bioresin concentric dome forms. Once removed, recycled transparent plastic domes are revealed inside the bioresin forms. By flipping the plastic domes and utilizing the metal clips provided in packaging, sealed terrariums can be built for low-maintenance optimal fern cultivation.

3

SPOROPHYTE TERRARIUM

- Materials:**
- Gravel
 - Dirt
 - FF Rhododendron Fern Spore Paper
 - Or FEE Gametophytes
 - Bryophytes (Optional)
 - 50 mL Water
 - 3x Metal Clips (Provided)
 - Grow Lamp (Optional)
- Directions:**
- Unscrew sides of centre ring.
 - Remove outer green concentric dome bulbous forms.
 - Once removed notice a transparent plastic dome contained inside green bulbous forms. Remove transparent plastic domes from green bulbous forms.
 - Add small amount of gravel to bottom of green bulbous forms and fill with dirt.
 - Make small hole in dirt with fingers and place either gametophyte from FEE or piece of Rhododendron Fern Spore Paper from FF. Cover gametophytes/paper with dirt. Add 50 ml of cold water. (Feel free to add bryophyte species for decoration as desired)
 - Flip transparent plastic domes and place on top of disc shaped end of green bulbous forms.
 - Add 3 metal clips provided in original packaging to secure transparent plastic dome to disc end of green bulbous form.
 - Place in a window with partial sunlight or under a grow lamp.



DISCLAIMER

FoF is specifically designed to the ecology of the geographic region it is retailed in (British Isles). It is strongly advised that the products do not be taken to location outside the British Isles during distant house moves or vacation. Furthermore, please do not gift to friends and family who do not intend on observing our unique global biomes. If you do move to a new global location, FoF is expanding its wearable fragrance line to include the petrological biodiversity of other various global ecological regions. With diligence and perseverance, we can eradicate non-native and/or invasive species, restoring the balance in both urban and natural environments.



FUTURE: FERN EVOLVED EVENTUALITY

Propagating ferns and building a connection between the human and the unseen gametophyte, this vessel explores two genus of ferns that evolved more recently, *Polypodium* and *Oreopteris*. The vessel design is informed by the biomorphology of fern gametophytes from the haploid life cycle. The outer arms of the wearable represent the developing angiotherium (sperm); whereas the center circular structure symbolizes the archegonium (egg). The material of the vessel is constructed from 3D printed bioplastic, using non-native invasive water fern filament for pigmentation. Larger bulbs of the wearable house scented hand sanitizer for experiment sterility and personal sanitation, while the smaller bulbs store media for spore cultures. The scented hand sanitizer is derived from the species Lemon-Scented Fern (*Oreopteris limbosperma*) and Polypody (*Polypodium vulgare*). The supplied media includes agar powder and Murashige + Skoog basal medium. The center circular structure houses a culture plate where rhododendron pinnae papers can be placed to propagate ferns. Users engage with gametophytes, observing growth as worn on the body via a magnetic clip. Lemon-Scented Fern has active essential oil glands, which can be experienced without distillation. It is not common for ferns to exhibit such qualities in the wild. How will ferns evolve in the future, could oil glands become a beneficial trait developed in more species?



E. J. Lowe 1859
Hart's Tongue, *Asplenium scolopendrium*



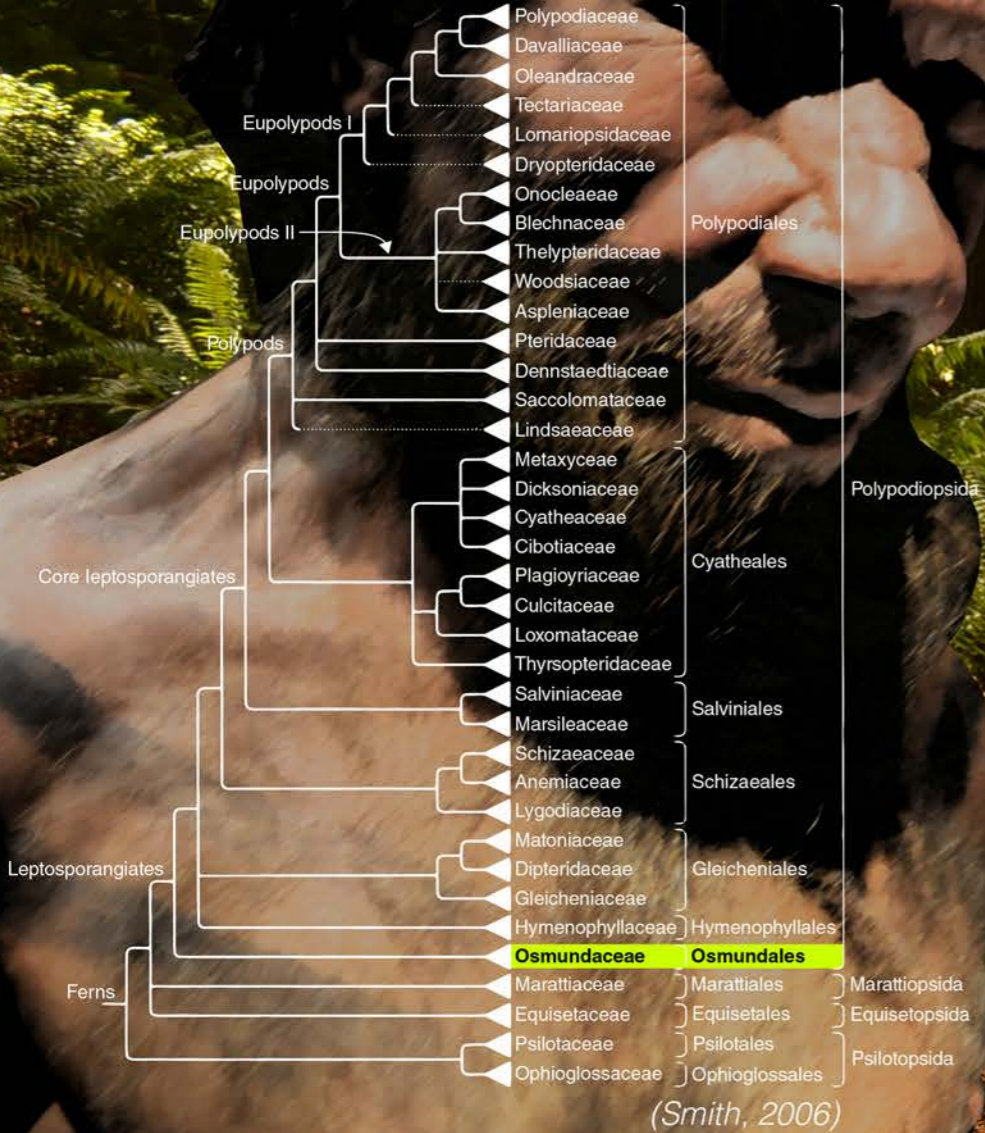
Flat Wrack, *Fucus spiralis*



Royal Fern, *Osmunda regalis*

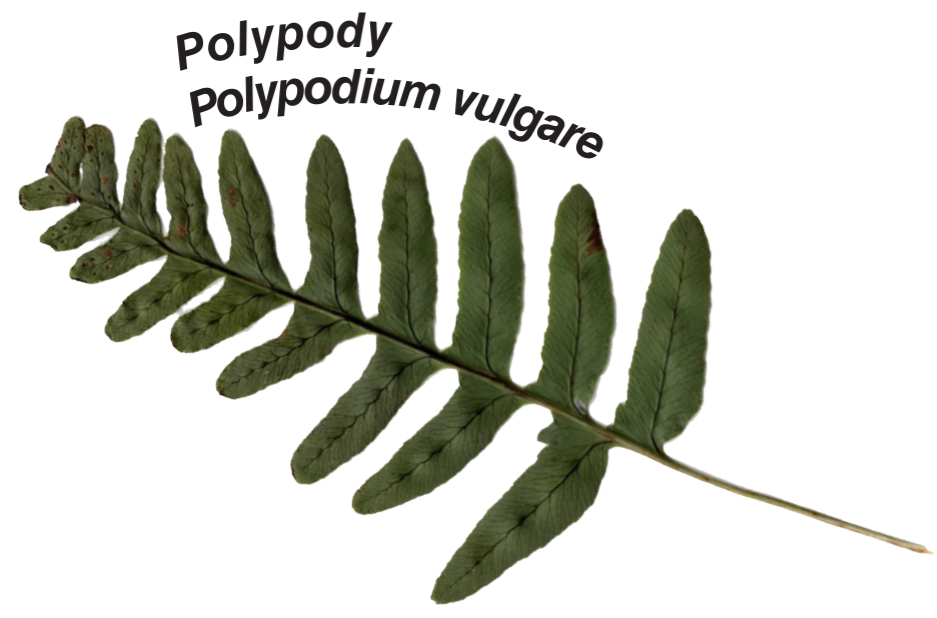


Grey-Cushioned Grimma Moss, *Grimma pulvinata*
x200



PAST: FF // FIRST FERN

**BIOMORPHOLOGICAL OBSERVATIONS:
FROND**



Polypody
Polypodium vulgare



Broad Buckler Fern
Dryopteris dilatata



Parsley Fern
Cryptogramma crispera



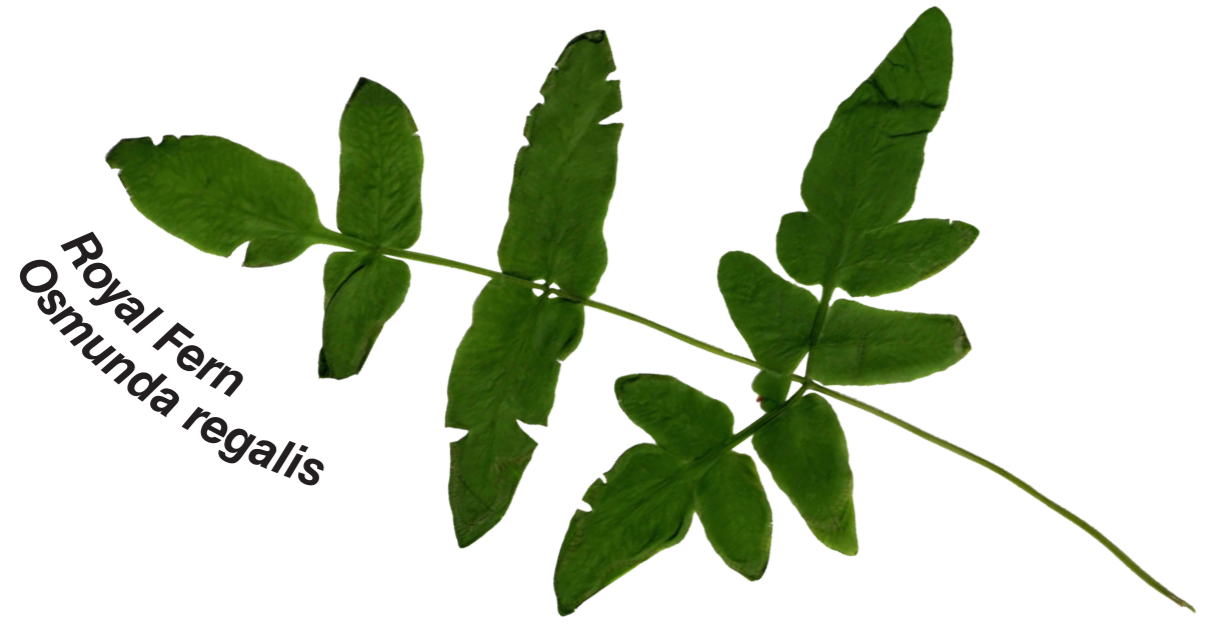
Maidenhair Spleenwort
Asplenium trichomanes



Tunbridge Filmy-Fern
Hymenophyllum tunbrigense



Golden Scaly Male Fern
Dryopteris affinis



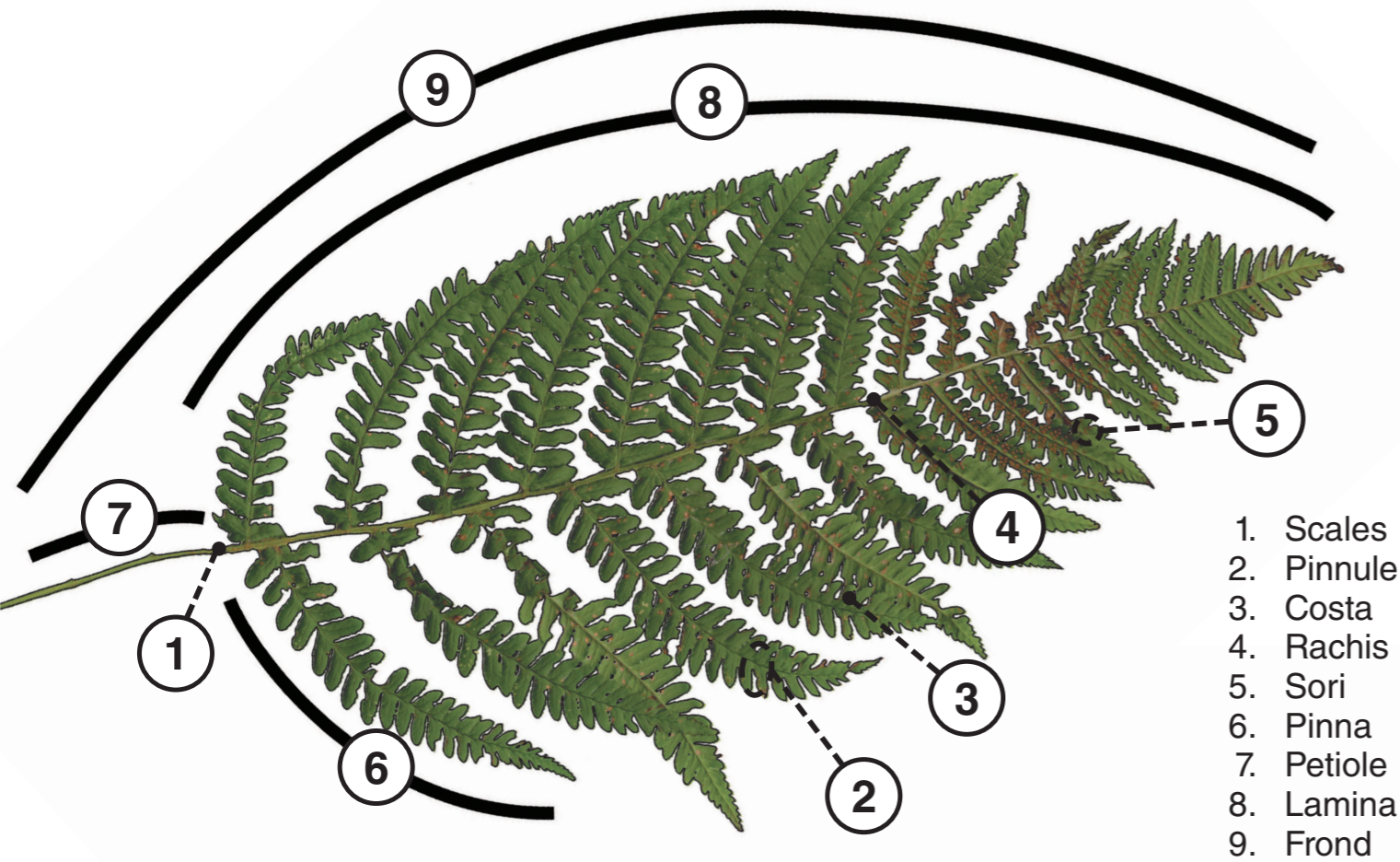
Royal Fern
Osmunda regalis



Hart's-Tongue Fern
Asplenium scolopendrium

FronD Biomorphology

BIO/DESIGN MORPHOLOGY: FROND



1. Scales
2. Pinnule
3. Costa
4. Rachis
5. Sori
6. Pinna
7. Petiole
8. Lamina
9. Frond

● ● **Flat Wrack // *Fucus spiralis***
 -Ancest Bryophytes

● ● **Grey-Cushioned Grimmia Moss // *Grimmia pulvinata***
 -Ancest Pteridophytes

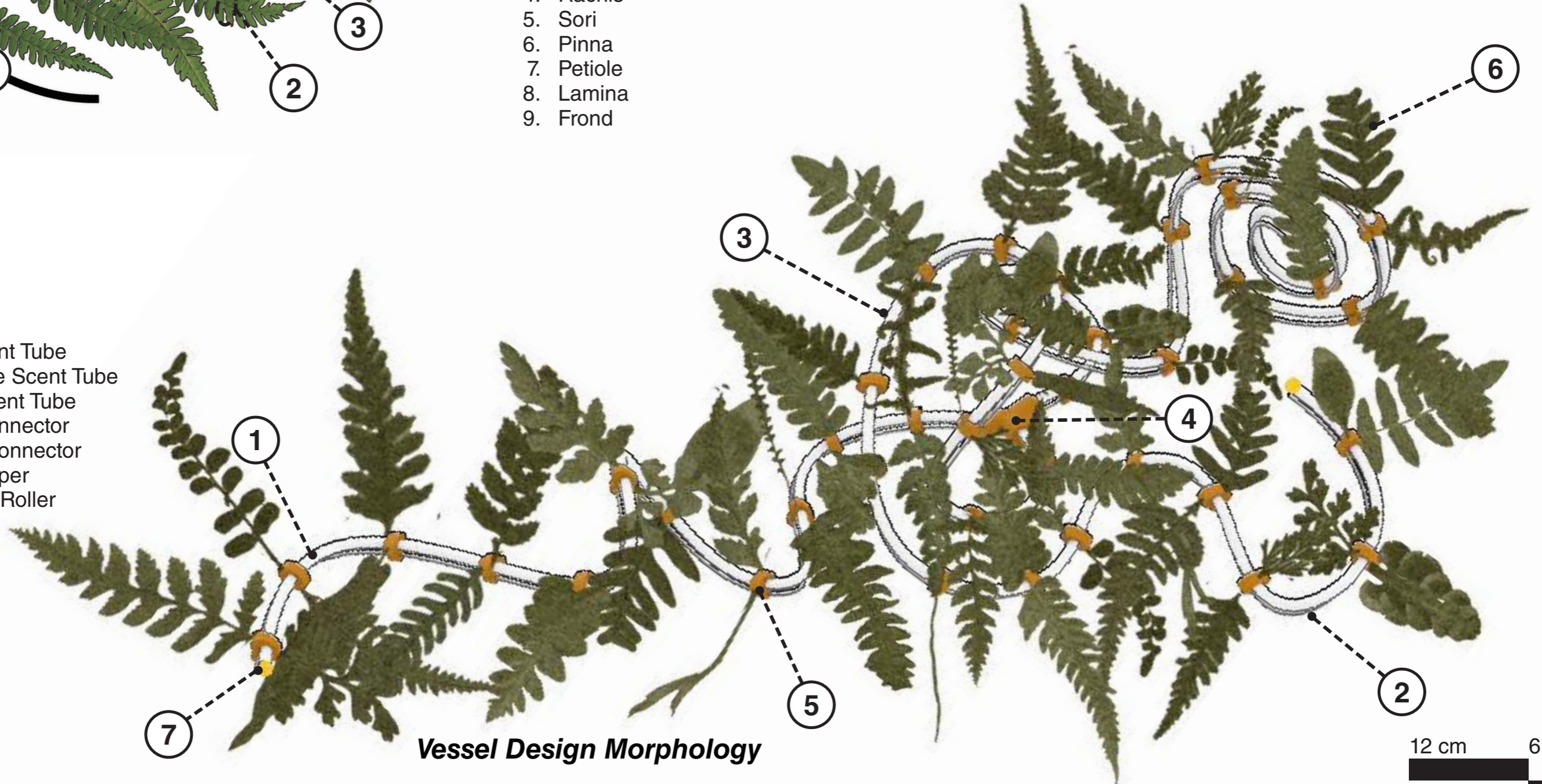
● ● **Royal Fern // *Osmunda regalis***
 -Genus *Osmunda* Evolved 180 Million Years Ago (*Quantrell, 2021*)
 -Specimens Recorded Age Over Century (*Merryweather, 2020*)

Vessel Identity

- Scents Representative of Fern Evolution Narrative
- Personal Usage on Bodily Pressure Points
- Material: Milk Casein+Ochre, Rhododendron Paper, Silicon
- Wearable Around Arms/Upper Torso + Waist/Legs
- Secondary Use: Spore Propagation of 66 Indigenous Fern Species



1. Costa // Fern Scent Tube
2. Costa // Byrophyte Scent Tube
3. Costa // Algae Scent Tube
4. Petiole // Tube Connector
5. Rachis // Paper Connector
6. Pinna // Spore Paper
7. Stomium // Scent Roller

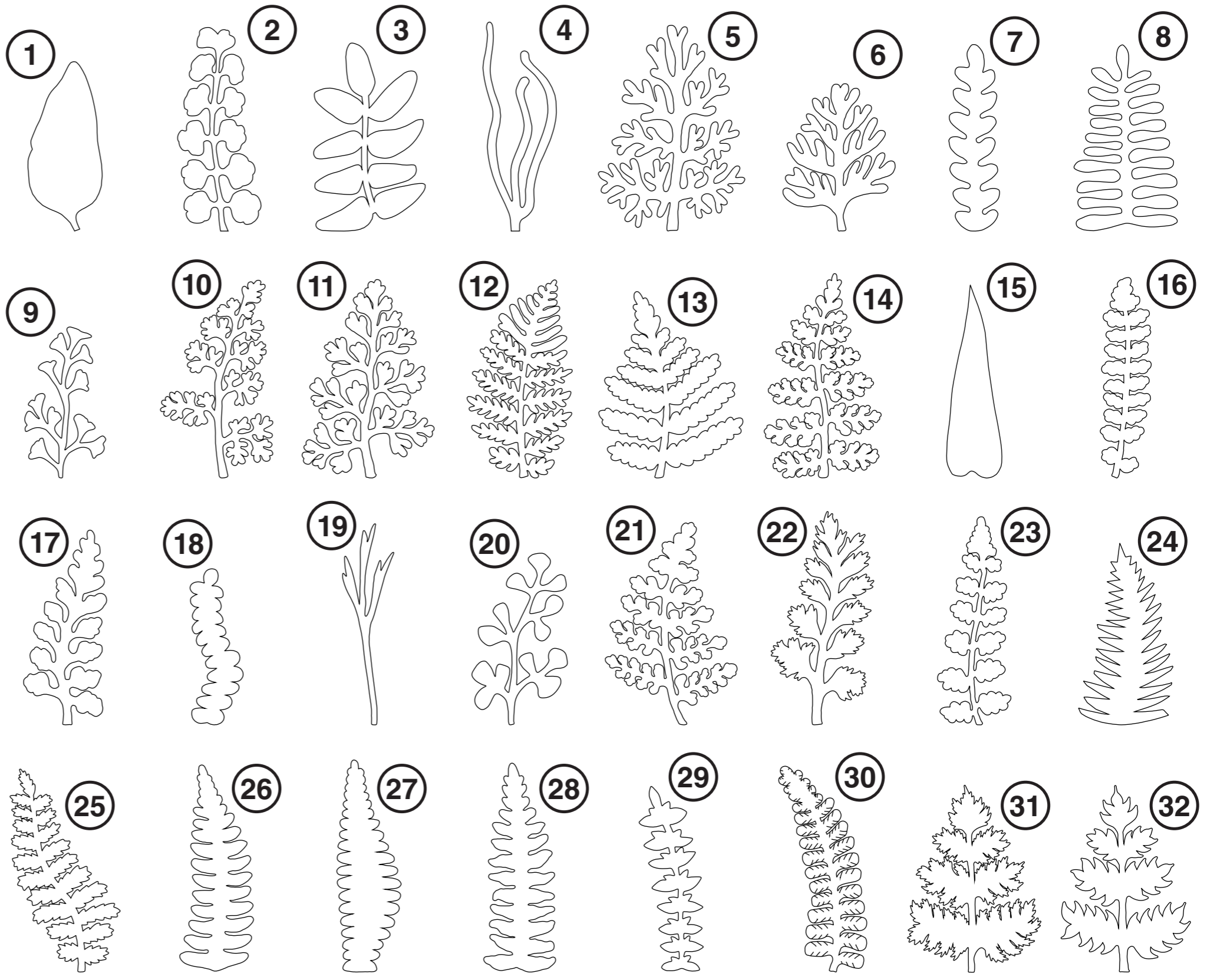
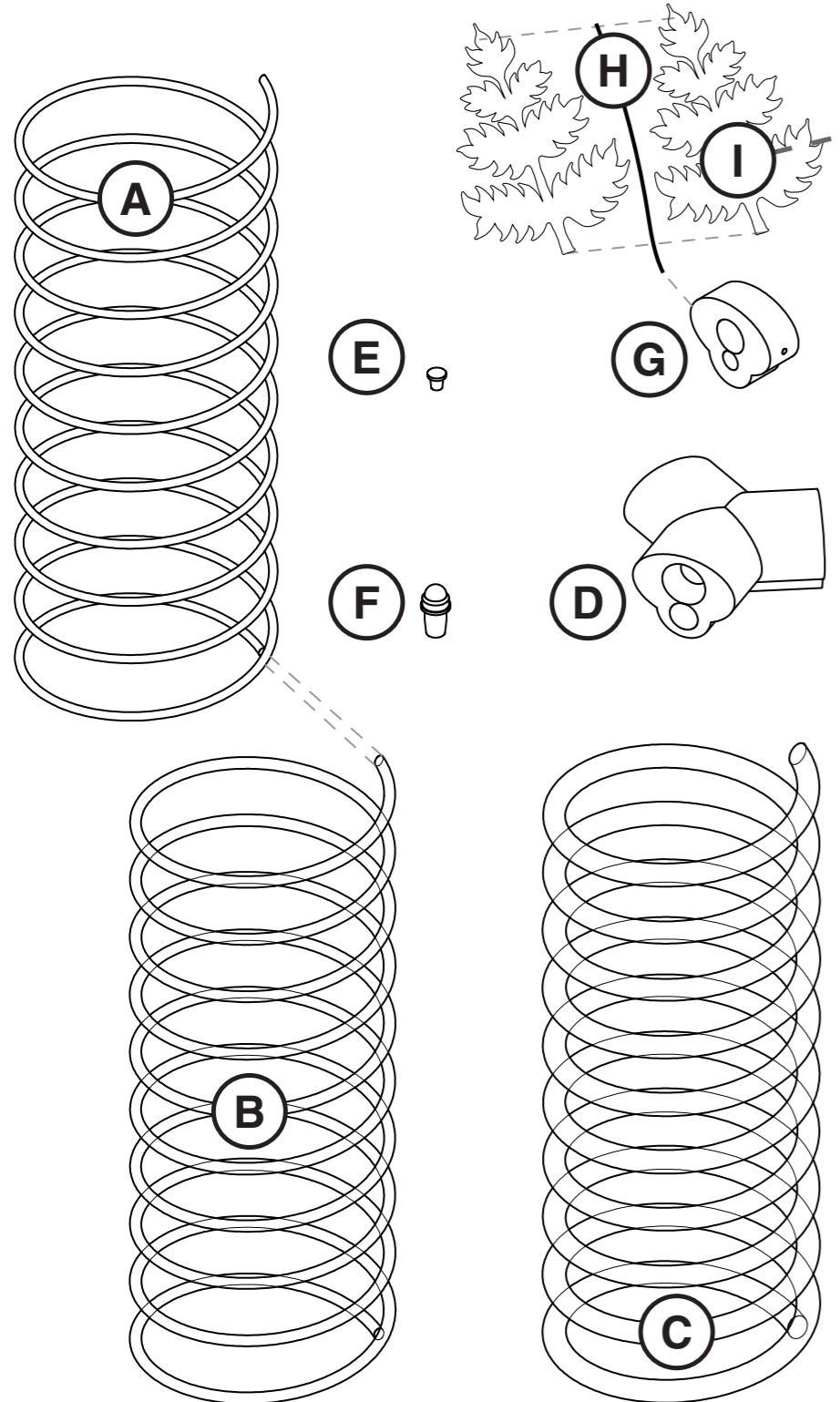


Vessel Design Morphology

12 cm 6 cm

EXPLODED AXONOMETRIC

- A. 3x Embedded Wire, Brass Coated Aluminum
- B. 3x Wrap Attachment, Silicone Tubing
- C. 3x Scent Tube, Silicone Tubing
- D. Tube Connector, Ochre Milk Casein
- E. 3x Tube Cap, Ochre Milk Casein
- F. 3x Scent Roller, Polished Brass Ball
- G. 66x Paper Connector, Ochre Milk Casein
- H. 66x Spore Paper Wire, Brass
- I. 132x Spore Paper, Rhododendron



- | | | | |
|----------------------|----------------------|-------------------------------|-------------------------|
| 1. 6x Adder's Tongue | 9. 2x Maidenhair | 17. 2x Sea Spleenwort | 25. 6x Lady** |
| 2. 4x Moonwort | 10. 2x Jersey | 18. 2x Rustyback | 26. 2x Lemon-Scented |
| 3. 2x Royal | 11. 2x Parsley | 19. 2x Forked Spleenwort | 27. 2x Beech |
| 4. 2x Pillwort | 12. 4x Bracken | 20. 2x Wall-Rue | 28. 2x Marsh |
| 5. 2x Killarney | 13. 4x Oak/Limestone | 21. 2x Lanceolate Spleenwort | 29. 6x Shield |
| 6. 4x Filmy | 14. 8x Bladder* | 22. 4x Black/Irish Spleenwort | 30. 18x Male |
| 7. 2x Mousetail | 15. 2x Hart's Tongue | 23. 4x Woodsia* | 31. 2x Crested Buckler* |
| 8. 8x Polypody | 16. 8x Spleenwort | 24. 2x Hard | 32. 12x Buckler |

4 cm 2 cm

* Contains Vulnerable/Endangered Species
 ** Contains Endemic Species







FUTURE: FEE // FERN EVOLVED EVENTUALITY

Polypody, *Polypodium vulgare*



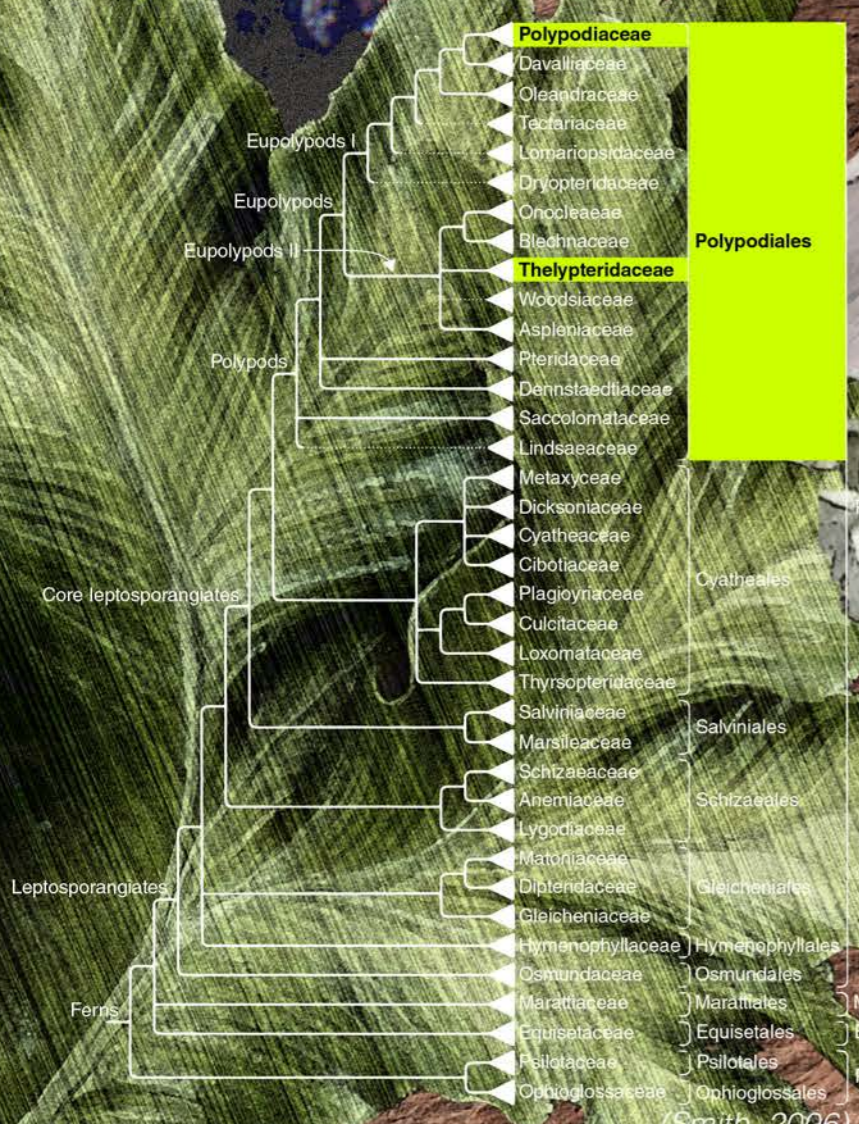
English Lavender, *Lavandula angustifolia*



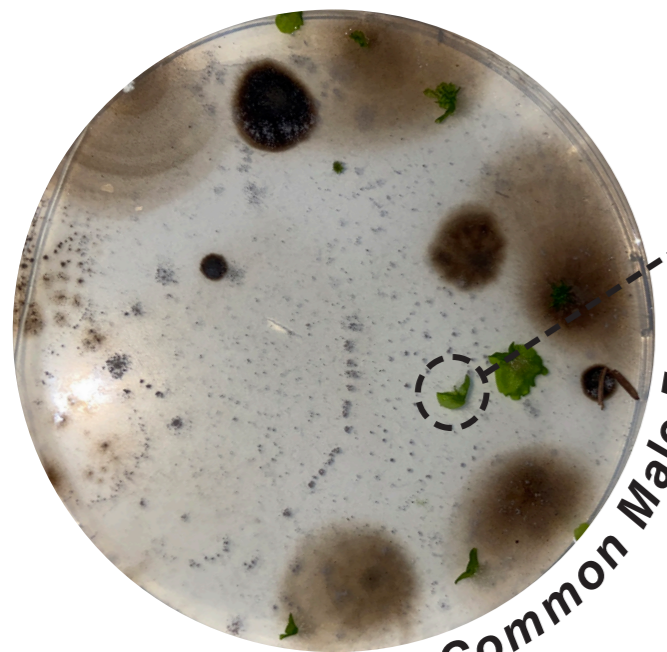
Lemon-scented Fern, *Oreopteris limbosperma*



Apple Blossom, *Malus sylvestris*

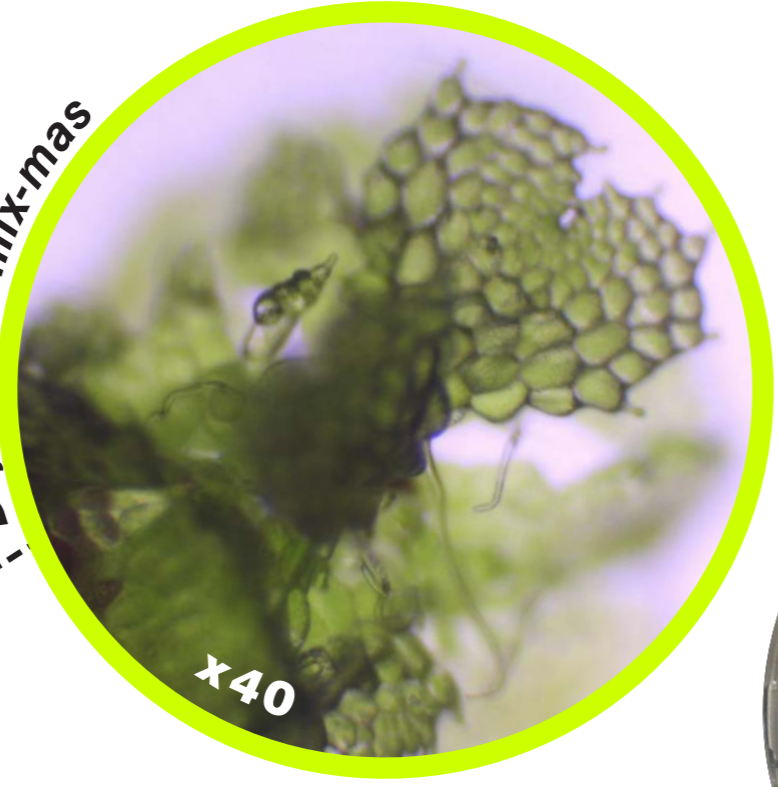


**BIOMORPHOLOGICAL OBSERVATIONS:
GAMETOPHYTE**

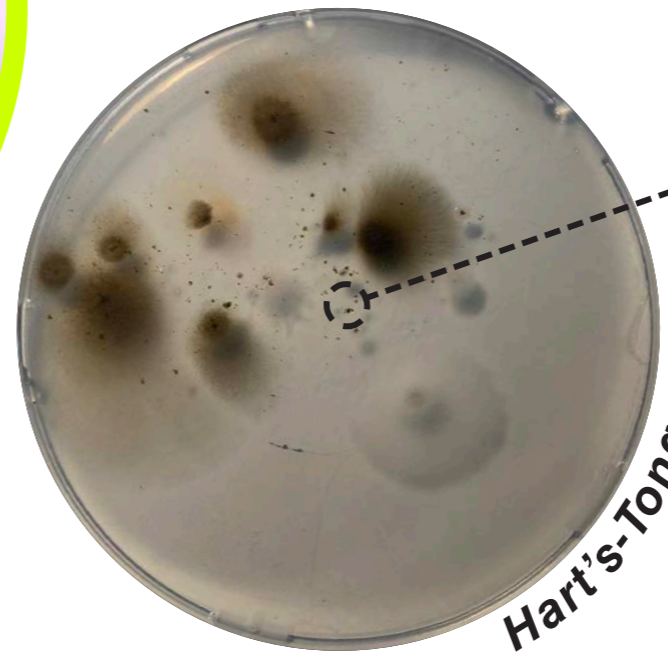


Common Male Fern

Dryopteris filix-mas

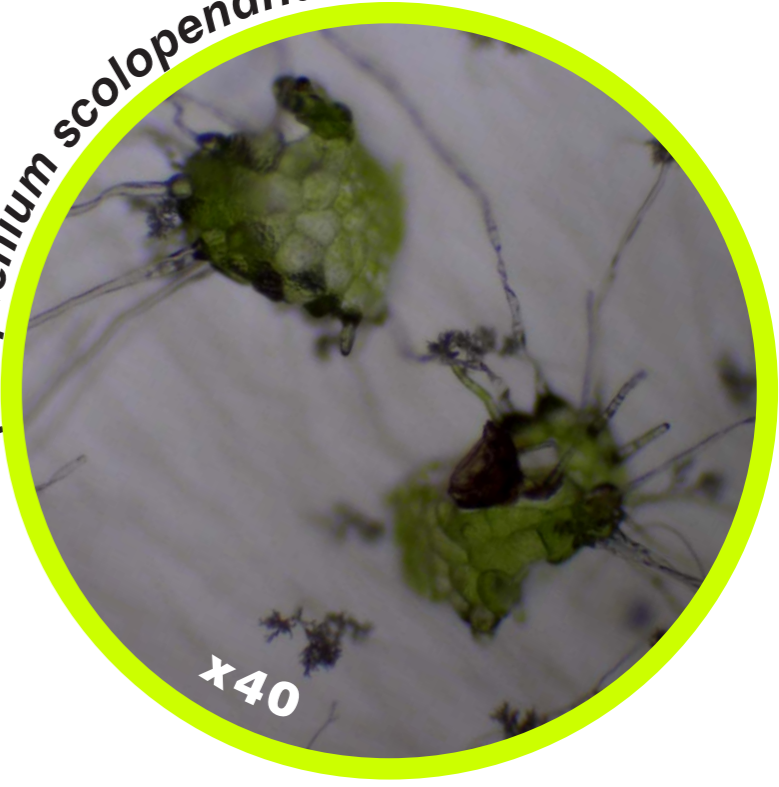


x40

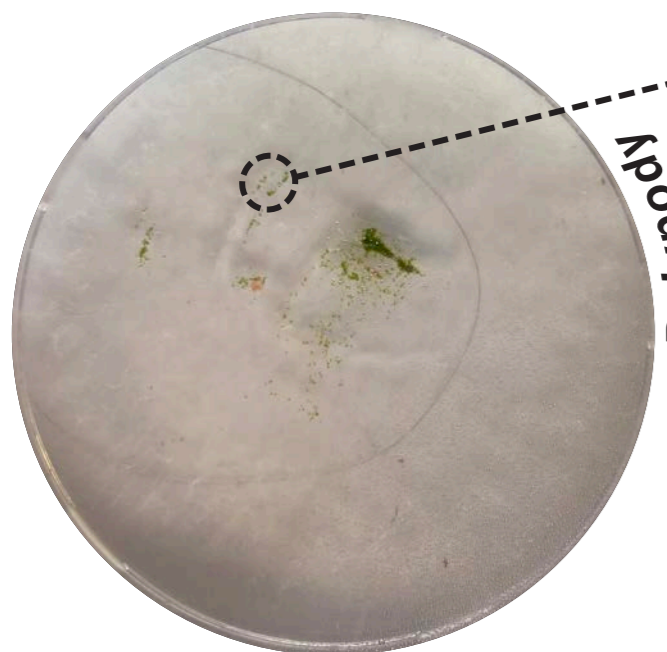


Hart's-Tongue Fern

Asplenium scolopendrium



x40

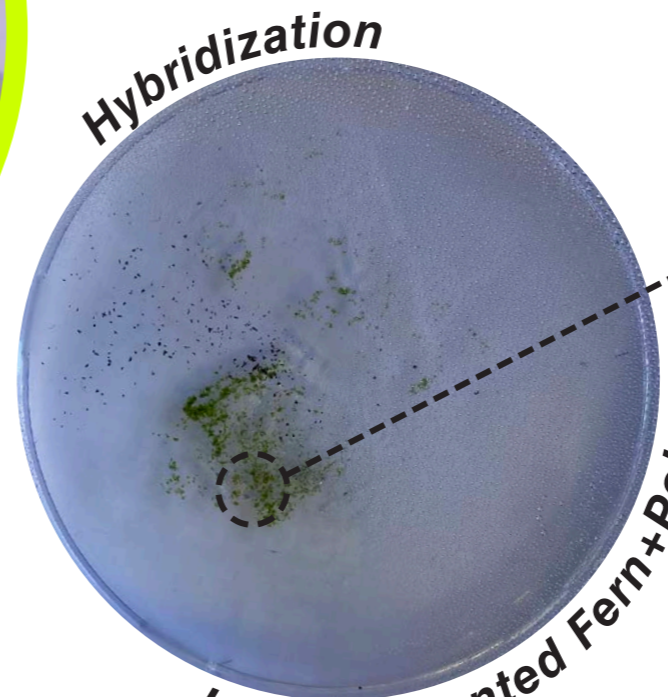


Polypody

Polypodium vulgare



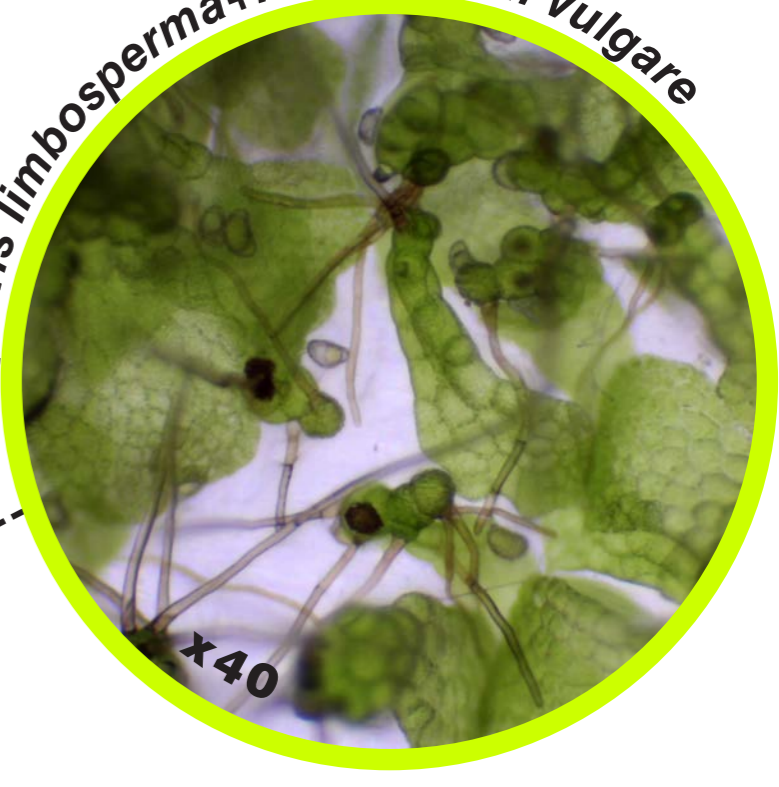
x40



Lemon-Scented Fern+Polypody

Hybridization

Oreopteris limbosperma+Polypodium vulgare

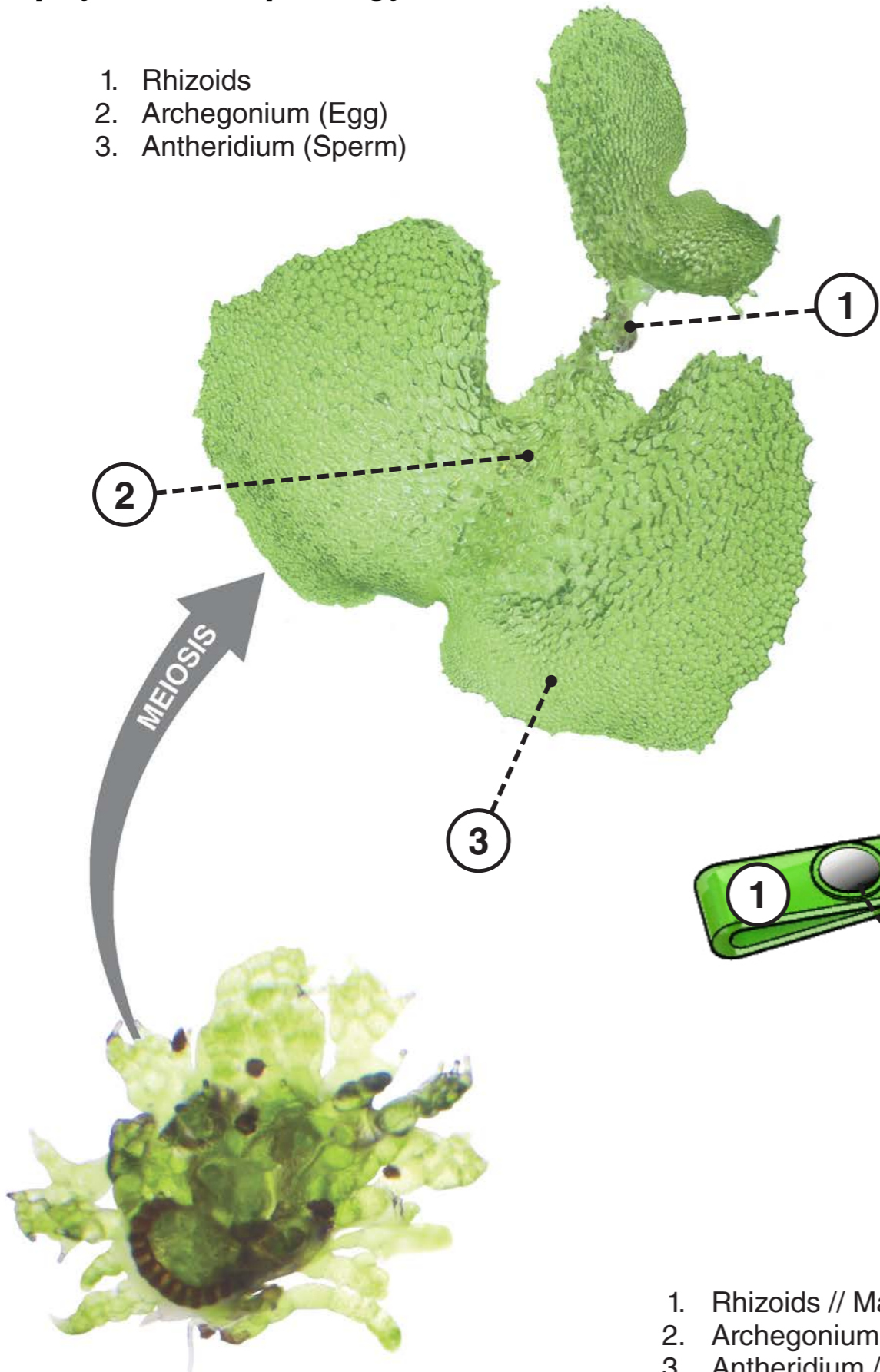


x40

**BIO/DESIGN MORPHOLOGY:
GAMETOPHYTE**

Gametophyte Biomorphology

- 1. Rhizoids
- 2. Archegonium (Egg)
- 3. Antheridium (Sperm)



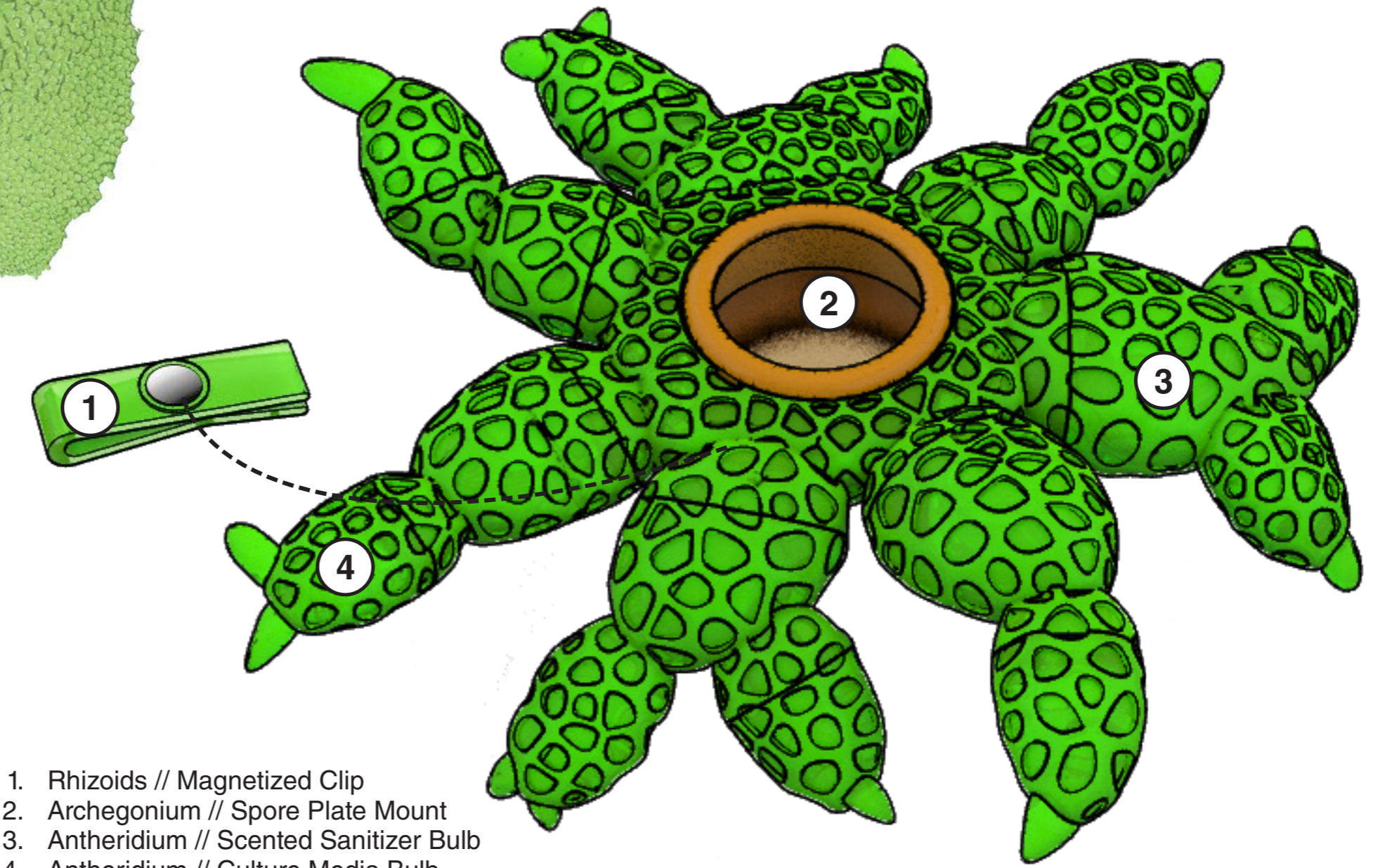
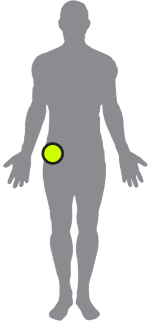
● ● **Lemon-Scented Fern // *Oreopteris limbosperma***
 -Pinnule Glands Contain Citrus Essential Oil (*Merryweather, 2020*)
 -Is There a Trait Advantage Evolving in This Genus?

● ● ● **Lavender Polypody // x *Polypolavandula* (*Polypodium* x *Lavandula*)**

● ● ● **Apple Blossom Polypody // x *Polypomalus* (*Polypodium* x *Malus*)**
 -Family *Polypodiaceae* Evolved Cenozoic Radiation Events (*Liu, 2021*)
 -One of Most Species Diverse Extant Fern Genus (*Liu, 2021*)
 -Speculative Future Species

Vessel Identity

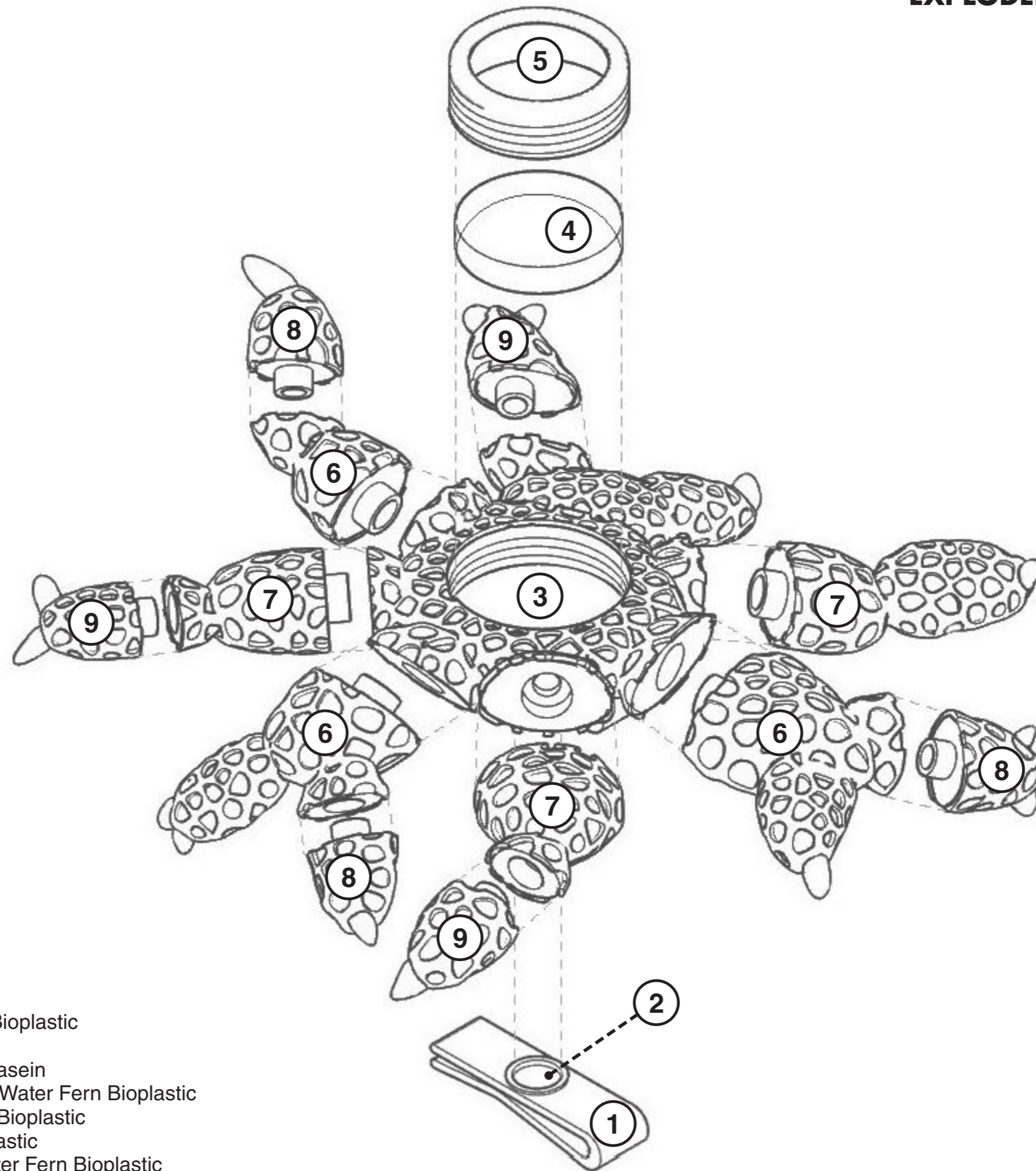
- GMO Assistance in Galactic Terraforming, Are Ferns from Earth?
- Scented Sanitary Alcohol Gel for Personal+Scientific Sterilization
- Material: Bioplastic+Water Fern
- Wearable on Waist, Collar, Head
- Secondary Use: Gametophyte Culture Growth



- 1. Rhizoids // Magnetized Clip
- 2. Archegonium // Spore Plate Mount
- 3. Antheridium // Scented Sanitizer Bulb
- 4. Antheridium // Culture Media Bulb

Vessel Design Morphology





1. Magnetized Clip, Water Fern Bioplastic
2. 15mm Neodymium Magnet
3. Spore Plate Threaded Mount, Water Fern Bioplastic
4. 45mm Petri Dish, Glass
5. Spore Plate Threaded Cover, Ochre Milk Casein
6. Lemon-Scented Fern Hand Sanitizer Bulb, Water Fern Bioplastic
7. Polypody Hand Sanitizer Bulb, Water Fern Bioplastic
8. Agar Culture Media Bulb, Water Fern Bioplastic
9. Murashige+Skoog Culture Media Bulb, Water Fern Bioplastic

VESSEL PROTOTYPE





VESSEL PROTOTYPE



PRESENT: CMMF // COMMON [MALE] FERN

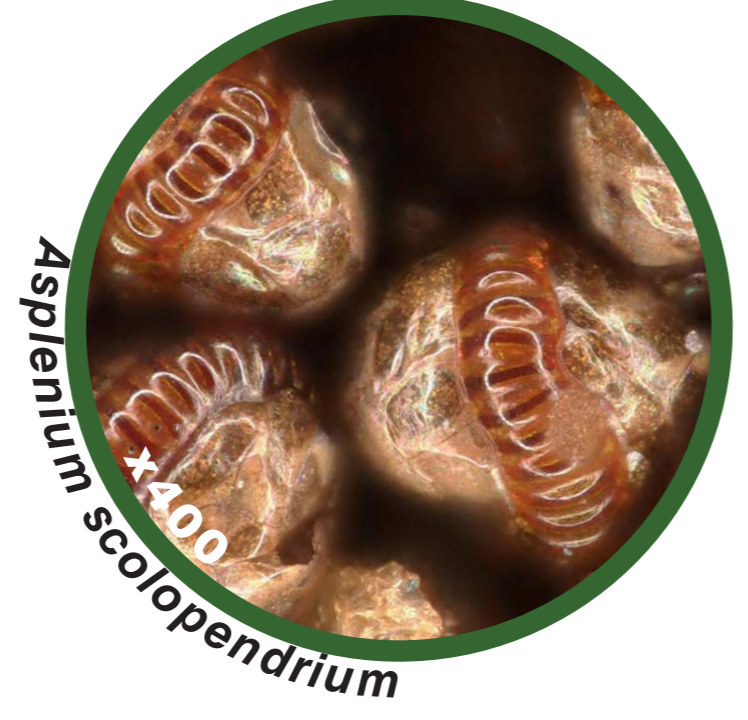
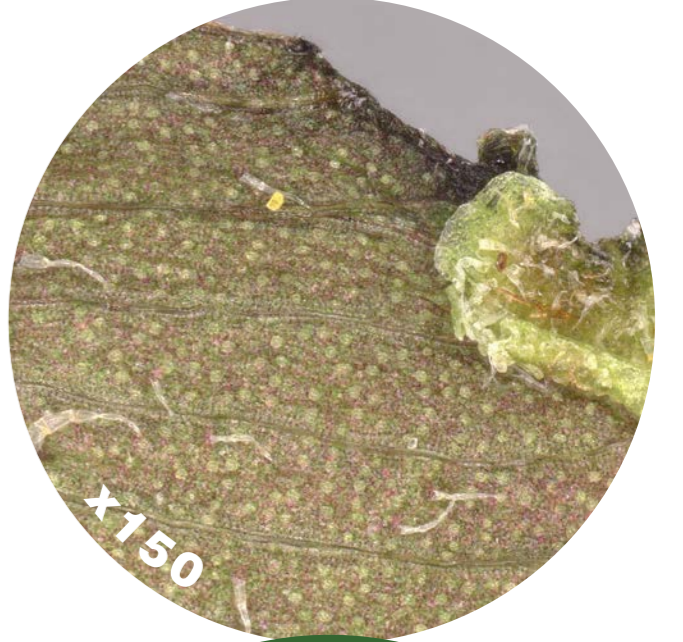


Dryopteris filix-mas // Pinna



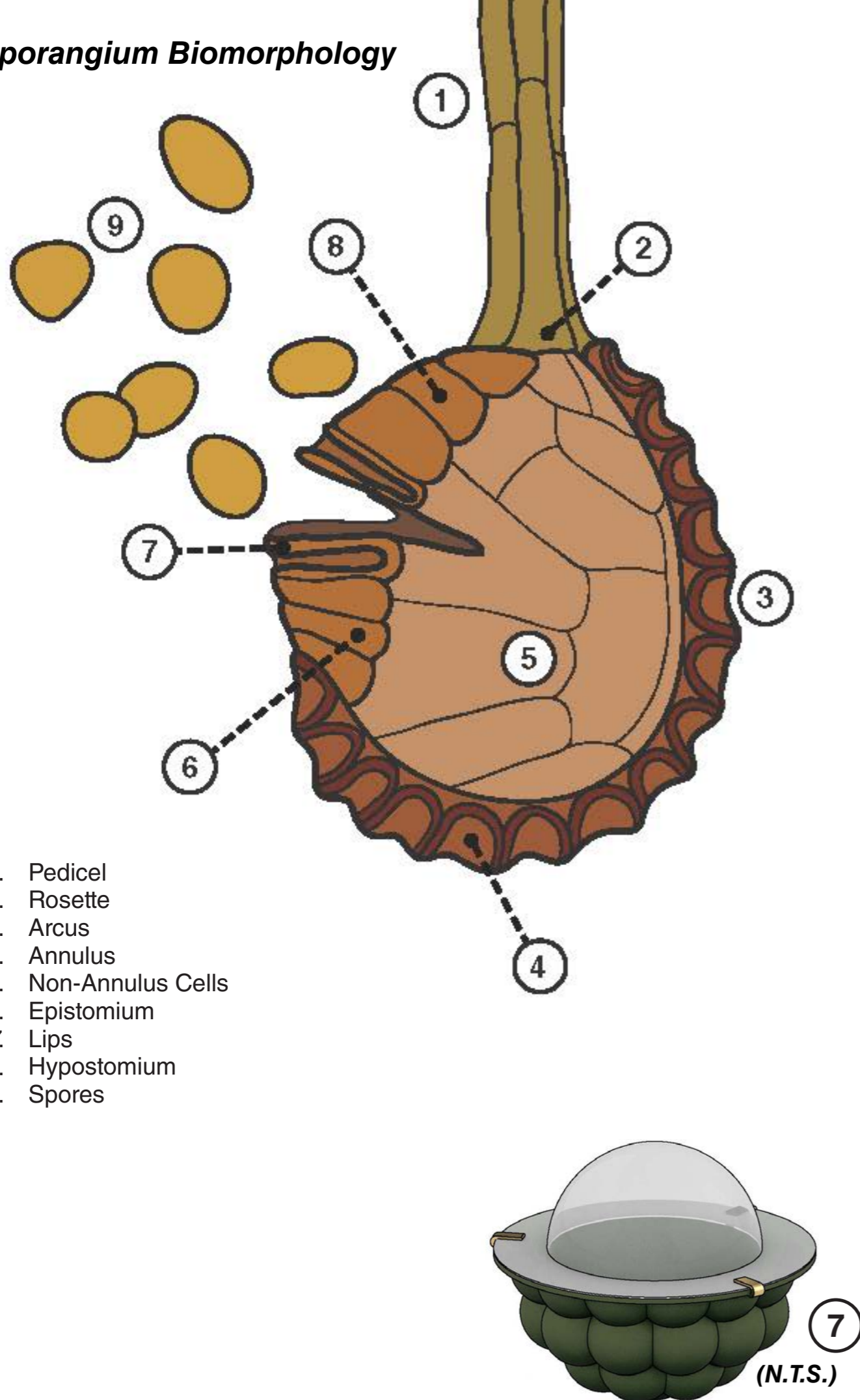
Dryopteris filix-mas // Sori

**BIOMORPHOLOGICAL OBSERVATIONS:
SPORANGIUM**



Sporangium Biomorphology

BIO/DESIGN MORPHOLOGY: SPORANGIUM

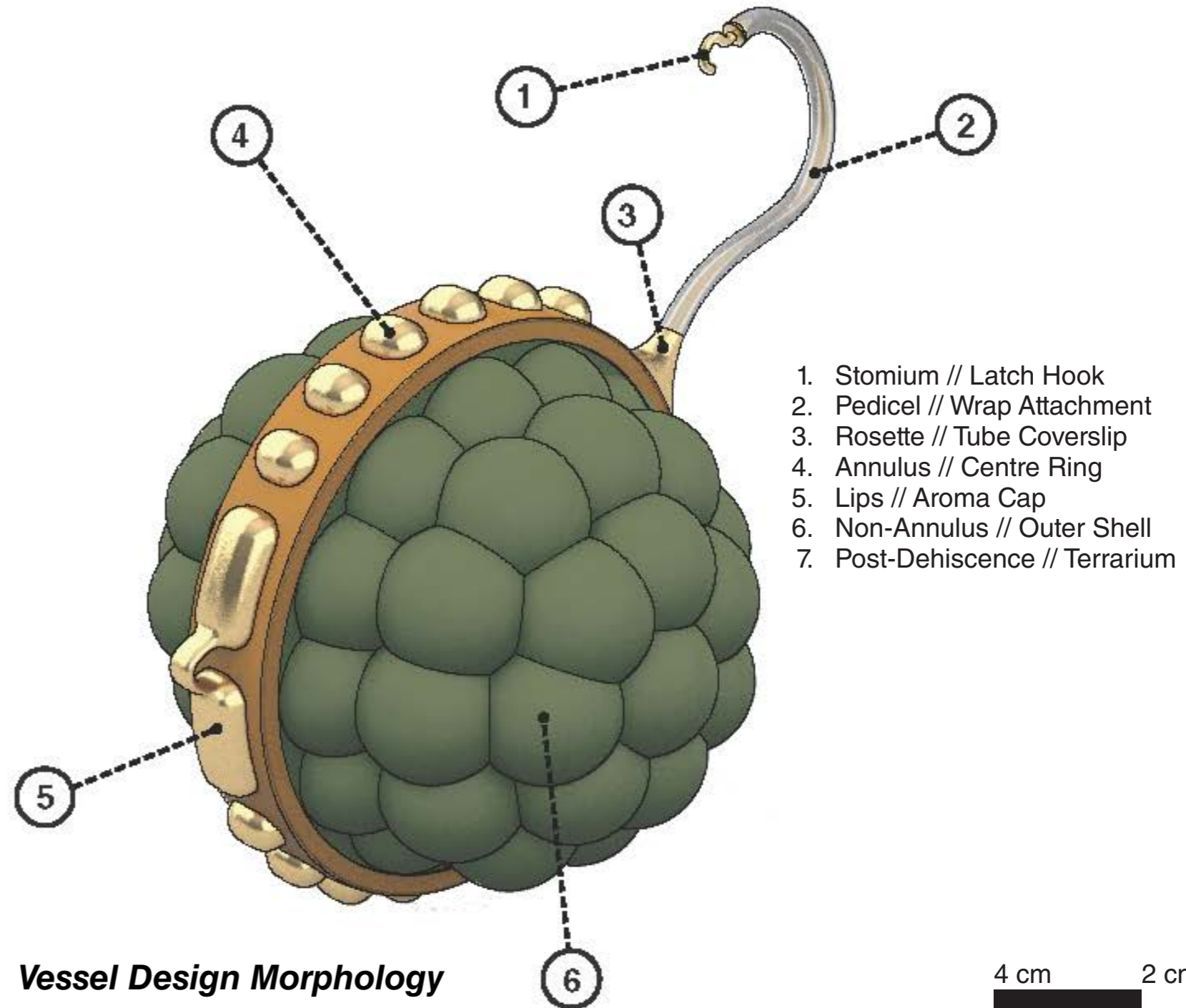


- 1. Pedicel
- 2. Rosette
- 3. Arcus
- 4. Annulus
- 5. Non-Annulus Cells
- 6. Epistomium
- 7. Lips
- 8. Hypostomium
- 9. Spores

● ● **Common Male Fern // *Dryopteris filix-mas***
 -Widespread Throughout UK Every 10 km² (Merryweather, 2020)
 -Thrives in Urban+Natural Settings (Merryweather, 2020)
 -Hardy; Survives Dry Conditions (Merryweather, 2020)

Vessel Identity

- Most Populous Fern in UK
- Room Fragrance, Sustainable Alginate Fragrance Beads
- Material: Bioresin+Water Fern, Milk Casein+Ochre
- Wearable on Bag Shoulder-Strap + Pants Belt-Loop
- Secondary Use: Urban Terrarium for Sporophyte Cultivation

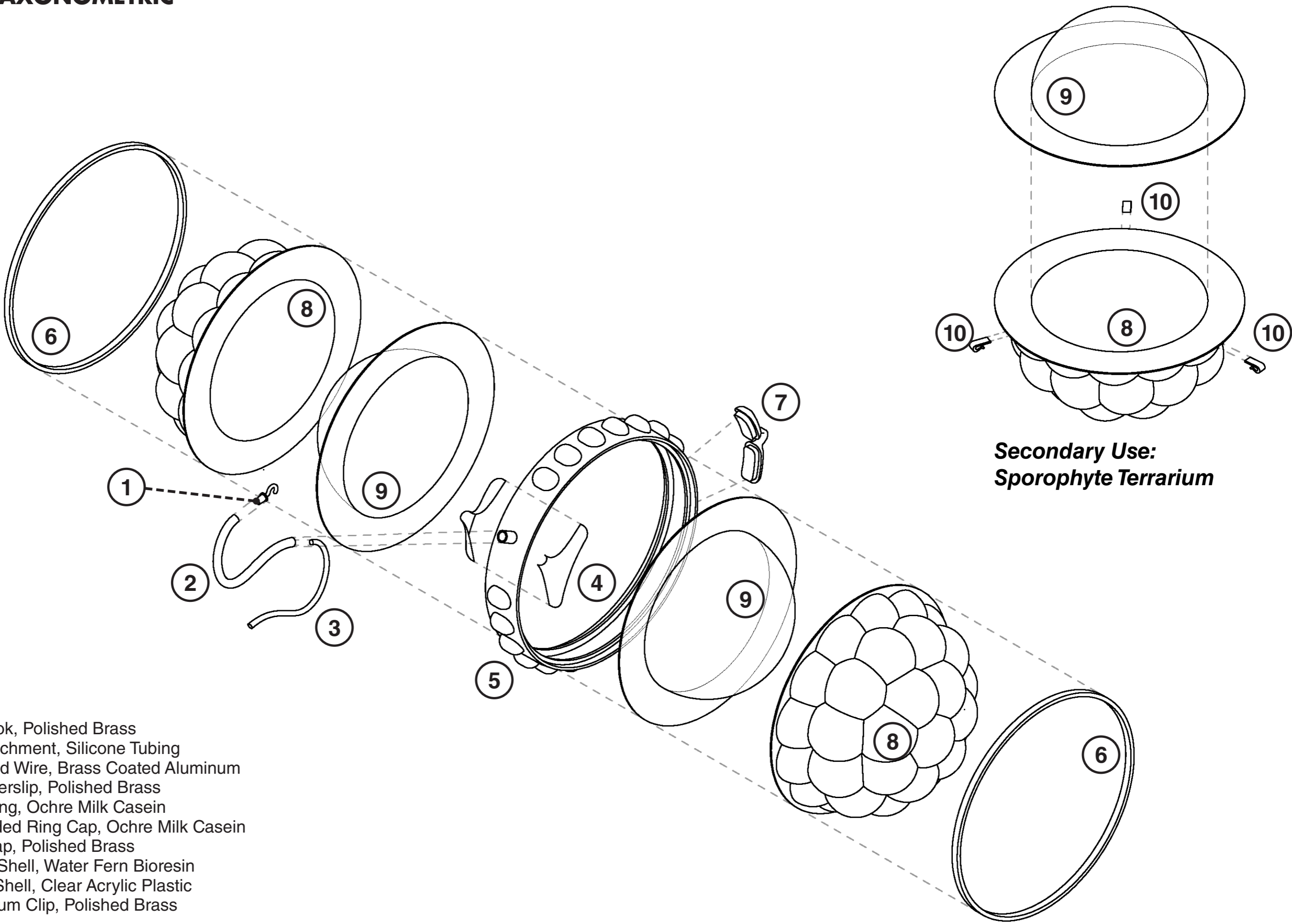


- 1. Stomium // Latch Hook
- 2. Pedicel // Wrap Attachment
- 3. Rosette // Tube Coverslip
- 4. Annulus // Centre Ring
- 5. Lips // Aroma Cap
- 6. Non-Annulus // Outer Shell
- 7. Post-Dehiscence // Terrarium

Vessel Design Morphology

4 cm 2 cm

EXPLODED AXONOMETRIC



1. Latch Hook, Polished Brass
2. Wrap Attachment, Silicone Tubing
3. Embedded Wire, Brass Coated Aluminum
4. Tube Coverslip, Polished Brass
5. Centre Ring, Ochre Milk Casein
6. 2x Threaded Ring Cap, Ochre Milk Casein
7. Aroma Cap, Polished Brass
8. 2x Outer Shell, Water Fern Bioresin
9. 2x Inner Shell, Clear Acrylic Plastic
10. 3x Terrarium Clip, Polished Brass

**Secondary Use:
Sporophyte Terrarium**

Primary Use: CMF Vessel







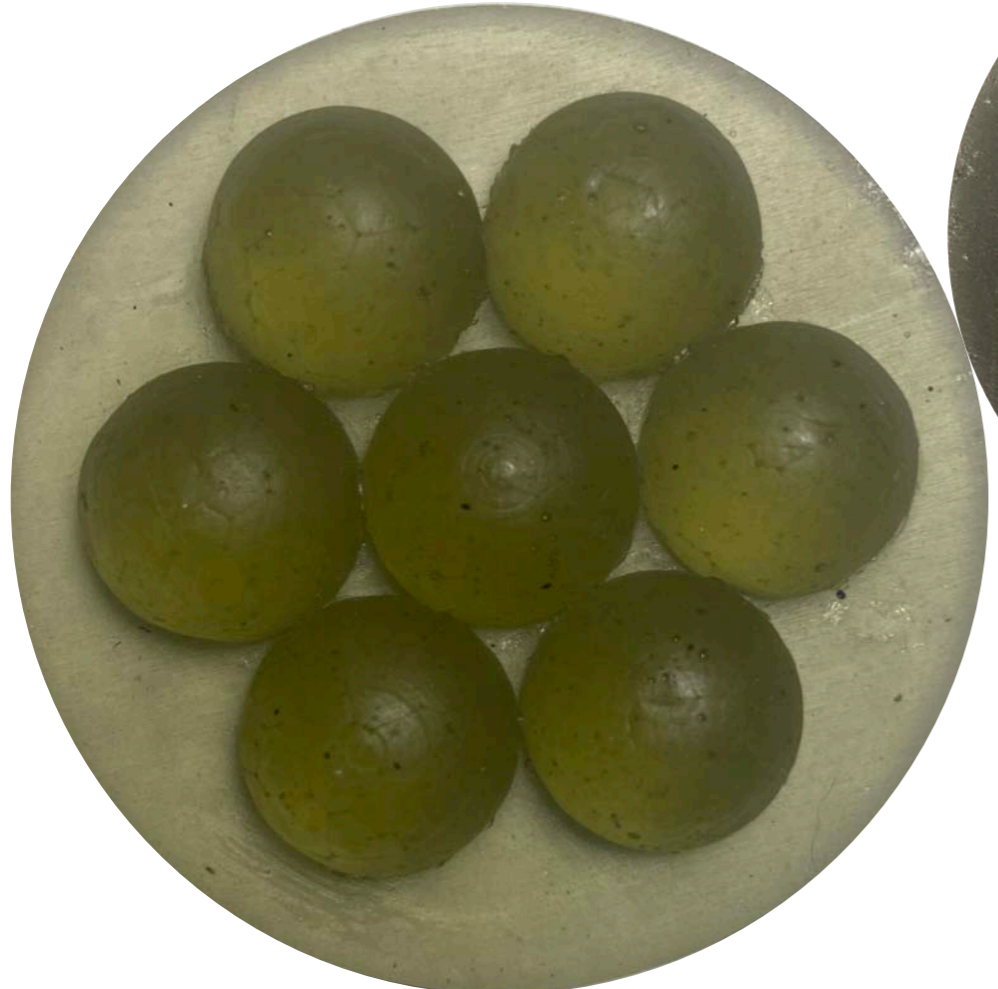


INVASIVE WATER FERN



Water Fern, Azolla filiculoides

VESSEL BIOPLASTIC



①
Bioresin

- 1. 100 mL Bioresin
0.3 g Water Fern Powder
- 2. 100 mL Tap Water
17 g Gelatin
8 g Glycerol
3 g Water Fern Powder
- 3. 100 mL Tap Water
4 g Agar
6.5 g Glycerol
3 g Water Fern Powder
- 4. 100 mL Tap Water
12 g Potato Starch
6 g White Wine Vinegar
7 g Glycerol
3 g Water Fern Powder



②
Gelatin



③
Agar



④
Starch

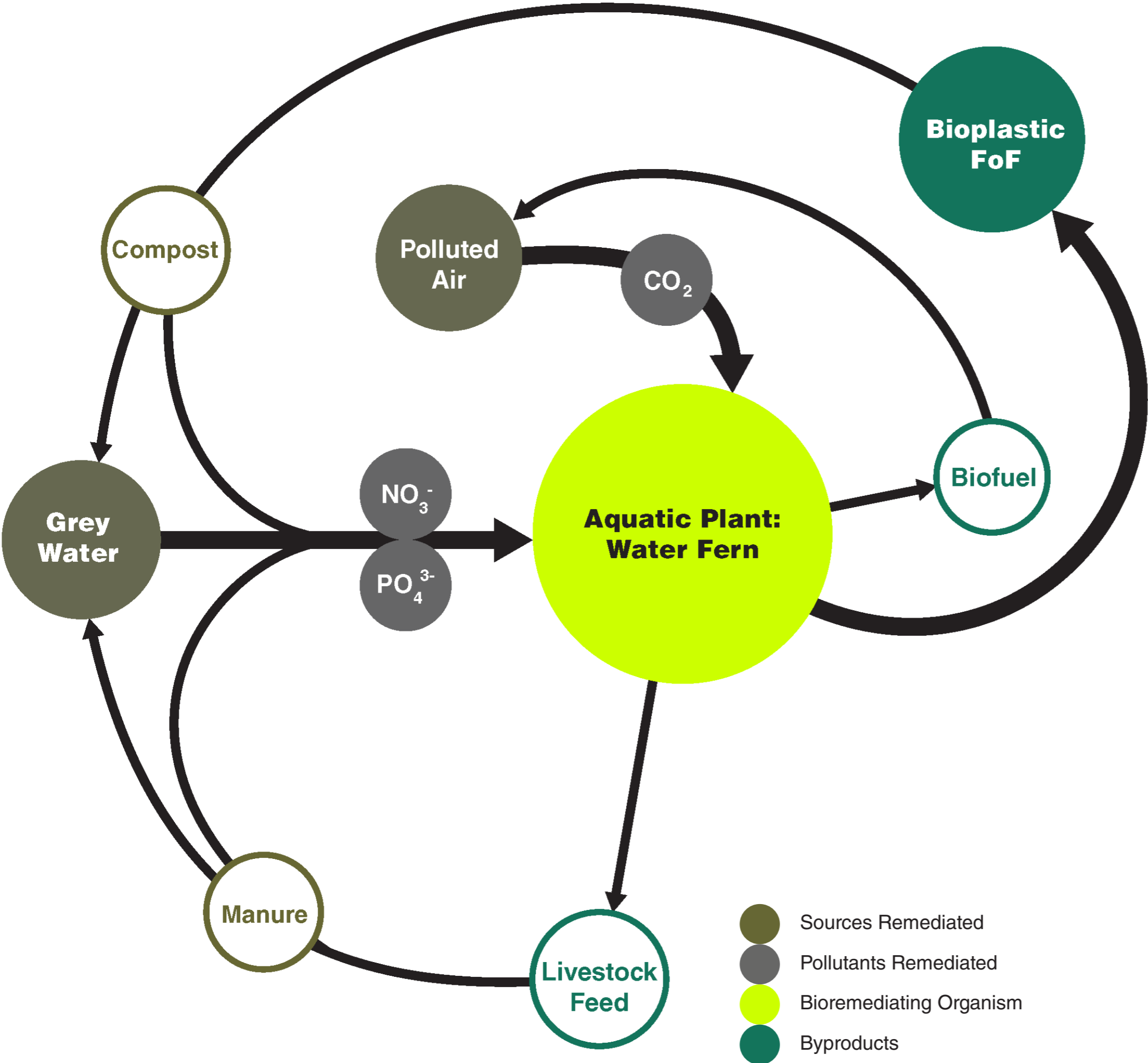


Drying Water Fern



**Collecting Water Fern
Regent's Canal, London, UK**

AQUACULTURE SYSTEM MAPPING



- Sources Remediated
- Pollutants Remediated
- Bioremediating Organism
- Byproducts



Azolla filiculoides
Native:
 N. America + S. America
Invasive:
 Europe
Carbon Sequestration:
 6 Tonnes / Acre Annually
Biomass Doubling:
 3 - 10 Days



Salvinia molesta
Native:
 S. America
Invasive:
 Africa, Asia, Europe + N. America
Biomass Doubling:
 2.2 - 2.5 Days



Salvinia minima
Native:
 S. America
Invasive:
 N. America
Biomass Doubling:
 7 - 10 Days

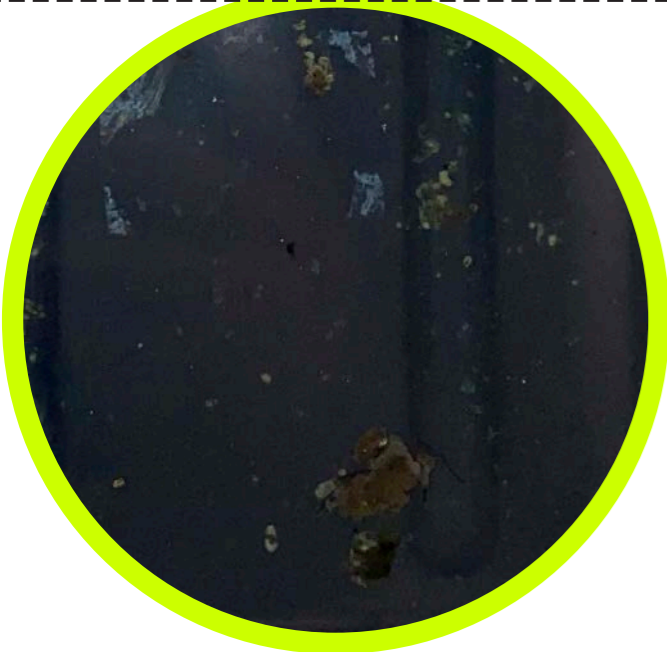
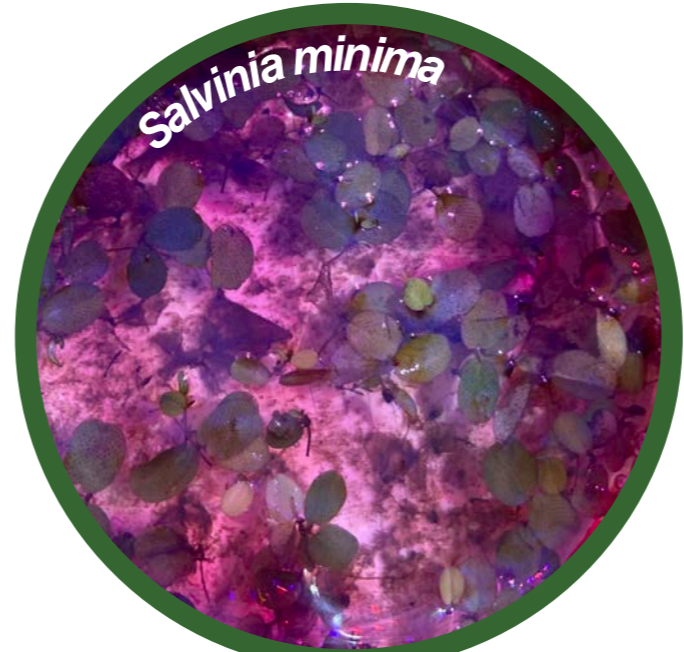
PROPAGATION EXPERIMENT

Hypothesis:

The three species of water fern *A. filiculoides*, *S. molesta*, and *S. minima* can be propagated at home in containers of water. Their biomass should double in approximately one week. By using an aquarium pump and silicon hosing, aeration along with Miracle Gro will encourage the water ferns to propagate faster. Once the biomass reaches a high exponential growth rate, it will be a viable source for raw material to conduct bioplastic experiments.

Conclusion:

Prior to setting up the aeration system, the water ferns were doubling biomass on schedule. However, the aeration system resulted in all three of the water fern specimens dying. After research, water ferns prefer still water. It was not the air itself that kill the plants, but rather the water movement caused by the air pumping into the small container. Further experiments of growing water ferns must be conducted applying same conditions without aeration system.

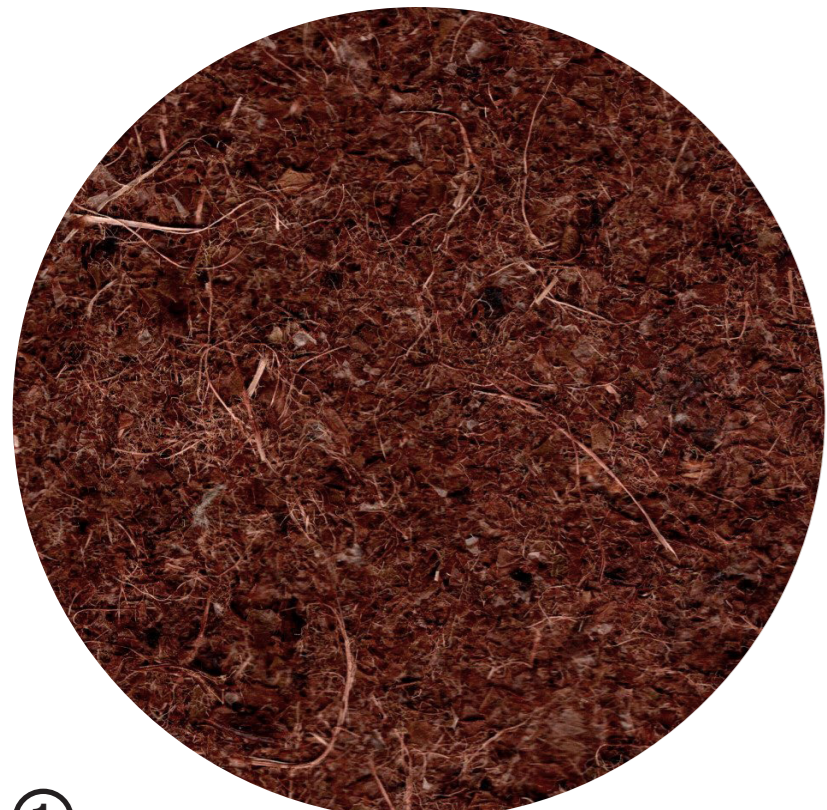


INVASIVE RHODODEN- DRON



Catawba Rhododendron, Rhododendron catawbiense

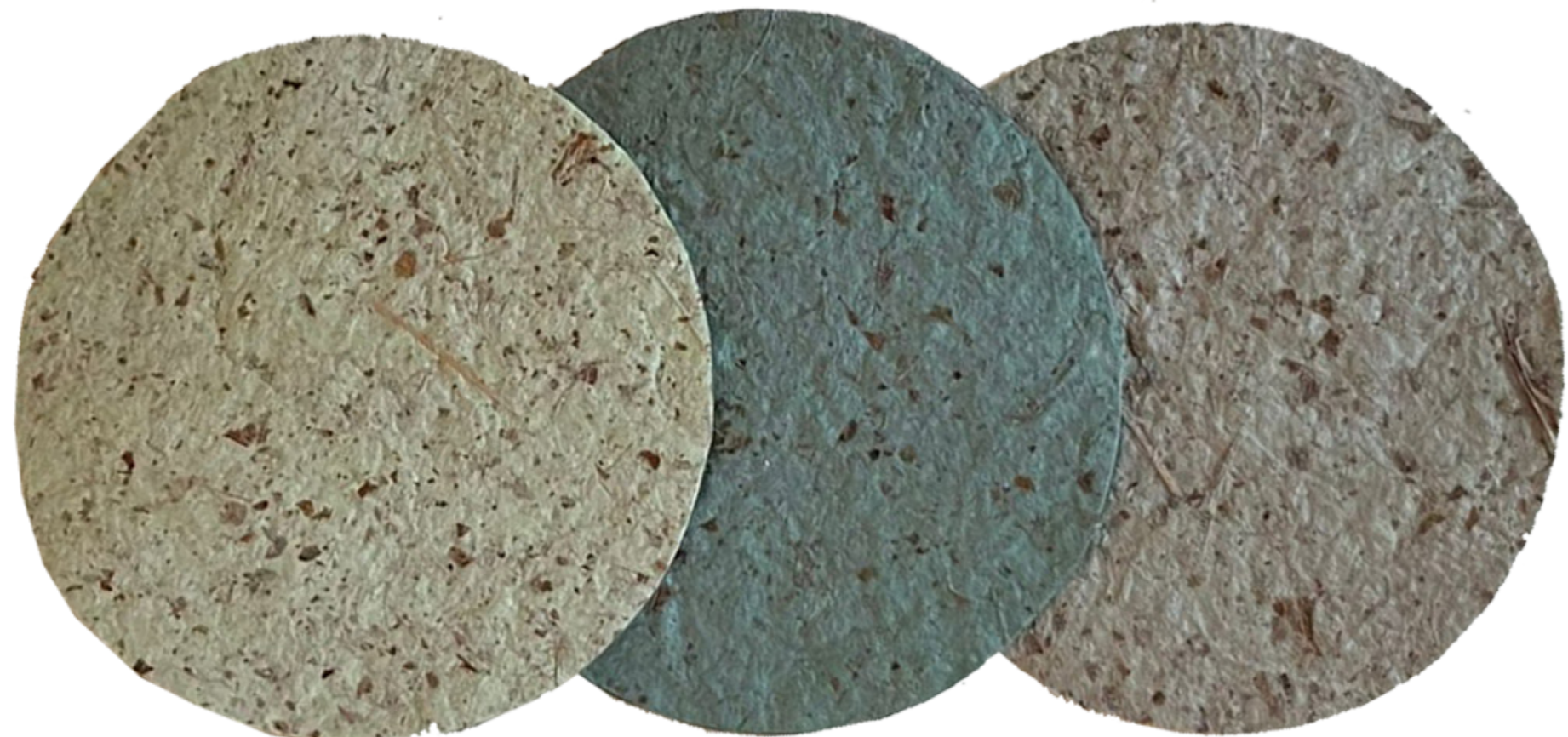
FF VESSEL FERN SPORE PAPER



① *Rhododendron Paper*

- 1. 30 g Rhododendron Leaves
6.5 g Soda Ash

- 2. 15 g Rhododendron Leaves
15 g Dyed Lokta Paper
6.5 g Soda Ash



② *Rhododendron+Lokta Paper*

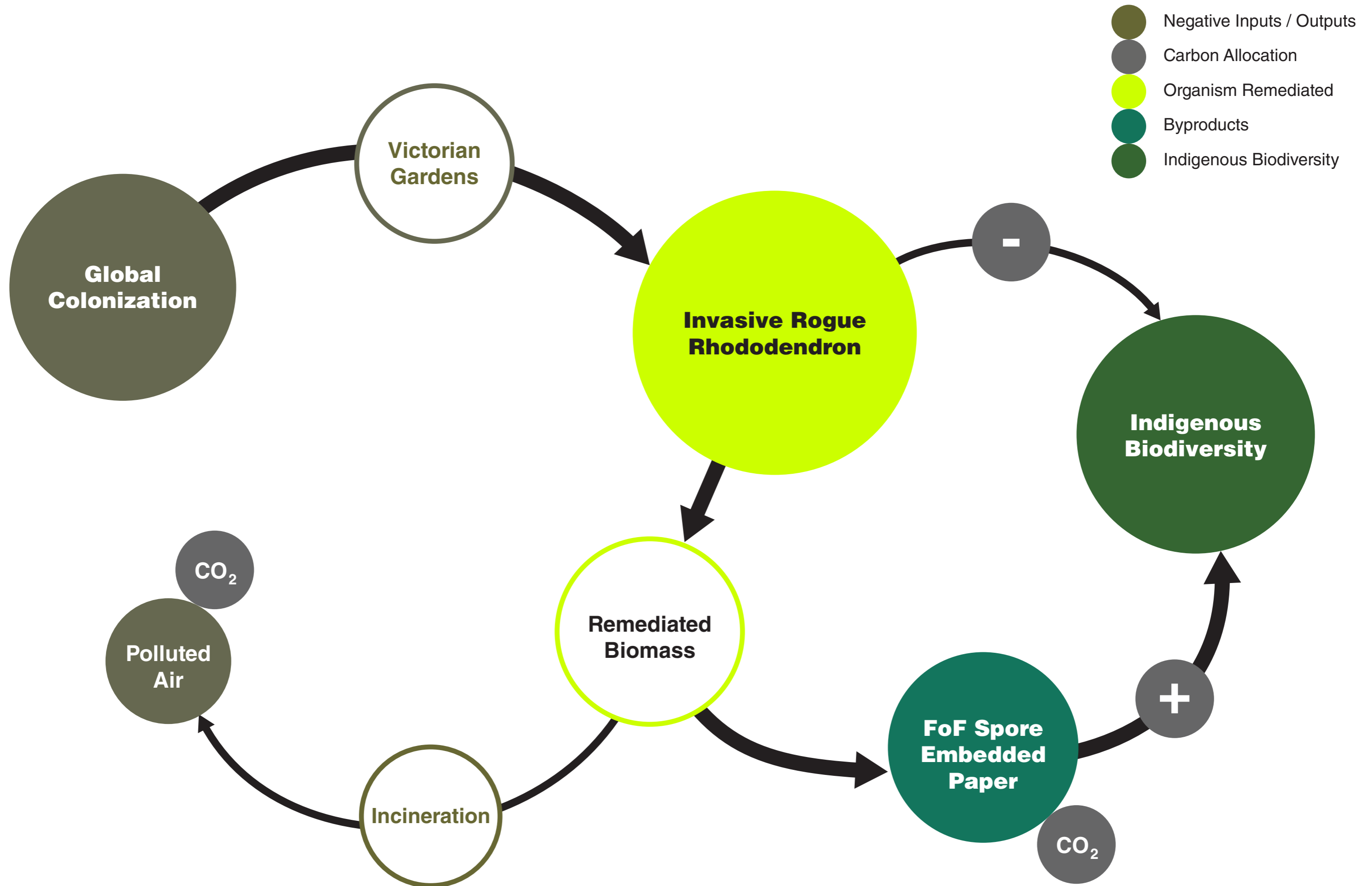


Deckle Dipping



Cooking Leaves

REMEDIATION SYSTEM MAPPING



FERN SPORE PAPER EXPERIMENT

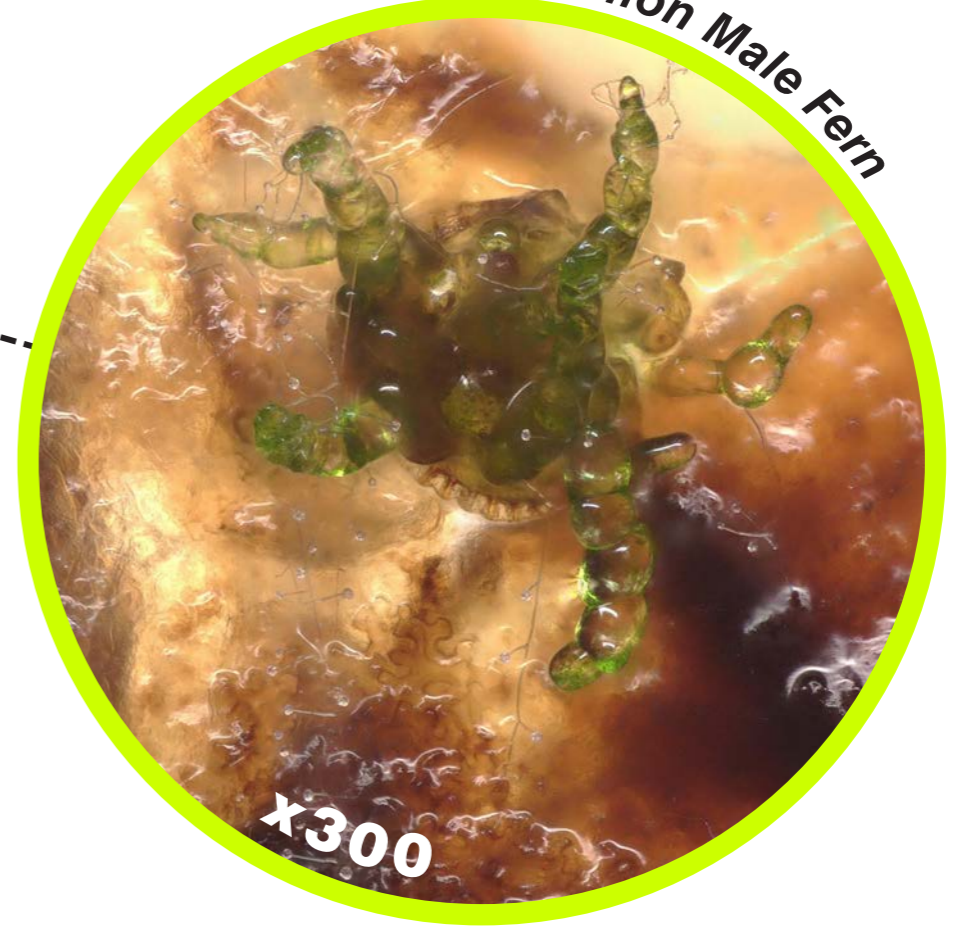
Dryopteris filix-mas



Hypothesis:
Embedding fern spores in natural paper made of remediated invasive Rhododendron clippings will provide a resting surface for fern spores until water activated for desired propagation. Furthermore, the natural Rhododendron fiber will help retain moisture development and provide additional beneficial nutrients for gametophyte.

Conclusion:
After just four weeks the first gametophyte of embedded *Dryopteris filix-mas* spore was observed. After seven weeks, many colonies of gametophytes were visible and developing healthily; non-competitive fungal colonies appeared to be developing as well. Is there a positive relation between the gametophytes and the fungus?

Common Male Fern



2 mm 5 mm

MILK CASEIN AGRIPRODUCT



Crinan Wood // Scotland, UK

VESSEL BIOPLASTIC

- 1. 700 mL Skim Cow Milk
3 g Earth Ochre
175 mL White Vinegar
- 2. 230 mL Skim Cow Milk
20 g White Wine Vinegar
0.5 g Water Fern Powder
- 3. 230 mL Skim Cow Milk
20 g White Wine Vinegar



①
Milk Casein+Ochre



②
Milk Casein+Water Fern



③
Milk Casein

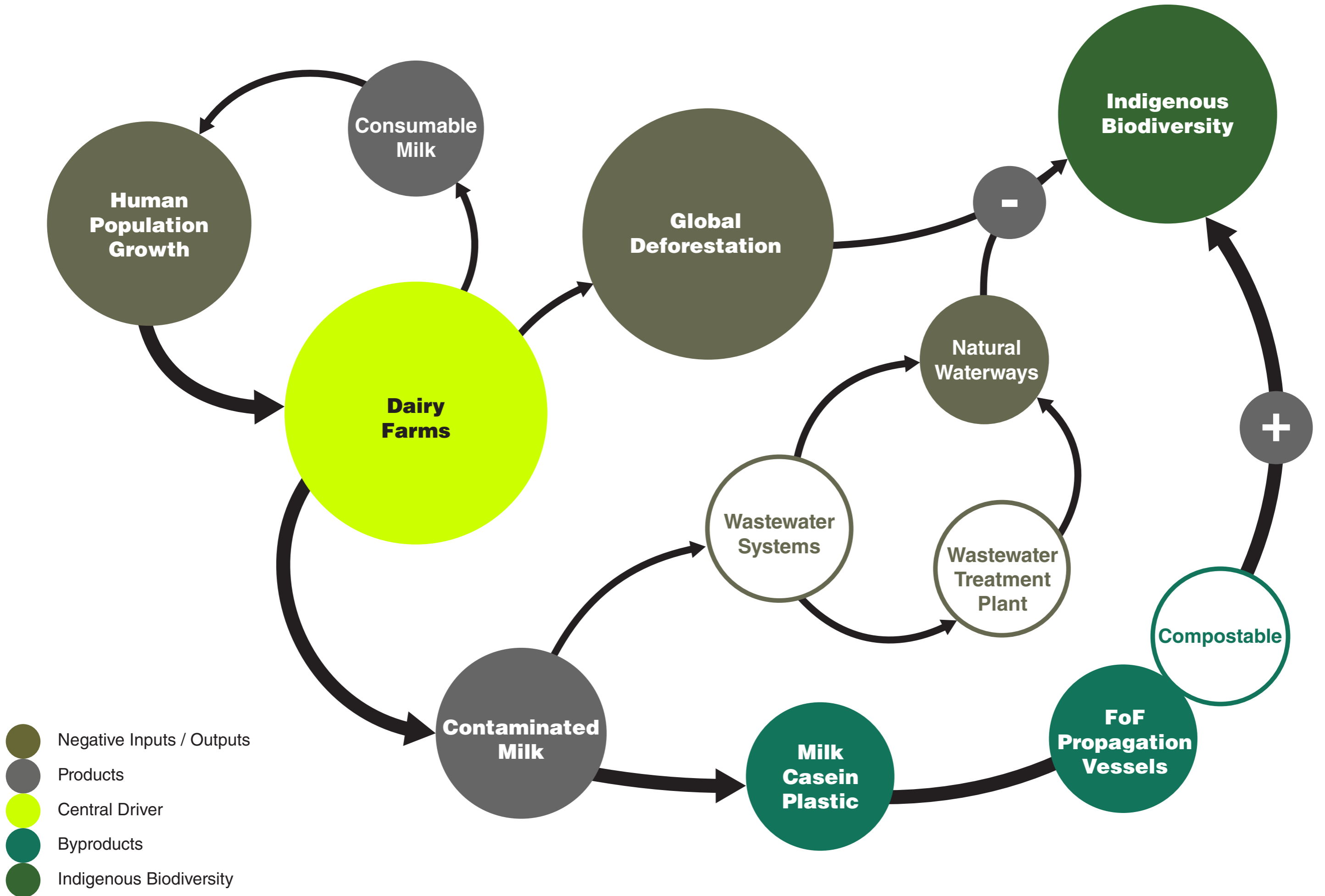


Drying Milk Casein



Adding Vinegar

DAIRY AGRICULTURE SYSTEM MAPPING



PLANT PRESSINGS

x20 ~ Polypody, *Polypodium vulgare* // Sori



EXHIBITION

x300 ~ Polypody, *Polypodium vulgare* // Sporangia



FINAL GRADUATE SHOWCASE

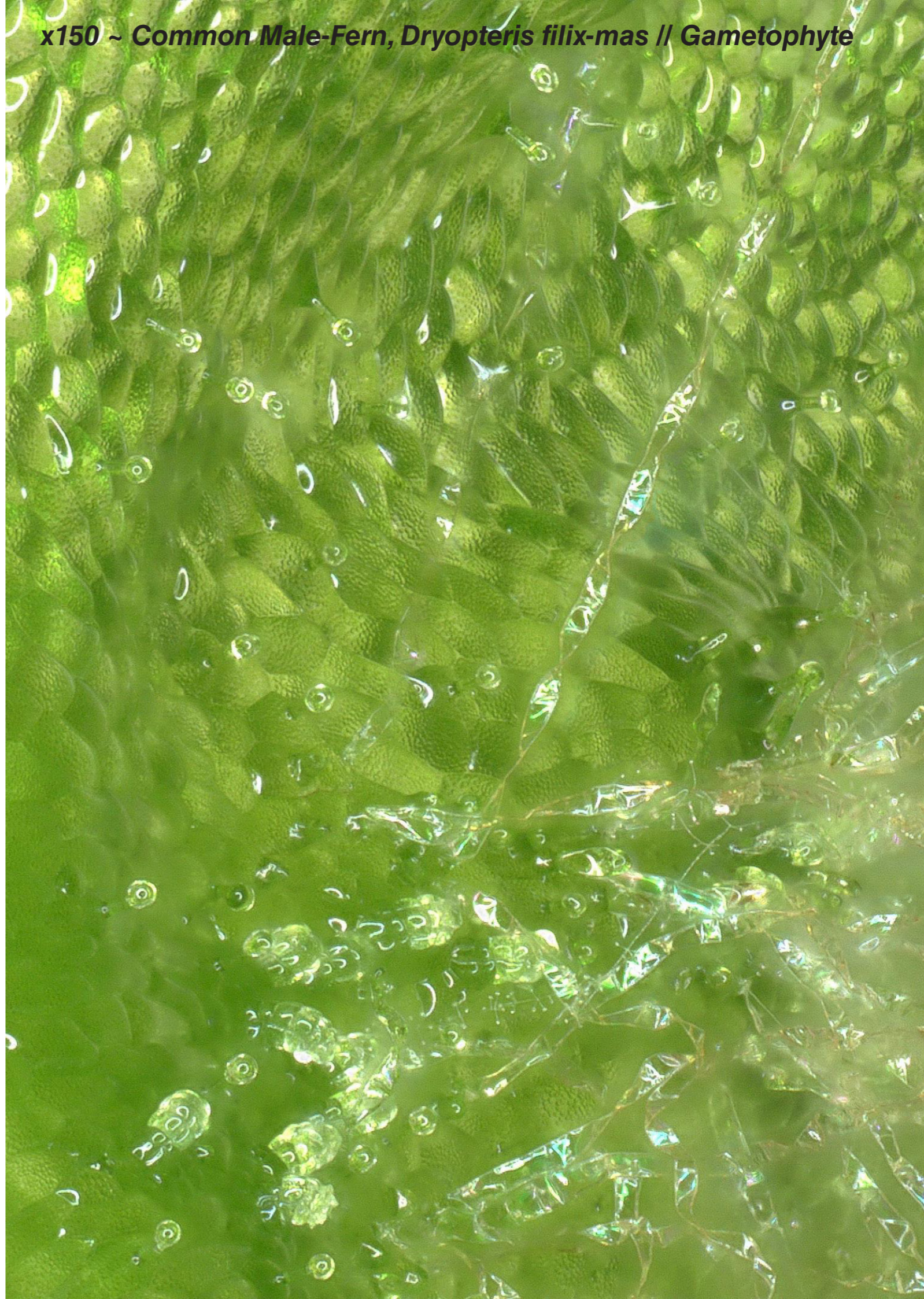


WORK IN PROGRESS

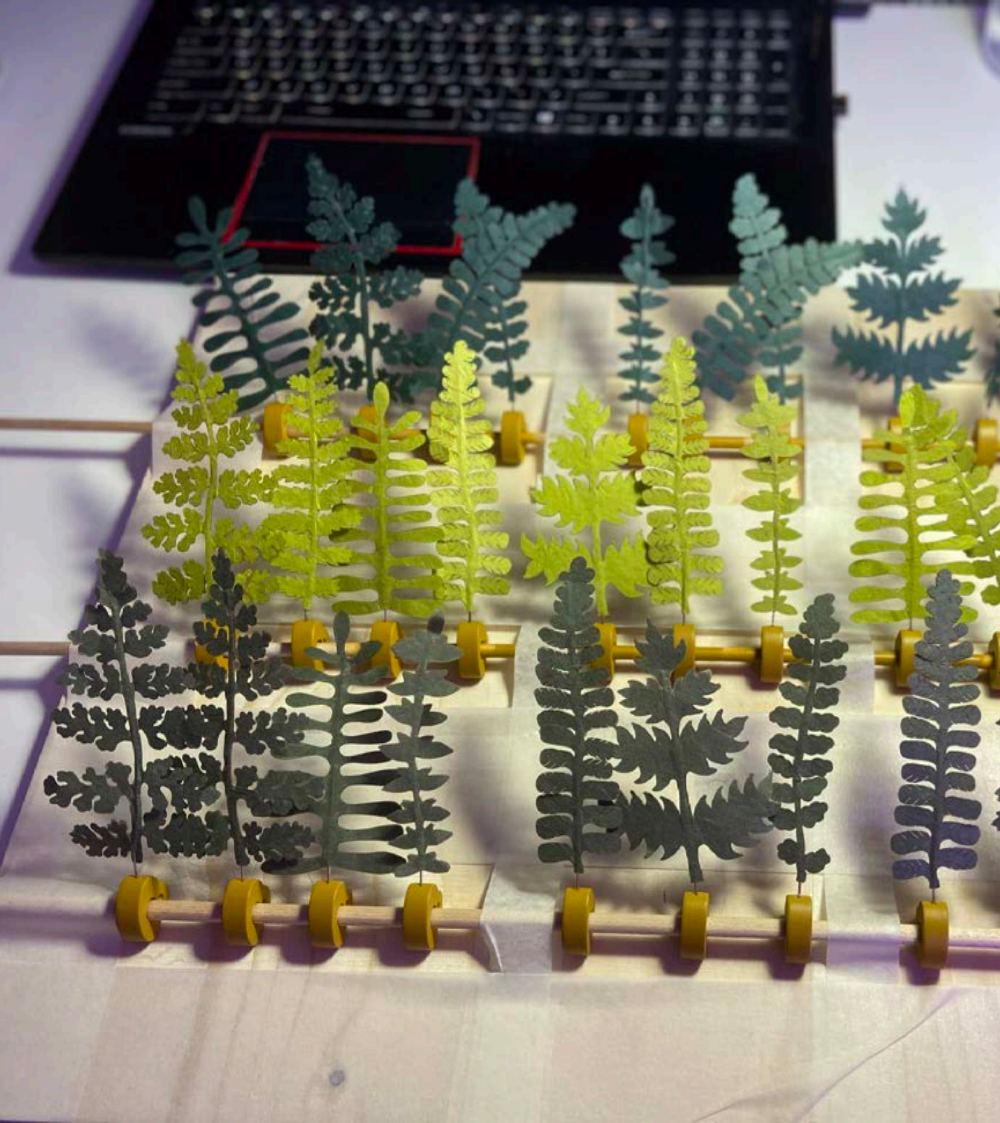


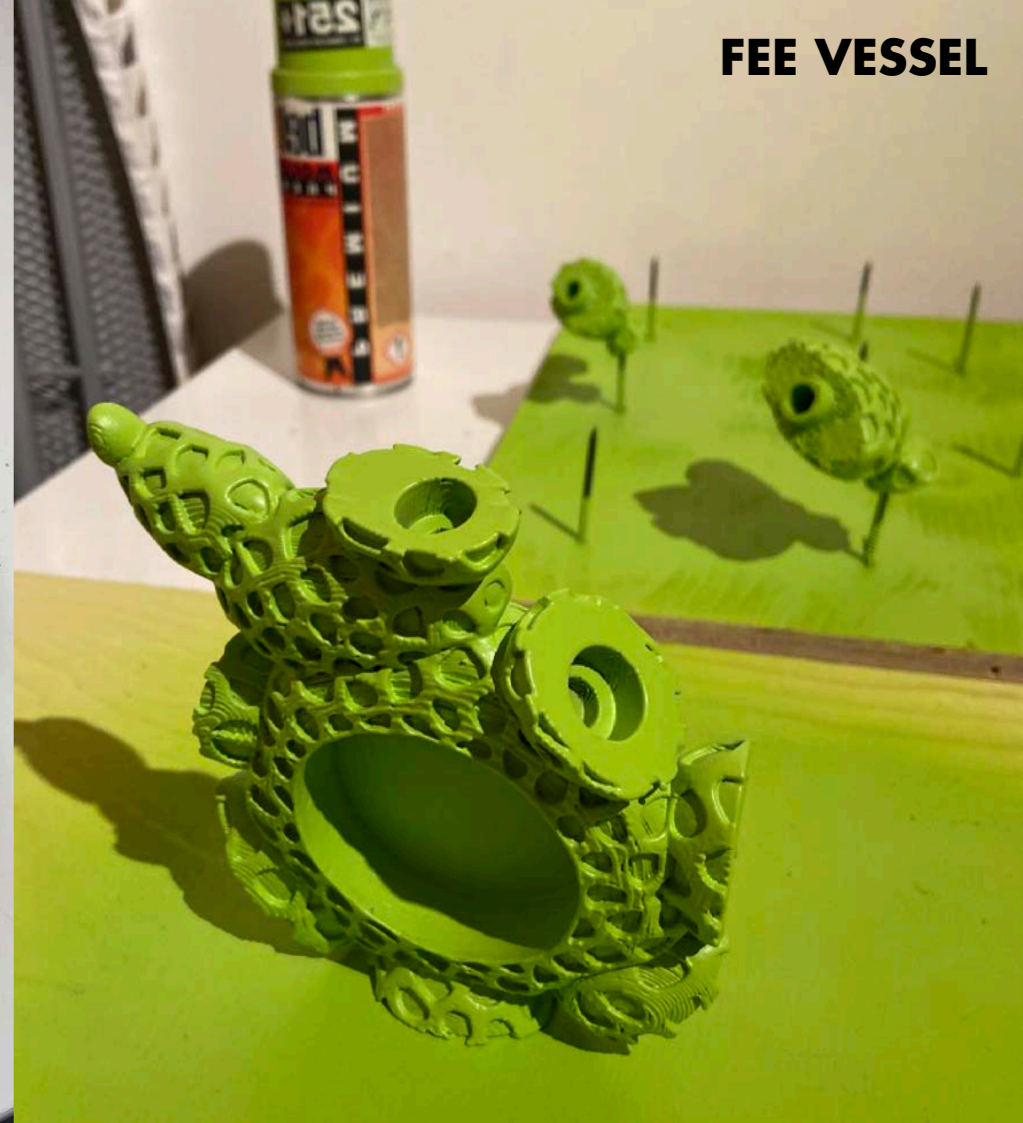
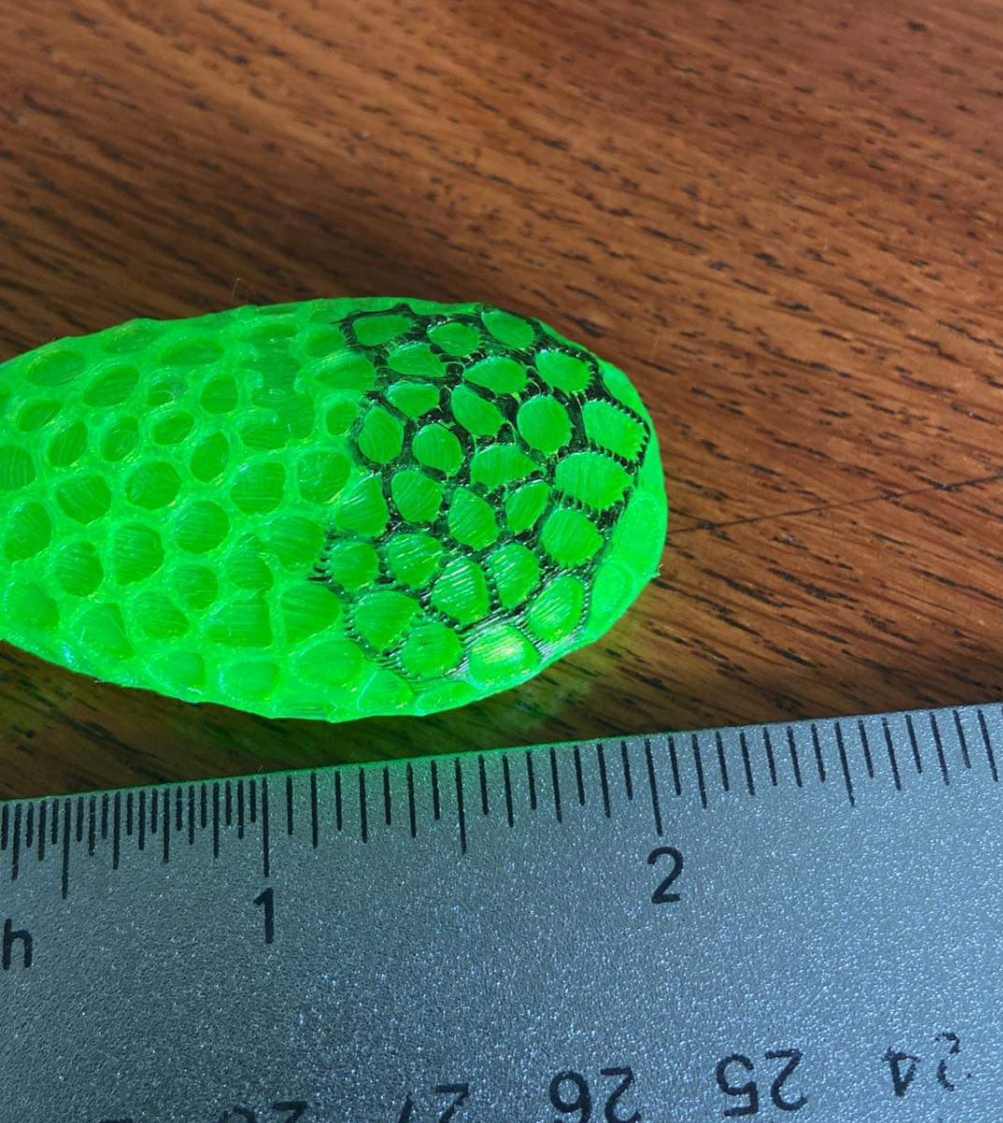
PROCESSES

x150 ~ Common Male-Fern, *Dryopteris filix-mas* // Gametophyte



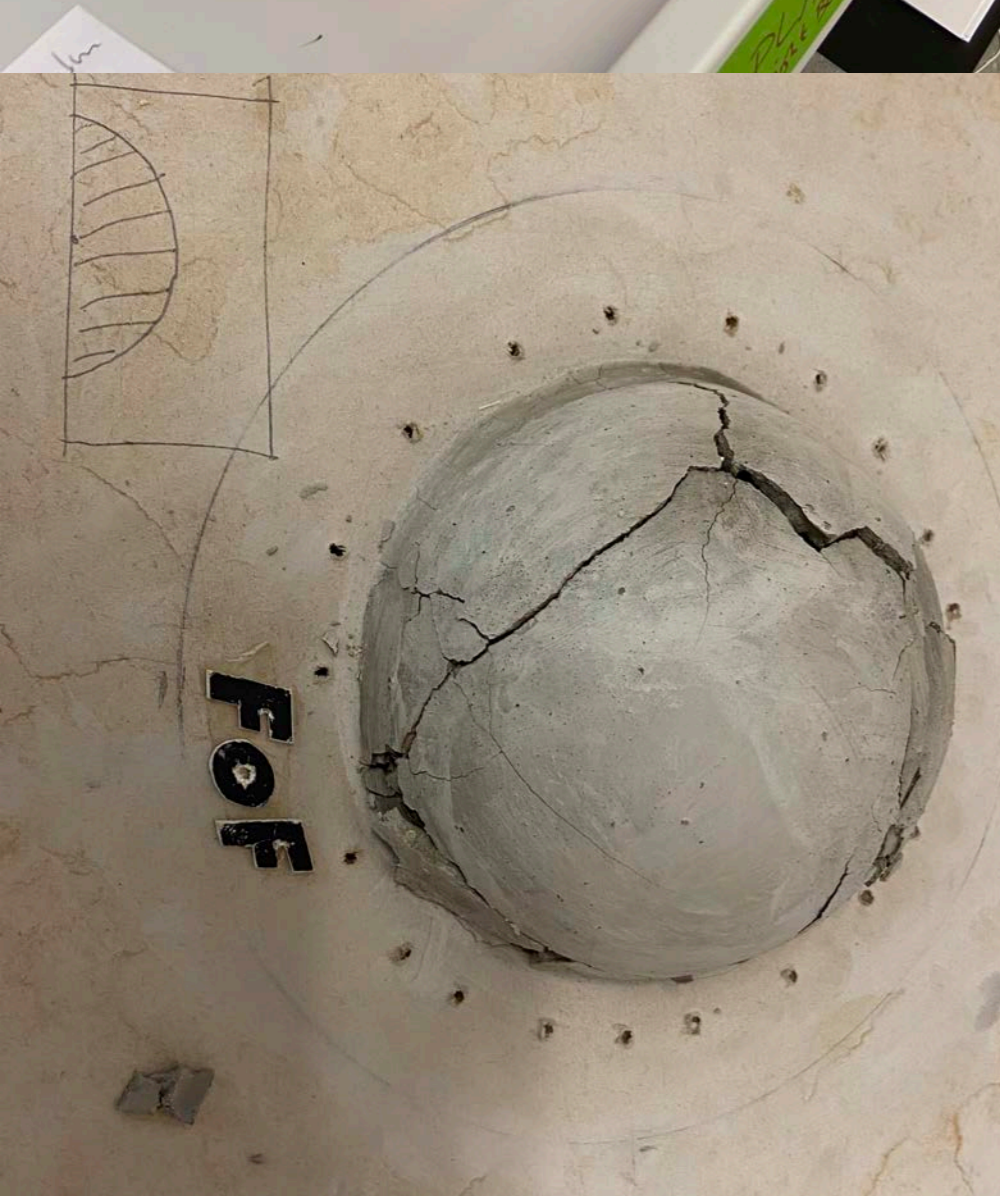
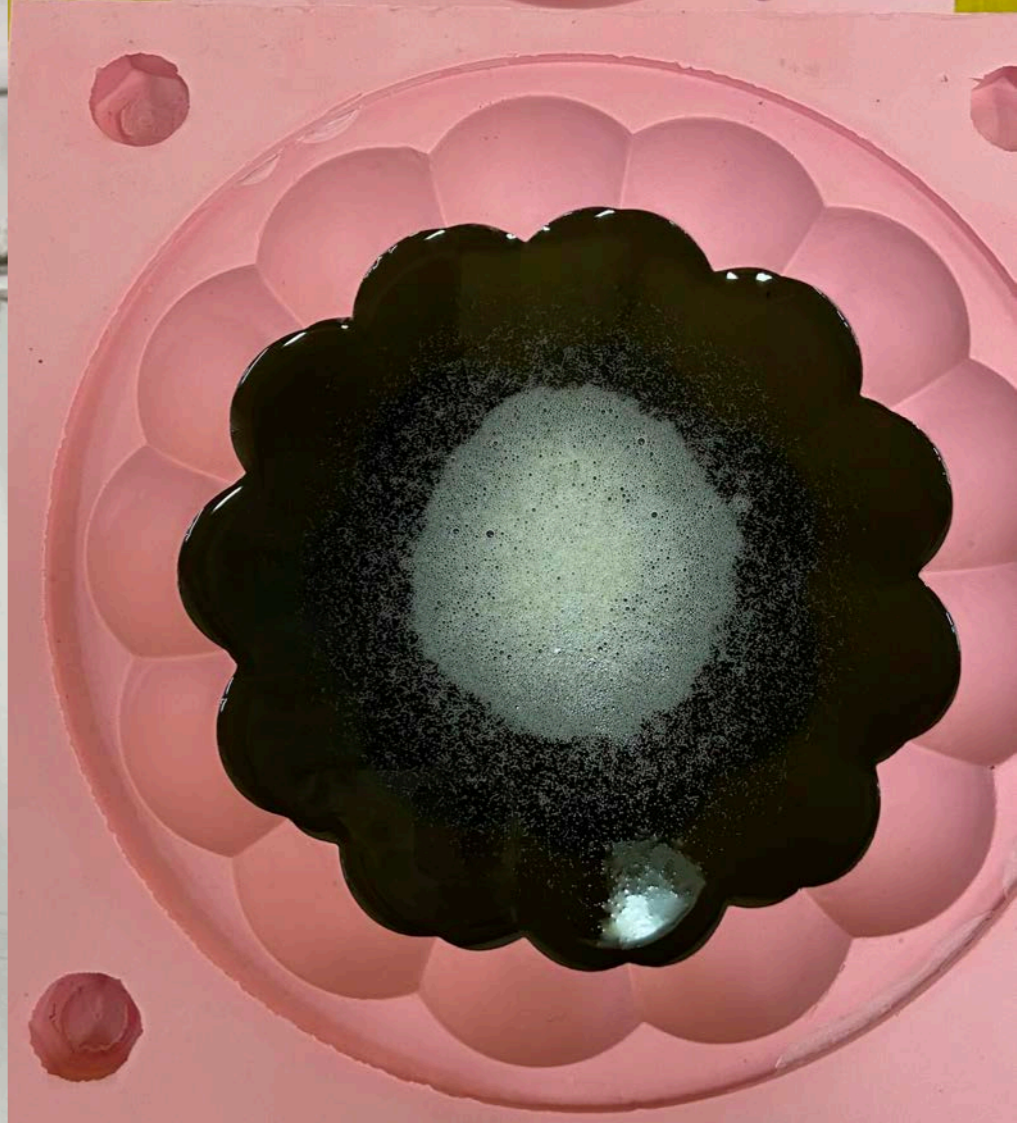
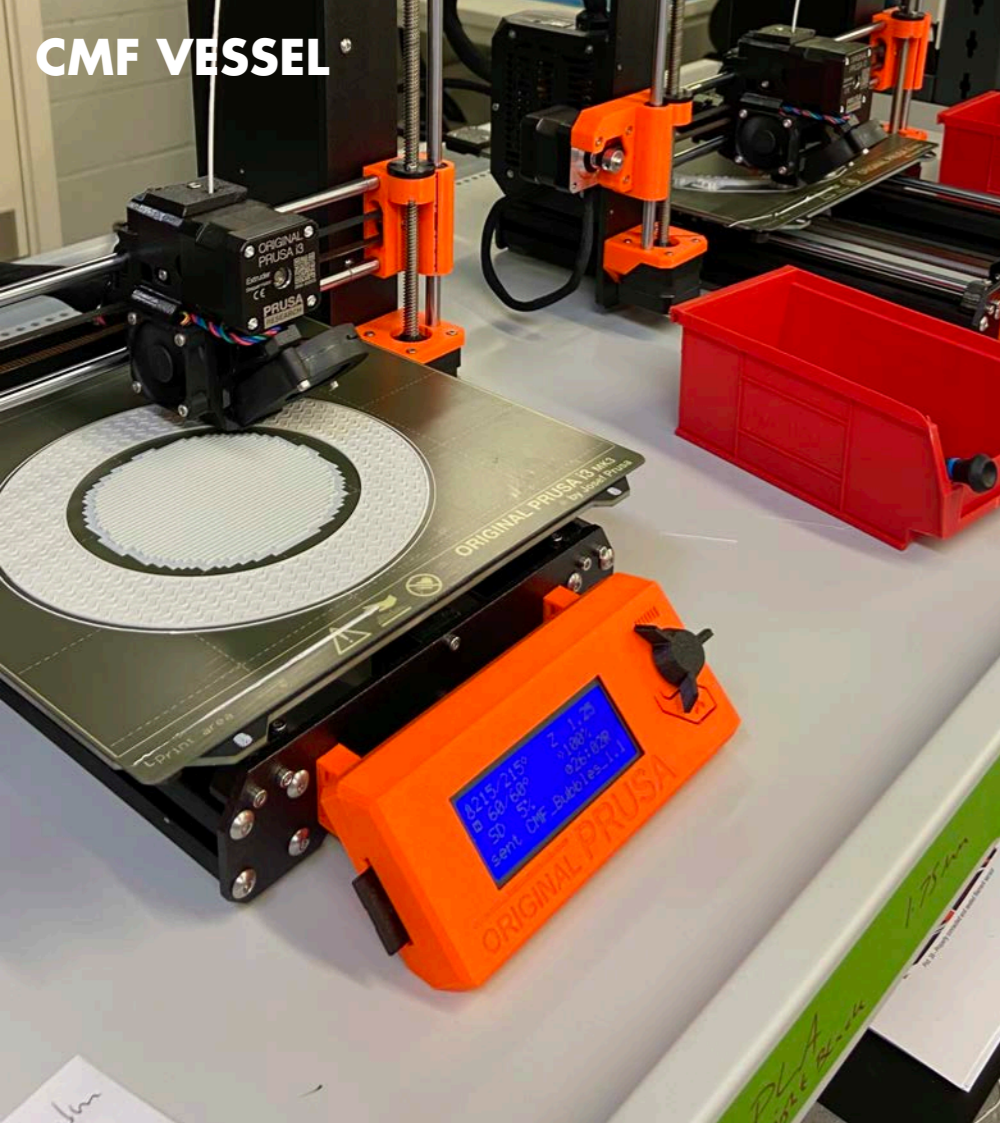
FF VESSEL





FEE VESSEL







OUTREACH + EDUCATION



x20 ~ Common Male-Fern, *Dryopteris filix-mas* // Fiddlehead

COMMUNITY OUTREACH: EARTH DAY SPORE PLATING WORKSHOP

Synopsis:
Ferns are ancient creatures, but how can humans help secure their rightful places in, now urban, native habitats? Participants built skills in the collection, cultivation, and propagation of indigenous ferns. This ferny afternoon workshop used hands-on activities to teach skills in harvesting spores from foraged fertile fern fronds. The opportunity to learn how to start a fern spore culture plate provided participants a takeaway home experiment to observe the growth of ferns in their haploid state. A stereoscope and microscope were available to encourage interaction with ferns in a multi-scaler perspective. Plant pressing and DIY home preservation techniques were demonstrated.

Outcome:
A diverse demographic participated in the workshop including elderly, children, young adults, and families. Furthermore, the participants were of different races, ethnicities, and nationalities. Most participants learned for the first time that ferns 1) propagate via spores, 2) have free swimming sperm, 3) predated seeds and flowers. Children enjoyed mostly using the microscope. Young adults were the keenest to learn how to harvest spores; however, all demographics were pleased to have a take home experiment to observe gametophyte growth. Approximately 30 spore culture plates were handed-out, zero of the participants followed-up with growth results. The most notable participant was an elderly Irish male who believed ferns to be “weeds”; however, he was willing to observe them under the microscope/stereoscope. Furthermore, he was pleased to take home a spore plate; although he was reluctant as to what he would do with the “weed” once grown.



Discussing Fern Evolution



Teaching Microscopy

COMMUNITY OUTREACH: CAMLEY STREET NATURAL PARK FERNERY

Synopsis:

Camley Street Natural Park opened in 1984 thanks to community efforts to prevent the vacant site from being purchased by land developers. Prior the site served as a coal drop for trains at King's Cross Railway Station. The park was closed to the public in 2017 and reopened in September 2021. Wildflower meadows and reedbed wetlands provide habitat for birds, invertebrates, and fish. The site of the fernery was in derelict, exiting ferns were in poor condition with low soil quality and moderate erosion. Located adjacent to my Camden flat and CSM campus, this park was selected for habituating my ferns from project research, due to my relocation back to United States.

Outcome:

Thanks to coordination with Mara Cutas, London Wildlife Trust team member, several species of native UK ferns were planted into the fernery. The topsoil was revitalized, while rockery and fallen timber as added for pteridophyte/bryophyte habitation. Species planted included: royal fern (*Osmunda regalis*), polypody (*Polypodium vulgare*), common male fern (*Dryopteris filix-mas*), holly fern (*Polystichum lonchitis*), broad buckler fern (*Dryopteris affinis*), soft shield-fern (*Polystichum setiferum*), tunbridge filmy-fern (*Humenophyllum tunbrigense*), and several unknown species of ground moss. Species were planted in best possible locations with fernery according to specific growing conditions required. For instance, polypodies were planted within cavities of fallen timber due to their epiphytic characteristics. Several volunteers assisted in the planting project.



Upper Fernery Plantings



Lower Fernery Plantings



CONTINUED EDUCATION: ANNUAL BPS MEETING

Agenda+Activities:

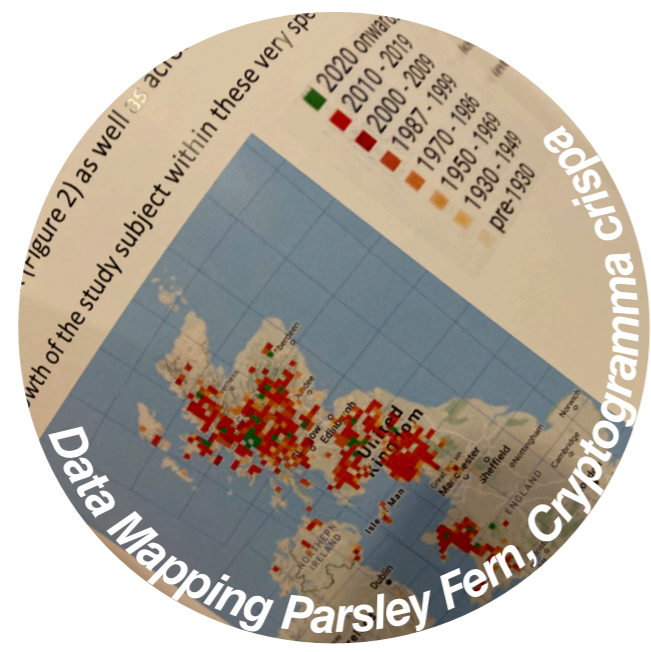
Occurring at Edge Hill University, Ormskirk, England, the annual British Pteridological Society meeting was a day full of lectures and presentations on ferns. The talks included data mapping tropical species in Central America, a beginner's exploration into ferns, cultivation methods of water ferns, and natural hybridization in British ferns. Reminders from last years spore exchange were up for offer. Additionally, a fern exchange took place, allowing members to exchange/donate/purchase grown ferns with one another. Similarly, there was a book drive facilitating the exchange of shared knowledge in fern research, identification, and cultivation/propagation. After luncheon, demonstrations with the university's new scanning electron microscope were provided. Many members brought in sori/sporangium samples for observation. Gametophyte samples of several different species were provided; however, the specimens were too wet to properly scan. Specimens were left with the lab technician to rescan once dried; however, the technicians never emailed results as promised. Networking face-to-face with BPS members was very enjoyable, and far more effective than virtual meetings of past year.



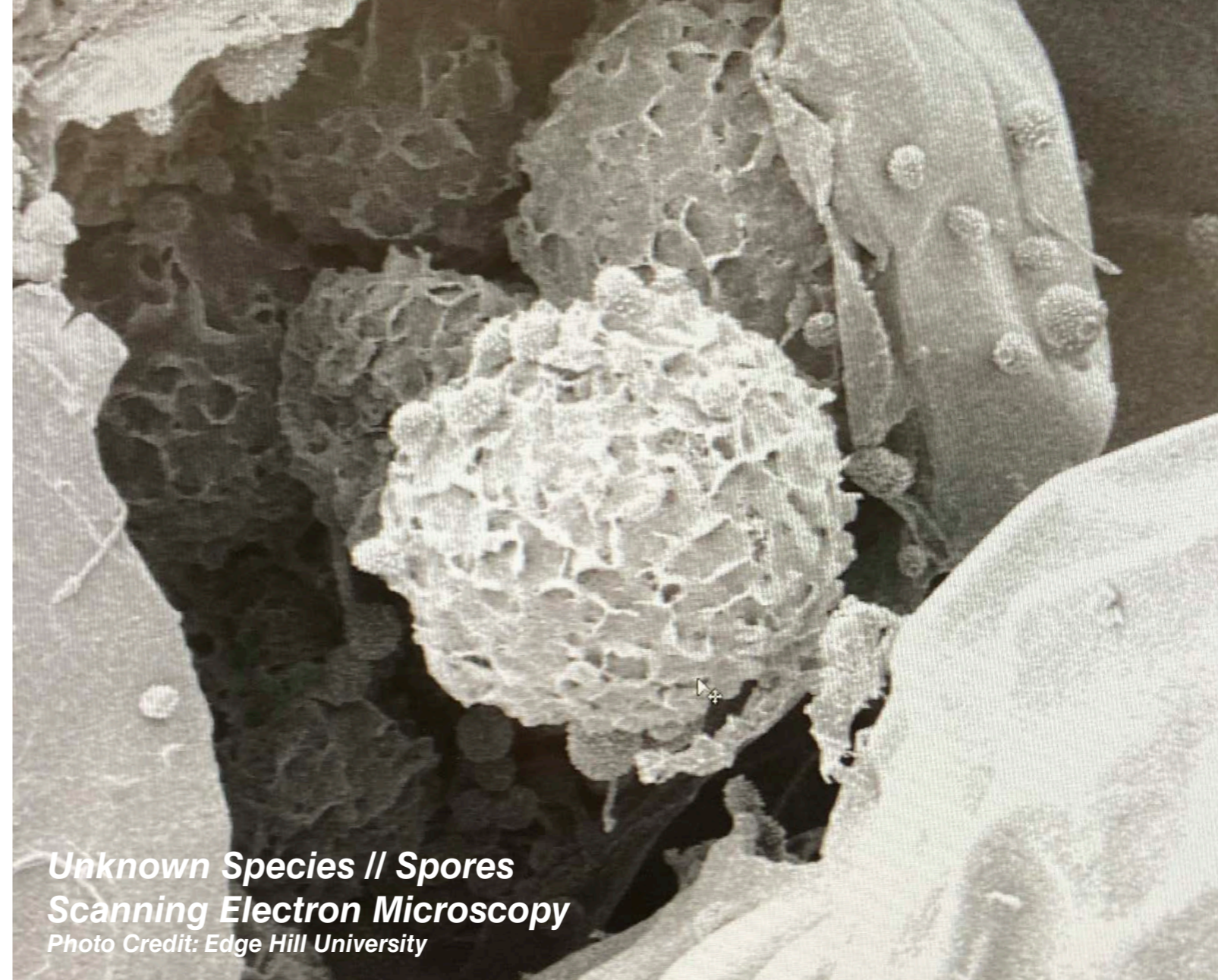
Gold Coat Prepping Specimens



Scanning Electron Microscope



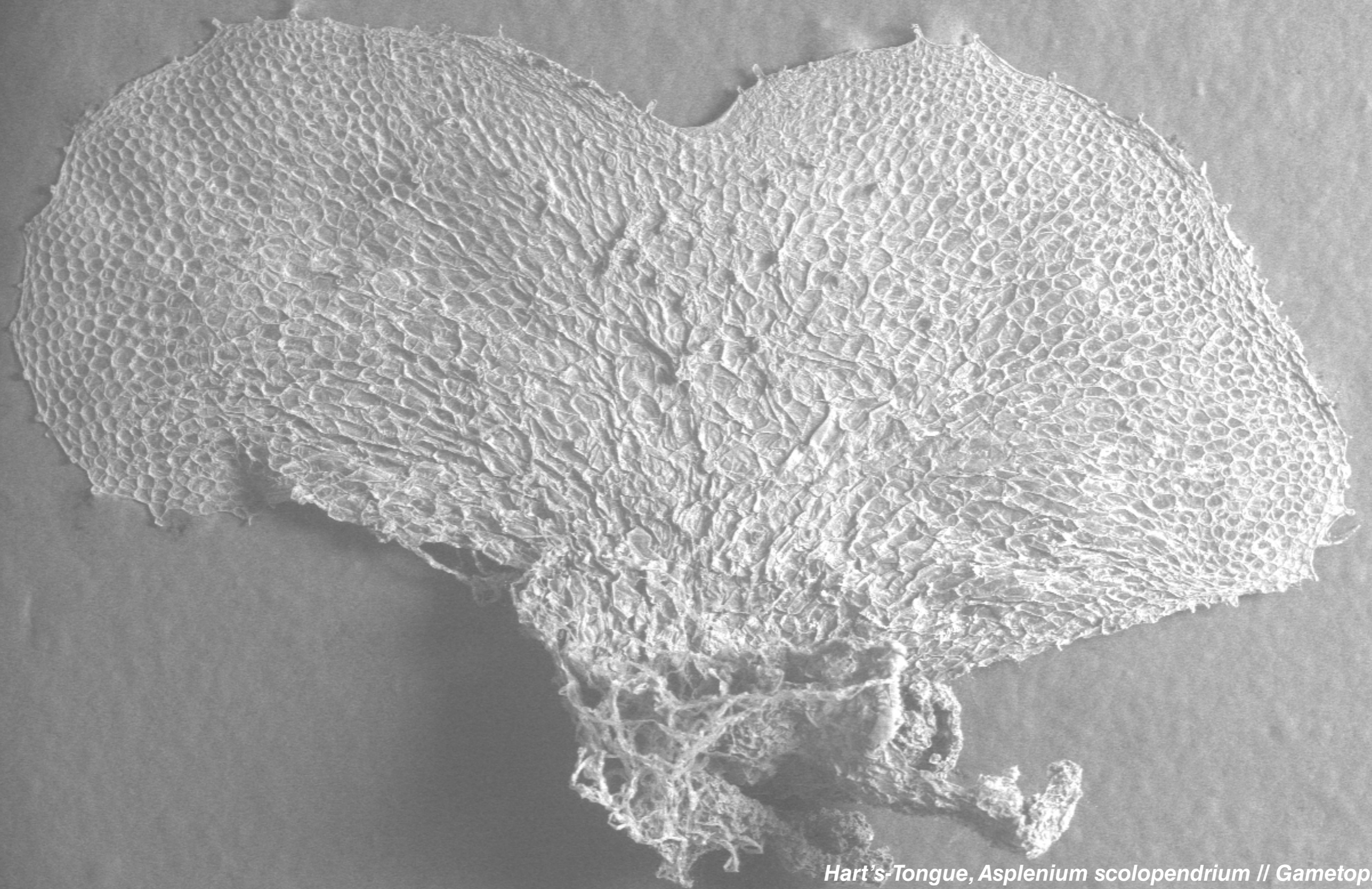
Data Mapping Parsley Fern, *Cryptogramma crispa*



Unknown Species // Spores
Scanning Electron Microscopy
Photo Credit: Edge Hill University



Scanning Electron Microscopy Specimens



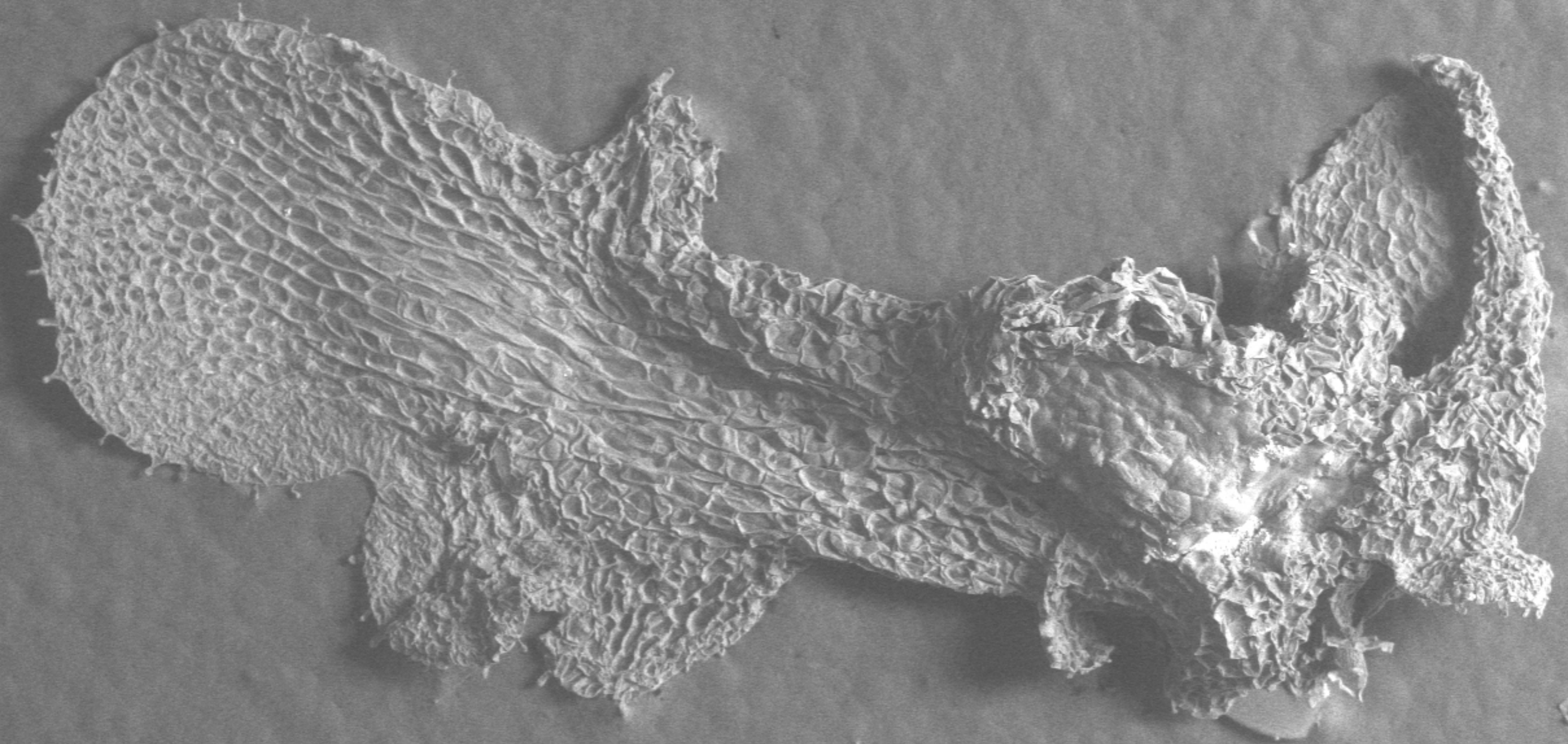
500 μm

250 μm

Hart's-Tongue, Asplenium scolopendrium // Gametophyte

Scanning Electron Microscopy

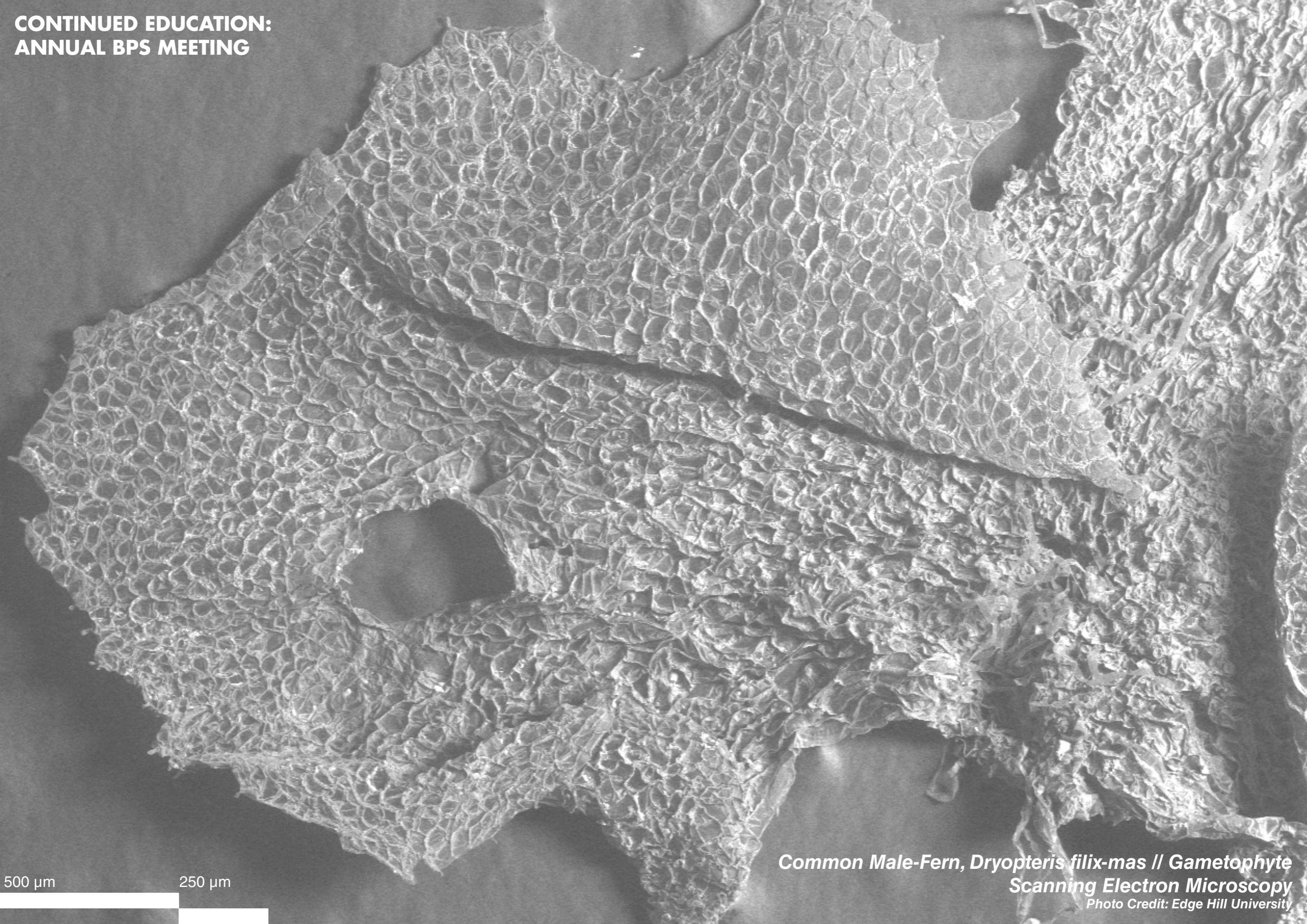
Photo Credit: Edge Hill University



500 μ m

250 μ m

Polypody, Polypodium vulgare // Gametophyte
Scanning Electron Microscopy
Photo Credit: Edge Hill University



500 μm

250 μm

Common Male-Fern, Dryopteris filix-mas // Gametophyte

Scanning Electron Microscopy

Photo Credit: Edge Hill University

**CONTINUED EDUCATION:
HISTORICAL GREENHOUSES**

Royal Botanic Gardens // Richmond, UK



Palmenhaus // Vienna, Austria



Palmhuset // Gothenburg, Sweden



Palmhuset // Copenhagen, Denmark



Benmore Botanic Garden Fernery // Scotland, UK



Linnaean Gardens // Uppsala, Sweden



CONTINUED EDUCATION: NHM PTERIDOPHYTE HERBARIUM



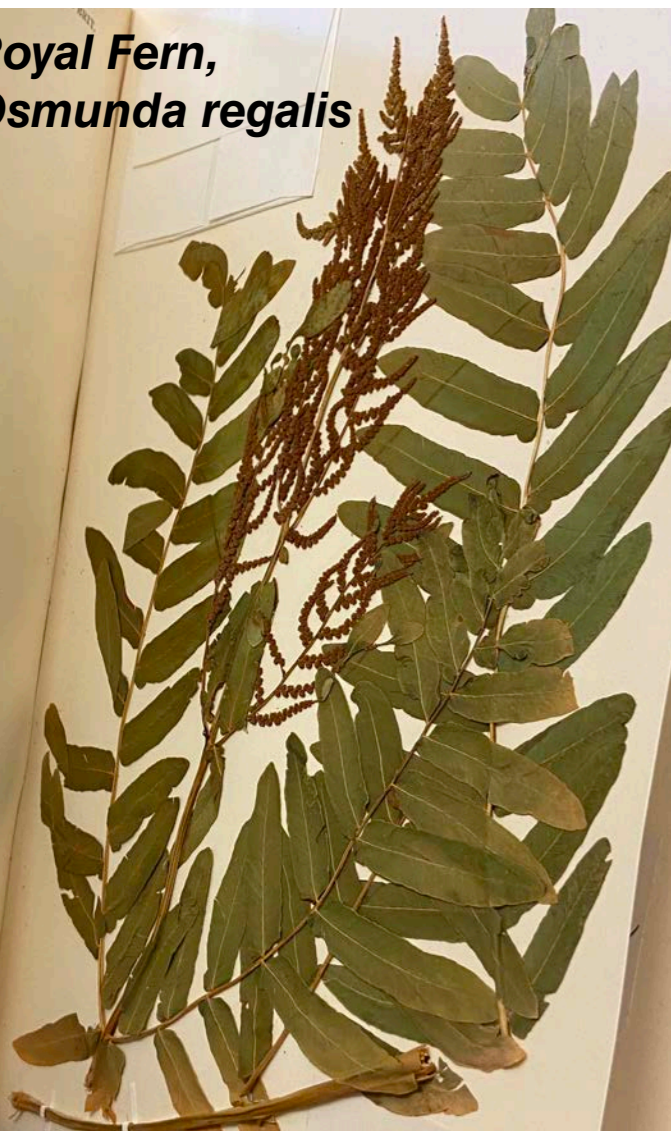
Synopsis:

The collection holds approximately 340,000 specimens total, covering approximately 20 percent of fern species (*Natural History Museum, 2021b*). It covers global fern diversity across Europe, Malesia, South Asia, Tropical America, and Macronesia. Scientific researchers may access the collection and borrow specimens to conduct their work (*Natural History Museum, 2021a*). The collection is curated by Alison Paul since 2007 (*Natural History Museum, 2021b*).

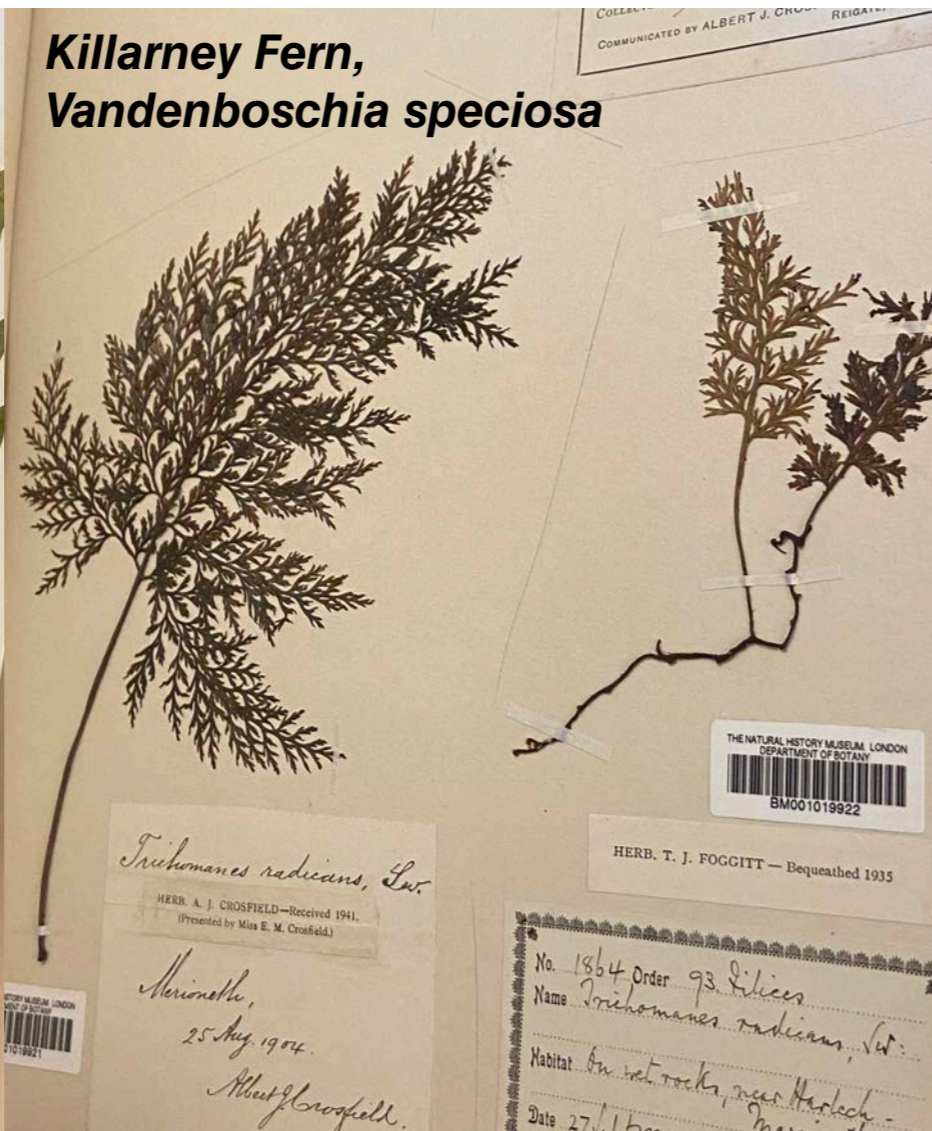
Outcome:

Due to COVID-19 pandemic access to the collection was not permitted until mid-spring 2022. During the annual BPS meeting, access was obtained via direct face-to-face networking with the Senior Curator, Alison Paul. During the visit, Alison and I discussed our memories of ferns as children, and how those memories informed our deep appreciation. Her favourite, beech fern (*Phegopteris connectilis*), reminded her of walks with her mother as a young girl; whereas, New York fern (*Parathelypteris noveboracensis*) reminds me of summers with my family at our Upstate New York cabin. The collection has specimens dating back to the 16th century. My favourite aspect of the collection visit was observing original pressings of Sir Joseph Banks during Captain Cooks expedition to New Zealand. Many of the pressing specimens have been scanned for digitization. Furthermore, it is commonplace for a drawing or picture of the entire fern and/or collection site to be documented along with the pressing. Could pressing methods for herbariums in the future utilize field 3D digital scans/photography of living specimens and their direct habitat for metaverse applications?

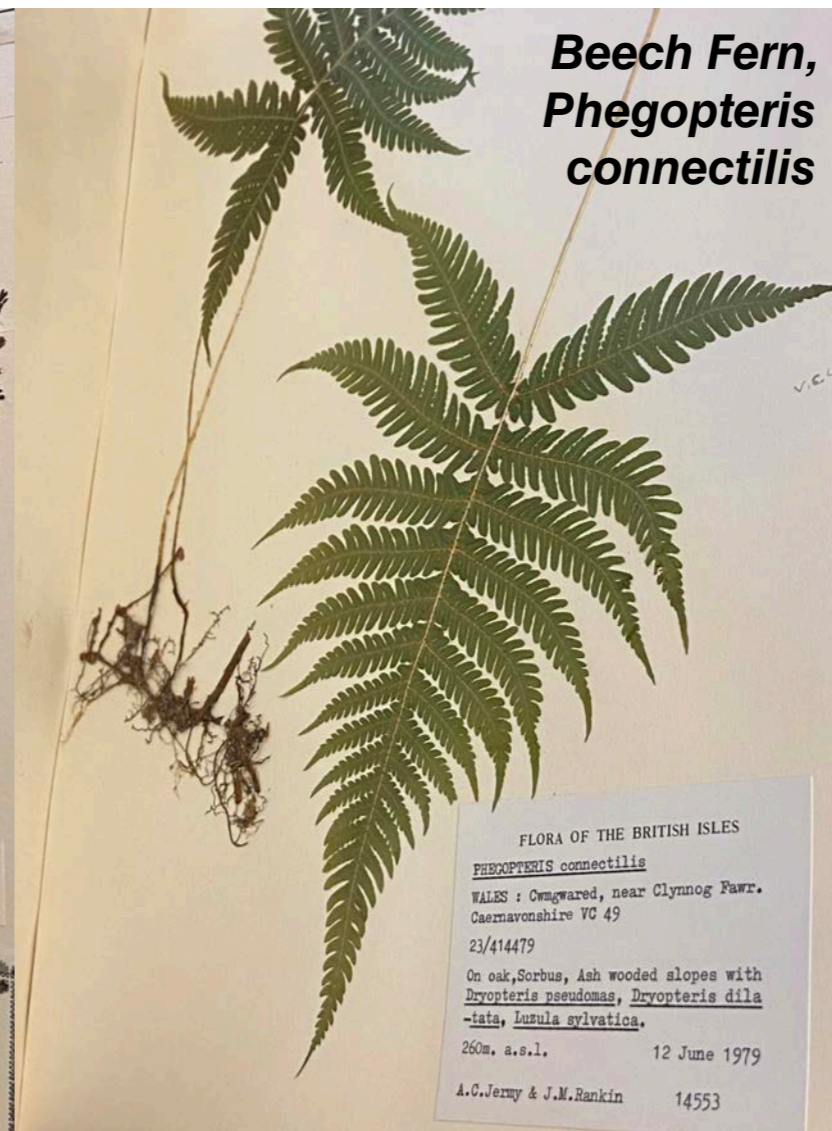
**Royal Fern,
*Osmunda regalis***



**Killarney Fern,
*Vandenboschia speciosa***



**Beech Fern,
*Phegopteris connectilis***



**Sir Joseph Banks,
Cpt. Cook Expeditions**



APPENDIX



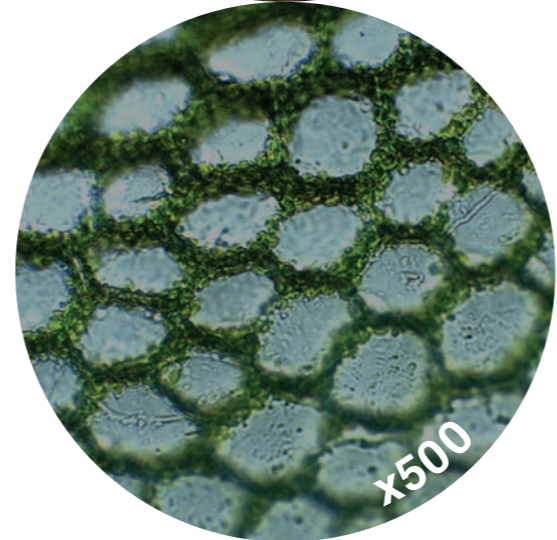
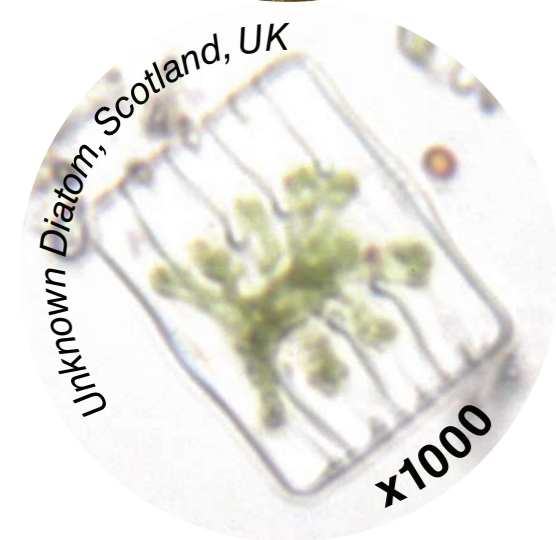
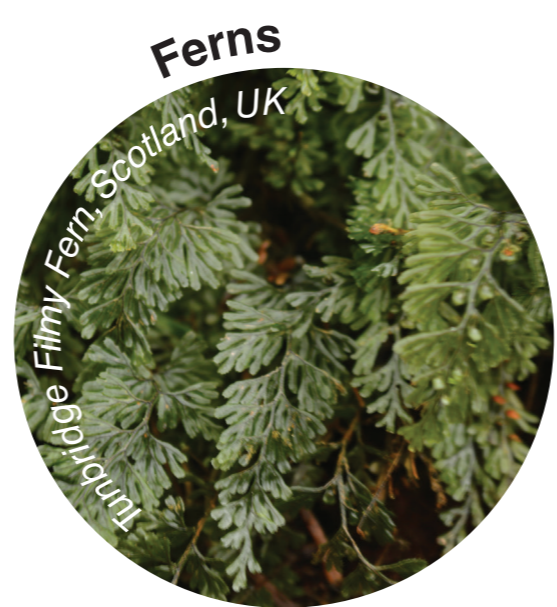
Crinan Wood // Scotland, UK

**EVOLUTIONARY NEEDS:
SITUATING FERNS**

DEPENDENCY ON WATER

DEVELOPMENT OF ROOTS

THREAT FROM DEFORESTATION



1.5 Billion
Years Ago

470 Million
Years Ago

360 Million
Years Ago

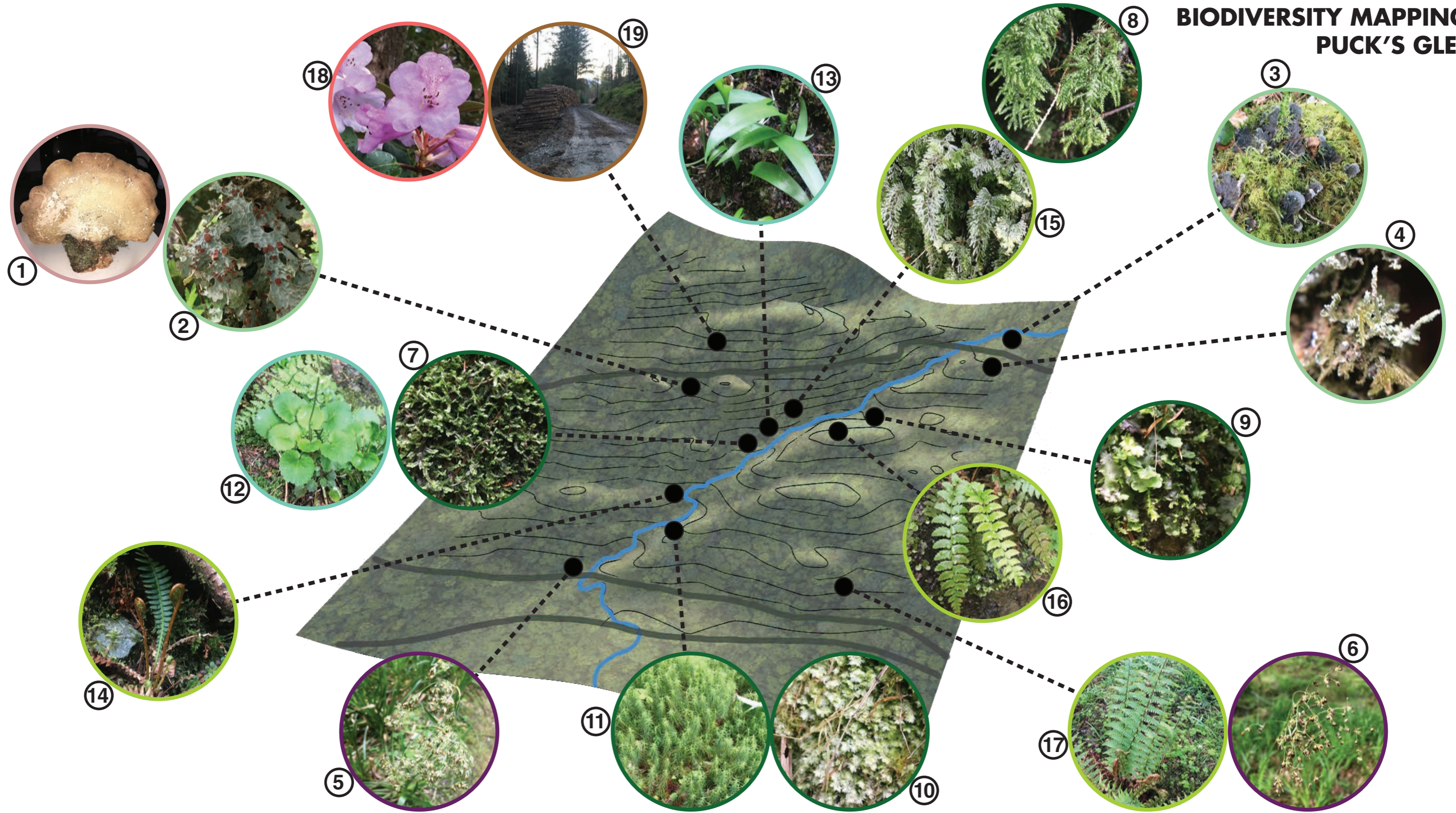
**Radiation
Event**

350 Million
Years Ago

**Radiation
Event**

150 Million
Years Ago

BIODIVERSITY MAPPING: PUCK'S GLEN



Fungi

- 1. Unknown Bracket Fungus

Lichens

- 2. Tree Lungwort, *Lobaria pulmonaria*
- 3. Dog Lichen, *Peltigera canina*
- 4. Cup Lichen, *Cladonia polydactyla*

Grasses

- 5. White Woodrush, *Luzula luzuloides*
- 6. Greater Woodrush, *Luzula sylvatica*

Bryophytes

- 7. Moss, *Eurhynchium riparioides*
- 8. Moss, *Brachythecium rivulare*
- 9. Liverwort, *Lunularia cruciata*
- 10. Pocket Moss, *Fissidens taxifolius*
- 11. Hair Moss, *Polytrichum commune*

Flowering Plants

- 12. Unknown
- 13. Wild Garlic, *Allium ursinum*

Ferns

- 14. Hard Fern, *Blechnum spicant*
- 15. Tunbridge Filmy Fern, *Hymenophyllum tunbrignese*
- 16. Holly Fern, *Polystichum lonchitis*
- 17. Scaly Male Fern, *Dryopteris pseudomas*

Invasive Species

- 18. Catawba Rosebay, *Rhododendron catawbiense*
- 19. Deforestation Site

FIELD RESEARCH: SOUND+VIDEO DOCUMENTATION

Scottish Celtic Temperate Rainforest

Sounds:

<https://freesound.org/people/iwilhelm13/packs/35524/>

Videos:

https://youtube.com/playlist?list=PLUy9-0ilW-4fDpKalq6S9kNLt_jt9lw4N

Welsh Celtic Temperate Rainforest

Videos:

https://youtube.com/playlist?list=PLUy9-0ilW-4cbqjPR89X1R5_-WYrnfASL

Cumbrian Celtic Temperate Rainforest

Sounds:

<https://freesound.org/people/iwilhelm13/packs/35525/>

Videos:

<https://youtube.com/playlist?list=PLUy9-0ilW-4fWCEwj0bdAO80NAN1BOiYk>

Costa Rican Urbanscapes + Rural Farms + Corcovado Tropical Rainforest

Sounds:

<https://freesound.org/people/iwilhelm13/packs/35527/>

Videos:

<https://youtube.com/playlist?list=PLUy9-0ilW-4deRNCApQE52KLJD1WSwvIW>

Ohio Rural Farms

Sounds:

<https://freesound.org/people/iwilhelm13/packs/35526/>

New York City Urbanscapes + Metroparks

Sounds:

<https://freesound.org/people/iwilhelm13/packs/35530/>

Copenhagen Urbanscapes + Metroparks

Sounds:

<https://freesound.org/people/iwilhelm13/packs/35531/>



Glenbranter // Scotland, UK

**FIELD RESEARCH:
SUPPLIES+EQUIPMENT**



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PROJECT VIDEO LINKS:

FoF: <https://vimeo.com/717693343>
How to Biodivurbanize Ferns: <https://vimeo.com/724109531>
Ferns i: <https://vimeo.com/724108651>
Biodivurbanization: <https://vimeo.com/724241030>



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