

FIBROLOGY: EXPLORING NEW FIBERS FOR ORIGAMI

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MISSOURI BOTANICAL GARDEN

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[@manila_folder](#)



CFC #3 – BOGOTA, COLOMBIA

11 FEBRUARY 2023



Osmoxylon mariannense
Luta, Northern
Mariana Islands
2016



Hoya carnosa
My living room
2023





Compound of Dodecahedron and Great Dodecahedron
120 uncut squares of Stardream



Bactrian Camel
One uncut hexagon of lokta

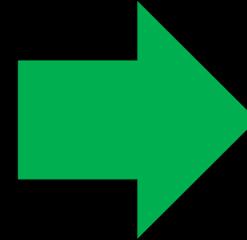
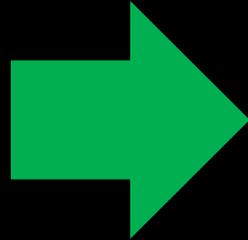


Tuliptree leaf
Liriodendron tulipifera
One uncut square of
white mulberry paper

Sassafras leaf
Sassafras albidum
One uncut square of
Grainy paper



Purple pitcher plant
Sarracenia purpurea
Several uncut sheets of
Elefantenhaut



ethnobotany (n.) – the scientific study of the relationships between people and plants



Linen



Lokta



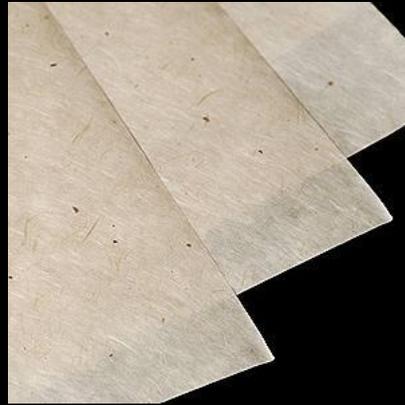
Abaca



Dó



Mitnan



Gampi



Mitsumata



Amate



Papyrus



Agua papel



Kōzō



Paper plants



Wikimedia, James Ojascastro



Origami paper plants





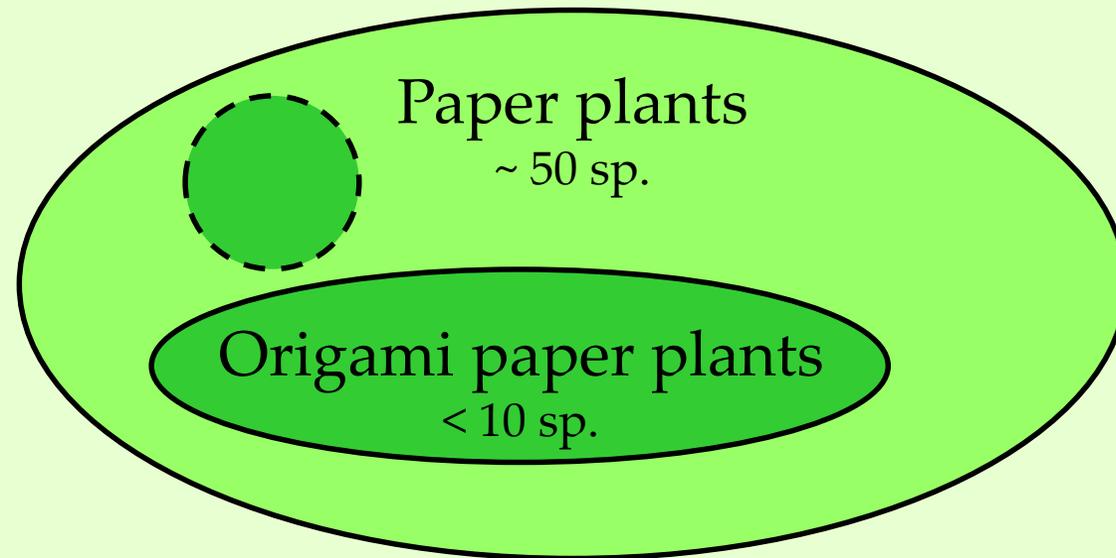
Origami paper plants

Plant kingdom
~ 320,000 sp.

Paper plants
~ 50 sp.

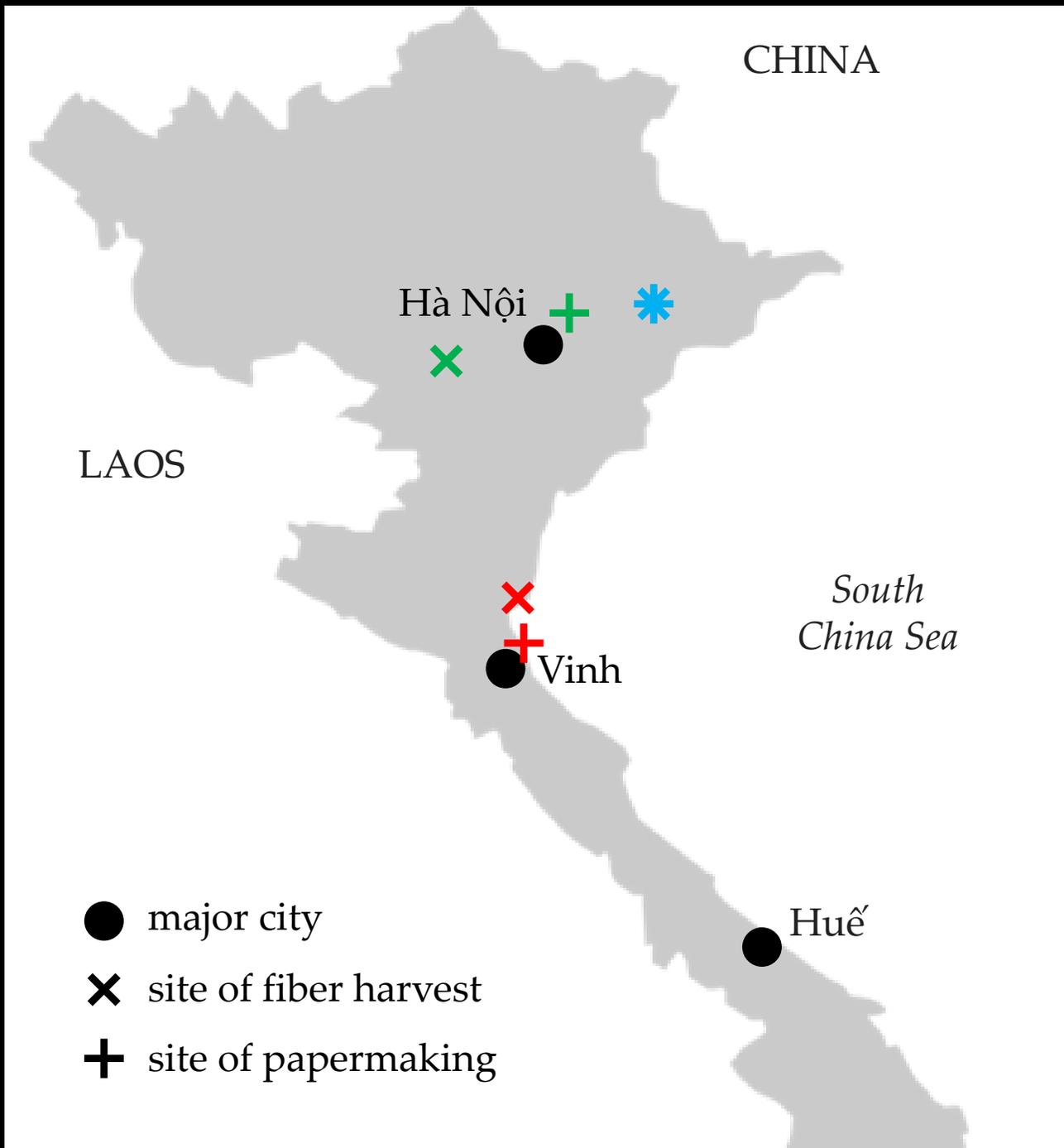
Origami paper plants
< 10 sp.

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~ 50 sp.

Origami paper plants
< 10 sp.



Vietnamese paper plants



Dó
Rhamnoneuron balansae
 Thymelaeaceae



Dó liệt
Wikstroemia indica
 Thymelaeaceae



Haupau
Linostoma persimile
 Thymelaeaceae

Maris the Otter
Designed & folded by
Jared Needle
One uncut square of dó



Jared Needle
Oregon, USA

Tarantula
Designed & folded by
Cekouat León
One uncut square of dó liệt



Cekouat León
CDMX, Mexico

Bactrian Camel
Designed by Shuki Kato
Folded by Ryan Charpentier
One uncut square of haupau



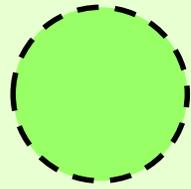
Ryan Charpentier
New York, USA

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Paper from Plants – Peter & Donna Thomas, 1999

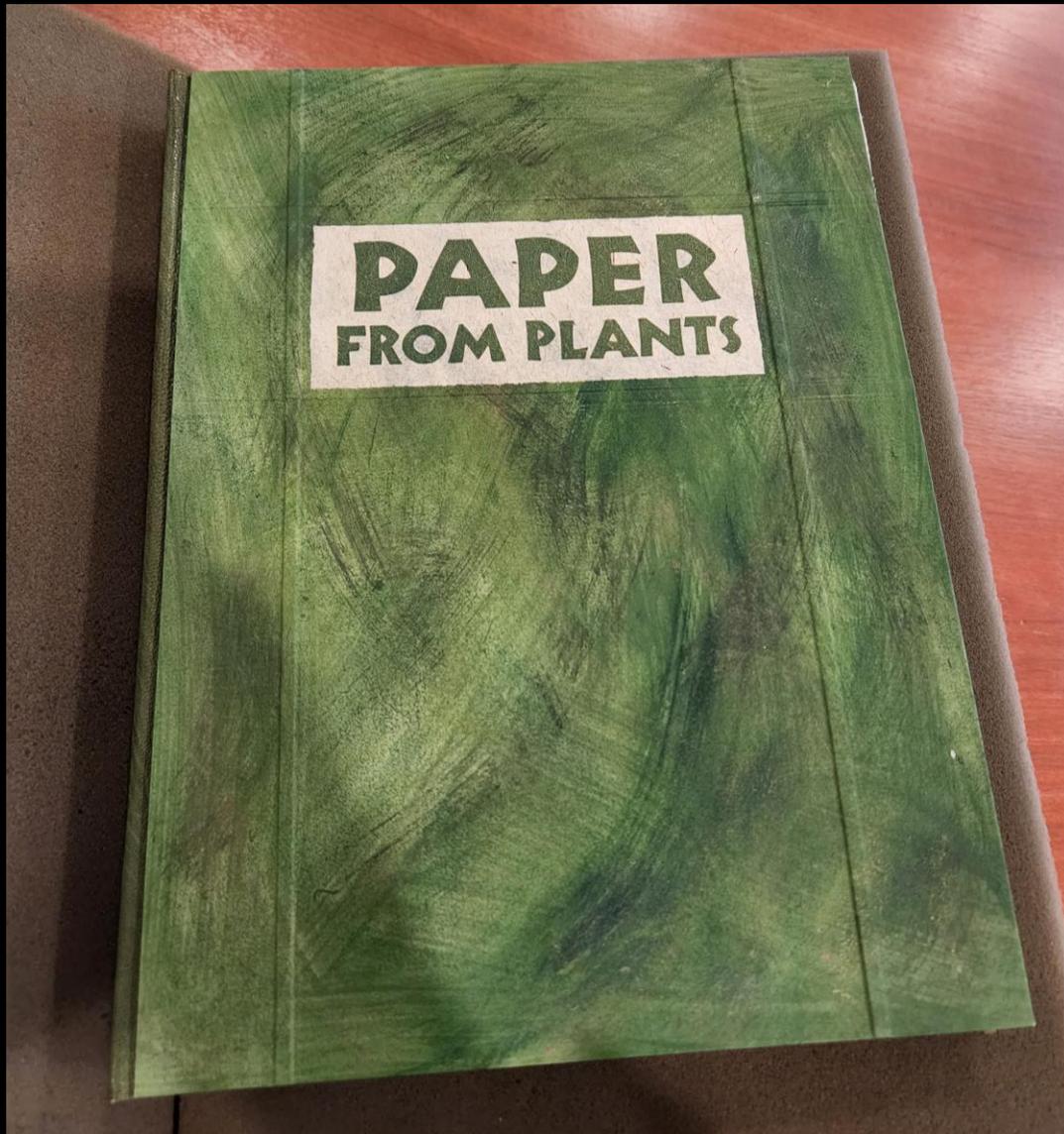


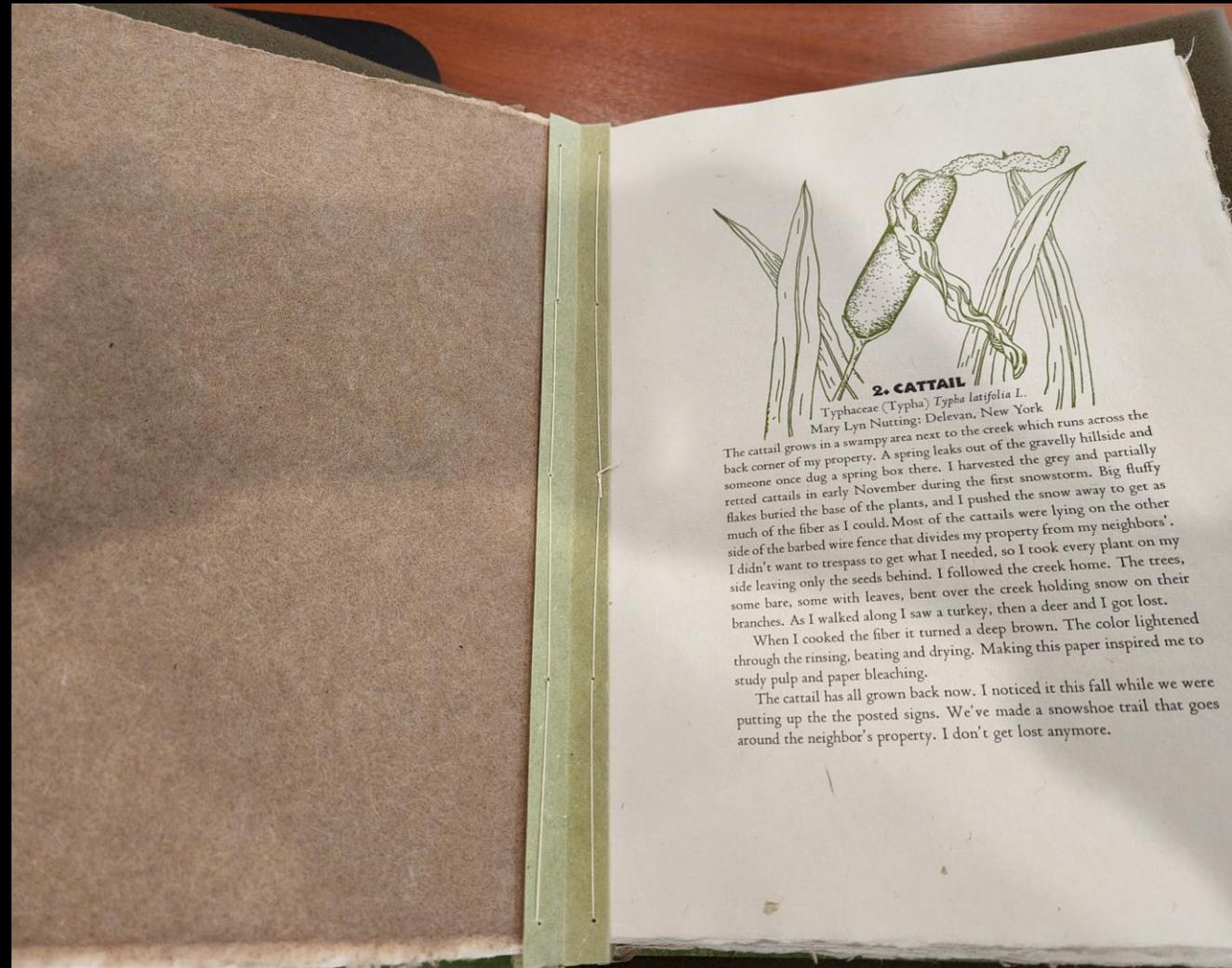
Table of contents:

1. Barley straw: Poaceae (Grass) *Hordeum vulgare*
2. Cattail: Typhaceae (Typha) *Typha latifolia* L.
3. Coconut husk: Palmae (Palm) *Cocos nucifera* L.
4. Corn: Poaceae (Grass) *Zea mays*
5. Daphne: Thymelaceae (Mezereum) *Daphne laureola*
6. Fennel: Umbelliferae (Parsley) *Foeniculum vulgare*
7. Ginkgo: Ginkgoaceae (Ginko) *Ginkgo biloba*
8. Gladwin iris: Iridaceae (Iris) *Iris foetidissima*
9. Hop: Moraceae (Mulberry) *Humulus lupulus* L.
10. Kozo: Moraceae (Mulberry) *Broussonetia papyrifera* L.
11. Marijuana: Moraceae (Mulberry) *Cannabis sativa*
12. Okra: Malvaceae (Mallow) *Hibiscus esculentus* L.
13. Pampas grass: Poaceae (Grass) *Cortaderia selloana*
14. Paper mulberry: Moraceae (Mulberry) *Broussonetia papyrifera* L.
Mugwort: Compositae (Composite) *Artemisia vulgaris* L.
15. Pine needles: Pinaceae (Pinus) *Pinus ponderosa*
16. Prairie cordgrass: Poaceae (Grass) *Spartina pectinata*
17. Reed canary grass: Poaceae (Grass) *Phalaris arundinacea* L.
18. Sisal hemp: Agavaceae (Agave) *Agave sisalana*
Rhubarb: Polygonaceae (Buckwheat) *Rheum rhabarbarum*
19. Soft-stem bulrush: Cyperaceae (Sedge) *Scirpus validus*
20. Sorghum: Poaceae (Grass) *Sorghum bicolor*
21. Spanish moss: Bromeliaceae (Pineapple) *Tillandsia usneoides*
22. Spartina: Poaceae (Grass) *Spartina alterniflora*
23. Stinging nettle: Urticaceae (Nettle) *Urtica dioica* L.
24. Sweet pea: Leguminosae (Pea) *Lathyrus odoratus*
25. Tawny day lily: Liliaceae (Lily) *Hemerocallis carolus* L.
26. Texas kozo: Moraceae (Mulberry) *Broussonetia papyrifera* L.
27. Tobacco: Solanaceae (Nightshade) *Nicotiana tabacum*
28. Wheat straw: Poaceae (Grass) *Triticum aestivum*
29. Yucca: Agavaceae (Agave) *Yucca baccata*
30. Colophon/Cotton: Malvaceae (Mallow) *Gossypium hirsutum*

Paper from Plants – Peter & Donna Thomas, 1999



Ponderosa pine
Pinus ponderosa
needles



Broad-leaved cattail
Typha latifolia
leaves

unnamed forthcoming PhD thesis – James Ojascastro, 2023

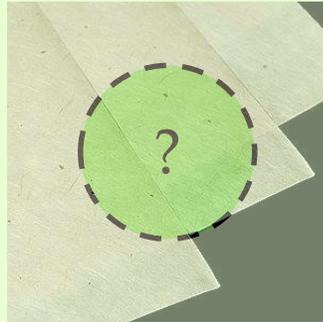


Pawpaw
Asimina triloba
phloem

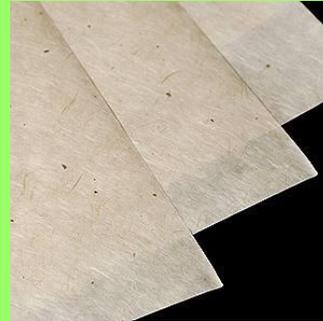


Hybrid wisteria
Wisteria ×formosa
phloem

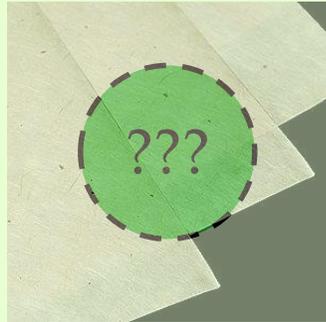
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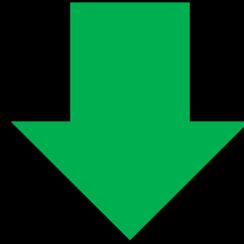
1 in 6400
0.015625% chance

Paper plants
~ 50 sp.

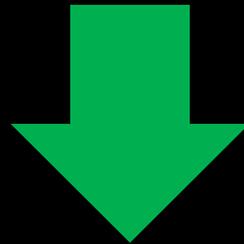
Is there an alternative to
pure trial and error?

Plant kingdom

~ 320,000 species



1. Long, strong, cellulosic fibers
2. Abundant
3. Regenerates after harvest
4. Easily processed
5. Toxic



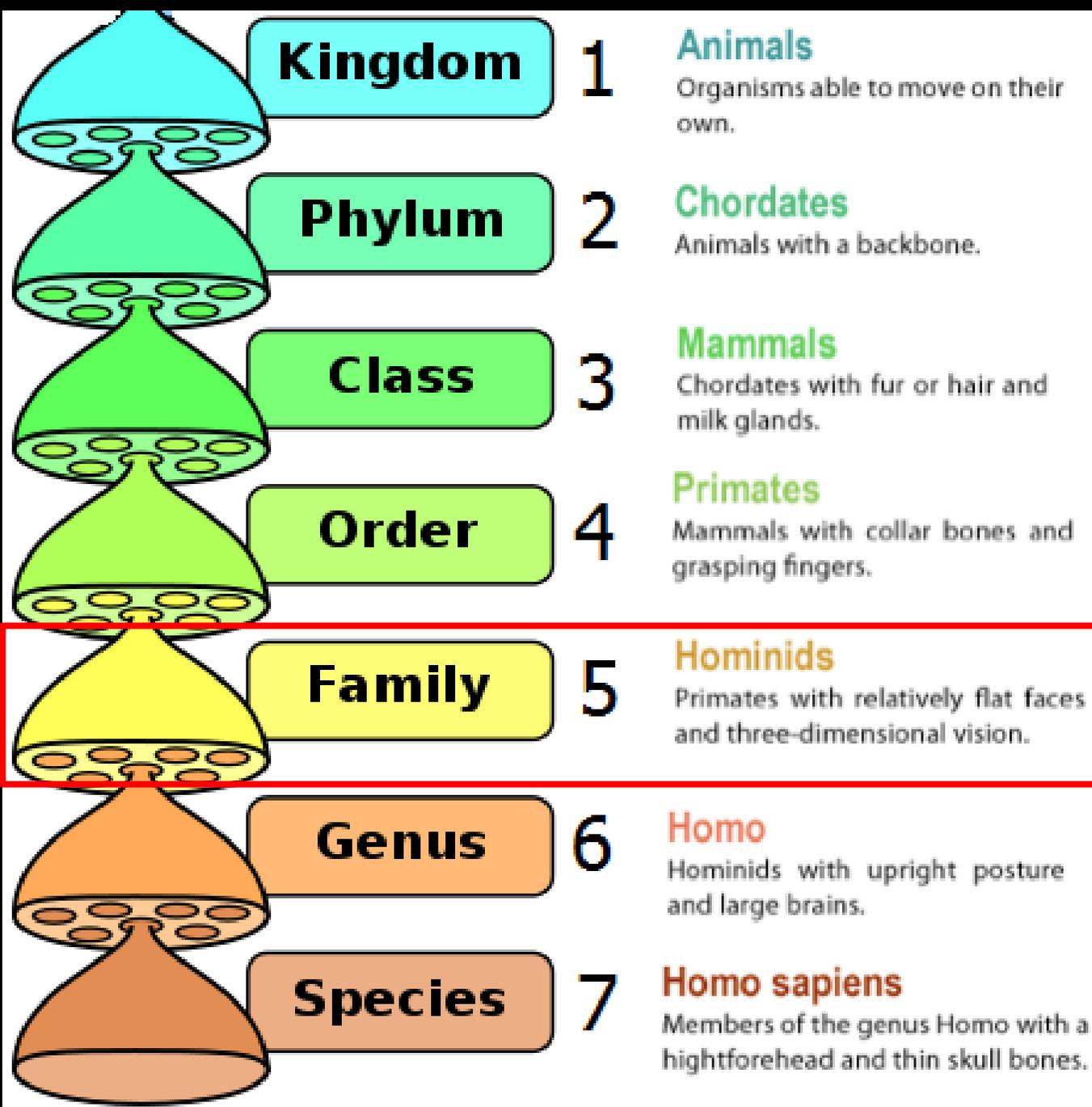
Paper plants .

~ 50 sp.



In general, plants with shared characteristics are more likely to have a shared evolutionary history!





-aceae

Thymelaeaceae

“There is one outstanding and unmistakable vegetative character: the thick homogeneous bark is *extremely strong* and *any part of it strips as a unit from twig or trunk base to apex.*”

– Alwyn Gentry



Mitsumata
Edgeworthia chrysantha
Japan



Lokta
Daphne bholua
Nepal



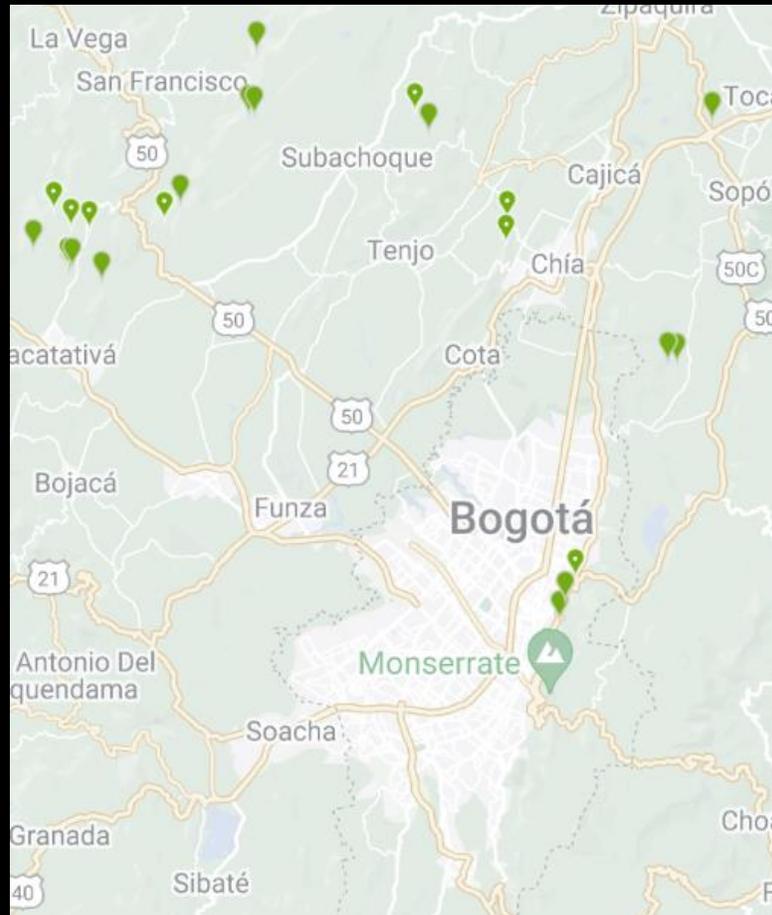
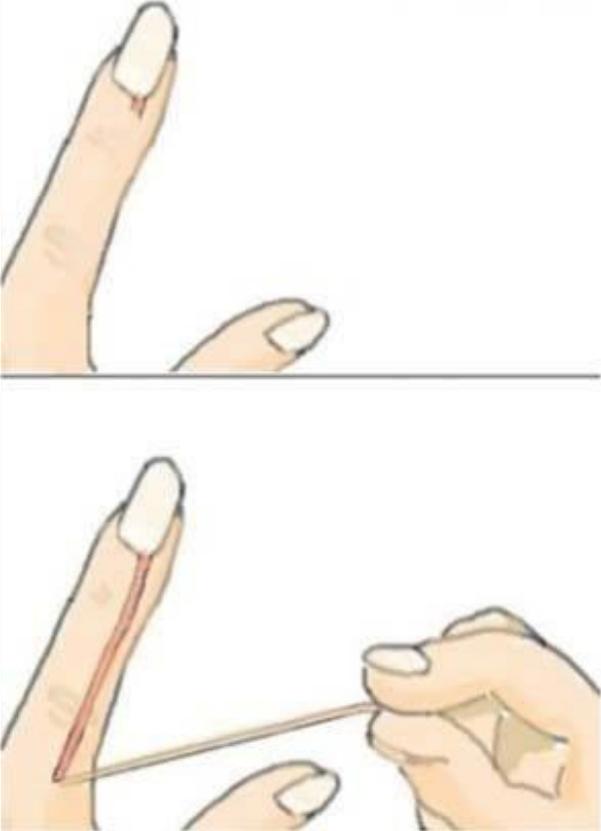
Eastern leatherwood
Dirca palustris
USA



Rechakpa
Stellera chamaejasme
Tibet

Thymelaeaceae cerca Bogotá

thymelaeaceae bark be like:



Uné
Daphnopsis caracasana
Thymelaeaceae

...also many Moraceae

“...the thick homogeneous bark is extremely strong and any part of it strips as a unit from twig or trunk base to apex.”

– Alwyn Gentry

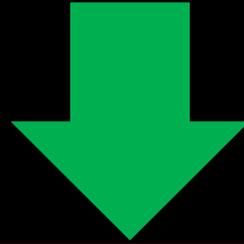
Paper mulberry / dương
Broussonetia papyrifera
Moraceae



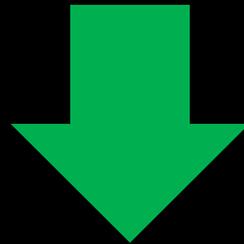
Can we use fiber physiology &
plant evolution to inform what
plants might be good
candidates for novel papers?

Plant kingdom

~ 320,000 species



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4. Easily processed
5. Toxic



Paper plants

~ 50 sp.



In general, plants with shared characteristics are more likely to have a shared evolutionary history!



FIBER PHYSIOLOGY

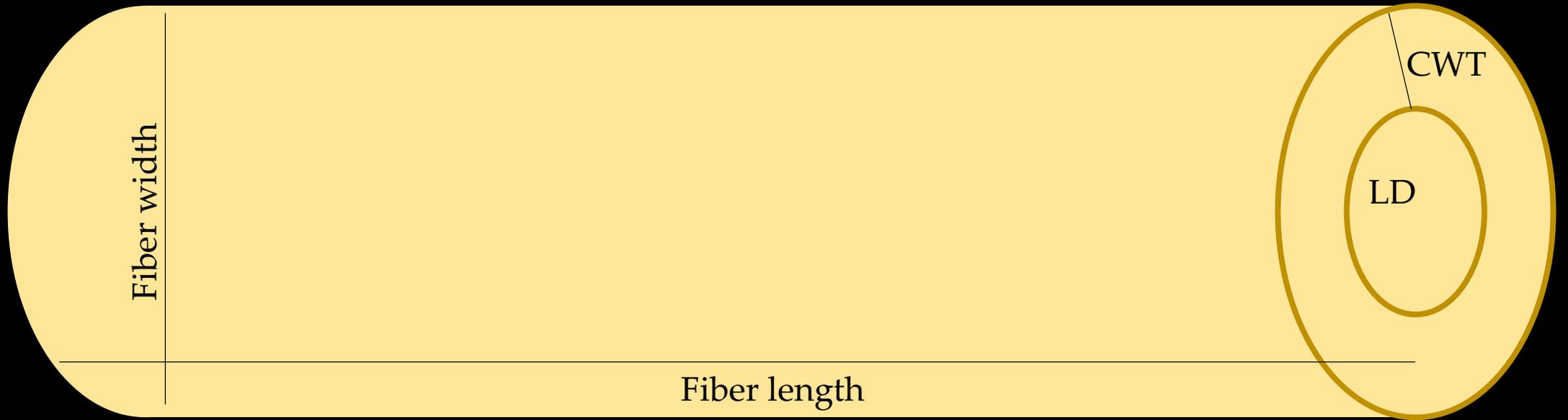


Table IV: Relationships between the morphological properties of fiber cells and the physical properties of paper (Dadswell 1961; Bostanci, 1987)

Relationships	BS ^a	TS ^b	DFS ^c	PD ^d
with increasing the fiber length	+	++	+	-
with increasing the cell wall thickness	-	+	--	--
with decreasing the cell wall thickness	+	-	++	++
with increasing the fiber length/fiber diameter			+	
with increasing the spiral grain	--	+	+	-

^aBurst strength; ^bTearing strength; ^cDouble folding strength; ^dPaper density; +it had been determined that it has a positive effect; ++There is certainly positive effect; -it had been determined that it has a negative effect; --There is certainly negative effect

FIBER PHYSIOLOGY

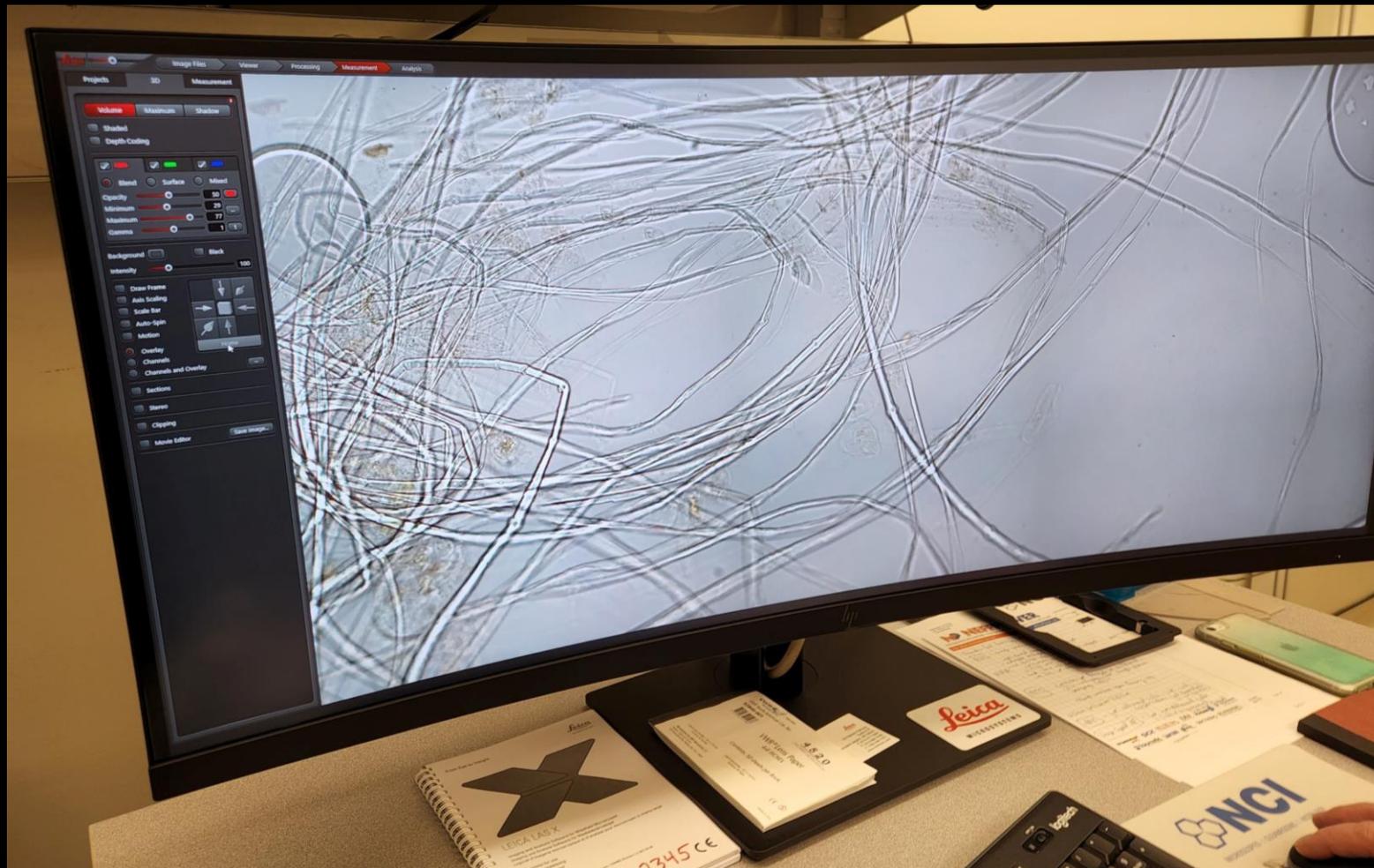


Thymelaeaceae Bast Fibres in Zinc Chloride Iodine and Cupric Oxide Ammonium

	<i>Edgeworthia gardneri</i>	<i>Daphne involucrata</i>	<i>Daphne bholua & Daphne papyracea</i>	<i>Daphne retusa</i>	<i>Daphne tangutica</i>
Vertical distribution in Nepal (m.)	1500-2400	1200-1800	1800-3600 1600-3000	3000-4000	(West China 600-3000)
Fibre length (mm.)	1 ½-5 (7 ½)	2-6 ½	2-7 ½	3-5 ½	2 ½-5 ½
Fibre breadth (μ)	4-20 (25)	3-20	6-20	6-20 (25)	6-20

<i>Daphne giraldii</i>	<i>Daphne sericea</i>	<i>Daphne alpina</i>	<i>Daphne mezereum</i>	<i>Wikstroemia canescens</i>	<i>Wikstroemia chamaejasme</i>
(West China 1000?-3000)	(East Mediterranean)	(South and Central Europe)	(Eurasia)	1500-3000	2500-4500 (N.B. fibres from roots)
2-4 ½	1 ½-4	1 ½-4 ½	2-4	½-4	½-3 ½
5-15 (20)	4-15	6-15 (20)	6-15 (20)	4-20	4-20

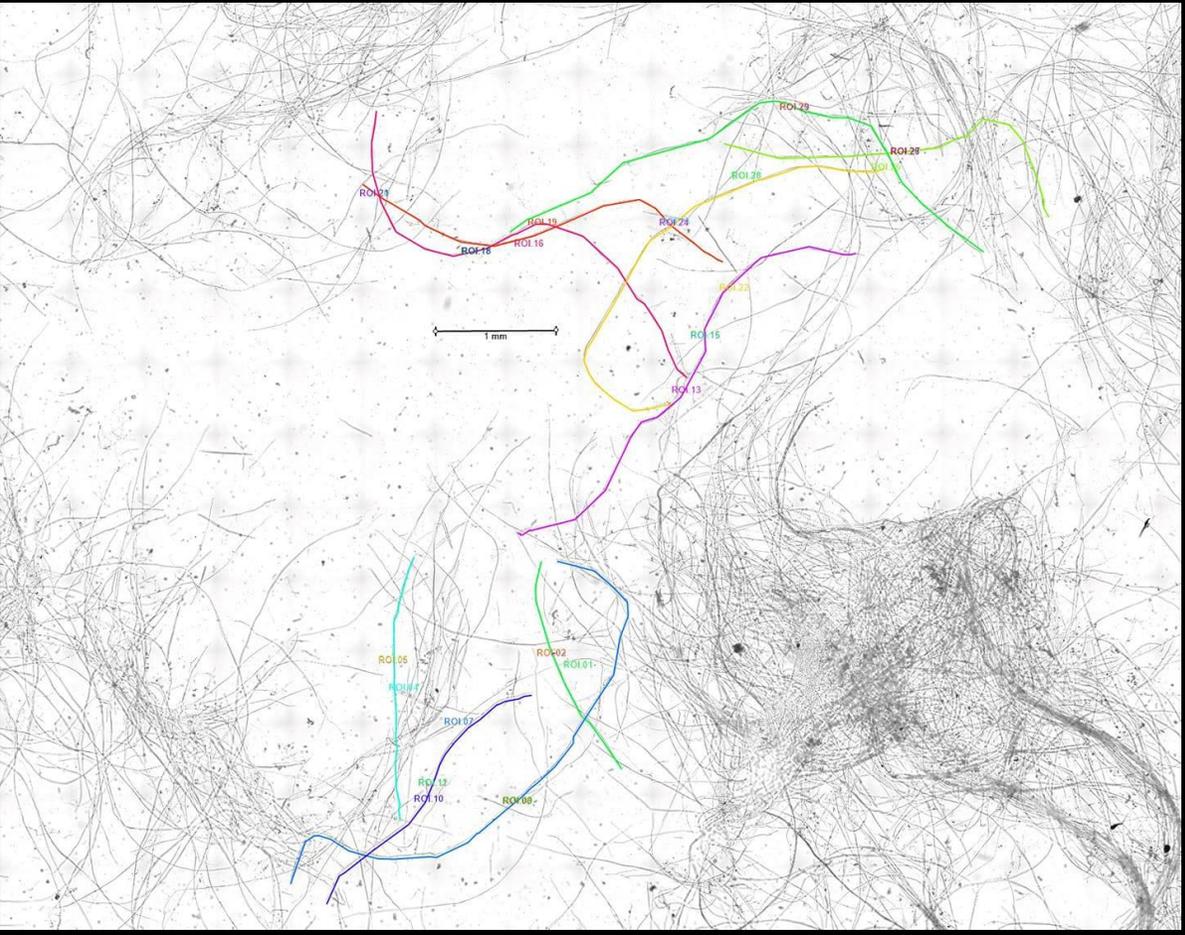
FIBER PHYSIOLOGY



Mitsumata
Edgeworthia chrysantha
Thymelaeaceae
Japan

Length	Width	Lumen	Cell wall
4458	15.68	5.47	5.105

FIBER PHYSIOLOGY



Length	Width	Lumen	Cell wall
3585	10.5	4.15	3.175

papier Antemoro
Avoha (*Gnidia linearis*)
Thymelaeaceae
Madagascar

FIBER PHYSIOLOGY

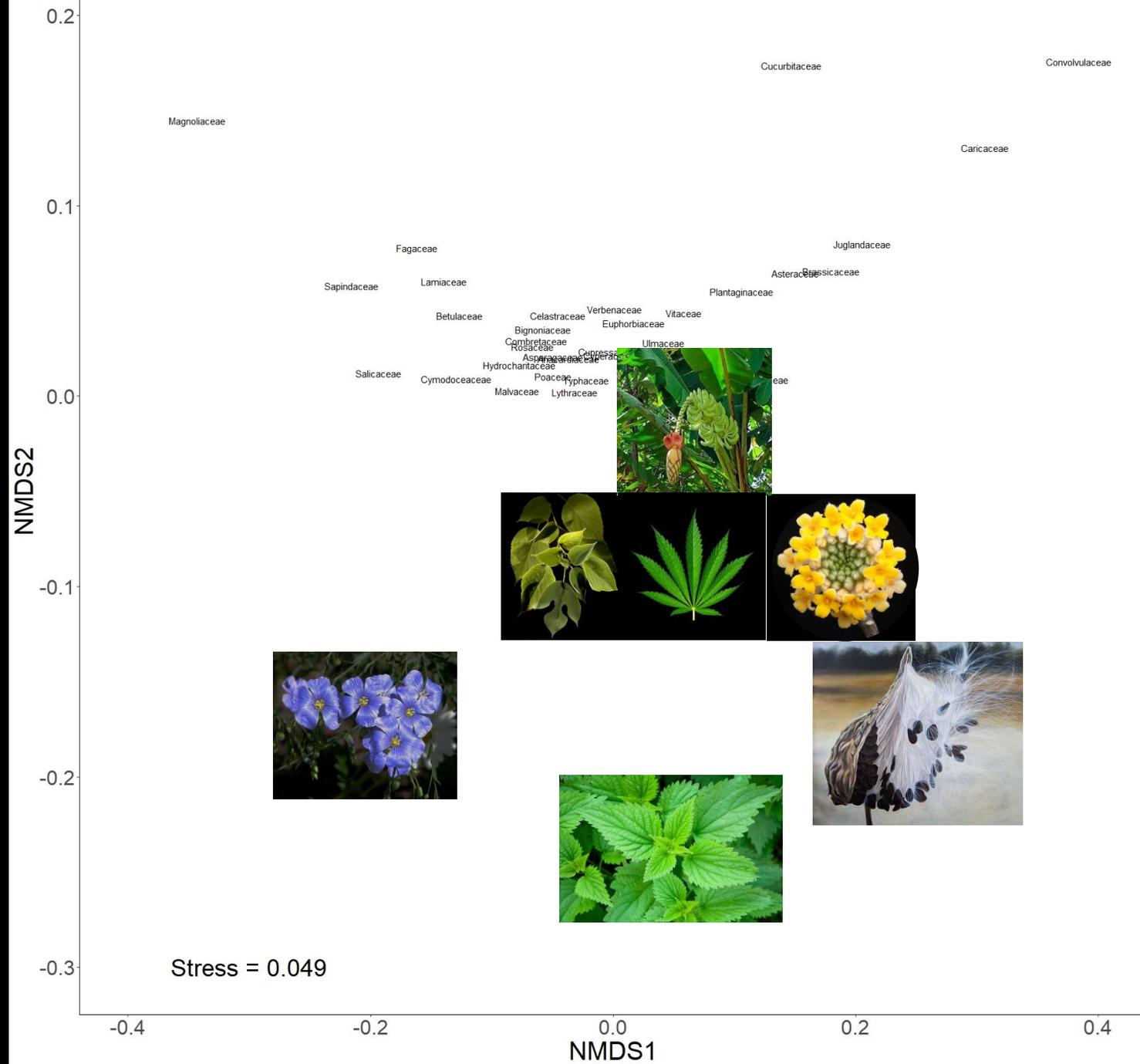
The image shows a Microsoft Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	family	species	tissue	paper	length	width	lumen	cell_wall	slenderness	flexibility	runkel	source	notes				
2	Anacardiaceae	<i>Mangifera gedibe</i>	stem	0	1649	24.6	10.1	7.2	67.03252	41.05691	1.425743	Budi 2009					
3	Apocynaceae	<i>Asclepias syriaca</i>	seed	0	33000	19	16	1.5	1736.842	84.21053	0.1875	Dischendo	https://books.google.com/books?hl=en&lr=&id=Yqp5d				
4	Apocynaceae	<i>Calotropis procera</i>	stem	0	12700	33.98	22.12	5.7	373.7493	65.09712	0.515371	Tarabi et al.	2016				
5	Apocynaceae	<i>Leptadenia pyrotechnica</i>	stem	0	700	18.2	11.4	7	38.46154	62.63736	1.22807	Saeed et al.	2018				
6	Arecaceae	<i>Arenga engleri</i>	leaf	0	1660	15.6	7.2	4.2	106.4103	46.15385	1.166667	Zhai et al.	2013				
7	Arecaceae	<i>Butia capitata</i>	leaf	0	1530	11.7	5.3	3.2	130.7692	45.29915	1.207547	Zhai et al.	2013				
8	Arecaceae	<i>Calamus brandisii</i>	leaf	0	1656	16	9	3.5	103.5	56.25	0.777778	Bhat et al.	1993				
9	Arecaceae	<i>Calamus dransfeldii</i>	leaf	0	1800	20	12	4	90	60	0.666667	Bhat et al.	1993				
10	Arecaceae	<i>Calamus gamblei</i>	leaf	0	1680	20	10	5	84	50	1	Bhat et al.	1993				
11	Arecaceae	<i>Calamus hookerianus</i>	leaf	0	1560	22	14	4	70.90909	63.63636	0.571429	Bhat et al.	1993				
12	Arecaceae	<i>Calamus karnatakensis</i>	leaf	0	1900	21	10	5.5	90.47619	47.61905	1.1	Bhat et al.	1993				
13	Arecaceae	<i>Calamus lacciferus</i>	leaf	0	2123	20	11	4.5	106.15	55	0.818182	Bhat et al.	1993				
14	Arecaceae	<i>Calamus lakshmanae</i>	leaf	0	1523	15	7	4	101.5333	46.66667	1.142857	Bhat et al.	1993				
15	Arecaceae	<i>Calamus metzianus</i>	leaf	0	1670	23	19	2	72.6087	82.6087	0.210526	Bhat et al.	1993				
16	Arecaceae	<i>Calamus nagbettai</i>	leaf	0	1980	21	10	5.5	94.28571	47.61905	1.1	Bhat et al.	1993				
17	Arecaceae	<i>Calamus pseudotenuis</i>	leaf	0	1811	22	13	4.5	82.31818	59.09091	0.692308	Bhat et al.	1993				
18	Arecaceae	<i>Calamus stoloniferus</i>	leaf	0	1778	17	9	4	104.5882	52.94118	0.888889	Bhat et al.	1993				
19	Arecaceae	<i>Calamus travancoricus</i>	leaf	0	1400	17	7	5	82.35294	41.17647	1.428571	Bhat et al.	1993				
20	Arecaceae	<i>Calamus vattayila</i>	leaf	0	1900	21	15	3	90.47619	71.42857	0.4	Bhat et al.	1993				
21	Arecaceae	<i>Calamus rotang</i>	leaf	1	1921	16	9	3.5	120.0625	56.25	0.777778	Tsien 1973; Bhat et al.	1993				
22	Arecaceae	<i>Calamus thwaitesii</i>	leaf	0	1700	19	8	5.5	89.47368	42.10526	1.375						
23	Arecaceae	<i>Carvota maxima</i>	leaf	0	1120	16.9	9.3	3.8	66.27219	55.02959	0.817204	Zhai et al.	2013				

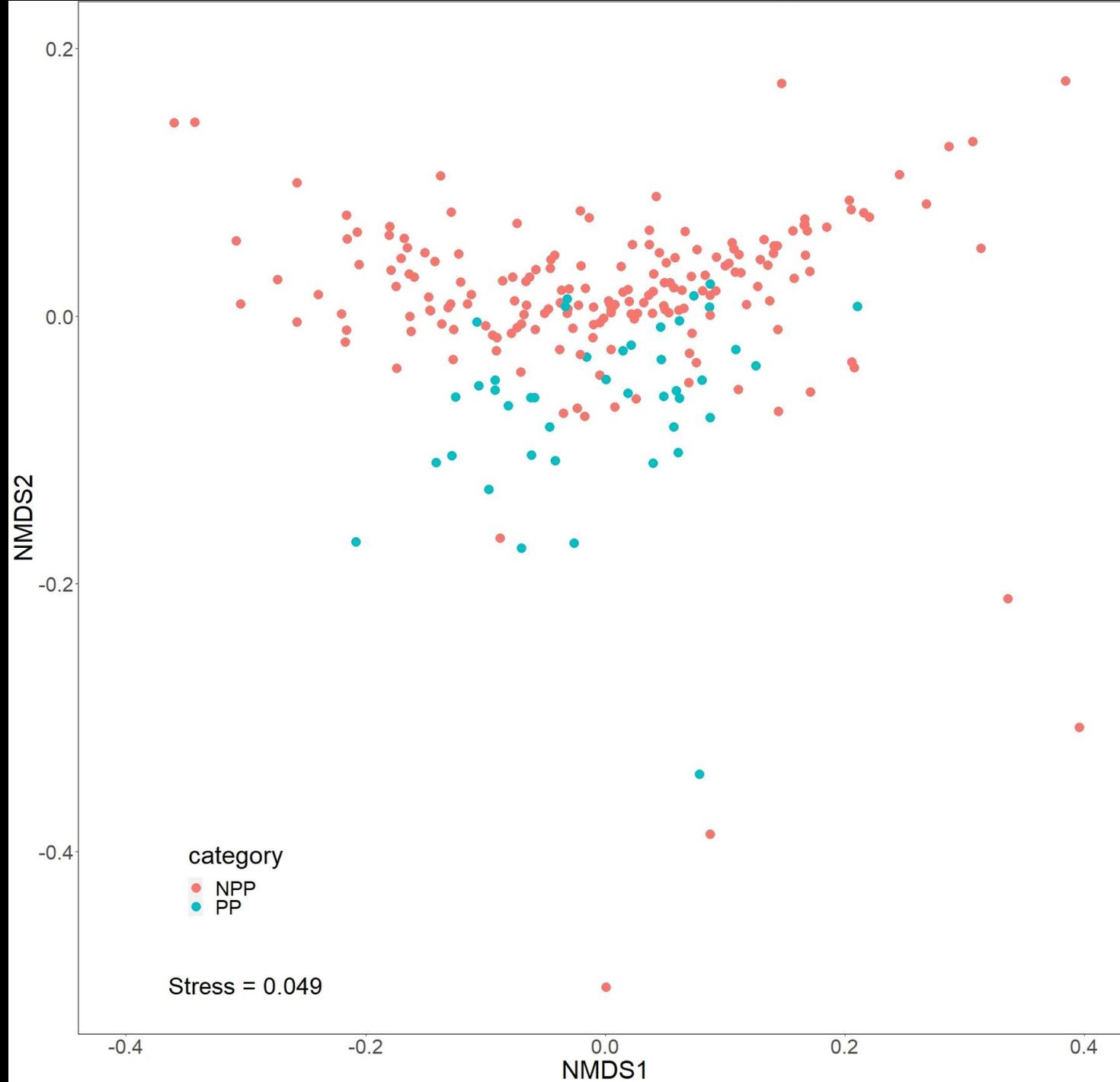
ANALYSIS

- NMDS (nonmetric multidimensional scaling): a way to reduce dimensionality of data for ease of interpretation
 - Clustering = similarity

RESULTS

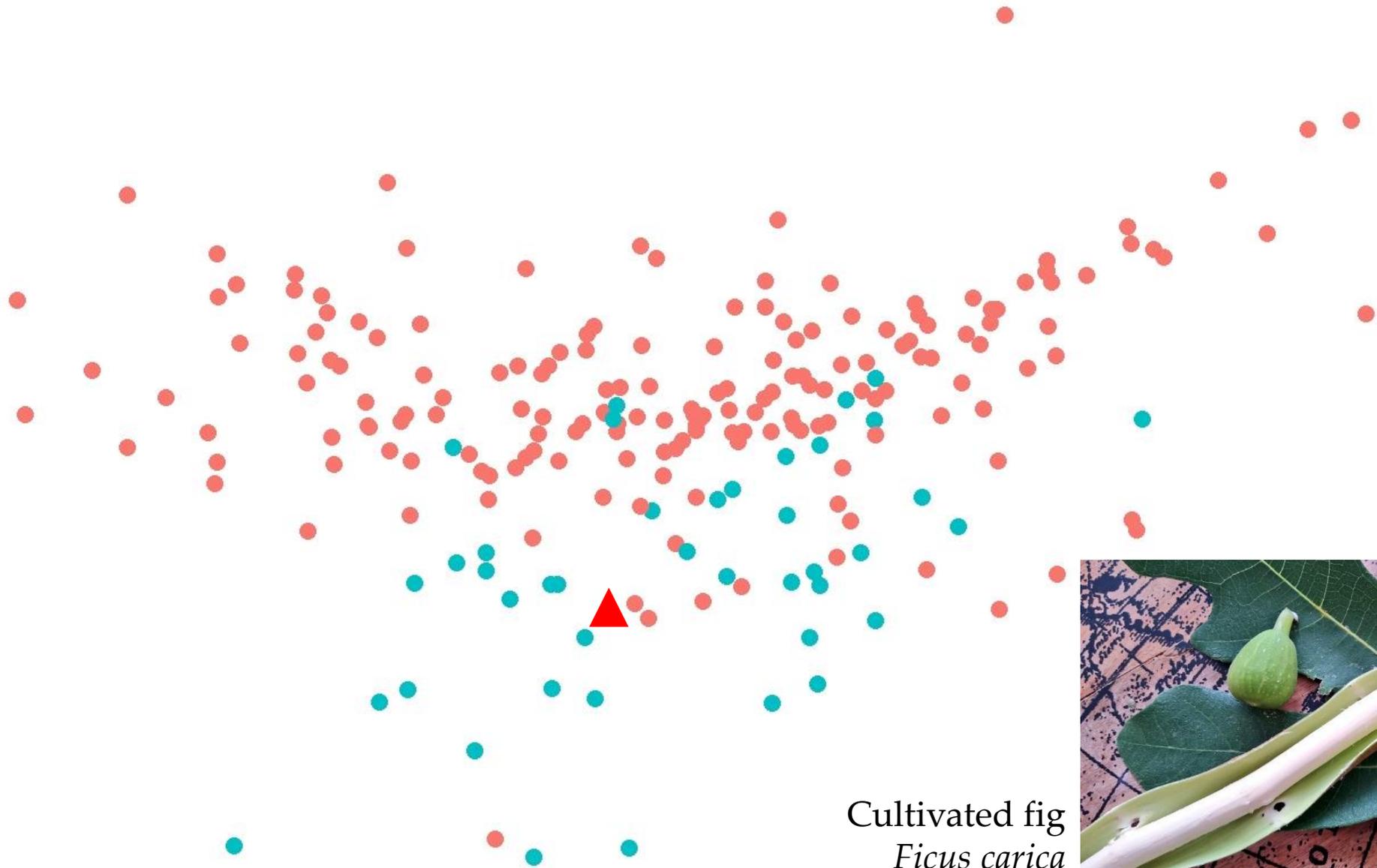


RESULTS



Fiber physiology and botanical family explain patterns of plant use and disuse in papermaking traditions.

($p < .05$ for both)



Cultivated fig
Ficus carica
Moraceae



Family	Common name	Species	Paper	Length	Width	Lumen	Cell Wall
Linaceae	Flax	<i>Linum usitatissimum</i>	1	25000	25	5	10
Moraceae	Paper mulberry	<i>Broussonetia papyrifera</i>	1	8440	17.5	5.1	6.2
Moraceae	Cultivated fig	<i>Ficus carica</i>	0	6181	20.59	8.49	6.05
Thymelaeaceae	Mitsumata	<i>Edgeworthia chrysantha</i>	1	4458	15.68	5.47	5.105

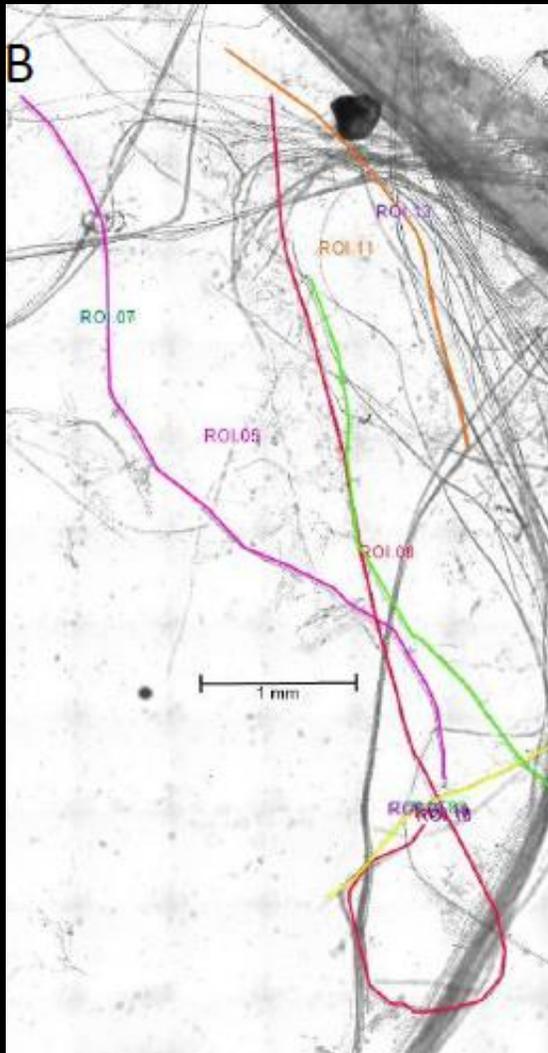
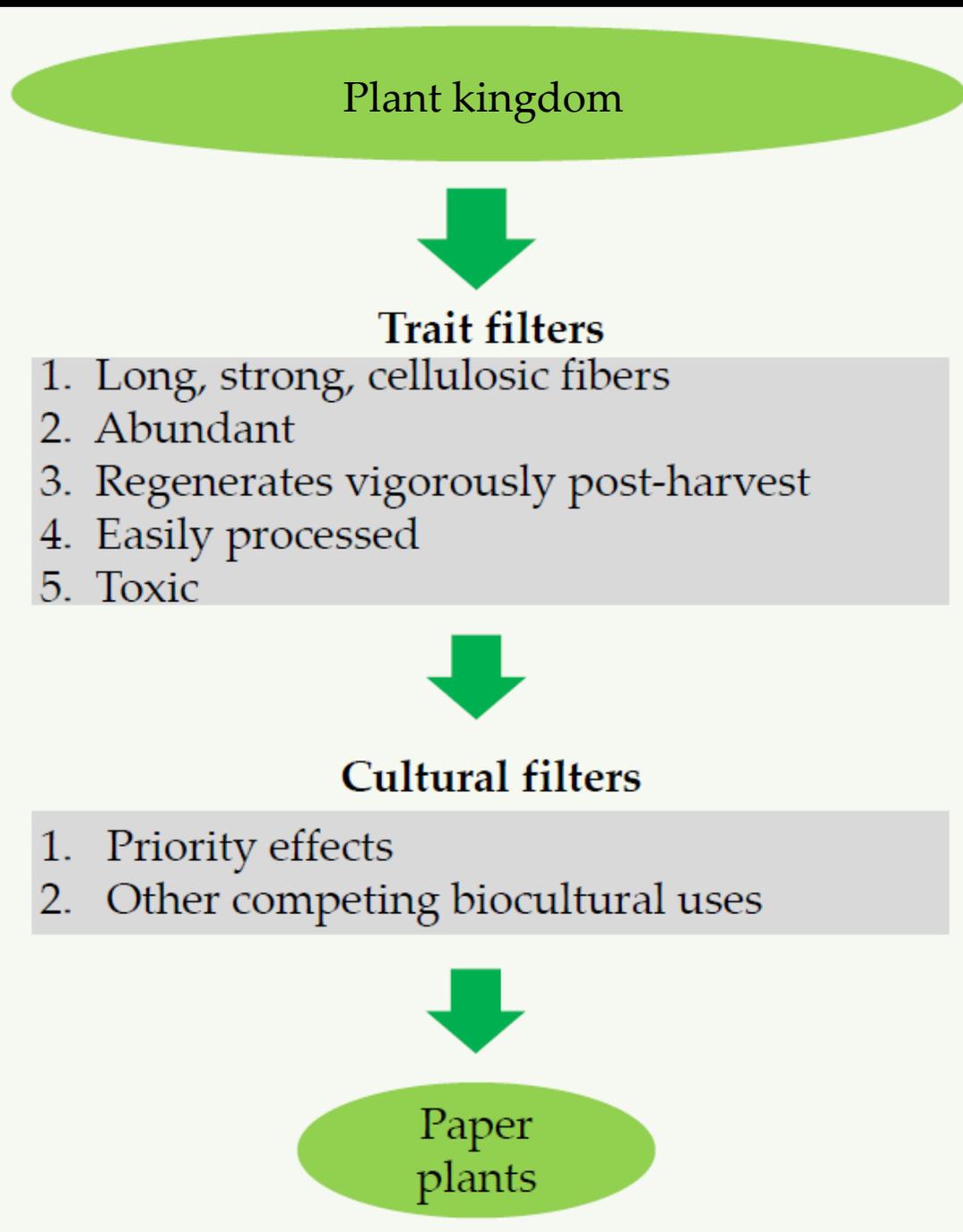


Figure 5. Common fig (A) may be culturally filtered from being a **PP** in Europe due to cultural preference in cultivating figs for food and flax for fiber, despite *F. carica* having long (5-10 mm), flexible phloem fibers (Figure 3) that experimentally yield strong handmade paper (B).

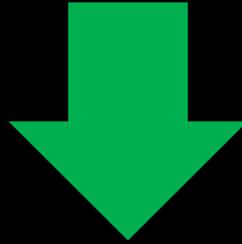




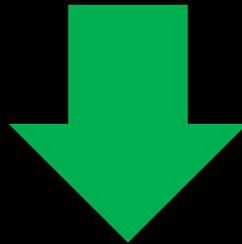
Physiologically suitable plants may be overlooked for papermaking for cultural reasons:

- Priority effects – a suitable plant was discovered for a use first, discouraging further experimentation
 - e.g., in Japan, kozo & gampi were used since 7th century, but mitsumata was not adopted for papermaking until 1596!
- Competing uses – a suitable plant has different and more preferred usage
 - Figs are very tasty!

Paper plants
~ 50 species



???



Origami paper plants
~ 10 sp.

AN ORIGAMIST'S FILTERS

6. What paper qualities are most important to you when selecting paper for origami? Rank these by importance.

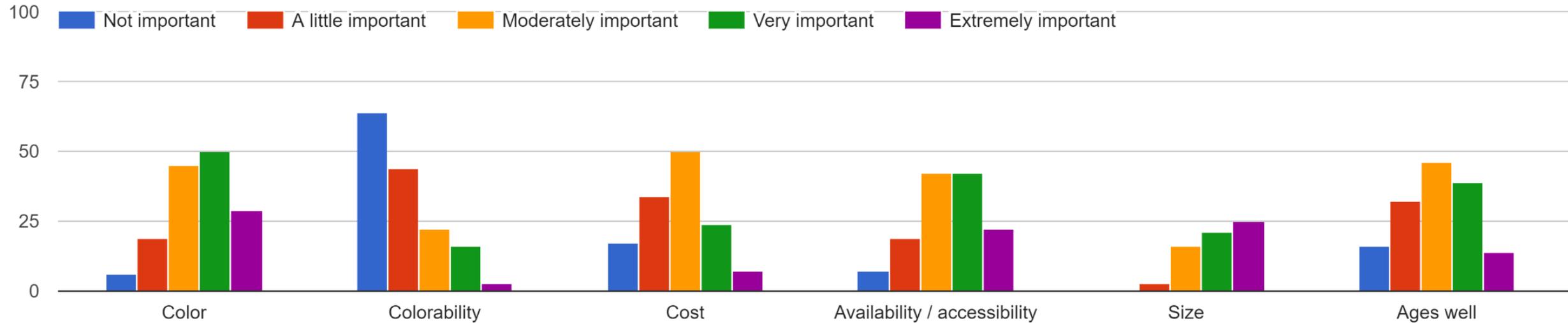
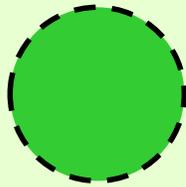


Table IV: Relationships between the morphological properties of fiber cells and the physical properties of paper (Dadswell 1961; Bostanci, 1987)

Relationships	BS ^a	TS ^b	DFS ^c	PD ^d
with increasing the fiber length	+	++	+	-
with increasing the cell wall thickness	-	+	--	--
with decreasing the cell wall thickness	+	-	++	++
with increasing the fiber length/fiber diameter			+	
with increasing the spiral grain	--	+	+	-

^aBurst strength; ^bTearing strength; ^cDouble folding strength; ^dPaper density; +it had been determined that it has a positive effect; ++There is certainly positive effect; -it had been determined that it has a negative effect; --There is certainly negative effect

Plant kingdom
~ 320,000 sp.

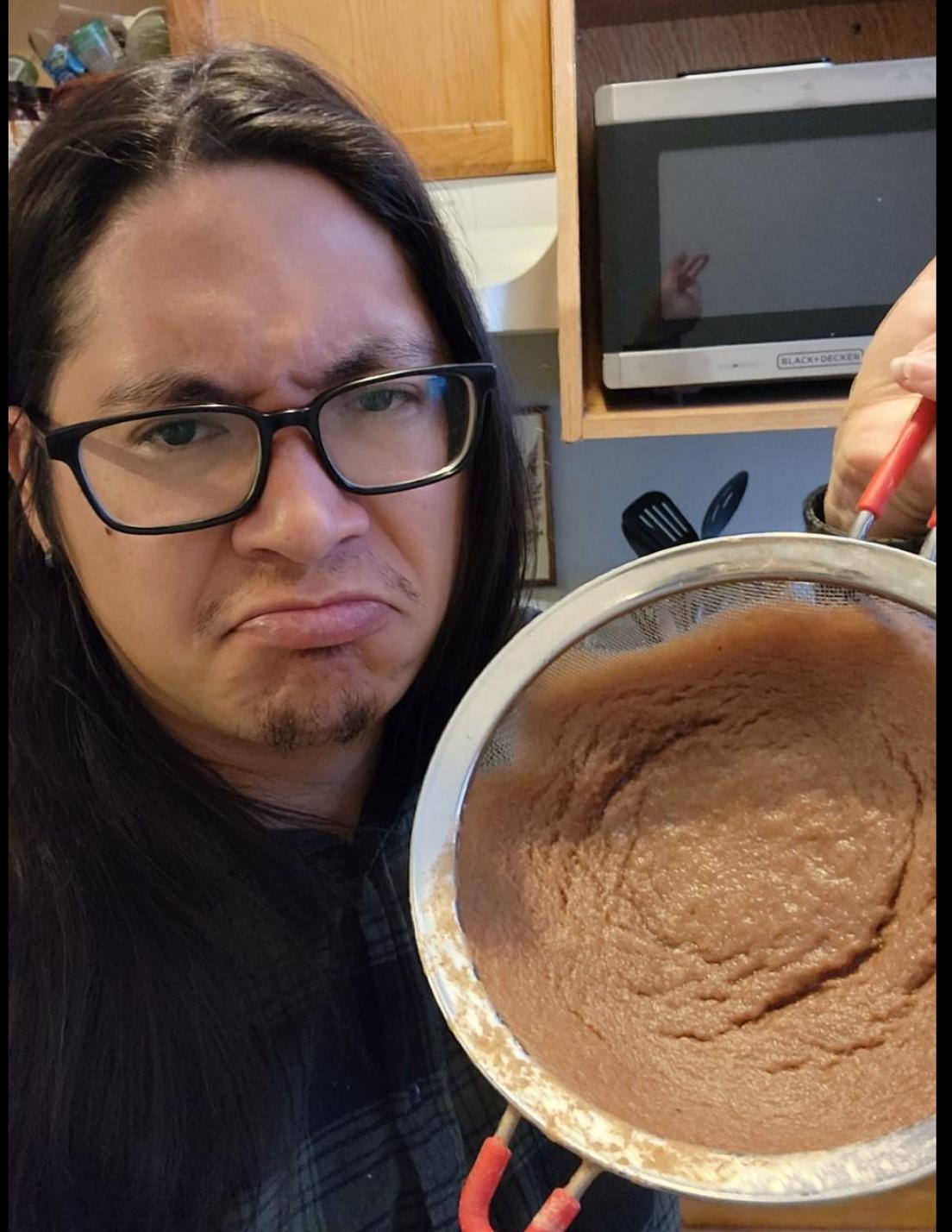


Paper plants
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Origami paper plants
< 10 sp.

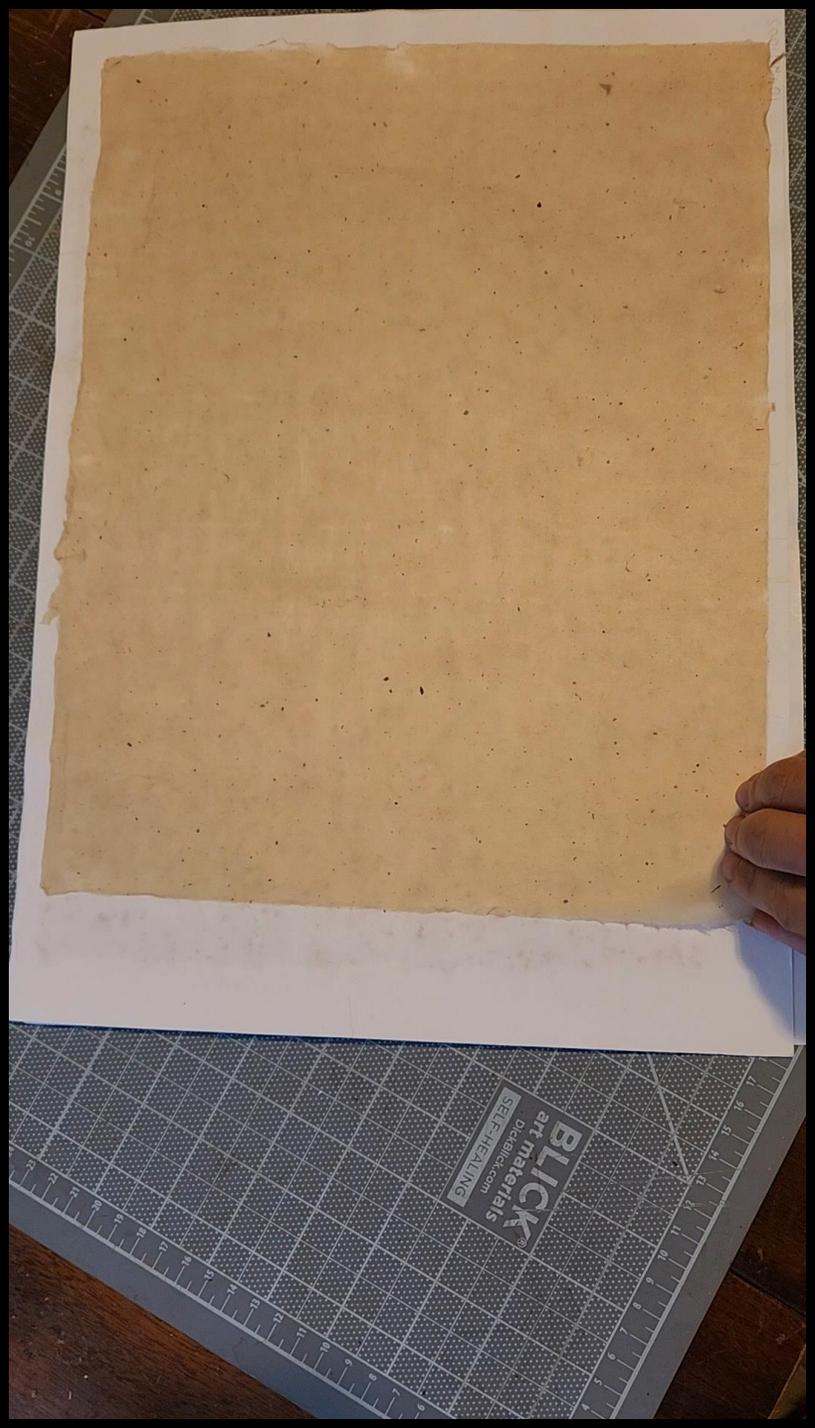
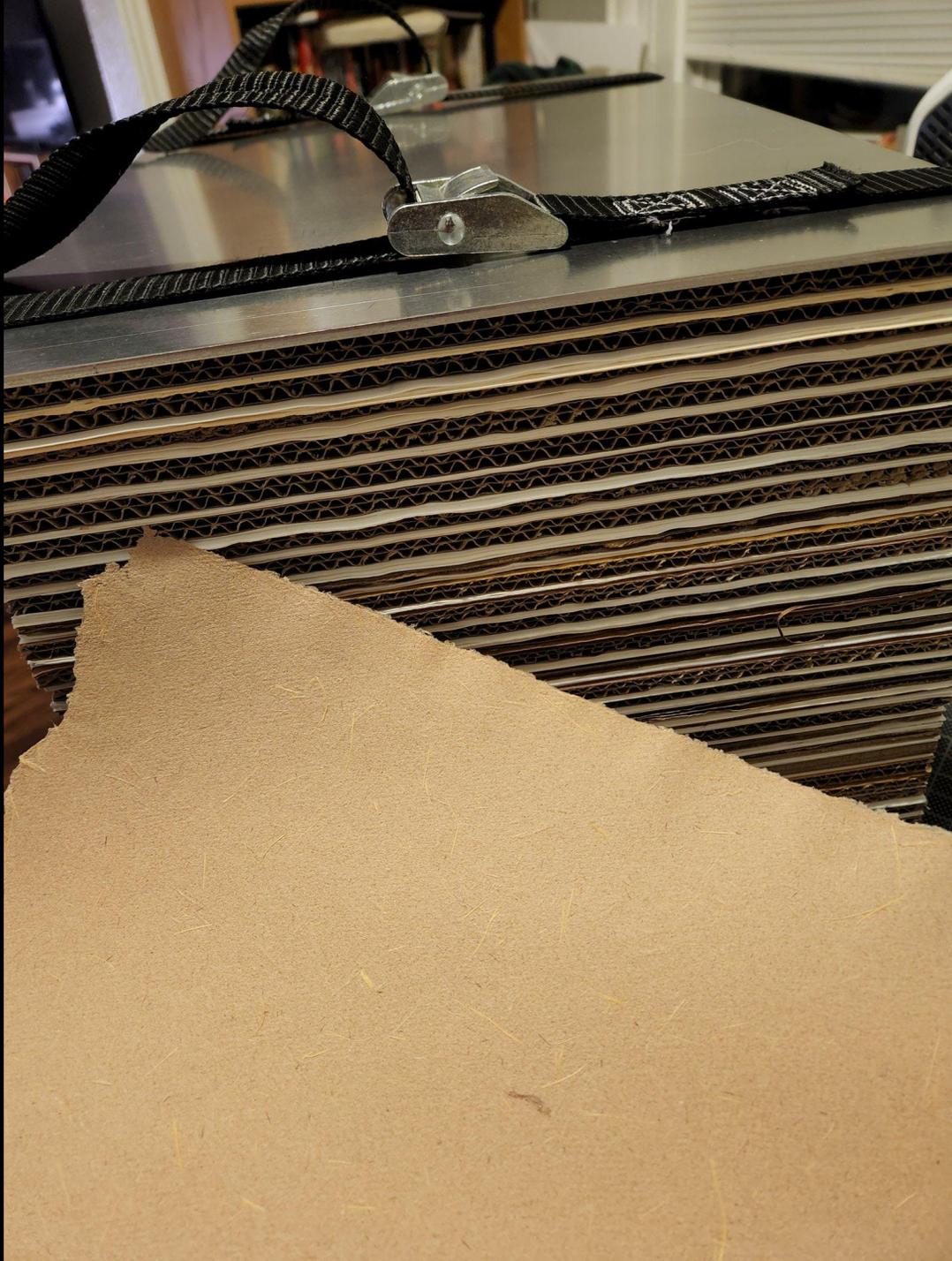




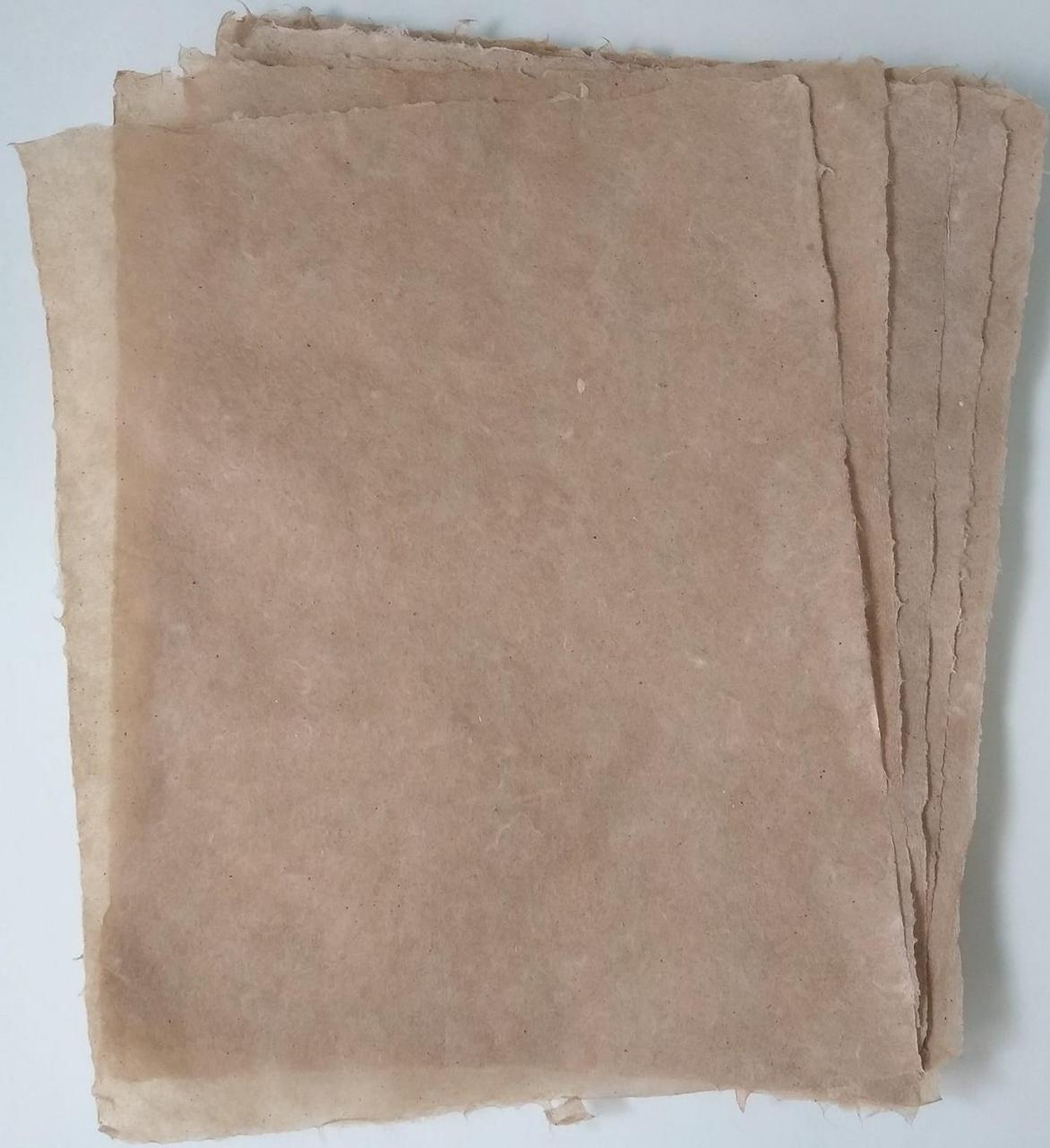








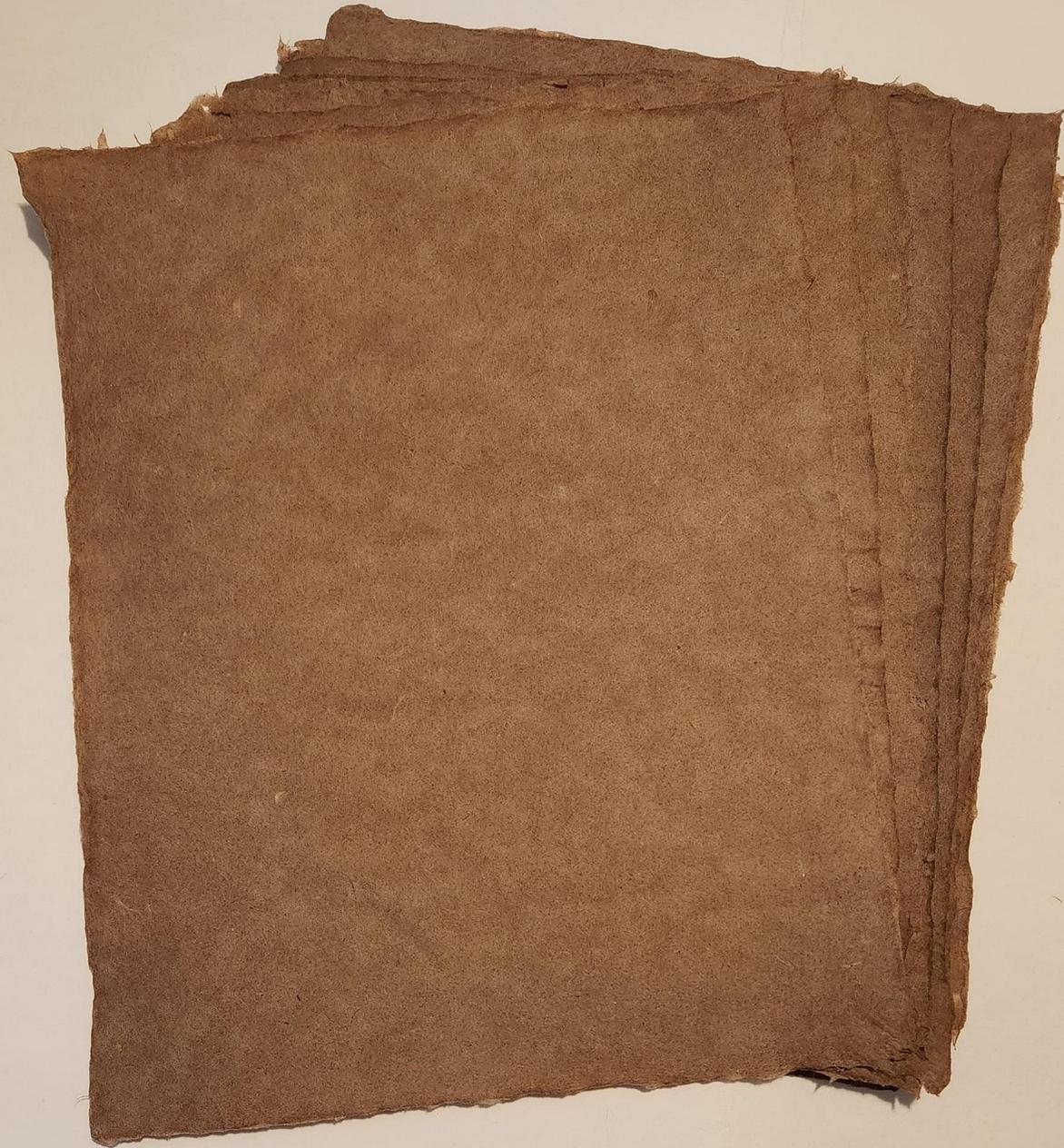




Cultivated fig
Ficus carica
Moraceae



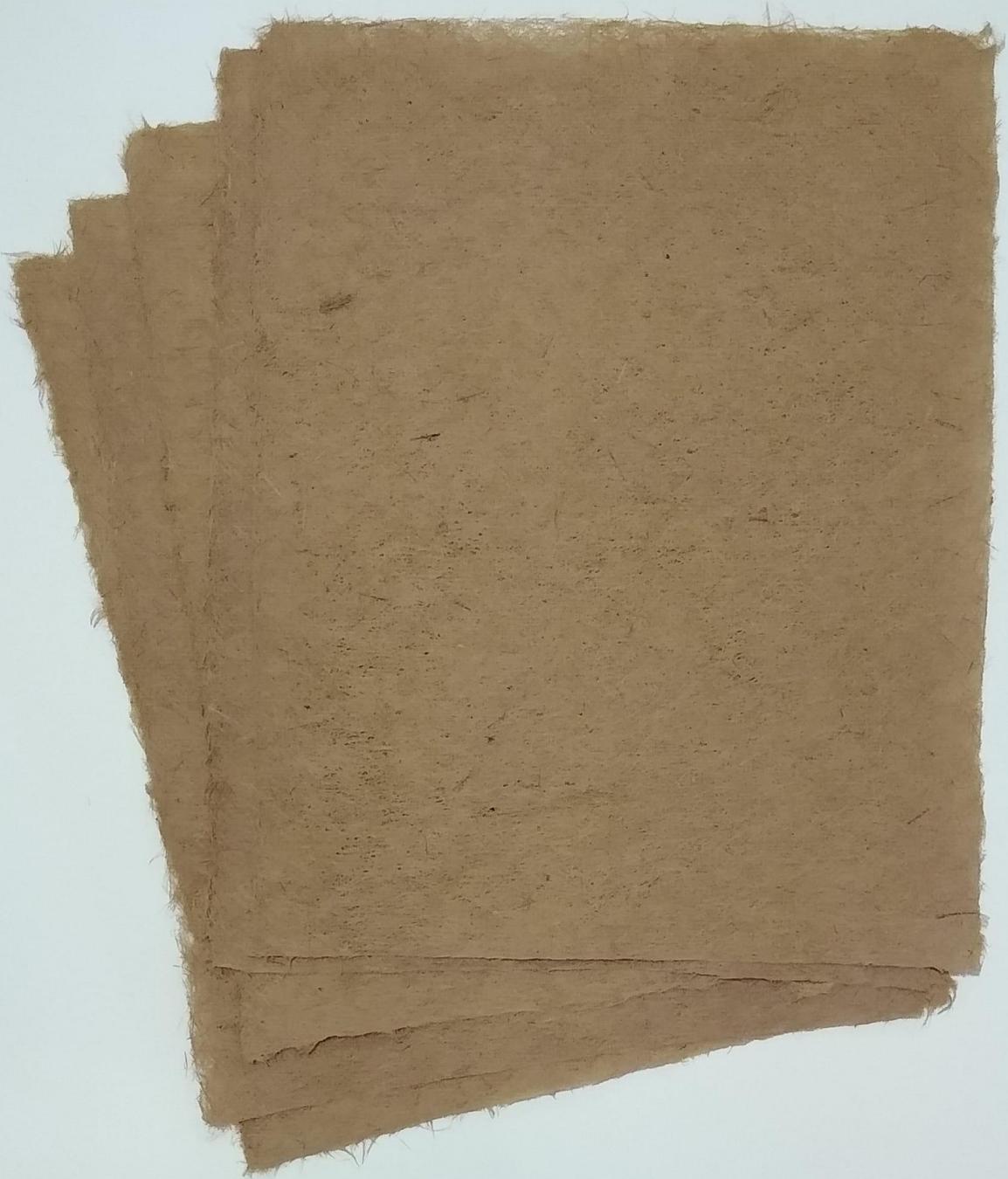
Shore Crab
Designed by Brian Chan
Folded by James Ojascastro



Osage-orange
Maclura pomifera
Moraceae



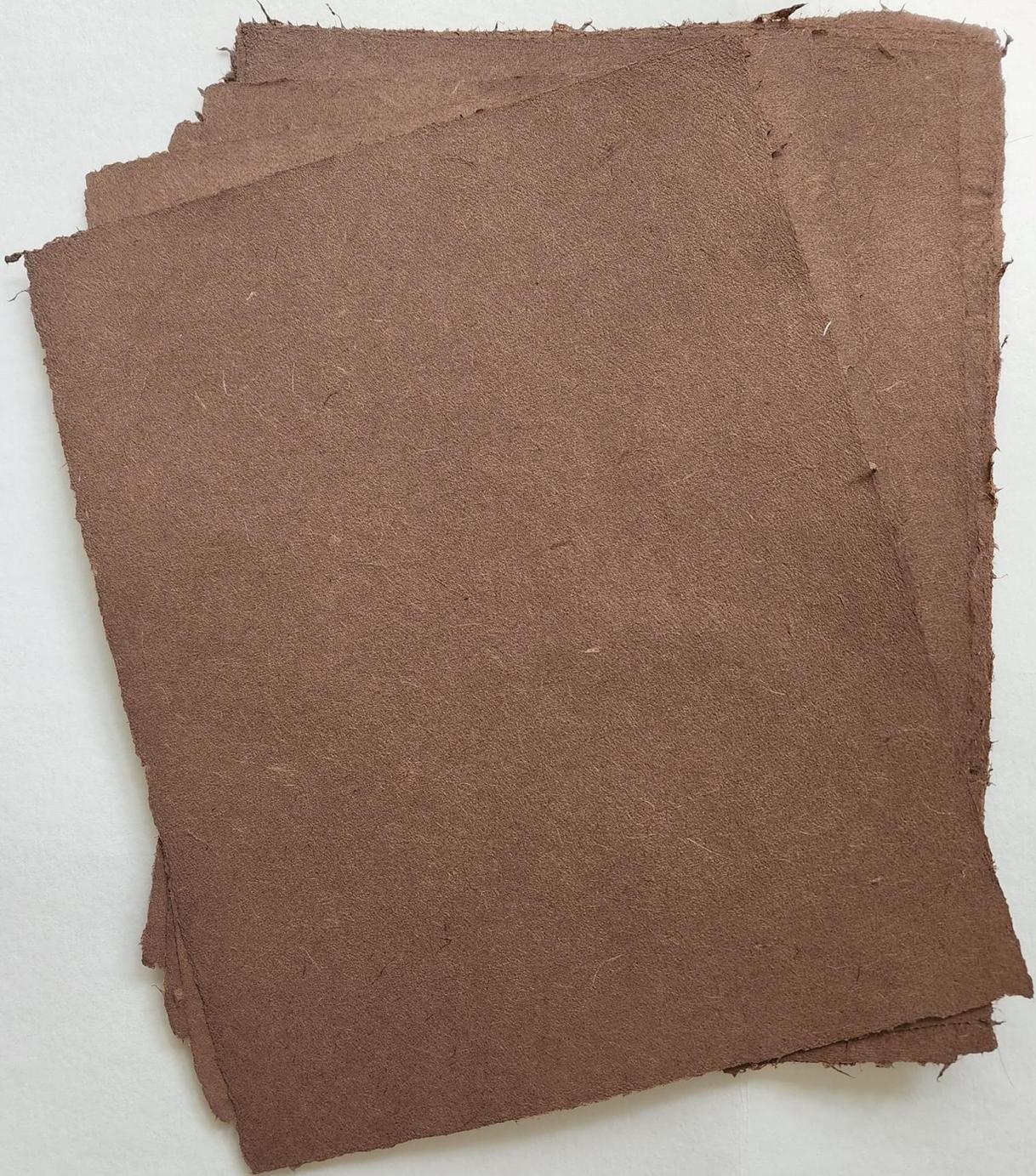
Kangaroo
Designed by Gen Hagiwara
Folded by James Ojascastro



Interior sandbar willow
Salix interior
Salicaceae



Bison
Designed and folded by Cekouat León



American elm
Ulmus americana
Ulmaceae



Dog
Designed by David Illescas
Folded by Matt LaBoone

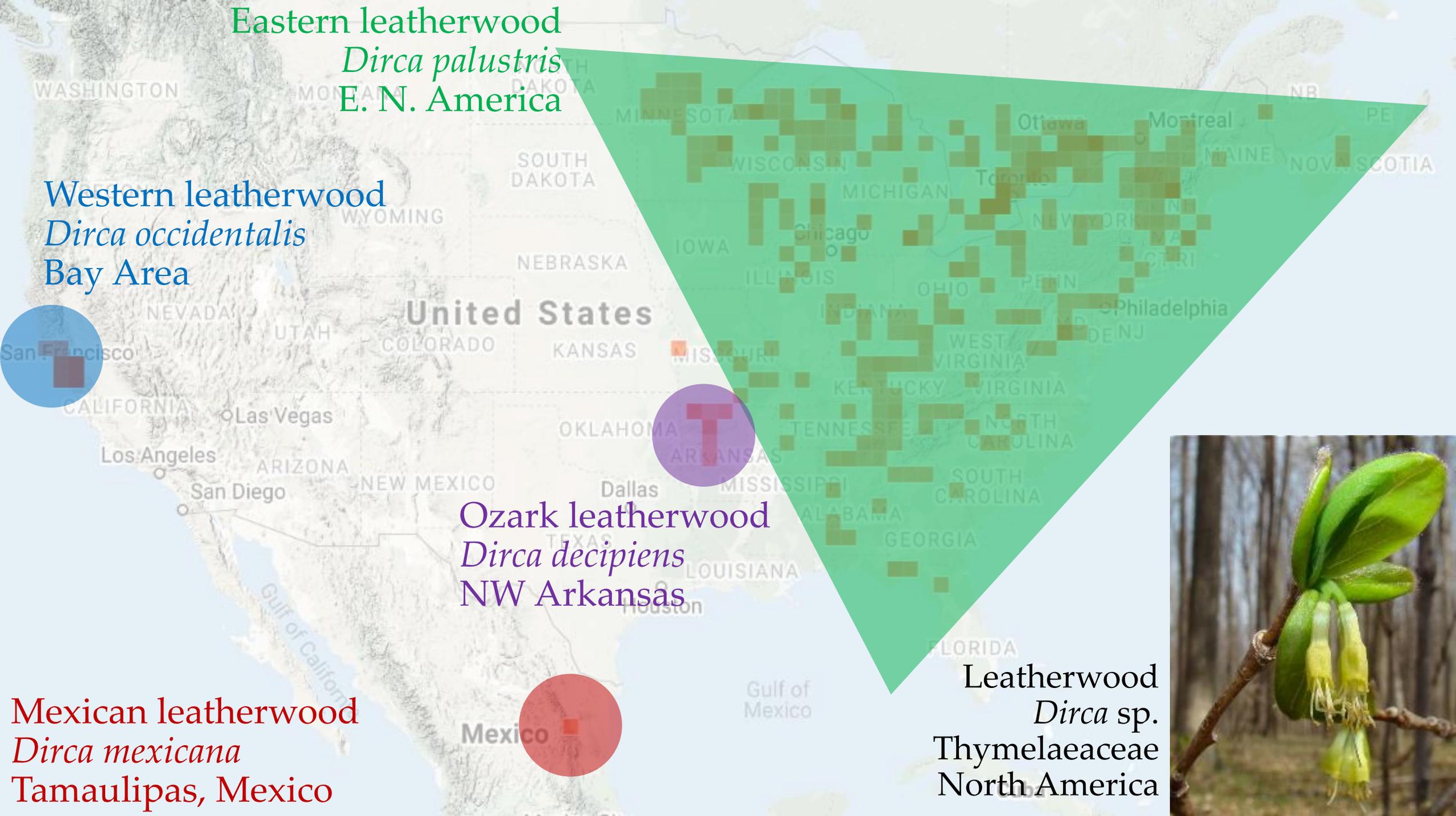
Eastern leatherwood
Dirca palustris
E. N. America

Western leatherwood
Dirca occidentalis
Bay Area

Ozark leatherwood
Dirca decipiens
NW Arkansas

Mexican leatherwood
Dirca mexicana
Tamaulipas, Mexico

Leatherwood
Dirca sp.
Thymelaeaceae
North America





Leatherwood
Dirca sp.
Thymelaeaceae
North America

Jared Needle
California, USA



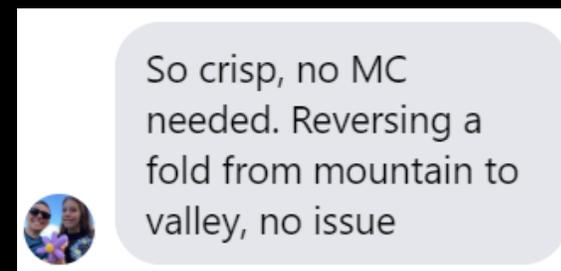
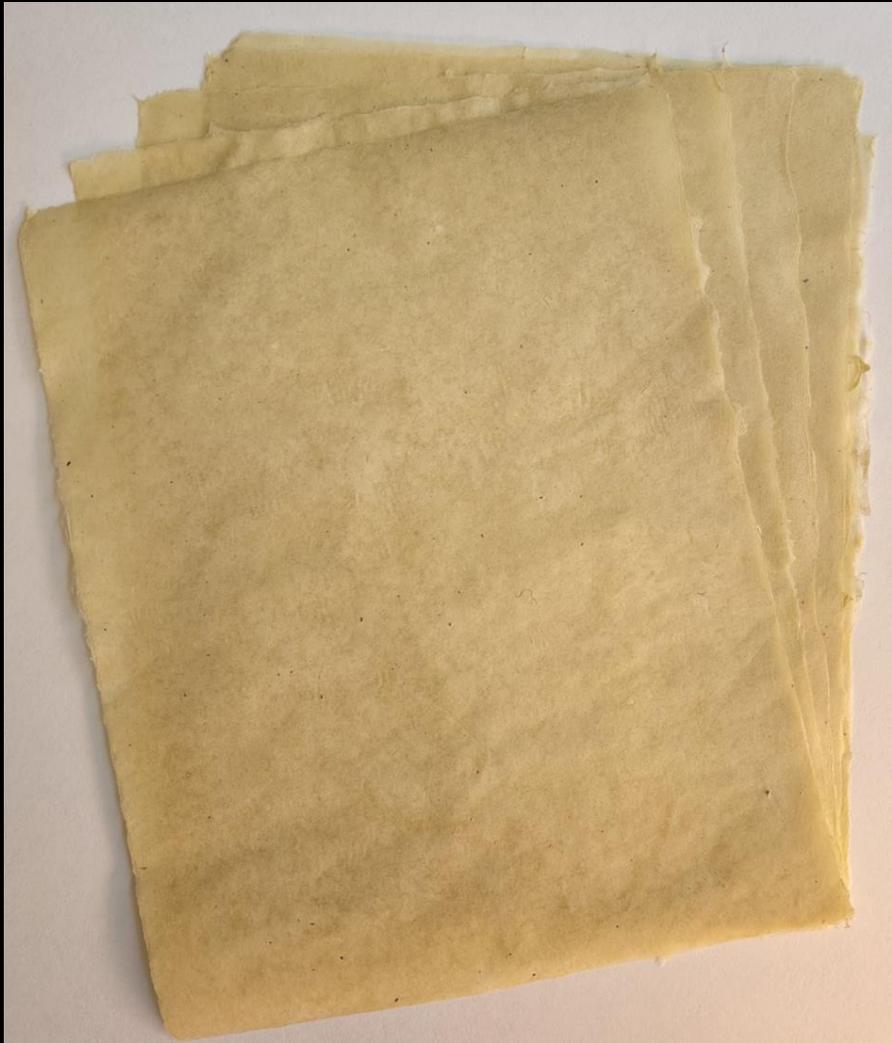
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Los Angeles, California

snowflake. This time I challenged myself to make a snowflake not just from a square, but using fully 22.5° folding. Needed extremely thin and strong paper for this, as a ton of tension is put on multiple points; and this rare leatherwood was perfect. Folded dry. No MC or PVA added before, during, or after folding. By far the most difficult snowflake I've made.



Snowflake
Design by Jared Needle



Leatherwood
Dirca sp.
Thymelaeaceae
North America



Satanic leaf-tailed gecko
Designed & folded by Matt LaBoone

Plant kingdom
~ 320,000 sp.



Paper plants
~ 50 sp.

Origami paper plants
< 10 sp.

Questions? / ¿preguntas?



@manila_folder