REBE FERALDI

PART I: DESIGN CHALLENGE – non-negotiable needs brainstorm

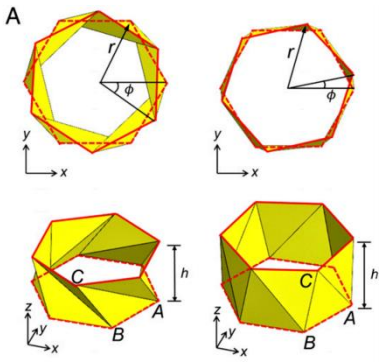
F(x) = Portable bag to produce market

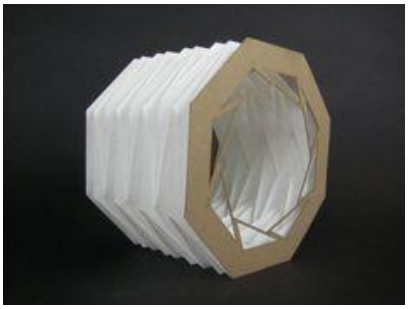
F(y) = sufficiently elegant to hang in home

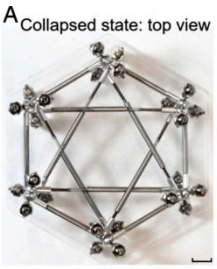
F(z) = Basket aerates produce

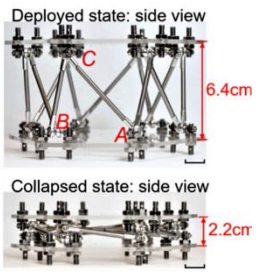
F(x) = Collapses

- Snapology
- Foldability
- Hoberman sphere
- Expandable structure
- Pneumatics
- Origami
    - Mechanical metamaterial with on-demand, manual, and selective deployability and collapsibility[1]
    - Load bearing capability in deployed direction
    - High stiffness in other direction
    - By connecting various metamaterials (w/ different stiffness) in series, can make continuously tunable stiffness









- Protein structural conformation
    - Conformational epitopes 3D structure of antigens[2]
- Brain folding[3]
    - Larger the cortical: subcortical ratio → stronger force exerted on surface
    - Cortexes are 3-dim folding mechanism of 2-dim fractal process (e.g., like crumpling paper)
    - Mota & Herculao Houzel theory: folding governed by paper SA and thickness

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[1] Zhai Z, Wang Y, Jiang H (2017). Origami-inspired, on-demand deployable and collapsible mechanical metamaterials with tunable stiffness, PNAS 115(9): 2032-20237. Accessed March 15, 2019 at: https://www.pnas.org/content/pnas/115/9/2032.full.pdf.

[2] Kulkarni-Kale U et al. (2005). Accessed March 14, 2019 at: https://molbiol-tools.ca/Protein_tertiary_structure.htm.

[3] Toro R (2008). Brain Folding, Model Release 1 by the University of Nottingham Brain & Body Centre on SourceForge.net. Last Updated January 6, 2008, Accessed March 15, 2019 at: http://brainfolding.sourceforge.net/.

- Van Essen also argues tension along axons in white matter determines folding
- Basket weave

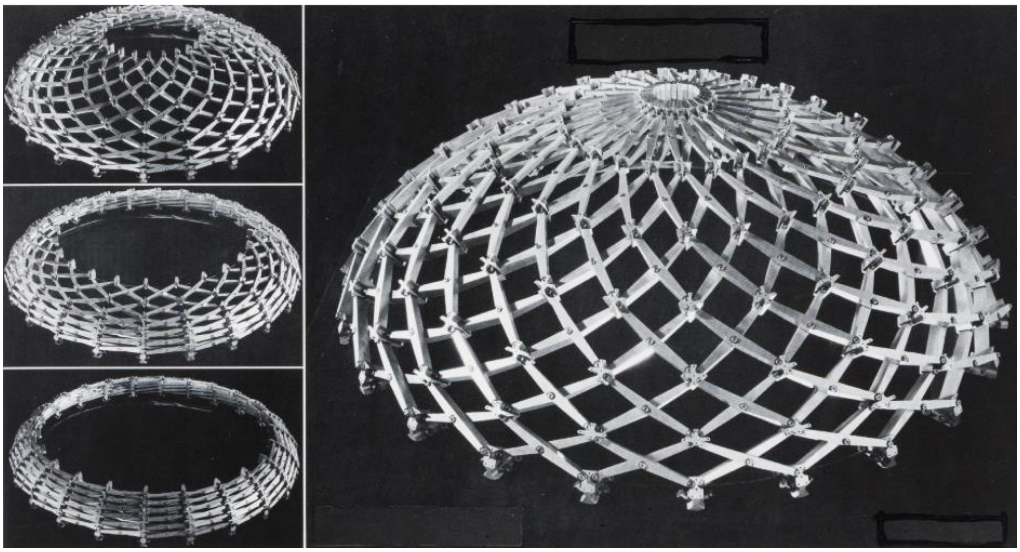
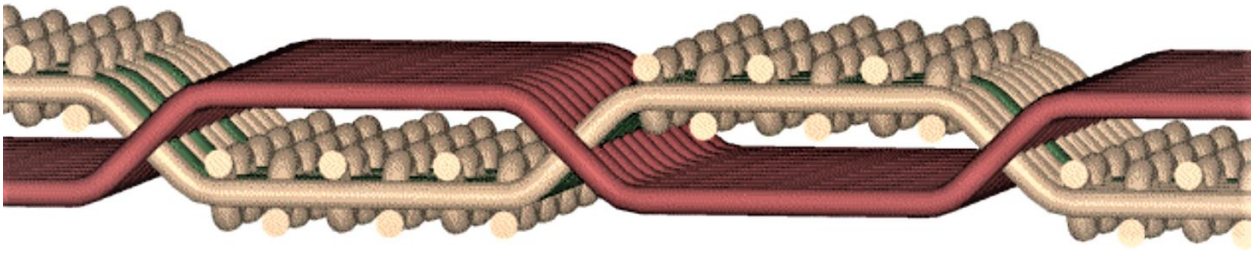
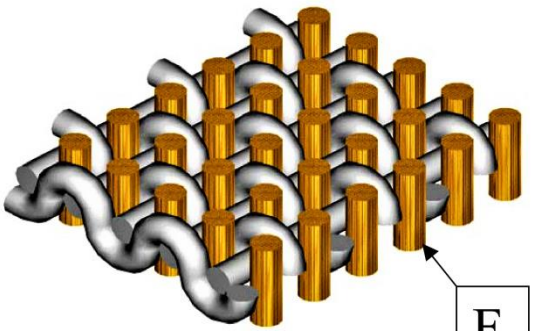


Image Credit: Chuck Hoberman at: http://www.hoberman.com

F(y) = aeration with structural integrity

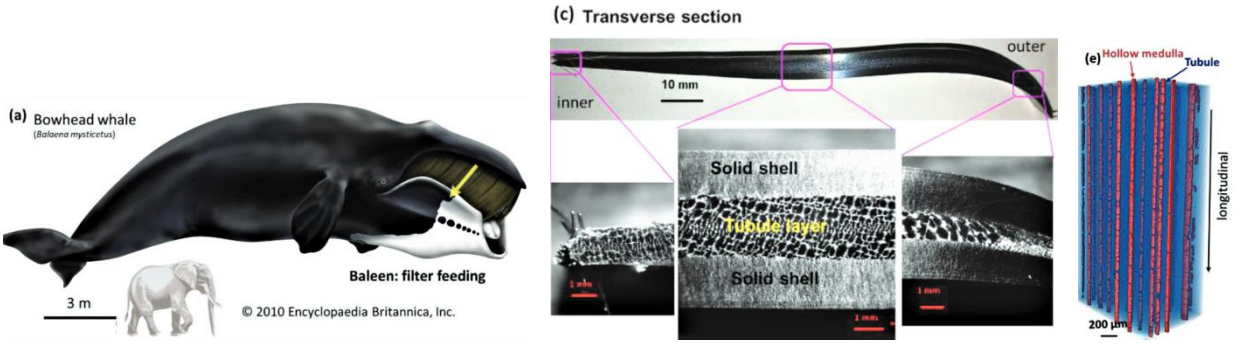
- Basket weave mesh (structural stability) – woven fabrics with double-layer joined by layer exchange method[4]





[4] Szosland J (2003). Modelling the structural barrier ability of woven fabrics, AUTEX Research Journal 3(3): 1-9. Accessed March 16, 2019 at: http://www.autexrj.com/cms/zalaczone_pliki/2-03-3.pdf.

- Baleen whale mesh[5] – keratin-based fracture resistance
    - Material subject to hydration and load
    - Intermediate filaments and mineral crystals embedded in amorphous matrix
    - Microscale tubular layers control crack propagation direction and limit buckling and shearing
    - high anisotropic toughness
        - longitudinally cracks propagate easily leading to delamination, fraying, and bristle formation allowing the filtering action
        - transversely crack propagation is resisted by tubular structure (resists load and impact)



- Wasp nest –hexagonal tubes

F(z) = contains/carries

- Spider web captures
- Chipmunk cheeks
- Water spider – water bell
- Wasp nest –hexagonal tubes; successive layers of comb added underneath existing layers so nest grows downwards

[5] Wang B, Sullivan TN, Pissarenko A, Zaheri A, Espinosa HD, Meyers MA (2019). Lessons from the Ocean: Whale Baleen Fracture Resistance, Advanced Materials: Communication Bioinspired Materials, 31: 1-6. Accessed on March 14, 2019 at: https://onlinelibrary.wiley.com/doi/full/10.1002/adma.201804574.

F(x) = hangs/suspend

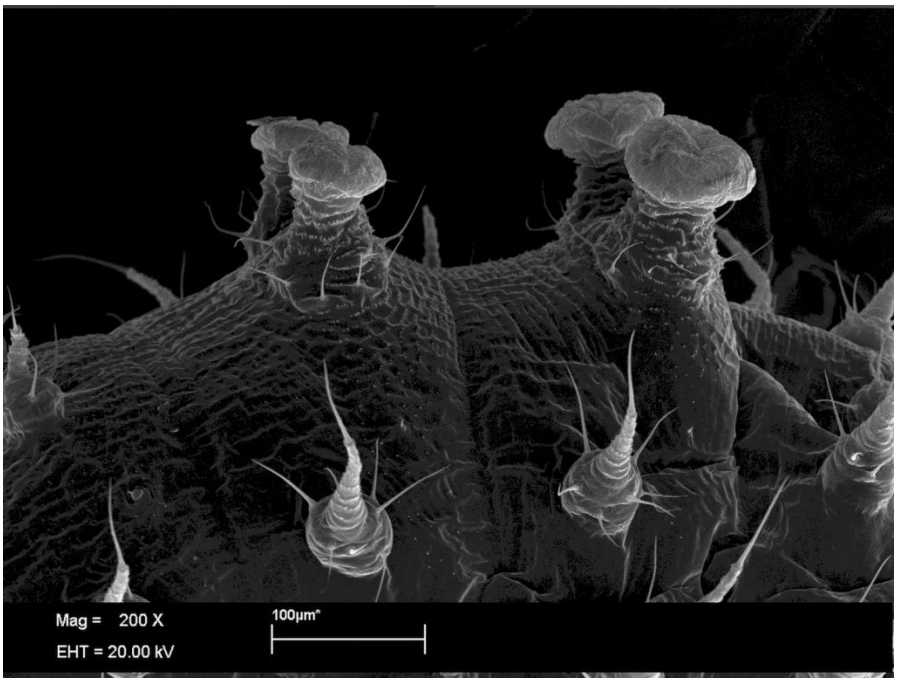
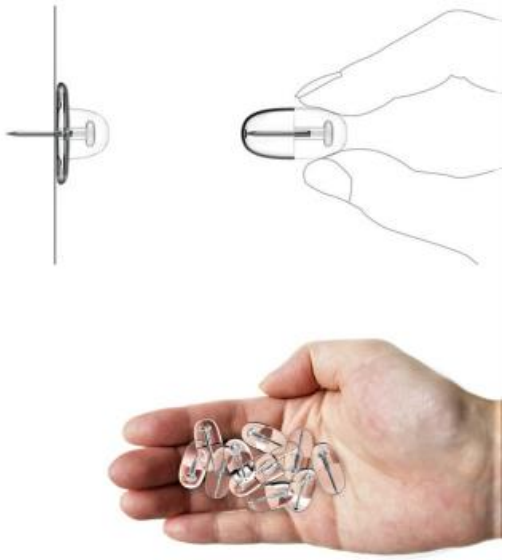


Image Credit: Adrian Smith at www.LiveScience.com

- Trap-jaw ant larvae have doorknob protuberances on their backs allowing them to suspend from walls and ceilings of nests; https://www.livescience.com/59062-trap-jaw-ants-have-hairy-baby-blobs.html[6] original article[7]
- Claws in animals (adhesion and friction will not scale well or be wet application[8])
    - Retractable claw inspired push pins[9]



- Hook and loop

[6] Pappas S (2017). Weird Ants Have Hairy Blobs for Babies, LiveScience Article May 11, 2017 summarizing research from Fox et al. 2017. Accessed March 14, 2019 at: https://www.livescience.com/59062-trap-jaw-ants-have-hairy-baby-blobs.html.

[7] Fox EGP, Smith AA, Gibson JC, Solis DR (2017). Larvae of trap-jaw ants, *Odontomachus* Latreille, 1804 (Hymenoptera:Formicidae): morphology and biological notes, Myrmecological News 25: 17-28. Accessed March 14, 2019 at: https://myrmecologicalnews.org/cms/index.php?option=com_download&view=download&filename=volume25/mn25_17-28_printable.pdf&format=raw.

[8] Labonte D, Federle W (2015). Scaling and biomechanics of surface attachment in climbing animals, Philosophical Transactions of the Royal Society of London Series B – Biological Sciences 370(1661): 1-17. Accessed March 16, 2019 at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4275900/pdf/rstb20140027.pdf.

[9] Strijbosch JL (2012). Fontanel – Retractable-claw-inspired push pin design, Winner Red Dot Award – Design Concept 2012. Accessed March 16, 2019 at: http://archief.fontanel.nl/inspiration/toshi-fukaya/.

ADDITIONAL REFERENCES:

Fox EGP, Smith AA, Gibson JC, Solis DR (2017). Larvae of trap-jaw ants, *Odontomachus* Latreille, 1804 (Hymenoptera: Formicidae): morphology and biological notes, Myrmecological News 25: 17-28. Accessed March 14, 2019 at: https://myrmecologicalnews.org/cms/index.php?option=com_download&view=download&filename=volume25/mn25_17-28_printable.pdf&format=raw.

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Labonte D, Federle W (2015). Scaling and biomechanics of surface attachment in climbing animals, Philosophical Transactions of the Royal Society of London Series B – Biological Sciences 370(1661): 1-17. Accessed March 16, 2019 at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4275900/pdf/rstb20140027.pdf.

Pappas S (2017). Weird Ants Have Hairy Blobs for Babies, LiveScience Article May 11, 2017 summarizing research from Fox et al. 2017. Accessed March 14, 2019 at: https://www.livescience.com/59062-trap-jaw-ants-have-hairy-baby-blobs.html.

Strijbosch JL (2012). Fontanel – Retractable-claw-inspired push pin design, Winner Red Dot Award – Design Concept 2012. Accessed March 16, 2019 at: http://archief.fontanel.nl/inspiration/toshi-fukaya/.

Szosland J (2003). Modelling the structural barrier ability of woven fabrics, AUTEX Research Journal 3(3): 1-9. Accessed March 16, 2019 at: http://www.autexrj.com/cms/zalaczone_pliki/2-03-3.pdf.

Wang B, Sullivan TN, Pissarenko A, Zaheri A, Espinosa HD, Meyers MA (2019). Lessons from the Ocean: Whale Baleen Fracture Resistance, Advanced Materials: Communication Bioinspired Materials, 31: 1-6. Accessed on March 14, 2019 at: https://onlinelibrary.wiley.com/doi/full/10.1002/adma.201804574.

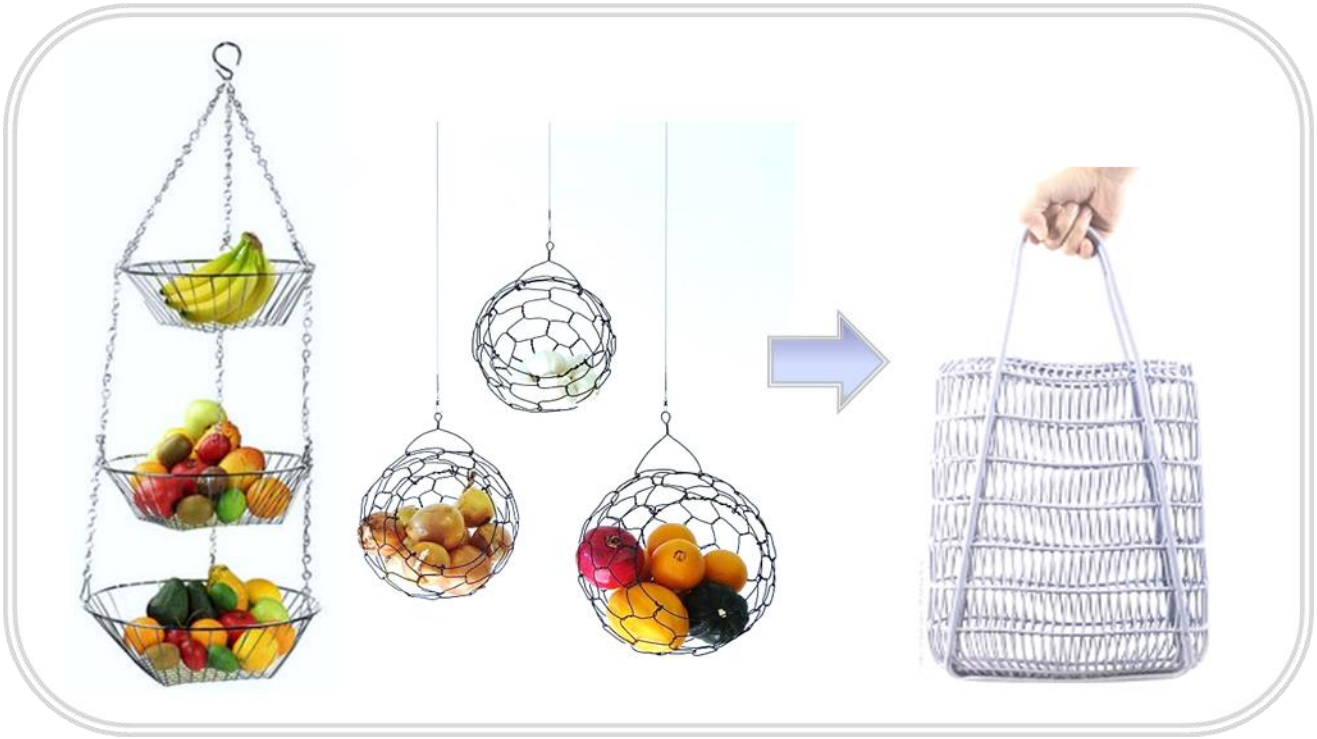
Zhai Z, Wang Y, Jiang H (2017). Origami-inspired, on-demand deployable and collapsible mechanical metamaterials with tunable stiffness, PNAS 115(9): 2032-20237. Accessed March 15, 2019 at: https://www.pnas.org/content/pnas/115/9/2032.full.pdf.

PART II:

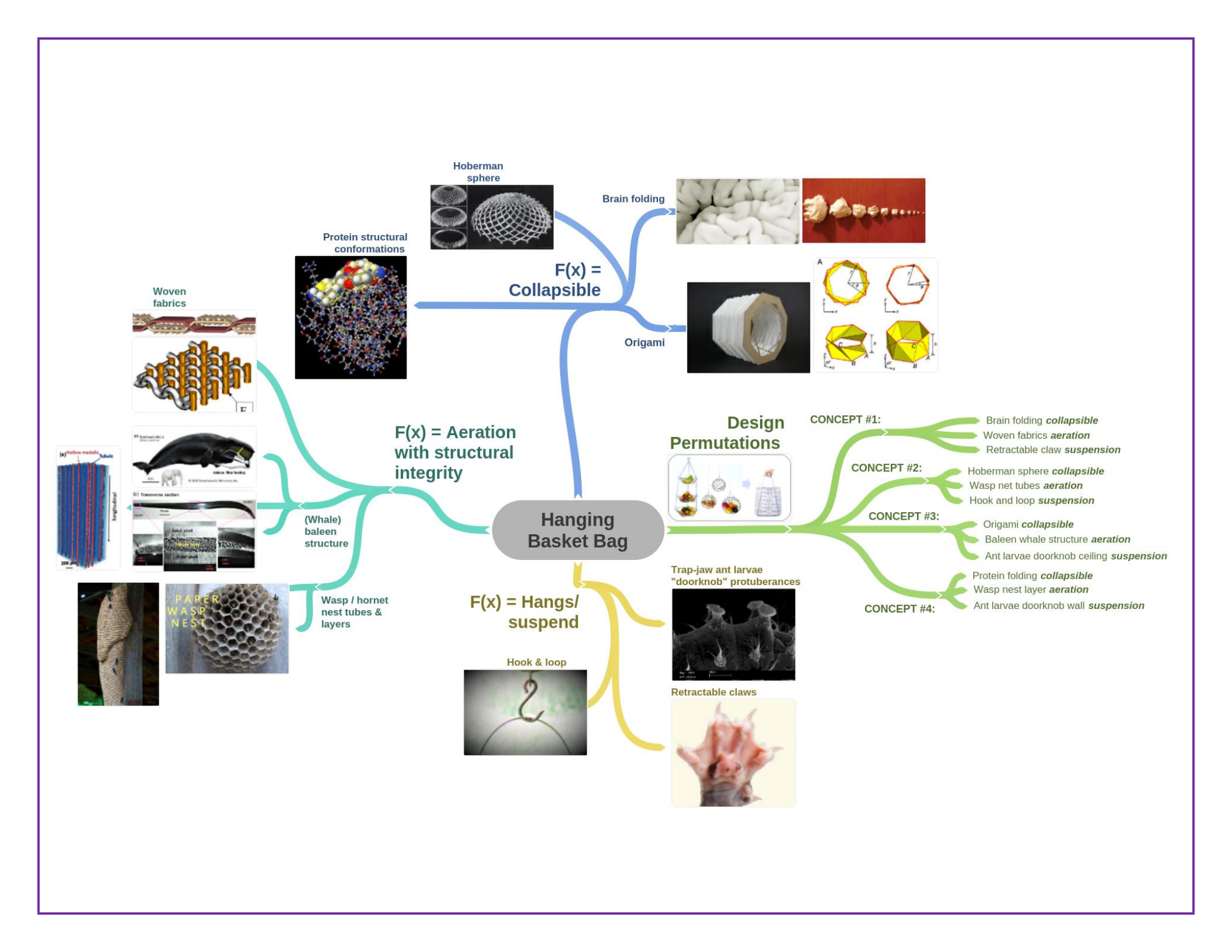
DESIGN CHALLENGE: DEVELOPING CONCEPTS

The design concept overview is as follows:

DESIGN CONCEPT OVERVIEW



I created a Google Coggle Mindmap to convey the decomposition break-out by functions = F(x). I then sketched the concept designs for 4 options (permutations of the functional options). The permutations include both biomimetic and non-biomimetic ideas but all 4 concepts have at least one biomimetic aspect. The Coggle Image is **here** (Links to an external site.). in case the zoom is not sufficient in the embedded image on the following page.

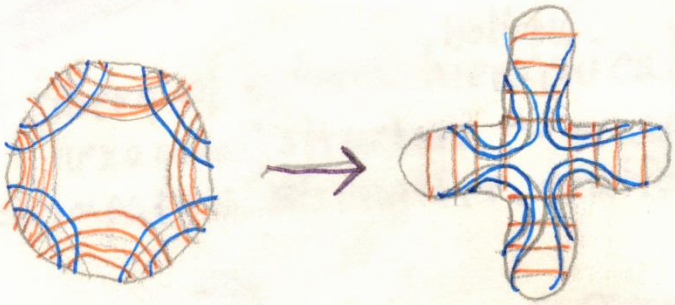

Hoberman sphere
Brain folding
Protein structural conformations
F(x) = Collapsible
Origami
Woven fabrics
F(x) = Aeration with structural integrity
(Whale) baleen structure
Wasp / hornet nest tubes & layers
PAPER WASP NEST
Hanging Basket Bag
Design Permutations
CONCEPT #1:
Brain folding collapsible
Woven fabrics aeration
Retractable claw suspension
CONCEPT #2:
Hoberman sphere collapsible
Wasp net tubes aeration
Hook and loop suspension
CONCEPT #3:
Origami collapsible
Baleen whale structure aeration
Ant larvae doorknob ceiling suspension
CONCEPT #4:
Protein folding collapsible
Wasp nest layer aeration
Ant larvae doorknob wall suspension
F(x) = Hangs/ suspend
Trap-jaw ant larvae "doorknob" protuberances
Hook & loop
Retractable claws

CONCEPT #1:

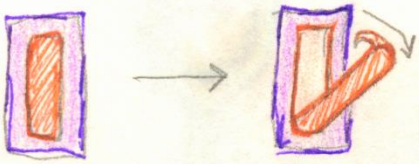
* Thin, woven fabric double layer exchange

- Lightweight
- Flexible
- *aeration
- Strong
- Thin

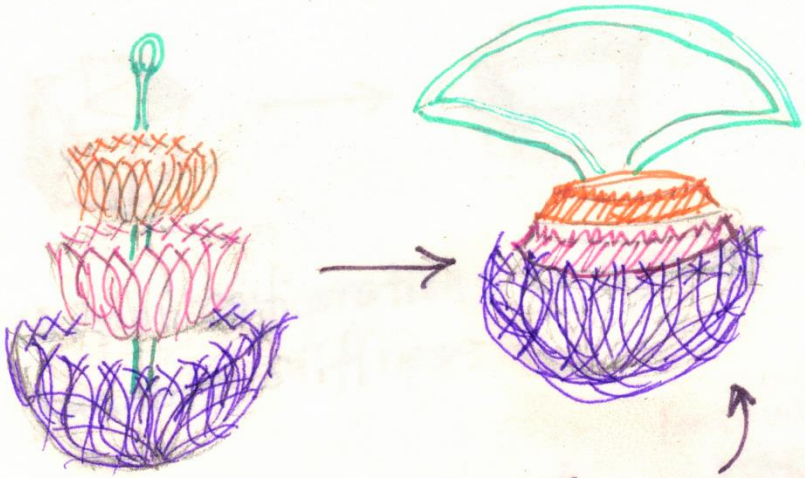
* Uses brain-folding conformation to convert from bag to basket (i.e., collapsible)



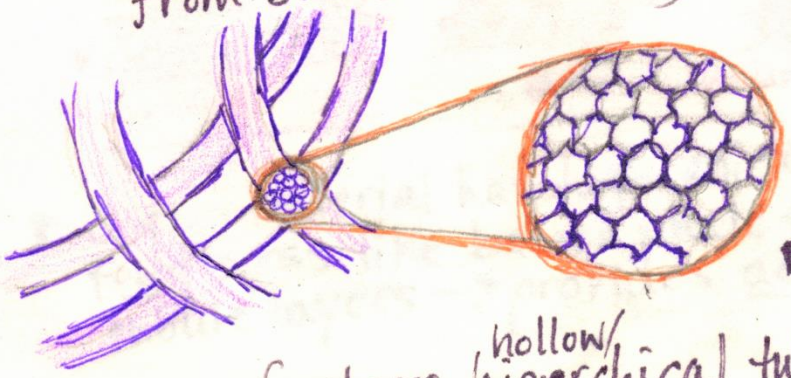
* and cat-claw-inspired retraction to suspend as a basket



CONCEPT #2:



* Hoberman spheres collapse from baskets → bag

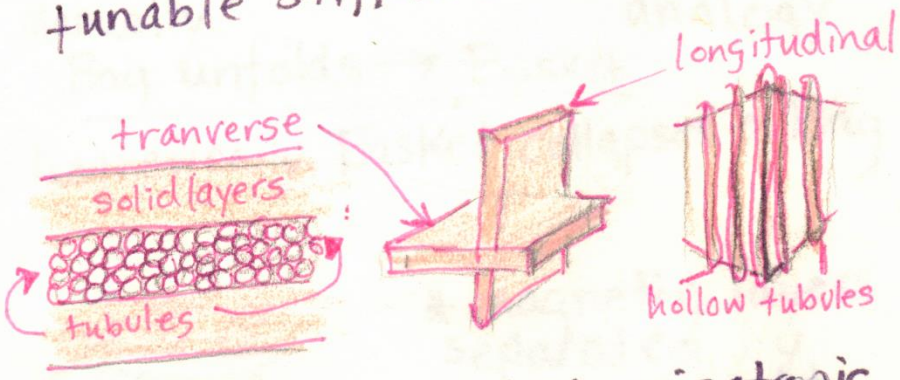


* fibers of spheres hollow/hierarchical tubular (hexagonal) structure ~ wasp nest
⇒ imparts strength + aeration

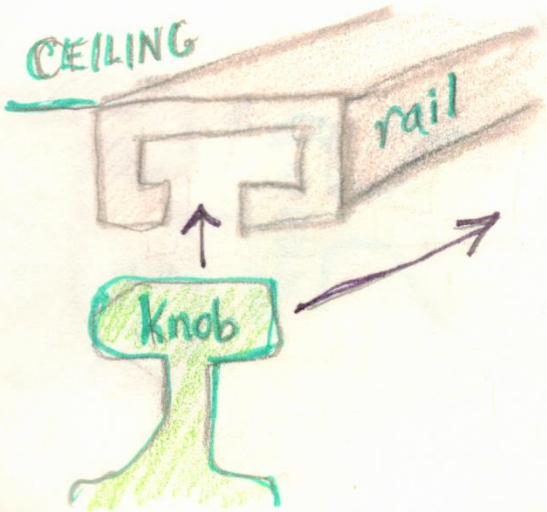
* Simple hook + loop suspension for basket

CONCEPT #3

* Origami configurations collapsible
tunable stiffness



* Origami material has high anisotropic toughness like baleen whale filter
tubule layers → provides aeration



* ant larvae "doorknob" protuberance slides into rail mount for suspension

CEILING

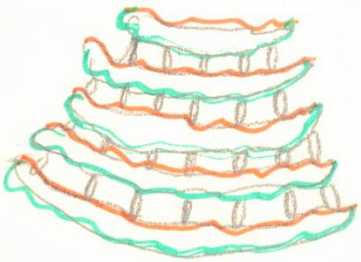
CONCEPT #4

* protein folding patterns

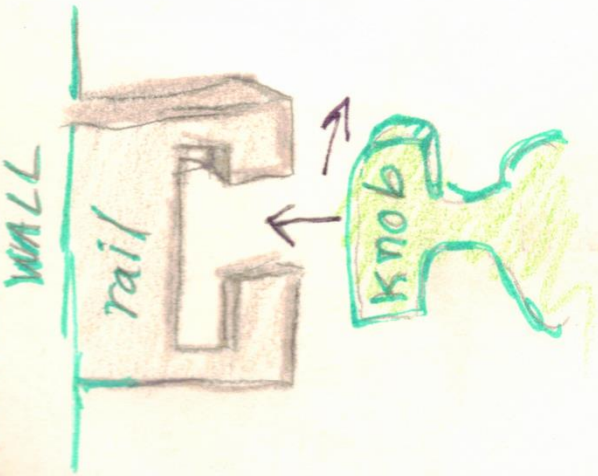
hydrophobicity → magnets analogy

Manually, Bag unfolds → Basket

Magnetically, Basket collapses → Bag



* magnetic layers separated by produce weight for aeration ~ wasp nest layers



* ant larvae "doorknob" protuberance slides into for suspension

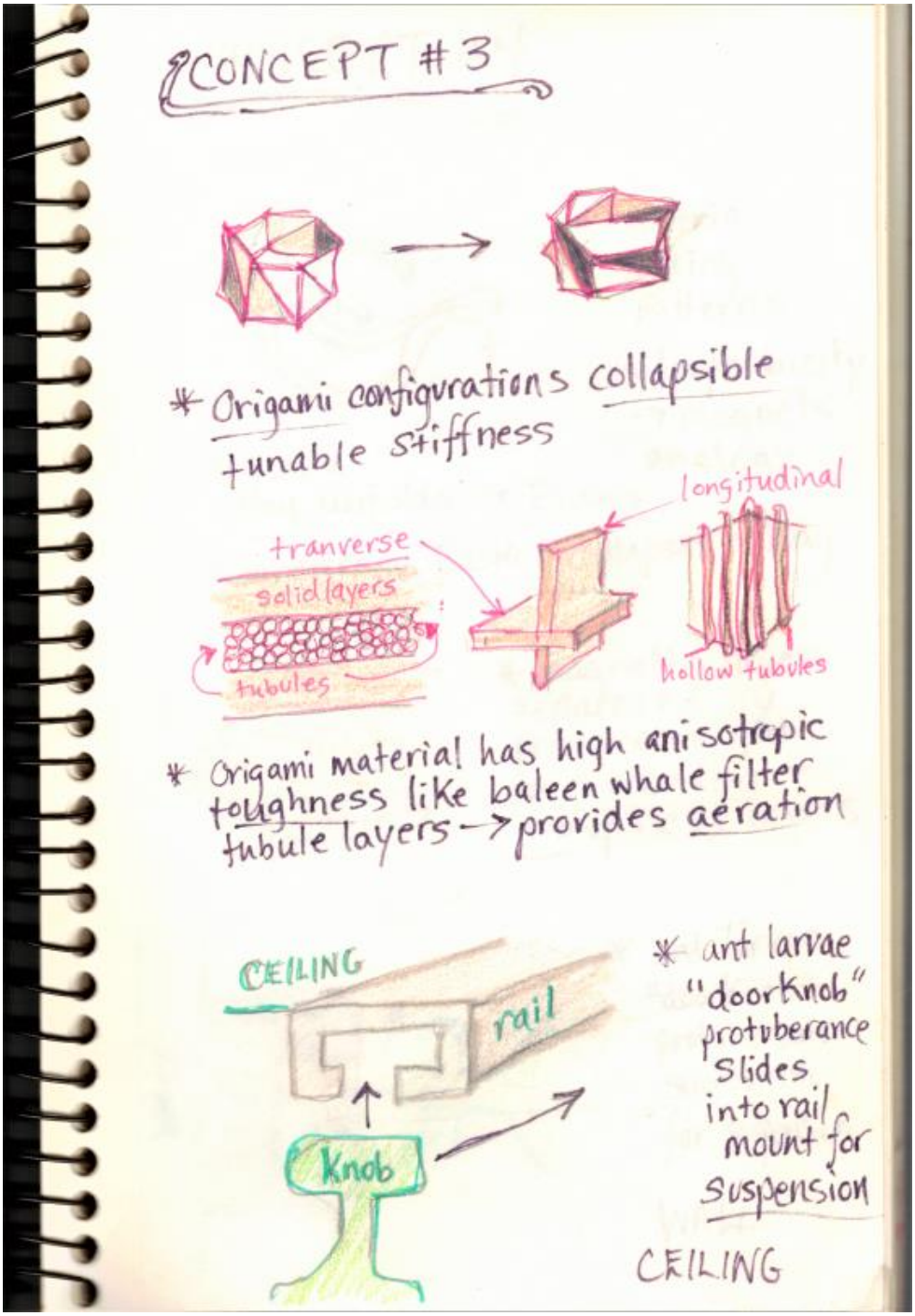
WALL

PART III:

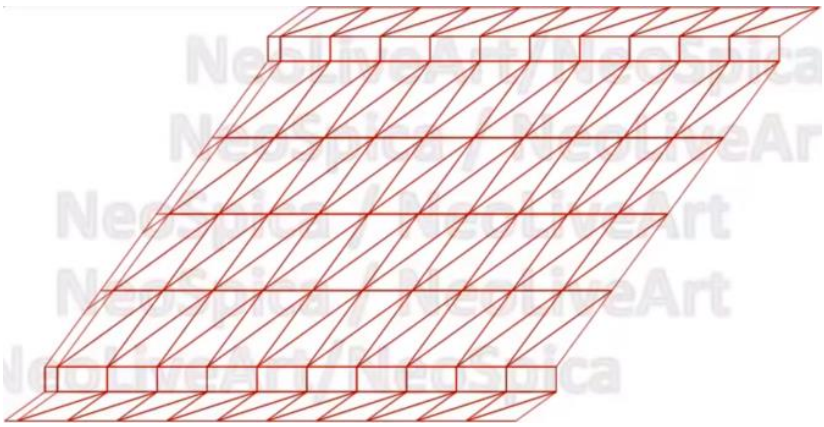
DESIGN CHALLENGE: PROTOTYPE PORTABLE HANGING BASKET

MATERIALS/PROTOTYPE USED

This prototype is more of a comprehensive than miniature proof-of-concept prototype. This is the original brainstormed design concept sketch:



I envisioned this material would be an engineered chitin polymer for the overall origami collapsible structural skeleton with wax coated microtubules emulating the whale baleen layers for aeration. Due to temporal, materials, and financial constraints, a miniature prototype was created with office supplies (e.g., paper, tape, string, markers) using this origami pattern:



The overall structure can hang decoratively in the home and hold produce. With additional time, I would have designed two (2) additional baskets for a tiered series of collapsible origami baskets that fit within one another for travel:

However, needs to be tiered like this basket design

The hanging version has a knob-type protuberance like the ant larvae that slides into a ceiling rail shown here. The colored holes indicate where the tubule layers that emulate the baleen whale layers for aeration.

The hanging basket & mechanism from above

Colored circles indicate "baleen" tubule layers

Here is the series illustrating the basket collapsing for travel (where I realized it needed a clasp):

Sequence to show collapsibility →

Needs a clasp here for maintaining flatness during travel →

PROTOTYPE PURPOSE

Will it work?

- The origami structure indeed has tunable stiffness and can be strong but still collapse; if the actual baleen tubules were installed, it would have even more structural integrity (anisotropic toughness)
- The origami structure both hangs and stands sturdily for easy of handling
- Collapsing the origami prototype indicates the basket(s) would need a button/strap/loop closure to keep it flat during transport; this mechanism should be quick release upon arrival at the market
- The hanging mechanism is sturdy and with an installed snap could provide pocket storage for an extra sack (e.g., for tiny items like nuts to be bagged separately)

Will the users like it?

- The design holds/contains fruits and vegetables but needs to be expanded to be a tiered basket to hold more volume and a higher variety of items
- The design does hang from the ceiling
- The design has tubules to aerate and maintain freshness of the contents; though it is breathable, the contents are not as visible as with some mesh-type baskets; also, the design needs to be a wider circumference-to-height ratio in order to eliminate stacking contact decomposition of the produce (i.e., so each basket tier is shallower)
- The design collapses well and is lightweight and configured to easily travel to a market
- The design is elegant and could be made to be very attractive with a variety of colors themes

PROTOTYPE MATERIALS/PROCESSES

- To achieve higher resolution, this prototype would need
    - The digital model to be refined and sent a 3D-printing process
    - Because chitin is a long-chain polymer of N-acetylglucosamine, it might be best to use it to strengthen a plant fiber or thick paper fiber; the wax coating would be required to moisture proof the surfaces
- During the proof-of-concept to alpha to beta and preproduction process, many aspects still need to be worked out to find the ideal point as concerns:
    - Speed of assembly (the design starts flat but the folding is tedious)
    - Materials choices being aligned with assembly processes
    - Materials stability and water-resistance testing
    - Flammability and food safety testing

This prototype evaluation has helped identify the aspects that will need fine-tuning. The fine-tuning would be required to move this nearly comprehensive prototype on to a TRUE proof-of-concept phase and ensure optimization of closing of the user need gap further along in the design process.