Project Notes:

Project Title: Identifying the relationship between nest architecture and strength
Name: Reed, Colleen

Note Well: There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

Contents:

Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

Knowledge Gap	Resolved By	Information is located	Date resolved
Different types of Bird Nests	Read Article and take notes on it	In my project brief, in the background section	10/20
Where to acquire bird nests	Research possible locations that may have bird nests online. Email experts in the field if they know of any resources I could use	In the logbook, in my professional communications	10/15
How does a compression test work?	Read manual for vernier material and structures tester	https://www.vernier.com/files/manuals/vsmt.pdf?srsltid=AfmBOoomngpCL983sGWBF0oP5xtmEVRpUWFytepMOQ_q9d9GIu8j0jOR	10/29

Literature Search Parameters:

These searches were performed between 8/24/2025 and XX/XX/2025.
List of keywords and databases used during this project.

Database/search engine	Keywords	Summary of search
WPI Library	Water sensor, level	I found the article "Smart Water Level Indicator with Dry Protection Based on Ultrasonic Sensor"
WPI Library	Plastic, bird, nest	I found the article "Do birds select the plastics debris used for nest construction? A case study in a Mediterranean agricultural landscape"
WPI Library	Bird nest simulation	I found the article "**A modeling algorithm for exploring the architecture and construction of bird nests"**
PubMed	Bird AND nest AND structure	I found the article "Differential use of nest materials and niche space among avian species within a single ecological community"
Google Scholar	geometry AND strength OR structural integrity OR stability	I started off by searching for material relationship AND structural integrity and found an article but I did not have access to it so I performed a couble more iterations of the same idea but different words until I found an article that was both availabel to me and related to my topic, I found the article "Manipulating the geometry of architectured beams for maximum toughness and strength"
WPI Library	structural support bird nests	I found the article "design

		principles of biologically fabricated avian nests”
WPI Library	material orientation AND strength	I found the article “Optimal material orientation of linear and non-linear elastic 3D anisotropic materials” I then decided that this article was not what I wanted to look for.
WPI Library	bird nest composition	I found the article “Composition of bird nests is a species-specific characteristic”
WPI Library	Loads on bird nests	I found the article “Load Transfer Behavior and Failure Mechanism of Bird’s Nest Anchor Cable Anchoring Structure”, then I realized this article is not talking about the thing I thought it was, so I kept scrolling through the pages and found the patent “Bird-nest type rope dome structure with load alleviating function”
Google Patents	patens for measuring dome strength	I found the patent “DOME STRUCTURE AND METHOD OF CONSTRUCTION”

Tags:

Tag Name	
#methodology	#plastics

Article #1 Notes: Title

Article notes should be on separate sheets

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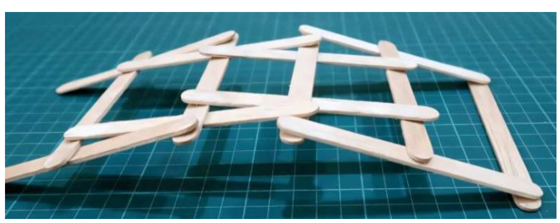
Source Title	
Source citation (APA Format)	
Original URL	
Source type	
Keywords	
#Tags	
Summary of key points + notes (include methodology)	
Research Question/Problem/ Need	
Important Figures	
VOCAB: (w/definition)	
Cited references to follow up on	
Follow up Questions	

Article #1 Notes: How do bird nests stay together? Researchers unravel entanglement between stiff, straight rods

Source Title	How do bird nests stay together? Researchers unravel entanglement between stiff, straight rods
Source citation (APA Format)	Harvard John A. Paulson School of Engineering and Applied Sciences. (2025, April 8). How do bird nests stay together? researchers unravel entanglement between stiff, straight rods. *Phys.org*. https://phys.org/news/2025-04-bird-stay-unravel-entanglement-stiff.html
Original URL	https://phys.org/news/2025-04-bird-stay-unravel-entanglement-stiff.html
Source type	News Article
Keywords	rod packing, jamming, physical entanglement
#Tags	
Summary of key points + notes (include methodology)	Researchers utilized the technique of X-Ray Tomography and computer simulations to reconstruct bird nests, because they wanted to understand what makes bird nests so strong and what keeps the materials together. After completing this task, they reconstructed the bird nests on their own with steel rods. These rods had varying lengths and widths. They found that if the rods were short and wide, the rods in the bird nest were found to be weakly entangled and only so in certain spots. However, when the structures with these qualifications were shaken up and down, the entanglement increased. Rods that were longer and had a shorter width, were entangled stronger, and the entanglement reached throughout the entire structure.
Research Question/Problem/ Need	How do stiff, macroscale components entangle with one another and how do these entanglements make bird nests so strong?
Important Figures	 This is a picture of a self-supporting bridge made from popsicle sticks. This picture helps to explain the idea of entanglement between components that are stiff and large.
VOCAB: (w/definition)	High aspect ratio: An object that is longer than it is wide Percolation: The spreading of something across an area

	Topological: relating to the way parts are arranged or interrelated
Cited references to follow up on	Liu, J., & Nagel, S. R. (2014). Jamming and rheology: Constrained dynamics on microscopic and macroscopic scales. *CRC Press*. Glover, A. L., & Barabási, A.-L. (2024). Measuring entanglement in physical networks. *Physical Review Letters*, *133*(7), 077401. https://doi.org/10.1103/PhysRevLett.133.077401 Dierichs, A., & Menges, A. (2016). Towards an aggregate architecture: Designed granular systems as programmable matter in architecture. *Granular Matter*, *18*, 25. 10.1007/s10035-016-0631-3
Follow up Questions	How is entanglement used in other biological structures? How does entanglement help to strengthen a bird nest? What degree of entanglement provides the most optimal structure for a bird nest(most support and strength)?

Article #2 Notes: Construction patterns of birds' nests provide insight into nest-building behaviours

Source Title	Construction patterns of bird's nests provifde insight into nest-building behaviours
Source citation (APA Format)	Biddle, L., Goodman, A. M., & Deeming, D. C. (2017). Construction patterns of birds' nests provide insight into nest-building behaviours. *PeerJ*, *5*. https://doi.org/10.7717/peerj.3010
Original URL	[Construction patterns of birds' nests provide insight into nest-building behaviours [PeerJ]]
Source type	Scientific Journal
Keywords	Construction materials, Structural properties, Bullfinch
#Tags	#Methodology

Summary of key points + notes (include methodology)	Throughout the study, it has been made clear that the materials chosen by Bullfinches to build a nest are not random. The study broke the nest up into three sections: the outer nest top, the outer nest bottom, and the cup wall. They found that the outer sections were composed of loosely interwoven materials, whereas the cup wall was composed of tightly interwoven material. Also, the material in the top of the outer nest was thicker, stronger, and more rigid compared to the material in the cup wall. Furthermore, the material found in the bottom of the outer nest was stronger than in the top of the cup. In addition, they discovered that the outer nest was nearly four times thicker than the wall of the cup, and the depth of the cup was nearly half of the height of the nest.
	
	Methodology notes:
	
	• Methodology was broken up into four sections;
	    ○ Nest Characteristics
	    ○ Nest Deconstruction
	    ○ Mechanical Analysis
	    ○ Statistical Analysis
	• 13 Bullfinch nests were collected
	• Forceps were used to deconstruct nests
	    ○ Prevent damage to materials
	    ○ Order of removal
	1. Top outer wall
	2. Cup
	3. The base was left over
	• They used a random number generator to randomly select pieces of a

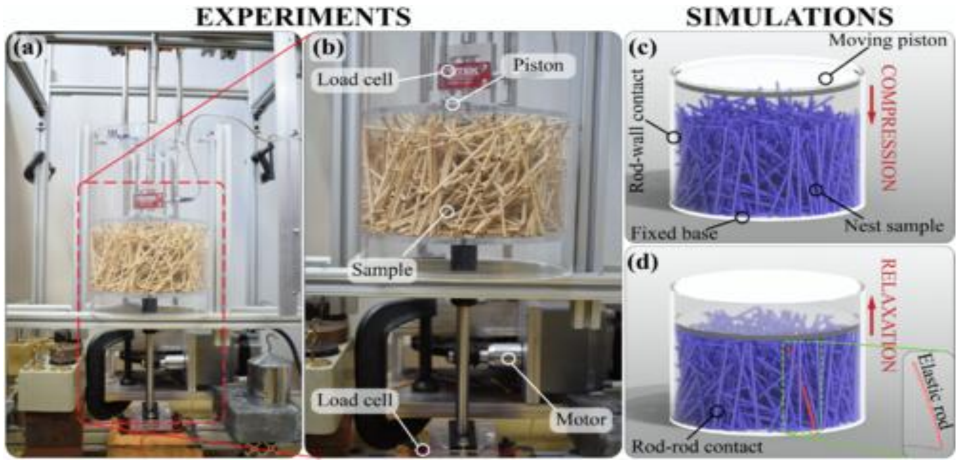
	nest from different sections 　　○ They examined the length of the sample and how many side branches it had • Used General linear mixed modeling to analyze differences in structural properties between the different areas of the nest
Research Question/Problem/ Need	The researchers want to know if the placement of materials in the bird nest and the structure of the bird nest are chosen purposefully. To do this, they researched the structural properties of the materials in different nests and how they corresponded to each other.
Important Figures	(a)  This figure helps to visualize what the author is referring to when they talk about the different regions of the bird nest. The grey area is the cup, the white area is the top outer nest, and the black is the lower outer nest.
VOCAB: (w/definition)	Morphology: the branch of biology that deals with the form of living organisms, and with relationships between their structures. Degree of Taper: Taper indicates conditions in which the diameter, width, or thickness of a long, narrow structure gradually becomes smaller toward the tip
Cited references to follow up on	Biddle, L. E., Deeming, D. C., & Goodman, A. M. (2014). Morphology and biomechanics of the nests of the common blackbird *turdus merula*. *Bird Study*, *62*(1), 87–95. https://doi.org/10.1080/00063657.2014.988119
Follow up Questions	• Do nests in colder climates have a stronger structural durability/integrity than those in warmer climates? • Are the individual regions of the nests in colder climates stronger than the corresponding regions in a nest from a warmer climate? • How can the structure of bird nests be applied to structures such as houses? • How much of a load would the nest be able to take from the top? 　　○ How much snow could be put inside the nest before the nest breaks? 　　　　▪ How does it break? 　　　　　　• What section of the nest breaks first? Does it snap or unravel?

Article #3 Notes: Micromechanical Origin of Plasticity and Hysteresis in Nestlike Packings

Source Title	Micromechanical Origin of Plasticity and Hysteresis in Nestlike Packings
Source citation (APA Format)	Bhosale, Y., Weiner, N., Butler, A., Kim, S. H., Gazzola, M., & King, H. (2022). Micromechanical Origin of Plasticity and Hysteresis in Nestlike Packings. *Physical Review Letters*, *128*(19), 198003. https://doi.org/10.1103/PhysRevLett.128.198003
Original URL	Micromechanical Origin of Plasticity and Hysteresis in Nestlike Packings | Phys. Rev. Lett.
Source type	Journal Article
Keywords	Jamming, Mechanical Deformation, Granular Materials
#Tags	

Summary of key points + notes (include methodology)	In an experiment, 460 rods of bamboo were scattered randomly inside a cylinder. The researchers found that as they applied more force to the rods, the contact point of the rods would rearrange. The researchers found implications of the increase of contact points between the rods. The first implication was that the overall system is more connected and can hold more stresses. The second implication was that the rods were moved to a position closer to the bending points of the other rods, ensuring that the rods are less likely to bend, which helps to increase stiffness. In addition, it was found that, during this rearrangement, more contact points between the rods were formed. Also, it was suggested that the rods would not rearrange until the initial friction between the rods was overcome by the force of the piston.
	
	Methodology Notes
	• Rods of bamboo were modeled in software *Elastica* as Cosserat rods
	    ○ They completed the experiment both within a simulation and within a lab using load cells
	    ○ Used the simulations to find the coordination number (number of contacts per rod)
	    ○ Also used simulation to find how much the rods will move along each other

Research Question/Problem/ Need	How to straight rods react to one another when pressure is applied? In addition, they wanted to investigate how the overall structure of something such as a

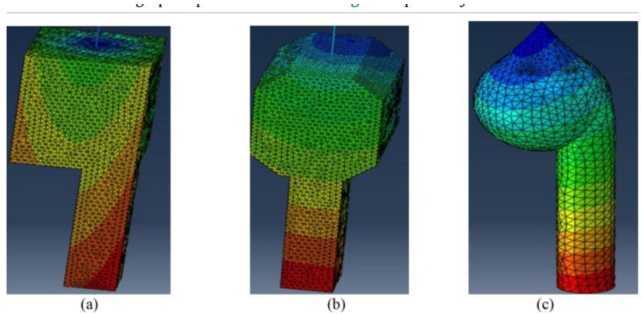
	bird's nest depended on the individual elements of the nest.
Important Figures	 This is a picture of the experiment they ran. It helps to visualize the rods they were using.
VOCAB: (w/definition)	Oedometer: A device used to measure a soil's compressibility Micromechanics: Analyzing a group of materials on the individual level
Cited references to follow up on	Dierichs, A., & Menges, A. (2016). Towards an aggregate architecture: Designed granular systems as programmable matter in architecture. *Granular Matter*, *18*, 25. 10.1007/s10035-016-0631-3
Follow up Questions	• How do nests respond to different elements (Snow, rain, hail, wind, etc.), and do those forces have enough force to stiffen the nest? ○ If this is the case, would the nests react to these forces differently based on the climate they are built in?

Article #4 Notes: Shape optimization of hanging structure using the concept of Biomimics

Source Title	Shape optimization of hanging structure using the concept of Biomimics
Source citation (APA Format)	Sindhu Nachiar, S., Anandh, S., Yegasainathan, N., & Kowsalya, M. (2023). Shape optimization of hanging structure using the concept of Biomimics. *Materials Today: Proceedings*, *93*, 46–53. https://doi.org/10.1016/j.matpr.2023.09.164
Original URL	Shape optimization of hanging structure using the concept of Biomimics - ScienceDirect
Source type	Scientific Journal
Keywords	Hanging Structures, Bio mimics, Weaver bird's nest, Finite element, Optimization
#Tags	

Summary of key points + notes (include methodology)	Summary:
	Hanging structures serve an important role in helping to reduce space that is occupied by structural supports. In addition, these structures show promise to help reduce concrete use in the future, and in turn help to reduce carbon emissions. Dr. Sindhu Nachiar S. examined the stability of the two traditional models of hanging structures (Rectangle and Octagonal) and compared it to that of a bio mimicked hanging structure under various loads. They did so by evaluating the stress, stiffness, and displacement. To calculate these values, a mesh structure was created in Abaqus for each structure. For displacement, the researchers varied the diameter of the connection wire for each hanging structure type. They found that as the diameter of the connection wire increased, the displacement of the hanging object decreased. Furthermore, the Weaver nest-based hanging object consistently had a lower displacement than the rectangular and octagonal shaped hanging objects. In addition, the bio mimicked structure was found to cause less stress on the connection wire. Finally, it was found that the bio mimicked structure has the highest stiffness. All in all, bio-mimicked structures are a more structurally stable option for hanging structures.
	Notes:
	• They made a bunch of different models of the same type
	    ○ Varied the diameter of the connection wire
	        ▪ The thicker the diameter of the connection wire, the more structurally stable the structure was

	• Meshing
	  ○ Mesh used was
	    ▪ C3D8 rectangular structured
	      • For the rectangular hanging object
	    ▪ B12 Linear
	    ▪ C3D10 tetrahedral structured
	      • For the weaver nest
	  ○ Beam column and hanging structure in host region
	  ○ Connection wire in imbedded region

Research Question/Problem/ Need	How does the structural stability of a bio-mimicked hanging structure compare to that of a conventional hanging structure?
Important Figures	 This is an image of the three different types of hanging structures that were evaluated in this study. (a) is the rectangular structure, (b) is the octagonal structure, and (c) is the bio mimicked structure
VOCAB: (w/definition)	Ferrocement: A type of material that is thin, strong, and hard Super structure: Part of a structure that is above the foundation Sub structure: Part of a structure that is below ground level
Cited references to follow up on	Sindhu Nachiar, S., Satyanarayanan, K. S., Lakshmipathy, M., & Sai Pavithra, S. (2021). Study on behaviour of compression members based on concept of biomimics. *Materials Today: Proceedings*, *34*, 518–524. https://doi.org/10.1016/j.matpr.2020.03.105
Follow up Questions	• What characteristics does the Weaver bird nest have that gives the bio mimicked hanging structure more structural stability than the conventional hanging structures? • Are there any other bird nests that could also be bio mimicked to improve the structural stability of hanging structures? • What material would maximize the structural stability of a bio-mimicked hanging structure?

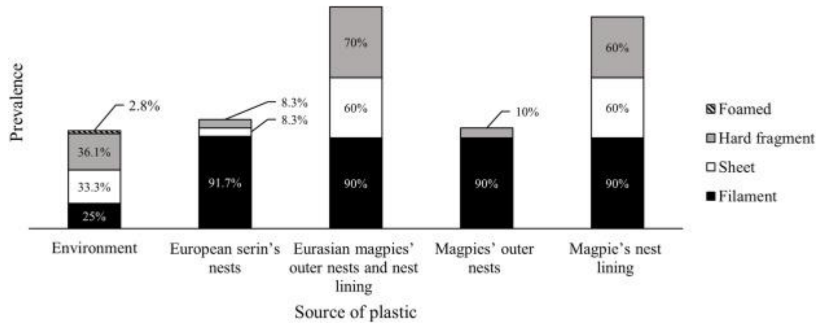
Article #5 Notes: Do birds select the plastics debris used for nest construction? A case study in a Mediterranean agricultural landscape

Source Title	Do birds select the plastics debris used for nest construction? A case study in a Mediterranean agricultural landscape
Source citation (APA Format)	Espinoza, M. J., Laviada, I., Taberner Cerezo, A., Luna, Á., Gil-Delgado, J. A., & Bernat-Ponce, E. (2024). Do birds select the plastics debris used for nest construction? A case study in a mediterranean agricultural landscape. *Environmental Research*, *255*, 119117. https://doi.org/10.1016/j.envres.2024.119117
Original URL	[Do birds select the plastics debris used for nest construction? A case study in a Mediterranean agricultural landscape - ScienceDirect]
Source type	Journal Article
Keywords	Nesting behavior Environmental pollution Fringillidae Corvidae Terrestrial birds Garbage
#Tags	#plastics
Summary of key points + notes (include methodology)	Currently, there is a dearth in knowledge surrounding plastics in nests of terrestrial birds, especially when compared to that of marine environments. Maria Jose Espinoza et al. aim to close this gap by presenting a study on the plastic prevalence within European magpies and European Serin. In addition, they aim to have a better understanding of why birds select plastics for nest construction and if there are any specific colors or materials that birds tend to opt for more frequently. To do so, they began by surveying the land to understand the overall prevalence of plastic in the environment. This is important to get a better understanding of how prevalence of plastic in the environment connects to the prevalence of plastic in bird nests. Next, they took apart the nests they found and classified the materials into categories of anthropogenic or natural and by where the material was found in the nest. For the assessment on plastic prevalence in the environment, they found 50 pieces in their tested area of 36 square meters. The most prevalent plastic found was hard filaments. As for the prevalence of plastic in the nets, plastic made of 3.8% of the weight of the lining of a magpie nest. In the serin nests, 117 pieces of plastic were found, with 31 pieces above 10.5 cm, 56 between 2 and 5 cm, and 30 less than 2 cm long.

Notes:

- Intro
  - Plastic available for birds to use in their nests is increasing each year
  - Info about selection about type and color of plastics that birds choose varies greatly and is inconsistent
  - Studying European Magpie and European Serin.
- Method
  - Background
    - Magpie is a medium sized bid
      - Their nest is relatively big, but size can vary based on the location of the nest
      - Nest type is a mud cup
        - Situated on spherical branches
        - Dome of branches
        - Thorny
        - Varying sizes of branches
    - European Serin
      - Smallest European finch
      - Small nest
        - Cup nest
        - Made from herbaceous roots, moss, and lichens
          - The Inside has hair, feathers, and hairy plants
  - Location
    - They found the nests in 17 ha of orange groves
    - Nests were collected in early August, then dried until they had a constant weight
  - Plastic debris availability
    - There were 18 groves in the 17 ha of orange groves and 6 were randomly selected
      - In those 6 randomly selected groves, 36 sections of 1 meter squared were selected for their survey of plastic debris availability
        - Surveyed in March because nest building season is usually in March
        - They then collected the plastics in these squares and analyzed it
          - They did include microplastics in their evaluation because birds would not be able to use that in their nests
          - Plastics found in soil and tree branches were also collected
          - The plastics were sorted by type and color in Ziplock bags.

	- To analyze it, they measured prevalence, abundance, type, size, and weight.
	  - Classifications for type were sheets, hard fragments, filaments, and foamed plastics
	- Nest analysis
	  - Disassembled using tweezers
	  - Material classification:
	    - natural or anthropogenic
	    - position within nest (where it was in the nest)
	  - Created a pool of all the filament plastics and calculated the mean length size of the filament that the species used during nest construction
	    - They chose 64 at random (they could choose 29, which they determined based on previous sampling methods), because they wanted to “bolster statistical power” (3).
	- Statistical analysis
	  - Fisher exact test was used to determine if one nest has more plastic than the other
	  - Magpies
	    - Prevalence of plastic in different parts of nest and complete nest were compared to plastic prevalence in the surrounding environment
	      - Not all nests were examined because not all nests were structurally complete
	- Results
	  - Debris
	    - 50 plastic fragments were found in the 36 meters squared soil sample (26/32 of the samples had plastic in them)
	    - Most prevalent plastic was hard fragments
	  - Debris in nests
	    - Magpie
	      - Nest lining weighed between 25.3 and 125.9 g
	      - Outer nest weighed between 1217.1g and 2305.2g
	      - Plastic made up around 3.8% of weight in nest lining
	    - Serin
	      - weighed between 3.6 and 12.5 grams
	      - 117 pieces of plastic were found in a group of 12 nests
	        - 31 pieces were above 10.5 cm, 56 between 2 and 5 cm, and 30 less than 2

	cm
Research Question/Problem/ Need	Does the type and color of plastic influence whether birds incorporate the plastic into their nests? More specifically, how do the European serin and magpie incorporate plastic into their nests and what traits do those plastic have?
Important Figures	 This image describes the distribution of the type of plastic and where it was found.
VOCAB: (w/definition)	Ubiquitous: omnipresent Anthropogenic: of human origin or creation
Cited references to follow up on	Blettler, M. C. M., Gauna, L., Andréault, A., Abrial, E., Lorenzón, R. E., Espinola, L. A., & Wantzen, K. M. (2020). The use of anthropogenic debris as nesting material by the greater thornbird, an inland–wetland-associated bird of South America. *Environmental Science and Pollution Research*, *27*(33), 41647–41655. https://doi.org/10.1007/s11356-020-10124-4 Corrales-Moya, J., Barrantes, G., Chacón-Madrigal, E., & Sandoval, L. (2021). Human waste used as nesting material affects nest cooling in the clay-colored thrush. *Environmental Pollution*, *284*, 117539. https://doi.org/10.1016/j.envpol.2021.117539 Alambiaga, I., Álvarez, E., Diez-Méndez, D., Verdejo, J., & Barba, E. (2020). "The tale of the three little tits": different nest building solutions under the same environmental pressures. *Avian Biology Research*, *13*(3), 49–56. https://doi.org/10.1177/1758155920943116

Follow up Questions	• How does plastic prevalence in birds' nests compare from a coastal ecosystem to a terrestrial ecosystem?
	• How is plastic being incorporated into the lives of other animals?
	    ○ What are they using it for? Any specific types of plastic that are more prevalent?
	• Would a bird be able to comfortably live in a nest made entirely of plastic?
	    ○ Would it affect the growth of the baby birds? Would it leave the nest entirely? Would the nest keep the birds warm enough?

Article #6 Notes: Human waste used as nesting material affects nest cooling in the clay-colored thrush

Source Title	Human waste used as nesting material affects nest cooling in the clay-colored thrush(Corrales-Moya et al., 2021)
Source citation (APA Format)	Corrales-Moya, J., Barrantes, G., Chacón-Madrigal, E., & Sandoval, L. (2021). Human waste used as nesting material affects nest cooling in the clay-colored thrush. *Environmental Pollution*, *284*, 117539. https://doi.org/10.1016/j.envpol.2021.117539
Original URL	[Human waste used as nesting material affects nest cooling in the clay-colored thrush - ScienceDirect]()
Source type	Scientific Article
Keywords	Nest Cooling, Nest Porosity, Urbanization, Urban nesting, Artificial materials consequence
#Tags	
Summary of key points + notes (include methodology)	Josue Corrales-Moya et. al. acknowledged that a lot of different bird species, especially in urban areas, have begun incorporating plastics and other human waste into their bird nests. This brought them to their question of how these materials affect the cooling of the nests in clay-colored thrush. To conduct their research, they received 46 nests from the Museo de Zoologia, which they stored at 20 degrees Celsius and 30% humidity. In addition, they only assessed bird nests that matched the elevation of a typical urban bird. For each nest, they conducted two experimental trials. The first one was used to simulate nest cooling when the female was away, whereas the second trial simulated when the female was incubating, in which a cotton ball weighing 20g was placed. To measure the nest cooling, the nests were heated up to 40 degrees Celsius for about twelve minutes. The nests were then left to cool for ten minutes, with their temperature being measured every minute. To account for differences in cooling time depending on size of nest, the dimensions of each nest were taken. The researchers found that all the nests that they tested had some sort of human waste in them, with the most common types being cotton threads, plastic broom fibers, and polyester cotton. On average, the artificial material took up between .001 and 30.8% of the total mass. Results also showed that when artificial material decreased, nest cooling decreased as well. In addition, nests with larger cups cooled slower than those with smaller cups. Notes: Intro: • Testing artificial materials on thermal properties of nests

Methods:

- Species Background
  - Clay-colored thrush
  - Found in range of Texas to Columbia
  - Open cup nest with plant material with mud in the middle layer and roots and parts of leaves in the outer layer.
- Artificial Material Mass
  - Only used nests that were between 318 and 1020 meters in elevation because that is the typical elevation of a bird nest in an urban environment
  - Two trials were conducted per nest
    - First trial simulated when the female was away doing self-maintenance
    - Second trial simulated when the female was in the nest incubating
      - A 20g cotton ball was placed in with to simulate the incubation
  - Measured temperature inside the nest cup using iButton data logger, which was placed in the middle of the cup.
  - Both the eggs and nest were heated from 20 degrees Celsius to 40 degrees Celsius using a 250 W light bulb for about 12 minutes during each trial.
  - Nest then cooled for 10 minutes, with the temperature being measured every minute until it reached a temperature of 20 degrees Celsius.
  - Nest dimensions were taken to consider for different nest sizes having different cooling times.
    - Nest length, nest height, nest base depth, cup length, cup width, cup height, nest wall thickness
- Results
  - Nest Dimensions
    - 46/46 nests sampled had artificial materials in them
    - 33 had cotton threads, 25 had plastic broom fibers, 25 had polyester cotton as most common artificial materials
    - Mass of artificial material between 0.1g and 17.5g
      - Percentage of total mass between .001-30.08%
  - Nest Cooling
    - When Adobe mass increased, nest cooling decreased
    - Nests with larger cups cooled slower than those with smaller cups
- Discussion
  - The bird uses a wide variety of materials
    - Most were materials usually left on the ground
  - Nest cooling increased with mass of artificial materials
  - Artificial Materials may be less compact and cause porosity and furthermore allow for heat to leave quicker
    - Bad for females because they would need to increase

- their metabolic rate to ensure that they are keeping their eggs warm enough for embryonic development
  - If the embryos develop below the required temperature, they may be smaller in size and less likely to survive
- Adobe retains some heat while the female leaves the nest

Research Question/Problem/ Need

How does anthropogenic material affect the cooling of bird nests for clay-colored thrush?

Important Figures

Table 1
Artificial materials found in the 46 studied nests of the clay-colored thrush and the number of nests with each type of material.

Artificial material	Number of nests
Electric wire	1
Silicon fragment	1
Metallic staple	1
Plastic mesh	1
Cloth closures	1
Concrete	2
Sponge	2
Fishing lines	2
Metal fragments	2
Plastic tie	3
Dental floss	3
Plastic thread	4
Polystyrene	4
Glass	4
Metal thread	5
Construction nails	5
Cigarette buts	5
Plastic fragments	5
Cloth fragments	6
Paint	7
Paper	20
Sack fibers	21
Cotton laces	21
Candy wrappers	23
Synthetic cotton	25
Plastic broom fibers	26
Cotton threads	33

This diagram describes what the most common human wastes to be used in the nests were.

VOCAB: (w/definition)

Porosity: the quality or degree of having minute spaces or holes through which liquid or air may pass:
Incubation: When a mother bird is sitting on her eggs in a nest
Substrate: an underlying substance or layer.
Orifice: Opening

Cited references to follow up on

Blettler, M. C. M., Gauna, L., Andréault, A., Abrial, E., Lorenzón, R. E., Espinola, L. A., & Wantzen, K. M. (2020). The use of anthropogenic debris as nesting material by the greater thornbird, an inland–wetland-associated bird of South America. *Environmental Science and Pollution Research*, *27*(33), 41647–41655. https://doi.org/10.1007/s11356-020-10124-4

Corrales-Moya, J., Barrantes, G., Chacón-Madrigal, E., & Sandoval, L. (2021). Human waste used as nesting material affects nest cooling in the clay-colored thrush. *Environmental Pollution*, *284*, 117539. https://doi.org/10.1016/j.envpol.2021.117539

	Crossman, C. A., Rohwer, V. G., & Martin, P. R. (2011). Variation in the Structure of Bird Nests between Northern Manitoba and Southeastern Ontario. *PLoS ONE*, *6*(4), e19086. https://doi.org/10.1371/journal.pone.0019086
Follow up Questions	What else besides nest size and human waste may impact nest cooling? Are all species flexible as to what human materials they use for their nests, or is that specific to clay-colored thrush? How does nest size correspond with how much plastic is in the nest?

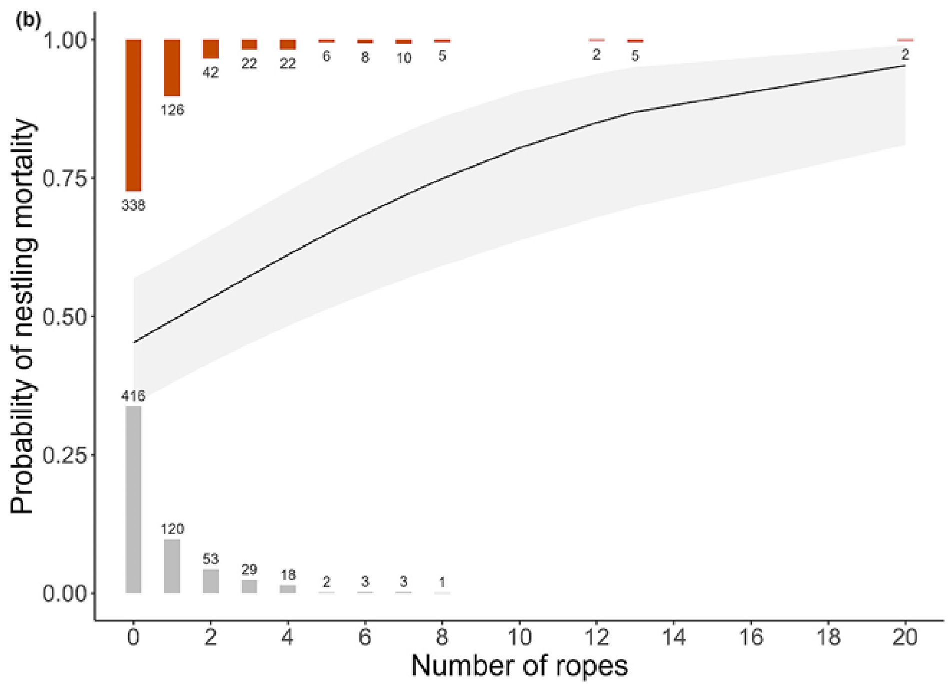
Article #7 Notes: A death trap in the nest: anthropogenic nest materials cause high mortality in a terrestrial bird

Source Title	A death trap in the nest: anthropogenic nest materials cause high mortality in a terrestrial bird
Source citation (APA Format)	Heinze, U. M., Acácio, M., Franco, A. M. A., & Catry, I. (2025). A death trap in the nest: anthropogenic nest materials cause high mortality in a terrestrial bird. *Ecological Indicators*, 113796. https://doi.org/10.1016/j.ecolind.2025.113796
Original URL	A death trap in the nest: anthropogenic nest materials cause high mortality in a terrestrial bird - ScienceDirect
Source type	Research Article
Keywords	Human debris, Waste, Plastic pollution, Baler twine, Entanglement, Breeding success, White stork
#Tags	

Summary of key points + notes (include methodology)	In recent years, global waste has reached a production rate of 2126 billion tons annually. Some of this plastic has worked its way into the nests of birds. To investigate the impact of those plastics, Ursula M. Heinze et al. conducted a study on nestling mortality because of plastic entanglement in nests in white storks. This study was held over a course of five years, with over 568 nests being studied. This study was broken up by year, with around 100 nests being studied each year. To study the nests, the researchers took photographs of the nests weekly from March to June. The final 93 nests were used to study nestling mortality, whereas the first nests were used to study plastic presence in the nests of the storks. Their results showed that 91% of nests had anthropogenic materials in them, with the most common material being soft plastics. The leading cause of entanglement was found to be ropes, at 63%. They also found that most of the entanglements occurred when the stork was very young (1-2 weeks old). To combat this problem, the researchers urge for new policies that decrease hazardous materials in terrestrial environments.
	
	Notes:
	• Intro
	    ○ Global waste at 2126 billion tons annually in 2020
	    ○ Some anthropogenic materials are mistaken for food and then incorporated into bird nests
	    ○ Some materials cause infant birds to become entangled and get injuries that are sometimes lethal
	    ○ Storks nest near human settlements and get food from landfills
	• Methodology
	    ○ Study Area
	        ▪ 568 nests measured over five years
	        ▪ Nests were in varied locations, some near urban areas, some near grassland
	        ▪ Nests were mostly found on trees, but some were found on artificial

structures
- Nest Monitoring
  - 100 stork nests and above were measured each year
    - Photographed weekly from March to July
      - Used a camera attached to a pole to take photos
- Nestling examination
  - 93 nests in 2023 physically examined on weekly basis
    - Took note of how many nestlings were entangled in the material
- Assessment of Nest Content
  - They selected two images from each nest
    - One from incubation and one from when nestlings less than two weeks old
  - ANMs were taken note of and categorized by type of material/function of material
  - Found the mean number of each material overall
- Origin of ANMs
  - Classified land use into 9 classes
  - Found mean population density in areas around bird nest
  - Measured distance to main roads, settlements, and landfills from nest colonies
- Statistical Analysis
  - Related presence or absence of chick entanglements with average number of hazardous material and rope
    - Used generalized linear model
  - In the same way, they related number of entanglements in rope to average number of ropes in the nest
    - Only hazardous material included
  - Modeled proportion of nest mortality in each nest
    - Used GLMM with binomial distribution and logit link function
  - Also used GLMM to evaluate correlation of presence of ropes to the surrounding habitat

- Results
  - 91% of nests had ANMs
    - Soft plastics most prevalent
  - 63% of entanglements were caused by ropes
    - Some nests had up to 22 ropes
  - Nestling entanglement
    - Most entanglements occurred when the chick was young (1-2 weeks)
    - Positive and significant correlation between number of ropes and entanglement probability
    - Probability of entanglements increased as amount of hazardous material in the nest increased
  - Nest Surroundings
    - Higher chances of finding ropes in the nests when the stork was near farming land
- Discussion
  - ANMs mortality

	▪ 12% entanglement is a lot higher than previous studies • Only other that reported similar numbers was a study on osprey nests ▪ White storks were used as an indicator species ○ Implications ▪ To show how baler twine poses a great threat to animal life ▪ New policies need to be made to reduce hazardous materials in terrestrial environment.
Research Question/Problem / Need	How do Anthropogenic materials in the nests of white storks influence nestling mortality? What environmental factors influence the materials found in the nest and what materials cause greater chances of entanglement?
Important Figures	 This diagram helps to visualize how the number of ropes influence nestling mortality.
VOCAB: (w/definition)	Garnered: gathered
Cited references to follow up on	Kang, K.-H., Nam, K.-B., Jeong, B.-S., Kim, J.-S., & Yoo, J.-C. (2023). The use of plastic litter as nesting material by the azure-winged magpie *Cyanopica cyanus* in an agricultural environment of South Korea. *Environmental Science and Pollution Research*, *30*(35), 84814–84821. https://doi.org/10.1007/s11356-023-28409-9 Battisti, C., Staffieri, E., Poeta, G., Sorace, A., Luiselli, L., & Amori, G. (2019). Interactions between anthropogenic litter and birds: A global review with a 'black-list' of species. *Marine Pollution Bulletin*, *138*, 93–114. https://doi.org/10.1016/j.marpolbul.2018.11.017 Francila, F. A., Prasanna, N. S., Shrotri, S., Nawge, V., & Gowda, V. (2023). Life amidst debris:

	Urban waste management affects the utilization of anthropogenic waste materials in avian nest construction. *Tropical Ecology*, *64*(4), 756–764. https://doi.org/10.1007/s42965-023-00302-z

Follow up Questions	• Why are White Storks a good model species?
	    ○ What is it about them that makes them representative of many bird species?
	• Can nestling entanglement differ based on nest type?
	    ○ If two nests have the same amount of hazardous material, will one have a higher nestling mortality rate?
	• How did the amount of plastic in the nest differ based on if the nest was found in a tree or on an artificial structure?

Article #8 Notes: A modeling algorithm for exploring the architecture and construction of bird nests

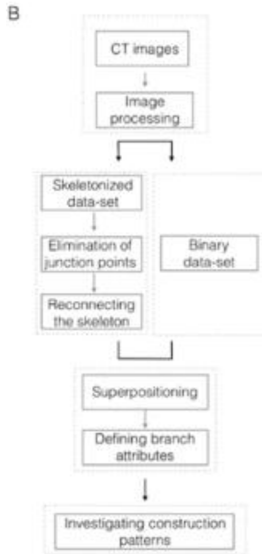
Source Title	A modeling algorithm for exploring the architecture and construction of bird nests
Source citation (APA Format)	Jessel, H. R., Aharoni, L., Efroni, S., & Bachelet, I. (2019). A modeling algorithm for exploring the architecture and construction of bird nests. *Scientific Reports*, *9*(1), 14772. https://doi.org/10.1038/s41598-019-51478-1
Original URL	A modeling algorithm for exploring the architecture and construction of bird nests | Scientific Reports
Source type	Scientific Article
Keywords	Simulation, Bird nests, structure-function relationship, CT scan, structural biology
#Tags	#Methodology
Summary of key points + notes (include methodology)	Ido Bachelet et al. focused their research on the nests of Dead-Sea Sparrow and made a algorithm to successfully model the nests of the Dead-Sea Sparrow. The researchers obtained three different nests from the Rift Valley in Israel, which were than scanned with a CT Scanner. In the next step, the scans of the nests were imported into Fiji, an image processing software. In Fiji, a set of filters were applied to the scans to reduce noise and it was also used for averaging. Also in Fiji, to segmentation tools were used to extract the data of the branches and to create the skeleton of the structure. Next, all the cavities in the nest were filled and a 3D thinning algorithm was applied. Using an algorithm in python, the researchers deleted all the junctions and forks in the model. In addition, the median thickness of the branches was calculated. To do so, the image had to be blurred a little bit. Finally, a simulation of the nest building process was created. They used to different methods to build the nest. The first method built off the skeleton and each incrementing stick was added based on which stick was the most gravity-connected. The second process was similar except that instead of the most gravity-connected stick being added at each step, the stick that was the least gravity-connected and had the most friction was added. They found that many sticks had a non-random orientation, with 66% of the sticks having an horizontal angle greater than 45%. They also found that the mean number of contact points per branch was 30±12. For future research, they look to see how this algorithm can be applied to other geometrically complex biological structures. Notes: • Intro ○ They focus on Dead-Sea Sparrow

        - Usually have 3-6 eggs in their nest
- Methods
    - Nests
        - Dead-Sea Sparrows build big oval nests in tree branches
        - The male chooses the site
            - Then builds nest structure which is made of stiff dry branches
                - They don't use any adhesive
            - In the inside of the nest there are softer materials
        - They used 3 nests from the Rift Valley in Israel
    - CT scans
        - Nests scanned with a dual source CT scanner system
            - X-ray tube voltage at 120 kVp
            - X-ray current: 33 mAs
        - They got best contrast using sharp convolution kernel filter(V90 µ)
        - in-plane resolution: .5mm
        - slice-to-slice separation: .1mm
    - Image Processing
        - CT scans imported into Fiji
            - Software for image processing
        - Filters were applied to the images
            - Neighborhood averaging filter
                - Used with sigma value of 5 on z-axis
            - 3D gaussian Blur filter
                - Used with sigma value 1
                - Reduce image noise and reduce detail level
        - Segmentation tools
            - Generated two data sets
                - For yielding structural skeleton
                - Extracting the volumetric data of a branch
        - A range of thresholds tested on each nest to make sure the branches were optimally identified
            - Performed step of manual validation on segment of nest
                - They tested if the nest met all the thresholds that come from the specific greyscale of their CT scan
                - Optimal threshold would ensure that the image noise is reduced while the significant data of the image is preserved
        - Eliminated inner branch cavities
            - A hole filling operation applied to fill inner voids
        - 3D thinning algorithm applied
            - To get the structure's skeleton

- Performed symmetrically
- Skeleton smoothed
  - False branches pruned
- Image exported to image sequence

- 3D model generation
  - Algorithm in python used to break skeleton into simple edges
    - Deleted all junctions and forks
  - Cleaning
    - 1. Tail edges pruned
      - Used iterative elimination process
      - Predefined length threshold of T=5mm
    - 2. Junctions identified and pruned
      - Removed pixels(=2mm) off each junction edge
    - 3. True Junctions reconstructed
  - Similar algorithm applied to rate correlation between endpoints at a predefined distance from each other
  - Used formula to determine whether two segments came from the same branch:
    - C=D·A·*max*(d1,d2)·*max(*a1,a2)·(t2/t1)T
      - C=branch friendship
      - D= distance between endpoints
      - A=difference in orientation
        - Angle between orientation vectors(v)
        - 180-(v1,v2)
        -
      - d1:distance between p1 and v1
      - d2: distance between p1 and v2
      - t: thickness of branch
    - cutoff values needed to be used before the numbers could be plugged into the formula
      - D min=1.0
      - dmin=.5
      - t2/t1min=.1
      - Tmin=3
    - Branches that had a high friendship were iteratively linked
    - List of branches made and described as set of voxels
  - Brach thickness calculated
    - Images were blurred
    - Branch thickness recorded at each skeleton point
      - Skeleton and binary image sets were superpositioned

	- Diameter values added to each voxel unit - Constant thickness value documented - Median thickness of samples along branch - Contact points identified - Distance between adjacent branch surfaces measured - Construction Patterns Investigation - Rhino-Grasshopper platform used - Nests described as directed networks - Greedy algorithm used to identify contact points from contact networks - Also assigned each branch a gravity-connected value - Identified scaffold of structure - Braches added one by one - Most gravity-connected branch added in next step - Most likely to be supported by existing structure - Gradual algorithm also used - 1. Identify structure scaffold - 2. Each branch added - Least gravity connected but most likely to stay put because of friction - Results - scanning resolution was good for identifying individual components(.5mm plane) - In the process of thinning branch centerlines connected with bridges - Branch positions non-random - 66% had horizontal angle greater that 45 degrees - 33% of nests lower than that # - Mean length of 159±11mm - Mean thickness: 2.28±0.33mm - Mean number of contact points per branch: 30±12 - Stability of the nest depends on spatial relationship - Between branches and geometric properties - Discussion - Future Research: - Structure-function of other complex biological structures
Research Question/Problem/ Need	How can a bird nest be modeled to explain the construction process of birds? How can an algorithm be used to isolate distinct parts of a birds nest from a CT scan?

Important Figures	 This diagram describes the steps taken in their algorithm to model the nest.
VOCAB: (w/definition)	Convolution: a coil or twist, especially one of many: Iterative: repetitive Voxel: A value on a 3D grid in modeling
Cited references to follow up on	Biddle, L. E., Deeming, D. C., & Goodman, A. M. (2018). Birds use structural properties when selecting materials for different parts of their nests. *Journal of Ornithology*, *159*(4), 999–1008. https://doi.org/10.1007/s10336-018-1571-y Jessel, H. R., Chen, S., Osovski, S., Efroni, S., Rittel, D., & Bachelet, I. (2019). Design principles of biologically fabricated avian nests. *Scientific Reports*, *9*(1), 4792. https://doi.org/10.1038/s41598-019-41245-7 Silva, B., Correia, J., Nunes, F., Tavares, P., Varum, H., & Pinto, J. (n.d.). Bird Nest Construction—Lessons for Building with Earth.
Follow up Questions	Why was the background filter assigned an 8-bit unsigned integer? What processing filters were used to “pre-process” the nests? Can this model be used for other bird nests? Is it possible to add elements into the nest that are not in the original nest that was scanned?

Article #9 Notes: Differential use of nest materials and niche space among avian species within a single ecological community

Source Title	Differential use of nest materials and niche space among avian species within a single ecological community
Source citation (APA Format)	Akresh, M. E. et al. (2024). Differential use of nest materials and niche space among avian species within a single ecological community. *Ecology and Evolution, 14*(9). **https://doi.org/10.1002/ece3.70142**
Original URL	https://onlinelibrary.wiley.com/doi/10.1002/ece3.70142
Source type	Journal Article
Keywords	Avifauna, niche breadth, niche differentiation, niche segregation
#Tags	

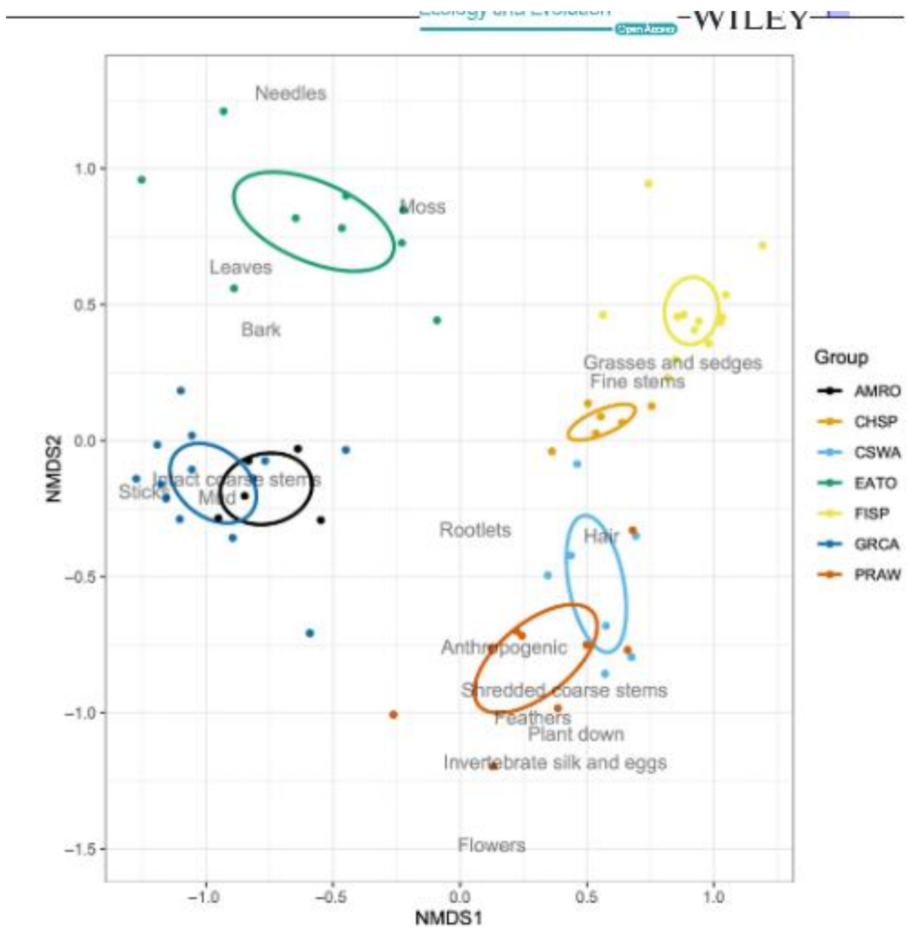
Summary of key points + notes (include methodology)	Michael E. Akresh et al. noticed that there was a lot of work done regarding prevalence of certain materials across a single species, however less work done than compared the use of materials in the nests of different species within the same ecosystem/area. For this study, the researchers went to a site in Lake Pleasant, MA and studied seven different species of birds. The environment that they studied in had a lot of pitch pines, tree oaks, and sparse woody vegetation. In May and June, they collected around ten bird nests from each of the 7 species. They then measured the nests with a ruler, considering nest width and height, nest cup width and depth, and average floor and wall thickness. The nests were then stored and cooled for three days. After that three-day period, the nests were then left to dry and were weighed. After the initial weighing, the nest was taken apart and the materials were categorized and weighed based off of the material type and location in the nest. The results showed that the material use between the different bird species in the same area differed greatly. It was also concluded that many birds chose materials that blended in with their environment for protection from predators. Six out of the seven species utilized anthropogenic materials in their nest.
	Notes:
	• Intro
	    ○ Birds select specific sites for their nests
	        ▪ Distribution of nesting sites reduces threat of predation
	    ○ Materials used for nest are picked from a criteria for design
	        ▪ To provide structural support and provide insulation
	    ○ They studied a group of bird species in pitch pine-scrub oak

ecosystem
- 7 species were studied that had the same breeding territory
  - Different materials are used in different parts of the nest
- Methods
  - The area they used is in the Montague Plains Wildlife Management Area, MA
  - Survey area had a lot of open tree canopies
    - Had a lot of pitch pine and tree oak
    - Sparse woody vegetation, lowbush blueberries, forbs, and more
- Sampling Methods
  - In May and June nests from ground species were searched for
    - Systemic searches were held and parental observations were used
    - They collected the nest once it failed or the young fledged
  - A ruler was used to measure:
    - Nest width and height, nest cup width and depth, average wall thickness, and floor thickness
      - Outlying sticks or other material were not included in the calculations
  - Nest was carefully removed and placed in a sealed plastic bag
  - Nests were placed in freezer for 3 days
    - To kill off any insects and bacteria
    - Once done, left to dry for three days
  - Nests were weighed after drying
  - 10-20 nests collected for each species
    - 9-13 nests chosen per species for disection
  - After nest dissection, weight of each material type in each section of nest weighed
- Statistical Analysis
  - Mass of individual types was divided by the sum of the masses of all material types in a particular nest
    - Did not divide by the mass of the entire nest because the mass of entire nest was often higher
    - Materials added after initial construction were not included in this calculation
  - Non-metric multidimensional scaling used to visualize the material use among the group of birds
  - To compare material prevalence between the different sections of the nest, a multivariate ANOSIM analyses was used
- Results
- Nest dimensions and mass
  - Smaller species built small and light nests
  - Larger species built nests that were larger and heavier
- Total nest composition
  - Materials differed greatly between bird species

	- Praierie warblers mostly made their nests with shredded coarse stems
	  - Typically made up around 32% of the nest mass
	- Chestnut-sided warblers
	  - 48% of nest made of shredded course stems
	  - 18% sedges
	  - Materials held together with invertebrate silk
	- Field Sparrow
	  - 60% grass
	  - 29% herbaceous materials and fine stems
	- Chipping Sparrow
	  - 37% rootlets
	- Variation between large and small species but also variation in each species
	- American Robin
	  - 66% mud
	  - Built on top of nest substrate
	• Discussion
	- Ground nesting easter towhees
	  - High proportions of pine needles, leaves and grasses
	    • All of which are materials that can blend in with the surrounding environment
	- Many of the birds chose materials that blended in with the environment they are surrounded with
	- One theory for why they all choose different materials is adaptation, so there is less competition for each material
	- Birds may travel up to 500m to find nest materials
	- Birds use some similar materials, but different proportions of them
	- Other nest material hypothesis
	  - Based on nest structure
	    • Certain materials are needed to create certain aspects of a nest to keep it up
	  - Size and mass of bird
	  - Bill shape and length
	  - Material available
	  - Foraging behavior
	- Microhabitat influences material choice
	- Their method of measuring is biased, because there is another way of calculating by quantity of materials in a nest rather than weight
	- 6/7 nests had anthropogenic materials in their nests
	-

Research Question/Problem/ Need	How does the material used in bird nests vary across different species of birds within the same area?

Important Figures



This figure describes the ratio of materials in a certain species' bird nest.

VOCAB: (w/definition)

Graminoid: herbaceuos plants
Taxa: a class of animals (ex. Group, phylum, classs, order, etc.)
Elucidate: to make clear

Cited references to follow up on

Deeming, D. C. (2023). A review of the roles materials play in deter-mining functional properties of bird nests. *Acta Ornithologica*, 58(1), 1–28.

Hebda, G. (2007). Utilizing material from old nests-a way to time- saving in a short breeding species? The case of the long-tailed tit Aegithaloscaudatus. *Vertebrate Zoology*, 57, 79–82.

Follow up Questions

Were there any special methods or devices that they used to find bird nests?
What type of container did they use to store the bird nests?
What materials does the bird travel the farthest to obtain?

Article #10 Notes: Birds use structural properties when selecting materials for different parts of their nests

Source Title	Birds use structural properties when selecting materials for different parts of their nests
Source citation (APA Format)	Biddle, L.E., Deeming, D.C, & Goodman, A.M. (2018). Birds use structural properties when selecting materials for different parts of their nests. *Journal of Ornithology, 159,* 999–1008. https://doi.org/10.1007/s10336-018-1571-y
Original URL	[Birds use structural properties when selecting materials for different parts of their nests | Journal of Ornithology]
Source type	Scientific Article
Keywords	Biomechanics · Bird nest construction · Fringillidae · Rigidity · Strength · Turdidae
#Tags	
Summary of key points + notes (include methodology)	It has been noticed by researchers Biddle et. Al. that many nests play a role in reproduction and overall fitness of a bird. For this reason, it has been hypothesized that materials that the nest is composed of are used to help improve the fitness of the bird. This includes being chosen for sexual signaling, parasite defense, camouflage, and more. Despite this hypothesis, there is still a lack of knowledge surrounding whether these materials are chosen by the birds to serve a specific role. There has been research done that suggests that birds know where to put their materials, but even this has not been tested enough times and must be tested experimentally to be backed up. An interesting thing that the researchers observed is that choosing materials purposefully is not specific to Birds. Research has shown that both Orangutans and Beavers choose specific materials in certain parts of their sleeping beds and lodges, respectively. The goal of this study is to compare nests built by different species and different families of birds, those being Turdidae and Hawfinch. Their Hypothesis was that the Outer nest would have stronger materials compared to the materials in the cup lining. In addition, they believed that the structural properties of the materials would not vary in families but would vary between different families. The nests were obtained from a program called “The British Trust for Ornithology’s Nest Record Scheme”. Nests were then stored at -20 degrees Celsius then put into plastic bags after air drying at room temperature. Once this was completed, the nests were broken into four regions, and the materials were dissected and lined up in order of increasing diameter size. The 20 thickest samples were extracted for further analysis. These materials were put into an environmental chamber for 2 weeks until the materials had equilibrated to a constant weight. Then, mechanical testing was carried out, using a three-point bending test. The sample was then bent until it failed. Their findings

were that, in the Thrush nests, the diameters of the materials in the outer nest were much larger than the ones in the cup lining. In addition, there was no significant impact of the location of the material in the nest on the rigidity and bending strength of the material. In the finches, it was found that they used the thinnest and least rigid materials. It was also found that Hawfinches used heavier materials than Bullfinches. Overall, thinner materials can be found in the cup lining, which matches with the function of being insulative, providing a comfortable surface, and allowing for room for expansion. It was noticed that there were not mud cups in many finch nests. In addition, finch nests were found to have lower values of strength in the lower outer nest. This is likely because of the presence of the mud cup. In addition, the structural materials in the nests are different between finch species, with Hawfinch having stronger materials on the top outer nest whereas the Bullfinch had stronger materials on the base. Based off their findings, the researchers conclude that birds are not aware of the structural properties, but they assess the mass and diameter of the sticks and decide whether to use it or not that way. Some limitations of this hypothesis is that there is overall a lack of data surrounding nest construction and not many species have been studied. A future direction may be to see the relation between nest structure and weight and clutch of the parent species.

Notes:

- Intro
  - Nests may have role in reproduction and overall fitness
  - Materials in bird nests selected for many reasons
    - Sexual signaling, parasite defense, camouflage, insulation, or structural role
  - **KG**
    - No one knows if the each materials in the nests are selected for a specific role
  - Variation in material type is dependent on the resources available to it in the environment
  - **Past Research**
    - Past studies use captive species
    - Nests from field
    - Used to try and determine what affects nest construction
    - Captive Zebra Finches (Bailey et.al)
      - Bird Experience and structural properties impact material choice
    - (Muth and Healy 2014)
      - Birds are sensitive as to what string they use
    - Common House Martins added polysaccharides to enhance the mechanics of their nests
    - Common Blackbirds
      - Plant materials in outer nests were thicker and stronger
    - Bullfinch

- Materials in outer nest thicker than materials in the nests of a much larger bird, the Common Blackbird.
- **KG**
  - Research suggests that birds know when and where to put their materials
    - Still needs to be tested experimentally to be backed up
- Birds are not the only ones!
  - Orangutans choose strong and rigid materials for the outer parts of their sleeping beds and weaker and flexible parts for the lining of the nest.
  - Beavers
    - Poplars and willow branches were used by beavers to build their lodges
    - Beavers restricted themselves to 1.5-3.5 cm alder branches to build their dam
- **KG**
  - There are not many descriptions of materials used in bird nests
    - Descriptions do not cover a wide range of birds
    - Not many of the structural properties are known
  - Studies on structural properties of the materials in nests are not very common
  - Unknown if species of same size can represent each other's nest materials
- **Goals**
  - Compare nests built by 4 members of Turdidae and Hawfinch
    - See how it varies between species and nest regions
- **Hypothesis**
  - Outer nest would haver thicker, stronger, and more rigid materials than the cup lining.
  - Structural properties would not vary in families, but would vary between different families.

- Methodology
  - **Nest Origin and Storage**
    - Nests used
      - In Turdidae family: Common Blackbird, Mistle Thrush, Song Thrush, and Ring Orzel
      - In Hawfinch nests(4 nests)
      - Bullfinch nests
        - Data collected from a previous study

- Nests from the public
  - Through a program british trust for ornithology's nest record scheme
  - Nests shipped from across the UK to the university of Lincoln
    - **How were they shipped?**
- Nests stored at -20 degrees Celsius to kill off biting invertebrates
- Then air dried and stored in plastic bags at room temperature

- **Deconstruction**
  - Nests broken up into component parts
    - Broken up into the 4 regions of a nest
      - Top of outer nest
        - Materials found beside the mud cup
      - Base of outer nest
        - Materials below the mud cup
      - Internal cup(mud) for thrushes
        - Most thrushes build these with mud and plant materials, but Song Thrushes use wood pulp to build this part of the nest
      - Cup lining
  - In each region, the materials were lined up in order of diameter size
  - 20 thickest samples were chosen for further analysis
    - Based on what was done in Biddle 2017
      - **Look at that article to find out why**
    - These samples are the ones that hold a structural significance
      - Considered structurally significant if it has a diameter greater than 0.3 meters
    - Samples were held in an environmental chamber for 2 weeks
      - 23 degrees Celsius at 50% humidity
      - Until nests had equilibrated to a constant weight
      - Testing happened within 12 hours after the materials were removed from the cabinet
- **Mechanical Testing**
  - Three point bending test was used on the materials
    - They used an Instron universal testing machine (model 4443) fitted with a 100N load cell
  - Used a caliper to find the midpoint diameter of the material

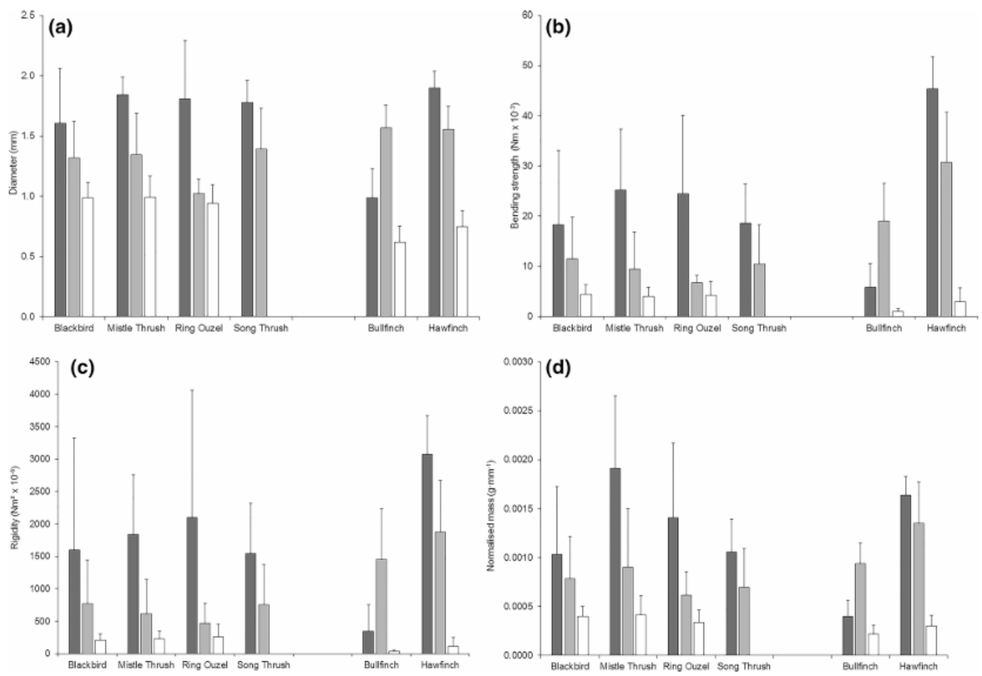
- The center of the circle
- Samples placed between 2 supports
    - Placed at a distance that was 20 times as big as the midpoint diameter
        - To prevent the materials from being split into two
- The probe they used had a radius of 5mm
    - It was lowered until it touched the sample and then it was lowered at a rate of 10mm/minute
- Sample bended until it failed
- Bending strength and maximum bending moment calculated using the equation
    - $\boldsymbol{M = F_{Max}L / 4}$
        - $\boldsymbol{F_{Max}}$**:** Maximum force the object can take before it fails
        - $\boldsymbol{L}$**:** Distance between supports
- **Bending Rigidity**
    - $\boldsymbol{EI = L^3(\frac{dF}{d\delta})/48}$
- Samples that slipped off the supports were not included in the results

- **Analysis**
    - Collected the mean of the samples for each version of the nest
    - Samples were transformed by log ten before they could be put into the general linear mixed modeling in Minitab
        - **Why?**
        - Had a control of nest origin and species, while having random factors of nest, and nested within species
            - **What is this saying?**
        - Did not include phylogenetic controls because they thought it would not impact the results

- **Results**
    - **Diameter in Thrush species**
        - Cup lining: No bigger than 1.3 mm
        - Base: No bigger than 1.9mm
        - Top Outer Nest: No bigger than 2.3mm
        - No significant differences between top and base of outer nest
        - Outer nest diameters were much larger than the ones in the cup lining
    - **Diameter in Finch**
        - Base<1.7mm
        - Cup lining<1.0mm
        - Hawfinch and Bullfinch nests had materials in their nests

made up of thinnest and least rigid materials
        - Significant species-region interaction
    - **Thrush Nests correlations**
        - Positive Correlation between 4 things measured
        - Materials found in the base and outer nests of the Thrushes showed no that the location did not have a significant impact on their rigidity, bending strength, etc.
        - Weight of materials was very different between different species
            - Mistle Thrush had the heaviest materials and Song Thrush had the lightest
        - Diameter of outer nest compared to inner nest, it was determined that Diameter is a significant covariate
    - **Finch Nests correlations**
        - Sample region, species, and species-region interaction were a non-significant factor for rigidity and bending strength of the materials
        - Weight of materials in nest were very different
        - Hawfinches used heavier materials than Bullfinches
- **Discussion**
    - **Thrush**
        - Thrush nests are identified by proportions of materials used in nest
        - No difference between structural properties of the thrush nest materials
        - The nests of Ring Ouzels, which have their nests on the ground, did not differ much from the materials in tree-nests
        - Supports idea of thrush nests being well supported
            - Shows how Trush choose materials based off structural requirements during construction
        - Thinner materials in cup lining
            - Have an insulative role
            - Providing a comfortable surface
            - Room for expansion
    - **Mud Cup**
        - Not found in many finches
        - Lower structural values in the lower outer nest
            - Because of mud cup presence
        - Song thrushes and American Robins use twigs and grasses to form the shape of a cup before putting wood pulp, mud, or dung in to form the mud cup.
        - Outer nest structural properties are like those in the outer nests of finches
        - Mud cup is the main structural component of the nest.
        -

- **Finches**
  - Structural properties differed between species
  - Hawfinch nests had stronger materials on top outer nest, whereas the Bullfinch had stronger materials on the base
    - Hawfinch adults are heavier
    - Eggs or nestlings
    - Nest site choice
      - Hawfinches on flat branches near tree trunk
      - Bullfinch nests on outer branches
      - **Previous study**
        - Nests built high in trees have woody stems with an average diameter of 5mm
- **Some title**
  - Nest construction patterns are specific to each bird species
  - Structural properties are not the end-all-be-all to why birds put each material in a specific spot
    - Ex: Previous Studies
      - Captive Zebra finches chose materials based on its color
      - Select length of materials to match nest box entrance hole
      - Laboratory settings do not necessarily represent the natural environment very well
        - If lab birds do one thing, who says that wild birds may not do the same thing
      - Robins and Song thrush chose long and strong materials first for outer nest and then worked their way in, choosing different materials as they went along
- **Nest Regions**
  - Hypothesis
    - Birds are not aware of the structural properties, but they assess the mass and diameter of the sticks and decide whether to use it or not that way
- **Future Work**
  - Lack of data currently surrounding nest construction
  - Not many species have been studied
  - Seeing how the nest relates to the weight and clutch of parent
  - Documenting composition of nests from different sized

	birds uses stronger materials in certain parts of nest
Research Question/Problem/ Need	How do the structural properties of the materials in the nests of birds of different species and families differ? How do these structural properties correspond with the diameter of the material and where it is placed in the nest? How do these findings show how Birds choose the materials for their nests(where they put them)?
Important Figures	 This diagram details the mean values of the materials that different nests have. For example, the mean diameter of each nest. This also compares the mean values in the different sections of the nest (that is what the different colors are). The dark grey is the materials in the top outer nest, the light grey is the materials in the bottom outer nest, and the white is the materials in the cup lining.
VOCAB: (w/definition)	Provenance: Origin Turdidae: Thrush bird Fringillidae: Songbird family Strong Positive correlation: both variables move in the same direction, strong relation Datum: Single Data Points Covariate: Independent variables can influence the trial, but is not of interest to the researchers Deposition: getting rid of something Corvid: bird in the crow family Mandibulation: action of a bird holding a material for its nest in its beak
Cited references to follow up on	Crossman, C. A., Rohwer, V. G., & Martin, P. R. (2011). Variation in the structure of bird nests between northern Manitoba and southeastern

	Ontario. *PLOS One*, *6*(4). https://doi.org/10.1371/journal.pone.0019086 Mainwaring, M. C., Hartley, I. R., Lambrechts, M. M., & Deeming, D. C. (2014). The design and function of birds' nests. *Ecology and Evolution*, *4*(20), 3909–3928. https://doi.org/10.1002/ece3.1054 Horváth, É., Solt, S., Kotymán, L., Palatitz, P., Piross, I. S., & Fehérvári, P. (2015). Provisioning nest material for Rooks; a potential tool for conservation management. *Ornis Hungarica*, *23*(1), 22–31. https://doi.org/10.1515/orhu-2015-0002
Follow up Questions	• Why do the biting invertebrates need to be killed on the nests need to be killed off before testing? • Why is it important to put the materials that were used for further analysis into an evironmental chamber? • How does the mud cup help with the strength of the nest? ○ How does the mud cup impact the material's strength over time?

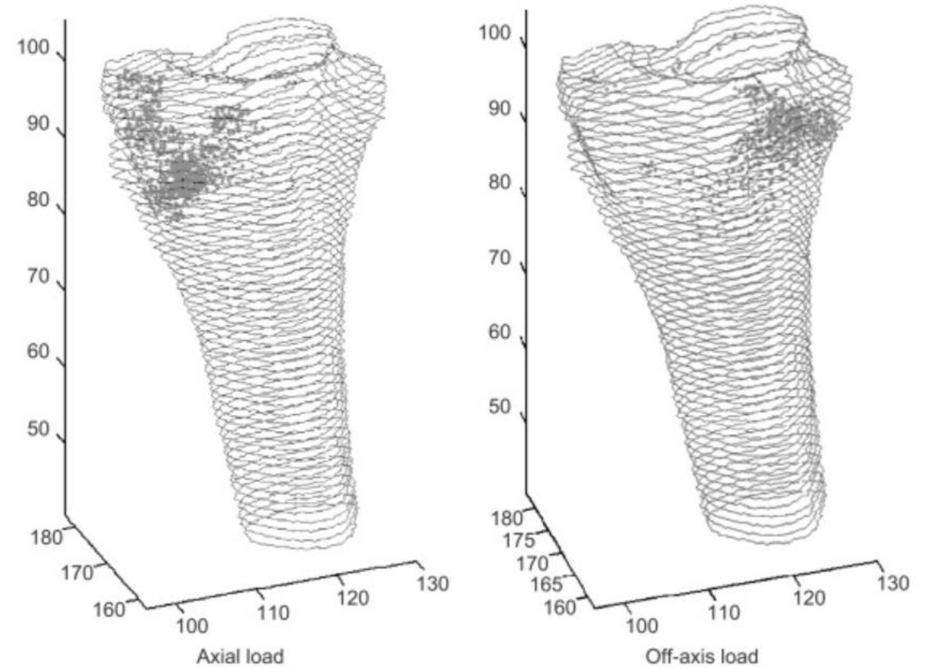
Article #11 Notes: Off-axis loads cause failure of the distal radius at lower magnitudes than axial loads: A finite element analysis

Source Title	Off-axis loads cause failure of the distal radius at lower magnitudes than axial loads: A finite element analysis
Source citation (APA Format)	Troy, K. L., & Grabiner, M. D. (2007). Off-axis loads cause failure of the distal radius at lower magnitudes than axial loads: A finite element analysis. *Journal of Biomechanics*, *40*(8), 1670–1675. https://doi.org/10.1016/j.jbiomech.2007.01.018
Original URL	https://www.sciencedirect.com/science/article/pii/S0021929007000644
Source type	Journal Article
Keywords	Bone Fracture Aging Upper extremity Distal radius Finite element Fall
#Tags	
Summary of key points + notes (include methodology)	Researchers Troy and Grabiner noticed that many older women experience a higher rate of distal radius fractures, which can lead to decreased motion, grip strength, and more. Many previous studies have focused on how they can use pharmaceutical solutions to help prevent fractures. However, the researchers wanted to take a closer look into the bone itself. Many past research suggest that small changes in bone density, especially in structurally important parts of the bone, can lead to a large change in overall bone strength. Many of these studies used finite element models to examine the stress and strain on the distal radius but do not adress how changes in the mechanics of the load affect the distal radius. That brought them to their quesiton of how load direction influences the predicted fracture strength. They also wanted to research how the bone mideral density would influence this fracture strength. To study this, they used the wrist of a 53-year-old lady and ran it under a CT scan. They then used MATlab and ANSYS

	to model the hand. In these models, they created 26 different ones, each one with varying bone density and loading direction. They then used a custom-written program in MATLAB to determine where the most failures occur. Their results suggested that that the load direction did influence the fracutre strength, with the axial loads causing the most fractures. They also found that the change in BMD had a nonlinear effect on the fracture strength. Finally, they concluded that the fracture initiation sight. Some inconsisencies witht his model is that it did not account for the natural human reaction when they fall, which is them restraining their carpal bones , which may lead the fracture to be less high than the model suggests. In addition, there research shows that searching for methods to increase bone mineral density may not be the way to fo to prevent fractures. It would be more worthwhile to focus on solutions connected to load-initiated remodeling of the architechture of the bone itself.
	Notes:
	• Introduction
	  o Distal radius fractures are highly prevalent in older women
	    ▪ Can happen when they fall on an outstretched hand
	  o Can lead to decreased motion, grip strenth, and many more
	  o Having a diminished bone quality is an increased risk factor for getting hip and those fracture near the wrist.
	  o Location of fracture depends on magnitude and direction of the force applied to the wrist as the person fell.
	  o When someone falls from their standing height they will have a force applied to their hand that is aroudn 2500-4000N
	  o Failure strength depnds on the density as well as the macro and micro structure of the bone
	  o Many previous studies have focused on the pharmaceutical solutions to osteoporosis
	  o Finite Element studies suggest that small chances in bone density in structurally important parts of the bone can lead to overall large impact on changes in oveall bone strength
	  o In the past, finite element models have been used to examine stress and strain on the distal radius
	    ▪ Do not help to specifically address changes in the mechanics will effect the distal radius
	  o Questions Addressed:
	    ▪ How does the load direction influence predicted fracture strength
	    ▪ How does bonde mineral density impact fracture strength
	• Methodology
	  o Used a CT scan of the right wrist of a 53-year-old female
	    ▪ Wrist positioning of 57 degrees and 7 degrees ulnar deviation
	    ▪ This is a relatively realistic position but a little extreme
	    ▪ They found the goemtry and density data using a custom-written software in MATlab.
	    ▪ Built a finite element model using ANSYS

	- Material properties assigned to each element
	  - Material properties assumed to be linear
	- Used Density to calculate the elastic modulus
	- Element assigned a value from 100Mpa to 20.1Gpa in 200Mpa increments
	  - Mpa is unit of pressure
	Created a layer of cartilige:
	- 2.5 mm thick
	- Materials assgined based off the assumptions that the largest impact would occur 30ms after contact
	- Cartilage assigned stiffness of 48Mpa
	  - Based off dyanmic high-frequency compression studies
	Ligaments
	- Ligaments that attached radius, scaphoid, and lunate included as nonlinear springs
	  - Toward bottom of the wrist, closer to arm
	  - Nonlinear spring: nonlinear relationship between force and displacement
	  -
	- Model validated by comparing the peak contact stress on the radius and the area of contact to previous studies.
	Parametric Series
	- They created 26 different models and all of them had varying bonde density and loading direction
	- A 3000N load applied to the radius
	- Also axial load
	  - Applied from the medial(from midline of body), dorsal(back), and axial(Horizontal plane across body) direction
	- They changed the bone mineral content in either the cancellous bone, cortical bone, or all radius bones.
	  - They combined this with simulations that did not have any change in BMD
	  - 13 simulations resulted
	Failure determination
	- Found first and third principle stresses, which were recorded during ramped load
	  - Max and min stress during complex loading conditions
	- Element failure determined by criteria from Keyak and Rossi, 2000):
	- Used Matlab to calculate where the largest number or cluster of failed elements was
	Results
	- Loading direction influenced fracture strength

	▪ Axial loads caused fractures easier ○ Change in BMD ▪ Nonlinear effect on fracture strength ▪ Degree in which BMD increased the fracture strength depended on the bone it was effecting ○ Fracture initiation site ▪ Depended on load direction ▪ Axial: failure in middle of ultradistal radius ▪ Off-axis: first in dorsal aspect of radius ▪ Loads on off-axis series led to the scaphoid and lunate bones to move towawards he beack edge of the surface of the radial bone. ▪ There was more compression • Discussion ○ Having both bending and compression coming from the off-axis side of the bone decreases the strength of the radius, nearly a drop in 50% strength ○ The dependence on direction explains how some falls result in fractures and others do not. ○ Model may have overestimated degree of loads on radius strength ▪ Because it did not simulate the human response ofhaving restrains on carpal bones ○ Increasing BMD may not be enough to increate fracutre strength ○ May consider increasing bone strength and.or improving the bone architecture to resist impact for older women.
Research Question/Problem/ Need	How does the load direction influence predicted fracture strength and how does bone mineral density impact fracture strength?

<table>
<tr><td>Important Figures</td><td>

This diagram shows a picture of where the fractures were most prevalent on the bone in the model</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>Distal radius: A part of the lower radius bone on the forearm
elastic modulus: measures stiffness or resistance to deformation that is permanent when introduced to stress
axial load: Force acting upon the center or axis of a structure in a uniform manner
Ramped load: A load that increases
Volar: Palm side</td></tr>
<tr><td>Cited references to follow up on</td><td>Ulrich, D., van Rietbergen, B., Laib, A., & Rüegsegger, P. (1999). Load transfer analysis of the distal radius from in-vivo high-resolution CT-imaging. Journal of Biomechanics, 32(8), 821–828. https://doi.org/10.1016/s0021-9290(99)00062-7
Røhl, L., Larsen, E., Linde, F., Odgaard, A., & Jørgensen, J. (1991). Tensile and compressive properties of cancellous bone. Journal of Biomechanics, 24(12), 1143–1149. https://doi.org/10.1016/0021-9290(91)90006-9
Keyak, J. H., Rossi, S. A., Jones, K. A., & Skinner, H. B. (1997). Prediction of femoral fracture load using automated finite element modeling. Journal of Biomechanics, 31(2), 125–133. https://doi.org/10.1016/s0021-9290(97)00123-1</td></tr>
<tr><td>Follow up Questions</td><td>• Why did you choose to use ANSYS as your modeling software?
• Why did you choose the loads that you did?
    o Are there any other loads that may be significant?
• How did you decide on the numbers assigned for linear stiffness for the</td></tr>
</table>

	different ligaments?

Article #12 Notes: Manipulating the geometry of architectured beams for maximum toughness and strength

Source Title	Manipulating the geometry of architectured beams for maximum toughness and strength
Source citation (APA Format)	Dalaq, A. S., & Barthelat, F. (2020). Manipulating the geometry of architectured beams for maximum toughness and strength. *Materials & Design*, *194*, 108889. https://doi.org/10.1016/j.matdes.2020.108889
Original URL	https://www.sciencedirect.com/science/article/pii/S0264127520304238
Source type	Scientific Article
Keywords	Architectured materials Segmented materials Structural stability Topologically interlocking materials (TIMs)
#Tags	

Summary of key points + notes (include methodology)	Researchers Dalaq et al. were fascinated by the interconnectedness of linear arrays within biological animals: structures such as spines. They also noticed that the way in which elements within such structures interlock can have a great impact on the overall strength of a structure. This brought them to their question of how the shape of those individual elements can effect the interlocking process. To do so, the researchers used finite element modeling to model various shapes of cubes They found that adding fillets to the edges of cubes, the local stresses were reduced whereas the stability deceased. Increasing waviness along the side where the force is being applied will help foster interlocking of blocks and jamming. Overall strength of beam also depended on individual blocks. Following their simulations, they tested their optimal designs using ceramic glass. They found that the optimal designs discovered via finite element modeling indeed led to improved toughness from a typical monolithic beam. In future studies, the researchers would like to explore how the waviness may impact strength in 2d panels.
	Notes:
	• Introduction
	    ○ Many materials need the combination of strength and toughness
	    ○ Brittle materials are good low weight materials that are brittle
	        ▪ Can help reduce carbon emissions
	        ▪ These materials are also stiff, are able to last a long time, and do not expand because of thermal reasons easily

- It is hard to make brittle materials more tough
    - If they did that they would be able to utilize these more eco-friendly materials for components such as beams, trusses, or frames.
- With the geometrical interlocking of stiff blocks, the structure can have improved toughness
- Individual blocks are stiff
    - There is not much deformation in the blocks
- The interlocking of the blocks allow for more elasticity
    - To account for that, people can always use stiffer frames on the outside or tension cables.
        - Tension cables may prevent that elasticity and movement between the various blocks
        - Spring supports
            - Used in pipelines, help have a controlled compression on the beams in a structure
- Many natural materials are also made of stiff and brittle individual components.
    - Relationship between geometry and the contact between each material resulted in a combination of stiffness, strength, and toughness
- Precompression can only increase stability and effective strength
- Changing arrangement of blocks slightly can induce a grand difference on the stability and strength of an object
- **Previous Study**
    - Used architectured materials based off of nature but found no improvements in strength
- **Research Gap**
    - Materials that are arranged in a linear way(like spines) have not been “extensively studied”
    - Some studies show that the “behaviour” of beams in this type of pattern depends on how many beams are in the structure, the friction between them, and also how they connect to one another.
- **Previous Study**
    - If a glass panel is arranged in a panel of rectangular prisms(with a flat surface), the toughness, strength, and tolerance will improve
- **Previous Study**
    - Failure depends on # of beams and friction btwn them
- **Previous Study**
    - In a sliding failure mode(When the horizontal forces are not equal and the parts start to slide away)
        - Geometry will have highest impact
- **Problems with Previous Studies**
    - Limited to 2D
    - Ignored internal stresses in individual blocks

	▪ Many mechanical properties of the materials were overlooked ○ **Goal of Study** ▪ Make an array of 5 blocks • To avoid hinging • Simulated behavior of linearly arranged materials • **Model Set Up** ○ They used an array of 5 identical blocks which were lined up between 2 rigid supports ▪ Modeled in a linear elastic way • Contact elements plqced inbetween each element of the design • End supports hold the blocks in place with dry friction • Transverse displacement applied at the middle of the structure ○ The reaction to this force was noted as Ft ○ Started with a beam made up of cubes placed right next to each other ▪ They varied the radius of the edges of these cubes ▪ Contact stress at edges of cubes are infinite • To combat this, they filleted all edges with radius of r/L ▪ Verified that the force they are applying is equivalent to the force being qpplied by those edges of the structure • Also allowed force to be displayed as normqlized force ▪ In different fillet values, there was a linear increase in transverse forces • This happened until a maximum point was reached when the cubes started sliding from each other ○ Because of decrease in compressive forces ○ Will decrease the amount of material between the supports and make the structure less stiff ▪ Will decrease axial stiffness of beam ▪ With less axial force, there is less frictional force ○ At this critical point, the transverse forces start to become compressive, which explains why the blocks almost shoot out of the structure ▪ Increasing radii of fillet changed initial stiffness

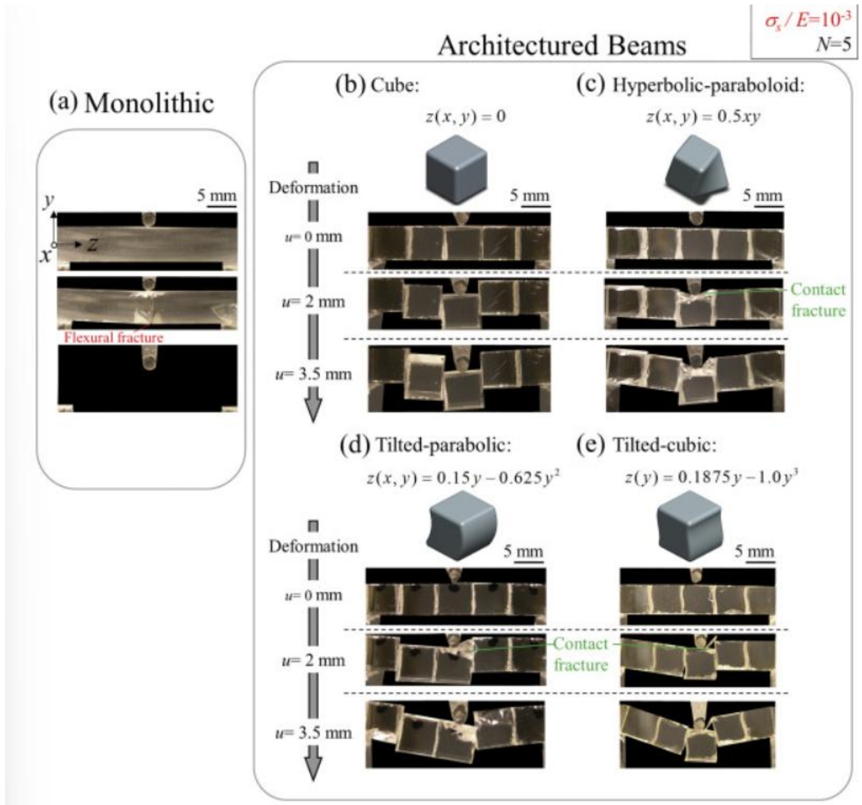
- Decrease in strength
- The instability of the structure came about quicker
- Sphere based beams have a negative transverse force(Everything is falling toward the ground(not a lot of pressure towards the sides of the model))

- Tensile Strength measured
  - Highest tensile strength at the far edges of the areas where the beams met
- The maximum stress of an object increased linearly with u/L until the critical point was reached
- As contact area decrease and contact area increased, stresses increased
- After sliding happened, they reached one more "max" point, then stress started decreasing until failure
- Maximum strength highest for a small r/L(Radius/Length)

- They made the assumption the bricks are made of brittle material
  - Their criteria for failure was when max principal stress exceeds tensile strength
  - Toughness and strength for cubes with perfectly sharp cubes was 0
  - When r/L=0.025: high stress, easily fractured
    - Apparent in the way that the curve for the toughness-strength map having little deformation
  - Lower max force and displacement of r/L values between 0.1 and 0.3 led to lower strength and toughness in comparison to 0.05
  - 0.025 and 0.05 fillets are optimal values for strength and toughness

- Geometrical enrichments with polynomial functions
  - One goal was to progressively interlock the blocks
    - This would help withhigher strength and toughness
    - They set all contact surfaces to be the same using an equation
      - Made the original cube have a more deformed shape
  - They did not use all variations of a monomial because not all of the shapes would allow the figures to interlock
  - When designs are assymetric around the x and y axis, there is not a lot of sliding
    - It has no force going outwards in the x direction, helping to hold the cubes up, so the structure is not very stable
    - Assymetric designs were excluded
  - When the height of the shape was higher, the strength increased whereas the stability decreased
  - Max potential energy and max force are proportional to the friction coefficient

	- The cube designs had lower strenght and energy absorbtion compared to wavy designs • Optimization of monomials and binomials for finite strength of blocks - Strength of the individual blocks impacts the interlocking between the structure ▪ Stresses tracked throughout simulation - Curved structures of blocks can still be strong without the precompression - Tilted cubic design was the strongest - As the interlocking decreases, there is a higher reliance on those forces pishing the materials together • Experimental testing - These beams were tested using ceramic glass - Materials tested under the same loads - Fabricated the hyperbolic-paraboloid shape, titled-parabolic shape, and tilted-cubic shape - Cube shape broke smoothly with the block simply sliding out - Hyperbolic failed slowly(twisted sliding path) - Toughness of titled beam was a lot higher than the monolithic beam - Flat cubes performed poorly -
Research Question/Problem/ Need	How does the shape of the elements composing a linear beam affect the loading strength and interlocking between the materials

Important Figures	 This figure describes their experiment using the ceramic glass. Each step describes how each of the cube shapes responded to different amounts of force and when it experiences failure. On the left is the monolithic beam. As can be seen, it had a fracture that split it into two parts, which then fell, which explains why a beam cannot be seen in the third image of the monolithic beam.
VOCAB: (w/definition)	**Transverse:** A beam or force that goes across something **Abrasion:** When a material is weaned away by friction **Topological:** Relating to how materials are interconnected **Viscoelastic:** When a material is both elastic and thick when deformed **Precompression:** Compressing a material before some event or action **Jamming:** Forcing a material into one position and preventing it from “moving”, per se **Axial stiffness:** Stiffness in different directions on the X,Y, and Z plane **Truncate:** Ending Abrubtly
Cited references to follow up on	https://www.sciencedirect.com/science/article/abs/pii/0020768395002553 https://books.google.com/books?hl=en&lr=&id=Do6WQlUwbpkC&oi=fnd&pg=PR9&ots=gsifgxhg8-&sig=xvOCY0mlr_qGWNbd1BZ5Uy3M-fI#v=onepage&q&f=false https://doi.org/10.1098/rsta.2007.0006
Follow up Questions	How would the results change if the elements were based off a rectangle or a

	triangle as opposed to a cube? Which structures can these elements be applied to to improve their loading strength? Could the type of material used with these different shapes influence which cube shape is optimal?

Article #13 Notes: The design and function of birds' nests

Source Title	The design and function of birds' nests
Source citation (APA Format)	Mainwaring, M. C., Hartley, I. R., Lambrechts, M. M., & Deeming, D. C. (2014). The design and function of birds' nests. *Ecology and Evolution*, *4*(20), 3909–3928. https://doi.org/10.1002/ece3.1054
Original URL	The design and function of birds' nests - Mainwaring - 2014 - Ecology and Evolution - Wiley Online Library
Source type	Literature Review
Keywords	Architecture, behavior, environmental adjustment, evolution, host–parasite coevolution, natural selection, nest, sexual selection
#Tags	
Summary of key points + notes (include methodology)	Authors Mainwaring et. al. found that there is a large variety of nests designs within the bird community and they wanted to research past studies that give light into the different possibilities that may give insight into these different designs. The first theory they explored was natural selection. Past research has demonstrated that many species may choose their nest locations in the hope of warding off predators or hiding from them. This comes in the form of camouflage, nesting near another protective species, or nesting far from their predators. In addition, height was also found to have an influence on nest predation, with higher nests having a higher likelihood of predation compared to nests on the ground. The research also investigated how the nest design may ward off predators. Their findings showed that many birds either cover or camouflage their nests. In addition, adaptation to predation did not happen within the bird's lifetime, it happened across the lifetime of multiple generations. Another possible reason that the researchers identified that may impact the difference between the nests in sexual selection. In many birds, the males that were bigger were able to carry more materials and therefore provide that the nest is built quicker and reproduction can begin earlier. The third reason for different nests is the interaction between birds and parasites. They found that aromatic materials helped to ward off ectoparasites. However, there was contradiction between whether feathers and green plant materials help or hurt the ectoparasites within the bird nest. The final reason the researchers observed is environmental adjustment. Birds tended to choose locations that were warmer and protected form the wind. However, some birds chose to nest in more open spaces to have the ability to watch for predators. Future work could examine how these different nesting species examined would be affected by climate change. Notes: **Natural Selection** • There are different ways in which design of nests minimizes risk of

predation

- Nest site selection
  - Dusky warblers selected higher nest sites when chipmunks were abundant
  - Veeries select places with not a lot of white-footed mice
  - Inca Terns tend to nest in places within inaccessible crevices on cliffs
  - Abundance in predation results in shifts in nest site location
    - Sometimes at the expense of the thermo-regulation
  - Choughs tend to nest in places near species that will fend off any possible predators
    - This is not always the case, sometimes those predators also prey on the birds
  - Many believe that if there is a higher density of bird nests within a given area then there will be higher predation rates
    - There is not a lot of studies done on this to confirm or deny this
    - A exception is the fieldfares
      - Mustelids eat rodents but they sometimes eat fieldfares
      - Predation on fieldfare nests increased when rodent population went down
      - During these times, fieldfares were more likely to form colonies
  - Height of nests
    - Nests placed higher up had higher predation rates than those at the bottom
      - Higher up had to deal with avian predators
    - Kestrels nest on churches and as the height went up, the predation rates went down
    - When a bird experiences predation, they will likely move the height of the bird nest to be farther away from that original height
- Nest Design
  - Ground nesting birds rely on crypsis to hide nests from predators
  - Many females chose materials of their nest in order to match the visual patterns of their eggs
  - Quails cover their nests
    - Nests that are covered have a lower rate of predation compared to those that did not
  - Small tree finch females prefer to mate with males that build nests that are not exposed
  - Smaller nests had a lower rate of predation compared with bigger nests
    - This study may be mixed up with other factors such as nest site selection, clutch size, and parent activity
- Evidence strongly suggests nest adaptation across generations of birds

however does not strongly support the idea of evolution within a bird's life

Sexual Selection

- Next extended phenotypic signals
  - Fetching materials can be costly
    - For that reason, some birds steal materials from others and or breed in other's nests(despite presence of ectoparasites)
  - There is a correlation between nest and phenotype of birds
    - Those in better body condition could put more energy into the creation of the nest
  - Australian reed warblers build multiple nests; some that are structurally capable of holding eggs and some that are not able ot do so
    - They were more likely to build unstable nests when they were given more food
  - In blue tits, when females fed more, they built heavier nests overall
  - When blue tits had their nests taken away from them, they built a smaller and smaller nest each time
- Male-built nests
  - Male that built bigger nests had higher chance of getting a female
  - Males with larger wingspan are able to carry more materials to build their nests
    - Therefore the nest was built faster and the female could begin laying her eggs earlier
  - Green plant material plays a role in sexual selection
- Female-built nests
  - Female-built nests are less common
  - Healthier females built bigger nests than less healthy bird
  - In blue tits, the phenotypes of the female did not affect the nest, but the size and characteristics of the nest did have a strong relation too the reproductive success of the blue tits.
- Bi-parentally built nests
  - Females paired with barn swallows with longer tails built thinner walls and larger nest cups

Host-parasite coevolution

- Parasite and Host fitness
  - Parasites may host live, fleas, mites, leeches, fungi, and bacteria in their nests
  - Parasites can harm the host's fitness
  - In great tit nests, when # of parasites increased, the bird eggs were laid later in the season than control groups
  - Hosts have developed ways to fight against the parasites
- Nest design as a host defense
  - Green plant materials have volatile secondary compounds (eg. hydrocarbons)

  - Bacteria on feathers in nest have bacteria that produce antibiotic substances
  - When the green material was taken away, the nest actually had fewer ectoparasites in it
    - Post fledgling survival did not differ
  - Ectoparasites similar between nests with green plant material and grass
    - Postfledgling survival was slightly higher in those that had green-plant material
  - Using aromatic materials reduced bacterial richness on nestlings
    - Blue tits use odor cues to know when their green-plant material needs to be replaced
  - In tree swallows, when more feathers were added, ectoparasites increased
    - A different study showed the opposite

Environmental Adjustment

- Nest site selection
  - Site chosen is based on availability of food, risk of predation, prevalence of conspecifics, availability of materials, and climate
  - Nests tend to be located in spots that lose less heat
    - Ex. Grasshopper sparrows build domed nests faced the opposite direction of the winds and located far from direct sunshine
    - Lesser black-beaked gulls nest near tall vegetation to avoid wind(those that did this had higher growth rates than those raised in the cold winds)
  - One bird species decided to move to open lands for ability to defend against predators
  - Spotted owls that chose nesting sites out of wind had higher reproductive success
- Nest Construction Materials
  - Structural materials make up general shape of nest whereas lining materials create suitable environment for the nestlings
  - Study on Australian birds suggest structural materials chosen solely for support
    - Other studies suggest those materials are chosen for thermal regulation
  - Smaller species created nests with more nest lining materials compared to larger species
    - Smaller species need to focus more on thermoregulation
  - Birds line their nests w/ feathers
    - Feathers provide most insulation, more than grasses
- Spring temperatures
  - The time it takes to build a nest decreases seasonally
  - No patterns between season and nest mass
  - Number of feathers used in nests declined as the breeding season progressed

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Quality of insulation did not change, however.
Altitude

In Hawaii, the nests of common amakhi found at higher altitudes were more likely to be placed towards the edge of the tree. They also had denser walls w/ more insulation material
All of them were under the canopy for rain protection

Latitude

Birds that breed earlier and are surrounded by lower temperatures had a higher likelihood of adding feathers to their nests
In Canada, yellow warblers that bred higher north had larger and more dense nests
absorbed more water, retained more heat, took longer to dry compared ot southern nests
Northern nests built on thinner branches
Southern nests protected form sun

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<tr>
<td>Research Question/Problem/ Need</td>
<td>What are the leading factors that lead birds to build their nests in the way and in the location that they do? How do these factors influence the fitness of the bird?</td>
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<td>Important Figures</td>
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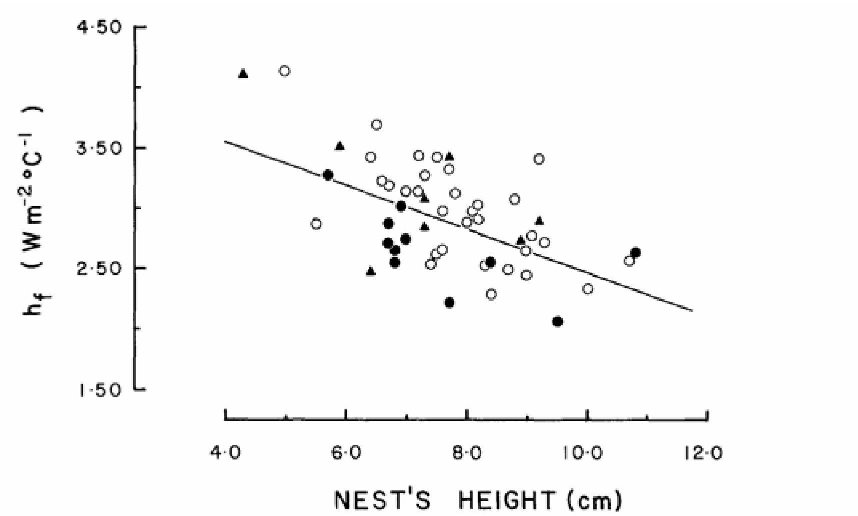

The review itself did not have any pictures, but above is a picture from one of the sources that discussed. This graph describes the warmth of the enst as compared to the nests hieight. The open circles are the nests in the incubating phase, the triangles are ones in brooding phase, and closed circles are the ones in the post fledgling phase.
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<tr>
<td>VOCAB: (w/definition)</td>
<td>Biocidal: designed to destroy harmful bacteria, viruses, rodents, etc.
Conspecific: Members of the same species
Ambient: Surrounding</td>
</tr>
<tr>
<td>Cited references to follow up on</td>
<td>Structural support, not insulation, is the primary driver for avian cup-shaped nest design | Proceedings of the Royal Society B: Biological Sciences</td>
</tr>
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	https://doi.org/10.2307/4088813 **https://doi.org/10.1017/S0952836902001620**
Follow up Questions	How do ectoparasites influence the duration of time it takes to build a nest? What is the most common way ectoparasites enter a nest? How does prevalence of ectoparasites early on in a nestling's life influence it's reproductive success later in life?

Article #14 Notes: Design principles of biologically fabricated avian nests

Source Title	Design principles of biologically fabricated avian nests
Source citation (APA Format)	Jessel, H. R., Chen, S., Osovski, S., Efroni, S., Rittel, D., & Bachelet, I. (2019). Design principles of biologically fabricated avian nests. *Scientific Reports*, *9*(1), 4792. https://doi.org/10.1038/s41598-019-41245-7
Original URL	Design principles of biologically fabricated avian nests | Scientific Reports
Source type	Journal Article
Keywords	Stress Analysis Bird Nests 3D model Bio architecture
#Tags	
Summary of key points + notes (include methodology)	Researchers Jessel et. al. noticed that there has been much work done regarding specific construction materials and methods followed by birds to build their nests. These past studies have found patterns among the nest materials that suggest deliberate choice of materials for structural stability within the nest. Many of these studies have been assed on a case-by-case, bird-by-bird basis. The researchers wanted to follow a similar route, studying *Aerodramus fuciphagus,* which are commonly known for their nests that are built via self secreted materials such as saliva. The researchers acquired these nests from farms in Malaysia dedicated to harvesting such nests. They were then collected and stored at 80% humidity and 25 degrees Celsius. There next step was to take a CT scan of the image. This image was then imported into a software for further image processing. Then a Finite Element model was developed. To create a more accurate model, the researchers sampled rectangular portions of each nest and tested for tensile strength. These properties were then added into the Finite Element model. Finally, they ran their simulation. There model revealed that the ends of the nests are more porous compared to the base of the nest. In addition, they found that if an element towards the rim of the nest failed, then it would not cause the entire structure to fail. In addition, in locations where birds are most prevalent, then the fracture strength was bigger than the stress. Finally, the stresses tended to follow the direction of the rim, moving stress away from the locations of the nest where the bird is likely to be located. This evidence supports the idea that birds of this species have evolved over time to create saliva structures that are more structurally able to handle the loads of the birds. Future work could investigate how elongating the model or the nests would impact this stress distribution.

Notes:
Intro

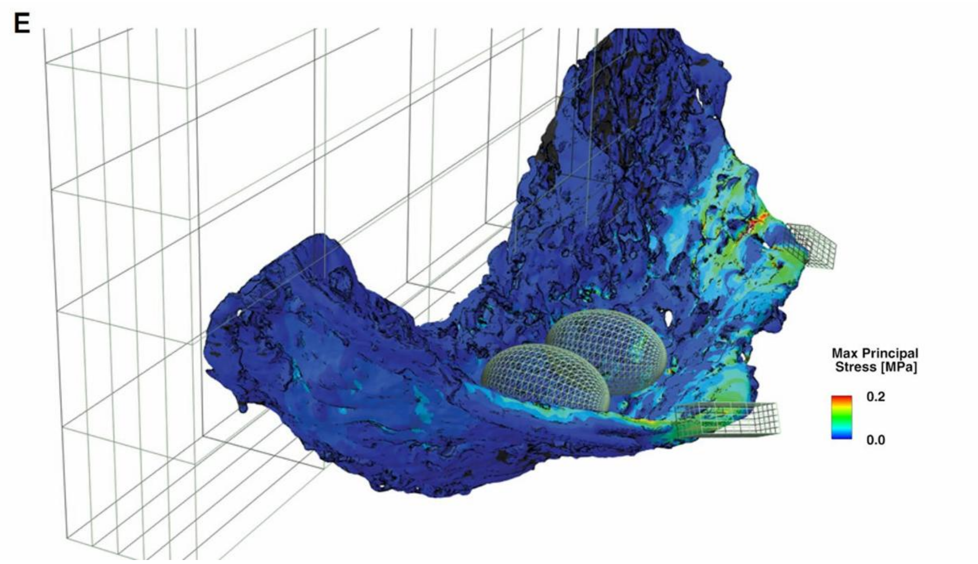
- Methods of construction are categorized into, piling up, molding, sticking together, interlocking, sewing, and weaving
- Many studies have studied construction materials and architecture of the nest to determine what affects the biomechanical characteristics of the nest
- In common Blackbirds, the materials in the outer nest were arranged more loosely believed to have an important role in providing support to structure
- Orangutans build nests in trees by weaving branches together
  - Built on a solid base then they use more rigid materials for the outer portion for more support
- Aerodramus fuciphagus uses additive manufacturing to make its nest: it is made out of mostly saliva
- Examined how properties of materials relate to structural design

Methodology

- Nest
  - Bought from farms in Malaysia
  - They were cleaned and processed without bleaching
  - Stored at 80% humididty at temp of 25 degrees ceclcius
- CT scans
  - Used SkyScan 1176 high-resolution CT scan
  - Scanned with resolution of 34.04
- Image processing
  - Imported into Simpleware Scan IP
  - Imported at value of 24.04 um
  - Noise was corrected using filtering strategies
- FE generation
  - Converted 3D image into volumetri meshes
  - Created elements with a mean edge length aspect ration of 4-5
- Tensile testing
  - First, nest were softened by being placed in distilled water for 20 minutes at room temperature
  - Then, the nests were cut into rectangular pieces
  - Samples flattened and dried
  - A holder was 3d printed to hold the nest up
  - Quasi-static uniaxial test caried out
- Scanning electron microscopy
  - Nests that were fractured were coated with gold and then had an image taken of them
- Finite Element
  - Meshed models imported into Abaqus
  - Material properties imported from the tensile strength data
  - Material assumed to be isotropic
  - Loading situation assumed two adult swiftlet birds and 2 eggs

	Results
	• Swiftlet nests were very similar in shape, dimensions, and weight.
	• Porosity increased toward the ends of the strucutre whereas it was lower in the base
	• The nest is horizontally biased
	• Many times, stress dropped when individual fibers within the nest dropped
	• All loads modeled as external loads
	  ○ Applied at spots birds are typically found
	• Fracture strength of materials is bigger than stress at locations where birds are most prevalent
	• Stresses distributed on the rim section along the direction of the fibers
	  ○ Reduces stress at the anchor
	Discussion
	• Base of nests have thicker materials than walls and outer rim
	• Nests all had highly similar properties, suggesting construction according to similar principles
	• The nest section where eggs were located was nearly stress-free
	• Swiftlet nest is elongated, which could help with distributing stresses
	• Evidence suggests that the secreted materials that the swifts use to make their nests has evolved over time to be able to bear loads in tension
	  ○ Collected materials help with bearing compression loads
	• The part glued to the wall has a higher surface area, making it better and ready for more load bearing responsibilities
	• Wide anchoring area reduces local stresses
	• If there is a fracture in the rim of the nest, it will not cause the entire structure to fail, for it will only flatten out only ellipsoid pores that are also located along the rim of the nest
	• Future work
	  ○

Research Question/Problem/ Need	What is the relationship between stresses and load capacities in the nests of *Aerodramus fuciphagus*

Important Figures	 This picture describes the stresses of the nest when two eggs are placed on it. As can be seen, there is less stress in the areas where the eggs are located and towards the anchor of the nest.
VOCAB: (w/definition)	**Isotropic:** Showing the same values in all directions **Deposition:** The process of laying something down **Ellipsoid:** Surface that is on circles or elipses
Cited references to follow up on	Hansell, M. Bird Nests and Construction Behaviour. (Cambridge University Press, 2000). Silva, B. et al. Bird nest construction- lessons for building with earth. WSEAS Trans. on Env. and Development 6, 83–92 (2010).
Follow up Questions	• How could this modeling technique be applied to other types of bird nests? • What conditions were the bird nests brought up in? • A fracture in what part of the nest would be the most likely to cause the structure to fail?

Article #15 Notes: Bird Nest Construction - Lessons for Building with Earth

Source Title	Bird Nest Construction - Lessons for Building with Earth
Source citation (APA Format)	B. Silva, J. C. (2010). Bird Nest Construction - Lessons for Building with Earth. *WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT*,*6,* 95-104.
Original URL	https://www.researchgate.net/publication/229151241_Bird_Nest_Construction_Lessons_for_Building_with_Earth
Source type	Journal Article
Keywords	Raw materials, Earth construction, Biomimetics, Nest bird, Characterization, Finite element analysis
#Tags	
Summary of key points + notes (include methodology)	Researchers Silva et. al. Found that an enormous population of the world lives in structures composed of earth-based materials. For this reason, they sought out to find a way to make these structures stronger. To do so, they wanted to look into how to use biomimicry, specifically based off chemical compositions of the andorinha-dos-beirais bird nest. They found 6 nests nearby and began by using ANSYS to model the nests. They found that the nests have a very low compression strength as a whole, however they are able to carry a typical load required of them (birds and eggs). For their next step, they used a variety of methods to determine the chemical composition of the nest, including electron microscopy, X-ray, colorimetric methods, and anion-exchange chromatography. The results showed that the most prevalent minerals in the clay found in the nests were clinocloro, aluminum potassium silicate, quartz, and muscovite. Finally, they found that all the samples of clay within the bird nests had some composition of sugar in them. This suggests that the birds must add a small amount of sugars into their nesting material. Their next step was to run mechanical tests. To do so, they created two different clay blocks, one with sugar added based on the sugar concentrations of the clay in the nests and one with no added sugars. The results showed that the material with sugars added had a higher compression strength. In the future, the researchers aim to bring in more species to this studyas well as more types of clay for the bird nest ot be compared to. This will allow for more generalizable results. Notes:

Introduction

- Half of the world population lives in buildings made of earth
    - Especially prevalent in third world countries
- Earth construction can have very good durability
    - Revealed by structures such as the wall of China
- Earth material has been used for construction of dams in many countries
- Earth materials are far more sustainable
- They used the andorinha-dos-beirais bird nest as their model
    - Used to find information about how biomimetics could improve durability, workability, and mechanical performance
- They identified chemical and mineral composiitions of the nests' materials
    - Used anion-exchange chromatography to identify sugars in the nests

Andorinha-dos-berais Bird

- Migratory brid
- Lays 4-5 eggs
- Nest made from clay
- Spends time in northeast part of Portugal

Nest of Birds

- Commonly found in urban areas near water
- Often found to be near a wall or in the corner where a wall meets the roof
    - Protection form rain and predators
- They obtained them from 3 different areas

Structural Behavior of Nest

- Used ANSYS to model nest
- Dimensions of model were averages between dimensions of the nests they collected
- Assumed linear elastic material
- Took into account location of the nest for the structural support (e.g. Wall, roof)
- Worst loading case was considered weight of six adult birds
- Max compression of .1kPa
    - Smaller than typical earth-based materials
- Shape of nest is optimal for the stresses that the nest is subjected to

Identification/Characterization of the Nest Material Samples

- Used scanning electron microscopy spectroscopy, X-ray, colorimetric method, and anion-exchange chromatography
    - To see if they added any additional elements to their clay
- Chemical composition of the nest materials were very similar
- Used a model X`Pert PRO with a detector of X`Accelerator in order to X-ray the nest for mineral detection
- Minerals found were clinocloro, aluminum potassium silicate, quartz, and muscovite
- Used colorimetric method to identify sugars in the nests
    - A color will form with the reaction with a chemical indicator, which will show prevalence of a specific compound

	◦ No significant prevalence of a particular protein in a substance
	• Tried using a different method and achieved totally different results(total sugar method)
	  ◦ Results suggested that the bird nest material had a higher concentration of sugars compared to the amount in the sample of clay that they tested
	• They ran another test using the total sugar method, this time with all the nests from the different locations
	  ◦ Comfirmed resutls of first tests, with the samples having a higher sugar content than the clay they tested
	• Anion-exchange Chromatography Test
	  ◦ Sugars extracted from samples using hydrolissi
	  ◦ They checked for sugars commonly found in nature
	  ◦ All nests materials, including clay, had sugars in them
	    ▪ Nests from Mateus and Sao Dinis had higher concentrations of sugars compared to the clay and the nests from Noura
	  ◦ Suggest there is a possibility the brids add a small amount of glucose to their nest materials
	Mechanical Tests
	◦ Material samples were manufactured using clay that was made from the same materials that the birds themselves would have used to build their own nests
	◦ They extracted sugars from the nest materials
	  ◦ 1. Nests cleaned and triturated
	  ◦ 2. Organic components extracted
	    ▪ Mixed 250g of these components w/ 50 cl of ultra pure water for 1 hour
	  ◦ 3. Aqueous solution filtered
	    ▪ Prevents from weight increase of solution
	◦ Tested using a compression testing machine after 7 days
	  ◦ Allowed for the material to dry
	◦ Specimens with sugars in them had higher compressive strength compared to those without them
	Conclusion
	• Compositions of nest materials are similar to local clay
	• Future work: more species and nest samples, more representative reference clay

Research Question/Problem/ Need	How can the chemical composition of a bird nest improve the strength of earth-based materials?

Important Figures

Table 7 - Compression strength (MPa)

Specimen					
I-1	I-2	I-3	II-1	II-2	II-3
0.27	0.65	0.49	0.71	0.68	0.76
Average (series I): 0.47 MPa			Average (series II): 0.72 MPa		

This table compares the compression strength of the reference clay samples(left) as opposed to the strength of the clay with sugars added(right). As can be seen, the samples with sugar added had a higher compression strength. (B. Silva, 2010)

VOCAB: (w/definition)

Estival: In summer
Shear stress: external perpendicular stress
Node: A place where two or more things intersect
Triturate: grind to a powder
Agglutination: group formed by combining different elements

Cited references to follow up on

A. Turner, C. Rose, Swallows & Martins: An Identification Guide and Handbook, U.S. Houghton Mifflin, Boston, Massachusetts, 1989, pp. 226-233.

D. Kralj, M. Markič, Building Materials Reuse and Recycle, WSEAS Transactions on Environment and Development, Vol.4, No.5, 2008, pp. 409-418.

ANSYS-Swanson Analysis Systems Inc. Houston, Version 11.0, 2008.

Follow up Questions

How could this sugar content found in the clay be used to improve other building materials such as cement?
What were the main differences between the environments of the nests that led to their compositions of sugars varying?
What reasons beside structure account for the cup shape of the when compared with the compression capacity of an andorinha-dos-beirais bird?

Article #16 Notes: Nest Architecture and Reproductive Performance in Tree Swallows (*Tachycineta Bicolor*)

Source Title	Nest Architecture and Reproductive Performance in Tree Swallows (*Tachycineta Bicolor*)
Source citation (APA Format)	Lombardo, M. P. (1994). Nest Architecture and Reproductive Performance in Tree Swallows (Tachycineta bicolor). *The Auk*, *111*(4), 814–824. https://doi.org/10.2307/4088813
Original URL	[Nest Architecture and Reproductive Performance in Tree Swallows (Tachycineta Bicolor) | Ornithology | Oxford Academic]()
Source type	Journal Article
Keywords	Reproductive Success Bird Nest Nest Box Tree Swallows
#Tags	
Summary of key points + notes (include methodology)	Researcher Lombardo wanted to investigate how the nest architecture influenced reproductive success between adult and subadult female Tree Swallows. To do so, he observed 53 subadult nests and 72 adult nests ranging from the years 1988-1990. During this time frame, he observed the nest construction behavior, when they started creating the nest. He also quantified how many eggs each bird laid and later on how many of those hatched and managed to reach the fledgling state. Finally, he measured the dimensions of the nest itself. He ultimately found that there was not a huge significant difference between the nests of the subadult and adult birds. However, subadult nests were more likely to not have as many feathers as well as nest on the wooden part of the nest box. He also concluded that nests built earlier in the season were generally larger than those built later in the season. Finally, it was discovered that during overcrowding of a nest, the eggs and fledgelings were more likely to get hypothermia as opposed to the smaller nests. **Notes:** Introduction • In some species, clutch size is positively correlated with area of nest floor • Nest location and insulation may influence breeding performance and timing of breeding • Materials may affect the thermoenergetics of the nests and risk the nestlings likelihood of contracting hypothermia • Parasite prevalence may also be correlated to materials, tightness of weave, and amount of feathers in the cup • Nest predation rates are higher closer to the ground • Tree swallows make nests with cup lined with feathers and the mat with dry

grasses whereas the males found most of the feathers
- Adult females had more feathers in their nests
- Feathers have insulative qualities
- Too much insulation could cause nestlings to get hypothermia whereas to little insulation could caus ethe female to spend more time foraging and may suffer from energetic stress

Method
- 1988-1990, tree swallow boxes at University of Michigan were studied. One hundred nest boxes were erected on metal posts in old field, on trails, and near the ponds.
    - Entrances faced south
- Breeding females vategorized as subadult or adult based off of plumage
    - Anyone younger than 2 years was considered subadult
- males captured and banded
- Nest architecture
    - Each year, the nest was visited once in April
    - Egg laying was monitored for first week of may
    - Nest not measured until second half of 14 day incubation period
        - Because males will continue to add feathers throughout incubation period
        - Measured, depth, height of bottom outer nest, diameter of top of nest and diameter of the bottom of the nest
        - Nest volume then calculated
    - Feather content scored from 0-4, with 0 being the fewest feathers and 4 being the most
    - Eggs numbered in sequence with inedible length. The egg dimensions were then measured
- Reproductive performance
    - Nests visited daily during egg laying to determine clutch size, number of eggs, how many nestlings had fledged
        - Also visited when 12 days old for banding
- Data Analysis
    - Used SAS
    - Tested for normality and homoscedasticity
        - Would help determine which analyses methods would perform the best
    - Wilcoxon two-sample tests used to detect differences between nest architecture and reproductive performance among the birds in different years

Results
- Nests
    - It took 1-3 weeks for Swallows to build nests
        - No significant difference in time between adult and subadult females
    - Females tended to fill around 30% of the nest box
    - Males did not add many feathers before incubation, but added a lot

during incubation and in early nestling periods

- Female age and nest architecture
  - Size of adult female nests was slightly larger
    - No significant difference
  - Three nests by subadults females had no feathers wherease the adult females always had feathers
- Nest architecture and box size
  - Big and small boxes alike were used with no preference
  - Nest sizes were bigger in those big boxes left to right, volume, and cup volume
  - Position of nest was unaffected by box size
  - Nest cups mostly found in positions 2 and 5
  - Smaller nests had a higher proportion of nests with two or more layers of feathers
- Within-season variations in nest architecture
  - Nests built earlier in the season were bigger
    - Within subadult females
- Nest architecture and reproductive success
  - Subadults began clutches later
  - Nests built earlier in the season correlated with clutch size
    - Front-to-back diameter of top of nest
  - Later in season
    - Positive correlation between number of eggs hatched
  - Amount of feathers not correlated with nestling production
  - The more crowded the cup was, the fewer young that fledged
  - Depth of material between nest-cup floor and the brood size
  - No significant correlation between nest architecture and reproductive performance
    - For adult females that layed before the mean date of nest construction

Discussion

- General nest architecture
  - Birds adjust insulative properties of their nests by either weaving the materials of their nests tightly or loosely depending on air temperature during the period of nesting
    - This was not tested
  - Depth of nest reflects trade off between thermal benefits and being easily accessed by predators
- Female age and nest architecture
  - Few differences
  - More subadult nests build rudimentary nests on the wood floor of the nest box
  - Nest feathers may be a barrier between nestlings and the ectoparasites that inhabit the nests
  - Differed most in feather content
- Nest box size
  - Big boxes would require more effort than smaller nest boxes

- Did not affect the reproductive performance
- Nest architecture and reproductive performance
  - Subadult females modify nest size to account for their increasing clutch size
  - Larger nests had more nestlings
    - However, later in the season smaller nests had produced more fledglings
    - Hypothermia was induced by crowding of nests in the bigger nests, causing more birds to die
  -

Research Question/Problem/ Need

How does the architecture of the nest lend to reproductive success? How is the architecture differ as the birds grow, and how do these differences influence reproductive success?

Important Figures

TABLE 1. Female age, box size, and nest architecture ($\bar{x} \pm SD$) in Tree Swallows using nest boxes. Wilcoxon two-sample tests corrected for continuity showed no significant differences between subadult and adult female nests in all measures of nest architecture except feather score (Wilcoxon $Z = 1.96$, $P = 0.051$). Wilcoxon two-sample tests corrected for continuitiy used to compare measures of nest architecture in big and small boxes (sizes given in text).

	Nests built by			Nest-box size		
Nest architecture	Subadult females ($n = 53$)	Adult females ($n = 72$)	All nests ($n = 125$)	Big ($n = 99$)	Small ($n = 27$)	Wilcoxon Z
Depth of nest material (mm)	40.47 ± 10.34	42.88 ± 9.15	41.86 ± 9.71	42.12 ± 9.05	40.85 ± 12.04	−0.18
Depth of nest cup (mm)	29.38 ± 9.21	31.00 ± 6.47	30.31 ± 7.76	30.36 ± 7.81	30.12 ± 7.72	−0.19
Depth of nest material beneath nest cup (mm)	11.09 ± 9.67	11.88 ± 8.34	11.54 ± 8.90	11.76 ± 8.88	10.73 ± 9.11	−0.72
Front-to-back diameter of top of nest cup (mm)	67.42 ± 8.92	67.46 ± 8.07	67.44 ± 8.41	67.90 ± 8.21	65.69 ± 9.07	−1.04
Left-to-right diameter of top of nest cup (mm)	68.85 ± 11.43	68.89 ± 8.98	68.76 ± 10.05	70.38 ± 9.61	62.58 ± 9.41	−3.56***
Nest-cup volume (mm^3)	80.82 ± 37.95	84.88 ± 28.90	83.16 ± 32.96	86.88 ± 33.17	69.84 ± 28.99	−2.34*
Cup index	0.13 ± 0.10	0.13 ± 0.05	0.13 ± 0.05	0.12 ± 0.07	0.16 ± 0.09	2.13*
Total nest volume (cm^3)	667.67 ± 197.10	706.13 ± 177.56	690.00 ± 186.20	727.94 ± 166.17	547.01 ± 191.15	−4.09***
Percentage of nest box filled with nest material	29.05 ± 7.91	30.34 ± 6.90	29.80 ± 7.34	29.96 ± 6.82	29.17 ± 9.16	−0.24
Feather score	2.96 ± 1.14	3.36 ± 0.90	3.19 ± 1.03	3.12 ± 1.05	3.44 ± 0.89	1.49

*, $P < 0.05$; ***, $P < 0.001$; other values not significant ($P > 0.05$).

This table describes the properties of the nests observed based off whether it was a subadult or adult as well as dependent on the size of the nest box itself.

VOCAB: (w/definition)

Plumage: A birds feather's
Penultimate: Second last
homoscedasticity: A sequence of random variables in statistics

Cited references to follow up on

CLARK, L. 1991. The nest protection hypothesis: The adaptive use of plant secondary compounds in European Starlings. Pages 205-221 in Bird-parasite interactions: Ecology, evolution, and behaviour (J. E. Loye and M. Zuk, Eds.), Oxford Univ. Press, New York.

COLLIAS, E. C., AND N. E. COLLIAS. 1964. The devel-
opment of nest-building behavior in a weaver-
bird. Auk 81:42-52.

KENNEDY, E. D., AND D. W. WHITE. 1992. Nest build-
ing in House Wrens. J. Field Ornithol. 63:35-42.

Follow up Questions

How does overcrowding within nests induce higher rates of hyporthermia?
How do the materials and the structure of the bird nests degrade over time?
How does the size of the clutch early on in life effect the bird's reproductive success later on in life(in adulthood)?

Article #17 Notes: Composition of bird nests is a species-specific characteristic

Source Title	Composition of bird nests is a species-specific characteristic
Source citation (APA Format)	Biddle, L. E., Broughton, R. E., Goodman, A. M., & Deeming, D. C. (2018). Composition of Bird Nests is a Species-Specific Characteristic. *Avian Biology Research*, *11*(2), 132–153. https://doi.org/10.3184/175815618X15222318755467
Original URL	https://www.proquest.com/docview/2055309897?accountid=29120&parentSessionId=vKU2KOJDCYWkdtIuNU1ykCuHyQWok1kc1csugfKwT2Q%3D&pq-origsite=primo&sourcetype=Scholarly%20Journals
Source type	Journal Article
Keywords	bird nest, composition, dimensions, Fringillidae, Muscicapidae, Turdidae
#Tags	
Summary of key points + notes (include methodology)	Researchers Biddle et. al. were curious to observe how the materials within different nests vary between species and if those differences in materials can be used to identify which nest they are looking at. To combat this, they began by collecting nests through the BTO. What they noticed among these nests is that, for the most part, they were elliptical shaped. For this reason, they were able to measure them all in the same way. They used digital calipers to measure the nest cup and diameter as well as the nest height and the depth of the cup. Following this, the researchers weighed the nests and measured the volume of the cup. Their next step was to deconstruct the nest. They began by extracting the cup lining within the nest, followed by either the bottom outer nest or upper outer nest depending on the species and if it had a mud cup or not. The final step was statistical testing. To do so, they ran a t-test to determine if their was a significant variation between the thicknesses of the nests in the same species. They ultimately found that this was not significant except for one species, so they used the mean values for the thicknesses in their results. They then used a GLMM to determine the differences in materials between different families. Finally, they ran a Principal component analysis to compare the total compositions of the nests between different species. Their results showed that there was a significant positive correlation between female body mass, volume, and the majority of dimensions of nest. In addition, across all the species, there was a total of 16 different types of materials and the outer nest had the greatest variation. They also found that the principal components did vary across species with the biggest variation occurring between Ring Ouzel, Hawfinch, Greenfinch, and Chaffinch. For future researcher, it is important to bring in more members of these families to have a more comprehensive understanding of the variation between the species

and families in regards with material choice.

Notes:

Intro

- Different cup shapes: cups, domes, scrapes, or burrows
- Role of nests is to signal fitness and help in the incubation of eggs
- Limited quantitative data on materials in bird nests
- Four functionally different parts of nest
    - Attachment, decorative outer layer, structural layer, and lining
        - Not all layers present in every nest
- Composition of nests reflects the materials available to birds in surrounding environment
    - Pied Flycatchers used branches from trees right outside their nest box
    - Blue and Great Tit had higher levels of wool in the nests when sheep were present in the local area
- Larger bird species build larger nests than small birds, but there is no specific proportion that is followed
- Higher elevated nests had more insulation
- Nests in colder locations and ones built earlier are larger
- 10,000 bird species. 325 have nest size available
- Quantified material lists are only available for 14 species

Methods

- Nests
    - 3 different families were studied
        - 6 finch species, 4 thrush species, 2 flychatcher species, and published data for European Robin and Pied Flycatcher.
        - Nests constructed by wild birds
            - Collected by BTO nest recorders
            - Nests were dried before being put into a plastic bag in a cardboard box.
            - 3-24 months after collection the nests were analyzed
- Nest Characteristics
    - Elliptical shaped
    - Digital callipers used to measure nest and cup diameter as well as nest height and cup depth
    - Wall thickness measured at four points around nests
    - Used electronic scales to weigh nest
    - Used cling film and poured beads in into it to measure volume of cup
- Nest deconstruction
    - Finch had outer nest and inner cup lining
    - Song thrush had 2 distinct regions aswell

- Other thrush had 3 regions
  - Outer nest, mud cup, and cup lining
  - In nests with mud cup, cup lining materials were not measured because they are considered to have no structural role within the nest
- Cup lining extracted first in thrush nests
- Then, base of outer nest was taken off
  - The nest was inverted first
- For bullfinch nests, top of outer nest taken off first

- Statistical testing
  - Paired t-test for wall thickness variation btwn dif orientations of the nest
    - Only one species had a significant variation, so they decided to take the mean for all species
  - Found mean for each value within each species
  - Used spearman's rank to see if there was a correlation between female body mass and the nest measurements
  - GLMM to see differences between families
  - Principal component analysis
    - Total composition of nests to compare dif species
    - Levene test carried out on each principal component
    - Kruskal-Wallis test to see if the Principal components affected by species or family

Results

- Nest dimensions
  - Goldfinch nests had smallest measurements for most measurements
    - It is the smallest bird
  - Hawfinches had largest cup
    - They were the largest bird
  - European Greenfinch had taller and higher cup depth and volume
  - Thrushes jad thinner upper wall than base wall thicknss(ration of 0.63)
  - Significant positive correlation between female body mass, volume, and majority of dimensions of nest
    - Nest wall and base thickness did not have significant correlation
- General Descriptions
  - Feathers and hair mostly found in finch nests
  - Mineral materials usually only found in thrush nest
    - Had btwn 20-77% of the total nest mass
  - Cup in Song Thrush composed of dried wood pulp
  - Manmade materials uncommon but more common in finch nests
  - Goldfinch had lightest nests
    - Outer nest of moss and stems
    - Internal cup of hair, feathers, and plant/seed fibres
  - There was a large amount of grass in most species

	- Blackbird nests were the heaviest
	  - Outer nest mostly grass, moss, and stems
	  - Cup lining mostly grass
	- 16 material types found across species
	  - Outer nest had more variation in material vompared to other parts of nest
	• Species and Family Comparisons
	  - Most finches grouped together
	  - Bullfinch and Hawfinch had high stem content, whereas other finches did not have a lot of stems or minerals
	  - Linnet nests had fibrous materials
	    - Also softer materials
	  - Thrush nests generally had higher contents of harder stems and minerals
	  - The PC1, PC2, and PC3 values were not the same across species
	    - Significantly affected by species
	      • Greatest variation between, Ring Ouzel, Hawfinch, Greenfinch, and Chaffinch
	• Comparison of cup lining and outer nest
	  - Grass, moss, and stems most common in outer nest
	  - Grass was only thing found in cup lining that was found in a great quantity
	  - Manmade materials typically found in cup lining
	  - Bullfinch and Hawfinch nests
	    - Stems distinguished between outer nest and cup lining
	  - Linnet nests
	    - Seed fibres greater in outer nest and hair greater in cup
	  - Stonechat nests
	    - Less moss in outer nest
	  - Robins
	    - More leaves and moss in outer nest
	  - Whinchat
	    - More roots in outer
	      • More grass and feathers in cup
	  - Pied Flycatchers
	    - More fern, leaves, and moss in outer nest
	      • More roots in cup
	  - Mud cup made up large amount of overall weight within the thrush nests
	  - Mineral content higher in outer nests of Blackbirds, Mistle Thrushes, and Song Thrushes
	Discussion
	• Nest weight and dimensions significantly correlate w/ female body mass
	• Can distinguish between species and family based off nest composition
	  - Thrush nests similar to each other but different to flycatcher nests
	• Can distinguish between different parts of nest by a material found commonly in a specific region

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Nest dimensions

Large thrush had beiggest thickness differences
Reflect greater support needed from below
Most dimensions found are similar to the ones that were found earlier
Different species had dif variability in nest size

Nest Composition

Hawfinch nests did not have a lot of grass
Different then previous studies
Not all bullfinch nests had hair
Contradicts previous study that suggested that all Bullfinch nests have hair
There are degrees of plasticity and species specificity in material selection for bird nests
May reflect a preference of a certain species to nest in certain locations
Future research
Compare more member of the families in the study

Variability in nest construction

Hawfinch, Bullfinch, and Robin nests have the lowest variation of materials
Climate affects nest construction
Warmer temperature nests had smaller nests
Time to construct nest
Smaller Blackbird nest are built quicker
Built at bigger heights as well as by less experienced females
Bird health
Heavier nests in Blue Titis constructed by females who were not sick with bird flue
Birds that received supplemental feedings were able to build heavier nests
Man-made materials did not make up huge proportion of nest
Chosen because of resemblance to natural materials
Camouflage
Structural properties
Bullfinches had stronger materials in outer nest

Seperation of nest regions

All species had a structural wall and lining(except for Song Thrush)
The cup typically had softer materials

Conclusion

More research needed for the composition of nests for more species

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<tr>
<td>Research Question/Problem/ Need</td>
<td>How can nests be distinguished between different species? Is it possible to identify a specific part of the nest based off the materials in that part?</td>
</tr>
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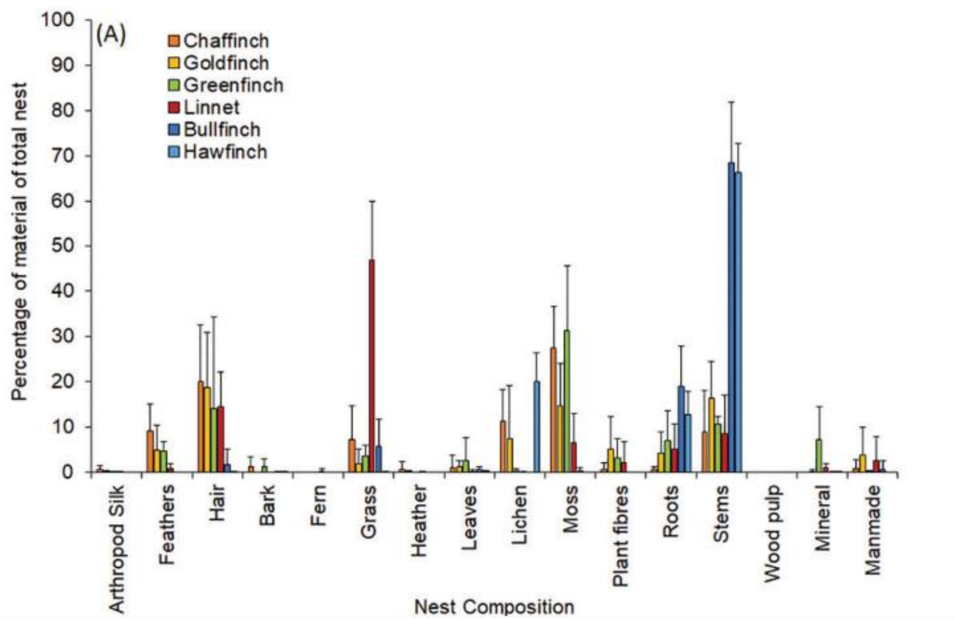
Important Figures	 This graph describes the percentage of each material that made up the nest of each of the species studied. As can be seen, certain species have higher composition of certain materials than others.
VOCAB: (w/definition)	**Receptacles:** An object or space used to hold something **Morphometric:** Quantitative study of the form or life of living things **Hydrological:** Relating to the study of water
Cited references to follow up on	Reynolds, S.J., Davies, C.S., Elwell, E., Tasker, P.J., Williams, A., Sadler, J.P. and Hunt, D. (2016) Does the urban gradient influence the composition and ectoparasite load of nests of an urban bird species? Avian Biol. Res., 9, 224–234. Mainwaring, M.C. (2015) The use of man-made structures as nesting sites by birds: A review of the costs and benefits. J. Nat. Cons., 25, 17–22. Cantarero, A., López-Arrabé, J. and Moreno, J. (2015) Selection of nest site and nesting material in the Eurasian Nuthatch Sitta europaea. Ardea, 103, 91–94. Collias, N.E. and Collias, E.C. (1984) Nest building and bird behaviour. Princeton University Press, Princeton.
Follow up Questions	Does the year that the nest was built influence the variation of materials? How strong are nests with a mud cup as opposed to nests without one? What are the benefits of having a cup shaped nest?

Patent #1: Dome structure and method of construction

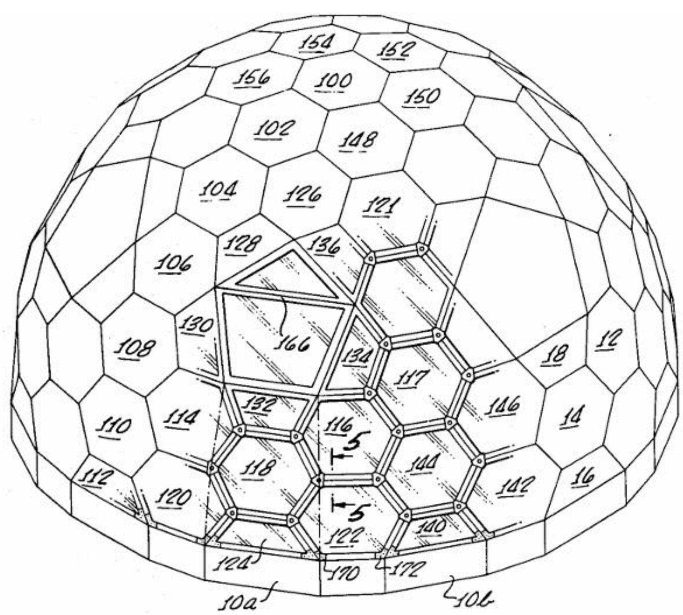
Source Title	Dome structure and method of construction
Source citation (APA Format)	Nalick, D.L. (1996). *Dome structure and method of construction* (U.S. Patent No. 4,075,813). U.S. Patent and Trademark Office. [US4160345A - Dome structure and method of construction - Google Patents](https://patents.google.com/patent/US4160345A/en)
Original URL	https://patents.google.com/patent/US4160345A/en
Source type	Patent
Keywords	Dome Structure, hexagon, geodesic, distortable, construction
#Tags	

Summary of key points + notes (include methodology)	Nalick noticed that the dome structure has many advantages such as good appearance, and high strength capabilities, but there was one thing that stood in their way of becoming "great". What stood in their way is that they are expensive, difficult, and Time consuming to build. What Nalick has devised to combat this problem is dome made from identical hexagonal shapes that can easily be connected together. It is not possible to make a dome shape form straight up hexagons, which Nalick noticed. Therefore, he made his hexagons easily shapable so that they are easy to manufacture and can be implemented based off the needs of a given design. As well as hexagons, the structure needs half hexagons to help fill in the recesses of space where the hexagons are unable to cover. These hexagons and "half-hexagons" are mounted atop a foundation block. Once construction is complete, the dome can easily be framed and cut from to add amenities such as doors and windows.
	Notes:
	• Background
	  ○ Domes have many advantages
	    ▪ Good appearance
	    ▪ Big strength to weight ratio
	    ▪ Can withstand a lot of stress and wind velocity
	  ○ Disadvantages
	    ▪ Expensive
	    ▪ Difficult
	    ▪ Time consuming
	  ○ It is hard to create a dome with hexagons that are uniform in size
	    ▪ In many previous models, there has to be many different sizes of the shape made, which is expensive
	• Invention Summary
	  ○ Dome constructed from regular hexagons that are eqaual in size

- Composed of elongated clusters of hexagons with breaks in the middle which are not hexagons
- Closure panel goes across area that is surrounded by the structural components made from the hexagons

- Detailed Description
  - Mounted on foundation blocks
    - Can be made from any material that is used for foundation
    - Set upon a ground support
  - A hexagonal unit can be placed anywhere in the dome
    - May require some tweaking for a perfect fit
    - Hexagonal units made of blocks at edges that connect and can easily be moved aroudn to adjust structure.
    - Arms made fro two by 2 inch wood stock
    - Perimeter
      - Each structural part is moved up by 60 degrees in relation to the arm before it
  - Flat metallic connector plates to hold the beams of the hexagons together
    - Flexible enough that the hexagons can be deformed easily
  - Semi hexagons
    - Second shape used in this dome structure
    - Looks like a trapezoid
    - Connectors made of flat metallic plates
    - Bolted at the acute angles
    - Not exactly half-hexagons
    - Short arms identical to arms of hexagon
    - Long arm shorter than the diagonal of the hexagon
    - This configuration improves the fit of all of the components within the structure
  - The hexagons can be used to create a structure that has sphericality to it
  - Made of 6 rows of straight hexagons
  - There is no one construction method that needs to be followed
    - Order of construction is recommnended
      - 1.) positioning of foundation blocks
      - 2.) first row of hexagons and semihexagons are placed atop the foudnation block
        - Attached via bolts
        - Hexagons bolted to semi-hexagons
      - 3.) another row is added ontop of that previous row
        - Bolted to hexagons on prior row
        - Units can be placed at any orientation
          - Will be guided into the correct position in contact with the bottom row

	• 4.) A subassembly is created consisting of hexagons connected to each other, making the shape of a flower(kindof)
	• 5.) Adding groups of 3 hexagons to one hexagon at a time
	  o Subassemblies placed on priorly placed hexagons
	• For optimal dome structure, 67 full hexagons and 42 semi-hexagons should be utilized
	• Angularly distorted hexagons should be used to fill any recesses
	  o It is possible to simply press the hexagon into place because the hexagons are easily deformable
	• There is not a lot of distortion needed in the bottom two rows
	o If they want to have more done first, the skeletons of the hexagons can be pre-attached to the panel that goes atop it.
	• Panel should have a snug fit within dado
	• Rigidness of lower hexagons enhances rigidity of entire structure
	• With hexagons with armlength of 15in gives a structure 8 ft high and 14 ft in diameter
	• Doors and windows can be added after the dome is made by cutting and framing
	•

Research Question/Problem/ Need	Arrangements of dome structures made with unit materials are complicated to produce and are made up of non-identical materials.
Important Figures	

	This figure shows how the different hexagonal units and half-hexagons would fit together, with them sitting atop the foundation blocks.
VOCAB: (w/definition)	relative pivotal motion: how domething moves in relation to another object flush: alignment of materials so they are perfectly level with eachother dadoed: A groove cut in a board reticulated: arranged as a network sheathing: protective casing
Cited references to follow up on	US20080066393A1 - Instant, pre-tensioned, tool free, polyhedral, enclosure construction system - Google Patents US3255556A - Panel and spherical structure - Google Patents US3881284A - Ellipse domed structure - Google Patents
Follow up Questions	How would including a door or window influence the makeup of the dome? What is the maximum height that this dome could extend to while still maintaining high structural stability? Would this structure require any beams on the inside of it?

Article #18 Notes: Convergent evolution of elaborate nests as structural defenses in birds

Source Title	Convergent evolution of elaborate nests as structural defenses in birds
Source citation (APA Format)	Street, S. E., Jaques, R., & De Silva, T. N. (2022). Convergent evolution of elaborate nests as structural defences in birds. *Proceedings of the Royal Society B: Biological Sciences*, *289*(1989), 20221734. https://doi.org/10.1098/rspb.2022.1734
Original URL	Convergent evolution of elaborate nests as structural defences in birds
Source type	Journal Article
Keywords	nest-building, weaverbirds, icterids, life history, phylogenetic comparative methods
#Tags	
Summary of key points + notes (include methodology)	Researchers Street et. al. noticed these beautiful ornate and complex nests in the wild, the pendant nest, and wondered how such a nest could come to be in the first place. They eventually came to common hypothesis that the pendant nests evolved as a form of structural defenses. More specifically, Street et. al. wanted to dive into the pendant nests within Weavers and Icterids to see how do the structures of elaborate nests protect against predation or parasites? This could give insight into a species ability to reproduce and give insight as to why the nest type became favored within the Weaver and Icterid species. To find information on the nests, the researchers scoured the site Birds of World online. This website gave them pictures of the nests, so that they could further classify nests into categories. For Weaverbirds, these categories consisted of a group in which the nests either had or did not have a tunnel as the entrance to the nest. These groups were then further categorized into nests hanging from a branch, nests on top of a branch or ground, and nest hanging from branch at exactly one point. Icterid birds followed the same categories as the Weaverbirds except for whether or not it had a tunnel entrance. They then found data on the incubation periods of those nests, heights, and locations. Next, they calculated phylogenic signals for nesting traits using D-values. The results showed that Weaverbirds with tunnel entrances had around a 1.3 day longer incubation period. In addition, pendulous nests had longer developmental periods. The same results were shown in the Icterid nests. These results suggest that more elaborate nests have longer developmental periods. A previous study noticed that Developmental periods in avians negatively correlated with predation in the nest as well as brood parasitism rates. Therefore, the longer developmental periods within the more elaborate designs of the nests proves the hypothesis that the pendulous nests were adapted for structural defense.

Notes:

- Bird nests range from stick platforms to woven cups and domes
  - Unkown why some birds build more complex structures than others
  - Most complex shape is the pendant shape
    - Most elaborate among weaverbirds and icterids
- Advantages of pendant nests
  - Protection from aboreal predators
  - Protection from brood parasites
    - Based mostly on observational accounts
- Weaverbirds have wide variety of nests themselves
  - Ranging from roughly constructed nests to highly intricate designed nests
- Icterids also vary
  - From typical cups to suspended pouches, with some birds not building nests and stealing from other species
- Both pendant nests are very similar using similar weaving methods
- If study shows that have more elaborate nests have are able to protect from predators better, it will show evidence of lower offspring mortality

Methods

- Data Collection
  - Data on nest design, life-history traits, body mass, and latitude were mostly retrieved from secondary sources
  - Variations in nest design determined via descriptions and images from Birds of the World Online
    - Did not have enough photographs of weaverbird nests, so they retrieved those through a project to have more images of bird nests called PHOWN
  - Photographs prioritized over text definitions
  - Weaverbird nests classified in two categories
    - With entrance tunnels or without
    - Broken up into
      - Nests hanging from a branch
      - Nests on top of a branch or ground
      - Nest hanging from branch at exactly one point
  - Icterid nests broken up into the three categories mentioned above
    - Nests that were borrowed were not counted in this study
  - Weaver birds and icerids often build their ensts in locations that are hard to reach by predators
    - A study found in India that nest location had a higher impact on fledgling survival compared to nest structure
  - Found height of nesting and gathered data on protective features of the places that the birds are nesting

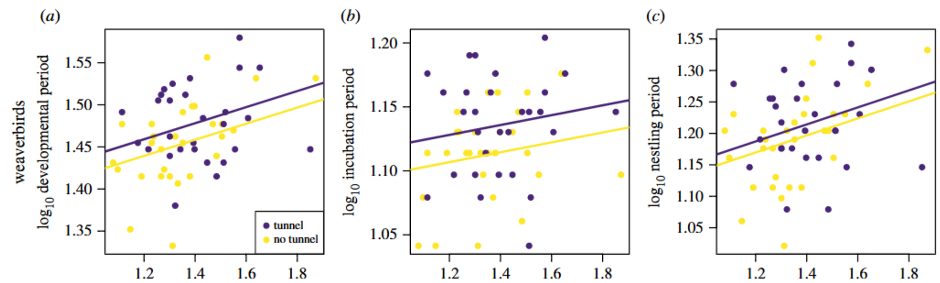
- Incubation data was gathered from Birds of the World Online
- They did more literature searches on life-history data so that they had a sufficient sample size
- Downloaded species distribution maps for all the species from the IUCN Red List and used that to find the ranges of the birds
- These data sets resulted with 56 weaverbrids and 48 icerids with complete data on nest design and developmental periods
    - 15 weaverbird and 17 icerid had data on tunnel or nest length

- Data Analysis
    - Ran analyses in the software R
    - Used regression models
        - Either icubation length, nesting length, or total developmental period was outcome variable
            - Body mass or latutude was predictor
    - Phylogenetic geralized least squares regression
        - Accounts for the non-independence of specieis data
    - Ancetral state recontruction on nest tunnels in weaverbirds and nest attachment in icterids
        - Used maximum-likelihood
    - Calculated phylogentic signal for nesting traits using D-values
        - A D value is based off sum of differences between binary traits and sister clades
            - Lower D values: similarity between traits
                - Higher phylogenetic signal
            - Negative D values:
                - Erxtreme phylogenetic clustering
            - D values greater than 1
                - Overdispersion

Results

- Weaverbirds
    - Nests with entrance tunnels have offspring with longer developmental periods
        - About 1.3 days longer
            - For weaverbirds with normal mass
    - Tunnels have longer incubation than nestling periods
    - Not very much developmental differences between the different types of bird nests
        - Pendulous nest have a slightly longer developmental period
    - Tunnel length and development period not correlated
        - Stats not very strong because n=15
    - Developmental period length not associated with latitude
- Icterids
    - Icterids with pendulous nests have longer developmental periods
        - Compared to those with suspended nests
        - Pendulous nests need about 2.7 more days in

	development o Nest type had significant impact on length of nestling period compared to incubation period length o Developmental period increased with height off ground o Nest location did not encessarily associate with longer developmental periods Discussion • More elaborate nests have longer developmental periods • Longer tunnels more effective at preventing invaders from entering the nest • Nest location also provides some protection o Nesting over water in weaverbirds o Higher off ground in icterids • Low phylogenetic signal among weaver bird development periods o Evolution not based on gradualistic model(Brownian) o High Pagel's δ, so rapid evolutionary changes o Suggest that elaborate pendant nests do protect against predators • Developmental periods in avians negatively correlated with predation in the nest as well as brood parasitism rates. o Therefore, developmental periods are a good indicator of nest predation • Future Work o How nest structure effects adult and juvenile mortality risk • Developmental period stronger association with tunnel length than attachment type o Tunnels make more difficult for parasites to access nests o Nest attachments do not really have any relevance to hindering or helping brood parasites access the nest • Finding of location not having significant impact on development and nest predation is not consistent with past findings • Climate does not have obvious connection to entrance tunnels • Elaborate designs may also help with mate choice • Pendant nests usually built by females • Sexual selection for the reason for the pendant design is not yet supported o In baya weavers, the choice of females is more greatly influenced over nest location as opposed to nest structure • Conclusion o 2 species evolved to similar threats o Used phylogenetic comparative methods o Findings support idea that elaborate nest designs help with structural defense o Complex structures may even be the reason we ourselves have been so successful
Research Question/Problem/	How do the structures of elaborate nests protect against predation or parasites?

Need	How has this caused icterids and weaverbirds species to evolve to have the same nest type?
Important Figures	 This table describes the length of the developmental period, incubation period, and nestling period in relation to the body mass. The results show that nests with no tunnels, on average, have a shorter developmental, incubation, and nestling period compared to the nests with a tunnel.
VOCAB: (w/definition)	**Clade:** Group of organisms that evolve from the same ancestor **Phylogenetic:** relating to the evolutionary development and diversification of a species or group of organisms **Confounded:** used for emphasis
Cited references to follow up on	Crook JH. 1963 A comparative analysis of neststructure in the weaver birds (Ploceinae). Ibis105, 238–262. (doi:10.1111/j.1474-919X.1963.tb02498.x) Collias NE, Collias EC. 1962 An experimentalstudy of the mechanisms of nest building in aweaverbird. Auk 79, 568–595. (doi:10.2307/4082640) Mainwaring MC, Hartley IR, Lambrechts MM,Deeming DC. 2014 The design and function of birds'nests. Ecol. Evol. 4, 3909–3928. (doi:10.1002/ece3.1054)
Follow up Questions	How did you classify the images by species from the data you collected? Did the incubation data match up with each individual nest? What other species have pendulous nests? What other benefits besides structural defense do the pendulous nests have?

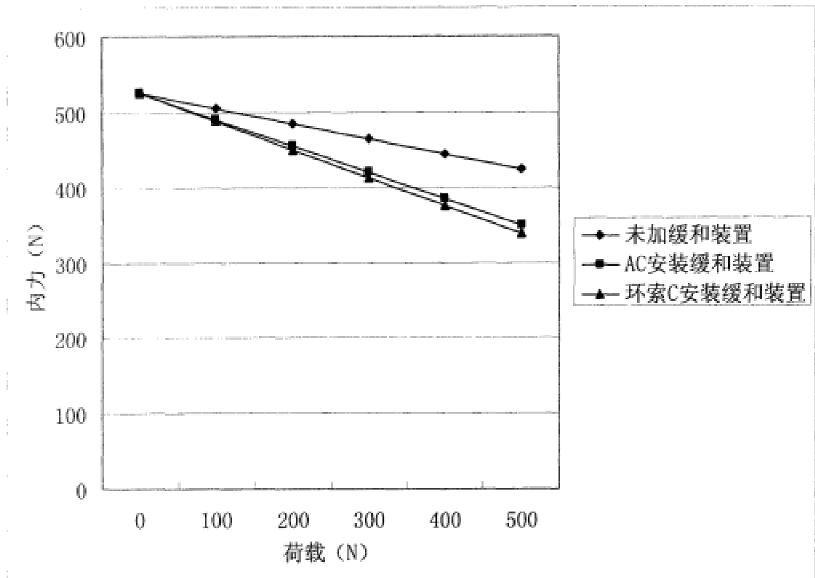
Patent #2: Bird's nest cable dome structure with load relief function

Source Title	Bird's nest cable dome structure with load relief function
Source citation (APA Format)	高博青, 赵超超, & 马洪步. (2007). *Bird-nest type rope dome structure with load alleviating function* (China Patent No. CN101041999A). Zhejiang University. https://patents.google.com/patent/CN101041999A/en
Original URL	https://translationportal.epo.org/emtp/translate/?ACTION=description-retrieval&COUNTRY=CN&ENGINE=google&FORMAT=docdb&KIND=A&LOCALE=en_EP&NUMBER=101041999&OPS=ops.epo.org/3.2&SRCLANG=zh&TRGLANG=en
Source type	Patent
Keywords	Cable Structure, Relief device, internal force
#Tags	

Summary of key points + notes (include methodology)	Inventor GAO BOQING ZHAO noticed that there is great opportunity to improve upon existing structures in the field, especially regarding internal stiffness. For this reason, they were drawn to cable-dome structures because they have a high tensile strength as well as high structural efficiency. More specifically, they wanted to see how they could use a bird nest inspired dome with the ability to relieve loads to improve the dome structure. To do so they used a variation of ring beams, vertical struts, ridge cables, oblique cables, hoop cables, and, most importantly, a relief device. The benefits of this design is that it is lightweight, there are few components, the compressive and tensile strength are excellent, it is able to absorb energy from large loads, and, finally, it looks sleek and modern. To determine where in their design to place the relief device, they tested internal force when the relief device was placed in different parts of the dome as it corresponded to the loads being placed onto it. This was then compared to the structure prior to the addition of a relief device. The results showed that the structure had the biggest decrease internal force when it was placed near the node of the hoop cable had the best result. The second best result was when it was placed between oblique cable and ring beam.
	
	Notes:
	• Cable-strut tension gets stiffness from prestressing of basic cables and rods
	  ○ The structure shaped like a dome developed by engineer Geiger
	    ▪ Tensile structure with high structural efficiency
	  ○ In 1980s, British scholars proposed a structure that had the ability to relieve itself of loads. Used cable net structure to apply onto

	landfills
	• Invention
	  ○ Purpose: bird nest shaped cable dome with the ability to relieve loads
	  ○ Consists of
	    ▪ Ring beam, vertical struts, ridge cables, oblique cables, hoop cables, relief device
	      • Ridge cables intersect at top of vertical struts
	      • End of oblique cables attached at bottom of vertical struts
	        ○ Oblque cables in the outer strts anchored to ring beam
	      • Hoop cables hinged at bottom of strut
	  ○ Ridge cable, oblique cable, and ring cable are prestressed
	  ○ Used compression ring beam
	  ○ Relief device
	    ▪ Has a steel plate on the ring beam
	    ▪ Has a spring unit and anchor plate
	    ▪ Has a pressure-bearing ball node
	• Benefits
	  ○ Light weight
	  ○ Not many components
	  ○ Excellent tensile strength, good compressive properties
	  ○ Good stress-bearing performance
	  ○ Internal force reduced using relaxation device
	  ○ Mid-span deflection increases
	  ○ Can absorb energy from large loads
	  ○ Good aesthetics
	• Figures:
	  ○ Tested a bird nest cable dome with span of 5m to axisymmetric loads
	  ○ Tested internal force when the relief device was in different parts of the “nest” and in different positions
	    ▪ Placing the device near the node of the hoop cable had the best result
	      • Reduce internal force by more than 15%
	    ▪ Placing between oblique cable and ring beam saw reduction by 13%

Research Question/Problem/ Need	how they could use a bird nest inspired dome with the ability to relieve loads to improve the dome structure?

Important Figures	 *Figure 1: In this picture, it is evident that when the relief device esd placed at the C node of the hoop cable(triangle), there was the biggest decrease in internal force from the structure without a relief device(diamond). This is followed by when the relief device was placed between the oblique cables and ring beam(squares).*
VOCAB: (w/definition)	**Oblique cable :** A cable positioned at an angle relative to the main axis of the structure **Ridge cable :** Cables that go from the center of the structure to the edge of the structure **Vertical strut:** A part of a structure that supports axial compressive loads **Ring beam:** Beams on top of a structure **Hoop cable:** A structure using rings of cables to make a dome-like structure
Cited references to follow up on	https://patents.google.com/patent/CN105804248A/en?peid=641dc2ce4bab0%3Ae4%3A8cc9c1d2 *Diamond type cable dome structure https://patents.google.com/patent/CN100487213C/en?peid=641dc2eb6bf78%3Af1%3A5144d96d *Beam string structure having load alleviation function and implementing method
Follow up Questions	How would the locations of the relief device change based off the material in use? How would the size of the structure change the location of the relief device? What other shaped structures could this relief device be implemented into to improve the structural stability?

Article #19 Notes: The role of climatic variables on nest evolution in tanagers

Source Title	The role of climatic variables on nest evolution in tanagers
Source citation (APA Format)	Colombo, S., Newman, K. D., Langmore, N. E., Taylor, C. J., & Medina, I. (2024). The role of climatic variables on nest evolution in tanagers. *Ecology and Evolution*, *14*(4), e11168. https://doi.org/10.1002/ece3.11168
Original URL	https://onlinelibrary.wiley.com/doi/epdf/10.1002/ece3.11168
Source type	Scientific Article
Keywords	avian nest, climatic variables, evolution, nest architecture, phylogenetic tree, tanagers
#Tags	
Summary of key points + notes (include methodology)	Nests are very important structures that effectively protect nests from extreme temperatures and strong winds. In addition, different materials and properties of the nest are used to protect against precipitation. There are three main types of nests that birds utilize, that being cup nests, domed nests, and cavity nests. Which nest is used often depends on the climate that they are found in. While diving deeper into the relationship between nest structure and climate, the researcher found that the prior studies were mostly confined to studies of European and Australian species. This led to the researchers wanting to examine how climate influenced the structure of nests within South America. To do so, they collected data from around 140 South-American nests from museums in germany and England. They then looked into the environmental characteristics of the different locations that the nests were from. More specifically, they looked into Temperature at 2m, Total precipitation, Net solar radiation, 20m eastward wind, and 10m northward wind. Their findings suggested that open nests were found in a much wider range compared to domed nests. In addition, they found that domed nests that were faced with higher solar radiation, the nests were shorter and longer. Finally, they found that birds with higher mass in nest cups have bigger diameters and thicker walls. The birds with higher masses in the dome nests had a bigger entrance. Overall, these results indicate that climate does influence the characteristics of the nest. The limitations of this study are that these nests are from a a large range of years which may influence which may change and influence the shape of the nest. Future work could explore these characteristics in relationship to climate in climates other than south America. Overall, Wall thickness, nest height, and total nest diameter, and cup depth evolved as a response to precipitation, wind speed, and solar radiation.

Notes

Intro

- Nests provide protection from strong winds and extreme temperatures
- Bad conditions inside the nests is dterimental to the development of the embryos
- Birds use certain behaviours to maintain ideal temperature within the nest
    - Ex. Fanning wings
    - Incubating longer
    - These behaviours require a lot of energy out of the parent
- The structure of the nest itself also helps regulate temperature
    - Ex. Eggs cool slower in thicker nest
- Some materials can help precipitation dry quicker
- Three types of nests in passerines
    - Cup nests
        - More common in northern temperate regions
    - Domed nests
        - With roof and small entrance
        - More common in tropics
        - Provide protection from extreme weather events
    - Cavity nests
        - Nests inside trees or rock walls
- Birds adjust traits of the nest based off climate or nesting season
    - Ex. Lining, diameter, nest height
- Zebra finches use more cotton strings when they nest at cooler temperatures as opposed to warmer temperatures
- There are not a lot of studies on the nest characteristics
    - Mostly limited to birds that nest in nest boxes
        - They are easier to study(logistical reasons
    - Also mostly studied European or Australian species
    - Not a lot of South America, even though they have such a wide variety of bird species

Materials and Methods

- Nest data collection
    - They went to two very big museums (Museum fur Naturkunde in Berlin and Natural History Museum in Tring) that, in total, had a collection of more than 5,500 nests
    - Around 140 nests were measured
        - They measured 35 domed nests and 54 open nests
        - These nests were from Central America from the years 1861-1971
- Environmental Variables
    - Information about where the nests were from were obtained from the records about the nests
    - For nests with no specific location, an approximated location was used based off either the general range of the species or a breeding site near the general area the nest was found

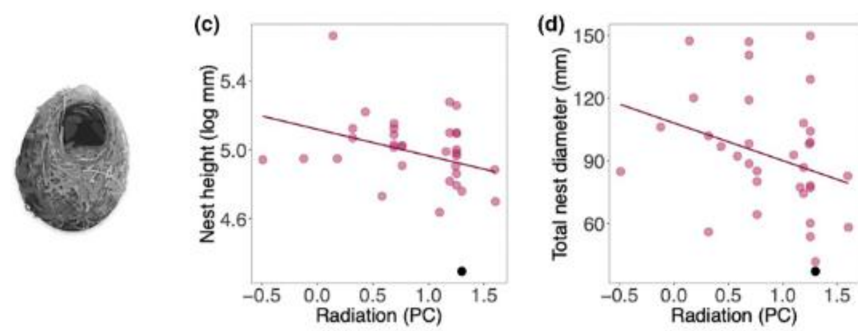
- Found time of year nests collected
    - For nests that did not have a collection month, they referred to the Handbook of Birds of the World Alive
- Found datasets analyzing the climates in the past for the locations where the nests were from
- They found:
    - Temperature at 2m
    - Total precipitation
    - Net solar radiation
    - 20m eastward wind
    - 10m northward wind
- Downloaded 10 years of hourly climactic data for month the nest were collected in
    - found maxes, mins, and means for each year, which was then averaged across all 10 years

- Statistical Analyses
    - They used RStudio
    - Used Bayesian Regression Models using R packages brms
    - Split into groups of those that built domed nests and those that built open nests
    - Ran 4 models for open nests
    - 5 models for dome-nest
    - Nest measurements were response variable
    - The temp, precipitation, etc. were the predictors
        - Also used log-transformed mass
        - To fix strong positive skew
    - Generated a maximum clade credibility tree
        - To account for relationship between species already
    - Used BRMS model with Gaussian distribution
        - Used Bayesian regression on set if 100 trees to see the uncertainty of the effect of the phylogenetics on the results

Results

- Open nests are found in a wider range of locations
    - Nests in locations with strong winds have longer nests and deeper cups
        - This effect is not aas great when the species *Sicalis flaveola* is removed
            - Produces negative association between precipitation and wall thickness
- Domed nests
    - Higher solar radiation= shorter and narrower nests
        - Effect decreases when take out species *Certida olivacea*
            - Means that the causes are weak
                - But still present
        - Negative effect of precipitation on wall thickness
- Log-transformed body mass affected some traits

	- Higher mass - Longer, bigger internal diameter, thicker wall - Domed nests - Nests wider +bigger entrance - Overall - Thicker walls w/ bigger mass - No definite influence of age of nest on the characteristics Discussion - Climate influences evolution of some nest traits - In both types of nest - Higher precipitation linked to narrower wall thickness - Higher mass has strong effects on characteristics of nest - Thraupidae species are found in a lot of different environments - Domed nest sin places with higher solar radiation, temperature, and wind - All dome nests except one were collected on islands - Contradicts fact that a study showed that island birds are less likely to build dome nests - Relationship between wind and nest characteristics is weak - However, similar results were found in another studysuggesting that bird that nest in colder and windier environmetns have longer nests - Wind envokes elevated heat loss - Nest mass plays biggest role in cooling nest - Chinese tits put their eggs in the domed nests to prevent them from falling out during windy storms - Thicker walls-more wind - Supports idea that nest traits are important for protecting eggs - Domed nests - Relationship between nest height, total nest diameter, and solar radiation - Suggests domed nests are specialized to protect against solar intensity - Shorter nests have less of a surface that is exposed to sunlight - Cavity nests in shade have higher survival rates - Precipitation and wall thickness - Conflicts with past data - Deeming found no relationship between thickness and precipitation - However, another study said the opposite - That birds selected materials with less insulation to speed the drying process - Mass can influence nest traits - Depends on variable tested - Limitations

	○ Nests collected in museums for many years ▪ Could change original shape of nest • However, no particular connection between year and nest shape ○ Nests collected in different years and locations • Future research ○ Explore the patterns identified in this paper more deeply ▪ Through experimental or field tests ○ Research is relevant to climate change ▪ Shows influence of climate on nest characteristics ▪ Climate change may effect the optimality of the nests • Conclusion ○ Wall thickness, nest height, and total nest diameter, and cup depth evolved as a response to precipitation, wind speed, and solar radiation.
Research Question/Problem/ Need	How have climactic factors influenced the evolution of the traits within a bird nest?
Important Figures	 This figure describes the relationship between nest height and total nest diameter as compared to solar radiation within domed nests.
VOCAB: (w/definition)	Gaussian distribution: bell-shaped curve
Cited references to follow up on	Biddle, L. E., Dickinson, A. M., Broughton, R. E., Gray, L. A., Bennett, S. L.,Goodman, A. M., & Deeming, D. C. (2019). Construction materialsaffect the hydrological properties of bird nests. Journal of Zoology,309, 161–171. https:// doi.org/10.1111/JZO.12713 Cardoni, D. A., Isacch, J. P., & Baladrón, A. (2017). Causes and conse-quences of nest mass and structure variation in the Bay-CappedWren-Spinetail Spartonoica maluroides. Acta Ornithologica, 52, 51–58. https://doi.org/10.3161/00016454AO2017.52.1.005 Duursma, E. D., Gallagher, R. V., Price, J. J., & Griffith, S. C. (2018).Variation in avian egg shape and nest structure is explained byclimatic conditions. Scientific Reports, 8, 4141. https://doi.org/10.1038/s41598-018-22436-0

Follow up Questions	What is the maximum wind speed that a domed nest could withstand? How was Deeming's study conducted that may have influenced the conflicting results? Why would open nests be found in a wider range of locations?

Article #20 Notes: The impact of valency and the orientation of the members on the global stability of lattice steel domes

Source Title	The impact of valency and the orientation of the members on the global stability of lattice steel domes
Source citation (APA Format)	Kolakkattil, R., Tsavdaridis, K. D., & Sanjeevi, A. J. (2023, April 11). *The impact of valency and the orientation of the members on the global stability of lattice steel domes* [Conference]. Annual Stability Conference, Structural Stability Research Council, Charlotte, USA. https://openaccess.city.ac.uk/id/eprint/30752/
Original URL	https://openaccess.city.ac.uk/id/eprint/30752
Source type	Conference or Workshop Item (Paper)
Keywords	Domes, lattice members, valency, structures, Kiewitt dome
#Tags	
Summary of key points + notes (include methodology)	Domes are a very commonly used structures for roofs of big open buildings, such as coal storage yards or indoor stadiums. However, domes are also very light, which brings concern to the engineers, because the likelihood of buckling is very high. To determine what configuration would help to decrease the likelihood of buckling, Kolakkattil et al. used a set of common single-layer dome arrangements and then subjected them to buckling analysis as well as geometrically and materially nonlinear analysis. This would help the researchers to understand how the orientation of the members as well as how many members surround each other will influence the load capacity. Their results showed that the Kiewitt dome(triangular members) was the most efficient. This is because it had a higher load capacity, fewer connections, fewer members, and less variation in member length. In all the configurations, as the number of members surrounding each other increases, the load increases. The Lamella dome(it looks like a spirograph) had a lower buckling load compared to the hexagonal dome. They also found that the number of radial(side-to-side) members within a dome help to transfer loads to the supports of the dome, increasing stability. Future work would include varying the span-to-height ratio to see if there is an optimum ratio, or if that even influence the structural efficiency of the dome. Notes:

Intro

- Domes used to cover a large distance with the minimum amount of columns necessary
  - Ex. Roofs of coal storage yard, petroleum storage tanks, and indoor stadiums
- They are overall lighter structures
  - Which is concerning for engineers
  - Likelihood of the dome snapping by buckling is very high
- Mesh density, shell geometry can influence stability as well as nonlinearity, imperfections, load distribution, etc.
- Discrete analysis is better to investigate shell stability
  - Faster and more accurate
  - Shows how the entire dome can collapse if one of the members buckles
- Many investigations on single-layer triangular domes
  - Most stable
- In study
  - Dif configurations of dome created and subjected to buckling analysis as well as nonlinear analysis
  - Optimizing arrangement of components to get higher load strength without the higher cost

Methodology

- Used parameterization
  - Made of three parts
    - Form
      - Overall shape
    - internal structure
      - Arrangement of members
    - Connections
      - System used to connect members of internal structure
- Effect of internal structures on stability of a single-layer reticulated dome
- Internal structure
  - Members arranged along domed surface
  - Elliptic or parabolic surface may result in the dome having a different configuration of its members
  - Used parameters to distinguish between these different types of domes
  - Internal structure defined as combination of vertices, edges, faces, and cells.
    - Defined on
      - Dimensionality
        - Degrees of freedom for an element
          - Vertex=0
          - Edge=1
          - face=2

- Valency
  - # of elements that connect to an element that has a different dimensionality then itself.
    - How many other elements abut it
    -
- Extent
  - Magnitude(ex. Length, area) of elements
- Orientating the members of the dome in different ways can also influence stability
  - They can have the same number of members around them but still respond to external loading in different ways.
  - They were subjected to Geometrical Material Nonlinear analysis
- Numerical Analysis
  - Span fixed at 40 meters
  - Rise-to-span ratio: 1:5
  - Hollow circular cross-sections inserted with a diameter of 89mm and thickness of 4mm.
    - Based off of design guidelines
  - For sections that were made up of steel members
    - Elasto-perfectly constitutive relation
    - Youngs Modulus: 200 Gpa
    - Yield Stress: 310 MPa
  - Dome configurations generated using Formex Algebra
    - Would vary the different parameters randomly
  - Created a finite element model in Abaqus
    - Used to test for buckling
      - "eigenvalue buckling analysis"
    - Members:
      - Element "B32(three-noded beam element)"
      - Divided into 4 elements
      -
    - Connections
      - Rigid
  - Calculated limit load using Riks method
  - Total vertices, edges, extent, and load capacity were varied
- Results
  - Kiewit-6 dome had highest load capacity
    - Also had fewer edges and less extent variation
  - Lamella dome
    - Lowest buckling load capacity
  - Edge valency high for lamella dome
  - Shows member orientation influences valency?
  - Material slenderness higher near support regions

	- For domes with radial members
	- The cross section between the different members were kept the same
	  - Restricted how much the extent of the members could change
	- To keep the valency of faces constant
	  - Number of faces along radial direction was fixed
	- Total weight varied in each strcture
	  - Weight was added as a parameter
	- Edge valencies were different at the support regions and the interior regions of the dome
	  - Part connecting to the “ground”-support region
	  - Part connected with the structure itself-interior region
	- Higher edge valency=higher buckling load capacity
	• Method
	  - Differing face valencies
	    - # of faces in radial direction fixed
	    - The number of faces in the direction of the circumference of the dome was varied
	• Result
	  - Kiewit dome
	    - As the number of faces in the circumferential direction increased, the total weight increased as well.
	    - Vertex valency in 500 range had maximum buckling load capactiy
	    - Chance of node buckling increases after optimum vertex valency is reached
	  - Lamella dome
	    - Load capacity was higher when there was only diagonal members of the dome
	    - Optimum vertex valency higher than 2000
	      • More expensive
	• Discussion
	  - Valency and orientation influences overall load resistance within a dome
	  - Edge valency of vertices go up, load capacity and stability increase
	  - Domes with triangulated members were more efficient
	  - Kiewitt dome most efficient
	    - High load capacity
	    - Low steel usage
	    - Not as much variation in member length
	  - Further studies could observe varying the span-to-rise ratio as well as the member cross-section size.

Research Question/Problem/ Need	What valency, orientation, and magnitude of dome members would increase structural efficiency within a dome?

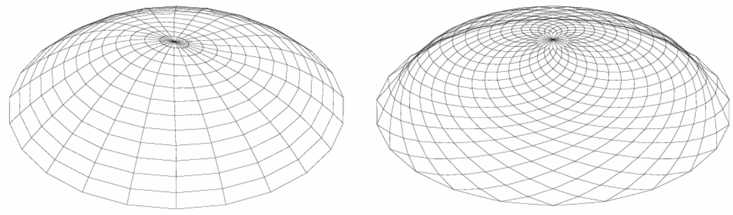
<table>
<tr><td>Important Figures</td><td>

Figure 4: First buckling mode is different for the configurations even though the edge valencies are the same, indicating the influence of member orientation on global stability: (a) Radial rib dome (b) Lamella dome

This picture describes the configurations of two different dome types in the first buckling mode. As can be seen, although they have the same valency, they have different buckling shapes.</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>Reticulated: constructed
Single-layer reticulated dome: A dome made from only a single layer of members, forming a lattice structure
Buckling: Large scale deformation in a structure
Valency: How many members surround a member at a vertex point
Geometrical Material Nonlinear Analysis: Analysis that analyzes how the displacement(buckling) in a structure affects the stiffness and stress distribution. Considers material plastic behavior and buckling
Rise-to span ratio: Ration between a dome’s width and height
Elasto-perfectly constitutive relation: A material’s behaviour under stress. Deforms until a point of no return
Riks method: non-linear finite element analysis to calculate stuff such as buckling or snap-through</td></tr>
<tr><td>Cited references to follow up on</td><td>Yang, Y. B., Yang, C. T., Chang, T. P., & Chang, P. K. (1997). “Effects of member buckling and yielding on ultimate strengths of space trusses.” Engineering Structures, 19(2), 179-191.
Tsavdaridis, K. D., Feng, R., & Liu, F. (2020). “Shape Optimization of Assembled Single-Layer Grid Structure with Semi-Rigid Joints.” Procedia Manufacturing, 44, 12-19.
Levy, M., & Salvadori, M. (2002). Why buildings fall down: How structures fail. WW Norton & Company.</td></tr>
<tr><td>Follow up Questions</td><td>How could this experiment be carried out mechanically(not on a computer)?
What other types of dome structures are there?
Would a single or double layer dome structure be the most efficient?
Is there a particular type of dome structure that is easier to assemble?
Where in the dome are the supports? What parts of the dome is the stress the highest?</td></tr>
</table>