

# Structures in Nature Guide

## Lightweight...but strong!!!

For natural objects, it is important to be strong (unbreakable) to survive. Most strong and sturdy man-made materials are heavy, which takes a lot of energy to make (produce) and move. Natural materials are “smarter” – they are strong AND lightweight so that organisms do not waste energy.

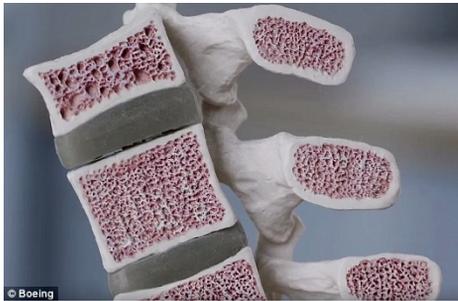
## Nature’s Smart Design: Lightweight Materials

Nature *reduces the amount of material* required for any structure by *adding material ONLY where strength is needed* and *removing it where it is not being used*.

### Examples of Lightweight materials in Nature

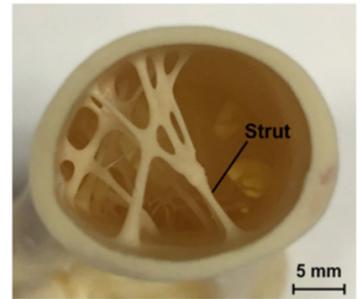
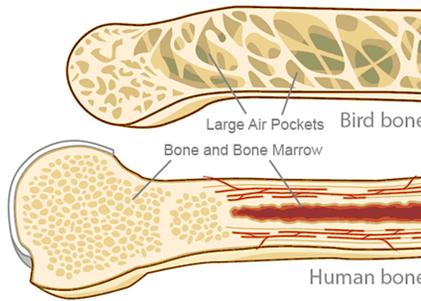
#### Bones Structure

Humans: Spongy Bone Segments

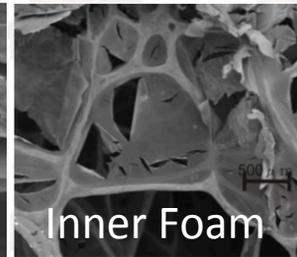
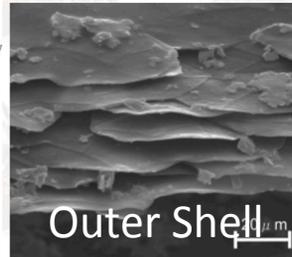
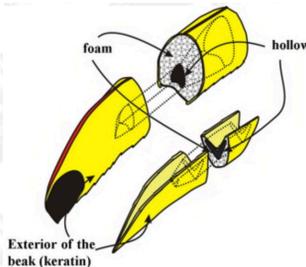


Images: Human Bone by Boeing (<http://www.dailymail.co.uk/sciencetech/article-3270060/The-end-heavy-metal-Boeing-shows-material-99-99-AIR-lead-new-generation-planes-spaceships.html>); Human and Bird Bones from ASU’s Ask a Scientist (<https://askabiologist.asu.edu/human-bird-and-bat-bone-comparison>); Bird Bone Cross-section from “Extreme Lightweight Structures: Avian Feathers & Bones” (<http://www.sciencedirect.com/science/article/pii/S136970211730072X>).

Birds: Hollow with Struts



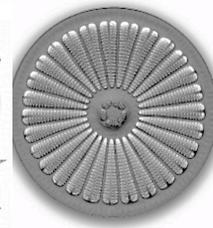
**Toucan Beak:** Hard outer shell is made of keratin layers cemented together and inside of beak is filled with lightweight “Foam”



Images from: Engineers Discover Why Toucan Beaks Are Models of Lightweight Strength ([http://jacobschool.ucsd.edu/news/news\\_releases/release.sfe?id=417](http://jacobschool.ucsd.edu/news/news_releases/release.sfe?id=417))

## Engineering Lightweight Materials

**Diatom Models:** Diatoms are single-celled algae with strong silica cell walls. Engineers from the ELISE company look through a Diatom Database for structures similar to what they want to create.



- Light weight
- Mechanical strength
- Homogeneous stress distribution
- Permeability
- Transparency
- Unique Design

## Mercedes’ Bionic Car



## Boeing’s Airbus



30-50% less material for “lightweight” models

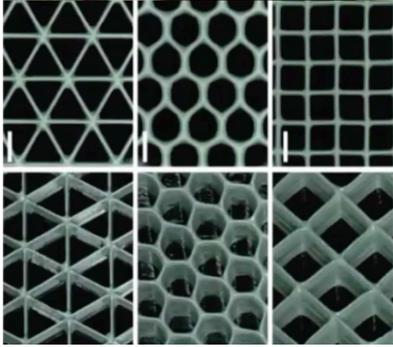
# Structures in Nature

## Nature's Smart Design: Strength from Levels of Organization

Nature can make lightweight materials **STRONG** by *combining shapes within shapes* to form **levels of organization (structural hierarchy)**. Nature combines lightweight **honeycombs** and **struts/trusses** into **sandwiches** and **circle packing**.

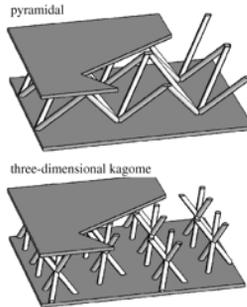
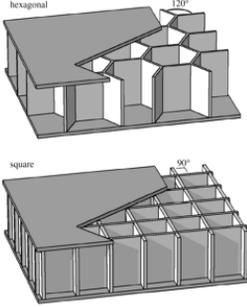
### Structural Patterns

Honeycomb



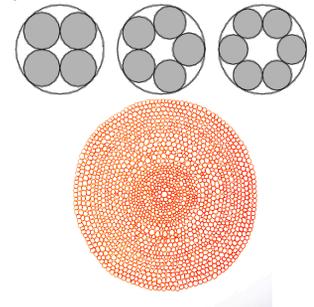
Sandwiches of

Honeycomb or Trusses/Struts



Circle Packing

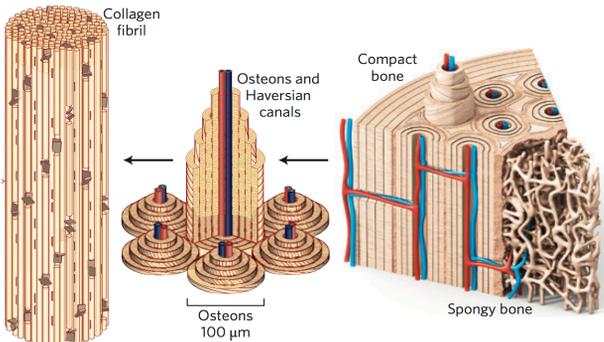
(circles within circles)



Images from: <http://rsta.royalsocietypublishing.org/content/364/1838/31.figures-only>

### Examples of Strong Materials in Nature

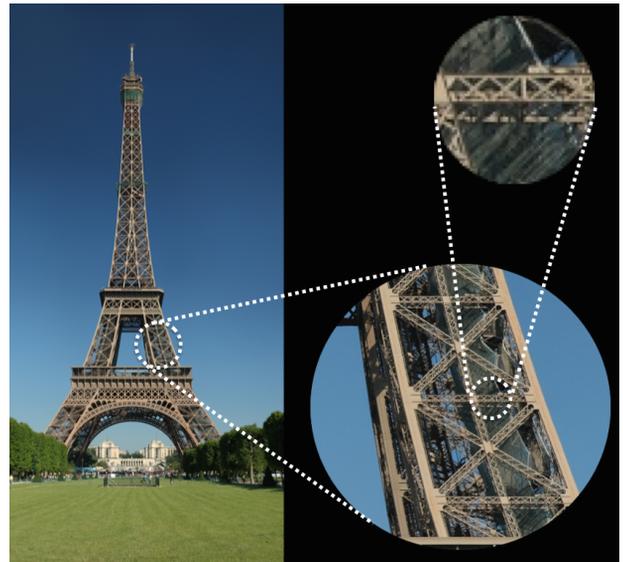
#### Bone Structure



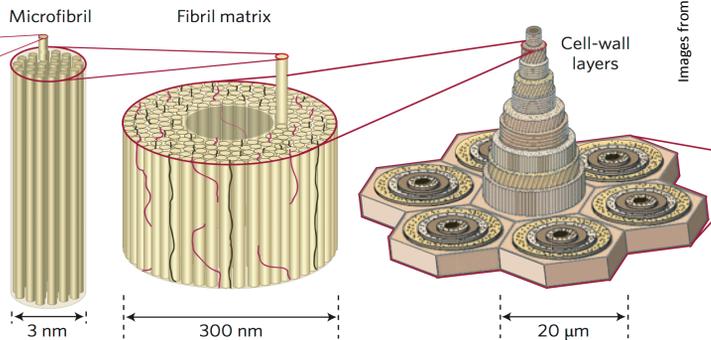
Images from: <https://www.nature.com/articles/hmat4089>

### Engineering Innovations

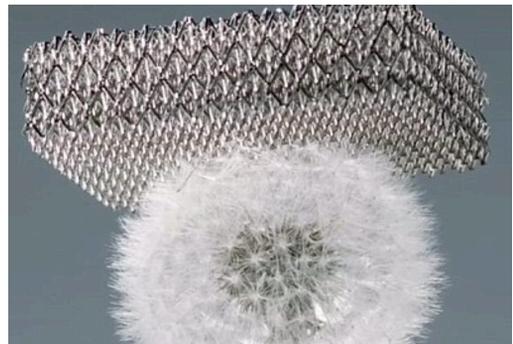
Eiffel Tower (*sandwich trusses*)



#### Bamboo Structure

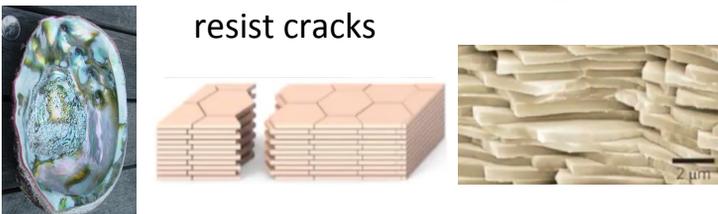


Boeing's Microlattice for Space Shuttles  
(*Super Strong but 99.99% air*)



Images: <https://aaitshb.com/2015/03/09/eiffel-tower/>; <http://www.dailymail.co.uk/sciencetech/article-3270060/The-end-heavy-metal-Boeing-shows-material-99-99-Air-lead-new-generation-planes-spaceships.html>

#### Abalone Shell: Sandwiched layers glued to resist cracks



# Wing Types Guide

## Soaring Wings



Description:

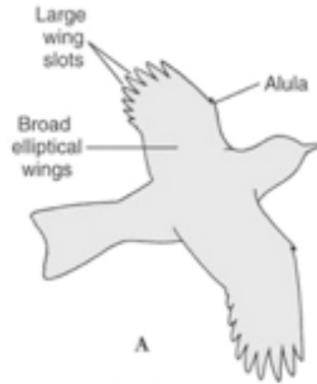
- Long and narrow

Uses:

- Slower flight
- Glide long distances

Common birds:  
Seagulls, albatross, terns

## Elliptical Wings



Description:

- Round, oval
- Wide

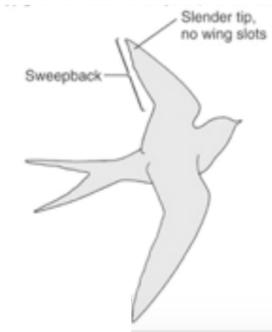
Uses:

- Easily move in small spaces
- Catch bugs in air

Common birds:  
Hummingbird, woodpecker, magpie



## High-Speed Wings



Description:

- Short, wide
- Angle back
- Pointed tips

Uses:

- Migrate long distance
- Fast take-off
- Fast dive

Common Birds:  
peregrine falcon, ducks, avocets, swifts, sandpipers



## Heavy-Lifting Wings



Description:

- long and wide
- Feathers separated at end

Uses:

- Hunt heavy food (fish, rodent)
- Carry food with claws

Common Birds: Herons, vultures, eagles, hawks

# Plane Types Guide

## WWII Fighter Planes



Description:

- WWII airplane
- Good maneuverability

Examples: Spitfire

## Cargo Planes



Description:

- Carry heavy loads (cargo or fuel)

Examples: Spirit of St Louis  
(carried Charles Lindbergh with  
3000 lbs of fuel across ocean)

## Passenger Jets



Description:

- Fast travel

Example:

- Boeing 777

## Gliders



Description:

- long thin wings
- No engine
- Towed by another plane to sky
- Slow flight

Examples: Schweizer Glider

# Pollinator Guide: Strategies for Attracting Pollinators

## What Is Pollination?

Pollination is the movement of pollen (flower sperm) from the male part (anther) of one flower to the female part (pistil) of another flower. Without pollination, most plants can't make seeds and fruits. Many plants rely on animals, primarily insects, to carry pollen from flower to flower.

Ellsworth, Denise. "AGRICULTURE AND NATURAL RESOURCES FACT SHEET ENT-47-14 Attracting Pollinators to the Garden." OHIO STATE UNIVERSITY EXTENSION, 2014.



## Flower Anatomy

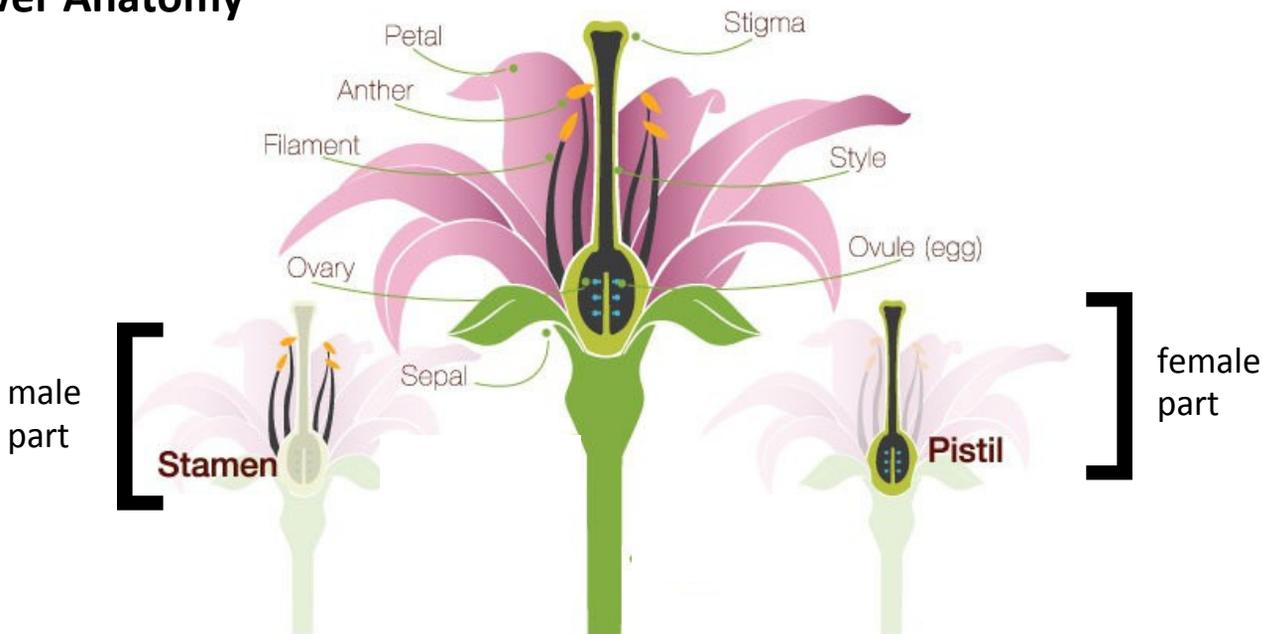
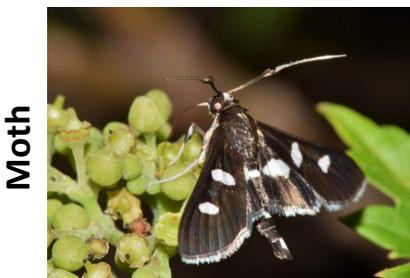


Image by: Pro Flowers (Link: <https://www.flickr.com/photos/proflowers/15099656846>)

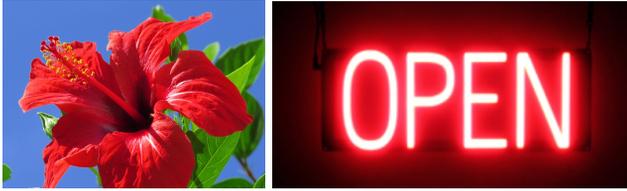
## Common Pollinators



# Strategies for Attracting Pollinators

## Advertising

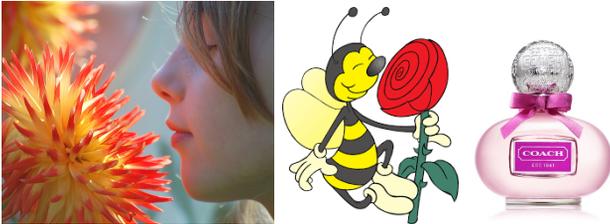
### Petal Color



### Nectar Guides



### Scent



### Petal Texture

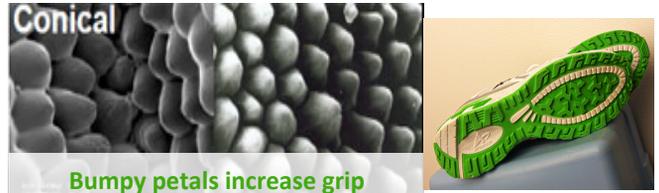
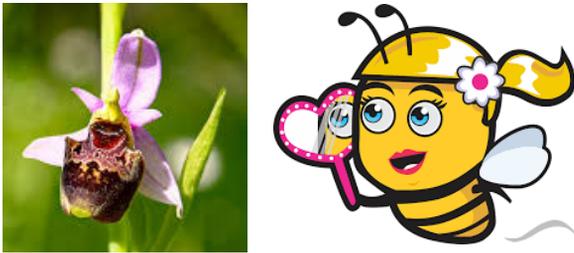
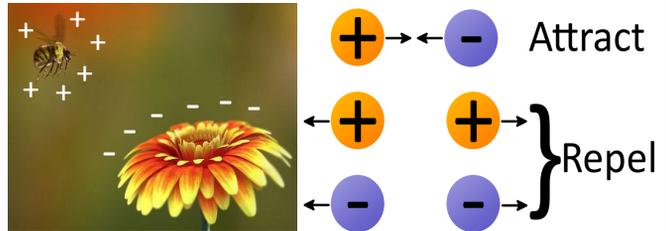


Photo: Whitney, H., Chittka, L., Bruce, T., & Glover, B. (2009). Conical Epidermal Cells Allow Bees to Grip Flowers and Increase Foraging Efficiency Current Biology

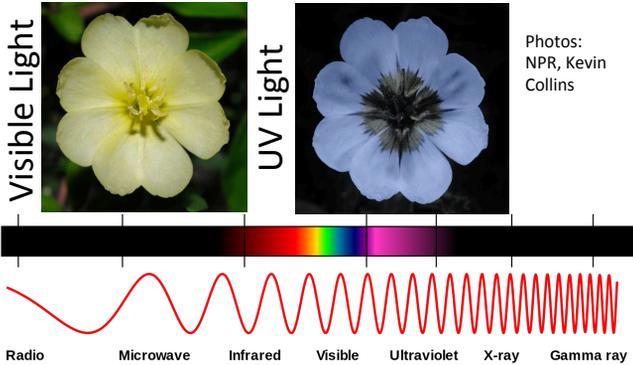
### Patterns



### Electric Charge

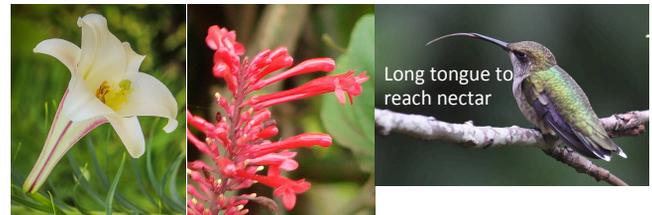


### UV Light Patterns



Photos: NPR, Kevin Collins

### Petal Shape



## Rewards: Food



Collects pollen as food for young / pollen sticks to bee and is delivered to other flowers

