

**Problem  
Card**

**Need to:**

**See**

**Need to:**

**Attach/  
Stick to**

**Need to:**

**Move**

**Need to:**

**Hear**

**Need to:**

**Support/  
Hold**

**Need to:**

**Detect/  
Sense**

**Need to:**

**Protect**

**Need to:**

**Change  
Shape**

**Situation  
Card**

**Where/  
When:**

**Under  
Water**

**Where/  
When:**

**In the  
Dark**

**Where/  
When:**

**On Ice**

**Where/  
When:**

**Without  
Water**

**Where/  
When:**

**In Extreme  
Heat**

**Where/  
When:**

**In a  
Forest**

**Where/  
When:**

**Under  
Ground**

**Where/  
When:**

**Inside a  
volcano**

**Species  
Card**

**Species  
Card**

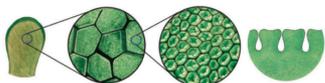
**Species  
Card**

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## TREE FROG



Hierarchical structure increases surface contact

- Tree frogs easily stick to wet surfaces
- Toe pad can increase in surface area to increase attachment strength
- Releases mucus to increase friction on surface

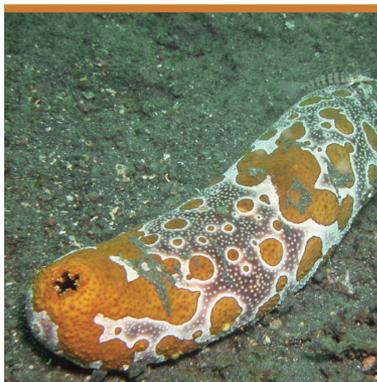


- Stick to slick surfaces • Attach temporarily • Increase surface area •

## SEA CUCUMBER



Fibers interlock to increase stiffness temporarily



- Protect selves from predators by adjusting body pressure to make skin rigid (hard)
- Collagen fiber "arms" (on skin) reversibly connect to make skin rigid

- Create temporary flexibility • Modify stiffness • Manage compression •

## ANTS



Employ simple rules to coordinate complex behaviors



- Release different chemical signals when searching for food, after finding food, and to show that trail was a failure to communicate with others
- Lift 20x times own weight

- Lift large mass • Self-organize work team • Breath through skin • Leave trail signs

## PINE CONE



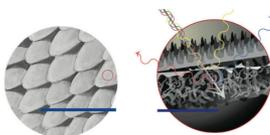
Varying response of layered materials controls shape

- Scales made of 2 layers of same material that is organized in different directions on each layer
- Different layers expand/shrink to bend differently in response to moisture to protect seed



- Change shape • Respond to environment •

## SCARAB BEETLE



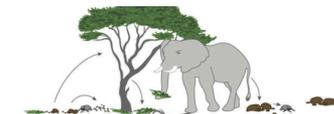
Randomized surface structures scatter all visible light



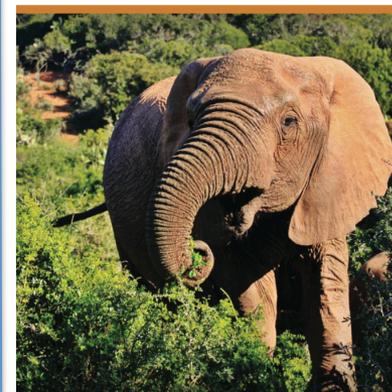
- Camouflage to match fungi near its home
- Thin, loose scales on body causes all wavelengths of visible light to reflect and spread in scale to make beetle appear white

- Create brilliant white • Send visible signals • Scatter light •

## ELEPHANT TRUNK



Redistributing system nutrients enhances food webs



- 100,000 muscles for strength and movability
- Layered structure for stretching
- Can suck up/hold water
- Fingers on tip for fine-motor pinching
- Senses scent and vibrations

- Multifunctional apparatus • Change shape • Breath through skin • Leave trail signs

**Species  
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**Species  
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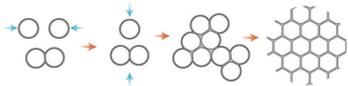
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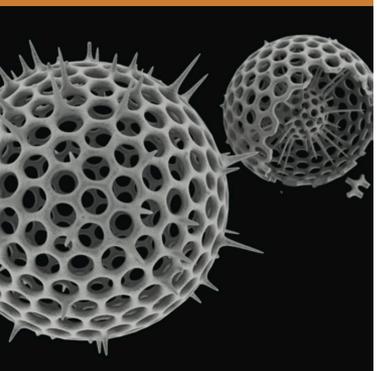
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Card**

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## RADIOLARIAN



Optimize structural design using responsive framework



- Single-celled marine species with glass skeleton
- Measure force of bubbles on surface to auto-release materials to improve/repair shape
- Basic skeleton preserves resources

- Self-assemble • Build to shape • Optimize distribution of forces •

## BARREL CACTUS



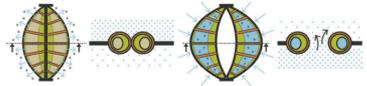
Cell shape allows expansion



- Store lots of water in tissue to survive drought
- Cells in surface have folds to allow for stretching to hold water
- Water storage cells release water only when needed

- Maintain structural integrity • Collapse • Expand • Store water •

## LEAF STOMATA



Valve opens/closes in response to moisture



- Leaf cools by releasing water vapor through stomata
- Cells on surface absorb or lose water to adjust size of hole to control amount of water released

- Respond to cues • Change shape • Regulate flow •

## BURROWING OWL



Concentrate desirable resources to lure higher value resources



- Lure prey for easy meal
- Produces sounds similar to rattle snakes to scare predators
- Eyes have more light-sensitive rods for seeing in the dark and a mirror at back of eye for concentrating light
- Skeletal structure allows neck to turn 270 degrees

- Attracts resources • Flexible shape • Optimize eye structure

## DOCK BUG WINGS



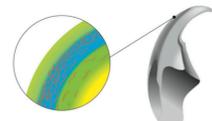
Microstructure creates flexible, yet strong attachment



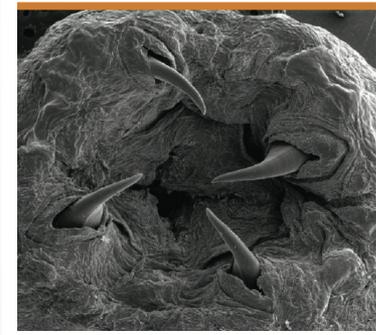
- Two sets of wings that reversibly lock together during flight
- Multiple wing pieces allows for flexibility to aid flight and for storage of wings in smaller spaces

- Maintain structural integrity • Temporarily attach • Provide flexibility •

## BLOODWORM



Material gradation changes physical properties



- Flexible jaw with hard tips for piercing prey and resisting abrasion from environment
- Uses differences in copper concentration in body to adjust stiffness

- Manage mechanical wear • Maintain integrity • Be hard yet flexible •