Life Cycle Approach to Dealing with Difficult to Recycle Materials

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Difficult to Recycle Materials

Single material

Multi-material
End-of-Life Strategies

Throw Away

Reuse

Recover
Product Life Cycle

EXTRACTION OF RAW MATERIALS → MANUFACTURING → PACKAGING AND DISTRIBUTION → PRODUCT USE → DISPOSAL
Product Life Cycle

EXTRACTION OF RAW MATERIALS ➔ MANUFACTURING ➔ PACKAGING AND DISTRIBUTION ➔ PRODUCT USE ➔ DISPOSAL

DESIGN FOR RECYCLING

- Minimize variety of materials
- Avoid hazardous/toxic materials
- Avoid materials incompatible with recovery processes
- Cluster similar materials
- Use joining elements that are easy to disassemble
- Make joining elements easy to access
- Minimize number and variety of joining elements

Bio-inspired Design Approach focused on Minimization of Material Diversity

- Different materials are often added to a product to add additional functionality. The trade-off is the product is not/less recyclable.

- Natural systems have adapted to changing conditions not by adding new materials but by using the building blocks of life (e.g., carbon, hydrogen, oxygen, nitrogen) in strategic ways - achieving function through shape, geometry, and structure.
Bicycle Helmet Redesign

- Made of at least 3 materials (more if you consider the strap/buckle)

- Foam liner, expanded polystyrene (EPS) - used for absorbing impact

- Plastic shell, molded polyethylene terephthalate (PET) - used as a substrate for the foam and reduces friction in a collision

- Adhesive, Polybutylene (PB) - used to adhere foam to substrate
Bicycle Helmet Redesign

- Inspiring morphology 1: vertebrae of water-diving birds. The holes form a truss-like shape that dampen the magnitude of compressive forces.

- Inspiring morphology 2: layers within the skull. The dura mater (hard) and arachnoid mater (flexible) provide protective layers that are durable while also providing elastic support.
Bicycle Helmet Redesign

Life Cycle Analysis
Traditional bike helmet:
- Uses $6.05 \times 10^9$ kcals of energy
- Emits $2.91 \times 10^6$ lbs of CO$_2$

Bio-inspired helmet:
- Uses $4.23 \times 10^9$ kcal of energy (35% less)
- Emits $1.74 \times 10^6$ lbs of CO$_2$ (40% less)
Floss Container Redesign

2 Materials: Plastic, Metal

Reduced to all plastic

Lamprey
Velvet mite, Sharks
Thank you for your time and attention!

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## LCA for Bike Helmet

<table>
<thead>
<tr>
<th>Material</th>
<th>Bio-Inspired</th>
<th>Traditional</th>
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<tr>
<td><strong>CO2</strong></td>
<td>1.74E+06</td>
<td>2.91E+06</td>
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</tbody>
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Alternative Bike Helmets

Wood Bike Helmet

Cardboard and Plastic Bike Helmet
Alternative Floss Container

- Paper box, but still has a metal tab for cutting floss