Introducing Biomimicry

We believe that biomimicry-based education is not only a great way to engage students with real world lessons in STEM and environmental literacy, but perhaps most importantly, it offers young people tangible solutions and a hopeful vision for the future of the planet. In this Introduction we provide a definition of biomimicry, along with ideas about why and how to fit biomimicry into your education programme.

Biomimicry practitioners (or “biomimics”) study the strategies used by living things to perform specific functions and apply what they learn to improve the design of products, processes, and systems. For example, looking to a leaf for ideas about how to make a better solar cell, or mimicking how a peacock feather selectively reflects light to produce beautiful colors without pigment. The core idea is that the rest of nature has had a 3.8 billion year head start on humans so, we would be wise to tap into that vast trove of “research and development” when looking for the ideas we need to solve our design problems.

Principles:

We are interested in more than simply making faster, stronger, or “better” things. Rather, through biomimicry, we see an important opportunity to apply lessons from nature to begin creating human technologies that are as sustainable (well adapted to Earth) as the living systems that surround us. Although it may be some time before we humans can power our cities entirely on sunlight or recycle all of our wastes as nature does, we can still use biomimicry as a pathway for improvement by asking, “How has nature solved this problem before?”

1. We are part of nature

A simple concept that underlies biomimicry is the understanding that humans are part of nature, and that we are dependent on and interconnected with natural systems just like all other living things. Although humans have developed a variety of cultural adaptations that camouflage our kinship with the rest of life, the truth is our similarities far outweigh our differences.

This is the basis for why biomimicry makes sense: humans need to do many of the same things that other organisms do. For example, acquiring resources, making and breaking down materials, processing information, and reproducing. We are also subject to the same resource limitations and habitat condition as the other 8.7 million species on Earth. The more we understand about how our planet-mates have leveraged the resources and constraints of this place, over billions of years, the better equipped we are to create technologies and systems that will enable all life to flourish long into the future.

2. Function and Strategy

In order for students to grasp and use biomimicry, they need to understand the concept of function as it relates to both biological strategies and design solutions. In biomimicry a function refers to an organism's adaptations which help it survive. For example, the purpose of bear fur is to keep warm, in technical terms its function is to conserve heat (insulation). A leaf is made to biodegrade, so one function of a leaf is to 'break down' after use. Human products also have functions; a kettle has the functions to both contain water and heat water (modify its physical state). In brief, a function is 'what it does.'

Organisms meet functional needs through biological strategies. This is a characteristic, mechanism or process which performs the function for them. In the bear example, fur is the strategy for delivering insulation. In a kettle, electrical energy is transferred into physical heat which modifies the temperature of water. In brief, a strategy is 'how it does it.'

We have included an activity called "Function Junction" to help students get to grips with these in nature.

3. Biomimicry and nature inspired design

By way of clarification, "bioinspired design" is a term that is generally accepted as an umbrella category for design and engineering approaches, including biomimicry, that use biology as a resource for solutions. However, while biomimicry is a type of bioinspired design, not all bioinspired design is biomimicry. An important factor that differentiates biomimicry from other bio-inspired design approaches is the emphasis on learning from and emulating the sustainable solutions living systems have for specific functional challenges.

Within the family of bioinspired design, a common misunderstanding that we encounter is mistaking biomorphism for biomimicry. Biomorphism refers to designs that visually resemble elements from life (they "look like" nature), whereas biomimetic designs focus on function (they "work like" nature). But it is important to realize that "looking like" nature is not a reliable indicator of biomimetic design because a biomimetic design might or might not look anything like the organisms that inspired it. Rather, the important indicator is *function*.

The distinctive feature of biomimicry is the study and emulation of functional strategies to create sustainable solutions.

In the introduction PowerPoint presentation, we have included lots of examples to make this clear.

4. Matters of scale

Matters of scale and systems thinking (below) delve deeper into biomimicry principles. Before discussing with your students, they should be familiar with biomimicry and already attempted to apply it.

There are two ways we can talk about scale in biomimicry: (1) we can use scale in a literal sense to describe the relative size of organisms, physical parts, or other components of a biological strategy or technological design, and (2) we can use scale to describe increasing levels of complexity in the application of biomimicry.

The first sense of scale is important to discuss because some strategies only work at one scale and cannot be “scaled up.” During a design project it can be very tempting for students to make assumptions that strategies that work at one scale or in one context in nature will work in another. Translating strategies between scales should be done only with a good understanding of the science behind the phenomenon at play. For example, the gecko has millions of microscopic hairs on its toe pads, which enable it to “stick” to and climb up vertical surfaces using attractive forces between molecules. Because these forces only work at the molecular scale, simply enlarging the hairs will not produce the same adhesive effect. Designs for synthetic adhesives based on the gecko’s hairy toe pad strategy apply the main mechanism for adhesion at the same scale as the gecko. To apply gecko inspired adhesion to larger and heavier objects, additional design features must be used to scale up the technology.

The second sense of scale is useful when it comes to categorizing our thinking about how biomimicry can be applied. When we look broadly at biological strategies, or at the various examples of biomimicry, they tend to fall into one or more of three scales of application: forms, processes, and systems.

BIOMIMICRY OF FORM is emulation of shape or structure.

BIOMIMICRY OF PROCESS is the emulation of a series of operations or behaviors that create a material or produce an effect.

SYSTEM-LEVEL BIOMIMICRY involves creating an integrated system that efficiently manages material and/or energy in an ongoing cycle the way natural systems do.

Many of biomimicry’s most well-known case studies describe biomimicry of **form**. It could be emulating the microstructure of a surface, such as a lotus leaf, or a larger physical trait that can be observed with the naked eye, such as the kingfisher’s beak. These examples are some of the easiest to understand and are therefore appropriate for younger students.

Process biomimicry is somewhat more complex.

Abalone create its durable nacre lining through a self-assembly process using water-soluble molecules that stimulate growth; scientists are exploring if molecules can mimic this to stimulate bone cell growth in humans. Computer scientists are creating algorithms (step-by-step procedures for calculations) based on lessons gleaned from the way foraging ants or swarming bees coordinate their movements as a group. Process examples can help older students understand the potential depth of biomimicry by underscoring how biomimicry is a practice of emulation, not simply physical copying.

Systems are about relationships and are usually made up of many forms and processes working together. System-level biomimicry is the most complex and, consequently, these examples are fewer in number. Eco-Machines that treat wastewater by mimicking how wetland ecosystems strip nutrients from water are an example of system-level biomimicry. The “circular economy” concept is another example. This alternative economic and industrial model is inspired by how matter and energy flow in living systems. Ultimately, in order for human societies to be truly sustainable, we will need to learn how to mimic nature at this systems level.

Biomimicry Example	Form / Process / System
Kingfisher and Shinkasen bullet train	Form
Humpback whale tubercles and wind turbine blades	Form
Plant burrs and velcro	Form
Mosquito and syringe	Form
Insect cuticle and biodegradable wrapping	Process
Ants and delivery routes	Process
Natural prairies and agriculture food growing	System
Nutrient recycling in nature and circular economy	System

5. Systems thinking

Systems are made up of interacting parts and the relationships between those parts. Our own bodies are systems of cells, tissues, and organs. We, in turn, interact with other systems every day, whether we are aware of it or not.

Learning to see, understand, and think in systems is essential to biomimicry. In order to appreciate the intricacies of living systems and become good problem solvers, students should be encouraged to look at the “big picture” and understand how the parts and pieces that constitute a whole interact and impact each other. This is especially important because some of the biggest challenges facing our world today are the product of systems failures, and require a systems view to solve. One of those challenges is our dependence on nonrenewable resources that are obtained at great expense. We can learn important lessons about how to solve these problems and redesign our world by looking at how systems work in nature. For example, in a healthy ecosystem, materials are acquired locally and constantly reused and recirculated among different organisms in the system, leaving no waste. The relationships within that ecosystem may provide clues for how to sustainably source and manage resources in our own designed systems.

Two excellent videos demonstrating the power of systems thinking are:

- How Whales Change Climate (video).
- How Wolves Change Rivers (video).