Introduction to Sustainable Development for Engineering and Built Environment Professionals

Unit 2 - Learning the Language

Lecture 7: The Concept of Biomimicry – An Historical Context

Quite simply, Biomimicry is the art of asking Nature for advice.
Janine Benyus, Author of Biomimicry: Innovation Inspired by Nature, 2004[1]

Educational Aim

To introduce the emerging field of Biomimicry and explain why it is such a powerful tool for innovation. Building on from knowledge gathered over centuries of *harvesting* and *harnessing* nature, engineers and designers are now exploring the exciting field of emulating nature's successes to assist sustainable development. Biomimicry is a tool for innovation to assist engineers and designers to move past efficiency and design sustainable systems learning from nature.

Textbook Readings

Benyus, J. (1997) *Biomimicry: Innovation Inspired by Nature*, HarperCollins, New York, Chapter 1. Available athttp://www.biomimicryguild.com/janinefirstchap.html. (10 pages), pp 1-10.

Hargroves, K. and Smith, M.H. (2005) *The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century*, Earthscan, London:

1. Chapter 1: Natural Advantage of Nations, 'A Critical Mass of Enabling Technologies' (2 pages), pp 19-20.

Hargroves, K. and Smith, M.H. (2006) 'Innovation inspired by nature – Biomimicry', *ECOS Magazine*, 129. Available athttp://www.naturaledgeproject.net/Documents/Biomimicry_000.pdf. (3 pages), pp 27-99.

Learning Points

1. Long ago, as hunters and gatherers, humans relied on their knowledge of natural systems to *harvest* food and materials for hunting, cooking, shelter and clothing. This knowledge accumulated and was passed on from generation to generation as we learnt more about natural systems, and how to make optimal use of their patterns and seasons.

2. As our knowledge of natural systems increased, we began to domesticate, or harness, those organisms that we needed, through farming and domestication of plants and livestock.

3. With this security in meeting basic human needs, societies began to consider higher applications to process nature's raw materials. Building materials, weapons and cooking equipment were the early applications of harnessing nature. This eventually led to applications where natural resources were harnessed through more advanced processing technologies, such as the Industrial Revolution's practices of metallurgy, petrochemicals, internal combustion and manufacturing.

4. Once we realised that we could make value-added products from nature's raw resources, we began paying less attention to natural systems, seeing them more as a source of inputs for our products and services. However, by paying little attention to the impact of our new solutions on natural systems, combined with the rapid increase in the scale of 'human systems' on the planet, we have now actually exceeded the planet's carrying capacity - in effect we are *destroying the world that we have been creating*.

5. Most of the solutions from the last 300 years have been poorly adapted (or mal-adapted) to natural ecosystems. In fact, many of these 'solutions' have lead to significant global challenges such as those caused by the creation and dispersion of pollution.

6. Faced with the need to address these challenges, engineers and designers will be tempted to emulate the way humans have problem-solved, rather than asking Nature's advice. A Patent Database developed by Russian researchers working on the Teoriya Resheniya Izobretatelskikh Zadatch (TRIZ)[2] method for inventive problem solving uncovered an overlap of a mere 10 -12 percent between man-made and natural systems. As Janine Benyus puts it, '*when we look to Nature, 90 percent of the time we will be surprised!'*[3]

7. If we are to achieve harmony between development and nature on a global scale, we need to combine our engineering knowledge with the knowledge contained in natural systems, rather than resources extracted from it; to deliver solutions that are *well-adapted* to our global environment ... in other words, *innovation inspired by nature*.

8. Innovation from nature can be drawn from a number of areas. We could pay attention to:

1. The structure, or *form*, of nature - aerodynamic shapes, non-chemical adhesive methods and structural finishes and colour.

2. The *process* of nature - cooling systems, nutrient cycling, filtration, desalination and energy supply and storage.

3. Nature's *ecosystem* - feedback loops, diversity, organism niches and interactions, symbiotic relationships, food webs, energy and material flows, resilience, and the role of redundancy.

9. Examples of innovations inspired by nature's *form* include:

- **Velcro®**: Studying cockleburs under a microscope led to the observation that their natural hook-like shape could be emulated to design the popular adhesive material, Velcro.

- **Gecko Tape®**: Studying the way that gecko lizards walk on surfaces led to the observation that the soles of their feet could be emulated to produce a new type of adhesive ('gecko tape').

- **Vortex Generator**: Studying the structure of wing plumage in owls led to the discovery that the design of the feathers could be emulated to design a surface that minimises turbulence in air, significantly reducing noise from Japanese high speed train (shinkansen) operations.

- **Stomatex**: Studying the function of stomata in leaves led to the discovery of a fabric that can provide passive humidity control. It was originally developed for bandage and apparel fabrics, but also has applications in building envelope and horticulture. Stomatex® has applications in building components such as soft walls, roof linings or curtains to facilitate humidity control.[4]

10. '*Biomimicry (from bios, meaning life, and mimesis, meaning to imitate) is a science that studies nature's ideas and then imitates these designs and processes to solve human problems.*'[5] As Benyus explains, '*This includes studying nature's best ideas, designs and strategies that have evolved over 3.8 billion years and then emulating them so that we might live more gracefully on the planet*'.[6]

11. In engineering terms, Biomimicry describes the enquiry-based process of studying and mimicking the design and behaviour of nature, to inform the development of solutions that meet the needs of society while being in harmony with the planet's natural systems.

12. Biomimicry involves asking ourselves a series of questions to help focus on which part of nature we want to emulate. These include for example:

- How do we evolve more sophisticated approaches than 'heat, beat and treat' in manufacturing?

- How do we design more sophisticated energy production such as solar cells? (i.e. by mimicking the way that plants harness solar energy so efficiently for their energy needs)

- How do we create renewable fuels such as turning cellulose into ethanol in a climate neutral manner? (i.e. by mimicking the way termites process cellulose)

Brief Background Information

Understanding Natural Systems

Human ingenuity may make various inventions, but it will never devise any inventions more beautiful, nor more simple, nor more to the purpose than Nature does; because in her inventions nothing is wanting and nothing is superfluous.

Leonardo Da Vinci

If one way be better than another, that you may be sure it is Nature's way.

Aristotle

Sustainable business strategies have previously focused on making industries more efficient such as using less waste, less energy, less material. This is an important first step, but without system change, it can still lead to deteriorating natural systems. Old-economy 'treatment' industries (e.g. waste management, potable water supply, etc.) have attempted to mitigate and manage the pollution and waste as an 'end of pipe' approach to system deterioration, but engineers and designers are now realising that this is not a sustainable approach.

So how do we innovate to truly achieve sustainability?

Consider that for the majority of our time on the planet as a species, we have been hunters and gatherers. As hunters and gatherers (*harvesting nature*) and then as agrarians through pre-industrial times (*harnessing nature*), we paid a great deal of attention to natural systems as a source of knowledge, as Janine Benyus puts it, '*we naturally mimicked the organisms that we admired*'.

As our knowledge of natural systems increased, we began to harness those organisms that we needed, then to process nature's raw materials to produce products and services (for example through agricultural practices, and steel and plastics manufacturing). Once we realised that we could make value-added products from nature's raw resources, we began paying less attention to natural systems, seeing them more as a source of inputs for our products and services. As we transitioned from organism domestication to mass production and industrialisation we adopted the mindset of 'animal as factory'.

Today, when we try to address problems arising from old-economy technologies (such as filtration, adhesion, desalination, energy harvesting), we tend to study the way human's have problem-solved, rather than looking to nature for advice. However, combining our knowledge of processes with our knowledge of natural systems, we now have the opportunity to build products and services that are in harmony with natural systems, we can create 'Biomimetic' solutions.

When we view nature as a source of advice rather than goods, the rationale for protecting wild species and their habitats also becomes self-evident. To have more people realise this is Janine's hope. In the end, she is confident that Biomimicry's greatest legacy will be more than a stronger fibre or a new drug. It will be gratitude, and from this, an ardent desire to protect the genius that surrounds us. Janine and her team are working to seed an 'Innovation for Conservation' program in which companies donate a percentage of the sales of bio-inspired products to restore the habitat of the organism that inspired the breakthrough.

Figure 7.1 summarises these transitions in human knowledge and the potential for Biomimicry to assist us in designing in harmony with natural systems.

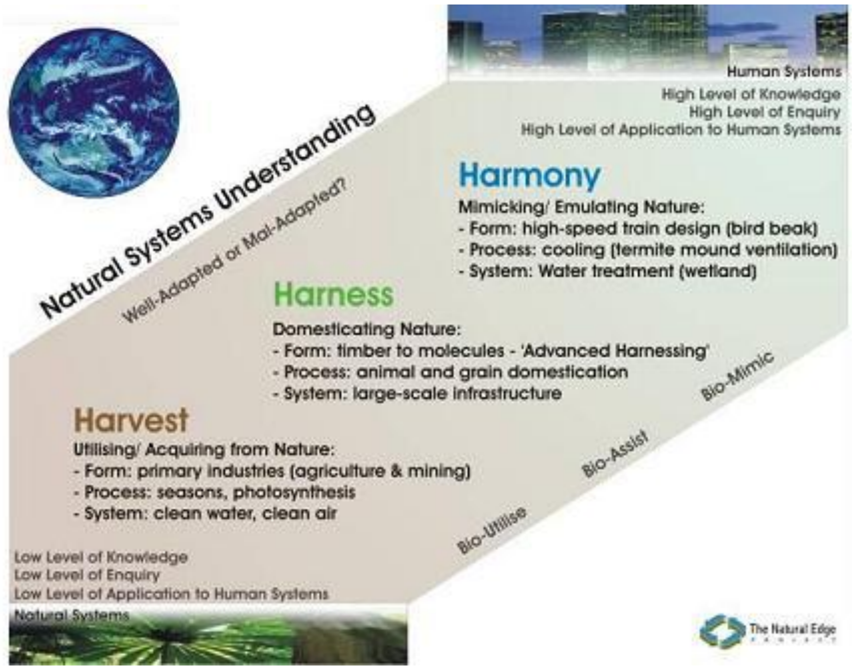

Figure 7.1. Natural Systems Understanding Map, showing the relationship between systems knowledge, enquiry, and the application of Biomimicry to human systems.
Source: The Natural Edge Project, Biomimicry Guild (2006)

Biomimicry - Case Study Examples

Velcro®: Getting home from a walk in the 1940s, Swiss inventor George de Mestral noticed both his clothes and dog were covered with cocklebur seeds. De Mestral studied the cockeburs and discovered they used hook-like spines to grip onto a softer surface, like the fabric of his pants. Inspired, de Mestral recreated this natural hook design and opposed it with the soft loop design that made up the fabric of his pants. The result was Velcro®, and its arrival heralded a new era of easy access clothing. It's nothing new for designers and inventors to look to nature for creative solutions and ideas, but now this science and design practice is being recognised as a field in its own right – biomimicry – and is quickly gaining momentum.

Gecko Tape®: University of Manchester Scientists developed a new type of adhesive which mimics the mechanism employed by the gecko lizard to walk on surfaces – even glass ceilings. The new adhesive ('gecko tape') contains numerous tiny plastic fibres, less than a micrometer in diameter, which are similar to natural hairs covering the soles of gecko's feet. These generate elecro-dynamic adhesion at a microscopic level. One square centimetre of the gecko tape can support a weight of one kilogram. In addition to a general adhesive, it can be used to move computer chips in a vacuum and pick up small fibres. The tape can be used several times over and does not use toxic chemicals found in common adhesives.

Vortex Generator: The 500-Series Shinkansen Japanese bullet train running between Tokyo and Hakata is one of the fastest trains in the world. The challenge for the design of the Shinkansen design team was to make it run quietly at high speed. Learning that the owl family is the most silent and stealthy fliers of all birds, the Shinkansen team discovered the bird's secret is in its wing plumage design – many small saw-toothed feathers protrude from the outer rim of their primary feathers. Other birds do not have these feathers. These saw-toothed wave feathers are called 'serration feathers' and they generate small vortexes in the airflow that then break up the larger vortexes that produce noise. 'Serrations' were inscribed on the main part of the pantograph (the collectors that receive electricity from the overhead wires), and this succeeded in reducing noise, enough to meet world standards for noise. This technology is now called a 'vortex generator' and has been applied to aircraft, as well as now being applied to the caps and boots of professional skaters.

Stomatex: Nigel Middleton, a dentist, was looking for a way to improve bandages. The issue with bandages is that they offer virtually no ventilation and thus promote sweating, which can irritate the skin and create a poor healing environment.[7] Middleton looked to nature for a solution and asked, *how does nature remove moisture?* A leaf's surface is covered in tens of thousands of stomata, small 'mouths' that regulate the exchange of water vapour, other gases and heat between the leaf and the immediate environment.[8] Middleton and his colleague Tome Armstrong[9] mimicked the function of stomata in a smart material called Stomatex®, a honeycombed foam that removes sweat from skin. When moisture begins to accumulate, the vapour is collected in the air space provided by dome-shaped chambers in the material. A tiny pore at the centre of each chamber then opens and releases the vapour before it condenses into a liquid. This mechanism maximises vapour diffusion and, since there aren't any large holes, minimises heat loss. Stomatex® has also been applied to clothing fabrics and building components such as soft walls, roof linings or curtains to facilitate humidity control.

Key References

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Key Words for Searching Online

Bio-Utilised, Bio-Assisted, Bio-Mimicked, Biomimicry, Adaptation, Ecosystem, Design inspired by Nature

[1] Boston Research Centre (BRC) (2004) *Video Interview with Janine Benyus - Author, Biomimicry: Innovation Inspired by Nature*. Available at http://www.brc21.org/carson/benyus_clips.html. Accessed 26 November 2006).(Back)

[2] For a background on TRIZ see *What is TRIZ?* at www.triz-journal.com/whatistriz.html. Accessed 3 January 2007. (Back)

[3] Benyus, J. (1997) *Biomimicry: Innovation Inspired by Nature*, HarperCollins, New York. (Back)

[4] Lloyd, C. (1995) 'Taking a leaf from Nature's book', *Sunday Times*, May 1995. Available athttp://www.stomatex.com/news.htm. Accessed 26November 2006. (Back)

[5] See The Biomimicry Guild at http://www.biomimicryguild.com/indexguild.html. Accessed 3 January 2007. (Back)

[6] Benyus, J. (1997) *Biomimicry: Innovation Inspired by Nature*, HarperCollins, New York. (Back)

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[9] Lloyd, C. (1995) 'Taking a leaf from Nature's book', *Sunday Times*, May 1995. Available athttp://www.stomatex.com/news.htm. Accessed 26November 2006. (Back)