HOT TOPICS

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Biomimicry: Biology inspires innovation

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Nature as a mentor

Jay Harman spent 20 years figuring out how to freeze a whirlpool in his bath. Most of us might have downed tools after arriving at this eureka moment, but for Jay it was just the start of a radical redesign of some widely used technologies. Moving air and water around is big business. It is estimated that pumps, fans and propellers are involved in 40 per cent of the world's energy use, meaning that just a 1 per cent increase in efficiency represents huge savings at a time when resources such as energy are under increasing pressure.

Freezing the whirlpool allowed Jay and his team at **PAX Scientific** (a Bay–area company Jay founded in 1997), to not only figure out the algorithm that describes it, but as it turns out, some general principles that dictate the shape of flow and movement in Nature – from the pores in our skin to seashells. Cracking this code was a significant step – it meant they could start to redesign a range of technologies to move substances like air and water in the same way that Nature does.

One such innovation – the **Lily Impeller** – is a mighty propeller in everything but size and in energy use. Measuring just six inches high, the **Lily Impeller** can move one million gallons of water in just 24 hours using the same energy as a single light bulb. Its predecessor stands at a good 20 feet tall with half the efficiency, and a much greater energy cost. For water treatment plants, it not only means less energy is used, but that water can be kept fresh without the addition of chlorine.

It makes sense to emulate Nature; it's had 3.8 billion years of experimentation and adaption and is continually evolving the fittest design for cooperating with the environment, while being 'clean, green and sustainable.' Biomimicry – mimicking Nature's designs to solve our own design challenges – can be applied to a whole range of problems from products to services, systems and the built environment, and even to organisational behaviour.

Biomimicry is certainly not a new concept. Some say it's modern incarnation began in 1941 with Swiss engineer Georges de Mestral, who after observing seeds of the plant cocklebur stuck to his clothes and dog, was inspired to invent a new type of fastener. In 2008, celebrating its 50th year, his company **Velcro Industries** achieved global sales of $298 million. What is new is that science and technology are rapidly changing the scale at which we can understand the world, and the types materials that we can create to live more smartly upon it.

Form: designed for function

It is clear that biomimicry is gaining momentum, and today's examples are numerous. One such innovation is the development of self–cleaning paints.

This event briefing was prepared by Carla Ross.

Find out more at: www.nesta.org.uk/biomimicry

#nestahottopics

Primula veris, stained section of primrose stem. Image: Rob Kesseler.

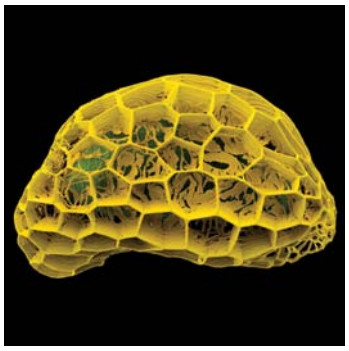
Hot Topics is a series of Nesta events driven by ideas and technologies. They aim to introduce the technological tools that will change how we do things in the coming years, and are designed to bring together the best of business, academia, start–ups and investors.

Find out more at: http://www.nesta.org.uk/events/hot_topics

Commercially developed recently by **Sto Corp.**, a company based in Atlanta Georgia, such paints were inspired by how lotus leaves remain spotless without a bar of soap. The secret lies in the fine microstructure of the leaf, which induces water to form tiny beads that roll off the surface taking dirt along with it. Given that we spend a large amount of money keeping things clean, often with the use of harsh detergents and chemicals, the development of such materials has a wide range of benefits – time, money and the environment.

Another recent example is **BAE Systems**' 'Bug Eye' technology. When out in the field at night, soldiers need the ability to see and have a wide field of vision. Night vision cameras typically don't have a wide field of vision, and current fish eye lenses often used to solve this problem also distort images and are problematic for monitoring and tracking. Alex Parfitt's team at **BAE Systems** took inspiration from a 4mm bug – the Xenos peckii – which have 50 separate lenses each creating a separate image that are stitched together to give a single, large panoramic view.

The team adapted this biology–inspired strategy, using nine lenses – each no bigger than a smart phone camera – and developing software to process these images in real time. The result is a vision system small and light enough to fit inside a soldier's helmet whilst doubling the field of vision. Miniaturising the system further could mean that the technology has wider applications – such as in medicine where a wide field of vision could enhance keyhole surgery.



Castilleja flava – seed, from *Seeds, time capsules of life*, Rob Kesseler and Wolfgang Stuppy.

The case for biomimicry

An ever growing awareness of biomimicry marks the start of a shift, some say, from an industrial model to an ecological one. Advocates suggest that the industrial age may have brought us many vital innovations, but it was also based on methods and systems of production that we can no longer sustain.

Take material production for example. Our current models of production are energy, resource, and often chemically intensive. Janine Benyus, who coined the term biomimicry in the book ***Biomimicry: Innovation Inspired by Nature***, calls such methods of production 'heat, beat and treat'. This process results in huge amounts of waste, during extraction, production and disposal. There is an estimate that 30 tonnes of waste are produced per tonne of goods that reach consumers, with 98 per cent of goods end up being thrown away within six months.

Architect, contributor to the Eden project, and author of *Biomimicry in Architecture*, Michael Pawlyn, cites a compelling example. **Kevlar**, the strongest synthetic material that we've manufactured so far, is made by boiling petroleum in sulphuric acid at 750°C before undergoing high–pressure treatment to rearrange the molecules, leaving behind toxic waste. By contrast, spider silk is stronger than **Kevlar**, made at ambient temperatures, with common, non–polluting elements and no waste.

Developments in nanotechnology and manufacturing are enabling us to build more like Nature does – from the bottom up, but there is still much to learn in developing materials that can be produced at ambient temperatures and still have desired properties, such as strength and with very little waste.

Indeed, there is very little waste in Nature – everything is part of a closed loop system, and advocates claim that this element in Nature is probably the most critical to learn if we are to move to creating zero waste systems. Part of the challenge is seeing waste as a resource and creating beneficial waste that has resource potential.

When civil engineer George Chan was tasked with developing a brewery in Namibia, he saw an opportunity to develop a system with as little waste as possible. The result was not unlike the old woman who swallowed a fly. By the time beer is brewed and has matured and is ready for bottling, several tons of waste grain and gallons of alkaline water need dealing with, at a high cost to the manufacturer.

In George's system, firstly the alkaline water is used to grow Spirulina – microalgae that thrive in such conditions and are used as nutritional supplements. The now naturally–treated water is then channelled to a lake to farm fish, with the lake giving a means for filtering and recycling ground

water. The leftover grains are used for growing mushrooms, as animal feed or for earthworm composting. The earthworms are fed to the chickens, and the chicken manure went to a digester to make gas to power the brewery – in turn using less wood. The resulting system produces 12 products instead of just one and seven times more food, fuel and fertilizer with just a smidgen of waste.

Spreading the message

Although there are a plethora of examples of biomimicry today, there is a broad sense that the adoption has been slow. One of the most commonly cited barriers to adoption of biomimicry is its interdisciplinary nature, particularly at the professional level. So how can biomimicry reach critical levels of adoption that it almost becomes the default solution in design?

Art and design can play a crucial role in bridging the disciplines, notes visual artist Rob Kesseler, a former NESTA–Fellow, and Professor of Ceramic Art & Design at **Central Saint Martins College of Art & Design**. *"There's an awareness that common ground is an increasingly important place to be."* Perhaps more so now than ever, design inspiration lies beyond the naked eye. Rob collaborates with scientists to visualize some of the hidden structures in Nature such as pollen grains. Often asked how this might benefit science, Rob replies that it's about exposing the territory in an engaging way: *"Scientists desperately need to get their images out there for communication – communication follows through to promotion, which follows through to funding."*

Rob Kesseler, Central Saint Martins College of Art & Design

Rob also works in design education, to help open biomimetic approaches to wider audiences, such as in the field of textiles – as big consumers of natural resources and one which *"seeps through into the high-street very quickly and directly."* Rob notes that in many ways, technology is helping to facilitate the shift towards a more multidisciplinary approach at the professional level as designers, artists, and scientists are increasingly sharing the same technological platforms – such as in graphic design platforms.

Exposure to ideas through routes such as the popular press and the arts, play key roles if biomimicry is to become widespread and inspire a relatively broad audience. One good example of this is the recently launched online magazine ***Zygote***, which attempts to bridge the worlds of science, technology and design and bring bio–inspired thinking to a wider audience.

Crossing disciplines

Biology hasn't traditionally been considered to be an important source of knowledge for designers. When a designer in any profession receives a prompt to design something new – be it components, products, buildings, or systems – the first challenge for biomimicry is then for Nature to be considered as a design sourcebook.

Unless a design function is already organised around looking to Nature for ideas, biomimetic design prompts can often be a process of serendipity. For example, a chance attendance at a lecture given by an aircraft engineer who described how his work was heavily influenced by birds, inspired Japanese engineer Eijii Nakatsu to do the same for trains. Eijii and his team redesigned the **Shinkansen** 500–series bullet train, drawing on design principles learned from kingfishers and owls. After a four–year effort, the new **Shinkansen** train not only travels faster, but more quietly whilst using 15 per cent less electricity.

Biomimicry 3.8 has been on a mission over the last 15 years. The US–based non–profit organisation is helping biomimicry make the leap from a chance encounter to a purposeful part of the design process. Biomimicry heavily relies on the dots being joined between the disciplines. The organisation's mission has been to introduce biomimicry into education at all levels, as well as bring together biologists and engineers at the design table. Other organisational and academic networks such as **BIONIS** in the UK and **BIOKON** in Germany have sought to increase the application of biomimicry too and equip designers with tools to do so.

The interdisciplinary approach works well when placed at the heart of the innovation process.

As Alex Parfitt notes – a biologist turned engineer and Head of Materials Research at **BAE Systems** Advanced Technology Centre – there are some 360 interdisciplinary scientists with bio-inspiration being very much part of the Centre's innovation process. Alex explains *"the pressures we're under on the battlefield are very similar to predatory pressures faced in Nature ... now it's always there as part of the thought process of what we're developing."*

Here too, some architectural firms are also leading the way. Michael Pawlyn's firm **Exploration Architecture** has also developed a cross-disciplinary team to work on architecture projects in new ways. **Arup's** UK Director, Peter Head is developing global practices to integrate biomimicry into new development models.

Alex Parfitt, BAE Systems

Translating research

Bringing professionals across the disciplines together is just one part of the nut to crack. There also has to be the ability to speak a common language, so that biology can be translated into engineering equivalents and vice versa. Several academics and organisations have grasped the nettle and are developing different responses to this problem. For example, Biomimicry 3.8, in partnership with **Autodesk**, has developed an open source searchable database called 'Ask Nature' which aims to connect biologists and designers and link problems with potential biological solutions.

Julian Vincent, recently retired Professor of Biomimetics at the **University of Bath**, observes – *"we don't always have to know anything new, we just have access what we already know in a different way"* and is developing a pattern-based tool to do just that, enabling challenges to be framed in the right language and connect people to biomimetic research. Work by others, such as Jacquelyn Nagel's **E2B thesaurus**, translates and matches concepts and terminology in biology with those in engineering, to increase the ease with which biologists and engineers can work across both domains.

Asking the right questions is also critical and Alex Parfitt notes that while there's much research being done in biology, it hasn't always been done with the frame of feeding research into bio-inspired solutions outside of biology, which requires a shift from learning about Nature to learning from Nature.

Swedish Biomimetics 3000 works to actively identify solutions in Nature that are likely to be realizable – both in terms of the ability to develop the technology and materials, as well as the ability to commercialise a solution. The group is working in partnership with cross-disciplinary scientists, universities and government with the help of some EU funding to realise innovations. Denise DeLuca, consultant to **Swedish Biomimetics**, describes two recently commercialised technologies, one of which is a fine misting technology based on the bombardier beetle's controlled valve system. Such an innovation has a wide range of applications in fire fighting, medical, automotive and consumer products – which could all benefit from an intelligent spray system with strong environmental credentials.

New models

Whilst firms such as **BAE Systems** look to biology for solutions, the long R&D lead time may not make biomimicry easy to adopt for all. Alex adds that there's a huge amount of qualification of a material that needs to happen first – and **BAE Systems** will typically initiate projects that might have a five to 15 year timeline from initial development to adoption.

For example, the development time for the proof of principle stage for the 'Bug Eye' technology was around four months, before being approved and funded for the next stage of development – making it a more robust structure

and fit for its context of use out in the field – a stage **BAE Systems** call 'shake, rattle and roll'. Here, the idea has to make this leap out of the lab and into the field, which costs about seven times the initial investment. For the 'Bug Eye' technology, adoption took four years.

For **BAE Systems**, as long as there is a core need and a funding model, this lead-time is sustainable, but in other sectors it can be prohibitive. It can mean that for many organisations, this investment doesn't always add up financially, or fit with traditional ways of thinking about the timeline of the return on investment (ROI).

On the LinkedIn forum 'Biomimicry & Innovation' one practitioner, Margo Farnsworth, notes that many commercial organisations will say *"Gotta have an ROI within the quarter."* However, Margo is starting to see systems springing-up that aspire to work with innovations that need longer lead times. Margo highlights an example, adding *"Pepsico even has an organized four stage way of looking at how they approach sustainability practices which could include biomimicry. Priority A items are high opportunity, low difficulty, short result cycle. Priority B items are high opportunity, higher difficulty and longer result cycle with sometimes higher payback and so on into C and D directives. Operating platforms like that coupled with inspirational leadership by business leaders like Ray Anderson have been 'early-stage tipping points' which, I believe, have driven more business to, not only biomimicry, but many sustainability practices."*

For smaller organisations, which often have promising new ideas, funding models are challenging. Jay Harman, for example, describes a community of SMEs in the US with promising biomimicry-based innovations, but a lack of funding to help test, iterate and commercialise them. Unlike Silicon Valley, the longer and more costly R&D periods mean that there isn't a strong venture capital market around biomimetic technology. Michael Pawlyn argues that there could be a role for government to create the conditions for new types of incentives – such as tax being based on overall resource use, which could prompt firms to invest in biomimicry.

Swedish Biomimetics 3000 has developed its own acceleration model for enabling ideas to progress more rapidly through innovation stages by addressing capital, technical, legal and business support, as well as forming cross-disciplinary and government partnerships.

This early work seems to be bearing fruit. New biomimicry design centres are forming – such as **The Wyss Institute for Biologically Inspired Engineering** at Harvard, which is using a philanthropic gift of $129 million to transform innovation in healthcare, manufacturing, and architecture using biomimicry. To achieve this, they're operating across disciplines and institutions – including working with new start-ups to develop and fast-track innovations. China, India, and Germany too are investing in major biomimicry-based projects across industry and architecture.

As momentum of biomimicry builds, whilst organisations like the **BBRSC** that support and invest in bioscience exist, many feel that the UK has missed the boat. Julian Vincent observes that when he and George Jeronimidis set up the **Centre for Biomimetics** between Bath and Reading Universities, it was pretty much the first one in the world. Julian adds that now much of the activity seems to be taking place elsewhere: *"In southern Germany they've ploughed large amounts of money into it; in the States they are producing lots of work from the biology aspect; Jilin University in China is putting money into it – their biomimetics laboratory is of national importance and receiving government money."*

In the UK, there is a sense that there needs to be renewed energy and focus in biomimicry, as increasingly this is where the innovation opportunities of the future lie.

Denise DeLuca, Swedish Biomimetics 3000

Speakers

Rob Kesseler
Central Saint Martins College of Art & Design

Rob Kesseler is a visual artist and Professor of Ceramic Art & Design at Central Saint Martins College of Art & Design. A recent NESTA Fellow at Kew and Research Fellow at the Gulbenkian Science Institute in Portugal, for the past 12 years, Rob has collaborated with botanical scientists and molecular biologists in an exploration of the plant world at a microscopic level. Reflecting the way in which the natural world migrates into many aspects of our daily lives, his images are translated into a wide range of contexts and media, ceramics, glass and textiles, video, and photography. He exhibits internationally and has published an award winning series of books on pollen, seeds and fruit. In 2010, a monograph of his work, *Rob Kesseler: Up Close* was published by Papadakis, London. For his contribution to plant imaging, Rob was recently made Fellow of the Linnean Society and Fellow of the Royal Society of Arts.

Alex Parfitt
BAE Systems

Alex Parfitt is the Head of Materials Research at BAE Systems Advanced Technology Centre. Alex leads a team of materials engineers responsible for a diverse range of materials research and its validation. This includes metallurgy, composites, welding, adhesives, paints and coatings, nano and micro technology, smart/functional materials, armour, structural health monitoring and the installation of new technologies to BAE Systems products. Alex's background is in biology and mechanical engineering, where his studies include penguin hydrodynamics (DERA/Dstl), and *A Biomimetic approach to Adaptive Camouflage.* (PhD, Mechanical Engineering department at Bath University, sponsored by EPSRC and the Defence Clothing and Textiles Agency).

Denise DeLuca
Swedish Biomimetics 3000

Denise DeLuca's career has spanned both the public and private sectors and included running her own sustainable resource consulting business, Emergent Solutions. As former Outreach Director for The Biomimicry Institute (2007–2009), Denise presented numerous lectures and workshops, helped expand the tools and concepts of biomimicry, and worked to integrate biomimicry into university-level education. Denise is currently working for Swedish Biomimetics 3000 where she is Project Lead on biomimetic innovation projects for external clients, and where she is also deepening the use of biomimetic concepts in business and innovation models. Denise is also Director and Co-Founder of BCI: Biomimicry Collaborative for Innovation, an emerging network to forward ecological thinking for radical transformation.

Agenda

8:00 – 8:30 Registration and breakfast in Nesta lobby

8:30 – 8:35 Introduction – Will Pearson, Director of Technology, Ravensbourne

8:35 – 8:40 Rob Kesseler, Central Saint Martins College of Art & Design

8:40 – 8:45 Alex Parfitt, BAE Systems

8:45 – 8:50 Denise DeLuca, Swedish Biomimetics 3000

8:50 – 9:30 Audience Q&As for the panel, chaired by Will Pearson

9:30 – 10:00 Drinks and networking in Nesta lobby

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