BIOMIMICRY *in* ARCHITECTURE

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Contents

Foreword: Jonathon Porritt

WHEN HISTORIANS come to look back on the twentieth century, from the vantage point of their genuinely sustainable society in the second half of this century, one of the most disputatious areas of enquiry will be fathoming out exactly why we did so little about 'sustainable living' in the second half of that century. It wasn't that we didn't have the knowledge, because we did. It wasn't that we didn't have the technology, because we could have. More mundanely, caught up as we were in our post-war cornucopian fantasies, we simply couldn't be arsed.

Broadly speaking, we were content with our model of consumption-driven economic growth, for all people, apparently forever, and just accepted the rising environmental damage as an acceptable price to pay for it.

Happily, we do at last seem to be waking up after these dismal decades of life-destroying arrogance. Illusions of the 'limitlessness' of the planet are evaporating as the ineluctable physical reality of scarcity impacts on more and more aspects of our economy. People no longer dismiss out of hand concerns about 'peak oil' or about diminishing supplies of critical raw materials.

And those control fantasies that once persuaded us that making war on nature would somehow turn out to be the best way of advancing humankind's special interests are giving way to a much more sophisticated understanding of the need for balance and reciprocity between ourselves and the rest of the living world.

Michael Pawlyn's fascinating work opens up one particularly intriguing aspect of that search for a new balance – biomimicry in architecture. He defines biomimicry as 'mimicking the functional basis of biological forms, processes and systems to produce sustainable solutions', and he invites us to explore not just its potential but specific case studies in architecture where biomimicry has already had an important influence.

I came away from reading this with the distinct impression that what's out there today, already in situ, provides just the tiniest insight into what lies ahead. Biomimicry is increasingly well established in the fields of industrial design, engineering and manufacturing, and even in medicine and fashion. The profession of architecture, however, has been slow to incorporate any of the basic principles – let alone the practice – of biomimicry into its teaching.

Most contemporary architects would be quick to attribute that to a lack of imagination on the part of their clients. However, there is a broader case to be made that relatively few architects have, as yet, used their professional skills and their standing in society to the full to help other people live more sustainably in buildings and spaces that are fit for purpose in a very different age.

Michael Pawlyn clearly feels much of that frustration himself, and is keen to demonstrate that even as architects become more mindful of the impact their work has on the environment, there is only so much they can do within the existing paradigm. If we remain stuck in a waste-generating, inherently polluting model of development (using raw materials in the 'heat, beat and treat paradigm', as Janine Benyus describes it), then we will only ever get to the 'less bad' (or 'less unsustainable' in my terms) in our use of the natural world – but never to good!

It's that entire paradigm that we have to render obsolete, designing out 'waste' as such by ensuring that as much as possible of what we create remains useful to us for as long as possible, in one way or another, and performs functionally with zero impact on the natural world. Biomimicry allows wealth-creators of every kind to emulate natural forms in their own work, using 'nature' as a critical sourcebook.

Happily, there's no shortage of role models. From the insect world alone, we are invited to learn from the mud-dauber wasp, compass termites, Eastern tent caterpillars, female bauble spiders and the extraordinary Namibian fog-basking beetle! Pawlyn introduces us to a veritable treasure trove of teachers. And at the heart of this celebration of evolution lies a wonderful paradox. Even as our politicians and economists focus ever more intently on the problems of scarcity (in terms of oil, land, water, precious metals, rare earths, and so on), we are only just beginning to appreciate the astonishing abundance with which we are surrounded.

In short, it's not the lack of biophysical plenty that will constrain the future of humankind, but rather the lack of vision and creativity on our part.

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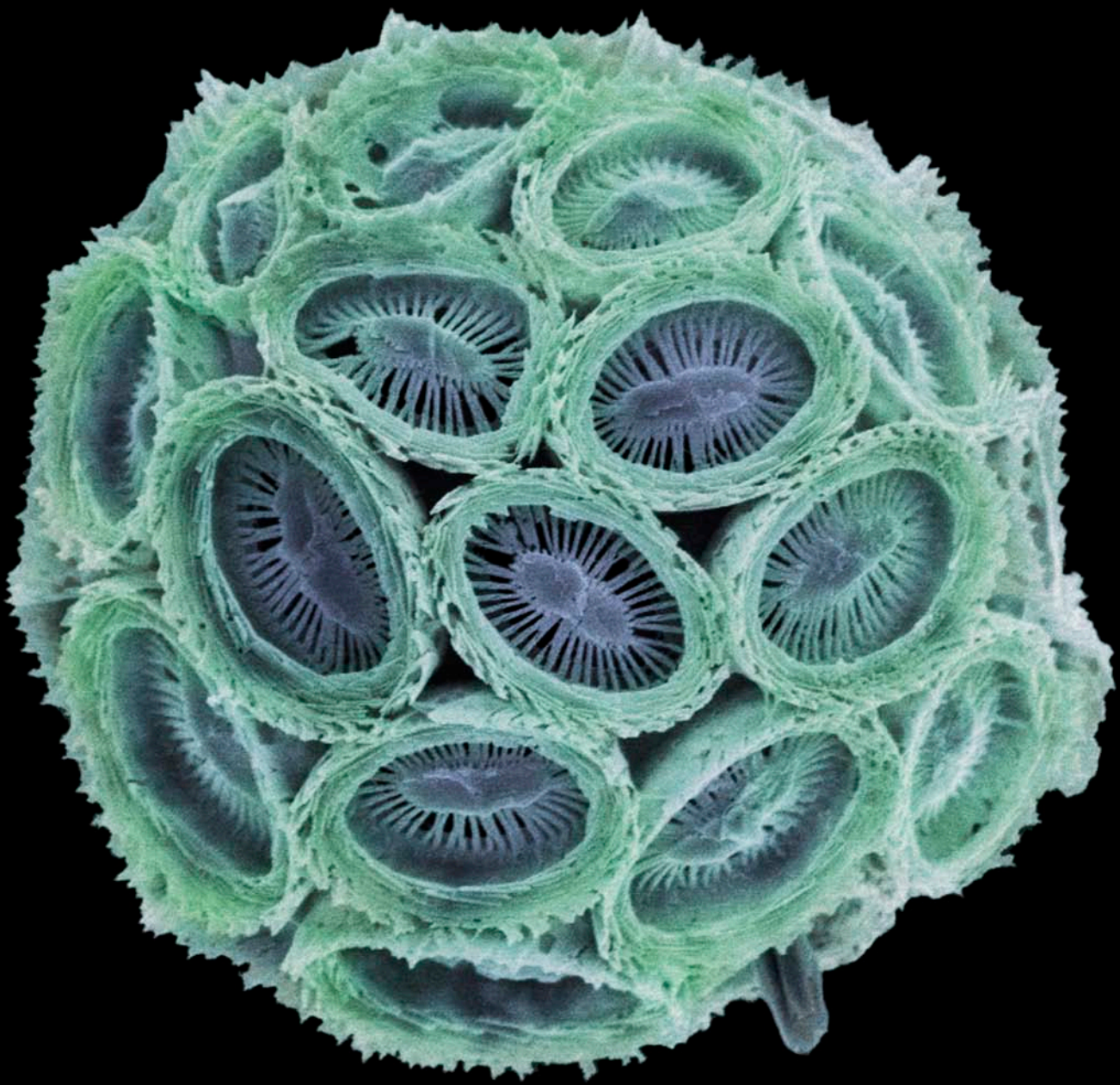

Introduction

You never change things by fighting the existing reality.
To change something, build a new model that makes the existing model obsolete.
RICHARD BUCKMINSTER FULLER

THIS IS A BOOK ABOUT SOLUTIONS. It is about learning from a source of ideas that has benefited from a 3.8-billion-year research and development period. That source is the vast array of species that inhabit the earth and represent evolutionary success stories. Biological organisms can be seen as embodying technologies that are equivalent to those invented by humans, and in many cases they have solved the same problems with a far greater economy of means. Humans have achieved some truly remarkable things, such as modern medicine and the digital revolution, but, when one sees some of the extraordinary adaptations that have evolved in natural organisms, it is hard not to feel a sense of humility about how much we still have to learn.

There are, I believe, three major changes that we need to bring about if the grand project of humanity is to endure: achieving radical increases in resource efficiency, shifting from a fossil-fuel economy to a solar economy and transforming from a linear, wasteful and polluting way of using resources to a completely closed-loop model in which all resources are stewarded in cycles and nothing is lost as waste. None of these will be easy but if we choose to embark on these linked journeys then there is, in my opinion, no better discipline than biomimicry to help reveal many of the solutions that we need.

1. Coccolithophores (marine micro-organisms) make their skeletons from calcium carbonate using elements in seawater and are thought to be part of the planet's long-term carbon cycle. In geological periods when carbon dioxide levels in the atmosphere have risen, coccolithophores bloomed and, when they died, fell to the ocean floor to form layers of limestone.

Architecture and the natural world

Throughout history, architects have looked to nature for inspiration for building forms and approaches to decoration. This book aims to study one particular aspect of 'nature as sourcebook' that is distinct from the majority of architectural references to the natural world. The intention is to study ways of translating adaptations in biology into solutions in architecture. We are entering the Ecological Age, and it is the contention of this book that many of the lessons that we will need for this new era are to be found in nature itself.

What has been commonly called 'The Industrial Revolution' (but could also be referred to as 'The Fossil Fuel Age') could now be seen as a diversion from the kind of ingenuity that we once had in common with nature's evolved solutions. The ubiquity and convenience of fossil fuels has allowed extreme inefficiency to develop, and has effectively undermined resourcefulness. The lessons from nature which informed many vernacular approaches to design and manufacturing were therefore abandoned and largely lost from our collective memory. Now that the folly of releasing many millennia of stored carbon is becoming increasingly apparent, there is an opportunity to explore the incredible effectiveness of the responses that natural organisms have evolved. For virtually every problem that we currently face – whether it is producing energy, finding fresh water or manufacturing benign materials – there will be numerous examples in nature that we could benefit from studying. While fascination with nature undoubtedly goes back as long as human existence itself, now we have an opportunity to revisit the idea of learning from biology with massive

advantages of scientific knowledge, better tools and aesthetic sensibilities unconstrained by historical dogma. There are few times when designers have been presented with such an opportunity.

Many current approaches to environmentally sustainable architecture are based on mitigation. The suggestion from the examples collected in this book is that it is possible to go further than this, and for buildings and cities to be regenerative. In some cases, buildings will cease to be static consumers and can become nett producers of useful resources. The intention is therefore to transcend the mimicking of natural forms and attempt to understand the principles that lie behind those forms and systems. Then we can look for opportunities to create works of architecture that are celebratory as well as being radically more resource efficient.

What do we mean by 'biomimicry'?

The term 'biomimicry' first appeared in scientific literature in 1962,[1] and grew in usage particularly amongst materials scientists in the 1980s. Some scientists preferred the term 'biomimetics' or, less frequently, 'bionics'. There has been an enormous surge of interest during the last ten years, brought about to a large extent by individuals like biological-sciences writer Janine Benyus, Professor of Biology Steven Vogel and Professor of Biomimetics Julian Vincent, who have all written extensively in this subject area. Julian Vincent defines it as 'the abstraction of good design from nature',[2] while for Janine Benyus it is 'The conscious emulation of nature's genius'.[3] The only significant difference between 'biomimetics' and 'biomimicry' is that many users of the latter intend it to be specifically focused on developing sustainable solutions, whereas the former can be, and on occasions has been, applied to fields of endeavour such as military technology. I will be using biomimicry and biomimetics as essentially synonymous, and I like to define the discipline as 'mimicking the functional basis of biological forms, processes and systems to produce sustainable solutions'.

There are two other terms that are worth clarifying: firstly 'bio-utilisation' and secondly 'biophilia'. Bio-utlisation refers to the direct use of nature for beneficial purposes, such as incorporating planting in and around buildings to produce evaporative cooling. We will see later in Chapter 3 that this approach has a major role to play in biomimetic systems thinking. Biophilia was a term popularised by the biologist E. O. Wilson, and refers to a hypothesis that there is an instinctive bond between human beings and other living organisms.[4]

From an architectural perspective there is an important distinction to be made between 'biomimicry' and 'biomorphism'. Modern architects have frequently used nature as a source for unconventional forms and for symbolic association. There are some examples of how this has produced majestic works of architecture, such as Eero Saarinen's TWA terminal (fig. 2) and Frank Lloyd Wright's Johnson Wax building (fig. 3). In the esoteric realm, Le Corbusier used allusions to natural forms extensively for their associated symbolism (fig. 4). The reason that it is necessary to make a distinction is because we require a functional revolution of sorts if we are to bring about the transformations described above, and I firmly believe that it will be biomimicry rather than biomorphism that will deliver the solutions we need.

Are there grey areas between biomorphism and biomimicry? There are certainly projects that have been based on a very detailed understanding of natural forms and have used this to great effect. The key, I believe, is whether the design engages with the function delivered by a particular natural adaptation. If it does, then it is fair to label it as biomimetic; if it does not, then I think it is correct to say it is biomorphic.

I do not want to sound too dismissive of biomorphic architecture. It is quite possible for the two approaches to coexist in one building, and biomorphism can add further meaning than would be achieved from a purely technical use of biomimicry. It is also worth considering the limitations of biomimicry. Just as with any design discipline, it will not automatically produce good architecture, and we should be wary of trying to become purely scientific about design. Architecture should always have an emotional dimension – it should touch the spirit, it should be uplifting and it should celebrate the age in which it was created.

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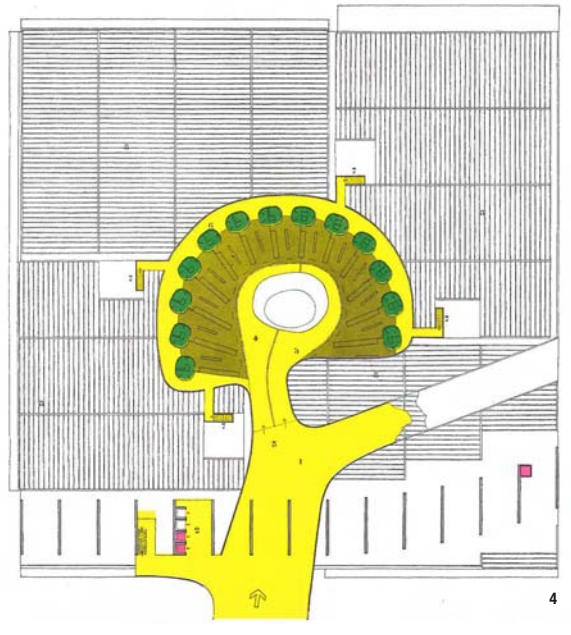

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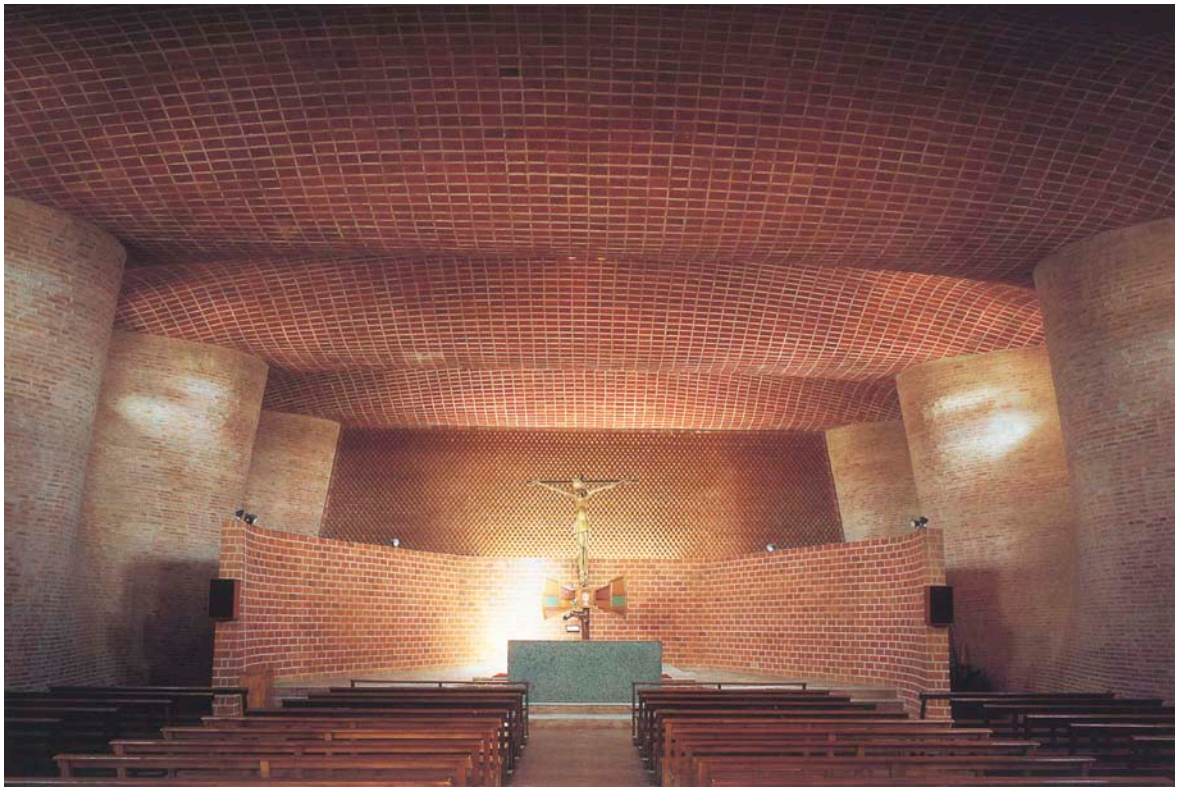
2. The TWA terminal at John F Kennedy Airport, New York, in which Eero Saarinen used biomorphic forms to capture the poetry of flight
3. Frank Lloyd Wright likened the columns in the Johnson Wax building to water lilies and, while they create a spectacular space, they have nothing functionally in common with lily leaves
4. Le Corbusier, possibly the greatest symbolist architect of all time, appears to have made deliberate reference to the cleansing function of kidneys in the design of the washrooms for the unbuilt Olivetti Headquarters project

There are some cases in which a biological example may already have some of these inspiring qualities – one could cite the Amazon water lilies that were translated into concrete beauty by Pier Luigi Nervi. In other cases, such as the principles of structural efficiency revealed in abalone shells, it is no more (or less) than a promising starting point from which to imagine all manner of spaces with, for instance, the magical qualities of Eladio Dieste's architecture (fig. 5).

The word 'natural' is used in many contexts to imply some kind of inherent virtue or 'rightness', and it would be easy to misconstrue biomimicry as being about the pursuit of solutions that are 'more natural'.[5] This is not the aim. There are certain aspects of nature that we definitely do not want to emulate – voracious parasitism to name just one. There is also a danger in romanticising nature. What I believe nature does hold that is of enormous value is a vast array of products (for want of a better word) that have benefited from an extremely long and ruthless process of selection and refinement. Evolution could be summarised as a process based on genetic variability, from which the fittest are selected over time. The pressures of survival have driven organisms into some almost unbelievably specific ecological niches and into developing astonishing adaptations to resource-constrained environments. The relevance of this to the constraints that humans will face in the decades ahead is obvious. We will, in the chapters of this book, study a beetle that can harvest fresh water from the air in a desert environment, a reptile that effectively drinks with its feet and another beetle that can detect a forest fire at a distance of 10 km.[6] We will also learn about projects that achieve alchemical transformations of waste into highly productive systems.



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Origins of biomimicry

While there is no proof, it is quite likely that the forms of eggs inspired the first human-made domes, and in this sense biomimicry is far from being a recent idea. Leonardo da Vinci was clearly a pioneer, and his visions were hundreds of years ahead of his contemporaries. Other examples abound, as Steven Vogel has clearly described in *Cat's Paws and Catapults*.[7] Around 1719, the production of paper shifted from using cotton and linen fibres after the French entomologist Réne-Antoine Réamur suggested that wasps' use of wood pulp demonstrated an alternative. In the field of naval architecture there are examples such as that of Sir George Cayley, who in 1809 studied the streamlined form of dolphins and trout in order to develop ship hulls with lower coefficients of drag.

More recently there are some well-documented examples such as the invention of Velcro around 1948, and in the last decade there has been a phenomenal flourishing of biomimicry as more and more designers respond to the demand for sustainable products. The Mercedes biomimetic concept car (fig. 8) is inspired by the surprisingly streamlined and roomy boxfish (fig. 7), Olympic swimsuits based on shark skin (fig. 9) and new types of drill designed after a wood wasp's ovipositor[8] have all delivered a superior product by learning from the functions delivered by adaptations in natural organisms.

To date, biomimicry has only been applied to building design to a fairly limited extent, often relying on frequently cited examples such as termite mounds and spider webs. In recent years, biomimicry has developed very rapidly in other fields such as industrial design and medicine. This book will explore the potential that biomimicry offers to architecture. It is not intended to be an exhaustive survey of works of architecture that are biomimetic, but it does aspire to be a comprehensive sourcebook to encourage other architects and students to explore a wonderfully rich range of solutions.

6

5. The Iglesia Christa Obero designed by Eladio Dieste
6. Burdock burr were the source of inspiration for George de Mestral – the Swiss engineer who invented Velcro. Apparently after some recent frustration with zips, he noticed the way that burdock burrs clung to his dog's coat and, after studying them with a magnifying glass, designed the first version of the now ubiquitous fastening

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7. The boxfish

8. In spite of its rather cubic form the boxfish has a very low coefficient of drag and inspired the designers of the new Mercedes

9. Sharks and other elasmobranchs have a very rough skin texture (as this scanning electron microscope image of spiny dogfish skin shows) which, somewhat counter-intuitively, creates a more streamlined surface. New biomimietic swimsuits based on shark skin were so successful in allowing swimmers to move faster through the water that they were banned by FINA the governing body for world swimming