Global Biomimicry Efforts
An Economic Game Changer

› Commissioned by San Diego Zoo Global
› Researched and produced by the Fermanian Business & Economic Institute.
The Global Biomimicry Efforts: An Economic Game Changer

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San Diego Zoo Global

Fermanian Business & Economic Institute
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The Fermanian Business & Economic Institute is pleased to present its original research report, Global Biomimicry Efforts An Economic Game Changer. Sponsored and published by San Diego Zoo Global, our intention is to provide to leaders from industry, academia, public policy, government and other interested fields a highly readable primary source for the emerging field and industry of biomimicry. Our mandate was to survey not only the world of biomimicry and what it is in 2010 but to look to the future and attempt to envision what it could economically become in the future. We have carefully reviewed research and information from a wide variety of sources and publications and then selected, interviewed, analyzed, and discussed many of the pioneering companies and products in biomimicry. From this, we then offer an economic opinion as to opportunity for this field, and we affirm in our report that San Diego is well positioned to become the global hub of biomimicry. All of the critical components that are needed for the emergence of San Diego to assume this role are in place, and the possibility of envisioning two similarly powerful global economic engines in California, one in Silicon Valley and one in San Diego, is a realistic possibility.

We hope that this report is an important first step in asserting the economic viability and potential of biomimicry, and that it offers information of use to the critical decision-makers who could work collaboratively to create this hub. At the Fermanian Business & Economic Institute this is what we refer to as “actionable economics”. We are grateful to San Diego Zoo Global for its vital leadership in biomimicry and in many other areas of conservation, sustainability, and global citizenship and look forward to additional opportunities to serve our community.

Randy M. Ataide, J.D.
Professor of Entrepreneurship
Executive Director
Fermanian Business & Economic Institute

About the Fermanian Business & Economic Institute

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Biomimicry could represent a revolutionary change in our economy by transforming many of the ways we think about designing, producing, transporting, and distributing goods and services.

Biomimicry, the discipline of applying nature's principles to solve human problems, provides the means to achieve both environmental and economic goals. Many of the mechanisms and systems found in nature are highly efficient, eschew waste, and are sustainable in a virtually closed system. Biomimicry could be a major economic game changer.

While the field today is just emerging, in 15 years biomimicry could represent $300 billion annually of U.S. gross domestic product (GDP) in 2010 dollars. It could provide another $50 billion in terms of mitigating the depletion of various natural resources and reducing CO2 pollution. Biomimicry could account for 1.6 million U.S. jobs by 2025. Globally, biomimicry could represent about $1.0 trillion of GDP in 15 years.

The applications of biomimicry to commercial use could transform large slices of various industries in coming years and ultimately impact all segments of the economy. Industries that could be particularly affected include utilities, transportation equipment, chemical manufacturing, warehousing/storage, and waste management, architecture and engineering.

Two very different approaches are followed in the use of biomimicry. In some cases, scientists see an interesting concept in nature and then find a commercial application. In other instances, firms are seeking a solution to a specific problem and find an answer in the natural world.

Firms selling biomimicry-inspired products in the marketplace have frequently seen a doubling of sales annually in the early years. Many of these products can offer customers reduced energy requirements, less waste, and enhanced performance while being sold at prices competitive with or even less than those of existing products.

Constraints faced by firms attempting to commercialize biomimicry products include the challenge of educating and convincing customers resistant to change, finding sufficient capital unless backed by a large firm, developing new supply chains, and moving from small to larger scale operations.

Investors should be attracted to biomimicry because of the prospects for rapid sales growth and high rates of return. Venture capital could flow into biomimicry at a pace at least equal to that of biotech, estimated at $4.5 billion for 2010.

San Diego appears well positioned to become a hub for biomimicry. The region possesses four key characteristics: intellectual resources, capital, a strong entrepreneurial base, and a collaborative environment. The San Diego Zoo, with its rich animal and plant collection together with its existing research institute for conservation, appears well suited to lead such a hub.

A cluster of 1,000 biologists, naturalists and other scientists could form in San Diego over the next 15 years as a biomimicry core to help take solutions in the natural world to commercial application. Including all of the ripple or multiplier effects, this cluster could generate a total of 2,100 jobs and add $325 million to San Diego's gross regional product annually by 2025. Biomimicry could emerge as San Diego's next major economic driver, complementing and enhancing such clusters as biotech and cleantech.
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I. BIOMIMICRY: THE BRIDGE BETWEEN THE ECONOMY AND THE ENVIRONMENT

Biomimicry--A Game Changer

Biomimicry provides the means to achieve both environmental and economic goals. As policy leaders throughout the world begin to focus more on “sustainable growth”, the clash between environmental and economic interests could potentially be greater than ever. As job growth following the “great recession” continues to be subpar, finding the proper balance between preservation of our natural resources and increasing employment poses great challenges.

While many large corporations and public agencies have implemented “green” initiatives, a focus on conservation is far from becoming ingrained in our culture. Many environmental objectives are being achieved only through legal mandates or subsidies. A greater emphasis on jobs along with public budget pressures could scuttle many of these efforts. Company programs directed to environmental ends could be vulnerable to another recession and the need to cut costs deemed not immediately vital to the bottom line.

A special report on sustainable business in the Financial Times\(^1\) noted that many companies, outside of agriculture, food and pharmaceuticals, seem to have “few obvious ties with the natural world”. That perception could be changing. Firms who heretofore have relied little on plants or animals are becoming aware of “how much their wealth depends on preserving natural ecosystems”.\(^2\)

Biomimicry could provide a critical bridge between business and the environment. Derived from the Greek word, bios, meaning life, and mimesis, meaning to imitate, biomimicry is a rapidly growing field where solutions found in the natural world are applied to human problems. Man has taken inspiration from nature for centuries to find answers. For example, Leonardo da Vinci (1452-1519) attempted to design a flying machine based on a study of the anatomy and flight of birds.\(^3\)

Only in recent years has biomimicry begun to gain true traction. Janine Benyus, author of six books in the field, has been one of the key pioneers advancing the discussion.\(^4\) Nature is increasingly being viewed as a model, mentor, and benchmark.

It should not be surprising that millions of years of evolution have produced in nature mechanisms and systems that are highly efficient, eschew waste, and are highly sustainable in a virtually closed system. As pointed out by Peter Foley, Associate Director of the Cognitive Science Group for Proctor & Gamble, nature entails “optimizing” rather than “maximizing”. Nature is also a model of sustainability since it is a “closed loop” system.\(^5\)

In the long-term, policymakers, business, and the public will only embrace efforts to protect the environment and safeguard our natural resources if it makes economic sense. Biomimicry provides that critical bridge. **By increasing efficiency and reducing costs, solutions inspired by nature can allow us to both raise standards of living and preserve the environment.**
A cost-benefit evaluation points to the merits of biomimicry. It holds the potential of reducing three major sources of costs:

--The economic cost of pollution
--The economic cost of waste disposal
--The economic cost of natural resource depletion

Based on World Bank estimates, the costs of the depletion of energy and mineral resources and the nations' forests, along with the pollution costs of CO2, currently amount to about $350 billion in the U.S. 6

The economic cost of pollution alone encompasses a wide range of effects, including health care expenses, lost work hours and wages, crop losses, and reduced property values.7  The potential economic costs of climate change and global warming are just starting to be understood.

Solutions from biomimicry also promise through the growth of new applications and markets, along with improved efficiency, three major sources of benefits:

--The economic benefits of improved efficiency
--The positive impact on jobs
--The positive impact on profits

A sense of some of the potential comes from the experience of firms selling low-carbon goods and services. Research by HSBC has estimated that in 2008, the worldwide sales of firms in the “climate change” sector (including firms involved in renewable power generation, alternative energy, water, and waste management) reached $534 billion. This exceeded revenues of the aerospace and defense sector estimated at $530 billion. Despite the recession, the sector saw sales rise by approximately 75% from the prior year. 8

Biomimicry also is not just about “green”. New product designs have the potential to lower product costs. This is important for consumers. Although polling suggests that two-thirds of American households believe that the environment should be considered when purchasing products, only about half are willing to pay a price premium.9  Nature’s ability to inspire more efficient solutions can yield lower-cost products for companies to market.

On balance, instead of positioning the situation as an “either/or” debate between the environment and jobs, biomimicry presents a “win-win” answer that allows both to be addressed.
II. REPORT STRUCTURE AND METHODOLOGY

This report analyzes both the microeconomic and macroeconomic dimensions of Biomimicry. The microeconomic aspects involve a focus on firm or business issues, including cost structure, competitive positioning, capital costs, and product pricing. The macroeconomic issues address the overall impact of biomimicry on such factors as gross domestic product (GDP), employment, and personal income.

Report Structure

The following chapter, Chapter III, analyzes several case studies to understand from the ground level the opportunities and challenges of various firms engaged in taking products to market that were inspired in some way by the natural environment. This is the part of the report which delves into many of the microeconomic aspects.

Chapters IV and V examine the macroeconomic issues with more of a top-down analysis. Chapter IV analyzes the potential impact on various major sectors of the U.S. economy of biomimicry with a focus on the proportion of sales that could be impacted by 2025. Chapter V then extends the analysis to quantifying the potential impact on total U.S. GDP and employment. An estimate is also made of the economic losses that could be avoided from the depletion of the nation's energy, mineral, and forest resources and from CO2 pollution. Finally, an estimate of the impact on total global GDP of biomimicry is presented for 2025.

Chapters VI and VII include both microeconomic and macroeconomic elements. Chapter VI analyzes the investment implications of biomimicry. It looks at potential sales growth rates and rates of return. A wider look at the financial markets examines prospects for capital flows, possible investment vehicles, and risks.

Chapter VII investigates the prospects for San Diego as a biomimicry hub by analyzing the requirements of industry hubs and San Diego's capabilities. It presents projections on the total economic impact a biomimicry cluster could have on the region’s economy in terms of total gross regional product, employment, and personal income. The report concludes with an investigation of the San Diego Zoo serving as a possible fulcrum for biomimicry’s hub.

Data Sources, Methodology, and Disclaimer

The case studies in Chapter III relied on personal interviews with the principals of the firms selected for the nature-inspired products. The firms were chosen to capture applications in various economic sectors, including consumer spending, energy, utilities, transportation, pharmaceuticals, and industrial materials. To understand the process of taking biomimicry concepts to market, companies at various stages of product development from pre-entry to successful launch and implementation were included.

The case studies in Chapter III and referenced elsewhere relied on a combination of public information available on the firms’ public websites during the time period of May-November 2010 and/or personal interviews conducted by the economic researchers with the principals of the firms selected for nature-inspired products. Disclosure was made to the firms as to the intended use of the information obtained from the interview. Some information contained on the websites may have been compiled from third party
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The analysis of the sales potential of various sectors of biomimicry in Chapter IV started with an investigation of the various industries classified according to the North American Industry Classification System (NAICS) to determine which parts of the economy might be the most likely beneficiaries of biomimicry. Based on the experience of the firms analyzed in this report and the literature on biomimicry applications, estimates of the sales penetration by 2025 were developed. The base figures for shipments (sales) and value added for the various industries were obtained from the U.S. Bureau of Economic Analysis.

The year 2025 was selected as the year for all projections to give a consistent timeframe for the various aspects of the study. A fifteen-year horizon was selected as an appropriate medium-term period consistent with standard economic and econometric practices. This timeframe allows for considerable advancement in biomimicry to take place. While a longer term horizon would certainly allow for a much greater potential to be realized, this study was focused on presenting business, investor, and policy interests with more tangible expectations for their planning purposes.

Chapter V developed projections of GDP over the next 15 years with the econometric models and estimates from the Fermanian Business & Economic Institute. The estimated shares for various sectors developed in Chapter IV were then applied to derive the total expected impact of biomimicry on the economy on real GDP for 2025. An estimate of the loss mitigation was based on numbers produced by the World Bank on the costs of resource depletion and pollution. The employment impact of biomimicry by 2025 was generated by projecting job totals over the next 15 years and assuming that biomimicry would affect approximately equal shares of sales, output, and jobs for a given industry.

The estimates for sales growth and rates of return in Chapter VI were based on the case study interviews and the typical performance of start-up industries. Forecasts for venture capital growth were developed by the Fermanian Business & Economic Institute.
The analysis of the potential economic impact on San Diego County of a biomimicry cluster discussed in Chapter VII was derived from the use of a dynamic input-output and econometric model. The IMPLAN® Model was used to analyze all of the multiplier effects (including supply chain and consumption related) of an estimated core group of 1,000 biologists, naturalists, and other scientists that could be formed by 2025.

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III. MAJOR EXAMPLES/CASE STUDIES: APPLICATIONS OF BIOMIMICRY IN VARIOUS INDUSTRIES AND THEIR ECONOMIC EFFECTS

Biolytix Water Australia Pty Ltd

Biolytix is an Australian company featuring a sewage treatment process and equipment that produces a much more ecologically friendly and energy efficient system than traditional technology. The on-site tank converts household sewage, food waste, and wastewater into high-quality irrigation water.

The firm’s founder, Dean Cameron, patented the process in 1994 and the firm has been in existence since 1996. Biolytix has won a number of major awards, including The Asian Innovation Award, the Global Eco-Tech Award, The EPA sustainable Industry Award, and two Australian and New Zealand Innovation Awards.

Product Inspiration

Mr. Cameron had observed the pristine state of a forest stream’s water despite the presence of large bat colonies. He had also noted that the fastest decomposition of forest litter did not take place in rivers but in the moist soil on river edges. Traditional sewage and wastewater facilities have implicitly assumed that a system emulating a river-based system would be most efficient.

Biolytix has taken nature’s more efficient approach. A tank (BioPod) contains an ecosystem of worms, beetles, and billions of microbes that decompose solid waste into humus. That humus is then used to filter wastewater into water that can be used for irrigation.

Advantages over Existing Products

Because the ecosystem treats the waste, no aerators are necessary, which reduces operating energy costs by around 90%. Aerators can typically be run up to 16 hours per day. Sludge transport and disposal are unnecessary. Only one annual servicing is required versus 3-4 in the case of traditional systems. The process is odorless and also does not need regular pump outs.

The system can be used both for residential and commercial properties. The BioPods can be networked for housing developments and towns and are fully scalable. For example, each of the 1,100 houses in Point Boston, South Australia, is designated to have a Biolytix System.

The cost to developers for the installation of the Biolytix System can be one-half that of typical gravity sewerage.
**Sales, Profits, and Future Plans**
In its brief 12-year history, Biolytix has seen its sales grow about 20% per annum. Profits have also grown substantially and the company envisions that the technology can eventually be embraced on a larger, global scale.

**Market Potential**
The technology has a large potential to replace traditional wastewater systems or be used when new developments are launched throughout the world. The use in both residential and commercial properties amplifies the possible significance of this technology. The ability to achieve major energy savings, particularly in a setting of rising energy costs or increased regulation, could spread the system’s adoption.

**Constraints**
The microbes and invertebrates necessary for the system can be sourced locally in virtually any country and climate except for the permanently frozen areas of the world. Resistance from utilities and water authorities probably represents the greatest constraint. Some of these entities that have been approached have been skeptical of the new technology, especially since it represents a radical change from the system that has been used historically. Consulting engineers who typically base their fees on the project cost have less incentive to advocate the new system since their services of design and engineering for more expensive customized waste treatment facilities are reduced.

Based on Interview with:

Dean Cameron  
Managing Director  
Biolytix Water Australia Pty Ltd  
www.biolytix.com
Biomatrica

Biomatrica is a biotechnology company developing products for preserving biological samples at sample collection, shipping and storage for use in research, clinical, or diagnostic analyses. The company also develops technologies for enhancing and improving PCR (polymerase chain reaction) and STR (type of allele) assays. In addition, it provides a laboratory management software application to track all samples stored for use in research and clinical laboratories. Together, they represent products that reduce the need for expensive refrigeration units as well as maintenance and operational costs of running cold storage systems.

Product Inspiration
Anhydrobiosis is a natural mechanism that prevents cell degradation. It is found in some eukaryotic extremophiles such as tardigrades (very small organisms) and brine shrimp. Essentially, the mechanism causes the organism to dry up while keeping its cells intact for extended periods of time. During this time of preservation the sample is completely protected in a thermo stable barrier that only reactivates when the sample is rehydrated.

Advantages over Existing Products
Biomatrica’s room temperature-based bio-sample stabilization, shipping and storage products offer a significantly lower cost structure than cold freezers and have added advantages of ZERO energy needs, ZERO carbon emission, and a much lower footprint in the biomedical research lab.

Sales, Profits, and Future Plans
Biomatrica has been doubling in sales every year since its inception in 2004. The price difference in comparison to standard refrigeration methods depends on the application and the scale. Migrating legacy biological samples from freezers to room temperature storage is a one-time expense, whereas cold storage requires ongoing electrical and maintenance costs. For the low end of pricing, the entire Biomatrica system could be half the cost for operating a standard research refrigerator for a year. In some cases, the Biomatrica investment could take two years of equivalent refrigeration expense to realize a cost savings.

Market Potential
The target market for Biomatrica has been academic research laboratories, forensics, government, pharmaceuticals, and diagnostic labs. One of the benefits and strong selling points that the Biomatrica system has is how much it lowers the carbon footprint as well as energy consumption of an organization. Large universities that have sustainability initiatives can benefit greatly from implementing a Biomatrica system in their biomedical research laboratories. This can help the university as a whole meet its energy cost reduction goals by lowering its energy consumption significantly, a common source of huge expenditure of many research labs.

Biomatrica hopes to have a sizable market share within the next ten years, as energy savings and eco-friendly technology (green-based) become increasingly important in research organizations of all sizes.
Constraints
The main constraint that Biomatrica is facing at this point is in educating the potential customer about the benefits of migrating from cold storage systems. Some institutions do not have budgets that are flexible enough to pay for the conversion to a Biomatrica system at one point in time. However, over time, this will become less of a challenge as the significant benefits of managing biospecimens at room temperature ramps up in the bio-medical research community.

Based on Interview with:

Judy Muller-Cohn
Founder and CEO
http://www.biomatrica.com/
**Brinker Technology**

The discovery of a marketable platelet technology was originally made through research conducted at the University of Aberdeen, Scotland. Brinker Technology was then formed to market and sell the technology in the water and oil piping industries. At this stage Brinker has three product lines: Telepath, Plasma, and Platelets. Telepath and Plasma are based around the original Platelet product and are designed to help better implement the Platelets.

**Product Inspiration**

Dr. Iain McEwan received a paper cut on his finger and realized that the platelets that are constantly being circulated in our bloodstream start working immediately when a cut occurs. This principle of having the platelets already imbedded in a system was perceived as being very useful and relevant to a wide range of circulatory systems and applications.

**Advantages over existing products**

Brinker has no direct competition that uses the platelet technology. The main advantage that Brinker has is that it is able to fix a leak with minimal downtime. A leak can be detected and within hours can be sealed with the pipeline flowing at normal capacity. Traditionally, similar leaks would involve shutting down the problematic pipeline for an extended period of time while the leak would be repaired.

Telepath is a software program that analyzes the leak and can determine the best suited platelet mixture to secure the leak most appropriately and effectively. Plasma is a fluid that complements the platelet system and can provide a barrier without solidifying or setting. The Plasma can also prevent future leaks and provide a corrosion barrier.

**Sales, Profits, and Future Plans**

Brinker is a privately held firm and as such much of its company information is confidential. Therefore, a company growth rate is not available. However, it is plausible that for a breakthrough product such as Brinker’s with global applications and markets, customer demand could be extraordinarily strong. Brinker has a dedicated research and development team that is constantly working on new products to better serve its market, underscoring its value discipline of product leadership.

**Market Potential and Constraints**

Brinker would appear to be in a unique position in that it potentially has imbedded in its platelet technology products with minimal need to currently develop additional markets. Since there is currently no competing product that can perform as effectively as Brinker’s in the field, the market share opportunity and firm profitability potential appear quite significant.

Based on:

http://www.brinker-technology.com/
Green Wavelength

Green Wavelength is a start-up company that is developing a windmill that can be placed in remote locations to provide a small consistent amount of power. The windmill could also supplement power to a building that is already connected to the power grid.

Product Inspiration
The windmill design mimics the movement of a bumble bee and a hummingbird. The goal is to have a highly efficient, relatively small windmill (20 ft diameter) that would be a source of power locally.

Advantages over Existing Products
Current windmills have a maximum efficiency of 30% and a maximum theoretical efficiency of 60%. Green Wavelength’s goal is to achieve at least 35% efficiency, making it a more productive windmill than current technology. The output goal is to produce one kilowatt/month.

Sales, Profits, and Future Plans
The product is still in the design phase and not available for purchase at this time. The windmill will have a target price range of $5,000 to $15,000. The price will vary depending on the location and size of the necessary tower structure. The windmill needs to be high enough to get adequate exposure to produce the required amount of electricity.

Market Potential
More market research needs to be completed to better understand the full market potential of this product in terms of where it can be placed and where it can be most beneficial to a potential customer. At this point, the most suitable application would be for remote structures in wind rich environments that would not necessarily have easy access to a power grid. The Green Wavelength windmill would provide the most immediate return in such an environment.

Constraints
The main constraints for Green Wavelength have been sourcing financing. Since the firm is a start-up and is pursuing a product in green technology there are some government grants available. The problem has been that there are so many start-ups looking for this same government funding that it is very difficult to be selected. The application fees for these loans can also be an obstacle, with some as high as $75,000.

Based on Interview with:
Sabri Sansoy, CEO
http://www.greenwavelength.com/
InterfaceFLOR

InterfaceFLOR is a publicly held carpet manufacturer that created the i2 carpet line in 2000, which is when the Biomimicry mindset was implemented throughout the company.

Product Inspiration
The i2 carpet line utilizes carpet squares that are unique and do not follow a specific pattern. It mimics the randomization of colors that naturally occurs on the forest floor. This design carries several cost-saving benefits that can be realized by all parties involved: the manufacturer, distributor, installer, and end user.

Advantages over Existing Products
The i2 carpet system is inexpensive to manufacture because it allows each carpet square to be made without the need to precisely replicate the same pattern and color in every tile. The dye lots that are used during manufacturing do not need to be matched since each tile is unique. This cuts down on inventory costs substantially. The tile design provides for more efficient use of space in warehousing and transporting compared to the broadloom that is large and cumbersome.

TacTiles are single-sided adhesive squares that keep the i2 carpet squares together but do not affix the carpet to the ground beneath it, thus eliminating the need for traditional wet adhesive. They allow for quick changes to specific carpet squares instead of changing the equivalent of an entire carpet roll. The TacTiles are made from recycled materials and cut down on the use of glue and adhesives significantly. The TacTiles also allow for a much quicker installation of the i2 system.

Sales, Profits, and Future Plans
The price point for the i2 system is competitive to the rest of the market. This advantage can be shown by how fast the i2 segment has grown in relation to the company’s other product lines. Revenues from the i2 line have increased by $120 million from 4.3% of total sales in 2002 to 39.5% of total sales in 2009.

The i2 carpet tiles are patent protected and the TacTiles are patent pending. There are currently no plans to begin licensing, but if demand were high enough then InterfaceFLOR would consider these options. The primary markets that InterfaceFLOR is targeting with these products are commercial office, government, healthcare, hospitality, end-use retail and education. They are also exploring other non-traditional end-uses in the transportation industry such as aircraft and cruise ships.

Market Potential
The 10-year long-term goal for InterfaceFLOR is to increase its market share of the i2 product line in the carpet industry. InterfaceFLOR also hopes to make the i2 carpet line the main product the company sells.
Constraints
A major constraint facing the company is its own goal of achieving a zero environmental footprint by 2020, though the company views this as an opportunity, not a constraint. Another constraint facing InterfaceFLOR is the need to educate the dealers and distributors that it primarily sells to. These distributors are not fully aware of the cost benefits that are available to them with this new technology. Financing for the i2 line was not difficult to obtain since the company was already well established and had other successful product lines.

Based on Interview with:

Scott W. Landa
Vice President Business Development

http://www.interfaceflor.com/
Joinlox Pty Ltd

Joinlox is an Australian company that has developed a technology to connect or join a wide variety of objects, including boxes, pipes, walls, and bridges. It can be used in a large range of applications involving packaging, storage, transportation, and logistics.

Product Inspiration
The product arose from Mr. Cameron, the inventor of the Biolytix System, who was searching for a cost-effective means to ship his waste treatment tanks. Plastics engineers had been skeptical about his efforts to find a solution. Mr. Cameron, however, had observed the ability of clams and other shellfish to forge a tight seal on rocks using only thin high tensile bysus threads. This ability inspired the Joinlox Technology, which is a spring-loaded joint formed by wedging together parts with inter-meshing pieces or hooks.

Advantages over Existing Products
The Joinlox solution and products have major cost advantages in terms of manufacturing, transportation, assembly, and servicing. Existing facilities for injection molding, pressing, laser cutting, and other processes can be used, but production costs are lower and few materials are required. Transportation costs can be dramatically lower. Items can be shipped, offloaded, and then reassembled as required. Packaging can then be flat-packed and returned for reuse. For example, the cost of shipping plastic drums from Malaysia to Australia can be reduced from about $35.00 per drum to $4.50 per drum.

Labor requirements for unpacking and assembly of various shipped items are generally substantially lower with the Joinlox solution than with typical methods. Because welding and other specialized skills are not required and assembly times are typically fairly short, labor cost savings can be significant. Servicing can also be done on-site with minimal disassembling and reassembly requirements.

Sales, Profits, and Future Plans
The company has only been in existence since 2008, but it has already developed significant sales opportunities. Joinlox this year signed a global licensing agreement with Xstrata Technologies to use in Xstrata’s new ZippaTank line of modular minerals processing tanks.

Joinlox plans to license its technology widely throughout the world to maximize the spread of usage across geographic areas and sectors.

Market Potential
The Joinlox technology has major applications for a wide range of industries, including food processing, water utilities, mining, and automotive. The cost savings for shipping bulky cargos could be particularly compelling.
**Constraints**

The major constraint will involve the dissemination of this simple and cost-efficient technology for various applications in firms where resistance to changes in methods or supply chains can sometimes be formidable.

Based on Interview with:

Dean Cameron  
Technical Director  
Joinlox Pty Ltd  

www.joinlox.com
PAX Scientific

PAX Scientific is an engineering firm that designs “fluid handling devices,” which include fans, mixers, pumps, turbines, and propellers. PAX Scientific was founded in 1997 with the intention of licensing the products that it develops to manufacturers.

PAX Scientific uses geometrics found in nature to help “grow” a digital model that can be fined tuned for the necessary application. PAX has come up with designs for devices that in most applications are either more efficient, have reduced drag, use less materials, or are cheaper to produce.

Product Inspiration
The product that has had the most commercial success to date for PAX is the water mixer. The inspiration for the PAX water mixer came from the way that seaweed found in the ocean forms a spiral.

Advantages Over Existing Products
The mixer is used in large municipal water storage tanks up to 20 million gallons in size. The impeller design provides top-to-bottom mixing in the tank that prevents nitrification, stratification, and the freezing over of water in colder climates. This makes the water less susceptible to contamination. The mixer’s unique design reduces the use of materials and therefore weighs less and consumes less electricity. It also greatly reduces the amount of chemicals that are added to the water to maintain purification.

The mixer can be powered by a solar unit that could be located on top of the water tank. This would allow the unit to be completely self sustaining and require less maintenance.

Sales, Profits, and Future Plans
Sales for the PAX water system have been doubling every year since it was introduced to the market. The success has been largely due to the fact that a specific market problem was realized; then, a solution was designed to solve the problem. Since going “green” and reducing carbon footprints has become more important, PAX has seen more interest in its designs.

Market Potential
Since PAX Scientific is an engineering firm, it has already come up with designs that are either more efficient, more productive or less expensive to manufacture. A wide range of applications is possible, including fans, mixers, pumps, turbines, heat exchangers, ducts, and propellers. The Department of Energy and other state and federal departments have granted PAX over $8 million in research funding that will help PAX further its technology and bring it closer to production-ready designs.

Constraints
PAX has experienced a difficult time licensing some of its designs to manufacturing partners. The firm has come up with designs that are beneficial in many ways, but the incentive for customers to buy the license and put the investment into a facility to produce a product to bring to
the market has not been great enough given manufacturing cycles and corporate inertia. Therefore, the company chose to build and sell certain products, such as the PAX water mixer, directly to end users. Now, with many more companies looking for ways to reduce energy consumption and become more conservation minded, PAX is in an ideal position to meet those needs.

Based on Interview with:

Francesca Bertone  
Chief Operating Officer, PAX Scientific

Laura Bertone  
Chief Financial Officer, PAX Scientific

http://www.paxscientific.com/
QUALCOMM MEMS Technologies

In the late 1980s a company named Iridigm developed a display technology combining thin film optics and MEMS that creates color by making light interfere with itself. This is commonly seen in nature. Typical displays like LCD or OLED don’t use pigments or inks (that would be print). They use light passed through filters, polarizers, and liquid crystal (for LCD) or chemicals that illuminate when charged with a current (OLED). In either case, the difference is reflected light versus created/emissive light.

The motivation was a realization of the possibility of what could be achieved when these efficiencies and technology benefits were applied to a display application: visibility outdoors, low power, and beautiful iridescent color.

Qualcomm acquired Iridigm in 2004 and formed Qualcomm MEMS Technologies (QMT) Inc., a wholly owned subsidiary. This division is responsible for developing and bringing to market Mirasol® displays. Mirasol is the first low power, color, video capable, and sunlight viewable display based on Interferometric Modulation (IMOD) technology. This unique approach to display technology is inspired by nature and based on the same phenomenon that makes a butterfly’s wings shimmer in sunlight.

Since the acquisition, QMT built a MEMS research lab in San Jose and a manufacturing facility in Taiwan. QMT will soon begin shipping the mirasol display units to partners. While QMT has commercialized a number of early generation devices, the next generation commercial (and color) version of the technology will be in a 5.7” video-capable display for an e-reader/tablet like device.

Product Inspiration
The technology was inspired by the way colors are created in butterflies. The color is generated when specific wavelengths are reflected off the surface of the butterfly and are visible to the human eye. The colors that are reflected are based on the microscopic structure of the butterfly wing. There is no pigment or ink, which means that the colors will not fade or lose their brilliance over time.

Advantages Over Existing Products
The product is unique in that this method allows it to be clearly seen in full sunlight. Battery units in devices that use the mirasol display typically last three times the duration of a comparable device with an LCD. With the savings in battery power, mobile devices are much more versatile and efficient.

Sales, Profits, and Future Plans
Qualcomm is very committed to this technology. Qualcomm plans to initially sell the display to manufacturers of e-reader devices and intends to expand into other mobile device applications soon after.

Market Potential
The mirasol display has the potential to be used in almost any mobile device that requires a display. That could include cell phones, e-readers, tablets, notebook computers, GPS units, and cameras.
**Constraints**
The main constraints that Qualcomm faces are in the fabrication process. Ramping up high volume production simply takes time.

Based on two separate interviews with:

Cheryl Goodman  
Director of Marketing for Qualcomm MEMS Technologies, Inc.

Rick Vingerelli  
VP Qualcomm MEMS Technologies, Inc.
STO Corp.

STO is a corporation based in Atlanta, Georgia that produces cladding, coating, and restoration systems. The Lotusan technology was discovered by a German scientist in the 1990s and was produced and sold in Germany before the technology was used in the United States by STO Corp. in 2005.

**Product Inspiration**
The main inspiration behind the Lotusan coating came from the lotus leaf. The lotus leaf has a microscopic structure that reduces the actual surface area that is in contact with water. This forces water to bead and attract dirt and other particles that are on the leaf. Simulating these properties, the Lotusan product allows dirt to accumulate and run off the painted surface with the beaded water.

**Advantages Over Existing Products**
The Lotusan product is a coating and a finish that can be rolled or sprayed on. It is meant for non-metal surfaces in outdoor environments. The product is designed to be used in locations where large amounts of rain fall and can then rinse the building walls on a regular basis. The product has had the most success on the East coast, specifically Florida as well as the Northwest.

**Sales, Profits, and Future Plans**
The cost of production is only slightly higher than conventional coatings, which translates to a pricing premium of only 10-15%. Part of the advantage of using this coating is its longevity; it will last 4 to 8 years, where comparable products will only last 3-4 years. The reduced frequency of required repainting produces significant cost savings. Buildings that have been painted with the Lotusan coating that are being sold have appreciated in value.

STO’s primary market is the commercial sector, which is currently seeing growth in renovation projects. Since introducing the Lotusan product in the U.S. in 2005, sales have doubled every year. There is no direct competitor in the U.S. market for this technology and, as a result, market share is growing rapidly as well.

**Market Potential**
At this stage, STO is not considering licensing, but it would be willing to if demand were high enough. In 20 years STO hopes to have 50% of the market with its Lotusan coating.

**Constraints**
One of the constraints that STO is facing includes pricing. Since the pricing advantage is not realized until a reapplication is avoided many customers are not willing to pay the premium for the Lotusan product. Another related constraint has been the communication and marketing of the product. Resistance to change and new products is sizable. Not enough people know about the product and they are less willing to pay more for something that does not have as prominent a brand as other conventional coatings.

Based on Interview with:

Michael Sweeney
LEED Green Associate Media Manager
Swarm Intelligence

An idea that is gaining traction with regard to biomimicry has been the implementation of swarm behavior. In nature, these would include ant colonies, bee hives and schools of fish. Swarm behavior has a huge potential significance for computer applications as well as robotics. This field of study has become known as Swarm intelligence.

Swarm Intelligence is a form of Artificial Intelligence where the individuals in a swarm do not think independently but act together to accomplish one common goal. They organize themselves but do not have a central leader. They simply communicate with each other about information around them.

Since individuals in swarms do not think (they simply react to their peers and the environment around them), their behavior can be analyzed and predicted using an algorithm. Some of these algorithms are being incorporated in computer software to help solve complex problems that firms face every day. Applications to this idea have been implemented in computer programs to solve complex problems. Firms that depend on their delivery systems to maintain efficiency have already started using software with great success. AntOptima is one company that has developed such a program. Software programs such as these can increase efficiency dramatically. In the case of a delivery service, less fuel would be consumed and time-sensitive items could be delivered sooner.

Robotics is another application where this technology could have a huge impact. Dr. Dorigo of the Free University of Brussels has been working on the “Swarmanoid” project that will use three different types of robots: hand bots, foot bots, and eye bots. These robots will cooperate with each other to accomplish one common goal together. Other organizations are developing robots that can self assemble to form a single unit that can accomplish tasks that would be impossible for a single robot. Once further development has taken place, these robots could be sent into environments that would be dangerous for humans, like disaster zones with collapsed buildings or other unstable environments.

Robots are already being used with remote technology for manufacturing, the military, and others. But Swarm Intelligence lets the robot make its own decisions and would not require an operator to oversee each individual unit.

Technology is advancing rapidly but these robots are not advanced to the point of being more efficient than a human yet. Although the cost of these systems would be less than a more complex single robot it is still a constraint at this point. This Biomimicry inspired field promises to make practical application of artificial intelligence much more attainable in the not too distant future.

Sources:

“Riders on a Swarm” Artificial Intelligence, The Economist. Aug 12 2010  
www.swarmanoid.org
The applications of biomimicry to commercial use could transform large slices of various industries over the next 15 years. In 2009 more than 900 patents containing the word “biomimicry” were submitted to the U.S. Patent and Trademark Office (USPTO) data base. New materials, products, designs, processes, and systems based on emulating the natural environment could all be deployed. Some of the potential industry impacts were suggested by the case studies discussed in the previous chapter. Chart 1 shows estimates of the total market shares for various industry groups, defined in terms of sales, that could be impacted by 2025.

**Mining, Utilities, and Construction**
New techniques for drilling, exploration, and extraction could affect approximately 3% of the oil, gas, and mining industry in 15 years. Ten percent of the utilities sector could be impacted, with new products and processes used for various segments, ranging from energy generation to water treatment. Construction could also be significantly impacted by about 5% by 2025. For example, studying the structure of termite mounds has inspired the construction of buildings with major enhancement in the efficiency of heating and cooling systems.

**Manufacturing**
Numerous manufactured items could see changes or substitutes with new products requiring fewer raw materials, reduced energy, and less waste while also accomplishing more tasks at lower costs. Many of the materials and compounds found in nature could cause biomimicry to influence around 10% of the textile and 15% of the chemical (including pharmaceutical) industries by 2025. These new products also could result in dramatic reductions in product toxicity.

New, more aerodynamic and energy efficient designs could transform up to 10% of the transportation equipment industry (including cars, trucks, planes, and boats). The example of enhanced display screens with better energy efficiency developed by Qualcomm MEMS Technologies, cited in the prior chapter, illustrates some of the major changes that could take place in electronics manufacturing.

**Warehousing, Storage, and Waste Management**
Improved methods of refrigeration, such as suggested by innovations by Biomatrica in the previous section, plus other naturally-inspired products and systems could affect up to 10% of the warehousing and storage industry by 2025. More efficient transportation, illustrated by the products of Joinlox, could impact some 3% of the transportation services sector. Waste management could see 15% of its industry transformed if some of the “closed loop” systems of nature are replicated or simulated.

**Information Technology**
The research into Swarm Intelligence discussed in the last section suggests the significant impact on information technology that biomimicry applications could achieve. An estimated 5% of the industry could be affected 15 years from now.

**Architectural, Engineering, and Related Services**
Biomimicry-inspired designs can be expected to increasingly influence architecture and engineering in the years ahead, impacting 10% of the sector’s sales within 15 years. The U.S. Defense Sciences Office (DSO) and its Defense Advanced Research Projects Agency (DARPA) are charged with identifying and promoting major new technologies that can
revolutionize military capabilities. Current examples of these biomimetic inspired defense applications include the Neovision2, which involves integration of recent developments in the understanding of the mammalian visual pathway with advances in microelectronics, to increased situational awareness for the warfighter. Another application is the PowerSwim program that explores new concepts in swimming propulsion based upon the oscillating foil approach to swimming exhibited by many fish and aquatic birds. This approach is more than 80% efficient in the conversion of human motion to forward propulsion. These programs and others have led biomimicry to be targeted as a “strategic thrust” to develop new materials, platforms, and systems to elevate our defense preparedness.11

The industries that could be impacted in significant ways account for close to one quarter of U.S. gross domestic product (GDP).
V. POTENTIAL ECONOMIC IMPACT ON U.S. AND GLOBAL ECONOMIES

Biomimicry’s Potential Impact on GDP and Employment

Biomimicry’s influence on various large industries will translate into a sizable impact on total U.S. gross domestic product (GDP) and employment.

GDP Contributions
Using estimates of the market shares developed in the prior chapter for various sectors and projections of total output over the next 15 years, biomimicry-based goods and services could account for approximately $300 billion of U.S. GDP by 2025. To put this figure in perspective, this year U.S. companies will spend an estimated $282 billion on computer software. While initially small relative to a total U.S. economy that is estimated to generate approximately $21 trillion of goods and services in 2025, biomimicry will still have a highly significant impact that can be expected to continue to grow rapidly as knowledge and the field expand.

Mitigating Economic Losses
Biomimicry could also help reduce the economic losses from the depletion of the nation’s energy, mineral, and forest resources and from CO2 pollution. Assuming that such losses would remain close to the 2.36% of U.S. Gross National Income estimated for 2008 by the World Bank, such costs would amount to about $514 billion by 2025 (in 2010 dollars). The capability of biomimicry to shrink these costs by about ten percent could yield an additional impact on the nation’s GDP of about $50 billion.

Job Effects
The number of jobs yielded by biomimicry-linked goods and services could also be substantial by 2025. Based on the market shares estimated in Chapter 3 and the related employment coefficients, biomimicry could account for approximately 1.6 million jobs.

CHART 2
Biomimicry's Estimated Impact on U.S. GDP, 2025
Billions of dollars

<table>
<thead>
<tr>
<th>Increased Output</th>
<th>Reduced Resource Depletion and Pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>50</td>
</tr>
</tbody>
</table>

Source: FBEI
U.S. jobs by 2025. While some of these positions would represent substitutes for older products and technologies, many others would represent whole new markets for additional and improved goods and services.

Biomimicry could also help the U.S. capitalize on its greatest potential comparative advantage—technology and knowledge-based industries and clusters.

**Global Impact**
Biomimicry could also spread rapidly on a global scale. Companies in the U.K., continental Europe, Africa, and Australia are already active in the field. Assuming a smaller GDP share of 1.0% than the 1.4% calculated for the U.S. (with lesser shares among less technically advanced nations), **biomimicry could affect about $1.0 trillion of the world’s total output by 2025.**

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Biomimicry holds the potential to attract sizable capital inflows, driven by the prospects of rapid growth and high rates of return. The motivation will not come just from the focus on green products and sustainable systems. The ability to improve efficiency, create products that perform better than those now available, and sell at lower costs than competing items all speak to the value of biomimicry.

**Returns on Investment**
Although firms are reluctant to say much about results for individual products, returns of 40-50% on new biomimicry-inspired products appear readily achievable. Annual sales growth rates of 75% to 100% in the initial years can often be expected. The economies of scale and advantages of dominant market share should yield advantages as production is ramped up. Significant licensing fees also may be earned.

**Capital Flows**
Venture capital could flow into biomimicry at a pace at least equal to that of biotech. Venture capital funding for biotech is estimated at about $4.5 billion in the U.S. for 2010. As credit markets heal, venture capital should start to rise significantly over the coming decade after slumping in 2008 and 2009. Compared to the keen interest now expressed for “green tech”, biomimicry could offer less risk since it is much less reliant on possibly varying regulations (e.g., mandates for alternative energy sources or reduced pollution) as well as fluctuations in subsidies.

Returns for biomimicry-based products could be highly variable, especially in markets where distribution channels may work against new products. Still, investors looking for new ideas and themes could direct increasing amounts of capital to the field as it becomes better known.

**CHART 3**
U.S. Venture Capital in Biotech Resumes Rise
Billions of dollars

Source: Pricewaterhouse Coopers / National Venture Capital Association; FBEI
**Investment Vehicles**
Investors could invest in biomimicry in one of two fundamental ways. They could invest in research, consulting firms or organizations scanning nature for possible ideas that can then be used for commercial application. Alternatively, they could invest in firms or groups of firms that have biomimicry-inspired goods and/or services.

Investment options incorporating the biomimicry theme could involve: (1) stocks of individual firms; (2) mutual funds of several such firms; and (3) exchange traded funds (ETFs), involving an index which would track the performance of a number of companies engaged in biomimicry. While individual stock analysts, mutual fund managers, equity index designers, and the investing public will need to become much more knowledgeable about biomimicry, the potential for above-average returns could cause this learning curve to be climbed quickly.

**Investment Risks**
The bursting of the “dot-com” bubble and the failure of nanotechnology to gain traction suggest the risks that an investment theme of biomimicry could encounter. Yet, the potential for diversification over a wide range of firms with different types of products and solutions suggests a significant benefit for this type of investment in addition to sizable potential returns.
VII. CASE FOR MAKING SAN DIEGO THE BIOMIMICRY HUB, WITH THE ZOO AS THE FOCAL POINT

San Diego as a Biomimicry Hub

The translation of concepts of nature to commercial applications, as discussed earlier in this report, can take two routes: Biologists and other scientists can scan the natural environment looking for useful applications in the economy or companies and other organizations can seek solutions to specific problems and focus on nature to find answers. While individual firms may support R&D efforts dedicated to biomimicry, a larger concentration of trained naturalists, biologists, scientists, and other professionals could form a crucial hub for driving answers from the environment to the economy.

Four primary elements would appear to be keys to creating a biomimicry hub. The San Diego region seems well positioned to become such a hub.

**Intellect**

Human capital is clearly critical for a biomimicry hub in terms of the intellectual resources and scientific methods required. San Diego is well suited in this field, with an important set of universities: University of California, San Diego (UCSD); San Diego State University (SDSU); University of San Diego (USD); Point Loma Nazarene University (PLNU); and others. The region has 21 Nobel laureates.\(^\text{16}\) The San Diego region has 37,000 employees engaged in scientific research and development.\(^\text{17}\)
Capital
San Diego has significant access to venture capital, with the region raising around $2 billion in both the peak years of 2000 and 2007. The recession has dampened some of the recent inflow, but the region should attract venture capital close to $1 billion in 2010. Venture capital has been drawn to the area’s various technology start-ups and has funded many of the region’s 600 cleantech and 550 biomedical companies.

Entrepreneurs
The San Diego regional economy is based on a large, granular network of small firms. In the City of San Diego, there are more than 70,000 small businesses, representing about 92% of the total number of firms operating in the City.

The outstanding public and private universities in San Diego currently offer excellent entrepreneurial programs at both the undergraduate and graduate levels, and these offer the potential for an efficient and expedited capacity for entrepreneurial innovation, application, and technology transfer for biomimicry in the San Diego region. In addition to entrepreneur curricula in the fields of sustainability, biology and related fields applicable to biomimicry, San Diego State University’s Entrepreneurial Management Center, University of California San Diego’s Entrepreneurial Challenge, Point Loma Nazarene University’s Entrepreneur Enrichment Program and other co-curricular programs and resources are just a few examples of what already exist. These could be powerful strategic entrepreneurial assets that could be harnessed to further establish San Diego as a biomimicry hub.

In 2008, I.B.M. released its 2008 Global CEO Study titled “The Enterprise of the Future”. Across industries, sectors and regions, this emerging model of enterprise identified by I.B.M. appears to be designed for the field of biomimicry, as seen in Chart 5. The San Diego region is thus positioned well to serve the model of the “New Economy”. This is a model that eschews the old hierarchical structure of top-down decision making in favor of smaller, flatter and more nimble organizations focused on innovation and creativity.

**Chart 5**

**The Enterprise of the Future**

- **Hungry for Change**
- **Innovative Beyond Customer Imagination**
- **Globally Integrated**
- **Disruptive By Nature**
- **Genuine, Not Just Generous**

Source: IBM Global CEO Study, 2008
Collaboration
Chip Heath, co-author of Made to Stick: Why Some Ideas Survive and Others Die, emphasized in a speech at the 2009 Biomimicry Conference in San Diego the critical importance of collaboration to the establishment of a biomimicry hub. He noted the role and value of informal Friday night meetings as a critical link in the formation of San Diego’s important biotech sector. The willingness of private and public organizations, including academic institutions, seems to be very much a part of San Diego’s culture. Organizations such as CONNECT®, a 25-year old group that has helped spawn the growth of entrepreneurship in the region, is one example. The endorsement of collaborative efforts in San Diego would serve the needs of a biomimicry hub well.

Economic Impact of a Biomimicry Hub on San Diego
A cluster of 1,000 biologists, naturalists and other scientists could form in San Diego over the next 15 years, employed in academic settings, consulting firms, or nonprofit organizations. Such a cluster could have a substantial impact on the region.

By 2025, the addition of this core group would generate both direct and indirect effects on the region’s economy. As discussed in Chapter II, the various multiplier or ripple effects were modeled using a dynamic input-output model (IMPLAN® Version 3.0). The presence of the 1,000 core biomimicry team would generate significant direct effects on output and total personal income in the region. In addition, there would be substantial indirect or secondary effects. These would include (a) the impact of various personnel hired, materials purchased, and facilities constructed to support the cluster and (b) the effects on consumer spending by all of the personnel employed either directly or indirectly.

CHART 6
Biomimicry Multipliers Are Strong
Estimates for San Diego’s Biomimicry Cluster, 2025

Source: FBEI
Modeling all of these effects, the cluster could add $325 million to San Diego’s annual gross regional product and $162 million in total personal income (both figures in 2010 dollars) in 15 years. As a comparison, 2009 direct delegate spending for the 248 conventions held at the San Diego Convention Center was approximately $500 million. Further, the biomimicry cluster would also initially generate a total of over 2,100 new jobs. By comparison, a total of just 2,800 jobs was created across all sectors in San Diego County during the first nine months of 2009.

Multiplier coefficients summarize the relationship between the direct effects this initial core group of researchers would have on the economy and the total impact (due to the hiring of various support workers and the spending by all of the new employees). The relatively high pay of the core group of 1,000 professions (average $109,000) results in comparatively high multipliers. For example in the case of employment, the multiplier is 2.11, which means that more than one additional extra job would be created for each of the core group.

These figures represent just the tip of the iceberg. If firms produced resulting products in San Diego, significant numbers of other jobs would also be created over time, further adding to the region’s output and total incomes.

Biomimicry could also be expected to have a much greater impact on the region than indicated by input-output models of output, income, and employment. Applications of biomimicry solutions could enhance the competitiveness of many industries in the
region, enabling them to grow further.

A biomimicry cluster also has the potential to grow very rapidly. By example, Chart 7 shows how employment related to the Internet (search engines, smart phones, and other web applications) quadrupled in just 15 years in Silicon Valley (Santa Clara County, California). **Biomimicry could be the next major driver of San Diego’s economy, complementing such important clusters as biotech and cleantech.**

**The San Diego Zoo as the Fulcrum for a Biomimicry Hub**

With its worldwide reputation, the San Diego Zoo, administered by San Diego Zoo Global, would appear to be in an excellent position to be the leader of a **biomimicry hub.** The two zoo properties in San Diego County (the San Diego Zoo and San Diego Zoo Safari Park) house nearly 8,000 animals representing 840 species.\(^{25}\) In addition to its vast animal collection, the San Diego Zoo is an accredited botanical garden with close to 40,000 plant species. San Diego Zoo Global has been heavily involved in animal research and preservation as well as conservation through its Institute for Conservation Research, which employs 180 researchers with expertise ranging from the molecular to the ecological landscape levels. San Diego Zoo Global also has a strong education program, involving 400,000 participants.\(^{26}\)

The San Diego Zoo is a primary driver of collaborative efforts in the biomimicry field. Its newly established council, the Biomimicry BRIDGE (Business, Research, Innovation, Development, Governance and Education), is playing a key role in fostering working relationships between the region’s various universities and leaders in the business and non-profit sectors.

The Zoo is currently the only facilities-based provider of biomimicry services in the world. The Zoo plans to build the first biomimicry research and education network to drive major biomimicry research and commercial applications.

**Biomimicry is clearly a major emerging area with huge potential. San Diego and the San Diego Zoo appear well suited to be major catalysts and play key roles in the sector’s development.**
Footnotes


3 Francesca Romei, Leonardo Da Vinci, (Minneapolis: The Oliver Press, 2008) 56.


12 Based on data from U.S. Bureau of Economic Analysis and FBEI estimates.


18 PricewaterhouseCoopers/National Venture Capital Association MoneyTree™ Report; estimate from FBEI.


26 “Georgeanne Irvine, Associate Director of Development Communications for the San Diego Zoo and San Diego Zoo Safari Park, 13 Oct. 2010.
References


Green Tech: Environmental Technology Atlas for Germany. Munchen: Verlag Franz Wahlen GmbH.


