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Ecomimesis: A Sustainable Design Paradigm Ecomimetic Solutions to Ecosystem Homeostatic Imbalances

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Abstract
In the last fifty years empirical evidence has shown that climate change and environmental degradation are largely the results of increased world population, economic development, and changes in cultural and social norms. During this time period, there have been over 500 international agreements to stem the deterioration of the land, sea, and air. Despite all the evidence and treaties, however, climate change is getting worse with ever increasing air and water pollution, soil and ocean degradation, and ecosystem decline. Based on extensive research, this paper provides an analysis of the negative anthropogenic impact on the ecosystem and proposes a new design solution to mitigate and repair environmental degradation: ecomimesis. It is different from other design models because it incorporates all the major components of the ecosystem and designs built and un-built ecosystems to minimize adverse effects and help stabilize the environment. Using nature as its template, econmimesis conserves, repairs, and improves existing ecosystems. This article uses homeostasis as an example of possible ecomimetic designs. It is described with emphasis on the damage inflicted by anthropogenic actions. It primary focus is to propose ecomimetic solutions to repair and mitigate the damage in both the built and unbuilt ecosystems. While there is no single solution to the environmental challenge, ecomimesis represents a comprehensive design paradigm that will slow and correct environmental decline. Ecomimesis represents an innovative and broad change in the way we design and use our ecosystems in order to support an ever growing world population.

Keywords: Climate change, Ecomimesis, Ecosystems, Green Infrastructure, Homeostasis, Sustainable design

1. Introduction

Concern about climate change is not new. For the last fifty years scientific research has shown that climate change and environmental degradation have been the result of a combination of factors: increased world population, economic development and industrialization, and changes in social and cultural norms. Although these fundamental components were highlighted in Gro Harlem Bruntland's report in 1987 for the United Nations, *Our Common Future,* which warned of the urgency to protect the world's environment and natural resources, the pace of economic growth and depletion of natural resources continues to gain momentum without regard to the health of the environment and the world population.

During this time period there have been over 500 international agreements to stem the deterioration of the land, sea, and air. Two comprehensive global plans were adopted in 2015. The first was the UN Sustainable Development 15 Year Plan, which calls for $3 trillion annual investment, an amount that will be almost impossible to meet through

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private and public sources. The second was the United Nations Framework Convention on Climate Change signed by 194 nations. Like other treaties, however, there are no binding commitments, and there remains a lack of enforcement mechanisms. Unless there are commitments and enforcement, this treaty will be mostly symbolic.

Another United Nations sponsored study, *The Millennium Ecosystem Assessment* conducted by 1,360 experts from 95 countries from 2001-2005, assessed the condition of ecosystems and human well-being. It concluded, "Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber, and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth."

The increased awareness of the damage human action has inflicted on the environment provides opportunities to re-emphasize the values of the natural ecosystems and the benefits they provide. The responses have included innumerable proposals to deal with the environmental crisis. Many focus on specific aspects of the environment such as energy, carbon, or greenhouse gases. The one addressed in this paper focuses on the entire ecosystem: ecomimesis.

Ecomimesis is a design model that uses Earth as a template. Its goal is to design a human community that does not interfere with nature's inherent ability to sustain life in the Earth's biosphere and minimizes disruptions to nature's ecosystems. Its primary goals are to re-establish ecosystem stability, preserve regional biodiversity and habitats through continuity of functions and connectivity, and conserve, repair, and improve existing ecosystems.

Ecomimesis design can be applied to both built and un-built environments.

In creating a built environment within nature's ecosystem, ecomimesis mimics the ecological cycles and environmental conditions so that built structures, communities, or society impose minimal breakdowns of the natural balance of the system. All aspects of the built environment – site use,

architectural and landscape designs and master planning, product designs, material selection and use, types of energy systems, and waste generation, for example – are incorporated into designs so that the resulting physical structures duplicate the properties, structure, functions and processes of ecosystems in nature and are systematically integrated physically and spatially with the existing ecosystem. The creation of new eco-sensitive man-made structures can also assist in reclamation efforts to restore cities and environments to a more congenial state with the natural ecosystem.

In planning and creating an un-built environment, the same ecomimetic principles apply. It is critical to protect the un-built environment and its ecosystems by designing and developing a green infrastructure to protect against natural disasters, reclaim damaged ecosystems, maintain biodiverse habitats, and create natural carbon stores and sinks.

Some of the benefits would include strengthening biodiversity, purifying water and bodies of water, reducing polluting emissions, reducing waste, stabilizing biogeochemical cycles and the nutrients in the soil, using land more efficiently, and restoring damage to ecosystems. (Yeang, *Ecodesign Manual,*45-58).

2. Ecosystem

Every ecosystem is composed of two components: biotic which includes plants, animals, and micro organisms and abiotic which includes minerals, air, water, soil, sun, and basic elements of the environment. Abiotic and biotic elements form a complex integrated unit which is controlled by external factors, like climate, temperature, rainfall, geological material, mineral nutrients, topography, water sources and retention, and internal factors which include processes (photosynthesis, energy flow, decomposition and nutrient cycling), disturbances, and changes that affect the composition and stability of the ecosystem.

The size of an ecosystem, known as its carrying capacity, is determined by food availability, water, rates of biogeochemical recycling, resource supply, climate, functional groups of organisms, energy flow, land, and intrinsic and extrinsic disturbances. Its stability, known as ecosystem equilibrium, is dependent on its ability to survive natural disasters like floods and hurricanes, land erosion, desertification caused by heat and drought, and degradation of the soil. When an ecosystem is in equilibrium, it is self sufficient and self regulating.

The fundamental structures and functions of ecosystems include biodiversity, spatial efficiency, ecological cybernetics, homeostasis, succession, energy, and biogeochemical cycles. Each element is necessary for the continuity and balance of an ecosystem. If any part is disrupted from its natural ability to adapt and adjust, other parts will also be affected.

Researchers estimate that approximately 40-50% of the land surface of Earth has been degraded by anthropogenic activities, 66% of marine fisheries have been over fished, carbon dioxide in the atmosphere has increased more than 30% since the beginning of industrialization, and almost 25% of the earth's bird population are now extinct. (Vitousek et al., 277: 494-499).

The following discussion of the disruption to an ecosystem's homeostatic function is representative of the degradation caused by human activities and disruption of the ecosystem's equilibrium. The proposed ecomimetic solutions are examples of what can be done without further harming the natural ecosystems and, hopefully, illustrates the potential of ecomimesis to repair damaged and degraded environments and return ecosystems to their natural equilibrium.

3. Homeostasis

An **e**cosystem's homeostasis is the dynamic equilibrium of ecosystem components in response to changing environmental conditions. Changes in existing biotic and abiotic elements and additions of new or foreign ones change the composition and stability of an ecosystem. When the symbiotic balance of interconnection and interdependence among ecosystem components becomes disordered and unbalanced, ecosystem succession results in a change in species composition and community structure because of the changes in the physical environment. (Biology Dept., University of Illinois, (2009); Biology Dept., University of Hamburg, (2003); Drudy et al., (1973), 331-368).

Largely sustained by factors that maintain populations within the carrying capacity of the environment, homeostatic equilibrium is established through the exchange of new information
(cybernetics) about changes in biotic and abiotic conditions and interlocking feedback loops which can reduce entropy of ecosystem components. (Odum, (1969); Patten and Odum, (1981) 886-895). The time it takes for a system's return to homeostatic balance depends entirely on the length and severity of the interruptions of the ecosystem. (Odum, (1969); Smith, 613, 619, 627). For example, the biotic information network on the semiannual great migrations in Africa depends on grazing, population density, attack-avoidance, prey abundance, natural selection, overcrowding, and nutrient cycling which can provide information (feedback) about overshoots and destructive oscillations. These conditions regulate the health and stability of an ecosystem community and determine its stability. (Volkov et al., 2006).
Although ecosystems have a strong ability to resist limited changes resulting from human activities, the extent of these activities can overwhelm the recuperative capacity of natural systems. As has been documented, the human impact on abiotic components has increased toxicity, global warming, increased ozone, increased carbon dioxide, increased greenhouse gases, fragmentation and degradation of biogeochemical cycles in the soil, water, and hydrologic cycles. In other words, human activities have been largely responsible for changes in climate, environmental pollution, and interference with normal cycling and flows of energy in ecosystems.

4. Human impact on ecosystem homeostasis

In addition to natural disturbances such as fire, floods, and drought, homeostasis is altered by anthropogenic activities that damage the atmosphere and disrupt cycles and abiotic and biotic components. The alteration of natural resources or polluting of the soil and air may change the structure and composition of biodiversity by eliminating certain species from that particular ecosystem.
The Green Revolution, which was designed to increase crop production in underdeveloped countries, unwittingly contributed to the negative effects of monoculture and severe soil damage. (Gillis, 2009). In addition to new crop hybrids suited for various climates, heavy use of chemical fertilizers, herbicides, and insecticides in both developed and underdeveloped countries has disrupted the soil's biogeochemical cycles (carbon, oxygen, nitrogen, sulfur, and water) and edaphic factors. (Cal State, 2009). Among the most serious changes have been: 1**)** increased susceptibility to diseases; 2) low tolerance to stresses of drought or temperature; 3) reduced resistance to insects; 4) famines resulting from crop failures; 5) decreased soil fertility and increased soil erosion; 6) increased habitat for pest species and reduced habitat for beneficial species. The same monoculture that disturbs homeostasis also has a negative impact on an ecosystem that leads to succession. (North Carolina General Assembly,1996).
A 2016 study found that climate change is making it more difficult to grow staple crops in sub-Saharan Africa, with maize, beans, and bananas most at risk. CGIAR Research Program on Climate Change, Agriculture, and Food Security scientists found that 40% of the maize growing areas will need to be transformed with either new types of crops or

abandonment of crop farming. The heat and drought conditions in this region of Africa make it necessary to replace the threatened crops with more
heat tolerant crops within the next ten years. Adaptation to climate change has become urgent in high risk countries like Guinea, Zambia, Senegal, Burkina Faso, Niger, Ghana, Namibia, Botswana, Zimbabwe, and Tanzania. The current situation affects not only the food supplies for these countries but also their economic markets and social changes. (Rowling, 2016).

Polluting factors like agricultural runoff, sewage, paper and textile mills and food processing have stimulated oxygen consumption in water by decomposers, like aerobic bacteria and algae. As biochemical oxygen demand (BOD) in bodies of water increases through the oxygen consumed in the
decomposition process, other aquatic organisms are robbed of the oxygen they need to live. The resulting eutrophication increases algal blooms and produces reduced water clarity, periods of hypoxia, loss of seagrass beds and coral reefs, and ecological changes in food webs.

Indisputably, by burning coal, oil, and natural gas, carbon dioxide is added to the atmosphere much faster than the atmosphere can absorb it. Burning forests to create agricultural land also converts organic carbon to carbon dioxide gas. While oceans and land plants absorb part of the carbon dioxide, the rest is added to the atmosphere.

The sulfur, nitrogen, phosphorous, and oxygen, hydrologic, and carbon cycles have all added elements to croplands as fertilizers that have resulted in the elimination of indigenous vegetation, destruction of wetlands, eutrophication, soil erosion, and alteration of water quality. (Carnegie Mellon; Environmental Literary Council; Houghton; International Fertilizer Industry Association; H T Odum.)

Overuse or depletion of natural resources like overgrazing and pasture degradation, over fishing and replacement of commercially valuable fish with trash fish, and forest depletion through over harvesting or fires have contributed to instability of ecosystem homeostasis.

Many designed solutions to integrate man-made ecosystems with natural processes of succession have actually been harmful to natural ecosystems. In dealing with rural and urban ecosystems, for example, human designers have ignored the natural process of ecological succession, preferring their own intensive inputs- built structures and infrastructures, intense use of artificial fertilizer- to maintain farmlands and cities and to develop urban sprawl haphazardly. These practices, in essence, are examples of human environmental succession in industrialized countries.

Conversely, in economically underdeveloped countries with long standing traditional societies, there remain many centuries old practices that take advantage of ecological succession in ways that allow them to use fewer inputs.

5. Examples of built ecomimetic designs to maintain or re-stabilize homeostasis

To maintain and ensure that the ecosystem factors needed for homeostasis are healthy and balanced, designs for the man-made ecosystem should include space efficiency and continuity, well functioning cybernetics, connectivity, and biogeochemical balances in soil and water. The following are design examples of elements needed to

maintain and repair the balance of homeostasis.
1. Maintain the balance of abiotic and biotic components in an ecosystem buildings through incorporated greenwall_systems. Figure 1.

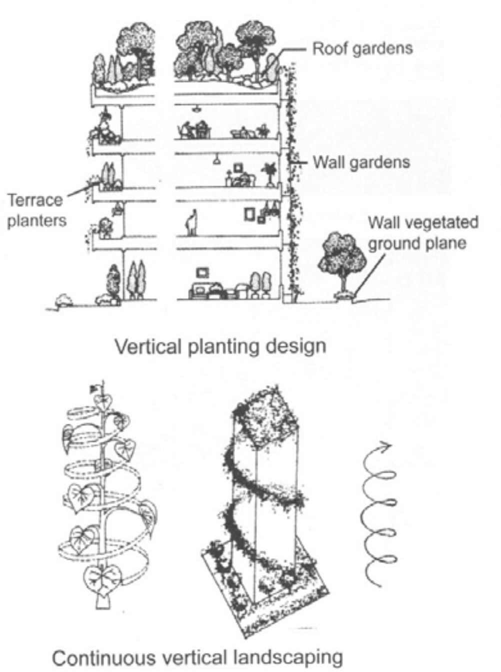

Figure 1. Illustration of green wall systems. (Yeang and Woo, 39).

2. Ensure that energy sources are renewable and materials can be reused. Design for efficient use of materials by l) designing to minimize amount of material used, resource depletion, and waste; 2) designing for adaptive use of buildings; 3) designing for disassembly–recycle, reintegrate, reuse, conserve non-renewable materials, and use renewable materials; 4) using materials with a low ecological impact. This includes low toxic materials, non-chemical materials, natural biodegradable alternatives, such as plastics from corn.
3. Utilize deep plan, double envelope, double layered façade, ecocell, green roof, light pipes, and light shelf designs for new structures to conserve energy.
4. Ecomasterplan with a blue infrastructure -a sustainable drainage system to manage surface water run-offs so that it stays on site. Create water management and conservation within the built environment. (Yeang, *Ecomasterplanning,* 24ff).
5. Design wastewater and sewage treatment and recycling systems to treat waste at its source. This can be done by controlling and integrating human waste and other emissions, capturing storm runoffs, reusing municipal wastewater for irrigation. Design wetlands for wastewater treatment, irrigation leach fields, aerobic wastewater treatment (Todd et al., 1996).

6. Treat waste ecomimetically with the design and use of living machines. Living machines are living organisms of all types that are housed in a casing or structure made up of lightweight materials. Living machines can be designed to produce food or fuels, treat wastes, purify air, regulate climates or perform a combination of these tasks at the same time. (Todd et. al., 1996).
7. Design and construction of bioswales, filtration strips, retention ponds, sustainable drainage (SUDS), lagoons. Return of water to its source will decrease ruoff and pollution of bodies of water. Figure 2.

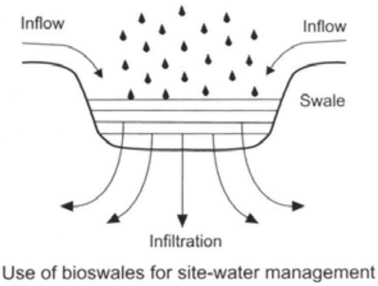

Figure 2. Bioswale (Yeang and Woo, 37).

8. Design shallow mound or shallow trench gray water systems. Figure 3 and 4.

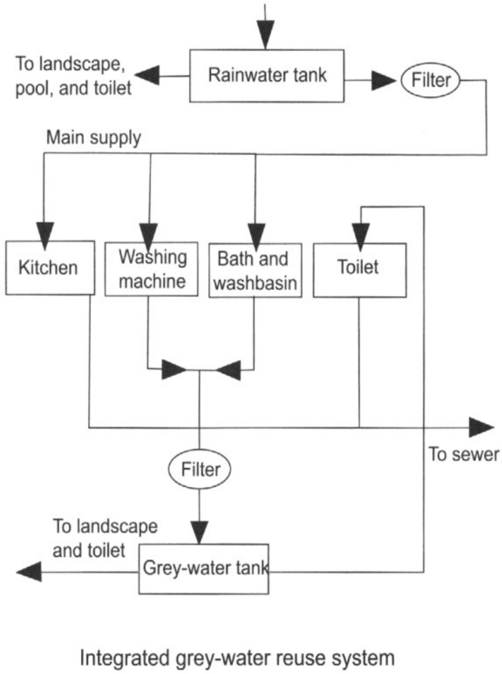

Figure 3. Integrated gray water reuse system (Yeang and Woo, 113).

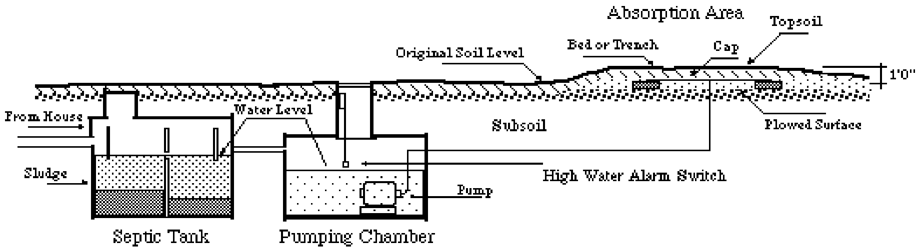

Figure 4. Shallow trench section view (Yeang & Woo, 213).

6. Examples of un-built ecomimetic solutions and designs to re-stabilize and maintain homeostasis

Too often, we have concentrated our focus on urban and developed areas and have not given enough attention to un-built natural areas. In addition to the ever increasing human population and unlimited economic growth and consumption, we have failed to protect the un-built environment and its ecosystems.

Planning and management of un-built (non structural) ecomimetic designs, commonly known as "green infrastructure", serve the dual goals of preserving ecosystems and protecting vulnerable areas and developing nations from natural disasters. Researchers believe that green infrastructures are more cost effective in reducing disaster risks like tsunamis, hurricanes, landslides, tidal events, and floods than construction of hard barriers. (Stolton et al, 2008). While green infrastructure and protected ecosystems cannot stop all natural hazards, there is increasing evidence that healthy ecosystems are more resistant to their impacts and reduce humanitarian disasters. (Dudley, 2010).

1. Establish protected areas in a defined geographical space which is dedicated and managed for long term conservation. Sites may range from being strictly protected with limited human access to protected landscapes and seascapes with settled human communities. ((Lopoukhine, et al., 2008). Through the creation of both green infrastructure and sustainable land management, these protected areas become natural buffers against tidal surges, flash floods, landslides and provide systems for natural restoration of degraded and lost habitats and flood plains. (Stolton et al., 2008; Dobson et al., 1997). They protect humans against disasters at the same time that habitats can be rehabilitated from over exploitation of resources and over human use.

2. Expand natural habitats to mitigate climate change by storing and sequestering carbon in vegetation and soil. (World Bank, 2010). It has been shown that terrestrial (forests) and freshwater and marine (salt marshes, mangroves, kelp and sea grass) ecosystems are important in the carbon cycle as major carbon stores and sinks, mitigating and reducing GHG emissions from energy production, transport, and land use change.(Parish et al., 2008). Without eco-planning and management these habitats could become net sources of carbon and habitat losses. (Gitay et al., 2002).

3. Rather than constructing seawalls, groins, jetties, breakwaters, and other hard barriers which cause erosion and rip tides, maintain natural ecosystems as buffers of tidal surge and important carbon sinks (mangroves, salt marshes, kelp, sea grass beds, and coral reefs) along shorelines, inlets, and rivers and streams. Structures are static, but water bodies are dynamic, constantly changing course and shape. Changing the course of

natural water flow has been shown to have a negative impact on intertidal habitat and diversity.

4. Conserve and maintain wetlands and marshes rather than dredging them. These natural bodies are habitats for birds and marine life as well as macro-invertebrate diversity and provide water storage capacity to prevent flooding during storms. They also filter pollutants from the water. Wetlands along with rivers and lakes are essential water recharge areas and important sources of water for irrigation and domestic and industrial use. Inland wetlands, particularly peat, are large carbon sinks. It has been estimated that 10-30% of global soil carbon is sequestered by wetlands. (Parish et al., 2008). Coastal and freshwater wetlands are natural productive fisheries in many Third World countries. (Stolton et al., 2008).

5. Plan, establish, and manage agroforestry systems with systematic maintenance of native trees, vegetation, and soil. The tree and plant root systems provide protection from landslides, and traditional crops are usually more drought resistance than imported ones. Forests cover 30% of the Earth's land surface but store 50% of terrestrial carbon, including soil carbon and serve as a sink for atmospheric carbon. (Parish et al., 2008). This plan would include restoration of degraded ecosystems, such as reforesting on steep slopes.

6. Protect water supplies.

a. Identify, establish management plans, and actively eradicate invasive alien plants that consume large quantities of water annually which result in polluting water supplies, impeding farming and irrigation, intensifying floods and fires, causing erosion, increasing siltation of estuaries, and destroying rivers. Agriculture is the biggest consumer of fresh water. It has been estimated to use 50% of fresh water in many countries and as much as 95% in developing countries. The World Bank predicts that by 2030 irrigated crop production will increase by 80% from 2010 levels in order to meet global food demand. It is, therefore, critical to protect fresh water supplies for both agricultural production and human consumption. (World Bank, 2010; Ecological Society of America 2009).

b. Create watersheds and conserve catchments.

c. Protect headwaters and source of rivers.

7. Design alternatives to traditional farming to stabilize, rehabilitate,and decrease pressures on

the soil. Some examples are alley cropping, hydroponic agriculture, aquaponic agriculture, permaculture, building integrated food production. Promote urban agriculture and permaculture; this would include warehouse farms for cities and suburbs, rooftop gardens, street orchards, bus stop aquaculture. (Todd and Todd, 118-127).

8. Use non-chemical, natural alternatives to chemical pesticides. This would include natural predators and development of new plants that resist pests.

9. Restore and maintain the biogeochemical cycles:

a. Stabilize oxygen cycle by decreasing runoff from agriculture, sewage, paper and textile mills, food processing that increase carbon dioxide and ozone at the ground level.

b. Stabilize nitrogen cycle and decrease eutrophication by decreasing the use of chemical fertilizers and emissions of greenhouse gases.

c. Stabilize phosphorous cycle and decrease algal blooms and eutrophication by decreasing the use of detergents with a high phosphorous content.

d. Stabilize sulfur cycle by decreasing the use of fossil fuels.
e. Stabilize hydrologic cycle by designing systems that ensure that water remains in the ecosystem of its origin, maintain wetlands, prevent flooding, prevent soil erosion.
10. Establish and protect natural drylands as biodiversity sites for native food crops, such as barley sorghum, cereals, nut forests, pollinators, and pest control. Cultivation of native crops will decrease land degradation.
11. Create marine protected areas for biodiversity conservation and sustainable fisheries. (Halpern, 2003). Maintain nursery, feeding, and breeding for fisheries. This practice will also prevent and control invasive species and protect water supplies. (World Bank, 2010).
12. Create local, regional, state, and national planning policies that regulate development and manage lands on the basis of the ecosystem concept. Ecosystem management would include the integration of ecological, economic, and social principles to manage biological and physical systems that protect long term ecological sustainability, natural diversity, biogeochemical cycles, and the productivity of the land. This approach would recognize that there is no dichotomy between humanity and the environment. (Barker, 1996).
13. Create public policy soil conservation regulations for not only agricultural land but also urban-rural landscapes.
a. Strengthen existing regulations and laws, such as required environmental impact statements that precede project approval; clean air and water laws; pesticide control laws; toxic substances control acts; conservation, forest, coastal, and endangered species laws, among others.
b. New public regulations to correct current imbalances that are detrimental to ecosystem functions, such as gas-exchange, water-purification, nutrient-cycling.
c. Enact public laws and treaties, increase the number of protected areas in the world from the present number of 200,000.
d. Limit city size or organize cities in modules, encourage city self sustainability with locally grown food, waste and water recycling, promote natural areas and greenbelts. (Cunningham, 347).

Conclusion

The findings cited show that human activities have had seriously negative effects on homoeostasis. The findings underscore the combined impact of human activities on ecosystems and their future ability to support an ever growing population without a dramatic change in the way that we design and use our man-made ecosystem.

The discussion of the various aspects of an ecosystem, the effects of anthropogenic activities, and proposed solutions through ecomimesis lead to a simple conclusion: Ecomimetic designs, both built and un-built, can slow the rate at which humans are altering nature for their own purposes. Ecomimesis can also help stem the despoilation of ecosystems and assist in repairing them by adopting natural circular processes rather than linear ones in creating anthropogenic structures and communities.

Ecomimesis and its inclusion of the entire ecosystem and the impact human activities have on the natural ecosystem represents a design paradigm that utilizes both new scientific solutions and respect for the stability of the natural ecosystem. Rather than resolving problems of individual segments of the ecosystem, ecomimesis is a design approach for the built and un-built environments that demonstrates the feasibility of restoring the natural balance in the environment.

Just the Industrial Revolution was made possible and flourished with advances in technology, present day scientific and technological developments can work toward minimizing climate change and rehabilitating nature that have been harmed by the centuries of industrial development, lack of conservation of resources, and population growth. Creative ecomimetic solutions, such as artificial photosynthesis, non-toxic batteries, and Solar Sewage Walls and living machines to treat waste, are being continually developed and refined by researchers, scientists, and inventors worldwide. (Air Force Materiel Command (2008); Australian Artificial Photosynthesis Network; Todd & Todd (1993).

Green infrastructures and sustainable land management are non structural ecomimetic designs that can minimize natural disasters and protect citizens.

Ecomimesis as a sustainable design strategy can become an integral part of stabilizing and rehabilitating our natural world at the same time that it addresses the needs of growing economies and populations around the world.

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