Biotecture: The Integration of Biology and Architecture

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ECOLOGICAL SYSTEMS

The biosphere has been evolving for billions of years, and eons ago became a self-regulating and self-correcting process (Bateson, 1996). In fact, the Gaia hypothesis suggests that life and its environment make up a kind of vast composite entity that regulates climatic conditions optimal for living organisms, an epiphany first proposed by James Lovelock almost 40 years ago (Lovelock, 1982). Although Gaia is disputed by scientists, it remains a powerful metaphor. Oceans, forests, prairies and atmosphere are produced and maintained by vast, interlocking biogeochemical cycles of carbon, nitrogen, water, and other elements. This complex organization, driven by solar input from the sun and organized by negative feedback loops, keeps the Earth warm, green and alive in the midst of a cold interstellar desert.

ROLE OF INTELLIGENCE

Human cultural evolution is Lamarckian in nature, and proceeds at a far greater pace than evolution through natural selection. Over the past 15,000 years, technologies such as agriculture, metallurgy, writing and organized industry have contributed to a massive positive feedback, where population growth and technology have continuously bootstrapped each other. This has resulted in a global population exceeding six billion people and increasing rates of pollution, extinction, deforestation and desertification. The infamous pesticide DDT, for example, is now found in the fat of penguins in Antarctic, once considered the most pristine ecosystem on the planet. The basic problem is that natural biological systems operate exclusively on negative feedback while human activity operates on positive feedback.

FEEDBACK

For any student or citizen, 'system analysis' is a key concept, particularly with respect to the principles of positive and negative feedback. Stated simply, positive feedback is uncontrolled. The results of a process, whether behavioral, chemical, economic or climatic, encourages greater and greater activity until the system collapses from internal stress. Examples are obsessive-compulsive behaviors, cancer, Ponzi schemes, and the runaway greenhouse effect on Venus, where air temperature is hot enough to melt lead.

Negative feedback, on the other hand, occurs when an activity is eventually checked by a countervailing influence, thus preventing an imbalance, like a furnace and its thermostat. The United States Constitution is another example, where the despotic tendencies of a bureaucracy are checked by other branches of government and, theoretically, by the voters themselves.

Consider the relationship between predator and prey populations. More deer, more wolves, less deer, less wolves, and so on, which can be described mathematically by chaos theory as dynamic oscillations around a "strange attractor" (Gleick, 1988).

A simple feedback loop can be combined with many other loops into larger and larger structures until a truly grand complexity is formed—an emergent property known as "self-organizing criticality." Cause and effect become paradoxically the same thing (Kelly, 1998).

SUSTAINABLE CIVILIZATION

Sustainability is a goal where civilization could be maintained without excessive degradation of the natural ecosystem. It requires minimal (or self-contained) use of energy, water and materials. Nature, as usual, provides some lessons for architects. Ecologists who study natural systems recognize that species diversity, efficiency, waste utilization, local adaptation, symbiosis, and co-evolution are essential for any sustainable system. In the superorganism known as the savanna, the grass, zebra and leopard all co-evolved together.

By studying forests, ecosystems, animals and plants and learning how they operate and interact cooperatively, we could carefully design those behaviors and feedbacks into both our built artifacts and cultural/technological systems into a kind of "reverse engineering." Some biologists call this process bio-mimesis or the mimicking of natural behaviors in artifacts. Reed-bed sewage lagoons, contour farming and other technologies that mimic natural patterns are simple but extremely effective examples of bio-mimesis.

Bio-mimesis applied to architecture would produce built environments that are more in harmony with natural processes—thermal, geochemical, genetic, ecological. Cities could be designed as active, complete systems, analogous to living patterns where energy and materials are carefully recycled and renewed.

PATHS TO THE FUTURE

There are two general technological paradigms available for pursuing sustainability: sophisticated machinery or sophisticated biotechnology. These could also be called the mechanical approach and the organic approach. The mechanical approach involves system design, "smart" materials, sophisticated network programming and modeling, reducing weight and energy use, and nanotechnology: essentially turning architecture into extremely active structures. In the end, these two methods may become essentially the same thing. Once nanotech begins assembling individual molecules, it is performing exactly like cellular activity based on DNA.

A quote from Freeman Dyson, from his book *Infinite in All Directions*:

> When I compare the biological world with the world of mechanical industry, I am impressed by the enormous superiority of biological processes in speed, economy and flexibility. A skunk dies in the forest; within a few days an army of ants and beetles and bacteria goes to work, and after a few weeks barely a bone remains. An automobile dies and is taken to the junkyard; after ten years it is still there. Consider anything that our industrial machines can do, whether it is mining, chemical refining, material processing, building or scavenging; biological processes in the natural world do the same thing more efficiently, more quietly and usually more quickly. That is the fundamental reason why genetic engineering must in the long run be beneficial and also profitable. It offers us the chance to imitate nature's speed and flexibility in our industrial operations. (p. 155)

The mechanical and organic approaches are vividly illustrated by the famous Hanna Barbarra cartoons: the Jetsons and the Flintstones. These two shows shared the same plot with virtually the same characters and the same appliances. However, they utilized different technologies—the space age Jetsons used a mechanical approach and the Paleolithic Flintstones used an organic one. In the Flintstones, every appliance and machine had a reptilian analogue—instead of the Jetson's atomic garbage disposal, Fred and Wilma had a fat little dinosaur under the sink, burping and picking its teeth.

BIOTECHNOLOGY

The use of biotechnology promises to be an extremely powerful tool. DNA is a self-replicating, error-correcting macromolecule and has been optimized through four billion years of evolution (Hoffman, 1994). Replacing machinery with organic technology offers enormous benefits: the bio-remediation of polluted sites, methods of collecting metals without open-pit mining and non-polluting energy from bacterial fuel cells.

Here is a modest example of current biotech: The fire beetle is a winged insect that is able to detect a forest fire 30 miles away, from as little as one molecule per billion. This insect lays its eggs in trees damaged by fire. Driven by selfish genes, its detection apparatus has been selected over millions of years to exquisite sensitivity. A German company is producing new super-sensitive smoke alarms by using proteins isolated from fire beetle antenna (Leary, 1999).

Imagine that architecture aspired to the truly organic integrity found in the natural world, with its' beautiful correspondence of form and environment. Perhaps the marriage of biotechnology and architecture, what I call biotecture, could become possible. Utilizing microtech and genetic/molecular engineering, architecture and cities will become actual living things—quasi-plant miles high, like a gigantic Banyan tree or huge coral reefs. The growth of this organic architecture would be guided by carefully induced tropisms to form cavities, rooms, terraces, lakes, and towers. It could feed and power itself, perhaps even its' human occupants.

Why not create living, warm-blooded cities that could sprout new neighborhoods, regenerate damaged sections, recycle wastes, rotate to track the sun, grow winter fur, inflate, crawl, or even swim? Are you cold? Wake up the furnace and feed the house a couple tons of "house chow." Soon it will be more than warm enough. Mother-in-law moving in? Squirt a few growth hormones around and bud another room. Even though these developments would probably eliminate the architectural profession, imagine if buildings 'built themselves' and we could all go to the beach.

BIOTECTURE

The biotecture projects are speculations of an ecological civilization supported by biotechnology. It has been a familiar theme in science fiction literature and films and even in architecture. There has always been a design tradition that used organic imagery—Gaudi, Finsterlin, Frank Lloyd Wright, Bruce Goff, Jujol, and Eugene Tsui; all of these architects used an organic aesthetic to create integrated and extraordinary designs. I am proposing the next step—a living architecture, capable of growth, birth, death, perhaps even self-directed evolution. In this kind of future, there might not be any architects; instead, there would be architectural veterinarians, psychologists, building nutritionist, pollinators and building isometric trainers to keep skyscrapers from developing flabby muscles.

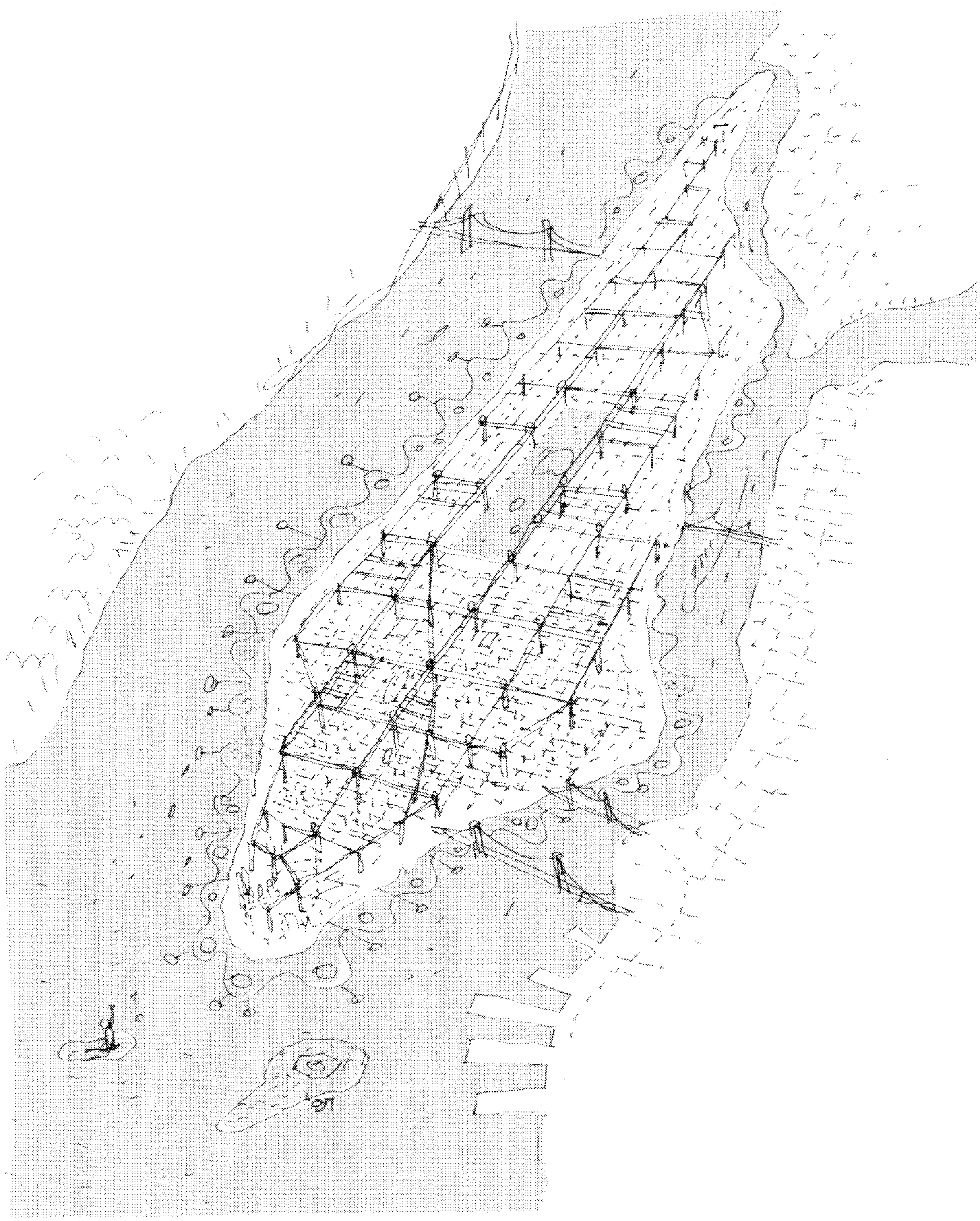


Fig. 1. New York City and Overcity surrounded by sewage lagoons (1998)

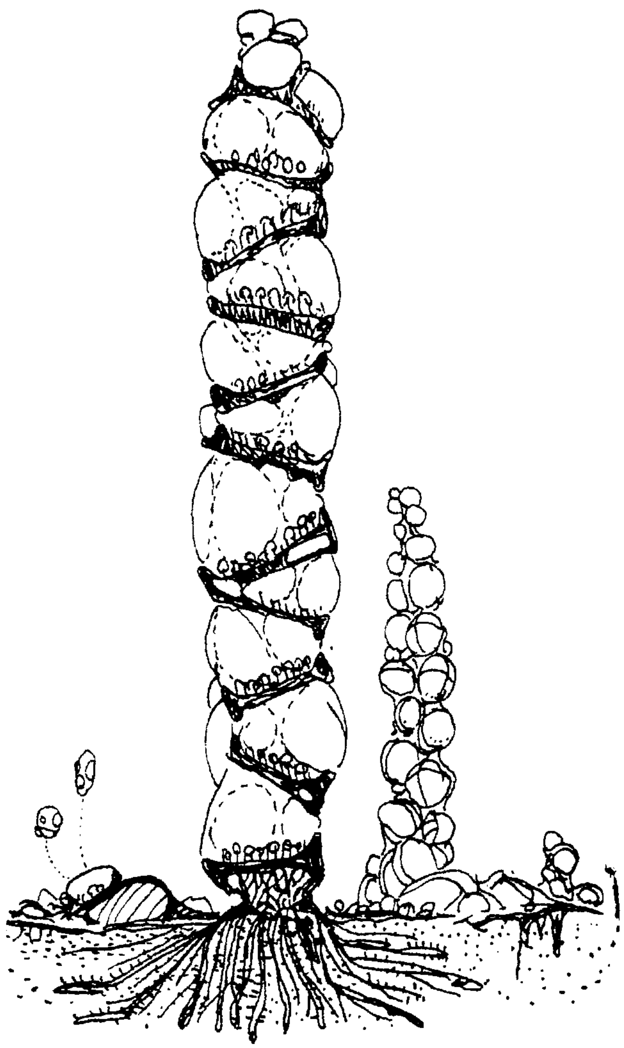


Fig. 2. Living Architecture (2000)

ARTIFICIAL LANDSCAPES

Even the most jaded sensibilities recognize that much vernacular architecture appear seamlessly integrated into their landscape. Contour, natural features local materials and local construction methods were the traditional form givers. This authenticity of place is largely unavailable in modern society but it is still a desirable goal. Perhaps a more "discreet urbanism" could be constructed using genetically-modified biotectures, which, like an organic species, would be uniquely adapted to local terrain and resources to reinforce the still-valid concept of "place." In similar ways, the New Alchemy arks in Cape Cod, the Earthships of Michael Reynolds, and especially Pablo Soleri's' first generation arcology in Arizona, are all experiments utilizing natural patterns to create new ecological vernaculars.

Growing a City from Bioengineered Wood

The maximum tree size is currently limited by transpiration pressure and the structural characteristics of wood. The Sequoia of California can reach over 300 feet. But if we were to add pumps made of vegetable muscle and sinews of bucky tubes in the xylem, a tree could grow as tall as the Empire State Building—the discovery last year of BAS-1, a multi-species gene regulating plant growth, makes this conceptually feasible (Fountain, 1999). BAS-1 can be used to stimulate or retard growth.

When I described this notion to cosmologist, Lee Smolin (author of *The Life of the Cosmos* and a great advocate of a living universe), he said, "Why not? We already make our houses out of wood!" I am proposing eliminating a few messy steps in conventional wood-framed construction—like harvesting, transport and assembly. As in a childs' fairy tale, we could just plant a magic bean and return the next year to a newly grown pumpkin-house.

Architecture as Land-form: An Antidote to Plop-itecture

New housing complexes seem to sprout up along the highway like mushrooms after a night rain. I call it Plop-itecture—buildings are placed indiscriminately on the landscape as thoughtless as cowpies. They are clearly designed to maximize income as opposed to minimizing environmental impact. Plop is sprawl, created through reinforcement of feedback of speculative land use and consumption patterns, population growth and subsidized fossil fuel.

One solution would be to build underground, or beneath vast earth-covered shells, built by micro-organisms patiently constructing carbon-reinforced limestone, much like the way sulfur-eating bacteria contribute to cave formation today, or the abalone mollusk produces nacre, one of the strongest substances on earth. Forests, lakes, orchards, parks and schools could cover the exterior, which would be pockmarked with courtyards and windows. Below this new landform would be the infrastructure: transportation and utility systems, power plants, factories, parking, recycling and sewage systems. Permanent reef-like structures could spread across the planet in a convergence of land use and natural form, where landscape and urbanism would be indistinguishable.

Ozone-Maker

The "Ozone-Maker" chemically repairs the deteriorating ozone layer that protects the biosphere from UVb radiation. The 425-meter long machine floats through the stratosphere, 30 kilometers above the earth and combines the elegance of a blimp, the technology of a chemical factory and the imagery of a horseshoe crab. While not alive, it uses the forces of nature and integrated industrial ecologies to create a deliberate ambiguity between animal and machine.

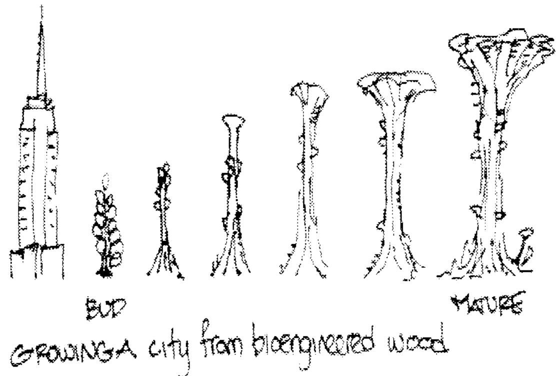


Fig. 3. Growing a City from Bioengineered Wood (1996)

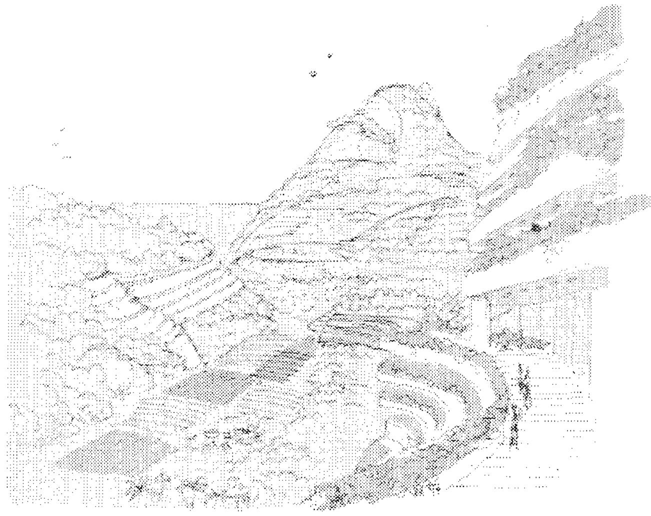


Fig. 4. Architecture as Landform (1997)

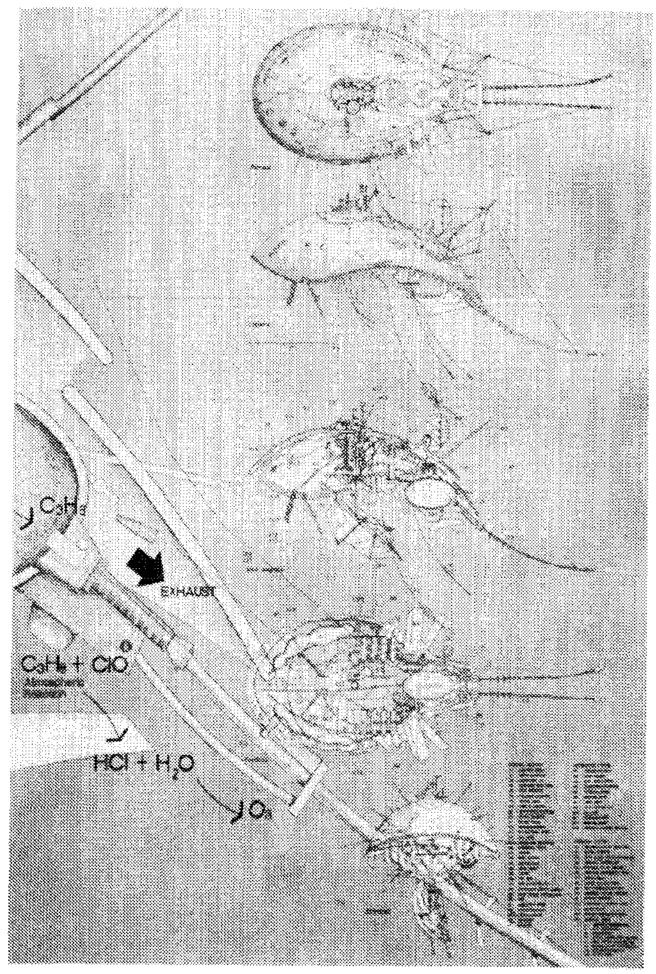


Fig. 5. Ozone-Maker (detail, 1993-4)

The Ozone-maker is essentially a floating, wind-cleaning gadget. It operates high in the upper atmosphere, removing chloroflorocarbons (CFC's) from the ozone layer. Extendable sails allow the huge craft to move back and forth, eliminating the chlorine with propane sprays (Cicerone, 1992). (Chlorine is the culprit molecule responsible for eroding the ozone shield.) Because of its remote location, all raw materials are collected from the atmosphere, including helium for buoyancy, carbon dioxide for propane production and hydrogen for steam turbines.

Artificial Island

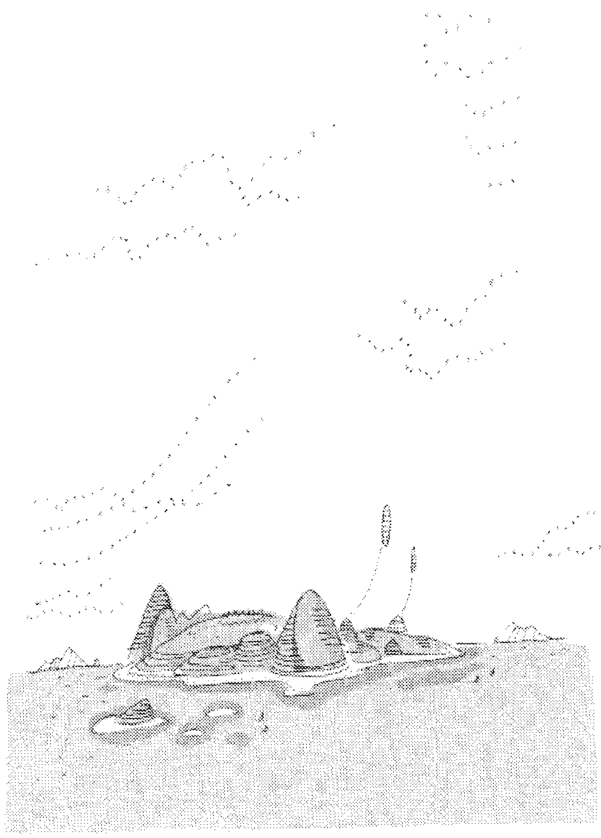
People love the Caribbean islands—why not grow a few more? Start with gene-modified land-coral, add sun and water, a few iguanas and palm trees and come back in 40 years. Such a place would be participating in a series of serendipitous biogeochemical cycles. Even Christopher Columbus noted that tropical islands make their own rain, when comparing Caribbean mountain islands to the deforested Canary, Madeira and Azores Islands off Spain.

Balloontown: An Aerial Suburb

The proper suburb would not destroy wilderness or agricultural land. It would have the appeal of the automobile-free commuter islands off Istanbul or Seattle, where everyone takes a ferry to work. Why not introduce balloontowns? Instead of a ferry, train or car, just take an elevator down the tether. Hydrogen would be continually produced from vats of specialized bacteria and stored in self-repairing bladders. According to my calculations, four million cubic meters of hydrogen would be necessary to float a village-sized population of 500 people.

THE DOWN SIDE

Biotechnology has great risks, both culturally and ecologically. It raises troubling ethical and moral issues surrounding cloning, genotype discrimination, and human modification, as well as the current debate about genetically modified food. Critics warn of transpones, jumping genes



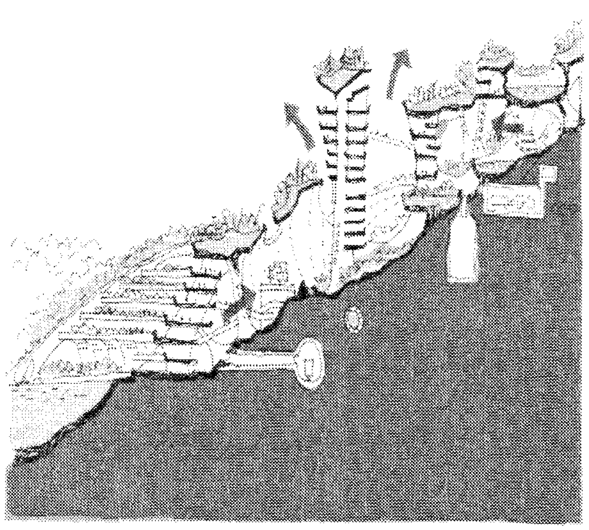


Fig. 6 caption: Artificial Island-Section with thermoregulation (1997)

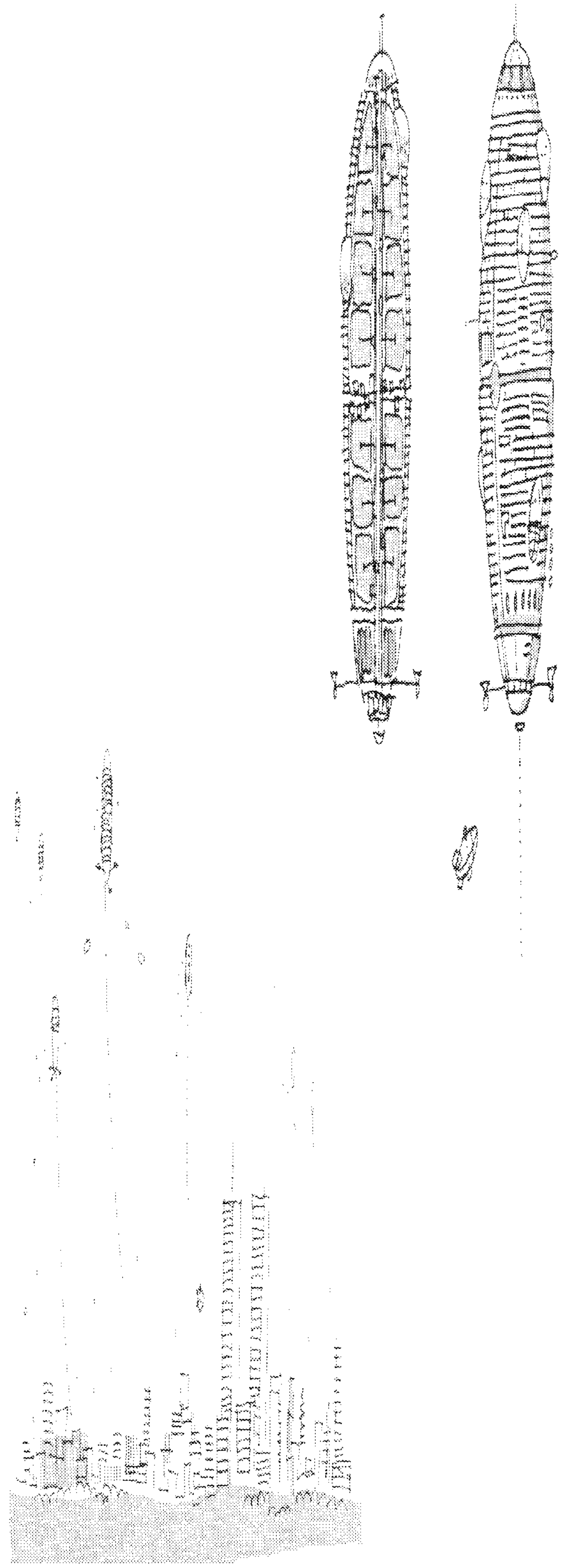


Fig. 7 caption: Balloontown (1993-5)

and "horizontal gene transfer" that could pollute wild genetic stocks or inadvertently cause a runaway ecological effect (Parkins, 1999), creating a kind of genetic equivalent of Kurt Vonneguts' doomsday invention, "ice-9."

In 1983, the US Supreme Court stated that genetically modified animals and plants are a patentable invention. Many countries, however, rightly view natural products as discoveries and not as inventions. It is troubling to consider that our common genetic heritage is being patented and exploited by individual. Cyclosporine, a drug used to fight transplant rejection, for example, was derived from a Norwegian mountain fungus. Rictec has even patented a form of Basmati rice and this summer, two Japanese scientists tried to patent curry! Unfortunately, laws and regulations notoriously lag behind technology (Batson, 1996 p.241).

Gene engineering is still in an infant development stage, despite the billions of dollars already spent on research. The big results have been in medicine and particularly in agriculture. Biotech research is a capitalist activity, intended to make investors rich, not necessarily solve environmental problems. Most egregious examples are Monsanto's' rBGH (Bovine Growth Hormone) and its new Bt corn (using a gene from bacillus thuringiensis, a toxic bacteria which manufactures its own pesticides). Bt corn was discovered last summer to kill monarch caterpillars (Baskin, 1999). It is sobering to realize that almost 25% of US corn crop are now Bt corn.

Mosanto and other biotech companies are not interested in grand biotectures that promote sustainable goals. Private business is organized to generate profits, not public benefits. The appropriate role of government to generate policy goals and attempt to balance the self-serving aspects of corporate activity.

THE BIG PICTURE

As farfetched as these sketches and ideas may appear, the idea of integrating humanity and the biosphere is a very sensible idea. As the failure of the Biosphere 2 project demonstrated, a functioning ecology is complex and quite difficult to replicate. As designers and educators, our main goal should be to promote a more sustainable and environmentally benign civilization. America should be leading the world out of this ecological dilemma, not promoting and selling more Superpower Consumerism. Retreat to some nostalgic pastoral vision of the past is not viable—the only true frontier is the future. We must aggressively shape that future: Break our addiction to exponential growth, cultivate new long-term strategies and tools, develop new social metaphors and ideologies to guide us.

The goal, though, should be the same: a civilization that is solar and hydrogen powered, with a controlled population, biome reserves, self-contained industrial ecologies and an economy de-coupled from nature. Biotechnology may well prove to be one of the most significant tools to assist this transformation.

As self-conscious beings, we inherit an obligation to the Earth, as well as to our ancestors and to those yet unborn. It is absurd to propose that human satisfaction is the only thing that matters—that the infamous spotted owls and the snail darter are merely an inconvenience and their extinction can be rationalized by some Republican cost-benefit analysis. Man is not at the center of creation—we are just a big-brained primate with thumbs, surfing the Big Bang energy like every other living thing.

I would like to believe Intelligence is not actively selected against and that there is a place in the universe for Mind. After all, the point of intelligence is to develop win-win situations (Orr, 1987). I have a splendid vision where humanity would actively participate in an evolving cosmos. I see Earth as a restored wild and green planet, with space colonies spreading life through a sterile solar system and human spacecraft (perhaps living spacecraft, genetically-modified for vacuum) swarming through the galaxy like honeybees across a dark garden.

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NOTES:

The term "Biomemesis" is from "An Efficient Swimming Machine" Scientific American March 1995.

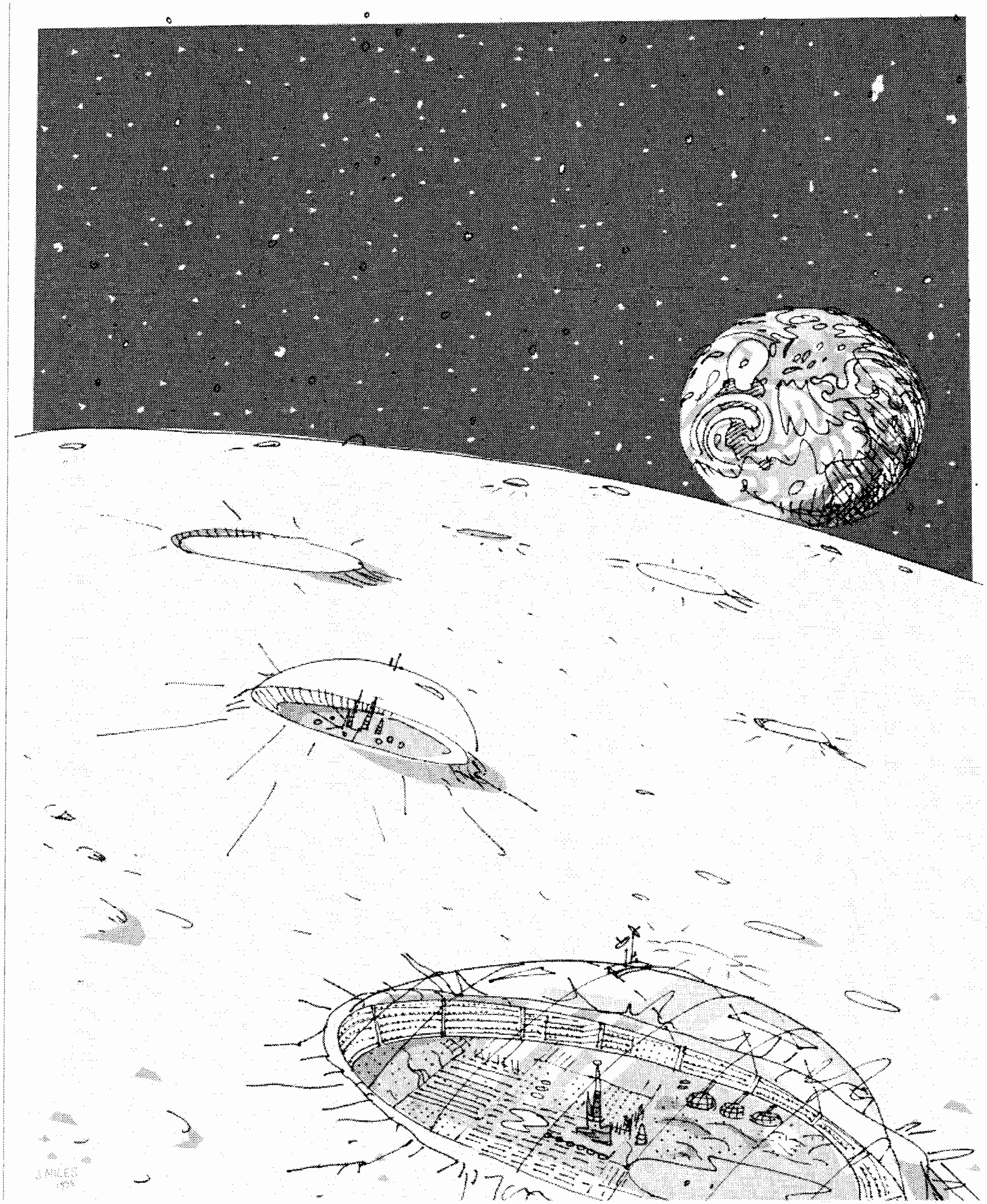

Fig. 8 caption: How to Build on the Moon A New Wilderness (1997).