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The Transgenic Zoo, *by Peter Yeadon, illustrates this article. The Zoo would be situated in downtown Toronto. It would cover an extensive stretch of land that would be available after an expressway and rail lines are buried. The work considers architectural possibilities for new nanotech and recombinant biogenetic materials.*

Architecture in the Age of Nanomatter

Peter Yeadon

They are, in a sense, neither bulk nor molecule and open a window into the fuzzy size region where bulk solid state properties rise out of the molecular noise.

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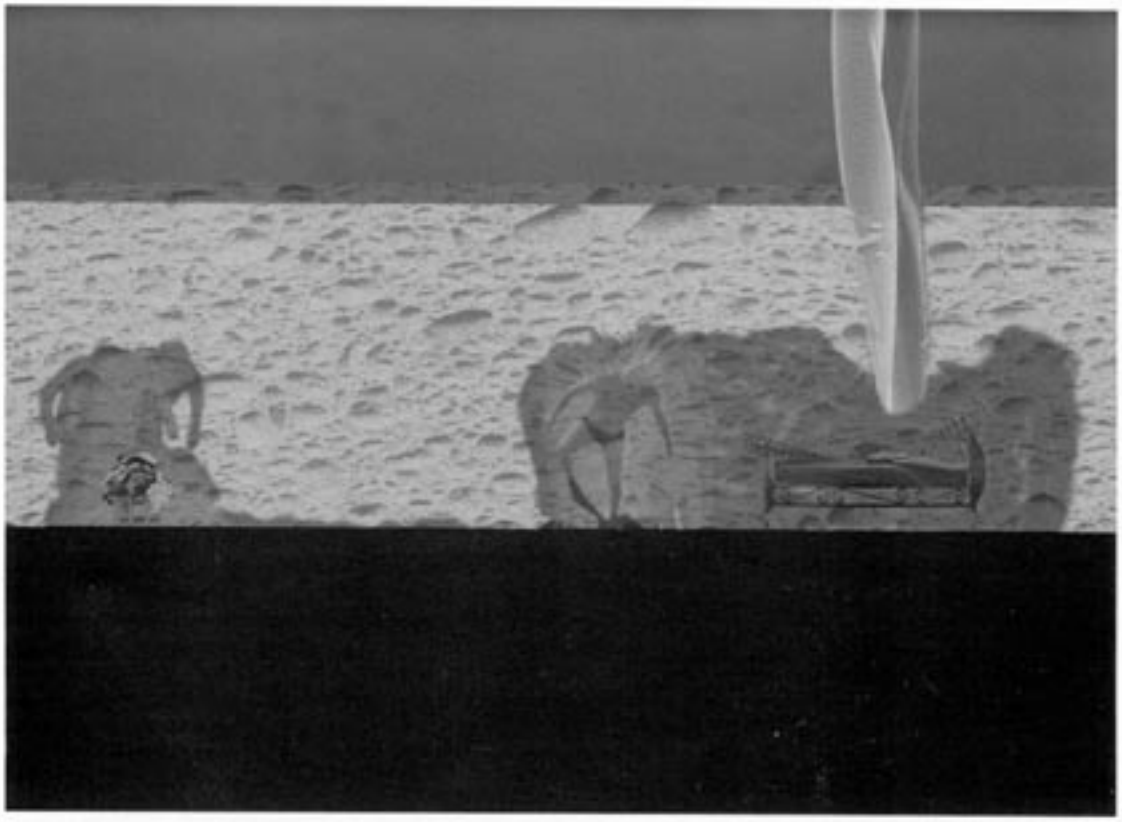
It is a challenge for architects to think small. We have been through the glorious Machine Age, the Space Age, the Digital Age and the Information Age. But none of it has prepared us for what has been emerging from the nanotech sector during the past decade. Nanotechnology is technology that is developed at the scale of nanometers, or billionths of a metre. These are technologies of a molecular scale and, as in those previous epochs, architecture will likely follow and embrace these atomic feats after they have become commonplace.

Who among us could resist working with a programmable substance that would appear to assume any shape, colour, and density? String could become wood. Glass could transmogrify into concrete, and then be instructed to return to glass. Paint could become leaves. The opening in that wall could follow you around the room. What is it, if it can become



Dwellings in the Zoo use carbon nanotubes to create bedroom scopes for viewing the stars at night. The scope is situated above the pillow and extends above the clouds and pollution. As the room is made of programmable matter, which is discussed in this essay, it can be any substance. This lack of material identity is used to register a memory of place by having the programmable matter configure around the movement of the body in space. The void, which is the space, is the result of all previous movements that one has performed within the room.

anything? This is one of the significant problems that nanotechnology has now introduced to architecture through the emergence of utility devices that self-assemble and *programmable matter*, a nanotechnology that can alter matter at the atomic level.

It has been more than a decade since Dr. J. Storrs Hall of Rutgers University proposed the possibility of a *utility fog* which can change from this to that. The fog would consist of *foglets*, silicon micromachines that are the size of dust. Each foglet would have twelve arms that would be capable of joining hands in various configurations to form substances of any shape and density, and the foglets could be programmed to change. Some scientists believe this might be achieved in ten years if atomic friction forces can be overcome. We can already make micro-electro-mechanical systems (MEMS) from silicon, such as microscopic gears, pumps, and motors. Zyvex Corporation in the United States specialises in the research and development of MEMS.

But let's think smaller than MEMS, a thousand times smaller. In addition to building tiny, mechanistic machines, Nanoscientists are now working on designing atoms that change the very substance of matter. Each known atom has a unique number of electrons, protons, and neutrons (including zero). Platinum has one less electron than Gold, and Gold has one less electron than Mercury. Nanoscientists are now able to trap electrons, confining their movements in three dimensions within a structure that is known as a *quantum dot*. Dr. Paul L. McEuen has been working with forming quantum dots at the Laboratory of Atomic and Solid State Physics at Cornell University.

left: The Transgenic Zoo *includes a number of mixed develop-ments wherein humans live and work alongside animals in their habitats. This image shows a collection of nanomembrane windsocks that filter pollutants out of the air by allowing only certain molecules to pass through.*

The park maintains, and is defined by, the city zoo. The existing Toronto Zoo would be relocated from its current suburban location to the site downtown, and it would be enhanced with bioengineered plants and animals.

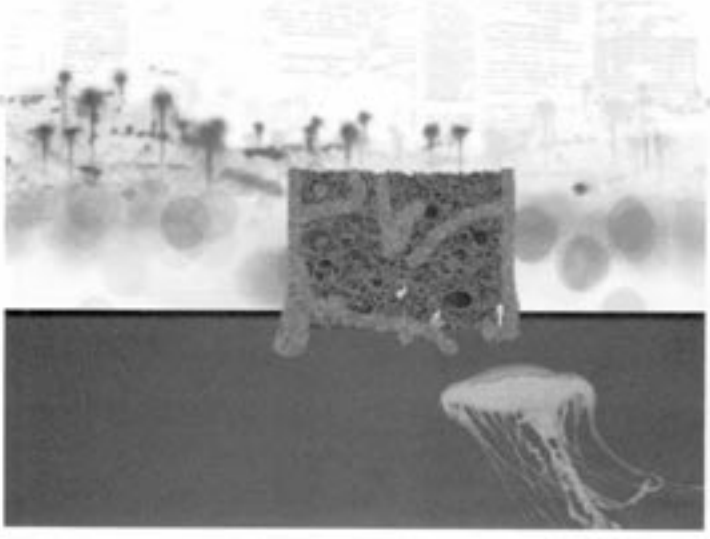
The bioengineered beings are a stock of genetically modified creatures that are already available to us today, and will be tomorrow. Through recombinant DNA practices, we already make beings that heretofore never existed. We have spliced phosphorescence genes from fireflies and jellyfish into plants and animals to make glow in the dark trees and trotters. We have tomatoes that resist freezing by hosting antifreeze genes from fish. We can easily change the color of peppers, even the taste. We have made cloned goats, transgenically modified with spider genes, to secrete spider silk for military and industrial applications. These are the 'designer' plants and animals of the biotech sector.

When the electrons are trapped in the quantum dot, they behave as though they were swirling about the nucleus of an atom even though no protons and neutrons are present. The number of electrons that are trapped determines the kind of atom they will emulate. So nanophiles are speculating about the possibility of making one atom become another by altering the number of electrons, as electrons can be added or removed from the quantum dot. For example, a Mercury atom would become a Gold atom if one electron were to be removed.

Interestingly, electrons trapped in adjacent dots will also form chemical bonds, just as their natural atomic counterparts do to form molecules. By programming the addition and removal of electrons, we might change the very essence of a molecular substance. But we are not so limited. Because we can introduce any number of electrons into these artificial atoms we can produce new atomic structures that are not yet known.

With nanotechnology, we would not be bound to the stable atomic elements that are presently available to us. We would be designing atoms.

Now think big. An architecture of meshed electric nanofibres, that act as quantum dots, could produce replicants of any desirable atoms by trapping and moving any number of electrons. Your Gold walls could be your Salt walls too, or any other substance at the turn of a switch. One extraordinary and unique characteristic of this nanotechnology is related to weight. The substance would appear to be Gold, or Salt, or any other substance, but would not have the same mass as those natural substances. As the electrons emulate atomic structures, but are without a nucleus, they don't have the same mass as the natural and synthetic atoms that are listed in the Periodic Table of the Elements. Your Gold would, instead, have the mass of the electro-trellis that supports it.



Of particular concern is the associations between the Zoo lands and the places of human activity, work, and dwelling. Here, recombinant materials and analogies present provocative associations between natural and artificial compositions.

A polymer scaffold is installed to grow nails in a hair and nail salon at the Zoo. The polymer scaffold was developed by Advanced Tissue Sciences and the University of Washington for growing human organs such as a liver or heart. The polymer biodegrades over time, leaving the organ intact.

This is not a building material; it is all building materials. It is all matter. As Christine Peterson, President of the Foresight Institute, stated at a U.S. House of Representatives Committee on Science meeting in April 2003:

> Humanity's drive to improve our control of the physical world is intrinsic to our species and has been in progress for millennia. A vast international economic and military momentum pushes us toward the ultimate goal of nanotechnology: complete control of the physical structure of matter, all the way down to the atomic level.

If the Committee is considering this technology with respect to accidents, economic disruption, access, and terrorism, what might it become in the hands of architects? ■|□

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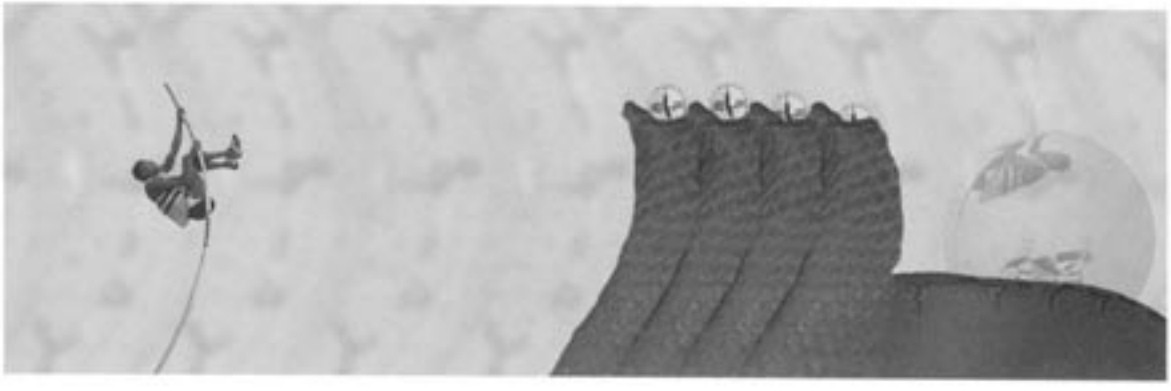

The use of the polymer scaffold is unique to certain conditions. In the nail and hair salon, above, it is used to decoratively cultivate and harvest growing parts of the human body. Here, it is used as cladding to support a snake-like skin that exfoliates and continually renews the facade.