Imitation of life

For new ideas in materials and engineering solutions, nature fills the bill

By Bruce Lieberman

M arc Meyers was a boy in Brazil when he first recognized the ingenuity of nature. Hiking with his father at the edge of a vast rain forest, he found the skeletal remains of a toucan and picked up its large beak.

He was astounded at how light it was — and how strong.

Today, the materials scientist at UCSD is studying what makes that beak, the product of millions of years of evolution, so exquisite and perfect for the tropical bird. The answers may someday lead to revolutionary designs for human innovation.

Meyers is one of many scientists and engineers who study biomimetics — a rapidly changing field that looks to nature for engineering innovations. Mimicking nature is not new. After all, the grace of a bird in flight inspired Leonardo da Vinci and the Wright brothers.

But today, scientists’ ever-increasing knowledge of genetics, modern computing and advances in materials science is providing new opportunities to learn from biology and copy it. Humans are great innovators, but the natural world has been evolving for hundreds of millions of years. Why reinvent the wheel?

“We need to learn how the creatures in nature do what they’re doing,” said Yo- wghi Bar-Cohen, a senior scientist at NASA’s Jet Propulsion Laboratory in Pasadena who has written extensively on biomimetics.

“You’re talking about the biggest lab that ever existed and ever will.”

Or, as Japanese biophysicist Hiroshi Ishiguro puts it: “Animals, plants and microbes are the real engineers.”

After 3.8 billion years of research and development, failures are few, and what surpounds us is the secret to survival.

Inspired by human and animal muscles, Bar-Cohen is developing artificial muscles by experimenting with electroactive polymers — plastics that change their shape in response to electricity. He foresees a day when human-like robots will be more than characters in science fiction novels.

LLOYD GROVE
Publisher Judith Regan is the target of the latest tell-all fiction by an ex-employee, the columnist says / F7

Wednesday
June 7, 2006
The San Diego Union-Tribune
Tensegrity — noun, an engineering concept in which tension and compression are combined to keep a structure in stable equilibrium.

Architecture of plants, animals inspires scientist

**Nature**

**CONTINUED FROM PREVIOUS PAGE**

Tensegrity structures — a structure akin to a honeycomb with each cell sealed tight.

The highly organized structure gives the bees’ nectar and structural integrity. With this perfect, lightweight tool, a tarsen can reach berries at the tips of branches, without strain or being thrown off balance.

"It’s as if the tarsen knew mechanics and knows materials," Meyers jokes.

Meyers can envision the day when the beet will inspire revolutionary structures for aircraft, cars and other vehicles where strength and weight are crucial.

The tarsen’s staggered tile structure is not unique. In a lab at Scripps Institution of Oceanography, Meyers and his students also study five abalone to understand how they grow their tough, tough shells.

The shells are composed almost entirely of a type of calcium carbonate called aragonite in complex arrangements of micro-scale tiles.

"These tiles are very well-ordered, like brick and mortar," said Albert Lin, one of Meyers’ graduate students. "It makes something that is literally orders of magnitude stronger than its very weak base material."

If scientists could replace abalone shell material, they might be able to manufacture mini-machines, or "composites for Kevlar-like tough, light, synthetic fiber used in bulletproof vests and other important applications for use these materials in a much more ingenious, intelligent way, in more creative ways," Meyers said.

In 1982, Shleton saw an interesting structure in the Netherlands that had been created by an artist, Kenneth Snelson. The sculpture, an 18-foot tower, consisted of an arrangement of metal rods connected by a cable. It sounds simple enough, but by balancing tension in the cables with compression in the rods — which don’t touch one another — the structure itself appears to defy gravity.

From a distance, the cables dissolve from view and the metal rods appear to be floating in air.

Shleton looked at it and experienced a kind of eureka moment.

"As an engineer and a scientist, I stood and looked at this thing and thought, ‘My god, this guy, this artist, has a better idea about structures than any engineer I ever met.’"

Shleton was using tensegrity — a term coined by Buckminster Fuller, creator of the geodesic dome, from a combination of the words tense and integrity. Tensegrity is an engineering concept that combines tension and compression to keep a structure in stable equilibrium.

Shleton and others have since viewed tensegrity as an idea that could lead to new applications for bridges, airplanes and spacecraft.

"Structures could be engineered light, strong, flexible and even adjustable," he said.

Shleton and his colleagues are working on developing aircraft wings that can change shape in flight — eliminating the need for flaps, rudders and flaps.

In his lab at UCSD, Shleton and his students have built small models of towers made from sticks and string. At the base of the structure, tension in the strings can be electronically adjusted to cancel out the bending of a simulated earthquake.

Tensegrity is a concept used by nature. Shleton has found, for instance, the strength of spider silk is based on a principle of tensegrity. Weight for weight, spider silk — called steel’s strongest fiber — is about six times stronger than steel.

On close examination, scientists have found that spider silk is made from amino acids or glycine into strands connected to ropelike sheets of material that can compress like an accordion. The strands provide the silk with the ability to stretch or endure tension, while the sheets give it the ability to compress.

Spider webs need to hold so much weight before being broken by a breeze and weighed down with gathering dew — both of which can exert tension and compression on the web’s strands. They also need to stop a fast-moving insect in its tracks — stretching but not breaking on impact.

Red blood cells use the same properties of tensegrity, Shleton and UCSD bioengineer Amy Song have found.

The cells carry oxygen through blood vessels and capillaries in every part of the body. They must be able to bend and break, adhere and stretch through very tight spaces.

"It is our belief that knowledge of the tensegrity mechanisms of red blood cells, and Shleton’s, should give medicine increased knowledge about what goes wrong in certain blood diseases such as hemolytic anemias, in which red blood cells are prone to rupture.

By exploring the beauty of both art and the intricacies of biology, engineers could be on the verge of creating an entirely new way of building things.

"I’m personally convinced that these tensegrity architectures, this way of putting matter together, will revolutionize the way we build structures of all kinds," Shleton said.

For Meyers, who spent years exploring the properties of metals and other inorganic materials, studying the natural world is now inertia.

"You see an animal, you see a crab, you see an abalone, and it’s like, ‘This is a better way. This is a better control.’"

There’s no mystery, no secret, to how a piece of steel is made, Meyers said. But a piece of synthetic material is very different.

You start to think about evolution and complexity, that this is an end point of millions of years.