UC San Diego
JACOBS SCHOOL OF ENGINEERING

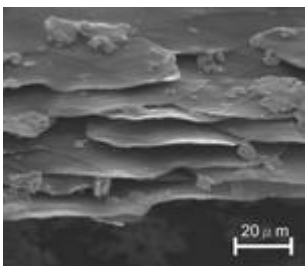
Engineers Discover Why Toucan Beaks Are Models of Lightweight Strength

November 30, 2005 -- As a boy growing up in Brazil 40 years ago, Marc A. Meyers marveled at the lightweight toughness of toucan beaks that he o ccasionally found on the forest floor. Now a materials scientist and professor of mechanical and aerospace engineering at UCSD's Jacobs School of Engineering, Meyers said makers of airplanes and automobiles may benefit from the first ever detailed engineering analysis of toucan beaks conducted in his lab.

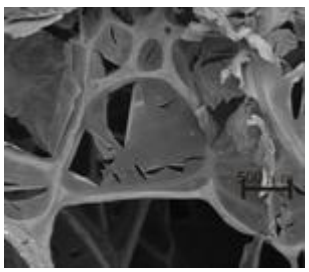
“Our computer modeling shows that the beak is optimized to an amazing d egree for high strength and very little weight,” said Meyers. “It's almost as if the toucan has a deep knowledge of mechanical engineering."

In a paper published Dec. 1 in *Acta Materialia*, Meyers an d graduate students Yasuaki Seki and Matthew S. Schneider reported that the secret to the toucan beak's lightweight strength is an unusual bio-composite. The interior of the beak is rigid "foam" made of bony

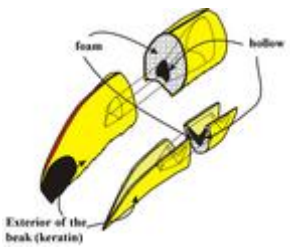
UCSD materials scientists discovered that the lightweight strength of the Toco Toucan's beak is due to a matrix of bony fibers and drum-like membranes sandwiched between an outer layer of keratin, the protein that makes up fingernails, hair, and horn.



The surface of the toucan beak is made of layers of keratin "tiles" that are glued together.



The interior of the the toucan beak is a "foam" made of bony fibers and d rum-like membranes.



The beak has a hollow region in an interior region where the mechanical stres ses were insignificant.

fibers and drum-like membranes sandwiched between outer layers of keratin, the protein that makes up fingernails, hair, and horn. Just as the hook-shaped barbs on cockleburs inspired the development of Velcro, Meyers said the avian bio-composite could inspire the design of ultra-light aircraft and vehicle components with synthetic foams made with metals and polymers.

"The big surprise was our finding that the beak's sandwich structure also behaves as a high energy impact-absorption system," said Meyers. "Panels that mimic toucan beaks may offer better protection to motorists involved in crashes."

Toucans are highly social, noisy residents of rainforests in the Amazon, although the birds live as far north as Mexico. They use their extremely large and o ften brightly colored beaks for a variety of purposes, from gathering fruit from the tips of tree branches, to defending themselves.

Bird beaks are typically either short and thick or long and thin. The Meyers team decided to prospect for a novel material in toucan beaks because they are both long and thick. Emerald Forest Bird Gardens, a California breeder of exotic birds, provided beaks from toucans that had died from natural causes to Meyers's team. They analyzed the beaks' density, stiffness, hardness, and response to compression and stretching. They also examined the beaks with a scanning electron microscope.

The beak's interior is a highly organized matrix of stiff cancellous bone fibers that looks as if it was dipped into a soapy solution and dried, generating drum-like membranes that interconnect the fibers. The result is a solid "foam" of air-tight cells that gives the beak additional rigidity.

"The beak is mostly air," said Meyers. "While the inner part of human bone also contains cancellous bone, we don't have the foam interconnections, which produce a much stronger structure with very little additional weight."

Like a house covered by a shingled roof, the foam is covered with overlapping keratin tiles, each about 50 micrometers in diameter and 1 micrometer thick, which are glued together to produce sheets.

The study in *Acta Materialia* also noted a hollow region extending ab out half the length of the upper and lower beaks. "When we did the calculations, we discovered that there are only very insignificant mechanical stresses in the center of the beak at the position of the hollow areas," said Meyers. "This is why I jokingly tell my students that toucans have a deep knowledge of mechanics. They don't bother adding structural support in a part of the beak that doesn't really need it."

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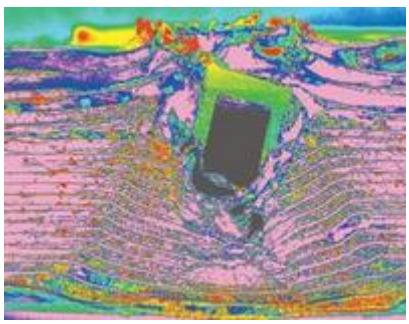
Materials scientists at UCSD are using the shell of the s eaweed-eating abalone as a guide in the development of a new generation of bulle t-stopping armor.



UCSD researchers used the abalone as a guide in developin g a lightweight metallic material that performed "spectacularly" in ballistic pe netration tests.

Professor Marc Meyers explains in this video how a "foam" made of bony fibers and drum-like membranes creates the surprisingly strong, lightwei gh beak of the Toco Toucan. Length: 4:07

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