The sharp beak of the Humboldt squid is one of the hardest and stiffest wholly organic materials known, used by the squid to disable, tear apart, and devour its prey. Engineers, biologists, and marine scientists at UC Santa Barbara have joined forces to discover how the soft, gelatinous squid can operate its knife-like beak without tearing itself to pieces. Their findings, published in a recent issue of Science, may lead to improved artificial limbs for people and improved adhesives for dissimilar materials.
The key to the squid beak's functionality lies in the gradation of its hardness and stiffness. The tip is extremely hard and stiff, yet the base, 100 times more compliant than the tip, allows it to blend with surrounding soft tissue. (This is true only when the base of the beak is wet; after it dries out, the base becomes close to as stiff as the already desiccated beak tip.)

?I?d always been skeptical as to whether there is any real advantage to ?functionally gradient? materials, but the squid beak turned me into a believer,? said Frank Zok, Professor and Associate Chair of the Department of Materials and a co-author of the paper. ?Here you have a ?cutting tool? that?s extremely hard and stiff at its tip and it?s attached to a material ?? the squid?s muscular buccal mass ?? that has the consistency of Jell-o.?

?You can imagine the problems you?d have if you attached a knife blade to a block of Jell-o and tried to use that blade for cutting,? Zok continued. ?The blade would cut through the Jell-o at least as much as the targeted object? In the case of the squid beak, nature takes care of the problem by changing the beak composition progressively, rather than abruptly, so that its tip can pierce prey without harming the squid in the process. It?s a truly fascinating design!?

Humboldt squid (Dosidicus gigas), also known as jumbo flying squid, can grow to seven feet long and 100 pounds. Their Eastern Pacific range extends from Tierra del Fuego, at the southern tip of South America, to California. Their common name comes from the Humboldt Current off South America, part of their habitat. They are a social species, often found traveling in schools of 1,200 or more individuals.

?Squid can be aggressive, whimsical, suddenly mean, and they are always hungry,? said Herb Waite, co-author and Professor of Molecular, Cellular, and Developmental Biology (MCDB) at UC Santa Barbara. ?You wouldn?t want to be diving next to one. They?re very aggressive feeders? a dozen of them could eat you, or really hurt you a lot.? The creatures are very fast, swimming by jet propulsion.

Besides humans, squid?s primary predator is the sperm whale, and those animals
frequently show the scars of battle with skin marked by the squid?s sharp suckers. (Waite notes that squid muscle is sold as ?calamari steak,? often served locally in sandwiches.)

Waite found the questions posed by the squid beak compelling, and he interested postdoctoral researcher and lead author Ali Miserez in joining the study.

Miserez, who is affiliated with UCSB?s Department of Materials, MCDB, and the Marine Science Institute, suggested the research could point the way to new types of medical materials. ?We could imagine creating a full prosthesis that mimics the chemistry of the beak, so that it matches the elasticity of cartilage on one side and, on the other side, you could create a material which is very stiff and abrasion resistant,? he recalled.

Considering another potential application of functionally gradient materials, Zok explained that most engineered structures are made of combinations of very different materials such as ceramics, metals and plastics. Joining them together requires either some sort of mechanical attachment like a rivet, a nut and bolt, or an adhesive such as epoxy; each of these approaches, however, has its limitations.

?If we could reproduce the property gradients that we find in squid beak, it would open new possibilities for joining materials,? explained Zok. ?For example, if you graded an adhesive to make its properties match one material on one side and the other material on the other side, you could potentially form a much more robust bond,? he said. ?This could really revolutionize the way engineers think about joining disparate materials.?

According to Waite, the researchers have been helped by the fact that the Humboldt squid seem to be moving north from their traditional habitats such as the deep waters off the coast of Acapulco, Mexico?they have recently been found in large numbers in Southern California waters. Dozens of dead Humboldt squid have recently washed up on campus beaches, providing the researchers with more beaks to study.

Additional authors of the Science magazine paper which published the squid beak findings include Todd Schneberk, affiliated with UCSB?s Materials Research Laboratory and MCDB, and Chengjun Sun, affiliated with MCDB and the Marine Science Institute. The research was funded by the National Institutes of Health, National Science Foundation, NASA and the Swiss National Science Foundation.

Relevant links:
The *Science* paper ?The Transition from Stiff to Compliant Materials in Squid Beaks: [sciencemag.org/cgi/content/full/sci;319/5871/1816](http://sciencemag.org/cgi/content/full/sci;319/5871/1816) [2]

KQED *Quest* show on the fierce Humboldt Squid: [kqed.org/quest/television/view/774](http://kqed.org/quest/television/view/774) [3]

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