JAWS OF DEATH

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Sharks, rays, and ratfishes share a special burden: these cartilaginous fishes are saddled with a reputation for being somehow inferior to vertebrates blessed with bony skeletons.

Bone is certainly a wonderfully strong material. It lets hyenas crush carcasses with their jaws and enables elephants to support their massive bodies. Bone tissue is crammed with cells known as osteocytes and blood vessels that keep them nourished. The osteocytes release calcium, phosphates, and other minerals, which help make bones strong. They form layers that wrap around the outside of the bone and create a dense web of branching columns inside it.

The cartilage in sharks and rays, by comparison, consists primarily of a mesh of collagen fibers embedded in a gelatin-like matrix, along with a scattering of cartilage-generating cells called chondrocytes. (Sometimes the cartilage is surrounded by a thin layer of mineralized tissue that gives it a little extra stiffness.) The result is a softness and flexibility that imply a certain weakness. After all, it is backbone we admire in a person, not cartilage.

Dating back at least 420 million years, cartilaginous fishes are sometimes referred to as primitive--as if cartilage were an intermediate step on the climb from invertebrates to bony vertebrates. The development of a human embryo seems to replay this imagined evolutionary ascent: the embryo starts out with a skeleton of pure cartilage that gradually turns almost completely to bone. As adults, we retain only a few vestiges of cartilage-in the nose, the ear, the voice box, the disks between the vertebrae, and at the ends of freemoving bones.

Adam Summers, a biologist at the University of California, Berkeley, is determined to show that this supposed inferiority of cartilaginous fishes is a biomechanical myth. Cartilage is indeed generally weaker than bone but at times can become remarkably stiff and strong. For the past few years, Summers has been studying the cownose ray (Rhinoptera bonasus). This three-foot-wide creature, which lives solely on hard-shelled mollusks, is a scourge of oystermen; a school of 3,000 rays can pick an oyster bed clean in an afternoon. A ray eats its prey by grabbing the mollusk in its mouth and crushing the shell with its jaws.

To discover how this fish can be so adept at breaking something so much harder than its own jaws, Summers x-rayed a cownose ray. Its cartilaginous jaws, he found, had a lot of mineral inside them. At first he thought he had picked a diseased individual to study. In humans, cartilage contains hard, calcified deposits only when a person is suffering from a disorder such as scleroderma (an ultimately fatal illness in which the joints and skin stiffen). Yet Summers discovered that ray after ray had the same sort of jaw, with a mineral-rich cartilage unlike any that had been described before.

The mineral, however, is not randomly distributed in the ray's jaws, nor is it spread evenly. Rather, it is the chief ingredient of hollow struts in both upper and lower jaws, and these struts are concentrated in the areas of the jaws that bear down on prey. Summers cannot yet say how these struts form, but their function is clear. Without adding much weight to a structure, struts allow it to resist bending and buckling. Struts are a favorite tool of engineers, whether they are designing a bridge or a piece of corrugated cardboard. Likewise, struts help a cownose ray's jaws hold up against the shell of a clam or an oyster.

But Summers suspects that the struts are responsible for only part of the cownose ray's shell-crushing ability. Species of rays that eat fish or softbodied invertebrates have loose ligaments connecting the upper and lower jaws. In these species, the jaws' left and right sides are separate, which means the ray can bite down with one while opening the other. That freedom gives these rays the flexibility they need to handle squirming prey.

The cownose ray has a different jaw design. To help crush hard prey, it has a solid lower jaw and a solid upper jaw. In addition, ligaments lash this ray's upper and lower jaws tightly together. Such a design, Summers proposes, would be ideal for a fish that uses its jaws as a nutcracker. Placing a shellfish between them, he says, the cownose ray might contract the muscles on the left side of its mouth. This side would then act like the handles of the nutcracker being squeezed together.

At first, bringing the left side of the jaws together would stretch the right side of the jaws apart. But because the ligaments are so tight, the jaws couldn't stretch very far, and soon the ligaments would begin acting like the fulcrum at the hinged end of the nutcracker. As the cownose ray continued squeezing the left side of its jaws closer and closer together, it could put more and more pressure on the shellfish, crushing it.

A nutcracker works by amplifying the forces exerted on it. Summers calculates that a cownose ray with prey caught at the center of its jaws would, because of the jaws' architecture, be able to double the force of its bite. He plans to test his nutcracker model by recording the activity of jaw muscles in live cownose rays as they feast on shellfish. The results of these experiments, he expects, will demonstrate just how a jaw that is more custard than steel can become with the help of some struts and proper leverage-shell-shatteringly strong.