

Connective tissue that changes stiffness under nervous control

When you keep raising your hand, your muscles will soon get tired. What if your skin stiffens in the raised position? You can let your muscles relax and still your hand maintains the raised posture. This is what sea urchins do. Skin belongs to the tissue called connective tissue. Most connective tissue is fairly inert: it works as a mechanically passive material proving support to cells and tissues keeping its stiffness constant. Connective tissue of sea urchins is, however, active: it changes the stiffness rapidly and reversibly in response to stimulation and the "will" of animals. When sea urchins want to hold their spines rigid, they stiffen a unique form of connective tissue known as catch connective tissue (CCT). Each spine makes a ball-and-socket joint with a shell on which it stands.

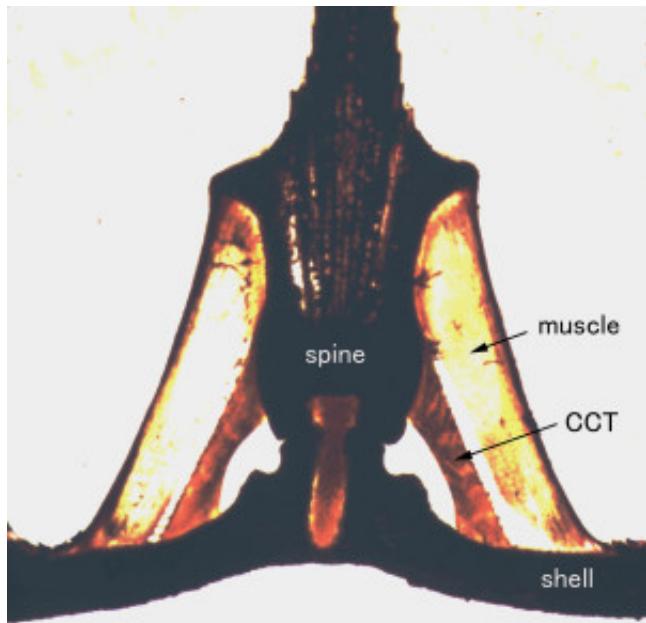


Fig. 1. Spine joint cut in half along the spine axis.

The joint is surrounded with an outer cone of muscles and an inner cone of CCT, both connecting the spine to a shell (Fig. 1.). The former is responsible for spine movement and the latter is for spine-posture maintenance. Stiffness changes in CCT and muscle contractions occur in a coordinated manner. For example, a touch on a spine on one hand makes it immobile through stiffening of CCT, and on the other hand causes adjacent spines to incline toward the touched spine, which is the result of muscle contraction and softening of CCT. The softening of CCT can be interpreted as a response that lessens impedance of the spine movements by CCT.

The coordination between CCT and muscle is mediated by nerves, which is clearly shown in the shadow response of *Diadema*. This sea urchin waves spines when a shadow passes over – in a bid to avoid being nibbled by a fish. In this response CCT becomes soft while muscles continue contraction-relaxation cycles. The shadow response abolishes after the nerve pathways from the radial nerve to spines had been cut, which shows that the shadow response is the reflex through radial nerves. Electrical stimulation of the radial nerve invokes a similar response to the shadow response.

Sea urchins are a member of echinoderms in which starfish, brittlestars and sea cucumbers are included. CCT is found in all members of echinoderms. When a soft starfish wants to prize apart a mollusk it stiffen CCT connecting skeletal ossicles to make the whole body rigid. When a brittlestar is nibbled by a fish on the arm, it drastically softens CCT connecting arm bones to cast off the nibbled arm and escapes. The merit of CCT is economy. It can maintain posture over lengthy periods with very little energy cost, unlike muscle, which requires a constant supply of energy.

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