What makes sense? Mechanosensing for soft locomotion

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The types of sensory information necessary to control movements in soft-bodied animals and robots are largely unknown. It is generally assumed that animals monitor strain in most tissues and that this is supplemented by force sensors in muscles and touch sensors on the body surface. Similar capabilities are built into traditional robots to provide feedback for posture control, manipulation and locomotion. However, in the absence of discrete joints and other skeletal elements it is not clear what sensors should be built into deformable robots. We have been studying such sensory-motor integration in the soft scansorial larval insect *Manduca sexta.* Because *Manduca* lacks image–forming eyes most sensory feedback for locomotion is mediated by mechanosensors on the body surface and stretch receptors attached to internal tissues. In addition, the internal body wall is tiled by a plexus of sensory neurons whose role in locomotion is poorly understood. Recordings from sensory nerves in the abdomen show that neurons associated with the body wall are sensitive to small amplitude strains, including vibration. The anatomy and response properties of these neurons suggest that they respond to body deformation. The validity of the control strategy is demonstrated with simulation and a soft crawling robot that uses deformation of its body to detect changes in friction on a substrate. This information is used to provide local sensory feedback for coupled oscillators that control the robot's locomotion. One goal of these studies is to determine how mechanical feedback is collected, processed and incorporated into the control of movements by highly deformable climbing animals and robots working in complex environments.