Stephenson School of Biomedical Engineering Seminar Series
presents
Lessons in Mechanical Design Learned from Insects

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The world insects inhabit often requires achieving feats that would be almost impossible for a larger animal. Jumping, spinning, accelerating and sensing the world around them are accomplished through an intricate use of mechanical structures within their bodies. The structures used to accomplish these feats present prototype designs for man-made devices to match an insect's capabilities. To illustrate this, I will discuss the mechanics behind three examples from the insect world. In the first example, the sub millisecond acceleration phase of jump of the planthopper (*Auchenorrhyncha*) [1,2], the power requirements are orders of magnitude larger than that provided by skeletal muscle. In addition, jumping planthoppers must extend their legs within microseconds of each other, requiring an incredible amount of synchrony. To meet the power needs, planthoppers use an internal spring that stores and releases mechanical energy in the same way a composite bow stores and releases energy into an arrow. This spring consists of a layered structure of a hard chitinous insect cuticle reinforced with a softer protein called 'resilin'. To meet the synchrony needs, juvenile planthoppers use a gear system which constrains each leg to extend at precisely the same time, the first observation of true mechanical gearing in nature [2]. In the second example, the acrobatic mid-air orientation of wingless preying mantises (*Mantodea*) [3], angular momentum must be precisely manipulated so that the mantis can reach a target with a given orientation. To do this, mantises first alter their posture so that the thrust generated by leg extension gives them an initial amount of spin (angular momentum). After take-off, mantises then transfer this angular momentum between their appendages so that the body rotates the appropriate amount to land on the target. The third example is the detection of electric fields by bumble bees (*Bombus*) [4]. Bumble bees can differentiate between flowers based on the flower's electric field. Bees do this by using their body hairs as electro-mechanical lever systems which bend in reaction to an incident electrostatic field. Each hair is electrically charged, contributing to the net electrical charge on the bee. Consequently, in the presence of an electric field, the hairs bend, sending information to the nervous system [5]. Each of these three examples provides mechanical solutions to intricate problems within the insect world.

[1] Sutton GP, Burrows M., *J. Exp. Biol*,. 213, 9, 1406-1416 (2010), [2] Burrows M, Sutton GP, *Science* 341, 6151 (2013), [3] Burrows M, Cullen DA, Doroshenko M, Sutton GP, *Current Biology,* 25(6), 786-789 (2015), [4] Clarke D, Whitney H., Sutton GP, Robert D, *Science* 340, 6128, 66-69 (2013), [5] Sutton GP, Clarke D, Morley EL, Robert D, PNAS 113, 26, 7261-7265 (2016).

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