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Structural and physical determinants of the proboscis-sucking pump complex in the evolution of fluid-feeding insects

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Abstract

© 2017 The Author(s). Fluid-feeding insects have evolved a unique strategy to distribute the labor between a liquid-acquisition device (proboscis) and a sucking pump. We theoretically examined physical constraints associated with coupling of the proboscis and sucking pump into a united functional organ. Classification of fluid feeders with respect to the mechanism of energy dissipation is given by using only two dimensionless parameters that depend on the length and diameter of the proboscis food canal, maximum expansion of the sucking pump chamber, and chamber size. Five species of Lepidoptera - White-headed prominent moth (Symmerista albifrons), White-dotted prominent moth (Nadata gibosa), Monarch butterfly (Danaus plexippus), Carolina sphinx moth (Manduca sexta), and Death's head sphinx moth (Acherontia atropos) - were used to illustrate this classification. The results provide a rationale for categorizing fluid-feeding insects into two groups, depending on whether muscular energy is spent on moving fluid through the proboscis or through the pump. These findings are relevant to understanding energetic costs of evolutionary elaboration and reduction of the mouthparts and insect diversification through development of new habits by fluid-feeding insects in general and by Lepidoptera in particular.

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