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Changes in hemolymph total CO$_2$ content during the water-to-air respiratory transition of amphibiotic dragonflies

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Abstract:

Dragonflies (Odonata, Anisoptera) are amphibiotic; the nymph is aquatic and breathes water using a rectal gill before transitioning to the winged adult that breathes air through spiracles. While the evolutionary and developmental transition from water- to air-breathing is known to be associated with a dramatic rise in internal CO$_2$ levels, the changes in blood-gas composition experienced by amphibiotic insects, which represent an ancestral air-to-water transition, are unknown. This study measured total CO$_2$ (TCO$_2$) in hemolymph collected from aquatic nymphs and air-breathing adults of Anax junius, Aeshna multicolar (Aeshnidae), Libellula quadrimaculata, and L. forensis (Libellulidae). Hemolymph PCO$_2$ was also measured in vivo in both Aeshnid nymphs and marbled crayfish (Procambarus fallax f. virginalis) using a novel fiber-optic CO$_2$ sensor. The hemolymph TCO$_2$ of the pre- and early-final instar nymphs was found to be significantly lower than that of the air-breathing adults. However, the TCO$_2$ of the late-final instar Aeshnid nymphs was not significantly different from the air-breathing adult, despite the late-final nymph still breathing water. TCO$_2$ and PCO$_2$ were also significantly higher in the hemolymph of early-final Aeshnid nymphs compared to the water-breathing crayfish. Thus, while dragonfly nymphs show an increase in internal CO$_2$ as they transition from water to air, from an evolutionary standpoint, the nymph’s ability to breathe water is associated with a comparatively minor decrease in hemolymph TCO$_2$ relative to the air-breathing adult.

Keywords: amphibiotic, insect, TCO$_2$, PCO$_2$, hemolymph, aquatic