

**IS CARDIOVASCULAR OXYGEN TRANSPORT NECESSARY  
IN FISH EMBRYOS AND LARVAE?**

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**EXTENDED ABSTRACT ONLY - DO NOT CITE**

Embryonic fish and amphibians have a functional heart and circulation, and often circulating red cells, well before hatching. Nonetheless, recent experiments suggest that the cardiovascular system has little role in oxygen transport in early developmental stages. For example, the distribution of oxygen uptake does not parallel the distribution of cutaneous blood vessels in Atlantic salmon yolk-sac larvae (Wells and Pinder, 1996). Moreover, carbon monoxide (CO), which prevents oxygen binding to hemoglobin, does not affect the distribution of oxygen uptake between gills and body surface, indicating that oxygen is not transported from the gills to other tissues (Pinder, Wells, and Sethi, unpublished data). Carbon monoxide also does not affect development, metabolic rate, or heart function in zebrafish embryos and larvae (Pelster and Burggren, 1996). Amphibian larvae have been raised to metamorphosis in CO, with little effect on growth, survival, metabolic rate, or cardiovascular development (Territo and Burggren, 1998). Cardiovascular oxygen transport is thus not necessary for normal development in several fish and amphibian embryos and larvae.

All of these examples are of fish and amphibians in normoxic water, which provides a relatively large PO<sub>2</sub> gradient for direct diffusion to tissues, and a high enough PO<sub>2</sub> to dissolve a significant amount of O<sub>2</sub> in plasma. There are circumstances, however, that seem likely to require hemoglobin and cardiovascular oxygen transport: large body size, environmental hypoxia, and high temperatures (thus high metabolic rates). Indeed, skate embryos, which can reach several grams, have specialized external gills (there is no point in having gills without

cardiovascular oxygen transport from gills to tissues), as do embryos of viviparous perch (Webb and Brett, 1972). Embryos of some tropical frogs have external gills that are resorbed within minutes of hatching into tadpoles and whose resorption is slowed by hypoxia (Warkentin, pers. comm.). Foster (this symposium) demonstrates that carbon monoxide does affect growth and cardiovascular development in Tilapia, a fish with large embryos, developing at 29°C. In brown trout at 15° (close to their upper temperature tolerance), treatment with CO decreases oxygen conductance by around 50%, indicating that roughly half the oxygen consumed is transported on hemoglobin (Pinder, Wells and Sethi, unpublished data).

There are thus circumstances in which oxygen transport in fish embryos and larvae can be entirely by direct diffusion to tissues, and others where cardiovascular transport of oxygen bound to hemoglobin is important. The relative importance of these two parallel routes of oxygen transport will depend on several factors, primarily metabolic rate, embryo size, and environmental PO<sub>2</sub>. Circumstances in which cardiovascular oxygen transport is most likely to be important include all ovoviviparous or viviparous fish, fish with large eggs, fish reproducing in stagnant shallow water, and tropical fish. Circumstances least likely to require cardiovascular oxygen transport include marine pelagic eggs and larvae, temperate and arctic fish, and eggs and larvae developing in flowing water. These factors have long been speculated to affect the degree of cardiovascular development seen in different species of fish. We may now be able to test these ideas by combining detailed studies of individual larvae with accumulated data on egg sizes and environmental conditions for large numbers of species. Although the first tests for an oxygen transport function of the cardiovascular system in fish larvae suggest that the cardiovascular system is less important than earlier assumed, there are still very few studies addressing the question, representing only a tiny proportion of the diversity of fish development.

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### **References**

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