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Case Study: Larval Development in Fishes

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Adult teleosts exhibit an impressive degree of plasticity with respect to gas exchange and ion regulation. Changes at multiple levels of biological organization can shift critical oxygen tensions and ion flux kinetics, including transport affinity (Km) and maximum capacity (Jmax), such that homeostasis is maintained despite great variation in environmental oxygen and ionic composition. The majority of the changes that underlie this plasticity occur at the gill, which is the principle site of gas exchange and ion regulation in adult fish.

Larval teleosts initially possess underdeveloped gills, thus gas exchange and ion regulation instead occur primarily across the skin. Perhaps unsurprisingly, larval teleosts display little evidence of plasticity early in development when the gill plays only a minor role in these processes. As the gill develops and begins to supplant the skin as the dominant regulatory site, plasticity begins to increase, albeit in limited fashion. Thus, it appears that increasing plasticity accompanies an increased role of the gill in gas exchange and ion regulation. However, a critical window exists within which plasticity is restricted to modifications that exclude structural remodelling of the gill. Predictably, plasticity within this window is severely limited. It appears that adult-like levels of plasticity are only approached upon closing of this window, which seems to coincide with full formation of the gill.

This apparent window of non-plasticity for gas exchange and ion regulatory capacity also applies to the relative timing for which these processes transition from skin to gill. Transition from skin to gill is widely believed to be driven by the dermal thickening and reduction in body surface area to volume ratio (SA:V) that accompanies growth. Changes to dermal thickness and SA:V decrease the skin’s capacity for trans-epithelial flux, thus necessitating transition to the gill to maintain homeostasis. Oxygen uptake was traditionally believed to be the primary driver for gill development, and thus most inhibited by changes to dermal thickness and SA:V. However, the gill of every teleost examined to date appears to become critical for ion regulation first. Even when rearing levels of oxygen and ions are manipulated, ion regulation still appears to shift to the gills earlier than gas exchange.

This seemingly hardwired development likely indicates that early larval teleost ontogeny of gas exchange and ion regulation is under strong selective pressure. Possible drivers for this lack of plasticity in capacity and developmental sequence are discussed, as are the implications for vertebrate evolution.