THE ROLE OF O_2 AND CO_2 SENSING IN BREATHING PATTERN FORMATION IN THE TAMBAQUI, *COLOSSOMA MACROPOMUM*

Stephen G. Reid
Division of Life Sciences
University of Toronto at Scarborough
1265 Military Trail
Scarborough, Ontario, Canada M1C 1A4
Fax: 416-287-7676

Lena Sundin, University of Göteborg, Sweden
Luis Henrique Florindo, Federal University of São Carlos, Brasil
Tadeu Rantin, Federal University of São Carlos, Brasil
William K. Milsom, University of British Columbia, Vancouver, Canada

EXTENDED ABSTRACT ONLY – DO NOT CITE

In all vertebrate groups, breathing patterns arise that can be classified as either continuous or periodic. Periodic breathing can be further classified as either "random" where the breaths occur with no obvious rhythm or episodic where breaths are clustered together into episodes separated by discrete non-ventilatory periods or apnea. These breathing patterns originate as the rhythmic neural output from a respiratory central rhythm generator located within the medulla. The respiratory rhythm generator is likely conditional in nature, operating at a sub-threshold level that requires some external (afferent) input to initiate breathing. Ultimately, the pattern of motor output to the respiratory muscles depends upon modification of the respiratory rhythm by various afferent and central inputs. These include inputs from chemoreceptors, mechanoreceptors and higher brain centres.

In water-breathing fish, respiratory-related afferent input to the brain arises from mechanoreceptors on the gill arches and O_2 and CO_2/pH chemoreceptors located on the gill arches and in the oro-branchial cavity (mouth and operculum). These receptors can monitor gill displacement and either O_2 or CO_2/pH levels in the water or blood and once stimulated initiate changes in cardiorespiratory function. The mechanoreceptors and chemoreceptors on the gill arches are innervated by branches of the glossopharyngeal (IX^{th} cranial; cnIX) or vagus (X^{th} cranial; cnX) nerves while the chemoreceptors in the oro-branchial cavity are innervated by branches of the trigeminal (V^{th} cranial; cnV) and facial (VII^{th} cranial; cnVII) nerves.

Previously we have analysed the effects of stimulation of O_2 and CO_2/pH chemoreceptors in the gills and oro-branchial cavity on the cardiorespiratory responses to hypoxia and hypercarbia in a neotropical fish, the tambaqui (Sundin *et al*. 2000; Milsom *et al*. 2002). Tambaqui are a water-breathing fish that perform aquatic surface respiration (ASR) under conditions of severe environmental hypoxia. Under these conditions, they remain at the surface of the water where they skim the O_2-rich surface layer. To facilitate this, the lower lip swells and acts as a funnel that directs the surface water into the mouth and over the gills. During the course of these studies we noticed that reduced chemoreceptor drive (i.e. hyperoxia) and/or removal of chemoreceptor input via denervation not only altered total ventilation but, at times, also altered the pattern of breathing in tambaqui.

Based on our observations we hypothesised that input from O_2 and CO_2/pH chemoreceptors in the gills and oro-branchial cavity not only produced respiratory drive affecting total ventilation, but also produced "biasing input" altering breathing pattern. Using a decerebrate and artificially ventilated preparation held in a stereotaxic device, this study quantified the effects of changing respiratory drive and the inputs from various receptor groups on the breathing pattern of tambaqui. The study addressed the role of both specific and general afferent input in the formation of complex breathing patterns in the tambaqui and explored the possibility that chemoreceptors specific for producing changes in breathing pattern (versus total level of ventilation) may exist in fish.

Three general breathing patterns were observed: 1) regular (continuous) breathing, 2) frequency cycling (continuous breathing with alternating fast and slow cycles), and 3) episodic breathing. Under normoxic, normocapnic conditions, 50% of control fish exhibited regular continuous breathing and 50% exhibited frequency cycling. Denervation of the gills and oro-branchial cavity promoted a pattern of frequency cycling. Central denervation of the glossopharyngeal and vagus nerves induced a pattern of episodic breathing. Regardless of the denervation state, hyperoxia produced either frequency cycling or episodic breathing while hypoxia and hypercarbia shifted the pattern to frequency cycling and continuous breathing.

We suggest that these breathing patterns represent a *continuum* from continuous to episodic breathing with waxing and waning occupying an intermediate stage. The data further suggest that breathing pattern is influenced by both specific afferent input from chemoreceptors and generalised afferent input from the periphery to the brain and that chemoreceptors specific for producing changes in breathing pattern may exist in fish.

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References

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