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Research question: How does chronic hypoxia and starvation impact lipid metabolism in teleost fish?
Relevant background and project overview:
Dissolved oxygen (DO) levels in global waters are on a rapid decline, primarily due to anthropogenic drivers such as global climate change and eutrophication (Friedrich et al., 2014). These states of low DO or hypoxia, are becoming far more frequent and longer lasting causing energetic issues for aquatic animals (Irby et al., 2018). Oxygen is required by most animals to generate cellular energy in the form of ATP using the process of oxidative phosphorylation within the mitochondria. Under hypoxic conditions fish can employ numerous strategies to increase oxygen uptake such as gill remodeling and increasing red blood cell counts. Or they can decrease energy expenditure by decreasing locomotive activity, metabolic rate depression, and in some cases reduced feeding or complete starvation to balance energy supply and demand (Wu, 2002).

Under normal oxygen conditions, starvation most often causes an increase in lipid metabolism to generate the required ATP as fats are often readily accessible since they can be stored in large quantities around the body (Morash et al., 2011). The preference for the oxidation of lipids also allows carbohydrates to be saved to act as a glucose source for the brain (Neumann-Haefelin et al., 2004). However, exposure to hypoxia generally causes a decrease in lipid metabolism as they require more O_2 to metabolize and can potentially increase reactive oxygen damage (Leverve et al. 2007). Thus, when exposed to hypoxia over longer periods of time without consuming food cells may be met with competing signals regarding lipid metabolism that may change depending on the duration of exposure.

To understand what is happening in the mitochondria during these periods of conflicting signalling we can look at an enzyme called carnitine palmitoyltransferase I (CPT I). CPT I is located on the inside of the outer mitochondrial membrane and is a key enzyme in regulating long chain fatty acid (LCFA) entry into the mitochondria for β-oxidation (the breakdown of fatty acids to generate acetyl-CoA) (Morash et al., 2008). CPT I is allosterically modulated by endogenous malonyl-CoA which inhibits the function of the enzyme stopping the entry of LCFA into the mitochondria (Morash et al., 2008). The sensitivity of CPT I to malonyl-CoA can be altered by various factors such as temperature, membrane fluidity, exercise, and diet (Morash et al., 2011). However, the impact of hypoxia on the sensitivity of CPT I to malonyl-CoA or its affinity for LCFAs is still largely unknown.

This research project seeks to understand what changes might occur to the sensitivity of CPT I to M-CoA, CPT I's affinity for fatty acids, and understand if/how lipid metabolism is altered in fish in response to chronic hypoxia and starvation. We hypothesize that during periods of chronic hypoxia and starvation fish will upregulate lipid metabolism, displaying a decreased sensitivity of CPT I to M-CoA, and an increased affinity of CPT I for LCFA. During chronic hypoxia fish may need to increase reliance on lipid metabolism because over time the glucose stores used for glycolysis during acute hypoxia will become depleted requiring them to switch to an alternative substrate to generate required ATP.
Methods:
Brook trout will be used to observe the effects of starvation and chronic hypoxia on the lipid metabolism of various tissues. Fish will be allocated into three groups; a control normoxia group (n=10), a group fasted for 10 days in normoxia (n=10), and a group fasted for 10 days at ~45% O_2. Tissue samples from heart, liver and muscle will be dissected and their mitochondria will be isolated and used to test 1) the sensitivity to of CPT I to M-CoA, 2) the affinity of CPT I to fatty acids, and 3) the rate of ATP production. We will also measure the enzyme activity of key enzymes in the beta oxidation pathway to determine if this is affected.
Research implications:
Understanding the impacts of chronic hypoxia and starvation on the metabolism of fish can aid in the development of conservation strategies, improvement of aquaculture practices, and allow us to make inferences on how these conditions may impact other related taxa. While many studies have looked at the effects of hypoxia or starvation individually, very few environmental stressors occur in total isolation and so it is crucial that we begin to understand how stressors work in tandem to better predict the impacts that these changes will have on fishes and how we may begin to mitigate them.

Statement:

At Mount Allison we are very lucky to have a STEM program filled with many incredible women doing research on campus. This isn't the case at many institutions and in the broader field of science and technology. Thus, getting the opportunity to work with Dr. Morash as a woman in STEM, doing research, is an opportunity that isn't available to many people. Getting to work with not only just a woman in STEM but another 2SLGBTQ+ woman in STEM would be amazing. I am a firm believer that you cannot be what you cannot see and therefore getting to work with someone who understands where you fit in the science world, and in society is essential for positive and impactful experiences. On top of this, I've always been interested in the life sciences and growing up on the coast of an island, have spent a large chunk of time watching and interacting with aquatic life. These interactions with aquatic life have included working with and handling fish, lobster, and crab on my family's commercial fishing vessel and simply spending time in and around the ocean, rivers, and lakes near my hometown.

Many courses I've taken previously and am currently enrolled in have prepared me well for this work. These courses include things such as Animal Biology (BIOL2401), Design & Statistical Analysis (BIOL2701), Conservation Biology (BIOL3811), and Human Physiology (BIOL3211). Additional courses which I believe are especially applicable for this research are Cell Biology (BIOL1501) which has allowed me to understand the mechanics of life at the cellular level, and Animal Physiology (BIOL3201) from which I've gained knowledge about energy production and general fish physiology. Along with the lecture-based components of these and other science courses, many have had laboratory-based activities. These labs have allowed me not only to gain foundational skills and techniques for hands-on work with organisms and lab equipment, but have also aided in building collaborative, group work skills which I can continue to refine, and build upon this summer.

I have also had many experiences outside of the academic science world that have helped me to be prepared for summer research. I have already completed an independent study in Women's and Gender Studies which required me to work efficiently in a self-guided, independent manner but also be able to work and consult with other students and faculty members which will be an important skill with this type of research. I am also currently a student athletic therapist with the women's basketball team which has forced me to manage my time efficiently to complete my schoolwork on time while still attending a large majority of their practices and games, as well as learn how to think quickly on my feet and problem solve on the fly. Beyond all this, I recently worked for two summers in the Cape Breton Highlands National Park where I got to learn lots about the impacts of human presence and climate change on the local flora and fauna as well as work in a team-oriented environment.

Beginning in September 2023 I will start working on my honours thesis with Dr. Morash and therefore this would be the absolute ideal scenario to prepare me for that work. My plans for further education are still rather undecided but include the option of doing research and field work in animal biology. Having previous research experience in this field would be a major asset when applying to prospective programs. Regardless of what type of education I pursue there are many basic skills such as scientific writing, group and independent work, laboratory work, time management, and communication that I would gain from this experience that will aid me moving forward.