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Is Hemoglobin Gelation an Adaptation to the Cold in Boreal Fishes?

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Principal Investigator: Hunt Von Herbing, Ione . **Award ID:** 0118372
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Title:
Is Hemoglobin Gelation an Adaptation to the Cold in Boreal Fishes?

Project Participants

Senior Personnel

Name: Hunt Von Herbing, Ione
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Cashon, Robert
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

DFO, St. Andrews Biological Station

Other Collaborators or Contacts

Dr. Mike Vayda, University of Maine

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

This award supported initial investigations on the unusual phenomenon of hemoglobin (Hb) gelation or crystallization that occurs in red blood cells of boreal fishes under low oxygen conditions. Preliminary data was obtained on the frequency and physiological nature of the phenomenon of hemoglobin (Hb) gelation in red blood cells of fishes that inhabit cold-water temperate and Arctic environments. In total, thirty-two species of marine fishes were examined during this project and only cold-water boreal fishes exhibited Hb gelation. Specifically, all fish in the family Gadidae or 'truecods' exhibited gelation, which included, Atlantic cod (Gadus morhua) and Arctic cod (Boreogadus saida) as well as 4 other species in this family. This study tested the hypothesis that hemoglobin gelation within fish red blood cells may be a feature of normal fish respiratory physiology and might be adaptive in extreme cold-water environments. Experiments included ligand binding kinetics using stopped flow spectrophotometry, oxygen equilibrium studies using tonometry, optical microscopy, and SEM characterization of Hb crystalline structures. Preliminary findings on purified Hb suggest that gelation is an intrinsic property of the Hb and occurs under conditions which are likely to be found in vivo. One preliminary experiment included sectioning for TEM whole juvenile Atlantic cod after they had been

exposed to low oxygen conditions. These results showed that Hb gelated in red blood cells within muscle arteries and provided evidence that Hb gelation occurs in vivo as well as in vitro and may therefore impact fish survival under low oxygen conditions. One M.S. degree student is presently pursuing this work and preliminary results were presented at the Society for Integrative and Comparative Biology meetings in 2001 and 2002.

Findings: (See PDF version submitted by PI at the end of the report)

Of all the species of marine fishes examined in this project, all fish species in the family Gadidae or 'truecods' exhibited gelation. Because Hb gelation occurred both in vitro and in vivo, it is likely that low oxygen, changes in pH and changes in temperature may all induce hemoglobin (Hb) gelation and impact the physiological condition and survival of boreo-Arctic fishes, specifically those fish in the Gadid family. This is of concern because gadid fishes are very diverse and abundant, and one of the most important groups of fishes in the North Atlantic ecosystem. The scientific relevance of these results was to determine that Hb gelation appears to be confined to only a few related, but important boreo-Arctic species of fishes. Future studies should include work to investigate at what organismal level Hb gelation is regulated, whether there are common morphological and physiological traits among hemoglobins of boreal fishes that exhibit gelation, and whether these traits are adaptive in extreme environments characteristic of boreal and polar regions.

Training and Development:

One MS student, Jennifer Galvin, in the department of Biochemistry, Microbiology and Molecular Biology is presently finishing off her degree based on this project. As an MS student in molecular biology, she was exposed to techniques in protein physiology and fish organismal physiology. In addition she also learned valuable skills in microscopy (preparation and viewing for TEM and SEM) and was able to sample fish from the field, which exposed her to environmental biology. This diverse project also provided an opportunity to view the problem of hemoglobin (Hb) gelation in fishes in an integrated, not isolated manner and address relevant issues facing the boreal and Arctic ecosystems. Several undergraduate work study and other graduate students also assisted in fish care, physiological experiments, and field trips.

Outreach Activities:

Preliminary results were presented at the SICB meeting in 2001 and 2002. In addition a short article was written for the magazine UMaine Today (Summer 2002). UMaine Today is a magazine published by the University of Maine designed to reach the public and inform them about research at the University of Maine.

Journal Publications

Hunt von Herbing, I; Cashon, R., "Hemoglobin gelation in red blood cells in marine fishes.", Biological Bulletin, p. , vol. , ( ). In preparation

Books or Other One-time Publications

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

The findings of this project suggest that Gadid fishes may be uniquely adapted to cold-water environments and that Hb gelation does not occur in most marine fishes. Because gadid fishes comprise one of the largest taxa in northern Atlantic Ocean, any physiological traits that are unique to this group may confer an adaptive advantage and faciltate their survival in the boreal oceans. However, if temperature conditions were to change in the boreal oceans, this may mean that gadid diversity, distribution and abundance may also be subject to change. In order to understand the impacts of global climate change on boreo-Arctic oceans, it is essential that we know the physiological nature of the most fish species that live there.

Contributions to Other Disciplines:

This is an integrative project and has contributed to molecular biology, by conducting 3-D structures on cod hemoglobin and by seqeuncing cod DNA.

Contributions to Human Resource Development:

Because gadid fishes represent one of the most important groups of fishes in the northern Atlantic Oceans, changes in their abundance and distribution will affect several sectors of the human resources. These include, fisheries, conservation, ecosystem managements and human

Contributions to Resources for Research and Education:

This project has upgraded the PI's lab for more detailed physiological analysis and also provided funds through charges to use the TEM in Murray Hall to maintain that facility.

Contributions Beyond Science and Engineering:

Results may in the future contribute to our understanding of the intrinsic and extrinsic factors that regulate blood physiology in vertebrates.

Categories for which nothing is reported:

Any Book

Any Web/Internet Site

Any Product

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