Ph.D. Candidate

Christopher David Small

Graduate Academic Unit

Biology

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February 9, 2021

10:00 a.m. (Atlantic)

Virtual Defence

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Examining Board:
Dr. Mike Duffy (Biology)
Dr. Aurora Nedelcu (Biology)
Dr. Yang Qu (Chemistry)
Dr. Tillmann Benfey (Biology) Supervisor
Dr. Bryan Crawford (Biology) Supervisor

External Examiner: Dr. Martin Flajšhans
University of South Bohemia in České Budějovic
Faculty of Fisheries and Protection of Waters
Czechia

The Oral Examination will be chaired by:
Dr. Kevin Englehart, Associate Dean of Graduate Studies

BIOGRAPHY

Universities attended (with dates & degrees obtained):

2014 – present PhD candidate, University of New Brunswick
2012 – 2014 MSc candidate in Biology, University of New Brunswick (transferred into PhD on Sept. 1, 2014)
2009 – 2012 BSc in Biology, University of New Brunswick

Publications:

Small, C.D., el-Khoury, M., Deslongchamps, G., Benfey, T.J., Crawford, B.D. Matrix metalloproteinase 13 activity is required for normal and hypoxia-induced precocious hatching in zebrafish embryos. *Journal of Developmental Biology*. **2019.** (Accepted)

Small, C.D. and Crawford B.D. Matrix metalloproteinases in neural development: a phylogenetically diverse perspective. *Neural Regen. Res.* **2016**, 11: 357-362. doi: 10.4103/1673-5374.179030.

Conference Presentations:

2020:

1) Title: Tissue-specific compensatory mechanisms in triploid zebrafish
Location: European Zebrafish Meeting, Online conference.

2019:

1) Title: Comparing somite morphology in diploid and triploid zebrafish
Location*:* Science Atlantic, Crandall University, Moncton, NB, Canada.
2) Title: The role of ploidy and cell size on vascular morphology in zebrafish
Location*:* Canadian Society of Zoology, University of Windsor, Windsor, Ont, Canada.
3) Title: Matrix metalloproteinase 13 is necessary but not sufficient for hatching in zebrafish embryos
Location: Development Day Symposium, Dalhousie University, Halifax, NS, Canada.
4) Title: The role of ploidy and cell size on vascular morphology and microcirculation in diploid and triploid zebrafish embryos
Location: Canadian Society of Ecology and Evolution, University of New Brunswick, Fredericton, NB, Canada.

Poster:

1) Title: Body size is independent of cell size in polyploid zebrafish
Location: Society of Developmental Biology, Boston, MA, U.S.A.

2018:

1) Title: Comparing tissue structure in diploid and triploid zebrafish
Location*:* Canadian Society of Zoology, Memorial University, St. John's, Nfld, Canada,AND Development Day Symposium, Dalhousie University, Halifax, NS, Canada
2) Title: The role of ploidy and cell size on myotome structure in zebrafish
Location*:* Canadian Society of Developmental Biology, Mont Tremblant, QC, Canada.
3) Title: Matrix metalloproteinase 13 regulates precocious hatching in zebrafish embryos
Location*:* Atlantic Regional Comparative Physiology conference, St. Andrews, NB, Canada

2017:

1) Title: Measuring the Rate of Erythropoiesis in Tg(GATA1a:dsRed) zebrafish
Location*:* Aquaculture Association of Canada, Halifax, NS, Canada. AND Atlantic Regional Comparative Physiology conference, St. Andrews, NB, Canada.

Several other Presentations and Posters

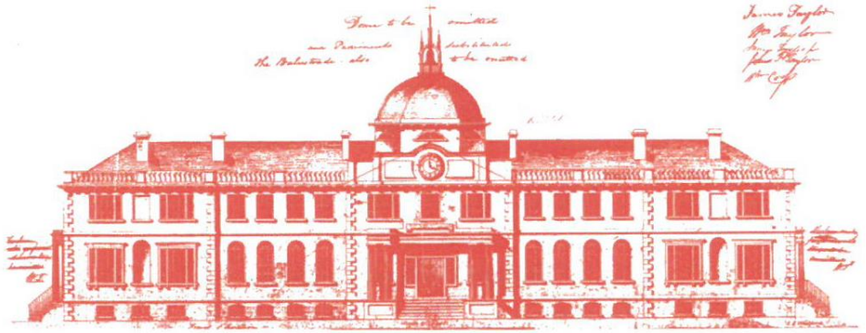
Tissue-Specific Compensatory Mechanisms and Erythropoiesis in Triploid Zebrafish

Abstract

In eukaryotes, cell size is proportional to the size of the nucleus and to the amount of genomic DNA housed within. Ploidy transitions, or Whole Genome Duplications (WGDs), double the amount of genomic DNA in the nucleus and cell size is increased consequently. Genome duplication is a driver for the evolution of novel traits by producing genetic redundancy that buffers the negative fitness consequences of mutations in highly conserved genes. WGDs have been discovered in nearly every major taxa of metazoan eukaryotes, but are more common in plants than in animals for reasons that are not clear. In plants, changes in ploidy and genome size produce larger organisms as the number of cells allocated to tissues does not compensate for larger cells. In contrast, cell size and body size is decoupled in vertebrates so polyploids are no larger than concomitant diploids. Research on the evolution of polyploids usually focuses on the fate of duplicated genes rather than on the developmental and physiological consequences of changing cell size and the quantization of tissues. Perhaps the relative scarcity of WGDs in animals pertains more to how these developmental and physiological consequences affect fitness rather than the evolutionary consequences that occur in later generations after polyploids have successfully reproduced.

Ploidy can be experimentally manipulated in most teleosts, but diploid/triploid comparisons are most common as triploids are reproductively sterile making them useful for the aquaculture industry. Triploids consistently underperform compared to diploids with reduced ability to tolerate stressful conditions and higher mortality rates when raised in conditions optimized for diploids. Triploids typically struggle to tolerate aerobic challenges leading many to suggest a cardiorespiratory limitation, but there is no clear mechanism explaining this difference between ploidies. The zebrafish is a popular model vertebrate that has been a boon for developmental biologists and, increasingly, physiologists. In this thesis, I have taken advantage of the many mutants and transgenic strains with tissue-specific fluorescent reporters to answer questions about the biology of polyploid vertebrates that would not be possible in classic, non-model species such as in Atlantic salmon.

For this thesis, I developed a novel ploidy determination technique to non-lethally measure the amount of DNA in the nuclei of zebrafish embryos *in vivo* using confocal microscopy and image processing (Chapter 2). I demonstrated for the first time that the compensatory mechanisms maintaining organ and body size in polyploids are tissue-specific by comparing the morphology of the blood, muscle, and the vasculature at single cell resolution (Chapter 3). Focusing in on the blood and erythropoietic system, I quantified hematopoietic stem cells in diploid and triploid embryos to show that triploids have fewer of these blood progenitor cells in their hematopoietic tissue. Triploids also produce erythrocytes at a slower rate compared to diploids suggesting that there are more aged, senescent erythrocytes in circulation perhaps contributing to the well-documented physiological limitations of triploids compared to diploids (Chapter 4). The utility of the zebrafish system makes it an ideal model organism for studying the biology of polyploids not only to improve the performance of triploids in aquaculture, but also to better understand why polyploidy is rarer in animals than in plants.



Home of the School of Graduate Studies, Sir Howard Douglas Hall was designed by J.E. Woolford in 1825 and is the oldest university building in Canada still in use.

The University of New Brunswick recognizes that the university sits on traditional Wolastoqey territory. The river that runs right by our university – the St. John River – is also known as Wolastoq, along which live the Wolastoqiyik -- the people of the beautiful and bountiful river.

UNIVERSITY OF NEW BRUNSWICK

SCHOOL OF GRADUATE STUDIES

ORAL EXAMINATION

Christopher David Small

IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY