Presentation Abstracts

Sorted according to surname of presenting author (underlined)

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Do differences between courtship of white-tailed and mule deer males reflect species differences in antipredator and social behaviour? / Est-ce que les différences de courtisage des mâles cerfs de Virginie et les cerfs mulets réflectent les différences d'espèces dans les comportements antiprédateurs et sociaux?

White-tailed and mule deer are closely related species that coexist on many sites in western North America. Although a few studies have described aspects of courtship behaviour for each species alone, there have been no quantified comparisons where the species are sympatric. To test whether differences described reflect species differences in courtship behaviour or are simply facultative responses to varying habitat conditions, we conducted focal observations of 229 males, which ranged in body size, on an open grassland study site during the 2014 and 2015 breeding season. As reported elsewhere, males of both species mostly used tending bonds (serial pair-breeding) during late-stage courtship, even though this habitat was extremely open and might be expected to lead to harem breeding. Consistent with our predictions, mule deer males were more likely to court in multiple male/multiple female groups than white-tailed males, and to tolerate concurrent courtship by other males in the same group. In contrast, white-tailed males almost exclusively tended females in isolated pairs, due in part to increased aggression between white-tailed males during late-stage courtship. Species differences in male courtship behaviour appeared consistent with species differences in antipredator and social behaviour and were not due to varying habitat conditions.

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Skin pentosidine does not covary with age in four species of wild seabirds / La pentosidine de peau ne covarie pas avec l'âge dans quatre espèces d'oiseaux marins sauvages

The process of aging is progressive, unavoidable and universal to all living beings. Unlike in many other organisms (fish otoliths, clam growth rings, mammal tooth wear), there is no known technique for accurately ageing birds in the wild. Recent studies identified pentosidine as a potential biomarker of chronological aging in several bird species. The objective of this study is to verify whether pentosidine accumulation is applicable as an aging biomarker in four species of long-lived seabirds. Skin biopsies were collected from foot webbings of known-age seabirds from four species: black-legged kittiwakes (*Rissa tridactyla*), Atlantic puffins (*Fratercula arctica*), razorbills (*Alca torda*), and thick-billed murres (*Uria lomvia*). Samples were analysed with High performance liquid chromatography (HPLC) to quantify pentosidine levels. Collagen levels were estimated through hydroxyproline assays to normalize pentosidine content across individuals. Kittiwakes displayed a weak correlation (r^2=0.39, P=0.009) between age and pentosidine concentration (pmol pentosidine/mg collagen). Puffins (r^2=0.02, P=0.65), razorbills (r^2=0.08, P=0.49), and murres (r^2=0.04, P=0.20) did not show any associations with age. We concluded that although determination of an individual's exact age would have invaluable applications, pentosidine does not appear to be a reliable method in these species.

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Filling in the gaps of 'leaky' epithelia: Branchial acid-base regulatory capacity and mechanisms of the Dungeness crab, *Metacarcinus magister* / Remplir les trous de l'épithélium poreux: La capacité

régulatrice acido-basique des branchies et les mécanismes du crabe de Dunganess, *Metacarcinus magister*

Osmoconforming invertebrates, whilst important ecologically and economically, have been poorly investigated for acid-base regulatory mechanisms – likely due to the attractive nature of euryhaline regulating species. Stenohaline osmoconforming crustaceans, such as the Dungeness crab, *Metacarcinus magister*, are expected to perform minimum iono-transport across their gill epithelium and possess a characteristically 'leaky' epithelium compared to ionoregulating species. Studies have shown, however, that *M. magister* is well-suited for active NH_4^+-excretion against a 16-fold inwardly-directed gradient suggesting their simplistic ionotransport capacity may be inapt regarding acid-base regulatory molecules and is thus worthy of investigation. Perfused posterior gills (7-9) of *M. magister* bathed in control seawater (pH 8.10) demonstrate active NH_4^+-excretion rates of 3.0 ± 0.5 $\mu molg^{-1}h^{-1}$, net HCO_3^--loss of 3.2 ± 0.5 $\mu molg^{-1}h^{-1}$, and slight alkalinization of perfusate (ΔpH +0.10 ± 0.02 units). HCl-induced environmental acidification (pH 7.10; HEPES-buffered) increased NH_4^+-excretion rates (5.3 ± 0.4 $\mu molg^{-1}h^{-1}$) and induced net-gain of HCO_3^- (-2.6 ± 0.5 $\mu molg^{-1}h^{-1}$) in slightly acidified perfusate (ΔpH -0.10 ± 0.02 units). Basolaterally applied ouabain and KM91104 abolish active NH_4^+-excretion across epithelia of control gills whereas in acidified seawater ouabain reduces excretion by 50% suggesting an alternative pH-induced mechanism exists. Basolateral application of colchicine, acetazolamide, amiloride, and EIPA will be discussed.

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Expression of insulin superfamily genes and functional characterization of insulin-like peptide 5 (INSL5) in Japanese medaka (*Oryzias latips*) / L'expression d'une superfamille de gènes reliés à l'insuline et la charactérisation fonctionnelle du peptide 5 (INSL5) chez le medaka japonais (*Oryzias latips*)

The relaxin peptides are a relatively recently discovered group of peptides hormones that belong to the insulin superfamily and appear to play diverse roles in vertebrate neuroendocrine regulation and reproduction. There are four relaxin family peptide hormones present in most vertebrates: namely relaxin (*Rln*) and relaxin 3 (*Rln3*) and insulin-like peptides 3 (*INSL3*) and INSL5. Fish additionally have two paralogous copies of RLN3 (*rln3a* and *rln3b*) and INSL5 (*insl5a* and *ins5b*). The relaxin family peptides signal via G-protein coupled receptors (GPCR) known collectively as the relaxin family peptide receptors (*RXFP*). In mammals, the cognate receptor for RLN and *INSL3* are *RXFP1* and RXPF2 respectively. On the other hand, the cognate receptors for RLN3 and *INSL5* in mammals are RXFP3 and RXFP4 respectively. In correspondence with the presence of paralogous copies of rln3a/rln3b and insl5a/insl5b in teleosts, teleosts also have a greatly expanded repertoire of rxfp3 and rxfp4 receptors through which they are hypothesized to exert their physiological action, although the primary binding relationship and function of rln3 and insl5 genes and the diversity of fxfp3/4 receptors in teleosts is not well understood. Of all of the relaxin peptides, the functional role of INSL5 is the least well understood. There is evidence in mammals that INSL5 hormone expressed in the colon acts in a paracrine manner on *RXFP4* receptors expressed on nerves innervating the colon, but there is also evidence that serum levels of INSL5 respond to multiple physiological cues including nutritional status (serum INSL5 levels increase during calorie restriction), stress (especially cortisol production), and gender. Despite these recent intriguing and highly debated hypotheses, no functional studies have been performed on this emerging peptide hormone in teleosts, despite there being several advantages to using a fish model. Studying the role of insl5 in a model fish species such as Japanese medaka or zebrafish should provide insights into the ancestral role of this peptide hormone in vertebrates. Moreover, since there are paralogous copies of both the peptides insl5a/insl5b and the receptors (rxfp3-2, rxpf3-3 and rxfp4) in teleosts, studying the functional role of insl5 in a model teleost opens opportunities for studying the processes of sub- and neo-functionalization during gene evolution.

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Sperm competition in a highly promiscuous African ground squirrel / Compétition de sperme chez l'écureuil terrestre Africaine à promiscuité sexuelle

When females copulate with two or more males, competition for fertilization can occur internally among sperm of different males. Cape ground squirrels (*Xerus inauris*) are African species that has a promiscuous mating system. Pre-copulatory sexual selection appears to be weak, as males are non-territorial, and fighting and aggression are rare. However, males have large testes and high operational sex ratios (F1: M11), suggesting very high levels of sperm competition. As litter sizes are small (1-2), most copulating males will not have fertilization success. Our genetic data found males had very low reproductive success, with only 28% siring offspring. The goal of this research is to understand how males maximize their reproductive success through sperm competition. We examined epididymal sperm numbers, abnormality, size, head shape, motility and vitality in males from southern Africa (N=20). Sperm number were explained by body condition and testis size. Sperm motility and vitality were high, and abnormality was low with most of sperm defects on the midpiece. Body condition, testis size, sperm motility and vitality are important traits for Cape ground squirrels' reproductive success via post-copulatory sexual selection. Our study brings a better understanding of mechanisms that account for successful fertilization of mammals.

Fry Lecture Abstract / Résumé de la conférence Fry

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Ecophysiology, a unique and exciting—but challenging—way to study adaptations of fishes to their environment

I have always defined myself as an ecophysiologist, but I am not sure that I ever saw a definition that completely encompasses my understanding of what ecophysiology is. In order to integrate all of the disciplines that are included in the "eco" portion of the word, I have built a large collaborative research environment over the years that has shaped my way of studying fish physiology. I am particularly interested by the physiological diversity that is present within species. Studying this diversity among ecotypes, populations, or strains (aquaculture) not only entails the integration of genetic, ecological, or evolutive factors into the interpretation of the physiological results, but also requires a reorientation of protocols and fieldwork to take into consideration this different perspective. Using examples from different fish species, I will illustrate how I have used ecophysiology in answering questions of interest in aquaculture, fisheries, or protection of fish biodiversity. With global climate changes on the way, I am more than convinced of the importance of integrating the ecophysiological approach into the conservation and management of our aquatic resources.

L'écophysiologie, une façon d'étudier l'adaptation des poissons à leur environnement qui est à la fois unique et excitante, mais qui comporte aussi ses défis Je me suis toujours définie comme écophysiologiste, mais je ne crois pas avoir jamais vu une définition de l'écophysiologie qui englobe complètement la vision que j'en ai. Afin d'intégrer toutes les disciplines sous-entendues dans la portion « éco » du mot « écophysiologie », je me suis entourée d'un important réseau de collaborateurs qui ont, au cours des années, changé ma façon même d'étudier la physiologie des poissons. Je suis particulièrement intéressée par l'étude de la diversité physiologique qui existe au sein d'une même espèce. Étudier cette diversité entre écotypes, populations ou souches (aquaculture) ne demande pas simplement d'intégrer des notions de génétique, d'écologie ou d'évolution dans l'interprétation des résultats physiologiques, mais également de réfléchir différemment à la conception des protocoles ou des approches de terrain. En utilisant des exemples tirés de l'étude de différentes espèces, j'illustrerai comment j'ai utilisé l'approche

écophysiologique pour répondre à des questions d'intérêt en aquaculture, en pêches, ou en protection de la biodiversité chez les poissons. Avec les changements climatiques en cours, je suis persuadée que l'approche écophysiologique peut jouer un rôle majeur dans nos actions visant la conservation ou l'exploitation de nos ressources aquatiques.

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Early life boldness predicts Richardson's ground squirrel fitness: Be shy and don't die! / Quand l'audace prédit la fitness des jeunes écureuils terrestres de Richardson: Être timide pour ne pas mourir!

Individual temperament, including boldness or willingness to take risks, has significant fitness implications. Bolder individuals often trade off survivorship for higher reproductive output. It is unknown, however, how early life boldness predicts lifetime survivorship or reproductive success, or how those factors relate to sex and territory size in modulating fitness. We quantified initial trapping order of post-weaned Richardson's ground squirrels (*Urocitellus richardsonii*) within litters and quantified their flight initiation distance and response to a novel object to assess boldness. We also quantified juvenile territory sizes, and tracked survival and reproductive performance through subsequent years. Lower survivorship of yearlings relative to adults necessitated independent modelling of survival using generalized hurdle count models. Shy squirrels trapped later, who did not emerge from burrows during novel object presentation, and that were female, were more likely to remain in the population in subsequent years. Females outsurvived males as adults, and squirrels with larger territories survived longer, however, this relationship was diminished for bolder individuals. Finally, the number of offspring produced increased for females with shorter flight initiation distances (bold) and those that did not emerge from burrows during novel object presentation (shy). Our results provide insight into the complex relationships among behavioural factors affecting fitness.

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Organismal pH compensation in response to elevated CO_2 is related to internal chloride concentrations in the ionoconforming Pacific Hagfish (*Eptatretus stoutii*) / La compensation du pH au niveau de l'organisme en réponse aux niveaux élevés de CO2 est reliée à la concentration interne de chlorure chez la lamproie du Pacifique (*Eptatretus stoutii*), un conformateur ionique

Pacific Hagfish, which represent the most ancient extant craniate, are among the most effective extracellular compensators with respect to responding to persistent hypercarbia (elevated environmental CO_2). This compensatory recovery of blood pH is both more rapid and greater in magnitude than that documented in any other water breathing vertebrate exposed to this challenge. In hagfish, as is the case for many other fishes, this compensation relies on a net equimolar exchange of HCO_3^- and chloride: consequently, speculation on the increased capacity of hagfish to compensate has focused on marine levels of these ions, but also internal chloride levels in these ionoconforming animals. We found no evidence for an increase in whole animal energetic demand associated with these high rates of pH compensation, but the magnitude of recovery was dependent on the osmolarity of the hagfish environment. Thus, energetic constraints appear less relevant with respect to this amazing response; internal chloride concentrations, however, may very well create the absolute limit to pH compensation during acute hypercapnia often referred to as "the bicarbonate threshold".

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Evidence for extra-gastric expression of the proton pump (H^+/K^+ ATPase *atp4a*) in the gills of the teleost *Oreochromis niloticus* / Évidence de l'expression extra-gastrique de la pompe à protons (H+/K+ ATPase *atp4a*) dans les branchies du téléostéen *Oreochromis niloticus*

It is well known that stomach acid secretion by oxynticopeptic cells of the gastric mucosa is accomplished by the H^+/ K^+-ATPase (HKA), which is comprised of HKα1 (gene: *atp4a*) and HKβ (gene: *atp4b*) subunits. However, the role of the HKA in extra-gastric organs such as the gill and kidney is less clear especially in fishes. The function, regulation, and the role of HKA in the gill and kidney in a teleost fish, *Oreochromis niloticus* was studied by focusing on the gastric HKα1 (*atp4a*). This pump may contribute to active ion and/or acid-base regulation either through direct ion transport or through secondary transport proteins against unfavorable concentration gradients via the energy derived from ATP hydrolysis. In the present work we have demonstrated uptake of the K^+ surrogate flux marker rubidium (Rb^+) *in vivo* in *O. niloticus*; however, we were unable to inhibit this uptake with omeprazole, a potent inhibitor of the gastric HKA. This contrast with a gill *ex vivo* preparation where tissue Rb^+ uptake is significant inhibited by omeprazole. Taken together these results indicate for the first time K^+ (Rb^+) uptake in tilapia and that the HKA can be implicated by the *ex vivo* uptake inhibition by omeprazole.

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Evaluation of host-pathogen interactions during the acute inflammatory response of bony fish / Évaluation des interactions hôte-pathogène pendant la réponse inflammatoire aigue des poissons osseux

Acute inflammation promotes early engagement of invading pathogens and contributes to the development of adaptive responses. This presentation will summarize recent experiments from our lab looking to define the role of leukocytes in the induction and resolution of acute inflammation in bony fish. Using combinatorial cellular and molecular approaches and an *in vivo Aeromonas* infection model we find that classic effectors such as macrophages and neutrophils elicit potent antimicrobial responses early in the acute inflammatory process. Interestingly, both subsets also contribute to the resolution of inflammation. A timely shift in phenotype, from pro-inflammatory to pro-resolving is largely driven by interactions with apoptotic cells at the site of inflammation as well as soluble mediators. Examination of blood and hematopoietic tissue compartments shows a tight correlation between immune cell production, their migration through circulation and discrete functional events at the infection site. In all, we find that the capacity of these immune cells to polarize towards pro-inflammatory or resolution roles existed before the divergence of fish and tetrapods, over 450 million years ago. We also find unique features within the teleost fish group, such as their capacity to respond efficiently to pathogen challenge despite maintaining much lower numbers of circulating neutrophils (<5%).

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Inferring evolutionary history of regeneration and asexual reproduction in annelids and nemerteans / Inférence de l'histoire evolutionaire de la régénération et de la reproduction asexuée chez les annélides et les némertes

Regeneration potential and reproductive mode are important elements of an organism's life-history that can have profound ecological and evolutionary consequences. It is apparent that regeneration and asexual

agametic reproduction (e.g., fission) are variable across animals and have generally been evolutionarily labile, but the specific evolutionary histories of these features remain poorly described. We have compiled datasets of regeneration and asexual reproduction ability, based on literature surveys and our own experiments, for numerous species within two phyla of invertebrate worms, Annelida and Nemertea. Analysing these data in the context of molecular phylogenies indicates both similarities and differences in the evolutionary patterns of these features between the two phyla. In both phyla, tail regeneration ability is reconstructed to be ancestral and fission is reconstructed to have been absent ancestrally and gained several times. However, head regeneration ability is reconstructed to be ancestral in annelids but not in nemerteans, and head regeneration ability is inferred to have been lost numerous times in annelids, but gained several times in nemerteans. Our data, the first to provide detailed phylum-wide reconstructions of these features, highlight both general and phylum-specific qualities to the evolutionary history of regeneration and asexual reproduction.

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Evolutionary physiology of the extinct Great Auk / Évolution physiologique du Grand Pingouin
Driven to extinction in 1844, the great auk *Pinguinus impennis* was a flightless member of the diving seabird family Alcidae. A textbook example of convergent evolution, the great auk is considered the northern hemisphere ecological equivalent—and original namesake—of southern hemisphere penguins (Family Spheniscidae), with which it shared alleged superior breath-hold diving capacity. Unlike penguins, the great auk has close, living, and flighted relatives, with intermediate diving abilities, such as the razorbill (*Alca torda*), making the Alcidae an ideal group for studying the mechanistic underpinnings of the convergent evolution of the avian underwater pursuit diving phenotype. Here we report on our ongoing efforts to use comparative structural and functional data of the respiratory proteins haemoglobin and myoglobin of penguins and alcids, including preliminary data from the great auk ancient DNA genome sequencing project, to reconstruct the mechanistic bases of convergent increases in underwater diving capacity in these distantly related families of seabirds. Our results illustrate independent evolution of increased myoglobin net surface charge in both lineages, likely allowing higher maximal myoglobin concentrations and thereby muscle oxygen storage capacities. These data are currently used to develop a predictive model that allows estimation of the maximal underwater endurance and dive depth of the great auk compared to other alcids and penguins. Analyses of adult-type alpha and beta globin genes further predict a convergent increase in oxygen affinity of great auk haemoglobin compared to the razorbill, similar to what has been reported for penguins compared to related non-diving seabirds. This prediction is currently being tested by establishing the oxygen binding characteristics on resurrected recombinant haemoglobins of the great auk, with the ultimate goal of increasing our understanding of the evolutionary physiology of this extinct iconic bird and its living and increasingly endangered family members.

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Hypothalamic-pituitary-interrenal axis regulation during chronic social stress in rainbow trout / Axe de régulation hypothalamique-hypophysaire-interrénal durant le stress chronique social chez la truite arc-en-ciel
Juvenile rainbow trout held in pairs form social hierarchies as a result of competition over limited resources. The dominant fish monopolizes these resources through agonistic interactions directed at the subordinate. Owing to the stressful nature of this relationship, subordinate fish exhibit elevated circulating

levels of the glucocorticoid hormone cortisol, production of which is mediated by the hypothalamic-pituitary-interrenal (HPI) axis. The regulation of this axis under chronic stress is poorly understood, and social subordination in trout provides a useful experimental paradigm to investigate this regulation, particularly negative feedback. We tested the hypothesis that negative feedback is impaired during chronic social stress in juvenile rainbow trout. Fish were paired for 4 days, and social status was based on behaviour and plasma cortisol. Transcript abundance of glucocorticoid receptors (GR) 1 and 2 were measured in the HPI axis tissues to measure sensitivity to negative feedback. Transcript abundance of the enzyme 11β-hydroxysteroid dehydrogenase type 2 (11βHSD2), which inactivates cortisol by conversion to cortisone, was measured. Receptor transcript abundance remained constant; however, transcript abundance of *11βhsd2* was higher in the preoptic region and pituitary of subordinate fish. This finding suggests a role for 11βHSD2 in the regulation of the stress response during chronic social stress.

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Physiological implications of an alternative lampricide treatment on juvenile lake sturgeon (*Acipenser fulvescens*) / Les effects d'une application alternatif de lampricide sur la physiologie des esturgeon jaune (*Acipenser fulvescens*)

The lampricide 3-trifluoromethyl-4-nitrophenol (TFM) is used to control sea lamprey populations in the Great Lakes. Typical treatments involve the application of TFM in lamprey nursery streams at the minimum lethal concentration (MLC) of the sea lamprey ammocoetes (99.9% mortality over 9h). Lake sturgeon, a culturally important fish and an endangered species in the Great Lakes, are particularly sensitive to TFM during early development (juveniles <15-20 cm). Since sturgeon can detoxify TFM via glucuronidation, we proposed that their detoxification capacity was overwhelmed during TFM treatments, leading to mortality. We investigated the effectiveness of an alternative TFM regimen, where fish were exposed to a lower concentration of TFM for a longer time, to decrease the burden on their detoxification capacity. Consequently, ammocoetes and lake sturgeon were simultaneously treated with the 9h and 24h MLC of the lamprey. Lamprey mortality was 100% over the two treatments, while sturgeon mortality decreased from 65% during exposure to the 9h MLC, to <5% during exposure to the 24h MLC. Our current study has shown that the "long-and-low" TFM regimen is an effective treatment alternative that eliminates lake sturgeon mortality without compromising the effectiveness of the lampricide.

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Diurnal foraging effort and risk assessment of naïve and predator conditioned Lake Sturgeon during critical life periods / Effort de l'alimentation diurne et évaluation des risques de l'esturgeon naïf et conditionné aux prédateurs pendant les périodes de vie critiques

Responding appropriately to foraging opportunities and predation risk can be the difference between life and death in year 0+ Lake Sturgeon (*Acipenser fulvescens*). In particular, this decision may be most costly to predator naïve, hatchery reared Lake Sturgeon released for conservation purposes. This study examines diurnal foraging effort and risk assessment of naïve and predator conditioned Lake Sturgeon during two critical life periods; early exogenous feeding (~60 dpf) and pre-winter (~160 dpf). Using an information theoretic approach (AIC), the analysis indicated the most parsimonious model of naïve Lake Sturgeon risk assessment to include the presence of food and time of day, and the conditioned Lake Sturgeon model to include presence of food, time of day, the presence of predator odour, life period, and the conditioning protocol (acute or chronic). Results suggest the importance of foraging during the early life stage of Lake Sturgeon and highlight context specific anti-predator responses of naïve and conditioned fish.

Additionally, whole body cortisol analysis revealed significantly ($p>0.05$) higher cortisol in chronic conditioned Lake Sturgeons, suggesting a deleterious stress response to predator odour conditioning.

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A flexible fish: Respiratory plasticity of the amphibious mangrove fish, may lead to improved respiratory performance on land / Un poisson flexible: Plasticité respiratoire dans un poisson amphibie peut mener à une amélioration de leur performance respiratoire sur terre
Amphibious fishes have evolved multiple adaptive strategies for respiring out of water. Less is known about the contribution of reversible phenotypic flexibility to aerial respiration. We tested the hypothesis that in amphibious fish that leave water, enhanced respiratory performance on land is the result of rapid functional phenotypic flexibility of respiratory traits. Four isogenic strains of *Kryptolebias marmoratus* were air exposed for either 1, 24, 72 or 168 hours. Blood O_2 carrying capacity (number of erythrocytes, hematocrit) and degree of cutaneous angiogenesis changed with time out of water in some strains. The critical oxygen tension (P_{crit}) measured in air, an indication of respiratory performance, was significantly lower after 24, 72 or 168 h of air exposure compared to control fish across all strains. Our findings indicate that prolonged air exposure across different genetic strains of *K. marmoratus* results in remarkable phenotypic flexibility. Whether blood O_2 carrying capacity and/or angiogenesis confer improved aerial respiration will be discussed.

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Metabolic adjustments of killifish (*Fundulus heteroclitus*) acclimated to intermittent hypoxia / Ajustements métaboliques du fondule (*Fundulus heteroclitus*) acclimaté à une hypoxie intermittente
Fish encounter daily cycles of hypoxia in the wild, but the physiological strategies for coping with intermittent hypoxia are poorly understood. We compared the coping strategies that arose with acclimation to constant versus intermittent patterns of hypoxia exposure in estuarine killifish. We acclimated killifish for 28 d to constant hypoxia (2 kPa O_2) or nocturnal intermittent hypoxia (12 h normoxia: 12 h at 2 kPa O_2), and then tracked their O_2 consumption rates (MO_2) and metabolite levels in the skeletal muscle, liver, and brain throughout a subsequent hypoxia-normoxia cycle. Fish acclimated to constant hypoxia had reduced MO_2, with normal tissue concentrations of lactate, ATP, and several other metabolites, suggesting a strong reliance on metabolic depression. Contrastingly, fish acclimated to intermittent hypoxia suffered little depression of MO_2 in hypoxia, dramatically increased MO_2 upon reoxygenation, and were better able to protect liver and brain ATP levels compared to naïve fish experiencing hypoxia for the first time, suggesting that they instead rely upon high capacities for O_2 transport and anaerobic metabolism. Our results suggest that divergent physiological strategies are used to cope with intermittent hypoxia compared to constant hypoxia in order to match O_2 supply and demand. Supported by NSERC.

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Early environmental effects on yolksac use, growth rate and muscle development in Lake Sturgeon, *Acipenser fulvescens* / Les effets environnementaux sur l'utilisation du vitellus, les taux de croissance et le développement musculaire chez l'esturgeon jaune, *Acipenser fulvescens*
Early rearing environment has a significant impact on phenotypic development in fish, especially during the first year of life when growth rate peaks, often determining an individual's life history trajectory. Temperature is considered the most pervasive environmental factor and along with substrate, plays an important role in influencing growth and muscle development during early life stages. In the present study, Lake Sturgeon were reared in temperatures (with or without substrate) that mimicked river temperature profiles, including a 40-day simulated overwintering event; or the stable temperatures used in a hatchery

setting for stock enhancement purposes. Fish were sampled from rearing tanks at least monthly for the first year of life and measurements of length, body mass and yolk sac area were taken. In addition, white and red muscle characteristics such as fibre size and myonuclear counts were recorded bimonthly. Larval yolksac use over the first three weeks was significantly different between all treatment groups with the fastest absorption occurring in tanks without substrate. At 6 months post hatch (pre-winter), there was a significant difference in the fibre area in both red and white muscle between the different temperature treatments regardless of substrate.

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Pathogen transmission as a function of roosting energetics and aggregation in little brown bats (*Myotis lucifugus*) / La transmission des pathogènes comme fonction dans l'expression énergétique et dans l'agrégation lors du perchage chez la petite chauve-souris brune (Myotis lucifugus)

Pathogen transmission can be influenced by host traits and environmental characteristics. Bats select warm roosts, huddle with conspecifics, or enter torpor, a state of reduced body temperature and metabolism, to reduce thermoregulatory costs. Torpor expression should reduce activity, potentially reduce an individual's risk of contracting pathogens. We tested the hypothesis that torpor expression and huddling would influence risk of pathogen transmission for little brown bats (*Myotis lucifugus*). We predicted that bats in small groups, and which used the most torpor would be least likely to acquire a contact pathogen. We housed bats in flight cages and attempted to manipulate aggregation by providing heated or unheated roosts. We quantified roost occupation each day, assessed torpor expression, using temperature dataloggers attached to the skin, and used ultraviolet (UV) fluorescent powder as a proxy for a contact pathogen. Transmission dynamics of our proxy pathogen (UV Powder) were very similar to those of natural pathogens and our heated roosts effectively manipulated aggregation by bats. Our analysis of the relationship between torpor expression, aggregation and transmission will have implications for understanding pathogen transmission in in the context of zoonotic pathogens relevant to human health and conservation pathogens that impact bat populations.

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Behavioural thermoregulation and performance of a benthic fish species: An investigation on the thermal biology of invasive round gobies (*Neogobius melanostomus*) / Thermorégulation comportementale et performance d'une espèce de poisson benthique: Une étude sur la biologie thermale du gobie (*Neogobius melanostomus*)

Fish are particularly adept at selecting microclimates to avoid potential thermal stresses evident in their native habitats. The invasive round goby (*Neogobius melanostomus*) became invasive to the Great Lakes in 1990, yet little is known about their thermal biology. The focus of this study is to gain a better understanding of round goby thermal preference and performance with acute temperature change. The behavioural thermoregulation of wild-caught gobies acclimated at 21°C was observed in a shuttlebox (temperature range: 10°C-30°C). Thermal preference was 19°C, with a mean lower escape temperature of 19°C and mean upper escape temperature of 23°C. Interestingly, almost half of the individuals chose to stay at either the extreme cool (10°C) or extreme warm (30°C) throughout experimentation. We subsequently examined burst velocity of gobies in a T-maze over a period of 3 days at 21°C, 24°C, and 27°C. Burst velocity significantly decreased with increasing temperature. This result was surprising, as it occurs well below the temperatures known to incapacitate gobies (i.e. CTmax). Our observations suggest that voluntary behaviours could reflect physiological performance curves in round gobies. This study is important in understanding the swimming performance and the individual differences in behavioural thermoregulation of a bottom-dwelling fish species.

Taylor Brooks and Grant McClelland
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Regulation of lactate production in C2C12 cell culture with the transition from acute to chronic hypoxia / Régulation de la production de lactate dans la culture cellulaire C2C12 avec la transition de l'hypoxie court à l'hypoxie chronique

For decades researchers have observed a reduction in exercise-induced blood lactate accumulation transitioning from acute to chronic hypoxia (the 'lactate paradox'). However, the underlying mechanisms that explain these changes in lactate production are still unclear. Hypoxia inducible factor (HIF-1α) is stabilized in low O_2 and helps mediate acute hypoxic stress by enhancing glycolytic capacity and angiogenesis. It also stimulates pyruvate dehydrogenase kinase (PDK1), which inhibits pyruvate dehydrogenase, and promotes lactate production. Previous work in our lab revealed that HIF1-α protein expression correlates with lactate production in acute and chronic hypoxia in mice, revealing a putative mechanism explaining the paradoxical reduction in lactate. To further define the mechanisms involved we turned to cultured C2C12 myocytes. We exposed differentiated C2C12 cells to 1% O_2 for 4h, 24h, and 4 days and compared them to 21% O_2-exposed control cells. We found intracellular lactate and lactate release to be higher in 4h hypoxic cells compared to controls. At 4h of hypoxia, PDK1 protein expression was also increased. Moreover, lactate and PDK1 protein expression decreased to control levels by 24h. These data show that the lactate paradox is expressed in cell culture and will allow for a detailed examination of mechanisms responsible for this phenomenon.

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Glial cells in the nervous system of planarians / Cellules gliales du système nerveux des planaires

Planarians (Platyhelminthes: Tricladida) regenerate all body parts after injury, including the central nervous system (CNS), and have emerged as a tractable model system in which to study this remarkable process. The nervous systems of many metazoans contain non-neural glial cells (glia) which – in addition to essential functions in neural development and physiology – also play complex or even paradoxical roles in facilitating or inhibiting neural repair and regeneration. In planarians, the existence of glial cells has been a matter of debate: classical morphological analyses have been used to argue both for and against the presence of such cells. As part of a transcriptomic and functional-genomic study of whole-brain regeneration in the planarian *Schmidtea mediterranea*, we identified a population of cells with cytological and molecular features expected of glia. In tail fragments of bisected worms, these cells modulate their expression of several genes, suggesting a coordinated response to CNS injury. Though the functional significance of the injury-response program in planarian glia is not yet clear, contrasting this response with that of glia in non-regenerating organisms may shed light on how such cells can promote the repair and reconstruction of damaged nervous tissue in metazoans.

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Uncoupling protein gene expression and thermal acclimation in Atlantic killifish, *Fundulus heteroclitus* / Découplage de l'expression des gènes de protéine et acclimation thermale chez le fondule Atlantique, *Fundulus heteroclitus*

Mitochondrial uncoupling proteins (UCPs) are known to play an important role in temperature responses in mammals, causing heat generation via futile energy cycling upon cold exposure or during hibernation. However, UCPs are also present in ectothermic organisms where their functional role is not well

understood. We have used Atlantic killifish, *Fundulus heteroclitus*, as a model organism in which to address the potential role of UCPs in thermal acclimation and adaptation in ectotherms. To characterize UCPs in killifish, we have determined the gene sequences and tissue-specific mRNA expression of members of the UCP family (*Ucp1*, *Ucp2*, *Ucp3*, *Ucp3-like* and *Ucp5*). The tissue-specific expression of these genes was similar to that reported for other fish species, with each tissue having a different isoform that is most highly expressed. Patterns of gene expression across acclimation temperatures varied greatly depending on the UCP isoform. Additionally, across most isoforms the overall levels of *Ucp* expression and the pattern with acclimation temperature differed between the northern and southern populations. We are currently investigating some of these interesting patterns to determine whether the differences in mRNA expression are also reflected at the protein and functional level within the mitochondria.

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Taurine acts through glycine and $GABA_A$ receptors to initiate spike arrest in anoxia-tolerant western painted turtle brain / La taurine agit à travers la glycine et les récepteurs GABAA pour initier l'arrêt des pointes dans le cerveau de la tortue peinturée de l'ouest tolérante à anoxie
Unlike anoxia-intolerant mammals, painted turtles survive extended periods of anoxia. This is partly accomplished by an increase in gamma-aminobutyric acid (GABA) which mediates spike arrest via shunting inhibition in brain. Taurine levels also increase significantly; however, its purpose is unknown but speculated to include actions similar to inhibitory neurotransmitters, acting through glycine and/or $GABA_{A/B}$ receptors. Given the general importance of inhibition in anoxia-tolerance, we investigated taurine's function as an inhibitory molecule in turtle cerebrocortical pyramidal neurons. Using whole-cell patch-clamp electrophysiological methods we found that taurine depolarized membrane potential by 8 mV, increased whole cell conductance by 6 pS and induced an inward current - all actions similar to those of GABA and glycine. These effects were reduced when glycine and $GABA_A$ receptors were inhibited but not when $GABA_B$ or glutamatergic receptors were inhibited, suggesting that taurine mediates its effects through both glycine and $GABA_A$ receptors. Additionally, the average rise time to the peak taurine-mediated current and decay time were significantly slower than GABA and glycine-mediated current times. Therefore, we conclude that taurine can act as an inhibitory signaling molecule and likely contributes to spike arrest in the anoxic turtle cortex.

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***Xenopus laevis* skin epithelial cell lines differ in their molecular signatures and response to treatment with poly (I:C) / Les lignées cellulaire épithéliales de la peau de Xenopus laevis diffèrent dans leurs signatures moléculaires et leur réponse au traitement par poly (I: C)**
Emerging pathogens, such as ranaviruses, are believed to be the proximal cause of declines in amphibian populations. While skin is the first innate immune barrier to pathogens, the contribution of frog skin epithelial cells to initiating an immune response is unknown. Two *Xenopus laevis* skin epithelial cells lines originating from dorsal skin (Xela DS2) and ventral skin (Xela VS2) expressed transcripts for collagen 1 A2, cytokeratin 19, vimentin, cadherin 1, claudin 1, and occludin, while only collagen1 A1, collagen type III, and cytokeratin 5 could be detected in Xela VS2. Claudin 3 transcripts were only detected in Xela DS2. Upon stimulation with poly (I:C), Xela DS2 and Xela VS2 exhibited a change in cell morphology and an increase in mRNA levels for IFN type I, IL-1β, TNF-α, IL-8, and Iκβ in a time-dependent manner. Upregulation of select transcripts occurred more rapidly in Xela DS2 compared to Xela VS2. These data suggest that Xela DS2 and Xela VS2 possess unique molecular signatures and are likely important producers of key cytokines that are essential to deployment of anti-viral programs in neighbouring cells and activation of underlying innate immune cells.

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Hidden Depths: Robust mechanisms to maintain homeostasis in rainbow trout exposed to novel environmentally-relevant treatments / Profondeurs cachées: Mécanismes robustes afin de maintenir l'homéostasie chez la truite arc-en-ciel exposée à un nouveau traitement pertinent à l'environnement

Physiological investigations have revealed a wealth of information about the mechanisms underlying the responses of animals to single acute stressors in their environments, including challenges such as thermal events or hyperoxic exposures. However, laboratory conditions rarely resemble those of the native habitats of animals, where challenges can repeatedly occur, or multiple stressors can occur simultaneously. Two studies were undertaken to assess the metabolic responses of rainbow trout to environmentally-relevant exposures in the form of three consecutive thermal insults, or an acute thermal insult combined with a hyperoxic exposure, respectively. These exposures were designed to mirror the native environment of the rainbow trout where water temperatures exhibit periodicity, and eutrophication can lead to co-occurring high temperatures and hyperoxia. Various metrics including protein expression and regulation, metabolite levels, enzyme activities, and cellular respirometry revealed that multiple thermal insults resulted in an anabolic phenotype which did not occur after a single thermal insult, and that the combination of hyperoxic and hyperthermic exposures induced a cardioprotective response and may have lowered metabolic stress when compared to a normoxic thermal insult. Together, these results suggest that rainbow trout may be well-equipped to respond to complex stressors commonly encountered in their natural habitats, and that the use of environmentally-relevant conditions may better inform future physiological studies.

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Les effets de l'hypoxie sur le métabolisme des protéines chez le cichlide amazonien, *Astronotus ocellatus* / The effects of hypoxia on protein metabolism in the Amazonian cichlid, *Astronotus ocellatus*

In the aquatic environment, fish are often exposed to large variations in dissolved oxygen (DO). Some fish are able to alter their behaviour and certain physiological processes when faced with hypoxic conditions in order to prolong survival. The Amazonian cichlid, *Astronotus ocellatus*, is highly tolerant to hypoxia. Some fish, including *A. ocellatus,* are able to reduce their metabolic rate by reducing the activity of energetically expensive metabolic processes, including protein synthesis when oxygen is lacking in their environment. The objectives of this research were to determine how protein metabolism is regulated in *A. ocellatus* during hypoxia. Fish were exposed to a stepwise decrease in DO (100%, 20%, 10% and 5%) for 2 hours at each level, and sampled throughout the experiment. This allowed us to determine for the first time in fish that a decrease in protein synthesis during hypoxia is controlled by signaling pathways (mTOR and eIF2-α), and not simply due to a lack of substrate. We also observed no effect on the capacity of tissues to degrade proteins. There is limited information on the effects of hypoxia on protein metabolism in fish. This relatively unexplored angle could help in our understanding of hypoxia tolerance, which has important implications in conservation.

Hoar award finalist / Finaliste du prix Hoar

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Body condition affects oxygen storage capacity and calculated aerobic dive limits in Beaufort Sea beluga whales / L'influence de la condition corporelle sur la capacité d'oxygène et les *limites aérobie* en *plongée* **des bélugas de la Mer Beaufort**

Arctic marine ecosystems are undergoing rapid environmental changes, and long-lived Arctic vertebrates with low reproductive rates are particularly vulnerable. Considering their declines in individual growth rates over the past 20 years, beluga whales (*Delphinapterus leucas*) may be an indicator species to predict the physiological response of Arctic marine mammals to environmental change. We explored relationships between body condition and physiological parameters pertaining to oxygen storage capacity in eastern Beaufort Sea belugas. Mean muscle myoglobin concentrations averaged 83.9 mg g^{-1} (77.9 mg g^{-1} corrected using spectral deconvolution), one of the highest values reported for marine mammals. Males had higher total body oxygen stores than females due to larger body sizes and higher hemoglobin concentrations, consistent with their deeper foraging dives. Furthermore, blood hematocrit and hemoglobin concentration, muscle myoglobin concentrations, and calculated aerobic dive limits were positively correlated with indices of body condition. Consequently, environmental changes that negatively impact condition appear to be linked to decreases in breath-hold endurance, which may be critical under stressful circumstances such as evading predators or ice entrapments. Importantly, the relationship between body condition and oxygen storage capacity may represent a positive feedback mechanism, in which environmental changes resulting in decreased body condition impair foraging ability.

Hoar award finalist / Finaliste du prix Hoar

Dillon J. Chung and Patricia M. Schulte

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Intraspecific variation and thermal acclimation effects on mitochondrial function in a eurythermal teleost (*Fundulus heteroclitus*) / Les effets de la variation intraspécifique et l'acclimation thermale sur la fonction mitochondriale chez un téléostéen eurytherme (*Fundulus heteroclitus*)

Whole-animal thermal limits and hypoxia tolerance are thought to be constrained by processes acting at the level of the mitochondrion. Understanding these mechanisms is becoming more important as anthropogenic climate change drives shifts in species' ranges. In the present experiments, we tested the effects and trade-offs of thermal acclimation on mitochondrial performance in locally adapted subspecies of the Atlantic killifish, *Fundulus heteroclitus*. We acclimated (5, 15, 33°C) northern and southern killifish and measured mitochondrial performance (respiratory capacity, O_2 binding affinity) and associated trade-offs (loss of mitochondrial membrane potential, increased ROS production). We demonstrate greater mitochondrial respiratory capacity in the northern subspecies and greater O_2 binding affinity in the southern subspecies. These data indicate a role for mitochondrial function in setting aerobic performance limits and putative targets of selection. Thermal acclimation was associated with large changes in mitochondrial respiration rate, particularly at 33°C. These shifts in performance occurred primarily through electron transport chain complex I and were not associated with large trade-offs in maintenance of membrane potential or ROS production perhaps accounting for the eurythermal physiology of this species. Our observations strongly support the probable importance of mitochondrial function in the setting of aerobic performance limits in ectotherms.

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Using a genome wide association study to highlight putative resistance specific variants to dengue in *Aedes aegypti* / Utilisant une étude d'association génomique pour mettre en évidence des variantes spécifiques de résistance putative à la dengue chez *Aedes aegypti*

Dengue viruses infect 50-100 million people annually and are transmitted principally by *Aedes aegypti.* Complications including dengue hemorrhagic fever or dengue shock syndrome can be fatal. There are currently no vaccine or treatment options available. In Cali, Colombia, approximately 30% of feral *Ae. aegypti* are resistant to Dengue through midgut resistance factors. We used a newly available genotyping chip, Axiom_aegypti1, to carry out a genome-wide association study comparing susceptible (Cali-S) and resistant (Cali-R) mosquitoes. After quality filtering and Mendelian inheritance tests using Plink, a total of 27,675 single nucleotide polymorphisms (SNPs) were analyzed. SNPs inducing a stop codon or amino acid change in exonic regions were investigated for possible relevance to the S or R phenotype, and flagged as variants of interest. Secondary validation of these variants is currently underway. If mosquito based dengue resistance could be tied to one, or a small number of SNPs, it would be feasible to develop an easy genetic test for resistance. In addition, CRISPR-Cas techniques could be used to create lines of permanently resistant mosquitoes in an effort to dampen dengue transmission.

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Good things come in small packages: Phenotypic regulation by microRNA / Dans les petits pots, les meilleurs onguents: Régulation phénotypique par les MicroARN

MicroRNA are small (~21-22 nucleotides in length), non-coding RNA that can bind to multiple target transcripts, effectively reducing translation. This can ultimately result in decreased functionality and altered phenotype of a given protein or pathway. MicroRNA have been an influential tool in studying pathologies of numerous human related diseases, such as cancer and heart disease. However, less than 3% of comparative physiology approaches examine the functional consequences of microRNA, which is instrumental in the regulation of phenotypic plasticity. This presentation will provide an overview of the recent advancements in understanding microRNA regulation of phenotype from individual pathways all the way to whole animal impacts. Emphasis will be placed on how the environment plays an essential role in mediating phenotypic response in teleosts, through changes in microRNA. Unique facets of microRNA will also be discussed, including the conservation of binding sites in key transcripts across millions of years of evolution, cross-kingdom transfer of microRNA(s) via the diet, and the implications of microRNA found in circulation. At the conclusion of this presentation, it is hoped that there is a greater appreciation and understanding of microRNA regulation of phenotypic responses related to environmental challenges.

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Sensory cues for recognition in a wild, amphibious mangrove fish, *Kryptolebias marmoratus* / Indications sensorielles pour la reconnaissance dans un poisson de mangrove sauvage et amphibie, *Kryptolebias marmoratus*

Fishes primarily use chemosensory and/or visual cues to recognize conspecifics, predators and food. Chemosensory cues may be particularly important in turbid or complex environments where vision is limited. We tested the hypothesis that the dark mangrove water characteristic of the mangrove rivulus' habitat obliges wild fish to preferentially use chemosensory cues over visual sensory cues. We measured the number of approaches to a 1) conspecific or 2) food source in a chamber divided by four barriers in mangrove water, with or without visual and chemosensory information. Our hypothesis was not supported in that we determined that visual cues trumped chemosensory cues in both experiments. When we compared latency to approach in a mirror test, there was no difference between clear and mangrove water suggesting that the murky mangrove environment is no impediment for visual recognition in these fish.

In preliminary lab experiments on an isogenic lineage of rivulus, we determined that visual cues are also primarily used to recognize conspecifics/kin.

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Microevolution of physiology–incorporating methods from quantitative and population genetics to study how energy metabolism evolves within and among populations / Microévolution de la physiologie–utilisation de méthodes quantitatives et de génétique de la population pour étudier comment le métabolisme énergétique évolue à l'intérieur et entre les populations

Many key insights into the mechanisms underlying the evolution of physiological traits have been, and will continue to be, made by studying divergence among distantly related species (i.e., macroevolution). However, fewer studies have made use of the microevolutionary variation present within and among populations to study how complex physiological systems evolve. In this talk I review some of the benefits of conducting inter-population comparisons, including the ability to make crosses among physiologically divergent groups and make use of existing population genetic information about the targets of natural selection. I hope to highlight these benefits by presenting our studies examining the mechanisms by which adaptive divergence in energy metabolism has evolved between ecotypes of migratory and non-migratory Threespine Stickleback (*Gasterosteus aculeatus*) and limnetic, 'dwarf' and benthic, 'normal' ecotypes of Lake Whitefish (*Coregonus clupeaformis*).

Presidents' award finalist / Le finaliste pour le prix du président

Neal J. Dawson[1,2], Catherine M. Ivy[1], Luis Alza[2,3,4], Rebecca Cheek[4], Julia M. York[5], Beverly Chua[5], William K. Milsom[5], Kevin G. McCracken[2,3,4] and Graham R. Scott[1]
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Muscle physiology and metabolic capacity in high-altitude ducks and geese from the Andes / Physiologie musculaire et capacité métabolique en haute altitude des canards et oies des Andes

High-altitude environments require that animals maintain high rates of O_2 consumption for locomotion and thermogenesis in exceedingly O_2-thin air. Specializations in respiratory physiology and metabolism have been suggested to help mitigate challenges at high-altitude, but we know little about whether convergent strategies are employed across independent highland lineages. We compared 8 highland versus lowland sister-taxa of Andean waterfowl, by measuring enzyme activities in locomotory muscles from key pathways of energy metabolism. Some convergent changes in flight muscle were pervasive in highland taxa, in which hydroxyacyl-coA dehydrogenase (involved in fatty acid oxidation) activity increased and cytochrome oxidase (complex-IV) activity decreased. Convergent changes were only present in the most established high-altitude taxa (in which there is no gene flow from low altitudes), including decreased hexokinase and lactate dehydrogenase activity, along with increased ATP-synthase activity. Interestingly, highland torrent ducks inhabit fast-flowing rivers and rely heavily on the gastrocnemius for swimming but fly very little. In this species, increased respiratory capacities and enzyme activities were observed in the gastrocnemius muscle but not in flight muscle. Our data suggest

that increases in capacity for fatty acid oxidation and other changes in mitochondrial function are common strategies to cope with the challenges of high altitudes.

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Investigating dietary patterns of Hudson Bay ringed seals (*Pusa hispida*) using fatty acid biomarkers / Étude sur les sources alimentaires des phoques à anneau de la baie d'Hudson (*Pusa hispida*) en utilisant des biomarqueurs d'acides gras

Ringed seals (*Pusa hispida*) are an abundant pinniped in the Arctic, dependent on sea ice for reproduction, molting and survival. We predict that ringed seals will show altered distribution and diet as sea ice dynamics deteriorate with climate warming. There is a large diversity of fatty acids in the marine environment, making them useful for determining feeding patterns of ringed seals by comparing the fatty acid composition found in the blubber layer with those found in the potential prey. Blubber samples (n=247) collected by Inuit hunters in the fall (1999 – 2008) were analyzed from three Hudson Bay communities (Arviat, Chesterfield Inlet, and Sanikiluaq, Nunavut). Seven potential prey species (e.g. forage fish and invertebrates) were also collected from the marine system (n=200). The 18 most commonly identified fatty acids in both the seal and prey databases were used to discriminate prey types and seal diet based on communities. Future work will focus on quantifying the proportion of prey found in the diet of individual ringed seals. Long-term diet monitoring of ringed seals using fatty acid biomarkers can reflect shifts in prey distribution and abundance and may provide insights into the structural and functional changes of the ecosystem.

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Niche shifts, directional change, and ecological release in White Sands lizard ecomorphology / Changement directionnel de niche et libération écologique chez l'écomorphologie des lézard de "White Sands"

Determining which traits enable organisms to be successful in new environments is key to understanding adaptation. These environments may present novel selective pressures on colonists' ecomorphology. To investigate ecomorphological change during adaptation and incipient speciation, we examine trophic and escape ecomorphology in three New Mexican lizard species (*Holbrookia maculata*, *Sceloporus cowlesi*, and *Aspidoscelis inornata*) from two distinct habitats. The 6000-year-old gypsum dune field of White Sands contains only these three lizard species. It is surrounded by the dark soils of the Chihuahuan Desert, home to over thirty lizard species. In White Sands, all three species have evolved cryptic white colouration. Yet, they show other striking ecological and morphological differences from their darker counterparts. Two of the three White Sands species are larger, with longer limbs and bigger heads than the same species in dark soils. White Sands species eat lower on the food chain, consuming harder and more diverse prey. They also out-perform dark soils lizards on both white and dark substrate - sprinting faster, and escaping more readily from predators. Differences between White Sands and dark soils lizards extend beyond cryptic colouration – the unusual ecosystem has also selected for parallel changes ecomorphology, affecting both predator avoidance and prey consumption.

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Assessment of metabolic performance metrics to detect family effects with implications for the conservation of an ancient fish / Évaluation de mesures de performance métabolique afin de détecter des effets familiaux avec implications pour la conservation d'un poisson ancien

The physiology of aquatic organisms is often highly dependent on environmental conditions but genetic contributions cannot be excluded to explain phenotypic variation. In this study, a series of physiological indices were used to assess the variability that exists amongst progeny of Lake Sturgeon produced from eight different families. To do so, we designed a controlled experiment aimed to evaluate metabolic performance of age-0 Lake Sturgeon where energy density, standard metabolic rate, swimming performance, critical thermal maxima (CTM), growth, and mortality were quantified for fish reared under the same temperature and density regimes. Results from this experiment were also compared to growth performance and survival metrics of fish reared at the Grand Rapids fish hatchery under similar conditions but where densities were not controlled. We found a strong family effect for all metrics that were quantified except for CTM. Furthermore, families that demonstrated poor growth and survival also exhibited low energy density levels and depressed metabolic rates early on in ontogeny. Lastly, the quantification of energy density at the onset of exogenous feeding appeared to be a good predictor of future growth and survival. Significance of these results for the long-term recovery of Lake Sturgeon throughout its native range will be discussed.

Jillian T. Detwiler
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Using integrative taxonomy to explore the diversity and host specificity of echinostome parasites / L'utilisation de la taxonomie intégrative pour explorer la diversité et la spécificité de l'hôte chez les parasites d'échinodermes

Ecomorphology is not a widely used term or concept studied by parasitologists. There are only a few studies that have examined how parasite morphology predicts host ecology and vice versa. One of the reasons why these studies are rare may be due to the state of parasite taxonomy. In particular, an increasing number of cryptic platyhelminth species have been discovered with DNA sequencing. Few studies have conducted detailed studies of morphology or host specificity among the members of these cryptic complexes. By conducting integrative taxonomy (morphology, genetics, host specificity), we can use these cryptic complexes to understand the processes involved in their evolution including ecomorphology. My research program focuses on echinostome trematodes which are globally distributed and use a wide variety of host species in their three-host life cycles. We are field-sampling first host snails and final mammal and bird hosts to confirm life cycles, and relate patterns of morphological, genetic and host specificity variation to understand species boundaries. These studies will increase our ability to test general ecological hypotheses with these ubiquitous trematode parasites and help determine the processes involved in their evolution.

Pranav Dhakal and Carol Bucking
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Microbiome and digestive physiology: A story of mutualistic relationship between gut microbes and their host / Microbiome et physiologie digestive: L'histoire d'une relation mutuelle entre les microbes intestinaux et leur hôte

The gastrointestinal tract (GIT) is the mediator for food intake, energy/nutrient absorption and providing fuel for cellular metabolism. Historically, this role was viewed as only dependent on intestinal enzyme activity, nutrient transport systems and genetics. However, the role of GIT-microbiome in the host's digestive physiology is recently gaining attention with the ultimate question being on the why of the presence of the microbiome and what their ultimate function is. *Firmicutes, Bacteroidetes and*

Proteobacteria (core-gut bacteria) are the dominant bacterial phyla's in the gastrointestinal tract. Changes found among species with varying external and internal factors has shown to increase the abundance of one phyla in expense of the other two. This phenomenon is thought to be likely linked to facilitate nutrient absorption and the production of multiple enzymes including but not limited to digestive enzymes like cellulase/ trypsin; glycolysis enzymes like pyruvate kinase, lactate dehydrogenase and transmembrane ATPases like Na/K ATPase. Through techniques such as Next-gen pyrosequencing, KEGG pathway analysis and enzyme assays, we predicted and analyzed the overall changes in the GIT-microbiome diversity, abundance and its subsequent effect on the enzyme activities with 3 months of alternate diet feeding treatment on *C. anomalum* (herbivore) and *E.carelum* (carnivore). Funded by NSERC.

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Mitochondrial and histone protein modifications in a hibernator / Mitochondrie et modifications des protéine d'histone chez un hibernateur
The mammalian hibernation cycle is characterized by dramatic changes in metabolism, which have the potential to induce dynamic alterations in the acetyl and methyl landscape of cellular proteins. At the hub of cellular metabolism, some mitochondrial metabolites regulate the activity of epigenetic enzymes, ultimately changing gene expression programs, including nuclear-encoded mitochondrial genes. In hibernators, this bidirectional regulation may signify an important response to environmental stressors. Here, we investigate the link between metabolite availability and both mitochondrial and chromatin protein states in 13-lined ground squirrels. We used an in-house mass spectrometry method to directly quantify stoichiometry of site-specific acetylation of the mitochondrial proteome. Over 600 mitochondrial proteins were quantified, revealing a wide range of acetyl stoichiometry, from <1% to >99%. The torpid state was associated with a significantly greater number of high-stoichiometry proteins. We also identified >50 uniquely acetylated and methylated histone states in several tissues, including liver, brain, and brown adipose. Clustering and principal components analysis of histone post translational modifications (PTMs) reveals segregation by tissue type and by phase of hibernation, which is most robust in liver. Together, these findings suggest an important, tissue-specific interaction between the endogenous metabolome and the PTM state of mitochondrial and nuclear proteins.

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Seasonal and flight-related alterations in the flight muscle transcriptome of a migratory songbird / Modifications saisonnières reliées au vol dans les transcriptomes des muscles d'un oiseau migrateur
The flight muscles of birds undergo physiological changes during migratory seasons. These alterations include increased aerobic and fatty acid oxidation capacity, which help sustain the high-intensity endurance exercise needed for long migratory flights. The degree and full coordination to which birds prepare for migratory season and flight is unknown. We used RNAseq to study flight muscle changes occurring in preparation for and during migratory flight. We sampled flight muscles from captive yellow-rumped warblers (*Setophaga coronata*) during the fall migratory period at rest, after a 4 h flight in a wind tunnel, and during the winter non-migratory period at rest. During the fall the birds had coordinated enrichment of fatty acid metabolism, including key regulators of lipid metabolism, PPARα and PGC-1. During flight, further modifications to fuel metabolism were observed with increased PPARβ and cytosolic fatty acid transporters abundance, and decreased glucose metabolism reflecting the shift to fat fuelled flight. Additionally, during flight evidence for both muscle inflammation and damage along with protein synthesis and growth were observed. This suggests that degradation of damaged proteins may

supply the building blocks for protein synthesis. These results provide a novel glimpse into how the flight muscle prepares for and sustains migratory flight.

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Microbiomes matter: Insights from the gut microbiome of *Drosophila* / L'importance des microbiomes: Indices de la part du système digestif des *Drosophiles*

Healthy animals are a habitat for microorganisms, most of which are benign or beneficial. It is becoming increasingly apparent that interactions with the resident microbiota modulate many aspects of the physiological and biochemical function of animals. Building on understanding of the composition of the microbiota and its functional capabilities, it is becoming possible to investigate how the microbiota interacts with animal host. In particular, the nutrition of *Drosophila* is influenced by the presence and composition of its gut microbiota. We have shown that these microorganisms contribute B vitamins and protect the insect against obesity. The underlying genetic determinants of these interactions are becoming clear, and we are developing strategies to investigate the patterns of metabolite exchange between the partners. Our core hypothesis is that the fundamentals of these interactions are conserved across the animal kingdom, and that *Drosophila* offers an excellent model system for animal microbiome science.

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Muscle fibre type distribution and plasticity in *Polypterus senegalus* / Distribution et plasticité des fibres musculaires chez *Polypterus senegalus*

The pectoral musculature of fishes display substantial variation in the distribution of muscle fibre type. We describe the distribution of fast and slow muscle fibres in the pectoral fins of *Polypterus senegalus*, an amphibious, basal actinopterygian fish using mATPase staining. Each of the four muscle groups examined possesses distinct regions of fast and slow fibres. Comparison between fish raised in aquatic and those raised in terrestrial environments reveals phenotypic plasticity in the relative proportions of fast and slow muscles, fibre diameter, and variation along muscles from origin to insertion. The pectoral muscles of terrestrialised *Polypterus* have a greater proportion of fast muscle fibres compared to aquatic *Polypterus*, which increases closer to the muscle origin. This may be a further example of adaptive plasticity in *Polypterus*, allowing for greater bursts of power during terrestrial locomotion.

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Altered covariance structure reveals relaxation of developmental constraints in an asexual hybrid vertebrate (fish) / Des modifications de la structure de la covariance phénotypique indiquent un relâchement de contraintes développementales chez des poissons hybrides asexués

Changes in developmental constraints affect phenotypic variability and, subsequently, ecology. In this regard, hybrid organisms are interesting models as interspecific hybridization disrupts genomic coadaptation which may change developmental constrains in hybrids with regards to parental species. While the effects of hybridization are observable in first generation hybrids, second generation hybrids display additional changes following sexual recombination. An ideal model system would thus be a group of asexually reproducing hybrids. The *Chrosomus eos-neogaeus* hybridization complex harbors such asexual hybrids known to display genotype-dependent differences in phenotypes and ecology, and

impressive phenotypic plasticity. This study aims to investigate how differences in developmental constraints affect phenotypic variability in *C. eos-neogaeus* hybrids. Morphological variation and covariation in the craniofacial skeleton were assessed and compared across two hybrid genotypes and their parental species using μCT imaging and three dimensional geometric morphometric analyses. Preliminary results reveal differences in morphology and in the structure of phenotypic covariation, between both lineages and between hybrids and parental species. Hybrids seem to benefit from relaxed constraints, allowing phenotypic transgression. It remains unclear whether changes in developmental constraints in hybrids lead to an increase in variability and if this affects the ecology of a given hybrid genotype.

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Hypoxia, a dish best served cold? Newborn hibernators and non-hibernators employ different physiological strategies when faced with thermal and hypoxic challenges / L'hypoxie, un met qui se sert froid? Les nouveau-nés hibernateurs et non-hibernateurs emploient des stratégies physiologiques différentes lorsque confrontés à un défi thermal et hypoxique

In newborn mammals, cold and hypoxia tolerance is well established, yet the mechanistic basis of their tolerance is essentially unknown. Here we ask, do all newborn mammals use the same strategies when faced with thermal and hypoxic challenges? To address this question, we exposed 0-5 day old hibernators (ground squirrels and hamsters) and non-hibernators (rats and mice) to either normoxia (21% O_2) or hypoxia (7% O_2). We varied ambient temperature from 40 to 10°C and measured their thermoregulatory, metabolic, and ventilatory responses. Our data indicate that all newborns: (i)were incapable of thermoregulation in the cold, especially in hypoxia, with rats maintaining the greatest body to ambient temperature differential, and ground squirrels the smallest; (ii)reduced oxygen demand in the cold, and exhibited greater metabolic depression when challenged with cold and hypoxia, with rats depressing metabolism the least, and ground squirrels the most; and (iii)increased ventilation in hypoxia relative to normoxia, except for ground squirrels, in which the hypoxic ventilatory response was absent at each ambient temperature investigated. Interestingly, strategies employed by mice and hamsters fell between those of rats and ground squirrels, but in unpredictable ways. Thus, when challenged with cold and hypoxia, newborn hibernators and non-hibernators employ different strategies.

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Development of endogenous cortisol production in Lake Sturgeon / Développement de la production endogène de cortisol chez l'esturgeon jaune

In fish, appropriate development of the hypothalamic-pituitary-interrenal (HPI) axis is vital to the integrity of early growth and ultimately fitness of the individual. Most of our current understanding of the development of the HPI axis is on research focused on short-generation-time teleost fish with little information available on longer lived, ancient species. Here we examine the development of the cortisol stress response in Lake Sturgeon, *Acipenser fulvescens*. Whole body cortisol was measured in developing Lake Sturgeon between 0 and 300 days post fertilization with measurable levels detected in all stages throughout the first year of life. The average maternally invested cortisol in unfertilized eggs was 3.75 ± 1.63 $ng \cdot egg^{-1}$. Baseline cortisol levels decreased to 0.18 ± 0.24 $ng \cdot g^{-1}$ in embryos and increased again to an average of 16.9± 5.21 $ng \cdot g^{-1}$ approximately 3 days prior to the onset of exogenous feeding. Baseline levels decreased once exogenous feeding began; variability was low throughout the first year of life with the exception of the over-wintering period where reduced environmental temperature had a significant effect on baseline and peak whole body cortisol levels. Data will be discussed in the context of early life history and over-wintering survival.

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Sex-specific differences in physiology, behaviour, and survival in Pacific salmon / Différences spécifiques au sexe dans la physiologie, le comportement, et la survie du saumon du Pacifique
Over the last 15 years, numerous studies have found that female Pacific salmon suffer higher mortality than males during their once-in-a-lifetime upriver spawning migration. Female mortality has been documented to be higher than males in tagging studies, holding studies, thermal stress experiments, and during dam passage. However, the proximate cause(s) of this increased mortality are poorly understood. This study exposed salmon to a moderate capture stressor and evaluated physiological recovery and post-release behaviour and survival. The latter was assessed by radio-telemetry for up to 3 months. Female sockeye salmon did not expend more anaerobic energy in response to the stressor, but did take longer to physiologically recover. Short term behaviour and long term survival were compared between male and female tagged at different stages of maturation. Collectively, this study identifies some potential mechanisms leading to increased mortality in female salmon.

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Is snacking success the secret to senescence in seabirds? / Est-ce que le secret de la sénescence chez les oiseaux de mer est le grignotage?
Organisms vary considerably in healthspan, with some species showing dramatically different patterns of physiological ageing in comparison to others. For instance, long-lived birds are thought to show no physiological ageing until terminal illness arises. To investigate the patterns of physiological ageing in Charadriiform seabirds, we studied demographic, behavioural and physiological ageing in Thick-billed Murres (*Uria lomvia*) and Black-legged Kittiwakes (*Rissa tridactyla*). In both seabird species, reproductive success increased with age until middle age, then levelled off, whereas mortality increased Gompertz-like with age. Reproductive success was lower during the final year of life compared to previous years, suggesting that death may be related to health issues in that last year of life. Hematocrit and metabolic rate appeared to decrease linearly with age, perhaps as a strategic adjustment to reduce the effect of heart disease in old age. Several measures of physiological or behavioural ageing did not vary with age: reproductive hormones, social behaviours and diving ability. In contrast, foraging success was lower in older individuals that did not survive. We concluded that seabirds maintained many components of health into old age, but that reduced foraging success appeared to be associated with senescence.

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Applying conservation physiology approaches to study a freshwater fish species at risk – the Carmine Shiner / Utilisation d'approches physiologiques de conservation pour étudier une espèce de poisson d'eau douce à risque - le mené Carmine

Carmine Shiner (*Notropis percobromus*) is a threatened cyprinid with a limited distribution in Canada occurring only in a few tributaries in the Winnipeg River watershed in southern Manitoba. The habitat requirements, life history, biology, and physiology of the species are not well understood. Subsequently, we studied (a) the species' habitat, (b) its behavioural responses to changing temperatures in a controlled laboratory setting, (c) the metabolic rate at different water temperatures and for a range of body mass, (d) its diet partitioning with its coexisting Common Shiner (*Luxilus cornutus*) in the Birch River, Manitoba, and (e) current distribution and spatio-temporal variability in projected suitable habitat using niche-based modeling approaches. Results indicated that Carmine Shiner display preferences for particular stream characteristics. Temperature preference results demonstrated that individual personality was consistent and repeatability. Individual preferred and maximum avoidance temperatures were significantly reduced in hypoxia compared to normoxia. Standard metabolic rate increased with temperature and body mass. Carmine and Common Shiner consumed immature stages and adults of both terrestrial and aquatic insects. Overlaps in resource use among the two species pairs suggested congruence of ecological similarities. Patterns of projected habitat change suggest the spatial extent of the current distribution of Carmine shiner will shift north. The southern extent of the distribution may become unsuitable for Carmine Shiner but suitable habitats are predicted to become available further north. The understanding of habitat requirements and responses to climate will aid management and recovery efforts for this threatened species.

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Pacific hagfish ventilation in high external and internal ammonia treatments /La ventilation de la myxine du Pacifique sous des traitements d'ammoniac interne et externe élevées

Ammonia is the third respiratory gas in ammonotelic fish, and recently it has been shown that physiologically realistic levels of blood ammonia can directly stimulate breathing, both in an ammonotelic teleost (the rainbow trout) and a ureotelic elasmobranch (the spiny dogfish shark). Pathological levels of ammonia have long been known to stimulate ventilation in mammals. This raises the question whether ammonia will also stimulate ventilation in the most primitive extant vertebrate, the ammonotelic hagfish. We exposed Pacific hagfish (*Eptatretus stoutii*) to high external ammonia by adding ammonia (as NH_4HCO_3 or NH_4Cl) to sea water or high internal ammonia by injecting these salts directly into the bloodstream. Hagfish increased ventilation in response to both high external and high internal ammonia treatments. Unlike the immediate changes in breathing seen in the high internal ammonia treatments, it took 3 h for the ventilation to increase in high external ammonia, possibly due to delayed ammonia accumulation in plasma from high external ammonia. Blood acid-base status was unaffected, so it is possible that blood ammonia could serve as a normal stimulant for ventilation in hagfish (NSERC Discovery).

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Discovery of microRNAs associated with antiviral immune responses of Atlantic cod macrophages / Découverte des microARN associés avec des réponses immunitaires antivirales des macrophages de morue de l'Atlantique

This study aimed to profile microRNAs (miRNAs) responsive to the viral mimic, polyriboinosinic-polyribocytidylic acid (pIC), in Atlantic cod (*Gadus morhua*) macrophages. Macrophages were isolated from individuals and exposed to pIC or phosphate-buffered saline (control) for different time points (i.e. 12, 24, 48, 72 h post-stimulation; HPS). Following sequencing of 12 RNAseq libraries, DESeq2 analyses determined four (i.e. miR-731-3p, miR-125b-3-3p, miR-150-3p and miR-462-3p) and two (i.e. miR-2188-3p and miR-462-3p) significantly differentially expressed miRNAs at 24 (n=3) and 72 HPS (n=3), respectively. RNAseq-identified miRNAs were subjected to qPCR assays using samples at all time points (n=6). The results of miR-731-3p, miR-462-3p and miR-2188-3p were validated by qPCR, and these miRNAs showed a time-dependent up-regulation by pIC. Also, qPCR and *in silico* analyses showed a co-up-regulation for miR-731-3p and miR-462-3p as well as putative interferon-sensitive response element motifs in the promoter region of the miR-731/miR-462 cluster. Additional Atlantic cod miRNAs, previously identified as immune responsive in higher vertebrates, were analysed by qPCR. As shown by qPCR assays at 48 or 72 HPS, miR-128-3-5p, miR-214-1-5p and miR-451-3p were up-regulated by pIC, whereas miR-30b-3p expression was down-regulated in response to pIC stimulation. This was the first report of pIC-responsive miRNAs in Atlantic cod, and the miRNAs identified herein are suggested to play roles in antiviral responses of this species.

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Hypoxia-induced remodelling of goldfish membranes could mediate metabolic suppression / La restructuration des membranes du poisson rouge induite en hypoxie pourrait causer la suppression du métabolisme

Temperature acclimation causes important changes in the membrane lipids of ectotherms, but it is unclear whether other environmental disturbances cause analogous responses. The effects of hypoxia (30 days; 10% air saturation) on the cholesterol levels and fatty acid composition of goldfish membranes were measured at two temperatures. Membrane lipids failed to respond to hypoxia in fish acclimated to 20ºC. At 13ºC, however, hypoxia had drastic effects on membrane cholesterol of muscle (+92%) and liver (-46%), as well as on the phospholipid composition of gill and liver. These last two tissues showed decreases in fatty acid unsaturation (-14% in double bond index) and average chain length that were mostly driven by decreases in % docosahexaenoic acid (DHA). Membrane DHA is a known activator of Na/K ATPases and muscle membrane cholesterol an inhibitor of Ca-ATPase. Therefore, the remodeling of membrane lipids uncovered here at low temperature could be an essential mediator of metabolic suppression during hypoxia. We conclude that higher environmental temperature is associated with: (1) higher metabolic rate, (2) higher incidence of oxygen minimum zones, and (3) absence of a hypoxia-induced membrane remodeling response. Fish will have to counter the cumulative effects of all these handicaps to cope with global warming.

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Not strictly for the birds: Unidirectional pulmonary airflow in sauropsids / Pas seulement pour les oiseaux: Flux d'air pulmonaire unidirectionnel chez les sauropsidés

Birds have long been thought to have a unique respiratory system in which air flows in a consistent direction during both inspiration and expiration, unidirectional flow. This pattern of flow is made possible by the topography of the conducting airways, which does not arborize like the airways of mammals, but instead forms a circuit. Aerodynamic valves prevent a tidal pattern of flow through this circuit, but their mechanistic underpinnings are poorly understood. Air sacs serve as bellows. The origin of the avian respiratory system is enigmatic and controversial: did it arise with birds or was it present in their ancestors? Although conventional wisdom holds selection for enhanced aerobic capacity was a prime selective driver, recent studies of pulmonary airflow in sauropsids are revealing that unidirectional airflow is not uniquely

avian, and support an ancient origin for this character. These results furthermore suggest the initial selective driver was not expanded capacity for exercise, and raise new questions about the functional role of unidirectional flow. The power of the comparative method and computational fluid dynamics models are yielding new insights into the mechanistic basis and phylogenetic distribution of unidirectional flow, and cradling new hypotheses for the evolution of the vertebrate respiratory system.

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Nature's natural knockouts: Cardiac capacities of Antarctic fishes without haemoglobin and myoglobin / Le KO naturel de la nature: Capacités cardiaques des poissons de l'Antarctique sans hémoglobine ou myoglobine

Notothenioids are the dominant endemic fishes in the thermally stable Southern Ocean. A working, perfused heart preparation assessed maximum cardiac performance for three notothenioids with contrasting expressions of haemoglobin and myoglobin: *Chaenocephalus aceratus* (Hb^-/Mb^-), *Chionodraco rastrospinosus* (Hb^-/Mb^+) and *Notothenia coriiceps* (Hb^+/Mb^+). When acclimated and tested at 1ºC, the Hb^+/Mb^+ condition had the highest maximum power output and lowest maximum cardiac output, with the Hb^-/Mb^+ condition having the highest maximum cardiac output and stroke volume; the Hb^-/Mb^- condition was slightly lower with its lower heart rate. When 1ºC-acclimated *Chaenocephalus* was tested at 4ºC, heart rate and maximum cardiac output were increased, but not maximum power output, whereas 1ºC-acclimated *Notothenia* tested at 4ºC increased heart rate and maximum power output, but not maximum cardiac output. After a 5-day acclimation to 4ºC, *Notothenia* had the same maximum cardiac performance as that produced by acute warming to 4ºC, while 4ºC-acclimated *Chionodraco* only elevated heart rate compared with 1ºC-acclimated fish. Thus, while the loss of Hb conveys a very poor pressure generating ability, likely because the ventricle is overly enlarged to accommodate an exceptionally large stroke volume, the additional loss of Mb modestly reduces heartbeat and maximum cardiac output. Supported by NSF and NSERC.

Presidents' award finalist / Le finaliste pour le prix du président

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Differential expression of acid-base and ammonia regulatory epithelial transporters along kidney tubules of the goldfish *Carassius auratus*, and their responses to feeding / Expressions différentielles acido-basique et régulation de l'ammoniac par les transporteurs épithéliaux le long des tubules rénaux du poisson rouge Carassius auratus, et leur réponse face à l'ingestion

While a predominant role for the gill in acid-base regulation in teleosts has been clearly demonstrated, less is known about the mechanism for renal acid-base regulation. We investigated the effect of feeding on kidney function of the common goldfish *Carassius auratus*. The observed 4-fold increase of whole animal total ammonia excretion 2-4 hours after feeding was accompanied by an increase in renal titratable acid excretion (indicated by a 4-fold increase in urine inorganic phosphate and drop in urine pH of 0.6 units). After 6h, these parameters returned to control values. Urinary total ammonia concentration increased 2-fold after 6h, suggesting delayed activation of the NH_4^+-mechanism for acid excretion. Micro-dissection of individual intact kidney tubules enabled us to investigate changes in mRNA expression levels for important epithelial transporters. All transporters had a specific expression pattern along the renal tubule sections at fasted conditions. The distal tubule seemed to play an increased role in dealing with the acid-load generated by feeding, indicated by the up-regulation of Na^+/H^+-exchanger-3, V-type-H^+-

ATPase, carbonic anhydrase IIa, and Rhesus-glycoprotein-cg1b. Our study shows that the kidney does indeed contribute to teleost acid-base regulation, excreting excess protons via the urine using a similar transporter inventory as the gill (NSERC Discovery).

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Ecomorphology and adaptive radiation in Darwin's finches / Écomorphologie et radiation adaptative chez les pinsons de Darwin
Adaptive radiation – the process by which a common ancestor diversifies into multiple descendant species adapted to different environments – is thought to be one of the main explanations for biodiversity. This process supposes a tight link between morphological variation and the features of the environment to which species adapt. As a consequence, selection on ecomorphological variation is expected to facilitate adaptive divergence within species as well as coexistence of species as adaptive radiation unfolds. However, ongoing adaptive radiations are difficult to observe, limiting our ability to explore the causal link between ecologically-relevant traits and diversification. Here, I explore this issue by analyzing ecomorphological variation in the ongoing adaptive radiation of Darwin's finches of the Galapagos. Specifically, I use a combination of historical and contemporary data to explore the causal link between variation in beak morphology and natural selection within and among species of ground finches on two islands of the Galapagos Archipelago. In addition, I explore the consequences of such a link for niche partitioning and species coexistence among closely-related species in the face of high environmental variability. Overall, our work suggests that selection on ecologically-relevant traits during times of drastic environmental change is a major driver adaptive radiation in nature.

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Predictors of abundance differ between red and grey squirrels in Winnipeg, MB / Les prédicteurs de l'abondance diffèrent entre les écureuils rouges et gris à Winnipeg, MB
Most mammals do poorly in cities, but a subset thrive. By exploring the ways that mammals adjust to living in cities, we can gain insights into how species cope with rapid environmental change. Red and grey squirrels are abundant in Winnipeg, but we know little about how they use urban environments. Grey squirrel densities tend to be higher in cities than in natural forest populations. This is particularly true for residential areas. Red squirrel populations in cities are less well studied and seem to be more restricted to green areas such as golf courses and parks. We hypothesized that grey squirrels are better urban habitat exploiters than red squirrels. We captured 96 red and 75 grey squirrels at 10 sites in Winnipeg. We used urban forestry data to test whether the number of trees at a site and human density could predict grey and red squirrel abundance. The number of trees and human density did not predict the number of grey squirrels captured. Red squirrel captures were positively correlated with the number of trees at a site and negatively correlated to human density. My results suggest that red squirrels are more restricted by city characteristics than grey squirrels.

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The evolutionary potential of hibernation phenology in *Myotis lucifugus* / Le potentiel évolutif de la phénologie de l'hibernation chez *Myotis lucifugus*

As global climate changes, animals must adjust the phenology of major life-cycle events to ensure that energetically costly activities coincide with peaks in resource abundance. It is assumed that an evolutionary response of phenological traits is required for natural populations to remain viable in response to climate change. We tested the hypothesis that hibernation phenology of *Myotis lucifugus* has evolutionary potential by quantifying the predictors and repeatability of hibernation phenological traits. Bats (n=6326) were outfitted with PIT-tags at five hibernacula in central Canada. PIT-tag dataloggers at the entrances of these hibernacula recorded the dates that bats immerged (i.e. entered) and emerged (i.e. departed) from hibernation. Immergence dates for males and females did not differ, and immergence date was not repeatable. Conversely, the emergence dates of females were 16 days earlier than emergence dates of males. For both sexes, emergence dates were significantly repeatable. For females, but not for males, individuals with larger masses emerged earlier from hibernation. Three alternative hypotheses for this relationship will be discussed. In conclusion, our results place bat hibernation phenology into the context of life-history variation, whereas previously, bat hibernation was seen only as an energy saving mechanism.

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Neuromuscular function and coordination of fin and body musculature during swimming and walking in *Polypterus senegalus* / Fonction et coordination neuromusculaire des nageoires et du corps lors de la nage et de la marche chez *Polypterus seneglus*

Muscle is responsible for an immense array of tasks essential to the function of all animals and integral to permitting vertebrate life to expand and diversify into virtually every niche. One of the most spectacular examples of niche expansion was the water-to-land transition, during which the evolution of terrestrial locomotion placed extraordinary demands on muscles accustomed to powering swimming. Recent work on *Polypterus*, basal ray-finned fishes that share many traits with stem tetrapods, has shown the importance of morphological changes to musculoskeletal structures for dealing with the locomotor challenges of terrestrialization. However, it is unclear how the neuromuscular control and coordination of their muscles differ during swimming and walking. We assessed muscle activity patterns of both the pectoral fin and body during walking and swimming in *Polypterus senegalus* using synchronized electromyography and three-dimensional high-speed video. We found some interesting differences in magnitude and coordination of muscle activity. For example, motor unit recruitment tended to be more intense, but shorter in duration, and pectoral fin abductor (propulsive) muscle activity occurred later during walking compared to swimming. These data will significantly advance our understanding of how muscle function can be modulated to perform novel behaviours in the face of changes in demand.

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A capture-recapture analysis of the influence of age, gender, and collaboration patterns on the longevity of academic careers in science / Une analyse capture-recapture sur l'influence de l'âge, du sexe et des modèles de collaboration sur la longévité des carrières académique en sciences

Scientific progress is hindered when there is a systematic loss of interested and capable researchers. Recognizing this, many research organizations have made efforts to improve the representation of women in science. These efforts have found some success, and gender parity has been achieved among the youngest cohorts in some disciplines. This has led to speculation that gender parity has been achieved and that time will resolve gender imbalances among scientists. We tested this hypothesis with capture-mark-recapture analyses treating the publication patterns of evolutionary ecologists as our capture histories. After controlling for differences in publication behaviour and age, men were more likely to persist in the publishing population of scientists than women. Our model suggests that without continued effort and intervention, parity in career longevity is unlikely to be achieved in the near future, even among the youngest generation of publishing scientists.

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L'effet du son des bateaux sur le comportement alimentaire des larves de plie rouge (*Pseudopleuronectes americanus*)
La plie rouge (*Pseudopleuronectes americanus*) est une espèce de poisson plat qui se trouve dans des zones peu profondes de la côte Est de l'Amérique du Nord. C'est une espèce ciblée par la pêche côtière et des déclins de population ont été observés tant au Canada qu'aux États-Unis. Comme cette espèce utilise des habitats où l'activité humaine est importante, elle constitue un bon modèle pour évaluer les effets des bruits anthropiques sur la faune marine. La présente étude a pour objectif de déterminer si un bruit anthropique émis par un bateau de pêche affecte le comportement alimentaire chez cette espèce et particulièrement durant la période larvaire alors que les individus sont pélagiques. Les données morphométriques des estomacs démontrent des plus petits tailles en présence de son, donc indiquent que les larves s'alimentaient moins en présence de bruit anthropique. Les mesures comportementales sont en accord avec les mesures de l'estomac, car les larves soumises au bruit avaient des taux de comportement de chasse significativement plus faibles. Le son a un effet négatif sur le comportement alimentaire des larves.

Effects of boat noise on the feeding behaviour of Winter flounder larvae (*Pseudopleuronectes americanus*)
Winter flounder (*Pseudopleuronectes americanus*) is a flatfish species found in shallow waters off the east coast of North America. This species is exploited by coastal fisheries, and a decline in the population has been observed both in Canada and the United States. Winter flounder is present in areas of high human activity and could therefore be a good model to evaluate the impact of anthropogenic noise on marine fauna. This study aimed at assessing the influence of boat noise on the feeding behaviour of winter flounder larvae, i.e., in the pelagic stage. Morphometric data showed that stomachs were smaller when sound was present, which suggests that they contained less prey in the presence of anthropogenic noise. Furthermore, behavioural analyses showed significantly fewer hunting events for larvae exposed to anthropogenic noise. The results suggest that noise has a negative impact on larval feeding.

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Differential hypoxia tolerance of killifish acclimated to different salinities / Tolérance différentielle à l'hypoxie du fondule acclimaté à différentes salinités

A large surface area and thin diffusion distances are characteristics of the fish gill that maximize gas exchange, but consequently also promote diffusion of ions across the gill epithelium. Due to the osmorespiratory compromise, when fish are exposed to hypoxia and need to increase the capacity for oxygen uptake at the gills, physiological trade-offs in ion regulation can arise. Salinity acclimation can play a role in hypoxia tolerance, which in *Fundulus heteroclitus* is reduced at acclimation salinities below 11 ppt (the isosmotic point), but not at salinities above this point. We hypothesized that the hyperventilatory response (HVR) in *F. heteroclitus* contributes to this response whereby fish acclimated to low salinities spend more energy on ionoregulation and thus have an overall lower capacity for increases in ventilation. We aimed to characterize the HVR to progressive hypoxia in *Fundulus* acclimated to 0, 11 (isosmotic) and 35 ppt. In freshwater (0 ppt), fish seem to preferentially increase ventilation frequency over ventilation amplitude at partial pressures of oxygen (PO_2s) lower than 45 Torr. The same is not seen in fish acclimated to the isosmotic point, where ventilation metrics are only upregulated at PO_2s under 30 Torr. (NSERC Discovery).

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Origin and diversification of the insulin superfamily and its receptors in vertebrates: revisited / Origine et diversification revisitée de la superfamille de l'insuline et de ses récepteurs chez les vertébrés

The vertebrate insulin superfamily is a diverse group of peptides that share a similar 3-dimensional structure, and are involved in broad range of endocrine and paracrine functions regulating cell growth, metabolism and reproduction. Gaps remain in the understanding of the origins of the vertebrate insulin superfamily ligand-receptor systems and of the evolution of certain genes (*Igf3, Insrr*) in vertebrates. Here we take advantage of recent genomic and transcriptomic data and state of the art computational techniques to revisit the origins of the superfamily and the processes by which it diversified in vertebrates. We collect genomic and transcriptomic data for the insulin-like peptides (ILP) in protochordates echinoderms, and vertebrates and use a combination of ancestral genome reconstruction mapping, small-scale synteny, gene structure, tissue-specific gene expression, motif analyses and phylogenetic reconstruction to probe the mechanisms of diversification and expression of the two major subfamilies of ILPs in vertebrates: 1) insulin (Ins) and insulin-like growth factors (Igf) and 2) relaxin (Rln) and insulin-like peptides (Insl), and their diverse receptors. These findings shed light into the processes that shaped the evolution of this important gene family with the goal of informing research into the physiological function of less well-characterizes members of the family.

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Differentiation-dependent antiviral capacities of amphibian (*Xenopus laevis*) macrophages / Capacités antivirales en fonction de la différenciation des macrophages amphibiens (*Xenopus laevis*)

Signaling of the colony-stimulating factor-1 (CSF-1) cytokine through its cognate receptor (CSF-1R) was though to be the primary means of macrophage (Mϕ) differentiation. However, the unrelated interleukin-34 (IL-34) cytokine is now known to serve as an alternate CSF-1R ligand. Remarkably, the anuran amphibian (*Xenopus laevis*) IL-34 gives rise to morphologically and functionally distinct Mϕs to those derived by CSF-1 and while the CSF-1-derived Mϕs are highly susceptible to the emerging Frog Virus 3 (FV3) ranavirus, the IL-34-differentiated Mϕs are resistant to this pathogen. Compared to CSF-1-derived Mϕs, the frog IL-34 Mϕs express significantly greater levels of pertinent cellular antiviral restriction factor genes, underlining a possible means of their antiviral resistance. Notably, interferon (IFN) cytokines represent a cornerstone of vertebrate antiviral immunity and intuitively, IL-34 Mϕs also possess robust

gene expression of key IFNs and their respective receptors. By contrast, CSF-1 Mϕs exhibit modest IFN ligand and receptor gene expression, presumably accounting for their viral susceptibility. Moreover, IL-34 Mϕ-conditioned supernatants confer antiviral protection to an FV3-susceptible frog kidney cell line (A6), confirming that IL-34 Mϕ produce potent antiviral mediators. Thus, we propose that the balance between CSF-1 and IL-34 Mϕ is pivotal to the immunological outcomes of amphibian ranavirus infections.

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Energetics of migratory bats during stopover: A test of the torpor-assisted migration hypothesis / La dépense énergétique des chauves-souris durant une pause en migration: Un test de l'hypothèse sur la migration assisté par la torpeur

The torpor-assisted migration hypothesis posits that migratory bats use torpor during daytime roosting to minimize refueling requirements and preserve fuel stores for nocturnal flights. Previous field studies indicate that bats regulate body temperature and time in torpor facultatively so that daily energy expenditure is independent of ambient roosting temperature. However, direct measurements of total roosting energy expenditure in relation to ambient and body temperature are lacking. Our objective was to measure full-day energy expenditure of bats roosting at different temperatures to test the prediction that energy use by bats is independent of ambient roosting temperature. We further tested whether torpor use is affected by migration season, sex and age. We captured silver-haired bats (*Lasionycteris noctivagans*) at Long Point Bird Observatory, Ontario, a prominent stopover site for migrating birds and bats. We used quantitative magnetic resonance analysis to measure change in fat and lean mass and to calculate total energy expenditure after roosting at 10, 17, or 25°C for 12 hours (the length of a daytime stopover). Body temperature was continuously monitored with radio-transmitters. This study will test key predictions of the torpor-assisted migration hypothesis and further our understanding of energy management at stopovers for migratory bats species.

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Endocrine, metabolic, and behavioural effects in quail exposed to a currently-used flame retardant / Les effets associés aux hormones, au métabolisme, et au comportement chez la caille exposée à un retardateur de flammes actuellement utilisé

There is growing awareness that many contaminants can affect behaviour and that these changes can have direct impacts on population health. Triphenyl phosphate (TPHP), a chemical that is commonly used as a plasticizer and flame retardant, has been detected in the environment and is known to disrupt hormones and behaviour in fish. However, little is known on the effects of TPHP in wildlife and especially birds, ideal sentinels of environmental contamination. We investigated the effects of TPHP on hormone levels (corticosterone, testosterone, and thyroid hormones), metabolism (resting metabolic rate), and behaviour in early life stages of Japanese quail (*Coturnix japonica*). Eggs and chicks were exposed to increasing doses of TPHP or a major metabolite of TPHP. We assessed tonic immobility (a fear response) and activity level, dominance hierarchy, exploratory behaviour, and neophobia in a social context, using a study design that allowed for direct competition between chicks from different treatments. Understanding connections between endocrine, metabolic, and behavioural endpoints is essential to link exposure to chemicals with reduced fitness and population-level effects.

Cameron Outstanding Ph.D. Thesis Award/ Prix Cameron pour une thèse de Ph.D. exceptionnelle

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The evolution of kin recognition / L'evolution de la reconnaissance des individus apparentés

Promiscuous mating systems create challenges for recognizing relatives because nestmates are not necessarily related. Biologists have discovered that most animals use one of two kin recognition mechanisms: "familiarity," whereby kin are remembered from interactions early in life, such as in a nest, or "phenotype matching," whereby putative kin are compared to a template of what kin should look or smell like based on relatives encountered during early life, or on one's own phenotype (called "self-referent phenotype matching"). The conditions favouring the evolution of one of these mechanisms over the other has been largely unstudied. In my thesis, I examined the factors influencing the evolution of recognition mechanism using two promiscuous fish species: bluegill (*Lepomis macrochirus*) and guppies (*Poecilia reticulata*). In bluegill, I showed that promiscuity, which causes low levels of relatedness within broods, led to the expression of self-referent phenotype matching. In contrast, in guppies, brood relatedness did not explain recognition mechanism, but is correlated with the intensity of recognition. Furthermore, I used phylogenetic analysis to show that recognition mechanism is not evolutionarily constrained in guppies. Together, this study provides new data on the factors that influence kin recognition mechanism, and addresses the ultimate questions of how these mechanisms evolve.

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Fryhood trauma: early-life stress affects zebrafish physiology and behaviour later in life / Le stress tôt dans le développement affecte la physiologie et le comportement du poisson zèbre adulte

Activation of the hypothalamic-pituitary-interrenal (HPI) axis in response to a stressor leads to production of the glucocorticoid stress hormone cortisol, which also functions as a mineralocorticoid in teleost fish. Although the function of the HPI axis has been well studied in mature fish, there is a lack of research examining how early life stress influences HPI axis activity later in life. In the current study, zebrafish were subjected to air exposure twice a day for two days at four different developmental stages. The effects of this repeated acute stressor on stress responsiveness, whole-body ion concentrations, anxiety-related behaviour, and sex ratio were then examined at four subsequent developmental stages. Individuals stressed early in life exhibited diminished HPI axis responsiveness, increased whole-body ion concentrations, greater activity, and male-biased sex ratios, with the magnitude of these effects being dependent on the ages at which the animals were stressed and examined. This research demonstrates that early life stress can have wide-ranging and long-lasting impacts on physiology and behaviour, providing groundwork for further investigation into the potential adaptive significance of these effects.

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The time-course of red blood cell intracellular pH recovery during venous transit in rainbow trout / La chronologie de la récupération du pH intracellulaire des globules rouge durant le transit veineux chez la truite arc-en-ciel

Teleost fishes have high haemoglobin (Hb) pH sensitivity and the ability to regulate the intracellular pH (pH_i) of their red blood cells (RBC), during a generalized acidosis, via adrenergically activated sodium-proton exchangers (β-NHE). The presence of plasma-accessible carbonic anhydrase (paCA) at the tissue capillaries can short-circuit RBC β-NHE activity, creating exceptionally large arterial-venous pH shifts, thus enhancing O_2 unloading from the pH sensitive Hb. However, to safeguard renewed O_2 uptake at the gill, RBC pH_i must be restored during venous transit (1-2 min) presumably in the absence of paCA. Using an *in vitro* preparation, changes in RBC pH_i were investigated by measuring closed system changes in PO_2, in response to i) β-adrenergic stimulation with isoproterenol, ii) short-circuiting with CA and iii)

inhibition of paCA with the extracellular inhibitor C18. Results indicate that RBC pH_i is recovered by 50% within 45 s after short-circuiting, thus β-NHE activity is sufficiently rapid to restore RBC pH_i during venous transit. Safeguarding O_2 loading at the gill is crucial for the unique mode of O_2 transport in teleosts, which relies on short-circuiting and recovery of RBC pH_i regulation with every pass through the circulatory system and may greatly enhance O_2 transport during stressful events.

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Running with snowshoes and shovels on soft sand: Foot function in the web-footed gecko, *Pachydactylus rangei*, from Namibia / Courir avec des raquettes et des pelles sur le sable fin: La fonction du pied chez le gecko palmipède, Pachydactylus rangei, de Namibie
Terrestrial vertebrates rely on the integration of multiple components within the limb to generate thrust during locomotion. This culminates in the transmission of force to the surface on which the animal is moving, making the foot a critical part of the system. Thus, it is not surprising that we observe a variety of specializations among vertebrate feet, including claws, adhesive toepads, toe fringes, and interdigital webbing. The web-footed gecko, as its name implies, exhibits interdigital webbing that likely assists with burrow excavation and walking on top of soft dune sand. However, the function of the feet during these behaviors is poorly understood. Using *Pachydactylus rangei*, I examined the multi-functionality of the interdigital webbing on the forelimbs and hind limbs. I examined the high-speed kinematics of limb motions during running on two substrate treatments: 1) a trackway covered in soft dune sand and 2) a trackway covered by stiff sandpaper. Additionally, both level and inclined (30 deg) surfaces were examined since these geckos often traverse steep dune surfaces in nature. I found that geckos, when running, use their feet like snowshoes on level surfaces covered with soft sand, but more like shovels when ascending an inclined sandy surface.

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Impact of ammonia-loading on the movement of ^{14}C-methylammonia and ^{14}C-urea across the intestine of North Pacific spiny dogfish (*Squalus suckleyi*) / L'impact du chargement de l'ammoniac sur le mouvement du ^{14}C-methylammoniac and ^{14}C-urée à travers l'intestin chez l'aiguillat commun (*Squalus suckleyi*)
During periods of starvation marine elasmobranchs experience a net loss of urea into the intestine. However, following feeding (<48h) this reverses to a substantial uptake, but the mechanisms are currently not well understood. Intestinal folds from the spiral valve of fed and fasted North Pacific spiny dogfish (*Squalus suckleyi*) were mounted in Ussing chambers with NH_4Cl (0.005 – 2 $mmol \cdot L^{-1}$) in elasmobranch ringers on the luminal side of the preparation to simulate dietary ammonia-loading following a feeding event. Radiolabelled ^{14}C-methylammonia or ^{14}C-urea were used to determine ammonia or urea transport. Following a 3-hour incubation period, uptake of ^{14}C-methylammonia increased significantly in the presence of NH_4Cl in fed (>1 $mmol \cdot L^{-1}$) and fasted (>0.5$mmol \cdot L^{-1}$) sharks. In a second series of experiments NH_4Cl was removed from the luminal side after 2 hours and replaced with ammonia-free ringers for a further 3 hours. This resulted in a significant increase in uptake of ^{14}C-methylammonia, but not ^{14}C-urea, suggesting a stimulation of only ammonia transport mechanisms initiated by the presence of ammonia on the luminal side of the preparation. Ornithine-urea cycle enzymes were also examined and

activities of these enzymes will be discussed in relation to intestinal ammonia uptake in fed and fasted sharks (NSERC Discovery 311909).

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The role of internal convection on respiratory gas transfer in larval zebrafish (*Danio rerio*) / Le rôle de la convection interne sur le transfère des gaz respiratoires chez la larve du poisson zèbre (*Danio rerio*)

In adult vertebrates, homeostasis of the respiratory gases, CO_2 and O_2, are dependent on the circulatory system. However, hemoglobin "knockout" studies in zebrafish (*Danio rerio*) have provided indirect evidence that the circulatory system is not critical for respiratory gas transfer in larval teleosts. My research is focused on elucidating the role of internal convection on respiratory gas transfer in larval zebrafish. Vascular endothelial growth factor A (VEGF-A) is critical to angiogenesis and VEGF-A knockdown results in incomplete blood vessel formation and a non-functional circulatory system. Transient knockdown of VEGF-A protein was achieved via the injection of anti-sense morpholino, causing zebrafish to develop with a beating heart but an incomplete circulatory system. In 4-day post fertilization larvae, loss of internal convection resulted in decreased resting rates of O_2 consumption and CO_2 production, indicating a decrease in resting aerobic metabolic rate. Internal convection may be linked to larval hypoxia tolerance because absence of internal convection resulted in the loss of ventilatory and cardiac responses during exposure to hypoxia (40 Torr). Despite the apparent impairment of gas transfer and hypoxic cardiorespiratory responses in fish lacking complete convection, there was no obvious negative impact on hypoxia tolerance as indicated by measurement of critical PO_2.

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Characterization and expression studies of the interferon regulatory factor gene family in Atlantic cod (*Gadus morhua*) / Caractérisation et études d'expressions de la famille de gènes du facteur régulateur d'interféron dans la morue de l'Atlantique (*Gadus morhua*)

Atlantic cod (*Gadus morhua*) has a unique immune system among teleost fish, making it of particular interest for immunological studies, and especially for investigating the evolutionary history of immune gene families. The interferon regulatory factor (IRF) family of genes encode transcription factors which function in the interferon pathway, and which also have roles in growth, development and regulation of oncogenesis. We previously characterized five IRF family members in Atlantic cod (*Irf4a, Irf4b, Irf7, Irf8, Irf10*) at the cDNA and putative amino acid levels, and in the current study we used molecular methods and mining of the latest Atlantic cod genome assembly to characterize the remaining family members. Reverse transcription PCR (RT-PCR) and quantitative PCR (QPCR) were used to investigate constitutive expression of each IRF transcript in multiple tissues, and during embryonic development. Notably, these studies showed unique transcript expression profiles of IRFs during development, indicating potential stage-specific roles. QPCR studies also showed the effect of immune stimulation with the viral mimic poly (I:C) on IRF transcript expression in Atlantic cod macrophages, suggesting a role in the antiviral response. Furthermore, to investigate a possible mechanism of IRF gene expression regulation, QPCR was also used to study the expression of several cod microRNAs (miRNAs) which potentially target IRF transcripts.

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Convergent evolution of the hypoxic ventilatory response in high-altitude ducks from the Andes / Évolution convergente de la réponse ventilatoire hypoxique chez les canards en haute altitude des Andes

Hypoxia at high altitudes constrains O_2 supply to support metabolism and exercise. Physiological specializations have arisen in numerous high-altitude taxa, but there have been relatively few attempts to examine whether convergent strategies have arisen in distinct lineages to cope with the challenges at high altitudes. In this study, we examined how the hypoxic ventilatory response (HVR) has been altered in five species of ducks that independently colonized the high Andes, by comparing ducks at high altitudes to their sibling populations/subspecies from low altitudes. We found that several high-altitude ducks had a blunted HVR compared to their low-altitude counterparts, suggesting that convergent specializations have arisen in multiple highland lineages. However, these changes only arose in taxa that are well established at high altitudes and experience little gene flow from low altitudes. Nevertheless, arterial O_2 saturation in hypoxia was similar or higher in high-altitude populations, in association with evolved increases in haemoglobin-O_2 binding affinity. Therefore, by safeguarding arterial O_2 saturation in hypoxia, increases in haemoglobin-O_2 binding affinity may allow high-altitude ducks to breathe less, reduce the metabolic cost of breathing, and minimize the disruptive effects of hypoxic hyperventilation on CO_2/pH homeostasis.
(Supported by NSERC of Canada and CSZ Travel Award)

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Multiple sub-lethal thresholds for cellular responses to thermal stressors in fishes / Seuils sublétaux multiples pour les réponses cellulaires des facteurs de stress thermiques des poissons

Increases in water temperature due to climate change profoundly impact aquatic ectotherms. Because many of the prevailing frameworks regarding thermal responses in ectotherms suggest multiple thresholds are crossed as temperatures increase, a better understanding of the shifts in cellular processes is necessary for predicting the effects of future climate warming on species of conservation concern. Sub-lethal thresholds can determine *what* cellular processes are impacted and *if* the organism can recover from the thermal stress event. Identifying the onset temperature for these responses can differentiate between adaptive response to routine increases in the water temperature compared with cellular responses at stressful temperatures that can lead to longer-term fitness impacts such as increased susceptibility to disease, decreased growth and reproductive success, or death. To test for sub-lethal thresholds for cellular responses, we examined the temporal change in the expression of genes involved in a response to moderate (inducible transcription factors) and severe thermal stressors (heat shock proteins) in the endangered delta smelt (*Hypomesus transpacificus*). Understanding the sub-lethal thresholds that lead to changes in the expression of suites of genes may be useful for developing predictive management thresholds for endangered ectotherms in the wild.

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Never cry wolf: climate change and the emergence of parasites and vectors in the North / Ne jamais crier au loup: changements climatiques et émergence des parasites et vecteurs dans le nord
The rapid climate changes experienced in the North have no precedent in scientific or traditional knowledge; in northwestern Canada, some regions are experiencing double the warming as compared to the Canadian average. Climate change is real, and a real driver of emerging diseases. There is increasing evidence of establishment of parasites and vectors in northern regions that previously may have been excluded by climate. But how do we know if something is new, or newly detected? Baselines on pathogen diversity are often lacking, especially in wildlife in the North, making interpretation difficult. Traditional ecological knowledge, veterinary medicine, wildlife biology and public health must work together to predict, detect, and mitigate emerging disease due to climate change. Predicting what animal and disease species might move north in a more permissive climate may be as simple as looking at what species are established immediately south of the region of interest. Or it could be more complex, such as modeling the current and predicted distribution and abundance of temperature-limited hosts and pathogens. Either way, claims that climate change is driving emergence of disease need to be critically evaluated and carefully interpreted if scientists are to maintain credibility with communities and policy makers.

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The importance of capelin (*Mallotus villosus*) spawning sites for foraging humpback whales (*Megaptera novaeangliae*) in eastern Canada / L'importance des sites de reproduction du capelan (*Mallotus villosus*) pour l'alimentation des baleines à bosse (*Megaptera novaeangliae*) dans l'est du Canada
During the summer, humpback whales (*Megaptera novaeangliae*) exhibit annual migrations to foraging grounds in coastal Newfoundland, when high net energy gain is crucial for individuals' future reproductive success. In this region, capelin (*Mallotus villosus*) is the dominant forage fish, on which many predators depend on as a food source. During July-August, capelin migrate to coastal regions to spawn in high abundances. We explored the importance of capelin in humpback whale diets and the importance of capelin spawning sites to foraging whales during July-August by integrating stable isotope analysis ($\delta^{13}C$ and $\delta^{15}N$), ship-based surveys, and photo-identification. During 2016, stable isotope ratios in whale skin (mean ± SE; $\delta^{13}C$: -18.90 ± 0.03; $\delta^{15}N$: 15.03 ± 0.12) confirmed a primarily capelin-based diet. During fine-scale surveys (10-25 km) over capelin spawning sites (2009-2016), whales did not aggregate until annual capelin density reached 0.02-0.08 g/m^2, suggesting a threshold prey density required for efficient foraging. Throughout six years (2011-2016), 233 individuals were photo-identified revealing that 2-14 % were re-sighted among years and 4-16% were re-sighted within years. These findings suggest that capelin is a key prey species and that annually predictable locations with high capelin densities (i.e. spawning sites) are important foraging grounds for humpback whales.

Kamal Khidas
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Ecomorphology, resource utilization and distribution patterns in terrestrial mammals / Écomorphologie, utilisation des ressources et patterns de distribution chez les mammifères terrestres
Similarities in morphological traits among species are viewed as results of adaptation to similar selective pressures. Species—species and species–environment interactions are key processes that determine species distribution patterns, and structure community assemblages. Mammals are morphologically highly diversified and exhibit remarkable capacities to adapt to all kinds of habitats across the globe. Here, I evaluate disparity of body mass and craniodental characters in terrestrial mammals to explore

microevolutionary processes and the relative importance of ecological and biogeographical factors. Body mass disparity in mammal communities in African rainforest and Greater Amazon rainforest (aseasonal zones), and North Africa and North America (seasonal zones) was not differentiable from random (null) communities', suggesting a limited role of species–species and species–environment interactions. Guilds of co-occurring North African mammals, however, show evidence of a strong competitive exclusion as demonstrated by displacement of craniodental characters in *Apodemus sylvaticus* co-occurring with *Mus spretus*. Morphogenetic characterization of mainland and insular *Lynx canadensis* indicate that genetic drift and natural selection allow for the adaptive divergence of important traits, including body size. I conclude that environment and competition driven processes exert a structuring influence in mammal communities subsequently to macroevolutionary processes and past dispersal–events.

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The effect of individual variation of sociality on reproductive success and survival in a Canadian population of black-tailed prairie dogs (*Cynomys ludovicianus*) / L'effet de la variation individuelle de la socialité sur le succès de la reproduction et la survie dans une population Canadienne des chiens de prairie à queue noire (*Cynomys ludovicianus*)
Research on animal social systems has focused on population-level costs and benefits of conspecific affiliation, with less attention paid to individual variation in these tradeoffs. Social network analysis (SNA) provides a tool to extend these analyses to the individual level and to interpret behavioural interactions between individuals of a population. These studies primarily use measurements of contact (often proximity) that ignore the likely importance of detailed social behaviours in estimates of sociality benefits. Black-tailed prairie dogs live in highly social colonies and display an elaborate range of social behaviours. As prairie dogs are highly social, I hypothesize that the benefits of social interactions outweigh the costs (as a result, levels of sociality should correlate positively with fitness). I will construct a social network of prairie dogs through behavioural observation and examined components of fitness (reproductive success and body condition) of each prairie dog. I will determine how sociality influences variation in fitness through a comparison of these metrics. By focusing on a study species with diverse and easily observed social interactions, this research should improve our understanding of the utility of SNA for wild populations and provide insight into the ecological consequences of natural individual variation in sociality in black-tailed prairie dogs.

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Biogeographical analysis of morphological variation and mitochondrial haplotypes reveals cryptic species and hybrid zones in the Junonia butterflies of the American Southwest and Mexico / L'analyse biogéographique des variations morphologiques et des haplotypes mitochondriaux révèle des espèces cryptiques et des zones hybrides dans les papillons de Junonia du sud-ouest américain et due Mexique
When compared to the rest of North America, the American Southwest and Northern Mexico has a significant degree of endemic diversity. The production of biodiversity in this region can be attributed to the Pleistocene glaciations and the subsequent dispersal of species from glacial refuges within this region. The New World species of the genus *Junonia* are a recently diverged group of butterflies which are thought to have taken refuge in these glacial refuges during periods of glacial advancement. Using phenotypic and genotypic information from preserved specimens in museum collections, we have reconstructed the plausible historic movements, and the contemporary geographic distributions of five *Junonia* taxa (*J. coenia*, *J. coenia grisea*, *J. litoralis*, *J. nigrosuffusa*, and *J. zonalis*) that are currently found in the American Southwest and Northern Mexico. Utilizing both morphological characteristics and mitochondrial haplotype data, evidence of hybridization and cryptic species were found. Two

morphologically similar taxa, *J. coenia* and *J. coenia grisea*, were found to have differences in morphology, life history traits, nuclear *wingless* sequences data, and district mitochondrial haplotypes suggesting that they are a cryptic species pair. Based on this evidence we suggest elevating *J. grisea* to full species status.

Hoar award finalist / Finaliste du prix Hoar

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Weather, wings, and timing: contrasting factors that influence the spring migration performance of purple martins (*Progne subis*)/ Météo, ailes et chronométrage: facteurs contrastants qui influencent la performance migratoire printanière des martins violets (*Progne subis*)

Optimal migration theory predicts birds migrate faster during spring migration to arrive earlier and secure resources at the breeding grounds. Due to previous limitations in tracking small birds (<60g) on migration, few studies had examined factors influencing songbird migration performance. Using miniaturized tracking units (light-level geolocators), we tracked the spring migration of purple martins (*Progne subis*), a 55g songbird that journeys between North American breeding sites and South American overwintering sites. We tested optimal migration theory by examining the effects of wing morphology, migration timing, and weather conditions on migration performance. Measurements of aspect ratio and wingtip pointedness did not have a strong effect on migration performance as predicted, but birds that departed later from overwintering sites travelled at a faster migration speed. Individuals also spent more days stopped at a location when temperature and precipitation amount were higher. Overall, our results show that wing morphology had little impact on spring migration performance, but that migration departure timing and weather conditions *en route* were stronger predictors of migration performance. We suggest future studies aimed at understanding the impacts of climate change on performance and fitness be focused on factors impacting migration departure and stopover locations.

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Modulation of protein metabolism by cortisol administration or social status in rainbow trout / Modulation du métabolisme des protéines par l'administration de cortisol ou par le statut social chez la truite arc-en-ciel

Salmonids rapidly form dominant-based social hierarchies where dominant individuals monopolize limited resources, such as space and food. The second fish is said to be subordinate and is characterized by the inhibition of certain actions, such as feeding and aggression. Subordinates generally have elevated plasma cortisol concentrations and reduced growth rates when compared to their dominant counterparts, even when pair-fed. We tested the hypothesis that reduced growth rates observed in subordinate fish are related to the effects of cortisol on protein metabolism. Glucocorticoids are known to suppress protein synthesis and stimulate protein degradation in higher vertebrates, however, little is known about the effects of glucocorticoids on fish protein metabolism. In a first experiment, fish were paired to promote the formation of social hierarchies and were allowed to interact for a period of four days prior to sampling. In a second experiment, slow-release implants were used to artificially increase the circulating cortisol concentration in fish for a period of up to nine days. For both experiments, fractional rate of protein synthesis and transcript levels of genes related to protein degradation were measured in the liver and muscle of fish. Rates of protein synthesis were lower in the muscle of subordinate and cortisol treated fish but, surprisingly, these fish had much higher hepatic rates of protein synthesis. Over all, similar responses of protein synthesis and markers of protein degradation were observed in subordinate fish and in cortisol treated fish. This suggests that the repressed growth rates observed in subordinate fish are, at least in part, caused by elevated cortisol concentrations.

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Reactive oxygen species metabolism varies in relation to hypoxia tolerance in intertidal sculpins / Métabolisme des dérivés actifs de l'oxygène varie selon la relation de tolérance à l'hypoxie chez le chabot intertidal

Intertidal sculpin fishes often experience diel changes in environmental oxygen (O_2), from hyperoxia to hypoxia, and show adaptive traits along the oxygen transport chain to enhance oxygen uptake and use during periods of hypoxia. However, changes in O_2 supply to mitochondria not only affect oxidative phosphorylation but also impact redox metabolism, and potentially lead to generation of damaging levels of reactive oxygen species (ROS). Given that hypoxia tolerant intertidal sculpins experience the most severe fluctuations in environmental O_2, we hypothesized that there would be an interspecific link between hypoxia tolerance and ROS generation whereby the most hypoxia tolerant species would overall accumulate less ROS. Contrary to the hypothesis, mitochondria from our more hypoxia tolerant species had a higher ROS/O_2 in leak state (state IV) compared with less hypoxia tolerant species. When challenged to redox status manipulations and *in vitro* anoxia recovery, mitochondria from the more hypoxia tolerant species generated ROS at higher ROS/O_2 and did not recover state III respiration following anoxia as well as the less tolerant species. We also use a mitochondria-targeted mass spectrometry probe, MitoB, to investigate whether ROS generation differs during whole animal exposure to both hypoxia and hyperoxia.

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Changes in hemolymph T_{CO_2} and P_{CO_2} during the water-to-air respiratory transition of dragonflies / Changements de l'hémolymphe T_{CO_2} et P_{CO_2} durant la transition respiratoire eau-air chez la libellule

Like other developmentally amphibious animals, dragonflies modify their respiratory physiology as they transition from breathing water to breathing air during metamorphosis. The respiratory changes that occur during the water-to-air transition has been studied in a variety of vertebrates and crustaceans across developmental and evolutionary time scales, and it has been found that water-breathers generally display lower internal CO_2 compared to air-breathers due to the lower O_2 availability in water and higher ventilation demand required to extract it. However unlike vertebrates and crustaceans, insects are ancestrally terrestrial and have modified their air-breathing physiology to function underwater. In light of this, dragonflies also undergo a water-to-air transition during development, and are thus expected to show similar changes in their internal CO_2 based on the ventilation constraints in water. However, measurements of total hemolymph CO_2 (T_{CO_2}) across development in Aeshnid dragonflies showed that nymphs of all developmental stages had much higher T_{CO_2} values relative to other water-breathers, while final instar nymphs just before metamorphosis had values that were not significantly different from that of adults. This finding that aquatic nymphs have unexpectedly high CO_2 levels is being followed up using implantable CO_2 microsensors to measure hemolymph P_{CO_2} *in vivo*.

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A tale of two climbers: life history, locomotion and metabolic strategies of climbing gobies in La Réunion / Champions de grimpe: cycle biologique, locomotion et stratégies métaboliques des bichiques de l'ile de La Réunion

Several gobies from Tropical islands are amphidromous, spending their larval life at sea and the remaining of their life in freshwater. This lifestyle presents unique metabolic challenges associated with the transition between the two environments, spanning a wide range of salinity, water chemistry and hydrodynamism. Interestingly, closely related gobies species have adapted divergent locomotory strategies for climbing waterfalls separating the estuary from their upstream habitat: some species slowly inch their way up obstacles while others climb up by repeated bouts of burst swimming. In this study, we examined two sympatric species of gobies, *Sicyopterus lagocephalus* (SIL) and *Cotylopus acutipinnis* (COA) from La Réunion Island (South West Indian Ocean), that each exemplifies these diverging locomotory strategies. In particular, we were interested in interspecific differences in life history, morphology, axial enzymatic capacity and in the climbing ability of migrating juveniles. Our results suggest that burst climber (COA) juveniles returned to freshwater earlier and thus were typically smaller than SIL juveniles. Further, in climbing tests the inching gobies (SIL) managed to clear the obstacle significantly faster, stayed in motion longer, and exhibited on average higher axial metabolic enzyme activities than COA. Collectively, these results suggest important ecophysiological differences between these two species.

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Evidence for inhibitory paracrine cell-cell interactions in the rat carotid body / Évidence pour l'inhibition des interactions cellule-cellule paracrine dans le corps carotide du rat

Mammalian carotid bodies (CB) are the main peripheral arterial O_2 and CO_2/H^+ chemoreceptors, strategically located at the bifurcation of the common carotid artery. Purinergic signaling pathways contribute to the increased afferent discharge during sensory transduction. For example, ATP, released from chemoreceptor (type I) cells, may stimulate ionotropic P2X2/3 and metabotropic P2Y2 receptors (P2Y2R) on adjacent afferent nerve endings and glial-like type II cells, respectively. Paracrine stimulation of P2Y2R on type II cells may lead to the further release of ATP via pannexin-1 channels, thereby boosting excitation. Using ratiometric calcium imaging, we investigated the potential of two major monoamines synthesized by type I cells, i.e. histamine and dopamine, to modulate communication between type I and type II cells. When applied alone histamine (10 μM) and dopamine (10 μM) evoked negligible intracellular Ca^{2+} responses in type II cells. By contrast, both attenuated P2Y2R-mediated Ca^{2+} signaling in subpopulations (20 – 50%) of type II cells. Overall, this study raises the possibility that during chemotransduction release of histamine and dopamine may attenuate P2Y2R-mediated intracellular Ca^{2+} signaling in type II cells. We hypothesize that these inhibitory pathways may help regulate CB excitation by modulating purinergic signalling. We wish to thank NSERC and CIHR for funding.

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Changes in energetic costs associated with the multi-stressor effects of low salinity and low pH in *Fundulus heteroclitus* / Changements du coût énergétique associé aux facteurs de stress multiples associés avec une faible salinité et un faible pH chez *Fundulus heteroclitus*

The estuarine and marsh environments of the Atlantic coast experience wide fluctuations in salinity, temperature, oxygen and pH. Resident organisms, such as *Fundulus heteroclitus*, have evolved coping mechanisms enabling them to respond to rapid changes in these environmental variables. The ability of *F. heteroclitus* to tolerate and compensate for exposure to individual stressors has been well described, however information on the response to multi-stressor effects that more accurately represent the natural conditions are limited. To obtain an estimate of the metabolic costs of living in a single versus multi-stressor environment, routine oxygen consumption (MO_2) was measured on 1, 5 or 7 days after transfer to

one of four treatments: ambient conditions (pH 6.8 and 16 ppt salinity); low salinity (2 ppt), low pH (4.5), and low salinity and low pH. A significant increase in MO_2 was observed in *F. heteroclitus* exposed to a reduction in pH alone and in concert with low salinity, whereas exposure to low salinity alone did not affect rates of MO_2. These results suggest the exposure to low pH requires a significant energetic investment, likely do to modifications at the cellular level, in order to maintain acid-base balance.

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Isotopic turnover rates and diet-tissue discrimination depend on feeding preferences in freshwater snails / Les taux d'échange isotopique et la discrimination entre les tissus et les régimes alimentaires dépendent des préférences alimentaires des escargots d'eau douce

Stable isotope analysis is increasingly being used to reconstruct consumers' diets and determine trophic structure in ecological communities. The accuracy of these analyses is influenced by diet-tissue discrimination factors (DTDF) and tissue turnover rates. Yet, these factors are often unknown for consumers, especially for freshwater invertebrates. To estimate accurate DTDFs and turnover rates, three snail species (n = 450 individuals each) were lettuce-fed for ten weeks, then half were changed to a high-protein diet. Isotopic values of snail muscle and gonad tissue were measured up to 80 days post-diet change. Snail DTDFs varied by diet (lettuce > high-protein), tissue (muscle > gonad) and species. Turnover rates were faster for gonad than muscle, and for $\delta^{13}C$ than $\delta^{15}N$ in muscle. Snail species differed in their preferred diet; some grew faster on high-protein (i.e. *Helisoma trivolvis*) while others grew larger on lettuce diet (i.e. *Lymnaea elodes*), and turnover rates were faster on the preferred diet. This study suggests that for omnivores, different DTDFs should be applied for high-protein items (i.e. animal prey) and plants. Further, turnover rates will vary based on a consumer's diet preference, which in nature may be related to seasonality and food availability.

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The continued importance of natural history museums as data sources for evolutionary studies / L'importance continue des musées d'histoire naturelle comme source de données pour les études sur l'évolution

Natural history museums house countless specimens, images, and documents that are invaluable sources of primary data for researchers exploring regional, national, or global biodiversity, evolution, or conservation. For example, historical specimens housed in natural history museums can provide information about species distributions. Past and current distributional data can be used to estimate past species movement and model future movement in light of predicted climate change. Additionally, museum specimens and their ancillary data can be used to test for presence and spread of diseases or parasites, and track evolution of genes or traits over time. With new methodologies to efficiently and economically obtain genetic and morphological data from museum specimens (including specimens that are over 100 years old), natural history museums are more valuable than they have ever been. Yet, museums are constantly under threat to prove their value. The materials held within natural history museums are windows into the past, and may also offer glimpses into the future. It is imperative to use these resources and advocate for the preservation of specimens and the museums that house them to facilitate studies to better understand organismal evolutionary history.

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Examining teleost leukocyte immune-type receptor mediated phagocytic pathways / Examen des voies phagocytaires médiées par le récepteur du leucocyte chez les teleostéens

Innate immunity is an essential component of the vertebrate antimicrobial defense system. This protection depends on specialized cells that perform potent effector responses. One of these responses, called phagocytosis, involves dynamic remodeling of the plasma membrane during the capture, engulfment, and destruction of targets (i.e. pathogens). The ability of phagocytes to 'eat' extracellular targets requires the surface expression of distinct immunoregulatory receptor-types that bind to specific targets and trigger the actin cytoskeletal machinery. To further understand the phagocytic process in vertebrates, our research focuses on characterizing the channel catfish (*Ictalurus punctatus*) leukocyte immune-type receptor (IpLITR) proteins. The goal of this study was to address the hypothesis that specific IpLITR-types regulate the deployment of membrane structures called filopodia that may participate in the early stages of phagocytosis. Using live-cell video imaging of IpLITR-expressing cells co-transfected with LifeAct (a marker to visualize actin cytoskeletal dynamics) and high-resolution SEM my results demonstrate that specific IpLITR-types do indeed use an alternative phagocytic pathway that is functionally distinct from the prototypical pathway observed in mammals. This novel pathway involves the formation of filopodia that actively facilitate target capture. Currently, the molecular mechanisms that regulate the generation of IpLITR-induced phagocytic tentacles are being investigated.

Presidents' award finalist / Le finaliste pour le prix du président

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Thermal conditions experienced during differentiation affect metabolic and contractile phenotypes of mouse myotubes / Les conditions thermales éprouvées durant la différentiation affecte les phénotypes métaboliques et contractiles des myotubes de la souris

In endotherms, thermogenic responses to cold exposure for maintenance of core body temperature (T_B) are centrally regulated. However, peripheral muscles routinely experience temperatures lower than T_B. It would therefore be advantageous for these tissues to adjust thermal sensitivities independently from regulation of T_B. Early developmental conditions are plastic and can influence offspring phenotypes. We tested whether developing muscle compensates for local hypothermia. Using a murine myoblast cell line (C2C12), we found that hypothermia (32°C) increased myoblast metabolic flux compared with 37°C controls. Importantly, myotubes that differentiated at 32°C compensated for hypothermia by increasing overall metabolic rate, ATP production and glycolytic flux. Myotube responses were also modulated by the temperatures experienced by "parent" myoblasts. Myotubes that differentiated under hypothermia increased activity of the AMP-stimulated protein kinase (AMPK), which may mediate metabolic changes in response cold exposure. Moreover, cold exposure shifted myosin heavy chains from slow to fast, presumably to overcome slower contractile speeds resulting from low temperatures. Adjusting thermal sensitivities locally in peripheral tissues complements central thermoregulation and permits animals to maintain function in cold environments. Muscle also plays a major metabolic role in adults, so that developmental responses to cold are likely to influence energy expenditure later in life.

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A glimpse into the past: can fin ray microchemistry be used to interpret environmental life histories of Lake Sturgeon? / Un aperçu du passé: la microchimie des rayons de la nageoire peuvent-elles être utilisées pour interpréter l'histoire de la vie environnementale de l'esturgeon jaune?

Chemical signatures in hard structures (otolith, fin ray) have proven useful to identify spatial and temporal movements of individuals in fish. Lake Sturgeon, *Acipenser fulvescens*, is the only exclusively freshwater sturgeon species in North America and is considered threatened throughout most of its natural range. To assess habitat use and investigate site-specific trace elemental signatures at different life stages, a historical

reference collection of Lake Sturgeon fin rays (age 20-60 years, n=50) was analyzed via LA ICP-MS. Fin ray Sr:Ca ratios were negatively correlated with ambient water chemistry Sr:Ca ratios at the juvenile stage (r^2=0.62) and classification success using linear DFA to site of capture at the level of river system was high (81%). Conversely at the late adult stage there was weak correlation between water chemistry and element concentrations in fin rays (r^2=0.01) suggesting a shift in physiological mechanisms for elemental incorporation as growth rate decreases with age. However, older individuals still classified successfully to river system (85%). These results suggest identification of natal origin in older fish may be possible if ambient water chemistry is known. This will lead to improved understanding of stocks within river systems and ultimately enhance management of populations currently at risk or threatened.

R.A. Wardle Award / Prix R.A. Wardle

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In the belly of the Beast: What factors determine which insect vectors transmit which parasites? The journey continues…

Vectors that feed on vertebrate blood ingest multiple parasites and pathogens, yet few are transmitted. Molecular interactions between the innate immune responses of the vector and the parasite determine the transmission outcome. Vectors recognize and eliminate most parasites, while successful parasites circumvent host immune responses. The mosquito *Aedes aegypti* is the principle vector of Dengue and Zika viruses. In Cali Colombia, however, 30% of feral *Ae. aegypti* kill all 4 serotypes of Dengue. We sequenced (RNA-seq) the midgut transcriptome of mosquitoes that are susceptible (S) or refractory (R) to dengue viruses, and designated differentially expressed genes as pro-viral (overexpressed in S) or anti-viral (over expressed in R). We used RNAi to knockdown the expression of selected genes and determined the S or R phenotype. While we understand some of the mechanisms involved we do not understand the "logic" of becoming refractory to a virus that has no significant impact on the vector, and which the vector is unlikely to encounter in its lifetime, especially when there are fitness costs associated with the R phenotype. If we could "convince" all *Ae. aegypti* to become refractory to Dengue and other viruses, we might significantly reduce human disease.

Dans le ventre de la bête: Quels facteurs déterminent quels insectes transmettent à quels parasites? Le périple continue…

Les vecteurs qui se nourrissent de sang de vertébrés ingèrent de multiples parasites et pathogènes, mais peu sont transmis. Les interactions moléculaires entre les réponses immunitaires innées du vecteur et le parasite déterminent le résultat de la transmission. Les vecteurs reconnaissent et éliminent la plupart des parasites, tandis que les parasites réussis contournent les réponses immunitaires de l'hôte. Le moustique *Aedes aegypti* est le vecteur principal des virus Dengue et Zika. À Cali Colombie, cependant, 30% des *Ae. aegypti* tuer tous les 4 sérotypes de la dengue. Nous avons séquencé (RNA-seq) le transcriptome de l'intestin moyen des moustiques sensibles (S) ou réfractaires (R) aux virus de la dengue et désignés gènes exprimés différentiellement comme pro-virale (surexprimée en S) ou anti-virale). Nous avons utilisé l'ARNi pour réduire l'expression de gènes sélectionnés et déterminé le phénotype S ou R. Bien que nous comprenions certains des mécanismes impliqués, nous ne comprenons pas la «logique» de devenir réfractaire à un virus qui n'a pas d'impact significatif sur le vecteur, et que le vecteur est peu susceptible de rencontrer dans sa vie, surtout quand il y a des coûts de fitness associés Avec le phénotype R. Si nous pouvions «convaincre» tous les *Ae. aegypti* de devenir réfractaire à la dengue et d'autres virus, nous pourrions réduire considérablement les maladies humaines.

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Neuromuscular control of fish swimming in viscous water / Contrôle neuromusculaire des poissons nageant dans l'eau visqueuse

Locomotion in invertebrates and vertebrates alike is accomplished by rhythmic neural signalling networks called "central pattern generators" (CPGs). These CPGs can create stereotypical motor output that is subsequently tuned to best suit a particular environment by changes sensory input, top-down control and physical limitations of the environment. While the presence of CPGs in most animals is widely accepted, the role that these tuning inputs play in creating motor output, especially in fish, is only now beginning to be understood. Here, we report the kinematic and muscle activation patterns during fish swimming that result from changes in sensory input and physical limitations due to water viscosity. We suggest that muscle activation patterns are tuned to maximize efficiency for swimming behaviour and so, as water viscosity increases, fish will change kinematic output by changing muscle activation patterns. How fish respond to changes in water viscosity improves our understanding of neuromuscular control and how it tunes motor output.

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Indirect quantification of lipid oxidation rates of submaximal thermogenesis during metabolic steady state in deer mice / Quantification indirecte des taux d'oxydation des lipides (pendants la thermogenèse a l'état stationnaire métabolique) chez la (souris sylvestre)

High-altitude environments are extremely challenging for small mammals such as deer mice (*Peromyscus maniculatus*) due to hypoxic-cold stress. To maintain constant body temperatures in the cold, these mice need to sustain the oxygen-demanding process of thermogenesis, despite the low oxygen availability in this harsh environment. Previous studies revealed that highland and lowland deer mice thermoregulate using primarily lipids, and highlanders supported higher rates of thermogenesis. However, fuel use was determined using indirect calorimetry with the assumption that mice remained in metabolic steady state during maximal cold-induced thermogenesis (VO_2summit). The underlying mechanisms responsible for increased lipid oxidation rates in highland deer mice are largely unknown. The purpose of this study was to determine if deer mice remained in steady state during submaximal thermogenesis so that respirometry can be used to determine whole-animal lipid oxidation. Using plethysmography and open-flow respirometry, our results revealed total ventilation, O_2 consumption and CO_2 production increased linearly with decreasing temperatures (30ºC-0ºC) for both highland and lowland deer mice. This suggests deer mice remained in steady state as metabolic rate increased to support thermogenesis. Future directions include quantifying lipid oxidation using 13-C breath technique during VO_2summit and characterizing the mice's' ability to mobilize, transport, uptake and utilize lipids.

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WTF: What's this fat? Identification of eye fat deposit discovered by water-fat MRI in hibernating squirrels / Quel est cette graisse? Identification de dépositions de gras dans l'œil découvert par un IRM eau-gras chez les écureuils en hibernation

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During the winter, hibernating mammals cycle between periods of low body temperature (~5°C) lasting two weeks and brief arousal periods (37°C). During arousals brown adipose tissue (BAT) is the primary source of heat production. BAT is thought to be restricted to the thorax in mammals. Previously, using MRI, we identified a tissue depot with similar properties to BAT surrounding the eyes in 13-lined ground squirrels. We predict that this eye fat deposit is BAT and warms the brain/head, especially during arousal. We used water-fat MRI to determine changes in volume of this eye fat deposit in two groups of juvenile squirrels; one housed at 25°C and the other 5°C, both with 12/12 photoperiod for a year. I will use thermal

imaging to determine if the area near the eye preferentially warms during an arousal, in comparison to the thorax. Because BAT exclusively contains uncoupling protein 1 (UCP1), immunoblot analysis will be used on dissected tissue for presence of UCP1. If the deposit of fat near the eyes is indeed BAT, this will be the first indication of BAT outside of the thorax, and may explain how the brains of hibernating Arctic ground squirrels are maintained warmer than the body core.

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Taurine depresses cardiac contractility and enhances systemic heart glucose utilization in the cuttlefish, *Sepia officinalis* / La taurine réduit la contractilité cardiaque et améliore l'utilisation systémique du glucose cardiaque chez la seiche, *Sepia officinalis*

Taurine is the most abundant amino acid in the blood of the cuttlefish, *Sepia officinalis*, where levels can exceed 200 mmol L^{-1}. In mammals, intracellular taurine modulates cardiac Ca^{2+} handling and carbohydrate metabolism at much lower concentrations but it is not clear if it exerts similar actions in cephalopods. Blood Ca^{2+} levels are high in cephalopods and we hypothesized that taurine would depress cardiac Ca^{2+} flux and modulate contractility in systemic and branchial hearts of cuttlefish. Heart performance was assessed with an *in situ* perfused systemic heart preparation and contractility was evaluated using isometrically contracting systemic and branchial heart muscle rings. Stroke volume, cardiac output, and Ca^{2+} sensitivity were significantly lower in systemic hearts perfused with supplemental taurine (100 mmol L^{-1}) than in controls. In muscle ring preparations, taurine impaired relaxation at high contraction frequencies, an effect abolished by supraphysiological Ca^{2+} levels. Taurine did not affect oxygen consumption in non-contracting systemic heart muscle, but extracellular glucose utilization was twice that of control preparations. Collectively, our results suggest that extracellular taurine depresses cardiac Ca^{2+} flux and potentiates glucose utilization in cuttlefish. Variations in taurine levels may represent an important mechanism for regulating cardiovascular function and metabolism in cephalopods.

Presidents' award finalist / Le finaliste pour le prix du président

Heath A. MacMillan, Gil Yerushalmi, Sima Jonusaite, Scott P. Kelly and Andrew Donini
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How to minimize accidental leakage: Thermal acclimation mitigates cold-induced paracellular leak from the *Drosophila* gut / Comment minimiser les fuites accidentelles: L'acclimation thermale atténue les fuites para-cellulaires induites par le froid dans l'intestin de *Drosophila*

Chill susceptible insects are incapacitated and killed by chilling, but adaptation and acclimation to low temperatures can facilitate substantial improvements in chilling tolerance. Cold exposure causes a gradual leak of ions and water down their concentration gradients. This loss of balance occurs most notably across the gut epithelia, where large ionic and osmotic gradients are normally maintained by high rates of transport. It is unclear whether this effect is related to a suppression of transcellular transport alone, or whether chilling also disrupts paracellular barrier function. In this talk we will demonstrate that some of the major proteins of the paracellular septate junctions of *Drosophila* are differentially expressed following cold acclimation. Cell-cell contact regions in the midgut epithelium also become more convoluted and contain more septate junctions in cold-acclimated flies. This plasticity in junction structure is associated with a reduction in the tendency for paracellular solute leak from the midgut before and during chronic cold stress. Thus, septate junction plasticity likely aids in the maintenance of solute and water balance and may represent an important mechanism of thermal acclimation.

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High-altitude ancestry alters muscle phenotype and plasticity of skeletal muscle mitochondria function to chronic cold and hypoxia in deer mice / Ascendance en haute altitude modifie le phénotype musculaire et la plasticité de la fonction des mitochondries des muscles squelettiques face au froid et à l'hypoxie chronique chez la souris sylvestre

High-altitude environments pose conflicting challenges to endotherms, because hypoxia limits mitochondrial ATP production while cold increases the ATP demands of thermogenesis. High-altitude deer mice (*Peromyscus maniculatus*) have evolved high aerobic capacities and capillarity in locomotory muscle, which should help counteract the challenges of cold hypoxia. Here, we examined how high-altitude ancestry affects the acclimation response to cold and/or hypoxia in setting the muscle phenotype. Deer mice native to high- and low-altitudes were raised in captivity and acclimated as adults to warm (25°C) normoxia; warm hypoxia (equivalent hypobaria to 4300m); cold (5°C) normoxia; and cold hypoxia. Muscle of highland mice generally had higher citrate synthase and cytochrome oxidase activities (markers of mitochondrial oxidative capacity), due in part to a decreased abundance of glycolytic fibres, and greater capillarity compared to lowland mice across acclimation environments. Respiratory capacities of isolated mitochondria were higher in highland mice in normoxic (warm or cold) and cold hypoxic environments, which may thus contribute to increasing tissue oxidative capacity as well. However, mitochondrial respiratory capacities were similar between populations in warm hypoxia, due to population differences in the hypoxia acclimation response. Therefore, both evolved differences and environmentally-induced plasticity help enhance muscle aerobic capacity and performance at high altitudes.

Cody W. Manchester and John R. Gray
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Response of a locust motion sensitive neuron and flight muscle activity during flight steering / Réponse de neurones sensibles au mouvement et activité des muscles de vol durant le pilotage en vol chez le criquet

Flying animals display a variety of adaptive behaviours to avoid predators and collisions with conspecifics during flight. The locust Descending Contralateral Movement Detector (DCMD) is a well characterized wide field looming sensitive neuron that responds vigorously to approaching objects. Increasing stimulus complexity reduces firing rates, delays peak firing, shortens the rise phase and lengthens the fall phase of DCMD response profiles whereas flow fields cause decrease peak firing rates. This is the first experiment to examine DCMD responses during flight steering. Preliminary data show that, compared to a non-flying condition, DCMD responded to a head-on approach (0°) with a narrower peak firing response profile and lower peak firing. During an approach from 45°, the peak occurred later relative to time of collision (TOC). Previously described DCMD bursting occurred in non-flying and flying conditions, suggesting that bursting is critical for coding object approach. Bursts also showed an earlier increase in firing rate during a 45° loom, compared to an approach from 0°. This indicates that bursting responses change with respect to stimulus direction and that bursts may work in conjunction with overall firing rate to moderate motor output during collision avoidance behaviour.

Milica Mandic, Velislava Tzaneva and Steve F. Perry
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Control of the hypoxic ventilatory response in larval zebrafish (*Danio rerio*) via hypoxia-inducible factor 1α / Contrôle de la réponse ventilée hypoxique à travers le facteur hypoxie-indicible 1α chez la larve du poisson zèbre (*Danio rerio*)

The hypoxic ventilatory response (HVR) is a key first line of defense in fish exposed to environmental hypoxia. Many mechanisms have been proposed for the control of the HVR, including the induction of

hypoxia-inducible factor 1α (HIF1α), a transcription factor that alters the transcription patterns of many hypoxia-inducible genes. In cyprinids, there are two paralogs of HIF1α (HIF1α-aa and HIF1α-ab), although little is known about the specific roles or potential sub-functionalization of the paralogs in response to hypoxia. In this study, we examined the HVR in wild-type, HIF1α-aa, and HIF1α-ab knockout lines of larval zebrafish (*Danio rerio*). In 4 days post fertilization (dpf) HIF1α-ab knockout zebrafish there was no increase in ventilation frequency (f_V) in response to hypoxia (30 mm Hg) in contrast to the significant increase seen in wild-types. As larvae developed, the magnitude of the HVR increased in HIF1α-ab knockouts but to a lesser degree than in wild-type larvae, until 15 dpf at which point there was no difference between the two groups. In contrast, there was no effect of HIF1α-aa knockout on hypoxic f_V. These results suggest that there is sub-functionalization of HIF1α paralogs, with HIF1α-ab playing a role in HVR during the early stages of zebrafish development.

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Parental and embryonic environment and thermal history can affect thermal tolerance and the heat shock response in Lake Whitefish (*Coregonus clupeaformis*) at multiple life history stages / Les environnements parentaux et embryonnaires et l'histoire thermique peuvent affecter la tolérance thermale et la réponse de protéine de choc thermique chez le grand corégone à divers stades de vie

Fish and their developing embryos may be exposed to a variety of natural and anthropogenic thermal stressors such as daily and seasonal fluctuations or industrial thermal effluents. The impact of these stressors may be further compounded if water temperatures rise due to climate change. As a cool water fish with a preference for deep, cool lakes and whose embryos spend much of their long embryonic period (100-150 days) at 1-2ºC, Lake Whitefish are an ideal species to investigate the long-term impacts of variable thermal environments and thermal stress. This presentation will discuss recent data on the thermal tolerance and the heat shock response (HSR) in Lake Whitefish from different lakes in Saskatchewan and Ontario throughout their life history in response to various thermal stressors. Our results indicate that the HSR in Lake Whitefish is plastic at all stages of life history from early embryogenesis to adults and that thermal stress in the embryonic period can have lasting impacts on the HSR. We also show that the thermal history of both parents (cool vs warm lakes) and embryos (fluctuating temperatures) can alter thermal tolerance and survival of embryos to acute high level stressors.

Jeffrey M. Marcus
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My Love-Hate relationship with DNA Barcodes, the Y2K Problem, and the search for something better / Ma relation amour-haine avec les codes barres d'ADN, le problème Y2K et la recherche pour quelque chose de mieux

DNA barcodes are indisputably useful for rapidly identifying many organisms. Often, DNA barcodes are used to provide insights regarding the phylogeny of organisms. However, short barcodes fail to correctly discriminate between species in about 30% of cases. In addition, there are instances when phylogenies generated from mitochondrial barcode sequences do not correctly reconstruct the evolutionary history of the mitochondrial genome, let alone the evolutionary history of the organisms. DNA barcode sequences are short, so the number of informative variable sites is very small, causing phylogenetic ambiguity especially among closely related organisms. This is a biological analogue of the Y2K problem in computer science: the ambiguity that arises when legacy identifiers contain insufficient information for new demands being placed on an information storage and retrieval system. Also, the *Cytochrome oxidase I* (*COI*) gene used for animal DNA barcoding is the most constrained coding sequence in the mitochondrial genome. Consequently, the few variable sites in *COI* saturate more quickly than other mitochondrial DNA. This causes phylogenetic ambiguity among distantly related organisms. Using examples from my research

program, I will present alternatives to the current conventional barcodes to resolve these issues, while maintaining much of the convenience and low-cost of conventional barcode approaches.

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Changes in the freshwater mussel (Unionidae) communities of the Rideau River and evidence of refugia from zebra mussel infestation / Changements dans les communautés de moules d'eau douce (Unionidae) de la rivière Rideau et évidence de refuges d'infestation par la moule zébrée
The Rideau River is a UNESCO World Heritage site managed by Parks Canada. Historically, the unionid mussel fauna of this drainage basin included 13 species. Early on, urbanization and land development contributed to habitat degradation. The arrival of the zebra mussel in 1990 contributed to a steep decline in the unionid population. We conducted the first surveys of native freshwater mussels in this river from 1998 to 2001. Zebra mussels continued to spread, impacting unionid-rich communities typically found in riffle habitats. In 2016, we re-surveyed these sites to evaluate the effect of the zebra mussel and documented habitats using underwater imaging. At many sites, unionids had been almost totally extirpated because of zebra mussel fouling. Live freshwater mussel abundance and species diversity declined significantly. However, at two sites, Old Slys and Kilmarnock, unionid survival rates were 20% to 60%. There is evidence of refugia for the dominant species of unionids in shallow habitats near or within macrophyte beds with suitable, mixed loose substrates, and also in thick layers of empty zebra mussel shells which enables deep burrowing, enough to smother zebra mussels. Identifying and protecting refugia areas for unionids will contribute to the preservation of unionid populations.

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Les copépodes peuvent-ils remplacer les rotifères comme nourriture vivante dans les élevages larvaires de plie rouge? / Can copepods replace rotifers as living food in the larval rearing of winter flounder?
La plie rouge (*Pseudopleuronectes americanus*) est une excellente candidate pour l'aquaculture en milieu tempéré. Cependant, son développement aquacole est limité par des mortalités larvaires importantes. Ce projet vise à évaluer la valeur nutritionnelle des nauplii de copépodes et de la comparer avec celle de rotifères enrichis utilisés traditionnellement en aquaculture. La croissance, la survie et la composition en acides gras (AG) des larves de plie ont été déterminées et reliées à la qualité lipidique des proies. Les profiles des acides gras essentiels (AGEs) démontrent qu'il n'y a pas de différence significative entre la qualité nutritionnelle des deux espèces de copépodes (*Eurytemora* spp. et *Acartia* sp.). D'autre part, aucune différence de croissance (poids et longueur) et de survie n'a été observée entre les larves nourries avec des *Eurytemora* spp. ou des rotifères. Nous avons cependant trouvé des différences dans le pourcentage d'EPA et de DHA des proies (p<0.001) et dans la concentration totale d'AG neutres des larves (p=0.023) qui représentent les réserves lipidiques. Finalement, le ratio AG polaires-larves : AG totaux-proies indique que les nauplii répondent mieux que les rotifères aux besoins nutritionnels des larves de plie rouge en termes de AA, EPA et DHA.

Tábata Martins de Lima, Danusa Leidens, Fábio Everton Maciel and Luiz Eduardo Maia Nery
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Is emersion behavior a way to avoid anaerobic pathway during aquatic hypoxia? / Es-ce que le comportement d'émergence est la façon de prévenir la voie anaérobique durant l'hypoxie aquatique?
The first response to hypoxia in aquatic habitats is to escape to more oxygenated areas. Due to bimodal breathing, some semi-terrestrial crabs as *Neohelice granulata* are capable of emersion when exposed to

hypoxic conditions. To better understand the emersion behavior in moderate and severe hypoxia, crabs were placed in an aquarium with access to air and observed for 270 minutes and lactate hemolymphatic was measured. In normoxia (6mgO_2/L), crabs spent only a small portion of the total time emersed from water (5%). When exposed to moderate hypoxia (3 and 2 mgO_2/L), the time spent emersed was not significantly different from the normoxic condition (3.3% and 2.9%, respectively). However, in severe hypoxia (1 mgO_2/L), the crabs spent most of the time emersed (63%). Therefore, the crabs only spent more time emersed when the oxygen concentrations were very low (severe hypoxia) and otherwise moderate decreases in oxygen did not affect emersion behavior. In severe hypoxia there was also a significant increase in hemolymph lactate content. These data indicate that when exposed to severe hypoxia, even with the possibility air breathing during emersion, crabs still have to use anaerobic pathways, but in moderate hypoxia this is not necessary.

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Changes in protein phosphorylation and acetylation correspond with suppression of mitochondrial metabolism during hibernation / Les changements dans la phosphorylation et l'acétylation de la protéine correspondent à la suppression du métabolisme mitochondrial durant l'hibernation
Small hibernators such as the 13-lined ground squirrel (*Ictidomys tridecemlineatus*) cycle between two distinct metabolic states during hibernation: torpor, lasting ~2 weeks, where body temperature (T_b) and metabolic rate (MR) are significantly suppressed, and interbout euthermia (IBE), where T_b and MR are briefly elevated to euthermic levels. Metabolic suppression during hibernation corresponds with a ~70% reduction in liver mitochondrial respiration as well as suppression in the maximal activity of electron transport system (ETS) complexes I and II in liver. Differential 2D gel electrophoresis (DiGE) and Blue-Native PAGE revealed several proteins that differed in isoelectric point or molecular weight between torpor and IBE, suggesting alterations by post-translational modification. I identified these proteins using MALDI mass spectrometry, and investigated their post-translational modifications using phosphoprotein staining and immunoblots for total acetylated lysine. Several mitochondrial proteins are differentially phosphorylated and acetylated between torpor and IBE, most notably phosphorylation of ETS complexes I and II increases significantly in torpor. Such reversible modifications may explain the suppression of ETS complex activity and mitochondrial respiration rates in torpor. Current work focuses on manipulating the phosphorylation state of these proteins in intact mitochondria in attempt to alter their activity and overall mitochondrial metabolism.

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Changing respiratory chemosensitivity during the water-to-air transition of Aeshnid dragonflies / Changement dans la chimiosensibilité durant la transition eau-air chez les libellules Aeshnidés
Dragonflies begin their lives as aquatic nymphs that breathe water using a rectal gill before emerging as an air-breathing imago (flying adult) during their final molt. While this amphibious life cycle is far from unique in the animal kingdom, developmentally amphibious insects are unique in that they have re-invaded the water as air-breathing animals, adapting a terrestrial respiratory physiology to function underwater. Given that the nymph and adult dragonfly experience vastly different respiratory environments, this study investigated whether the water-to-air transition was also associated with a change in respiratory chemosensitivity and ventilatory behaviour. To investigate changes in ventilatory control across development, Aeshnid dragonfly nymphs and adults were exposed to varying levels of environmental hypoxia and hypercapnia while their abdominal ventilation rate was recorded. This revealed that the nymphs increased their ventilation frequency in response to hypoxia, but not hypercapnia. In contrast, the air-breathing adult dragonflies appeared remarkably insensitive to both low O_2 and high CO_2 and did not vary their ventilation, even when breathing 5 kPa O_2 or 10 kPa CO_2 in normoxia. This

finding is unexpected, but could indicate that autoventilation by the flight muscles, and not abdominal pumping, is critical for controlling gas exchange in these insects.

Allison E. McDonald
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Micro-relationships: The amazing world of endosymbiosis / Micro-relations: Le monde fabuleux de l'endosymbiose
Since Lynn Margulis proposed the endosymbiotic theory in a seminal paper in 1967, it has gone from a fanciful and ludicrous idea to one that is well accepted by most biologists. Understanding endosymbiosis more fully as a process may allow us to one day answer questions about the origin of life on our planet and the origin of eukaryotes. The best studied outcomes of endosymbiotic events are the mitochondria and chloroplasts of eukaryotic cells, but many other fascinating examples of these "micro-relationships" exist in nature and are being explored. I'll introduce several of these relationships as case studies and will discuss what tools have been brought to bear in order to explore these fascinating interactions. As we continue to learn more about endosymbiosis as a process and what its evolutionary consequences can be, we gain a greater appreciation of the natural world around us. This forces us to ask new and challenging questions about the basic assumptions that we make as biologists.

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Abiotic drivers of winter movements in a cold-adapted songbird / Conducteurs abiotiques des mouvements hivernaux chez un oiseau chanteur adapté au froid
Temperate winters are changing rapidly, with less snow and warmer winter temperatures predicted for many parts of North America. The Snow Bunting (*Plectrophenax nivalis*) is a nomadic, Arctic-breeding songbird that winters in temperate regions of Canada and the northern US. We applied 40 digitally-coded radio tags to Snow Buntings within an automated tracking array (Motus Wildlife Tracking System) in southern Ontario in 2016, to quantify their nomadic winter movements and determine abiotic correlates of this behaviour. Birds were captured in baited ground traps and fitted with a backpack-style radio tag. Unique tag frequencies were then detected by receivers stationed across southern Ontario. We first describe Snow Bunting movements by modeling distance and bearing between detections as a function of date, age, and sex. We then examine abiotic environmental factors (snow depth, snow fall, temperature) as drivers of bunting movements between sites. To account for the non-random distribution of radio-receiving towers, we compared the conditions at the site where each bunting was detected with concurrent conditions at the site each bunting was detected previously. Our model results will allow for predictions about winter detectability and population trends for this cold-adapted, temperate-wintering species.

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Extending the dogfish model of CO_2 excretion to the gills and blood of other chondrichthyan fishes / L'extension du modèle roussette d'excrétion de CO_2 aux branchies et le sang des autres poissons cartilagineux
The enzyme carbonic anhydrase (CA) catalyzes the conversion of H^+ and HCO_3^- to carbon dioxide (CO_2) and H_2O and is essential for CO_2 excretion. In most teleost fishes, membrane-bound plasma accessible CA (paCA) is lacking in the gills, restricting this process to the red blood cell (RBC). In the dogfish *Squalus suckleyi,* however, the RBC and plasma compartments appear equally important for CO_2

excretion because of paCA at the gill, higher plasma buffering capacity, slower RBC CA and the absence of a plasma CA inhibitor. It is not known whether these traits apply to all chondrichthyans. Blood and gill samples were collected from several chondrichthyan species and assessed for CA characteristics and plasma buffering capacity. CA characteristics of blood were consistent with that of *S. suckleyi*, and paCA was found in the gills of blacktip reef sharks (*Carcharhinus melanopterus*) as well as Atlantic stingrays (*Dasyatis sabina*) and ocellate river stingrays (*Potamotrygon motoro*). These results suggest that the dogfish model of CO_2 excretion may be representative of chondrichthyan fishes as a whole, and provides important information regarding general patterns of gas exchange and acid-base balance among this phylogenetically diverse group.

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Multi-stressor impacts on fish energetics: a comparison between lab and field studies / Impacts de multiples conditions de stress sur l'énergétique des poissons: comparaison entre les études de laboratoire et sur le terrain

Aquatic organisms are continuously exposed to multiple environmental stressors that work cumulatively and synergistically to alter ecosystems. The objective of this study was to compare the impacts of multiple stressors under lab and field conditions using two fish species, zebrafish (*Danio rerio*) and rainbow darters (*Etheostoma caeruleum*). Under lab conditions, the study examined the impacts of chronic exposure to environmentally relevant concentrations of venlafaxine and elevated water temperatures, on the energetics and stress response of zebrafish. Venlafaxine is a frequently prescribed antidepressant that is readily detectable in many Canadian waterways that receive discharged wastewater treatment plant effluent. Under field conditions, rainbow darters were collected upstream and downstream of the Waterloo wastewater treatment plant in the Grand River. Enzyme activities of major metabolic enzymes and metabolites were measured in muscle tissue of both species. Oxygen consumption was measured to assess the effects of stressors on routine metabolic rate, active metabolic rate, aerobic scope, and critical swimming speed, all of which are significant ecological performance indices. Aligning field and lab results will highlight the importance of including multi-stressor approach assessments in making predictions regarding the impact of environmental stressors on non-target organisms.

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Respiratory mechanics and morphology of Tibetan and Andean high-altitude geese with divergent life histories / Mécanique respiratoire et morphologie en haute altitude des oies tibétaines et andéennes avec des histoires de vie divergentes

High-altitude bar-headed (*Anser indicus*) and Andean geese (*Chloephaga melanoptera*) have been shown to preferentially increase tidal volume over breathing frequency when increasing ventilation during exposure to hypoxia. This is an effective but metabolically expensive breathing strategy. We hypothesized there would be differences in the morphology and mechanics of the respiratory systems of these high-altitude species compared to a low-altitude migratory species, the barnacle goose (*Branta leucopsis*), which would minimize the cost of breathing more deeply. We ventilated anesthetized birds to measure the mechanical properties of the respiratory system and used CT scans to quantify respiratory morphology. We found the size and dynamic compliance of the respiratory system of Andean geese were greater than those of the other two species, allowing use of a deeper breathing strategy for the same energetic cost. The relative size of the respiratory system of bar-headed geese was also larger than that of the barnacle goose, although the dynamic compliance did not differ. The cost of breathing was estimated to be <1% of basal

metabolic rate in normoxia, and to increase 7 to 10-fold in the bar-headed and barnacle geese in hypoxia, but less than 1-fold in the Andean goose. Supported by the NSERC of Canada.

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Matrix-based mitochondrial H_2O_2 scavenging capacities: a novel correlate to longevity?

The search for physiological correlate of longevity among animals begun with Weissman (1889). As of now, only the resistance to oxidation of membrane lipids and the resistance of proteins to unfolding are such accepted correlates among a majority of comparative physiologists. My presentation at last year's CSZ meeting reported on our finding that the rodent naked mole-rat (*Heterocephalus glaber,* longevity > 30 years), is characterized by mitochondria with a greater capacity to scavenge (the deleterious ROS) H_2O_2 as compared to mitochondria of the (similarly sized) shorter-lived mouse (*Mus musculus*). The present study reports that the longest-lived metazoan species (the Atlantic clam *Arctica islandica*) also possess mitochondria with higher H_2O_2 scavenging capacities when compared to two short-lived (similarly sized) clam species. When normalized to mg of mitochondrial proteins, the capacity of gill and mantle mitochondria of *A. islandica* is significantly (factor of two and nine, respectively, n = 3) greater than for the two other species. These preliminary results remain to be confirmed with larger sample size. If the conclusions are maintained, the present and previous study on naked mole-rat would form the basis for suggesting the mitochondrial H_2O_2 scavenging capacities is a novel and third physiological correlate to longevity.

Les capacités mitochondriales (matricielles) de consommation du H_2O_2: un nouveau trait physiologique corrélé à la longévité?

Les deux seuls traits physiologiques acceptés comme étant corrélés à la longévité animale sont la résistance à l'oxydation des lipides membranaires et la résistance à la perte de configuration des protéines. Ma présentation de l'année passée (CSZ) rapportait que le rongeur rat taupe-nu (*Hétérocephalus glaber,* longévité > 30 ans) possède des mitochondries qui neutralisent plus rapidement le dérivé toxique de l'oxygène H_2O_2 que celles de la souris (*Mus musculus*, longévité = 4 ans). La présente étude rapporte que les mitochondries de l'animal ayant la plus grande longévité parmi les métazoaires, la palourde *Arctica islandica,* (longévité > 500 ans), sont également capables d'éliminer le H_2O_2 plus rapidement que celles de deux espèces de palourdes de courte longévité. Lorsque normalisé par mg de protéines mitochondriales, la consommation de H_2O_2 des mitochondries de branchies et du manteau d'*A. islandica* est au minimum de deux et neuf fois supérieure, respectivement (n = 3). Ces résultats préliminaires doivent être confirmés par une plus grande taille d'échantillon. Si les conclusions se maintiennent, cette étude et celle sur le rat taupe nu suggèrent que la capacité mitochondriale de consommation de H_2O_2 est un nouveau facteur physiologique corrélé à la longévité.

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When friends become enemies: environmentally relevant dietary selenomethionine exposure impaired learning and memory in zebrafish (*Danio rerio*) / Quand les amis deviennent des ennemis: l'exposition alimentaire spécifique à l'environnement de la sélénométhionine handicape la mémoire chez le poisson zèbre (*Danio rerio*)

During recent years, there has been increasing concern regarding some essential elements which can also be hazardous to living organisms if present at high levels. Selenium is an essential micronutrient for all vertebrates. However, there is a narrow margin between its beneficial and toxic effects. In this study, we aimed to investigate the effects of dietary form of selenium (selenomethionine) on learning and memory,

which are two fundamental functions of the brain, using zebrafish as the model organism. To this end, adult zebrafish were exposed to different concentrations of dietary L-selenomethionine (control, 3, 10, 30 or 60 μg/g dry mass) for 30 days. Learning performance was tested in individuals using a latent learning paradigm. Low levels of L-selenomethionine (3 and 10 μg/g) exposure did not significantly affect learning performance in zebrafish. However, fish treated with higher L-selenomethionine doses (30 and 60 μg/g) exhibited impaired performance in the latent learning task. Impaired learning performance was associated with disruption in dopaminergic system as evident by change in expression of dopamine receptors in fish brains treated with high L-selenomethionine. Enhanced oxidative stress was found to be a possible mechanism by which L-selenomethionine disrupted dopaminergic system and consequently impaired learning performance in zebrafish.

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Physiological responses of *Carcinus maenas* acclimated to a tidal emersion cycle / La réponse physiologique de Carcinus maenas acclimaté à un cycle d'émersion de la marée

Animals inhabiting the intertidal zone are exposed to abrupt changes in environmental conditions associated with the rise and fall of the tide. For convenience, the majority of laboratory studies on intertidal organisms have held and acclimated individuals permanently submerged in seawater tanks. However, this is not representative of the daily fluctuations intertidal organisms experience in their natural habitat. We used the green crab *Carcinus maenas* to identify whether individuals exposed to a 6h tidal regime of emersion and immersion exhibited different physiological responses compared with animals that were held permanently submerged. Aerial and aquatic oxygen consumption, hemolymph PaO_2 and pH, hemocyanin and L-lactate concentration were measured in individuals acclimated to both a tidal cycle of emersion-immersion and constant submerged conditions. The submerged group exhibited higher oxygen consumption rates upon re-immersion. This was due to the onset of acidosis during emersion in the submerged animals, suggesting that they may lose important physiological control mechanisms when acclimated to laboratory conditions. The results of this study emphasise the need to acclimate intertidal organisms to appropriate conditions in the lab, in order to develop a more accurate understanding of how marine organisms will respond to environmental stressors.

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The osmorespiratory compromise in the rainbow trout (*Oncorhynchus mykiss*): the effects of fish size, hypoxia, and strenuous exercise on gill diffusive water flux rates and net sodium loss rates / Le compromis osmorespiratoire chez la truite arc-en-ciel (*Oncorhynchus mykiss*): Les effets dû à la taille du poisson, l'hypoxie, et l'exercice ardu sur le taux de diffusion de l'eau sur les branchies et le taux net de perte de sodium

In the context of the osmorespiratory compromise, hypoxia has been little studied relative to exercise, and diffusive water flux rates (as assessed by ^3H_2O efflux) has received almost no attention. We investigated the effects of fish size, hypoxia, and exercise on diffusive water flux rates and net sodium loss rates in juvenile rainbow trout. Trout weighing 10-20g and 25-50g were used to determine the effects of fish size under normoxia. Thereafter 25-50g trout were selected to assess the effects of different dissolved oxygen levels (15-40% DO) and strenuous exercise. Small fish had higher diffusive water flux rate than larger fish, turning over a greater percentage of their body water pool per hour. Hypoxic exposure exerted a biphasic effect, increasing the diffusive water flux rate at 40% DO while reducing it at 25 or 15% DO. Prolonged hypoxia (40% DO) reduced diffusive water flux and increased Na^+ loss rates. Strenuous exercise increased both the diffusive water flux and net Na^+ loss rates. We observed only a weak relationship between diffusive water flux and net Na^+ loss rates under hypoxia, in contrast to a strong relationship with exercise. (NSERC Discovery).

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Behavioural and thermoregulatory responses to acute hypoxia and anoxia in the naked mole rat (*Heterocephalus glaber*) / Réponse comportementale et thermorégulatrice face à l'hypoxie et l'anoxie aigue chez le taupinet tondu (*Heterocephalus glaber*)

In response to environmental hypoxia, mammals typically exhibit behavioural responses that help to lower metabolic demand by reducing physical activity and body temperature (T_b; *i.e.* hypoxic hypothermia). Naked mole rats (NMRs) are among the most hypoxia-tolerant mammals but their behavioural and thermal responses to acute hypoxia are poorly characterized. We examined the effects of acute hypoxia (3-9% O_2) and anoxia on behaviour and T_b in groups if 1, 2, or 4 NMRs held within their thermoneutral zone (30˚C), or at temperatures above (38˚C) or below (20˚C). In all experiments, distance moved decreased by up to 50% in acute hypoxia. Time active decreased similarly in most treatment conditions, but not in groups of 4 NMRs at 38˚C. Groups of NMRs tended to huddle less in hypoxia but individual NMRs preferred warmer temperatures to cold, indicating a mixed employment of the hypoxic hypothermic strategy. T_b decreased by ~ 1-3˚C in acute hypoxia in all treatment groups. Taken together, our data suggest that NMRs exhibit atypical behavioural strategies in hypoxia and remain active and warm relative to other small mammals. Energy savings from behavioural changes are not sufficient to explain the > 85% reduction in metabolic rate exhibited by NMRs in acute hypoxia.

Hoar award finalist / Finaliste du prix Hoar

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A sublethal dose of a neonicotinoid insecticide disrupts visual processing and avoidance behaviour in *Locusta migratoria* / Une dose subléthale d'insecticide néonicotinoïde perturbe le traitement visuel de l'information et le comportement d'évitement chez *Locusta migratoria*

Neonicotinoids are known to affect foraging behaviour and navigation in insects, although the mechanisms of these effects are not fully understood. A visual motion sensitive neuron in the locust, the Descending Contralateral Movement Detector (DCMD), integrates visual information and is involved in eliciting escape behaviours. The DCMD receives coded input from the compound eyes and synapses with motorneurons involved in flight and jumping. We show that imidacloprid (IMD), a neonicotinoid insecticide, impairs neural and behavioural responses to visual stimuli at sublethal concentrations, and these effects are sustained two and twenty-four hours after treatment. Exposure to 10 ng/g IMD attenuates escape manoeuvers while 100 ng/g IMD prevents the ability to fly and walk. Behavioural and neural effects are correlated: IMD disrupted DCMD bursting, a coding property important for motion detection. Specifically, IMD reduced the DCMD peak firing rate within bursts at ecologically relevant doses of 10 ng/g (ng IMD per g locust body weight). Thus, IMD causes significant and lasting impairment of an important pathway involved with visual sensory coding and escape behaviours at ecologically-relevant doses. These results show, for the first time, that a neonicotinoid pesticide directly impairs an important, taxonomically conserved, motion-sensitive visual network.

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Mitochondrial thermal sensitivity and resilience to environmental warming in fish: integrating field and laboratory approaches / Sensibilité thermique mitochondriale et résilience au réchauffement environnemental chez le poisson: combinaison des approches en laboratoire et sur le terrain

Mitochondrial thermal sensitivity is an important determinant in the capacity of fish to survive in a warming environment. Typically, warm-acclimation in the laboratory reduces mitochondrial thermal sensitivity, likely to limit reactive oxygen species production and oxidative stress. However, our understanding regarding how warming affects mitochondrial thermal sensitivity in nature is scant. This is mainly due to the lack of relevant natural models exposed to chronic warming along with natural temperature fluctuations over several decades. Here, we evaluated mitochondrial plasticity and oxidative stress in European perch (*Perca fluviatilis)* from the Baltic Sea (Reference, 16°C), and from the Biotest enclosure (23-25°C) which has been chronically heated for over three decades by cooling water effluents from two nuclear reactors. Fish from the Biotest enclosure maintained mitochondrial respiration *in situ*, as well as after long-term laboratory acclimation to both 16 and 23-25°C. In comparison, Reference fish displayed decreased mitochondrial respiration rates both *in situ* and after long-term acclimation to 23-25ºC. Moreover, Biotest fish had increased damages to proteins (carbonyls) *in situ*, despite an increase in anti-oxidant enzyme activities (catalase and superoxide dismutase). This suggests that a metabolic trade-off may exist between mitochondrial thermal sensitivity and oxidative stress in fish exposed to a warming environment.

Hoar award finalist / Finaliste du prix Hoar

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Ammonia independent Na^+ uptake mediated by Na^+ channels and NHEs in the freshwater ribbon leech *Nephelopsis obscura* / Absorption de Na+ indépendante de l'ammoniac et médiée par les canaux Na+ et les NHEs chez la sangsue d'eau douce Nephelopsis obscura

Ion regulation is key to survival and basic physiological processes in freshwater organisms. Yet, the mechanisms employed in Na^+ uptake and ammonia excretion by freshwater invertebrates remains poorly understood. In the present study, we investigated the mechanisms of Na^+ uptake and their links to ammonia excretion across the skin of the freshwater leech *Nephelopsis obscura*. Through immunofluorescence we identified the presence of at least two epithelial cell types in the skin, termed VHA+ and VHA- cells based on the presence of the H^+-ATPase. Inhibition of the VHA suggests this protein is involved in both Na^+ and ammonia transport. Pharmacological inhibition together with ^{22}Na and ammonia flux measurements demonstrated at least two ammonia independent mechanisms for Na^+ uptake, Na^+ channel and Na^+/H^+ exchanger mediated mechanisms. Although NHE function in freshwater is questioned on the basis of thermodynamic constraints gene expression and inhibitor experiments in dilute freshwater (50μM Na^+) highlight the importance of this transporter for Na^+ uptake. The results of this study suggest that ammonia excretion and apical sodium uptake are uncoupled processes and that at least two cell types are present which maybe involved in ion regulation. We also hypothesize that NHEs may overcome thermodynamic constraints through electrogenic transport.

Hoar award finalist / Finaliste du prix Hoar

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The hypoxic metabolic response: how time and P_{O_2} shape the way fishes combine aerobic, anaerobic and depressed metabolism in hypoxic environments / La réponse métabolique hypoxique: comment

le temps et PO$_2$ déterminent la manière dont les poissons combinent l'aérobie, l'anaérobie et la depression du métabolisme dans des environnements hypoxiques

Prolonged hypoxic survival demands the maintained balance of ATP supply and demand. Animals can accomplish this using three overarching metabolic strategies: sustained aerobic metabolism, up-regulated anaerobic metabolism, and metabolic rate depression (MRD). Much work has explored these strategies in isolation, but comparatively little has explored how animals combine these strategies as a total 'hypoxic metabolic response' (HMR). Thus, we investigated the HMR of fishes and how time and P_wO_2, the two main dimensions of hypoxic exposure, influence it. We addressed this using goldfish and threespine stickleback as model organisms, and calorespirometry as a method to simultaneously measure aerobic metabolism (via O_2 uptake rate), anaerobic metabolism (via goldfish ethanol excretion) and MRD (via metabolic heat). The results reveal the HMR to be a dynamic response that is influenced by biotic and abiotic factors. Time influences the expression of HMR-related plastic phenotypes such as gill morphology and haemoglobin-O_2 binding affinity, and this influences how P_wO_2 affects the HMR. Furthermore, MRD is used by goldfish only at near-anoxic P_wO_2, and only by sticklebacks that are native to winterfreeze lakes that experience deep, long-term hypoxia. This suggests that MRD is a strategy reserved for, and perhaps only selected for in, extreme hypoxic environments.

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Fluorescent implantable elastomer tags for the measurement of oxygen within insects / Étiquettes élastomères fluorescentes pour la détermination de la consommation d'oxygène chez les insectes

Monitoring oxygen partial pressure (PO_2) within an organism provides essential information for understanding oxygen uptake and numerous other aspects of respiratory physiology. However, *in vivo* measurements using current implantable O_2 probes are limited by the small size of many organisms; This study sought to develop fluorescent implantable elastomer tags (FIETs) as an alternative method for accurate measurement of PO_2 within small semi-transparent organisms. The FIETs were designed with an O_2-permeable matrix and a fluorescent, ratiometric dye system: the fluorescence of an indicator dye (emission 650 nm) is quenched in the presence of O_2, whereas the fluorescence of a reference dye (emission 530 nm) does not change. A custom microfluidic chip produced highly uniform batches of spherical FIETs, with FIET diameters as small as 67 μm. The FIETs response to O_2 was quantified by measuring both dyes' fluorescence intensities across a range of O_2 tensions (0-20.26 kPa) using an inverted fluorescence microscope. A Stern-Volmer plot shows a linear relationship between the fluorescence ratios and PO_2 (R^2=0.963), although over time photobleaching causes an apparent drift in the PO_2 signal. Next, we will demonstrate the FIETs' use in a biological context and observe whether auto-fluorescence interferes with their accuracy.

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Developmental and adult plasticity of thermogenic capacity in high altitude deer mice / Plasticité de la capacité thermogénique du développement et chez l'adulte de la souris sylvestre en haute altitude

High-altitude deer mice have enhanced thermogenic capacities compared to lowland conspecifics that aid in surviving the low oxygen and temperatures characteristic of this environment. This phenotype has a genetic component; however, the role of developmental and adult environment is unclear. To understand the influence of developmental and adult plasticity on thermogenic capacity we bred mice within captive low- (LA) and high-altitude (HA) populations. Pups were exposed to cold (14°C) during the prenatal period or postnatal until 30 days of age. We also tested the effect of early life cold exposure on the adult acclimation response to chronic cold. We tested the hypothesis that early exposure to cold would alter developmental trajectories of thermo-effector organs, permanently enhancing adult

thermogenic capacity of HA mice. We predicted that the early life cold would enhance the acclimation response in HA adults. We found that postnatal cold-exposed LA pups increased brown adipose tissue (BAT) growth and accelerated the onset of independent thermoregulation by 4 days. Surprisingly, only LA mice exposed to cold postnatal had enhanced thermogenic capacity as adults without limiting adult phenotypic plasticity. These data suggest that thermogenesis in the wild is likely driven by the complex interaction of genetic and environmental factors.

Beren W. Robinson
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Eco-mechanics and plasticity of lamellar self-amputation in larval damselflies / La plasticité biomécanique de l'auto-amputation des lamelles caudales chez la larve de demoiselle (Zygoptera)
By focusing on the causal relationship between trait form and function, the performance paradigm is an important approach to evaluating adaptive hypotheses. Autotomy, the self-amputation of a body part, is an unusual example of performance where function involves the failure of a biomechanical trait under certain conditions. A general theory of adaptive autotomy exists but has not been extended to functional variation in autotomy performance. We hypothesize that the autotomy threshold regulates a fitness trade-off between survival benefits and post-amputation costs that accounts for variation in performance. We test this with larval damselflies, which autotomize caudal lamellae off their abdomen when grasped by predatory dragonfly larvae. We test a biomechanical hypothesis that joint diameter and cuticle thickness regulate the force required to break a lamellar joint; two selection hypotheses: that variation in performance generates selection on joint traits by influencing mortality, and that selection varies among populations because of variation in the abundance of dragonfly larvae; and an evolutionary hypothesis that heterogeneity in predator risk among ponds favours plasticity in autotomy performance. This is the first demonstration of functional plasticity in autotomy and in underlying biomechanical traits, and highlights the general utility of the performance paradigm.

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Climate change and amphibian immune defenses against chytridiomycosis / Le changement climatique et les défenses immunitaires des amphibiens contre la chytridiomycose
Amphibians have been declining around the world for more than four decades. One recognized driver of these declines is the chytrid fungus, *Batrachochytrium dendrobatidis* (*Bd*), which causes the disease termed chytridiomycosis. Amphibians have complex and varied immune defenses against *Bd*, but the fungus has a number of equally important counter-defenses. Climate change is an unknown factor that may alter host interactions with *Batrachochytrium* fungi in unpredictable ways. The fungi are cold tolerant and may be able to exploit temperature-dependent host vulnerabilities. This presentation will briefly review what is known about interactions between the host immune system, temperature, and the fungus. Climate change may benefit some species able to tolerate environments with elevated temperature while other species restricted to cooler temperature regimes may be harmed.

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The role of morphology, performance, and behavior in the ecological diversification of bats / Le rôle de la morphologie, de la performance, et du comportement sur la diversification écologique des chauves-souris

Diet evolution is considered a major driver of morphological differences and species diversification in mammals, but quantitative tests of ecomorphological diversification are scarce. Bats are an ideal system to investigate whether and how morphological, performance and behavioral traits evolved in tandem with dietary ecology and resulted in lineage diversification; they represent 20% of all mammals and encompass nearly the full spectrum of mammal diets. To identify the role of ecomorphology in bat diversification, we focus on the most ecologically diverse bat family (Phyllostomidae) to (1) document the macroevolution of traits associated with feeding, (2) test how trait differences translate into feeding performance and resource use, and (3) quantitatively link these patterns and mechanisms to observed differences in lineage diversification. We demonstrate that bite force evolution is strongly associated with changes in body and head size, but cranial morphology explains a large proportion of the interspecific variation in bite force upon accounting for size. Within a phylogenetic context, changes in cranial morphology and behavioral plasticity are associated with dietary transitions, and seem to have led to the adaptive radiation of frugivorous phyllostomids via ecological opportunity. These results illuminate the potential drivers and mechanisms of morphological, functional and lineage diversification in mammals.

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Metabolism and excretion of nicotine in the Cabbage Looper, *Trichoplusia ni* / Métabolisme et excrétion de nicotine chez la fausse-arpenteuse du chou, *Trichoplusia ni*
Many insects survive on plants that produce herbivory defense compounds such as alkaloids. Two major hypotheses for their survival have been proposed. Rapid excretion of the compound by insects' Malpighian tubules (MT), and metabolism in the midgut by cytochrome P450 (CYP) mediated oxidative detoxification. This study examined the metabolism of dietary nicotine in the cabbage looper (*Trichoplusia ni*). Concentrations of nicotine, and its common metabolites, cotinine, cotinine N-oxide, and nicotine N-oxide were measured in various locations *T. ni* after dietary exposure. The concentration of nicotine and its' metabolites were measured using liquid chromatography mass spectrometry (LCMS). LCMS provided accurate and proportional representation of nicotine and its metabolites in our insect derived samples. We propose that these results provide further insight into CYP mediated oxidative detoxification. In addition, we have assessed the effects of nicotine and its major metabolites on the fluid secretion rate and flux of metabolites by the Malpighian tubules of the cabbage looper. These results provide novel insights into metabolism of plant alkaloids by insects. A greater understanding of how insects metabolize insecticidal compounds, such as nicotine, could lead to the development of more targeted and environmentally friendly control measures for insect agricultural pests and disease vectors.

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An examination of the timeline and changes in exudate composition during refilling of slime glands in hagfishes (*Eptatretus stoutii* and *Myxine glutinosa*) / Un examen du chronologie et des changements dans la composition des exsudats pendant remplissage des glandes slime dans les myxines (*Eptatretus stoutii* et *Myxine glutinosa*)
Hagfishes rely on their unique defensive slime to ward off attacks by gill breathing predators. Slime exudate, comprised mainly of gland thread cells (GTCs) and gland mucus cells (GMCs), is released from slime glands and mixes with seawater to form slime within milliseconds. Much is known about the slime cells; however, how long gland refilling takes, or how the exudate composition changes during refilling, is unknown. In a laboratory setting, individual slime glands can be electro-stimulated to express exudate. Hagfishes had a portion of their glands exhausted and exudate collected from them during refilling. A refilling curve was created from data comparing exudate from refilling and full glands. Exudate from successive stimulations of glands was also collected for composition analysis. Slime gland refilling took

up to four weeks in both species. Full glands were exhausted after six stimulations, and consistently released similar sized GTCs. GTC size increased with refilling, and mucus vesicles 'recharged' faster than GTCs. There are likely implications for the clogging ability of slime with changes in proportions of slime cells. Exhausted glands were found to retain slime cells, which likely allows for refilling to be kick-started and prevents hagfish from being completely without defense for too long.

David C. H. Metzger and Patricia M. Schulte
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Changes in developmental temperature and adult acclimation temperature cause changes in DNA methylation patterns in threespine stickleback / Changements de températures du développement et températures d'acclimation chez l'adulte causent des changements dans les patrons de méthylation d'ADN chez l'épinoche à trois épines

Epigenetic modifications such as changes in DNA methylation have been suggested to play a role in the adaptation of organisms to environmental change such as changes in temperature, yet very little is known about the effects of temperature on DNA methylation in vertebrates. Here we use reduced representation bisulfite sequencing (RRBS) to examine the effects of temperature during development and in response to thermal acclimation on DNA methylation patterns in threespine stickleback (*Gasterosteus aculeatus*) across the entire genome. Both developmental temperature and thermal acclimation significantly increased global levels of DNA methylation. We identified 2,130 differentially methylated cytosines (DMCs) across all treatments, and these DMCs were not concentrated on any particular chromosome or genomic feature (promoters, introns, exons or intergenic regions). Although the majority of differentially methylated regions were specific to a given thermal treatment, more than 25% of the differentially methylated regions were common between developmental and adult acclimation thermal exposures. Taken together, these data suggest that both developmental temperature and thermal acclimation have widely distributed effects on DNA methylation across the genome, and demonstrate that changes in DNA methylation may play a role in the response to environmental temperature in vertebrate ecotherms across multiple time scales.

R. G. Boutilier New Investigator Award / Prix R. G. Boutilier pour jeune chercheur

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Living the high life: integrative functional mechanisms of high-altitude adaptation / Regarder de haut: mécanismes fonctionnels intégrés des adaptations en haute altitude

High-altitude environments provide fertile ground for investigating the mechanisms and evolution of physiological systems underlying animal performance. The cold and oxygen-depleted ('hypoxic') environment at high altitudes requires that endothermic animals sustain high rates of O_2 consumption for thermogenesis and locomotion while facing a diminished O_2 supply. My research examines the ways in which high-altitude natives overcome these challenges, in an effort to understand how complex physiological systems evolve. I will present our work on the respiratory, cardiovascular, and mitochondrial mechanisms of high-altitude adaptation in deer mice (*Peromyscus maniculatus*). High-altitude populations have an enhanced respiratory capacity (VO_2max) in hypoxia compared to their low-altitude counterparts, due to evolved differences and environmentally-induced plasticity. This adaptive increase in VO_2max arises from functional enhancements across the O_2 transport pathway, including lung O_2 uptake, O_2 circulation in the blood, and tissue O_2 extraction. The basis for these evolved differences in systems-level function involve coordinated changes at tissue, cellular, and transcriptomic levels of organization. Responses to chronic hypoxia (e.g., hypoxic chemoreflex, erythropoiesis, etc.) also appear to be altered in high-altitude populations to blunt maladaptive plasticity while safeguarding tissue O_2 supply. Therefore, high-altitude adaptation involves a series of integrated changes across the O_2 pathway.
Supported by NSERC.

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Impact of maternal nematode infection of the fetus / Impact de l'infection par les nématodes maternels sur le fœtus
Gastrointestinal nematode parasites influence many aspects of the biology of the infected host. This paper provides evidence that intestinal nematodes in the pregnant host also negatively affect growth and brain development of the fetus, even though the fetus is not directly infected. Controlled experimental infection of pregnant dams with *Heligmosomoides bakeri* resulted in reduced fetal crown-rump length and increased placental mass, but fetal brain mass was not altered. This led us to hypothesize that regulation at the level of the placenta (including the observed differential placental gene expression) spared the fetal brain from negative impacts of maternal infection. However, almost 100 fetal brain genes were differentially expressed in response to maternal *H. bakeri* infection. Expression of 88 genes was up-regulated, including genes involved neurodevelopment, neural differentiation, synaptic plasticity, neuro-inflammation, and glucose metabolism. Expression of 8 genes was down-regulated. Together, these results indicate that the increased mass of the placenta and altered placental gene expression were not sufficient to protect the fetal brain from the stress of maternal *H. bakeri* infection.

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Stingrays receive an A- on the grade scale for their performance in burying behaviours / Les raies reçoivent un A- pour leur comportement d'enfouissement
Stingrays show a remarkable ability to rapidly bury and cover themselves with sediment for concealment. We studied burying mechanisms and performance to better understand their functional morphology, and to provide insight into potential designs for underwater robotics inspired by biomimicry. High-speed video was used to analyze fin kinematics and burying performance during burying behaviours of the ocellate river stingray. Stingrays are dorsoventrally flattened fishes with large and flexible pectoral fins that act as control surfaces in locomotion, prey capture and camouflage (i.e. burying into the substrate). Rather than digging their fins into the substrate and lifting sediment onto their dorsal surface, it appears that stingrays use their body and fins to generate suction forces that lift the sand off the substrate. The head pumps up/down as the pectoral fins fold up/over towards the dorsal midline, shedding vortices of water and sediment up and over their fins and onto their dorsal surface. From 4 animals (20 trials total), mean body-surface-area covered was 82% (SEM +/- 3.04), an A- on the grade scale. Of note, flow patterns of sediment promote less surface-area covered at the head and tail, which may be a mechanism to maintain vision and tail mobility when buried.

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Metabolic suppression in the pelagic red crab, *Pleuroncodes plannipes*, in oxygen minimum zones / Suppression métabolique du crabe rouge pélagique, *Pleuroncodes plannipes*, dans les zones minimales d'oxygène
The pelagic red crab, *Pleuroncodes planipes*, is abundant throughout the Eastern Tropical Pacific. Juveniles of the species are among the most prevalent components in the diets of major oceanic predators, including tunas, whales and squids. Crabs migrate daily from the surface to mesopelagic depths where oxygen is a fraction of air saturation. These crabs regulate aerobic metabolism to a critical PO_2 of ~0.8

kPa but encounter much lower PO_2 at depth. In hypoxia, oxygen consumption suppressed and we show a modest increase in lactate levels indicating elevated anaerobic metabolic ATP production. Metabolic suppression is achieved via posttranslational modifications on histone H3, which are associated with a condensed chromatin state (and hence decreased transcription). Under hypoxia, p-H3 S10, Ac-H3 K9, Ac-H3 K14 were 39, 68, and 36% of control values, respectively. Several translation factors also decreased under hypoxia. Transcription and translation are major sinks for metabolic energy. Global suppression of these processes is a common strategy for temporary survival of extreme environmental conditions. Elevated heat-shock proteins suggest that the cellular stress response is triggered during hypoxia in *P. plannipes*. These results are important for the ecology of zooplankton and their predators, as well as the biogeochemical cycles to which they contribute.

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Endogenous controls are the primary drivers of spring migration timing in a long-distance migratory songbird, the Purple Martin (*Progne subis*) / Les contrôles endogènes sont les principaux moteurs du chronométrage de migration de printemps dans un oiseau chanteur migratoire de longue distance, le Martin Violet (*Progne subis*)

Climate change is altering spring phenology and long-distance migratory songbirds must adjust their migration timing to these changes, or face negative fitness consequences. We used light-level geolocators to track the spring migration of 165 purple martins that traveled between South American nonbreeding and North American breeding sites. We hypothesized that migration departure timing may be flexible to advancing springs at breeding sites, but environmental conditions en route mask this flexibility. If conditions along migration drive breeding arrival dates, then spring green-up or wind speed will predict arrival date and individual repeatabilities will be low. We found that migration timing was primarily predicted by departure date from South America, in both the date birds passed the Tropic of Cancer (23.4º latitude) and their arrival date at breeding sites. Using data for 30 individuals tracked during spring migration in multiple years, we found high repeatability in migration timing in departure date from the nonbreeding grounds, crossing 23.4º latitude and arrival at the breeding grounds. These results show strong endogenous control of spring migration timing in purple martins, suggesting that microevolution, rather than phenotypic plasticity, may be required for an adaptive response to new conditions with climate change.

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Physiological basis of life-stage and species-specific differences in the acute sensitivity of rainbow trout and white sturgeon to waterborne cadmium /

Fish often exhibit wide variations in species-specific as well as life-stage specific differences in sensitivity to metals, however the physiological mechanisms underlying these differences are not very well understood. We demonstrated that rainbow trout and white sturgeon are two such fish species with substantial life-stage (larval, swim up and juvenile) and species-specific differences in acute waterborne Cd sensitivity, with trout being generally more sensitive than sturgeon. Although the acute toxicity (96h LC_{50}) of Cd was similar in both species at the larval stage, trout demonstrated an increased sensitivity to Cd in later life-stages, whereas an opposite trend was observed in sturgeon. We also found that despite of their lower sensitivity to Cd, sturgeon tend to accumulate greater amount of Cd than trout at each life stages. Moreover, the evaluation of the effect of Cd exposure on calcium (Ca) uptake as well as wholebody Ca level across life-stages and species demonstrated that Cd disrupts Ca homeostasis in trout by a greater degree relative to that in sturgeon. More importantly, our study also revealed that the apparent difference

in both species-specific and life-stage specific Cd sensitivity could be explained by the relative difference in the magnitude of Cd-induced disruption of Ca homeostasis.

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Which way is which: Directional introgression in American mink (*Neovison vison*) haplotypes in Ontario and Nova Scotia / Sans dessus dessous: introgression directionnelle dans les haplotypes du vison américain (Neovison vison) en Ontario et en Nouvelle-Écosse

The American mink (*Neovison vison*) is an invasive species in many parts of the world because of deliberate releases and accidental escapes from mink farms. In North America, domestic mink that have escaped can interact with wild conspecifics. Domestic and wild mink are phenotypically and genotypically distinct populations for which there is evidence of hybridization and introgression. The wild mink population has declined in recent years and hybridization with the domestic mink may be one of the causes. We used a 300 base pair sequence from the mitochondrial control region to test our two main predictions: (1) that the domestic population will have low genetic diversity and will have haplotypes specific to the source population, and (2) domestic and wild mink will have directional gene flow with domestic females breeding with wild males. We examined variation in mtDNA to determine regional differences and the direction of hybridization occurring in the wild and domestic populations. We sequenced in 319 individuals of wild, domestic, and hybrid origin from both Ontario and Nova Scotia. Many haplotypes were specific to the region of origin but several haplotypes overlap into multiple populations making sex-bias hybridization hard to determine. Though directional introgression was able to be determined.

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Enhanced tissue oxygen extraction in migratory salmonids / Extraction améliorée de l'oxygénation du tissu chez les salmonidés migratoires

Recent findings indicate that teleost fishes may be able to greatly enhance tissue oxygen (O_2) extraction under stressful conditions that result in catecholamine release. The putative system relies on pH-sensitive haemoglobins (Hbs), intracellular red blood cell pH regulation via Na^+/H^+ exchanger activity, and plasma-accessible carbonic anhydrase at the tissues that short-circuits pH regulation. Previous studies show that in rainbow trout, Hb-O_2 unloading may double compared to resting conditions. These studies support the presence of the system in these fish; however, only saturating catecholamine concentrations were used, and may not be *in vivo* relevant. Here, we show that: 1) enhanced Hb-O_2 unloading is possible at more physiologically relevant catecholamine concentrations, and even at low, resting levels; 2) other salmonid species, in particular migratory Atlantic and coho salmon, show β-adrenergic Na^+/H^+ exchanger activity – a key component of this system – indicating that these salmonids may benefit from enhanced O_2 unloading as well; and 3) Atlantic and coho salmon may be able to increase Hb-O_2 unloading by up to 74% and 159% respectively. In view of the life history of these salmonids, a system to enhance Hb-O_2 unloading during exercise may be a determinant of a successful spawning migration and thus reproductive success.

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Evolution of high affinity hemoglobins in the family Paridae on the Qinghai-Tibetan Plateau / Évolution d'hémoglobines à haute affinités dans la famille des Paridés sur le plateau Qinghai-Tibétain

Life at high altitude challenges air breathing vertebrates to maximize O_2 uptake in the face of hypoxia while simultaneously ensuring sufficient O_2 delivery to tissue capillaries. Highland areas, namely the Andean Altiplano and the Qinghai-Tibetan Plateau, provide an opportunity to compare and contrast the modes of high-altitude adaptation by native species. Birds native to the Andes have generally evolved derived increases in hemoglobin (Hb) O_2 affinity with respect to their lowland counterparts in order to increase pulmonary O_2 loading under hypoxia. Here we test whether different high-altitude species in the family Paridae on the Qinghai-Tibetan Plateau have independently evolved increased Hb-O_2 affinities in comparison to their closest lowland relatives. We tested the Hb-O_2 affinity from the blood of six parid species (three high-/lowland pairs) and the recombinant Hbs from two additional species. These analyses show a significant positive relationship between altitude and Hb-O_2 affinity. However, despite the phenotypic parallels between these species and previously examined high-altitude taxa, there appears to be multiple biochemical mechanisms that underlie these phenotypes. To elucidate the mechanism that underlies the high Hb-O_2 phenotype in a subset of high altitude parids, we have combined ancestral protein reconstruction and site-directed mutagenesis with recombinant protein expression.

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Plasticity in axial polarity during postembryonic development / Plasticité de la polarité axiale durant le développement post-embryonique

Axis polarity is specified during early embryogenesis and remains largely unaltered during the lifetime of most organisms, yet novel axes can develop during agametic asexual reproduction. The acoel genus *Convolutriloba* is unique among bilaterians in the ability to transiently reverse the anterior-posterior (AP) axis during reversed polarity budding and to respecify left-right (LR) polarity during longitudinal fission. We have developed *C. macropyga* and *C. longifissura* as models for understanding the developmental modifications of body axis polarity during postembryonic development. A region of tissue at the transitional zone between parent and bud where AP axis reversal occurs at the initiation of bud outgrowth in *C. macropyga,* and a zone of apoptotic activity develops along the midline during longitudinal fission in *C. longifissura*. Chemical genetics screens along with targeted functional studies have identified candidate signaling proteins that may function in the disruption and respecification of body axes during asexual reproduction in these species. We are currently investigating the role of Hedgehog signals in the disruption and modification of the AP axis during reversed polarity budding and have identified putative roles of Notch and Slit/Robo signaling in modification of midline polarity that occurs during longitudinal fission.

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The role of gut yeasts in insect thermal biology / Le rôle des levures gastroentériques en thermobiologie des insectes

Understanding the role of the microbiota in determining animals' physiological phenotypes remains a grand challenge in organismal biology. Although yeasts are a key component of the insect gut microbiota, the role of yeasts has often been overlooked in favor of the readily-sequenced bacteria. Here we describe an experimental system of *Drosophila melanogaster* and an associated gut yeast, *Lachancea kluyveri*. We show that colonization of the gut by yeast reduces chill-coma recovery time (an important proxy for thermal tolerance in insects), and that the yeast has to be alive to elicit this phenotype. There is some evidence that yeast colonization determines inter-individual variation in chill coma recovery time.

Together, these results imply that variation in insect cold tolerance (and likely other aspects of physiology) may be driven, at least in part, by the gut microbiota.

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Urban habitat predictors of body condition in red and grey squirrels / Les prédicteurs de l'habitat urbain sur la condition corporel chez les écureuils rouges et gris

Urbanization is creating the planet's newest major habitat type. This is having negative consequences for those species that lose habitat and is creating a strong driver for evolutionary change for those species that persist in cities. North American tree squirrels are one of the few examples of native species that thrive in cities. Thus, they are good species with which to explore the ways that animals cope with urbanisation. We investigated the effects of urbanization on body condition of urban tree squirrels across Winnipeg. We used human population density and site-specific tree characteristics as measures of urbanization. We hypothesized that, as the more successful urban species, grey squirrel body condition would be greater in more urbanised areas than that of red squirrels. Grey squirrel body condition was positively associated with human population density and large hardwood trees. Conversely, the greatest red squirrel body condition measures occurred in areas with the lowest human population density, the greatest abundance of conifers, and trees in the poorest condition. These results suggest that grey squirrels are better exploiters of urban environments than red squirrels.

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Osmolyte adjustments in elasmobranchs as a requirement for deep-sea living: An intraspecific test in Arctic skates (*Amblyraja hyperborea*) occurring along a depth gradient / L'ajustement de les osmolytes chez les elasmobranchs pour la vie en la mer-profonde: Une expérience intraspécifique utilisant les raies boréale (*Amblyraja hyperborea*) le long d'une pente de profondeur

Accumulation of organic osmolytes (e.g. TMAO) by deep-sea animals is proposed to be an adaptation to protect proteins against the destabilizing effects of high hydrostatic pressure (the "piezolyte hypothesis"). Elasmobranchs provide an interesting test of this hypothesis because they already have elevated TMAO levels, to counteract the destabilizing effects of the high urea levels accumulated for osmoregulation. Limited interspecific studies on shallow- and deep-sea elasmobranchs suggest that deep-sea adaptation is associated with decreased urea and increased TMAO levels, suggesting a dynamic balance between destabilizing forces on proteins (high urea concentration, hydrostatic pressure) and osmolytes (e.g. TMAO) that can counteract these forces. Indeed, a potential inability to minimize urea levels or maximize TMAO levels may explain why elasmobranchs are absent in the abyss. An unresolved question is whether the depth-related changes in elasmobranch osmolytes are a flexible response to depth or if phylogenetic differences in species-specific physiological 'set-points' for osmolytes confound interpretation. We sampled Arctic skates (*Amblyraja hyperborea*) across a 1000 m depth gradient in the Beaufort Sea, finding that muscle urea:TMAO ratio decreased with depth. These data provide the first intraspecific evidence that osmolyte system adjustments are a key response for deep-sea living in elasmobranchs, supporting the peizolyte hypothesis.

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Developmental response to hypercapnia in golden-Syrian hamsters / Réponse du développement face à l'hypercapnie chez le hamster syrien doré

It has been suggested that rodents display a "sensitive period" during respiratory development where ventilatory responses to hypercapnia and hypoxia increase. Semi-fossorial rodents such as the Golden-Syrian Hamster, a facultative hibernator, have a blunted ventilatory response to these conditions as adults, hypothesized to be due to conditions in the burrow. This study examined whether hamsters display the same sensitive period as other rodents during development. We used pneumatography to study ventilatory responses to hypercapnia in awake, neonatal Syrian hamsters (P0-P30). Preliminary data suggest that oxygen consumption (V_{O2}, mL/min/kg) increases during the developmental period examined (P0-P30) with no visible plateau. The introduction of hypercapnia (fractional composition of inspired CO_2 (FI_{CO2}) of 1%, 5%, and 7%) produced increases in both breathing frequency (f_R) and tidal volume (V_T) with age in comparison to levels seen in normoxia (FI_{O2} 20.95%, FI_{CO2} 0%) and mild hypercapnia (FI_{CO2} 1%). Interestingly, the ratio of total ventilation to oxygen consumption (V_E/V_{O2}) (the air convection requirement) decreased with age when animals were breathing 5 and 7% CO_2; i.e. V_E increased disproportionately less relative to V_{O2} during severe hypercapnia. These data suggest that hamsters have a robust ventilatory response to CO_2 at birth that decreases progressively throughout development, even when animals are maintained in normoxia and not under burrow conditions.

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Effects of Alberta oil sands process-affected water exposures on mammalian immune parameters / L'effet de l'exposition de l'eau des sables bitumineux de l'Alberta sur les paramètres immunitaires des mammifères

The oil sands in northern Alberta contain approximately 2.5 trillion barrels of crude oil (i.e. bitumen). Bitumen is commonly extracted using a caustic hot water extraction method. This process generates high volumes of residual tailings water known as oil sands process-affected water (OSPW), which is a complex mixture of clay, sand, fine silt, dissolved ions, heavy metals, organic compounds, and unrecovered oil. It is estimated that by 2025 the oil sands industry in Alberta will have produced more than one billion m^3 of OSPW-containing tailings ponds. OSPW exposure affects the health of a variety of organism including bacteria, aquatic invertebrates, fish, birds and mammals. Since OSPW exposures are known to cause acute and sub-chronic toxicity in a variety of animals, the storage of such large quantities of OSPW presents a formidable challenge for industry and a significant concern for the environment. Substantial research efforts have concentrated on identifying the principal toxic agents in OSPW and the development of strategies for the removal and/or neutralization of these substances. This seminar describes our ongoing research efforts focused on examining the immunotoxic properties of OSPW using a combination of *in vivo* and *in vitro* studies in mammals.

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Athletes vs Parents: life history tradeoffs in an amphibious mangrove fish / Les athlètes contre les parents: compromis exigés par diverses stratégies de survie chez les poissions amphibies de mangrove

Environmental heterogeneity can result in phenotypic divergence in behaviour, physiology, and life-history strategies. We investigated the consequences of habitat variation on the athletic performance and reproductive investment of the amphibious fish *Kryptolebias marmoratus* to test the hypothesis that life-history tradeoffs are mediated by environmental quality, such that fish in a relatively well oxygenated freshwater pond would preferentially invest energy in reproduction while those from hypoxic crab burrows would have higher athletic capacity to improve competitive ability. To test these hypotheses we collected wild fish from a freshwater population and a salt water population on Long Caye, Belize. We measured body condition and tested biomechanical performance in water (predator escape response), leaving water (hypercapnia emersion response), and on land (tail-flip jumping). Contrary to our predictions, freshwater fish were both in better condition and showed better endurance compared to their salt water counterparts. Our findings suggest that there is no obvious trade-off between athletic performance and reproductive investment in wild mangrove rivulus; higher quality habitats produced higher quality fish.

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The role of proline oxidation and metabolome dynamics during the flight of *Bombus impatiens* / Le rôle de l'oxydation de la proline et de la dynamique du métabolome pendant le vol de *Bombus impatiens*

Several insect species can use the amino acid proline as a major energy substrate, a unique characteristic of these animals. Although initially thought to be limited to blood feeding dipterans, studies revealed this capability may be more widespread. Recent work showed that the bumblebee *Bombus impatiens* can oxidize proline at a high rate, as measured using isolated flight muscle. However, its role as a metabolic fuel to power flight is unclear. To elucidate the extent to which proline is oxidized to power flight and how its contribution changes during flight, metabolites of central carbon and proline metabolism were profiled at key time points in hemolymph and flight muscle tissue. Analysis using UPLC-MS-QTOF has revealed trends in fuel use and changes in pathway metabolites. Of 30 targeted metabolites, 19 were detected. In flight muscle tissue, 6 of 19 metabolites significantly decreased in concentration within the first 15 minutes, increasing in the second portion of a 30-minute flight. Concentrations at the end of prolonged flight are similar to those at rest, indicating homeostatic regulation of intermediates and replenishment of fuels. This targeted metabolomics approach will clarify the role of proline and carbohydrate metabolism and pathway regulation during flight in *B. impatiens*.

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Does epinephrine protect trout spongy and compact ventricular myocardium from depressive effects of hypoxia? / Es-ce que l'épinéphrine protège les myocardes ventriculaires spongieux et compacts des effets dépressifs de l'hypoxie?

Hypoxia results in elevated circulating epinephrine in many fishes, which may help maintain cardiac function. Our aims were to assess how hypoxia impacts contractile capacity of the compact and spongy ventricular myocardium in rainbow trout (*Oncorhynchus mykiss*), and if epinephrine protects myocardial performance from a depressive effect of hypoxia. Effects of normoxic and hypoxic PO_2, as the compact and spongy layers would experience in fish breathing environmentally normoxic (PO_2 = 20.2 kPa) and hypoxic (12 kPa) water, and of high (500 nM) and low (5 nM) epinephrine, on work output and maximum

contraction rate of isolated spongy and compact ventricular myocardium were measured. We hypothesized hypoxia would depress performance of both tissue layers, perhaps more so in compact myocardium which experiences a greater drop in PO_2 with environmental hypoxia, but that epinephrine would mitigate the effect. Hypoxia resulted in a similar relative decline in net work output of both tissue layers, and a decline in maximum contraction rate but only of compact myocardium. Epinephrine restored maximum contraction rate in hypoxia, but appeared to restore work output of only spongy myocardium, not compact. In conclusion, increased epinephrine during hypoxia may help maintain inotropy in spongy myocardium and chronotropy in compact myocardium.

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Is intraspecific phenotypic variation influenced by local adaptation? / La variation phénotypique intratraspécifique est-elle influencée par l'adaptation locale?
Species adaptation to environmental changes happens on population level, thereby contributing to genotypic and phenotypic variation within a species. The population dimension is often missing in evolutionary experiments with *Daphnia* species, only a few clonal lineages act as representatives for a whole species. Hence, the importance of intraspecific variation for the adaptive potential of a species is scarcely investigated. I use a combined approach of ecological and genomic techniques to contribute to the understanding of the genetic background of rapid adaptation to environmental changes. In a common garden experiment with four European *D. galeata* populations, each represented by six genotypes, life history traits have been recorded in the absence and presence of a vertebrate predator (proxy: fish kairomones). By applying analytical association tools on the existing transcriptome dataset for studied genotypes and the established dataset for phenotype in a certain environment, I hope to identify the molecular basis of phenotypic variance and its distribution *on D. galeata*. Fitness traits and single nucleotide polymorphisms (SNPs) will be checked for correlation to provide an answer to following question: Is there an association between differentiation at the genotypic and phenotypic level?

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Does social stress inhibit cellular proliferation in the forebrain of male zebrafish? / Le stress social inhibe t'il la prolifération cellulaire dans le cerveau antérieur du poisson-zèbre mâle?
Many animals, including zebrafish (*Danio rerio*), form social hierarchies as a result of competition for limited resources. These social interactions increase the production of cortisol, the main glucocorticoid stress hormone in fish, via activation of the hypothalamic-pituitary-interrenal (HPI) axis. Socially subordinate fish experience chronic activation of the HPI axis, leading to prolonged elevation of plasma cortisol. In mammals and fish, elevated cortisol levels have been found to reduce cellular proliferation and neurogenesis in the brain. Thus, the present study tested the hypothesis that social stress suppresses cellular proliferation in the brain of zebrafish. Neuroproliferation was assessed in the forebrain of paired male zebrafish using the incorporation of BrdU, a thymidine analogue, as a marker. At both 2 and 4 days of social interaction, significantly lower numbers of BrdU-positive cells were present in the forebrain of subordinate fish compared to dominant or control fish, suggesting a suppression of cellular proliferation in fish experiencing chronic social stress. Interacting male zebrafish were then exposed to metyrapone, a cortisol synthesis inhibitor, to assess the role of cortisol in inhibiting cellular proliferation.

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Proximity and grooming patterns in Rwenzori Angolan colobus monkeys show strong female-female relationships / Les motifs de proximité et de toilettage chez les singes de colobus Angolais Rwenzori montrent de fortes relations femme-femme

Close proximity and social grooming are important bonding mechanisms in primates and many studies have found that these behaviours correlate positively with relatedness. We used one year of data collected via instantaneous scan sampling (N=7593 scans) on *Colobus angolensis ruwenzorii* at Lake Nabugabo, Uganda to examine partner preferences for grooming and nearest neighbours in each age-sex class. Little is known about Angolan colobus, so we based our hypotheses on congeners. Of the five species in the black-and-white colobus radiation, data on sex-biased dispersal patterns are available for three (*C. guereza*, *C. vellerosus*, and *C. polykomos*), all of which show male-biased dispersal with occasional female dispersal. We thus predicted that female *C. a. ruwenzorii* would be more strongly bonded than males. This prediction was supported in both proximity and grooming patterns. The proximity index within 3 m for female dyads was 0.53, while for male dyads it was 0.32. Adult females also groomed one another almost twice as much (0.14) as adult males groomed other adult males (0.09). These observations support a male-biased dispersal pattern in *C. a. ruwenzorii*. However, the highest grooming indices overall were between adult males and adult females (0.2), indicating important relationships between the sexes as well.

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Bioenergetics of two Mediterranean fish species are related to their swimming behavior / La bioénergétique de deux espèces de poissons méditerranéens diffère en fonction de leur comportement de nage

The sardine *Sardina pilchardus* and gilthead seabream *Sparus aurata* are two emblematic species in the Mediterranean Sea that have very different lifestyles and activity levels. Sardines are pelagic, they swim and school constantly and have high body fat contents. Gilthead seabream are bentho-pelagic, they show more discontinuous spontaneous swimming patterns and are leaner (Grigorakis et al., 2002; Steinhausen et al., 2010). Muscle bioenergetics of these species may provide insights into how metabolic pathways sustain these different lifestyles and activity patterns. We studied red and white muscle fiber bioenergetics, using high-resolution respirometers (Oxygraph-2k, Oroboros® Instruments, Innsbruck, Austria), to compare the ability to oxidize lipids versus carbohydrates. Based upon their activity patterns and muscle lipid stores, we expected that 1) sardine red muscle would have a higher oxidative capacity than gilthead seabream and 2) sardine muscle bioenergetics would show a greater reliance on lipids as a substrate. Our results support these hypotheses, with a 2-fold higher aerobic scope of sardine muscle compared to gilthead seabream, for both substrates. While the sardine muscle exhibited the same capacity to oxidize lipids and carbohydrates, gilthead seabream muscle fibers were predominantly geared toward carbohydrate metabolism. This study provides novel insights into physiological mechanisms underlying the lifestyles of these highly-prized species.

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Using molecular genetic techniques to understand a novel cellular migration in the *Caenorhabditis elegans* pharynx / L'utilisation de techniques en génétique moléculaire pour comprendre une nouvelle migration cellulaire dans le pharynx de *Caenorhabditis elegans*

The nematode *Caenorhabditis elegans* possesses an invariant cell lineage and transparent body that are invaluable tools for observing and understanding cellular dynamics during development. Our lab uses the worm foregut, or pharynx, to understand the basis of organ and cell morphogenesis. I am interested in how a single gland cell called g1P migrates through the worm pharynx during embryonic development. While the pharynx transitions from a general cyst to its ultimate tubular shape, the g1P cell uses a novel migration termed retrograde extension: part of the cell remains anchored at its origin, leaving behind a long projection as the cell body moves posteriorly. Currently, only a handful of factors from varying developmental pathways have contributed to understanding the molecular pathway controlling this movement. By mutating *C. elegans* with ethyl methanesulfonate (EMS), I have isolated 24 strains with premature termination of migration and incorrect location of the cell body. So far, *cwn-2,* a Wnt ligand, and *cam-1,* a ROR receptor belonging to a non-canonical Wnt pathway, have been identified from this screen. Genetic analysis, next generation sequencing, and confocal microscopy are being used to characterize strains and further investigate how these developmental defects occur.

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Functional assessment of cryoprotectants in the freeze-tolerant spring field cricket, *Gryllus veletis* / Évaluation fonctionnelle des cryoprotecteurs chez une espèce de criquet tolérant au gel, *Gryllus veletis*

At sub-zero temperatures, ectotherm body fluids may freeze, resulting in damage and death. Some insects are freeze tolerant, surviving internal ice formation. However, we have limited understanding of the mechanisms underlying insect freeze tolerance. Lab-acclimated, freeze-tolerant juveniles of the spring field cricket, *Gryllus veletis* accumulate three potentially cryoprotective molecules (trehalose, proline, and *myo*-inositol) in their hemolymph and fat body tissue, relative to freeze-sensitive *G. veletis*. To investigate the function of these cryoprotective molecules in freeze tolerance, we manipulated their concentrations *in vivo* and *ex vivo*. By injecting cryoprotectants into freeze-tolerant *G. veletis*, we demonstrated that elevated *in vivo* trehalose concentrations improved survival at the lower lethal temperature (-12 °C). When we froze fat body tissue excised from freeze-tolerant *G. veletis* in artificial hemolymph, cell survival was high at -8 °C, but decreased substantially at -16 °C. High exogenous *myo*-inositol concentrations improved fat body cell survival at -16 °C. No cryoprotectant – either in isolation or in combination – was sufficient to confer freeze tolerance on freeze-sensitive *G. veletis* or their fat body tissue. These results suggest differential function of cryoprotectants in freeze-tolerant *G. veletis*, which will lead to improved investigations of the mechanisms underlying insect freeze tolerance.

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Lean, mean, lipolytic machines: glycerol kinetics of rainbow trout during graded exercise / La locomotive lipolytique: cinétique du glycerol chez la truite arc-en-ciel pendant la nage à intensité croissante

The high energy density of lipids makes them the essential fuel for migrating salmonids. In mammals, the mobilization of lipid reserves is known to reach a maximum during moderate exercise, but the effects of swimming intensity on fish lipolysis have never been quantified. Continuous infusion of [2-^{3}H]glycerol was used to measure R_a glycerol (=rate of appearance of glycerol or lipolytic rate) in catheterized rainbow

trout kept under baseline (resting) conditions, or during graded swim tunnel exercise up to critical swimming speed (U_{crit}). Results show that mean R_a glycerol is 1.67±0.18 μmol $kg^{-1}min^{-1}$ in control animals, and remains at a steady level of 1.24±0.10 μmol $kg^{-1}min^{-1}$ in exercising fish at all swimming intensities. This baseline lipolytic rate provides enough fatty acids from adipose reserves to cover all the energy needed for swimming at up to 2 body lengths/s (BL/s), and more than 50% of the energy used at speeds approaching U_{crit} (3.4±0.1 BL/s). Maintaining steady lipolysis at rest and throughout graded exercise is strikingly different from the metabolic strategy of mammals that stimulate R_a glycerol by 2 to 5-fold to cope with endurance exercise. Instead, trout are "lipolytic machines" that do not modulate R_a glycerol even when their metabolic rate triples.

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Female Barbary ground squirrel responses to conspecific (un)modified alarm calls / Réponses des écureuils terrestre Barbary femelles aux appels d'alarme conspécifiques (non)modifiés

Sentinel behaviour is a special form of vigilance where individuals forego foraging and take turns being vigilant and warn conspecifics by visual and auditory signals of potential danger. Sentinel alarm calls can contain information on the level of urgency and predator type. We have observed that the invasive Barbary ground squirrels (*Atlantoxerus getulus*) of Fuerteventura (Canary Islands) will position themselves on top of rock walls when they observe danger and alarm call to group mates. These behaviours conform to descriptions of sentinel behaviour. However, nothing is known about the information these calls convey. We used playbacks of manipulated conspecific, but unknown, repeated alarm calls to indicate imminent danger to test whether receivers increase their vigilance levels and whether alarm calls contain information on the level of risk. We found that focal females responded similarly to the unaltered, only first syllable, and only second syllable repeated alarm calls, but not to the control. Thus, Barbary ground squirrels increase their vigilance level after hearing an alarm call, but the syllable structure does not convey specific information about the level of risk.

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Does fish color matter for sperm motility in *Pseudocrenilabrus multicolor victoriae*? / La couleur des poissons est-elle importante pour la motilité du spermatozoïde chez *Pseudocrenilabrus multicolor victoriae*?

The objective of our study was to determine whether a correlation exists between red colour prevalence and sperm swimming performance in *Pseudocrenilabrus multicolor* from four different sites from Uganda, Africa. Significant variation in body colour across sampling sites was observed ($F_{(3,53)}$= 8.610; $P < 0.0001$). Swamp fish had a greater percentage of red than fish from the lake and stream. Body weight significantly correlated with fish colour ($P = 0.0002$). Fish sperm motility significantly varied across sites ($F_{(3.54)} = 10.667$; $P < 0.0001$). Sperm linearity was the best predictor of sperm motility across sites and times ($P < 0.0001$), followed by sperm morphology ($P < 0.03$) and sperm swimming longevity ($P < 0.006$). Despite these colour and sperm performance variations across sites, results did not show a direct significant correlation between these two traits. It is worth noting that the inter- and intra-individual variation in the sperm traits measured could explain the lack of correlation with colour. Our results suggest that perhaps in *P. multicolor,* red hue prevalence does not provide an honest signal for females, although investigation of colour contrast with light environment could be important. Future studies should focus on whether sperm traits and fertilization success are correlated.

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Bridging pattern and process: How do snails grow shell sculpture? / Combler modèle et processus: Comment les escargots produisent la sculpture de la coquille?

Mollusc shells are a prime example of "endless forms most beautiful" and exhibit many diverse and complicated patterns, including both colour and sculpture. The shell is secreted by the mantle, a flexible hydrostatic tissue that lines the opening of the shell (aperture). Great strides have been made in recent years to understand the molecular processes involved in calcium carbonate secretion. Furthermore, the patterns of shell shape and sculpture has been modelled extensively, but whether these models reflect the biological reality is unclear. Nothing is known about the how the process of shell secretion can be modified to yield different patterns of shell sculpture. Here we work to answer: What aspect of the mantle changes to produce different shell sculpture? Nucella ostrina (Ocenebrinae: Muricidae) is a small predatory intertidal snail whose shell varies from strong spiral ribs to a smooth shell. We examined the mantle of ribbed and smooth snails using histology, TEM, 3D reconstructions, and histochemistry. Altogether, these observations revealed a relatively simple mechanism: in a rib, the mantle is longer with taller cells. This would increase the volume of shell secreting tissue, producing the thicker shell of a rib when compared to the adjacent, thinner, inter-rib.

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Mechanisms of oleic acid uptake in the hindgut of the Pacific hagfish (*Eptatretus stoutii*) / Mécanismes de l'absorption de l'acide oléique dans l'intestin postérieur de la myxine du Pacifique (*Eptatretus stoutii*)

Hagfish are capable of withstanding months of food deprivation and our previous research has highlighted intracellular micelles of lipid in multiple tissues including heart, archinephric duct and intestine. Additionally, metabolic enzyme analysis demonstrates early dependence on carbohydrates with an eventual conversion to dependence upon lipid metabolism. The aim of this study was to characterize intestinal acquisition of the lipid oleic acid in Pacific hagfish (*Eptatretus stoutii*). Using ^{3}H-labelled oleic acid and an isolated gut sac technique, we measured saturable oleic acid transport along the length of the hindgut (Km= 78.7, Vmax = 143.0). Moreover, significant post-prandial up-regulation of oleic acid transport was observed. Bioinformatic analysis revealed putative hagfish fatty acid transport proteins (FATP) of which certain isoforms have been demonstrated to be apically recruited in mammalian models following insulin treatment. We characterized the effect of 24h insulin (bovine insulin, 0.5 IU/kg, intramuscular) treatment on hagfish oleic acid transport and found that while insulin induced elevations in metabolic oxygen consumption, there was no significant effect on oleic acid transport. This is the first examination of lipid acquisition in a basal member of the vertebrate lineage and may offer insight into the evolution of lipid acquisition strategies in vertebrates.

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Cardiac mitochondrial ROS (reactive oxygen species) production and consumption response to acute temperature increase on two Actinopterygii species: *Acipenser fulvescens* and *Cyprinus carpio* / Réaction de la production et de la consommation de ROS (espèces réactives de l'oxygène) mitochondriale cardiaque à l'augmentation aiguë de la température sur deux espèces *d'Actinopterygii: Acipenser fulvescens* et *Cyprinus carpio*

Acute temperature stress is an important physiological influence in ectotherms, like fish. Rapid increase in temperature is known to induce oxidative stress in cells and thus appears to produce imbalance between the cellular antioxidant systems and the production of ROS (reactive oxygen species). In fishes the heart is important for physiological adaptation and performance, and one of the organs that may be acutely compromised with temperature change. Mitochondria possess both ROS producing and consuming (antioxidant) capacities and in the current study the response of cardiac mitochondrial ROS metabolism to acute, ex vivo, increased temperature in two *Actinopterygii* fishes was examined. Mitochondrial H_2O_2 (hydrogen peroxide) efflux and consumption was measured over a 10°C range of increasing temperature for two mitochondrial substrate combinations. The ratio of H_2O_2 efflux and consumption was used as an index of relative potential for ROS overproduction. ROS consumption rates increase with temperature. Furthermore, across species is found significant differences in average H_2O_2 ratios for substrate, species and temperature as factors.

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Size matters: Allometry and the control of invasive sea lampreys in the Great Lakes (*Petromyzon marinus*) / La taille est importante: l'allométrie et le contrôle des lamproies marines envahissantes dans les Grands Lacs (*Petromyzon marinus*)

Sea lampreys invaded the Great Lakes in the early 20th century, and their parasitism of fishes contributed to the collapse of commercial, recreational and culturally significant fisheries. An integrated pest management program, that relies heavily on the piscidide 3-trifluoromethyl-4-nitrophenol (TFM), subsequently suppressed sea lamprey populations allowing some fisheries to recover. Applied to nursery streams every few years, TFM treatments eradicate multiple generations of larval sea lampreys (ammocoetes). However, treatments can be compromised by "residual" lampreys, which survive treatment, undergo metamorphosis, and subsequently migrate to the Great Lakes as parasitic juveniles. One source of "residual" lampreys could be older, larger ammocoetes, which we predicted would have lower mass specific rates of TFM uptake (J_{TFM}) compared to smaller, younger animals. Accordingly, J_{TFM} was measured in ammocoetes of different body masses using ^{14}C-TFM and compared to rates of oxygen consumption ($\dot{M}_{O2}$). Both $\dot{M}_{O2}$ and J_{TFM} were inversely related to body mass, being up to 5-fold and 15-fold greater in smaller (< 0.5g) compared to larger ammocoetes (~3.6g). Each also scaled allometrically to increases in body mass (M) as described by the power relationships: $\dot{M}_{O2} = 1.89 \cdot M^{0.57}$ and $J_{TFM} = 6.47 \cdot M^{0.26}$. Neither body mass or length affected the $LC_{99.9}$ (MLC; Minimum Lethal Concentration) of TFM, but larger animals survived exposure longer, with LT_{50}'s (median lethal time) approaching 9-12h when exposed to environmentally-relevant TFM concentrations. We conclude that larger ammocoetes are more likely to survive TFM treatment, which could compromise sea lamprey control efforts in streams with large populations of relative large ammocoetes.

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Hosts, humans and habitats: Factors affecting pathogen transmission in endangered bats / Hôtes, humains, et habitats: Les facteurs qui affectent la transmission de pathogènes chez les chauves-souris menacées

Wildlife infectious diseases are on the rise worldwide with implications for human, animal and ecosystem health. Understanding transmission of wildlife pathogens can inform management of disease outbreaks but, despite a rich theoretical history, there are few experimental studies testing how host behaviour and human activities might influence transmission. Pathogens of bats are of growing interest because bats have been implicated as reservoir hosts of many zoonotic pathogens and because multiple North American

species are currently imperilled by white-nose syndrome. Here we review recent studies from our lab addressing the influence of host behaviour and physiology, and human activities, on transmission and proliferation of pathogens within colonies of bats. Our epidemiological models, informed by data on social network characteristics, suggest that habitat alteration resulting from deforestation and human development could aggregate colonies of bats in ways that increase pathogen prevalence. Our experiments using ultraviolent fluorescent powder as a proxy for a contact pathogen, also suggest that human impacts which increase aggregation, as well as individual personality, increase transmission within bat colonies. These results suggest that loss of natural forest habitat could increase risk of zoonotic spillover from bats, especially if alternative anthropogenic habitats (e.g., buildings, bat-boxes) alter natural patterns of aggregation.

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Characterization of a novel cytosolic carbonic anhydrase in the larval sea lamprey, *Petromyzon marinus* / Caractérisation d'une nouvelle anhydrase carbonique cytosolique dans la lamproie molaire larvaire, *Petromyzon marinus*
Carbonic anhydrase is an important metabolic and transport enzyme that reversibly catalyzes the hydration/dehydration of CO_2/HCO_3^-. The sea lamprey is a basal vertebrate with a complex life history. The long lived larval stage lives in the sediment of freshwater streams as a filter feeder but following a dramatic metamorphosis transforms into a free swimming parasitic blood feeder that will migrate downstream to the sea for feeding. We have identified a novel carbonic anhydrase isoform *ca19* in larval lamprey that decreases during metamorphosis and is replaced by the previously identified isoform *ca18* in juveniles with the highest expression in blood and gill for both orthologs. They share 67.5% amino acid (aa) sequence identity but no major differences in the substrate pocket aa residues. The ammocoete Ca19 is much more sensitive to Cl^- inhibition which would be consistent with its loss proceeding the lamprey's migration to a marine environment. This contrasts with the juvenile Ca18 isoform which shows higher expression post metamorphosis. The ammocoete Ca19 also has a lower affinity for CO_2 and acetazolamide but a higher Vmax. Finally, we have found CA-like immunoreactivity in the branchial epithelium of larval lamprey consistent with localization to ammocoete mitochondrion-rich cells.

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Nitrogen recycling in the elasmobranch intestine: a potential role for microbial urease / Le recyclage de l'azote dans l'intestin élasmobranche: un rôle potentiel pour l'uréase microbienne
Ureotelic elasmobranchs require nitrogen not just for protein growth, but also for urea-based osmoregulation, and therefore are probably nitrogen-limited in nature. They have mechanisms for retaining and/or scavenging nitrogen at gills, kidney, and gut. Intestinal sac preparations of the Pacific spiny dogfish shark (*Squalus acanthias suckleyi*) incubated *in vitro* strongly reabsorbed urea from the lumen, but curiously, luminal ammonia concentrations increased with incubation time. We therefore developed a sensitive [^{14}C]urea-based assay to examine the potential role of urease in ammonia generation in the intestinal lumen. Urease activity was detected in chyme/intestinal fluid and intestinal epithelial scrapings of both fed and fasted sharks. Levels in bile were negligible. Urease activities were highly

variable among animals, but generally greater in chyme than in epithelia, and greater in fed sharks than in fasted sharks. Comparable urease activities were found in chyme and epithelia of the Pacific spotted ratfish (*Hydrolagus colliei*), a holocephalan which is also ureotelic, but were much lower in ammonotelic teleosts. Urease activity was sufficient to explain the rates of ammonia generation measured in dogfish gut sacs *in vitro*. A model is presented in which microbial urease plays an important role in nitrogen recycling in the elasmobranch intestine (NSERC Discovery).

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Both behavioural and physiological traits suggest amphibiousness may be ancestral in Aplocheilod killifishes / Ensemble les comporements et les traits physiologiques suggèrent que l'amphibie peut être un caractère ancestral des poisons Aplocheilod

Amphibious habits are widespread in killifishes (Cyprinodontiformes), as species that leave water (emerse) have been reported in 6/10 killifish families. We tested the hypothesis that amphibiousness is a trait ancestral to the suborder Aplocheloidei, a clade of killifishes including the families Nothobranchiidae, Rivulidae, and Aplocheilidae. This hypothesis predicts that extant amphibious Aplocheiloids use conserved behavioural and physiological traits during emersion, while repeated, independent evolution of amphibiousness would be expected to result in dissimilar strategies. Voluntary emersion behaviour, acute hypoxia sensitivity, and nitrogen excretion routes in water and air were determined in *Anablepsoides hartii*, *Cynodonichthys hildebrandi*, *Rivulus cylindraceus*, *Kryptolebias marmoratus, Fundulopanchax gardneri* and *Aplochelius lineatus*. Each species emersed voluntarily (spending 1-20% of one week emersed). Severe acute aquatic hypoxia (0-10% DO) induced emersion in every species. Although some other amphibious fishes convert toxic ammonia to urea during air exposure, none of the killifishes were ureogenic during emersion. Instead, a significant portion (50-90%) of nitrogen waste was eliminated as gaseous NH_3 (volatilization) during air exposure (6h) in all species. Taken together, these data support the hypothesis that the Aplocheilod killifishes share an amphibious ancestor because of the remarkable similarities in emersion behaviour and route of nitrogen excretion during emersion.

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Why two? Subtle functional benefits of bilaterally paired sensory structures in the nudibranch *Tritonia diomedea* / Pourquoi deux? Bénéfices fonctionnels subtils des structures sensorielles appariées bilatéralement au nudibranche *Tritonia diomedea*

Larger aquatic animals primarily use odour-gated rheotaxis to find odour sources. This navigational strategy, moving upstream in the presence of odour, works because larger animals tend to experience higher Reynold's number conditions which create turbulent odour plumes. The turbulence breaks down chemical gradients, making them a poor option for finding an odour source. Instead, the animals trigger rheotaxis when odour is detected, and thus follow the flow (that transports the odour) back to the odour source. Theoretically, this navigational strategy requires only a single sensory structure to detect both the presence of odour and flow direction. Indeed, we have shown that sensory input from single rhinophore (cephalic sensory organ) is sufficient for the sea slug *Tritonia diomedea* to find the source of turbulent prey odour plumes in a flow tank. However, slugs have bilaterally paired rhinophores, and input from both might improve the slugs' ability to navigate in challenging odour plumes. We tested this hypothesis in odour plumes with either reduced odour concentration or plume disruption created by an obstacle, comparing performance of animals with either one or two rhinophores. Navigational performance was subtly affected by the loss of a rhinophore in reduced-concentrated odour plumes. The plume disruption created by the obstacle probably created an overly challenging plume for navigation, and thus we were unable to discern any clear differences in the overall poor performance of animals with either one or two rhinophores. These results suggest that although one rhinophore is sufficient for normal navigation, two

rhinophores may help slugs navigate in odour plumes with lower concentrations, as might be expected with more distant odour sources.

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Influence of temperature and dissolved oxygen on the development of metabolic phenotypes in Lake Sturgeon (*Acipenser fulvescens*) / Influence de la température et de l'oxygène dissous sur le développement de phénotypes métaboliques chez l'esturgeon jaune (*Acipenser fulvescens*)
The impact of changes in environmental factors on phenotypic development are likely most pronounced during early life history where alteration of rearing environments can have a profound effect on the performance and ultimately fitness of the individual later in life. Environment-phenotype interactions in fish has focussed mostly on teleosts, often examining species with short generation times. However, less attention has been paid to the ancient fishes such as sturgeons, which are known for their longevity and 'slow' life history traits. In this study, we examined the influence of temperature, dissolved oxygen and substrate on the development of metabolic phenotypes in Lake Sturgeon. At 55 days post hatch (dph) fish raised in no substrate had significantly higher energy density than those raised in substrate regardless of temperature and dissolved oxygen. Preliminary analysis of metabolic phenotypes for the different rearing environments suggests no effect on metabolic scope at 122 dph. Changes in metabolic rate and energy density will be further discussed in relation to survival following a simulated over wintering period and sampling of fish at 270 dph. This research provides information regarding early rearing environment-phenotype interactions for Lake Sturgeon, which is threatened or endangered across most of its natural range.

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Testing the potential for Semaphorins 3A and 3F to kill endothelial cells by inducing DNA damage and damage-associated apoptosis / Testant le potentiel des Sémaphorines 3A et 3F pour tuer les cellules endothéliales en induisant des dommages à l'ADN et une apoptose associée à un dommage
As tumours progress, they constantly induce angiogenesis to establish a vascular supply that satisfies nutrient demand. Anti-angiogenic treatment has proven to be a powerful tool to counter this tumour growth induction property. This study tested the hypothesis that Semaphorins 3A and 3F (Sema3A and Sema 3F) together, will induce endothelial cell apoptosis in mixed cultures isolated from mouse skeletal muscle. Primary cells (protocol F16-031) were grown to 25% confluence and treated with Sema3A and/or Sema3F (100µg/mL) to evaluate changes in cell viability (counts, DNA synthesis) and apoptosis (TUNEL staining) in CD31+ endothelial and/or desmin+ muscle cells using multi-channel immunostaining. Interestingly, Sema3F increased DNA damage in endothelial and muscle cells, detected via enhanced gamma-Histone 2A.X (γH2AX) staining (Tukey's test post hoc to ANOVA). DNA damage-associated apoptosis was higher after Sema3F vs. controls or Sema3A alone. Combined Sema3A+Sema3F treatment increased DNA damage and apoptosis, 20-25-fold vs. either protein, alone. Results (negated by neutralizing anti-Semaphorin antibodies) showed Sema3A sensitized endothelial but not muscle cells to Sema3F-induced DNA damage. Findings help identify a mechanism of tissue angiogenesis, and suggest semaphorins as a second-line therapy to combat cancer. How semaphorins regulate angiogenesis, sensitize cells, induce DNA damage, and cause apoptosis, remains to be explored. Supported by an NSERC Discovery grant.

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Locust flight muscle activity and body orientation in response to objects moving along complex trajectories / L'activité musculaire du vol du criquet et l'orientation du corps en réponse aux objets se déplaçant selon des trajectoires complexes

Locusts are ideal model systems to study complex behaviours, such as flight responses to objects approaching on a collision course. Thus far, flight muscle activity, wing kinematics and aerodynamic forces of locusts have been recorded during collision avoidance behaviour and measured from rigidly-tethered locusts flying in open-loop conditions. However, loosely-tethered flying locusts are capable of changing orientation in response to looming stimuli within a single wing beat, and generate avoidance responses within a single downstroke. To better understand neural control of flight steering, we placed a loosely-tethered flying locust inside an existing flight simulator, and presented visual stimuli of objects moving along complex trajectories. Preliminary analysis of video and EMG recordings suggests that locust initiate stereotyped avoidance behaviours during objects approach. Continued analysis will explore putative relationships between flight muscle activity and body orientation in response to complex object motion. This is the first study of loosely-tethered locusts responding to various visual stimuli, and will provide valuable information for the future construction of a closed-loop recording system.

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The role of acid-sensing ion channels (ASICs) in Na^+ uptake by larval zebrafish / Le rôle des canaux ioniques sensibles à l'acide (ASIC) dans l'absorption de Na+ par le poisson zébré larvaire

Freshwater fish are hyperosmotic relative to their environment and must counteract passive ion loss with active ion uptake. Recently, acid-sensing ion channels (ASICs) have been implicated in Na^+ regulation by zebrafish (*Danio rerio*), facilitating apical Na^+ uptake across the gill via the electrogenic action of H^+-ATPase. We hypothesized that ASICs are also expressed in the skin of larval zebrafish, the site of ionoregulation at this stage, and similarly facilitate Na^+ uptake. In support of our hypothesis, ASIC (specifically ASIC4.2) expression was localized to H^+-ATPase-rich cells on the skin. However, morpholino knockdown of ASIC4.2 did not reduce Na^+ uptake by larvae at 4 days post-fertilization (dpf), relative to sham larvae. In fact, in larvae reared at pH 4, knockdown stimulated Na^+ uptake and this was correlated to the upregulation of non-ASIC Na^+ uptake pathways, namely Na^+/H^+-exchanger 3b (NHE3b). These findings were puzzling as Na^+/H^+-exchange should theoretically be limited at pH 4, yet NHE3b emerged as an important pathway in response to ASIC4.2 knockdown. Overall, we found limited direct support for a role for ASICs in Na^+ uptake by larval zebrafish and our results shed light on the need for a better understanding of thermodynamic principles governing Na^+ uptake by freshwater fish.

Poster Abstracts

Sorted according to surname of presenting author (underlined)

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An investigation of stress in a mammal on the brink of extinction: Implications for the re-establishment of the Vancouver Island marmot (*Marmota vancouverensis*)

The Vancouver Island marmot is a species of ground squirrel that is endemic to British Columbia, Canada. They were once widespread across Vancouver Island, but went into decline in the late 1980s. In 1997, a captive breeding program was established to safeguard the species from extinction. Despite 20 years of management, the Vancouver Island marmot remains critically endangered. It is possible that the marmot's fitness is compromised by management activities and other human disturbances. To investigate possible sources of chronic stress among Vancouver Island marmots, we analyzed hair cortisol levels from marmots subjected to different disturbances associated with conservation: captivity, surgery and captive release. We also measured stress levels in marmot hair samples from 1910 and 1931, during an era when marmot population were stable. We found no evidence that surgery nor captivity are a source of stress in Vancouver Island marmots. However, marmots released into the wild for at least 12 months before sampling had higher cortisol levels than their wild-born or captive-born counterparts. We also found evidence that stress levels in free-ranging marmots have increased since the early 1900s. It is possible that habitats on Vancouver Island have become less suitable for marmots than habitats found on the island in an earlier era.

Une enquête du stress d'un mammifère en voie d'extinction: les implications pour le rétablissement des marmottes de l'île de Vancouver

La marmotte de l'île de Vancouver est une espèce endémique au Canada. Historiquement, elle était répandue sur l'île cependant, lors des années 1980s, les populations de marmottes ont commencé à diminuer. En 1997 un programme d'élevage conservatoire a été établi afin de sauvegarder cette espèce de l'extinction. Malgré vingt ans d'effort, elle est toujours en danger critique. Il se peut que les marmottes subissent des conditions nuisibles à leur fitness à cause des activités humaines. Afin d'investiguer cette possibilité, le niveau de stress chronique parmi les marmottes de l'île de Vancouver a été mesuré en utilisant les niveaux de cortisol dans leurs poils. Nous avons comparé les niveaux de cortisol des marmottes exposés à différentes perturbations liées à la conservation : la captivité, les interventions vétérinaires et la remise en liberté. Nous avons aussi mesuré le niveau de stress historique parmi les marmottes lors des années 1910 et 1931, quand les populations de marmottes étaient stables. Ni les interventions vétérinaires ni la captivité ne sont une source de stress chronique pour les marmottes. Cependant, les marmottes libérées de la captivité ont des niveaux de cortisol plus élevés que les marmottes nées en nature ainsi que les marmottes nées en captivité. Ceci indique que la remise en liberté est un facteur de stress putatif.

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Glucose transporter (GLUT) regulation in response to carbohydrate availability in the ruby throated hummingbird, *Archilochus colubris* / Régulation du transporteur de glucose (GLUT) en réponse à la disponibilité des glucides dans le colibri à gorge rubis, *Archilochus colubris*

Ruby-throated hummingbirds (*A. colubris*) exhibit some of the highest metabolic rates per unit tissue amongst vertebrates. . Their respiratory quotient (RQ) can shift from ~0.7 to ~1.0 within ~20 minutes of carbohydrate ingestion, which indicates that they can rely entirely on recently ingested carbohydrates to

power energy-demanding short-distance flights or hovering. Unlike mammalian systems, hummingbirds lack an insulin response to ingested sugars, relying on glucose transporters (GLUTs) at the cell-surface level for hexose sensing and transmembrane transport. GLUT regulation may account for the rapid shift to pure carbohydrate metabolism, and may also play a crucial role in sugar transport and damage prevention by extreme blood hyperglycaemia (~40mM in fed hummingbirds). This study aims to observe co-localisation of *A. colubris* GLUTs 1, 2, 3, and 5 with cell-surface membranes of intestinal, renal, hepatic, and muscle tissue in response to availability of carbohydrates. We hypothesize that carbohydrate ingestion will increase co-localisation of GLUTs 1, 2, 3, and 5 with the cell-surface membranes. We expect to see a decreased co-localisation when fasted. This may provide an insight into a unique glucose sensing and hexose-regulating system that both operates at a rapid pace and is also insulin independent.

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Nitric oxide-based treatment attenuates muscle-disuse atrophy during hind limb suspension / Une traitement basé à l'oxyde nitrique atténue l'atrophie désuétude-musculaire durant la suspension du membre postérieur
Effective treatment for muscle disuse atrophy is not available. Since nitric oxide (NO) activates muscle stem cells, we tested the hypothesis that treatment with the NO-donor drug, isosorbide dinitrate (ISDN) during hind limb suspension (18days) would reduce muscle atrophy (UM protocol F11-029). Suspended and ISDN-suspended groups of C57BL6 mice (M+F, 3wk and 6-8wk old) were compared to age-matched controls (n=4/group) for changes in muscle (weight, fiber diameter, atrogin-1, myostatin), liver lipid, and hypothalamus (genes regulating metabolism, inflammation and microglial activation). Suspension induced atrophy in quadriceps and soleus ($p<0.01$) and ISDN attenuated loss of muscle mass (quadriceps, soleus) and fiber diameter (gastrocnemius) ($p<0.05$). Suspension-induced increases ($p<0.01$) in atrogin-1 (negative regulator of muscle mass) and myostatin precursor (which inhibits myogenesis) were attenuated by ISDN ($p<0.05$). ISDN increased MyHC-1 and MyHC-2b in unloaded muscles at 6-8wk vs. suspension alone. Suspension-induced fatty-liver changes in 6-8wk mice were attenuated by ISDN ($p<0.05$). Suspension increased Agrp mRNA in 6-8wk hypothalamus vs. control ($p<0.05$). Suspension and treatment effects varied with age and muscle, including forelimb muscles, and body positioning varied among mice. Potential use of NO-based treatment could help attenuate disuse atrophy, delay the serious impact of age-related sarcopenia, and improve metabolic health; findings merit further investigation. Supported by NSERC Discovery Grant and URGP (University of Manitoba) (JEA) and NSERC Undergraduate Student Research Awards (AZ).

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Does the size of the tall-grass prairie's spring-emerging pollinators change across latitude? / Est-ce que la taille des pollinisateurs émergents du printemps dans la prairie à herbes haute change en fonction de la latitude?
Allen's and Bergmann's rules predict an animal's body should become rounder and larger, respectively, in cool climates because lower surface area to volume ratios help to maintain body heat. Studies of these rules in insect taxa have been few, with most studies producing conflicting results. The size and shape of pollinator can have strong selection effects on flowering plants, especially those with size restrictive flowers. We conducted research on the pollinator community surrounding *Cypripedium candidum* across its latitudinal range from Manitoba to Iowa. *Cypripedium candidum* is a threatened tall grass prairie endemic orchid that is pollinated through a restrictive flower trap. Previous research has shown that size constraints on pollinators may limit reproductive success. We found that larger insect genera were more abundant in northern sites, and some taxa showed a within-genus size increase with latitude.

Corresponding changes in the size of orchid flowers were not apparent. Orchids in Iowa were smaller than the other areas, but flower size did not vary between other regions. Southern populations showed the greatest range of orchid fruiting success (2-84%) in comparison to plants from further north (11-34%). Ongoing analyses will explore the contribution of changes in insect size to variation in fruit production.

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Mite-y freeze-tolerant / Acariens qui se gèle, et survivre!
Freeze-tolerance, the ability to survive freezing of internal body fluids, is an adaptation that has been found in many insects. Thus far only one species of arachnid has been known to survive freezing: the scorpion *Centruroides vittatus*. However, we have discovered that a red velvet mite (*Trombidium* sp.), collected near London, Ontario, can also survive freezing during the winter (November - March). In winter, the average temperature at which the mites' body fluids freeze ranges from -6.8 ± 0.2 °C in November to -8.4 ± 0.2 °C in January, and they survive to temperatures far below this value (between -17 and -24 °C). During the winter, their hemolymph osmolality dramatically increases from 428 ± 28 mOsmol in November to 1025 ± 85 mOsmol in January. Outside of the winter months, although they freeze at similar temperatures (-7.7 ± 0.2 °C, September), the mites do not survive this process. The mechanisms that underlie the red velvet mite's freeze-tolerance are unknown. Our immediate future investigations will involve identifying the molecules that are involved with the increased osmolality of the red velvet mite hemolymph, thereby identifying any further similarities among freeze-tolerant organisms from different taxa.

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[2]*Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba, R3T 2N6***Landscape influences on spatio-temporal patterns of Arctic Charr migrations in Nunavut / L'influence du paysage sur les modèles spatiaux et temporels des migrations de l'omble chevalier au Nunavut**
Aquatic habitats are heterogenous across landscapes in terms of suitability for growth, survival, and reproduction. Individual fish therefore maximise fitness by balancing the benefits of moving to more suitable habitat with the energetic costs and risks of migrating. Understanding which environmental factors influence these fitness decisions provides insight on population reactions to climate changes or anthropogenic impacts. Arctic Charr (*Salvelinus alpinus*) exhibits diverse life histories across Nunavut, with populations demonstrating differing proportions and patterns of anadromy. Previous studies have investigated charr migratory choices in specific systems or areas of Nunavut, but not at a landscape scale. Understanding Arctic Charr migration patterns and drivers across the territory will inform the management of a widespread, culturally and economically important fishery, as well as coastal planning and impact assessment. Inuit knowledge and tracking data will be spatially analysed against landscape variables including river length, predator presence, and aquatic productivity to assess drivers of annual charr migration patterns. The influence of these variables on life history choices will be investigated by comparing to age-at-first-migration, determined by otolith microchemistry, for 10 populations. Anadromy is expected to be the preferred life history choice in areas of greater marine productivity, lower freshwater survival, and easier ocean access.

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Preliminary genetic analyses of the population structure of narwhals (*Monodon monoceros*) / Analyse génétique préliminaire de la structure de la population des narvals (*Monodon monoceros*)
Narwhals (*Monodon monoceros*) are ecologically and culturally important Arctic species. Their populations are expected to face increasing stress in the near future due to climate warming, human industrial development, and range expansion by killer whale (*Orcinus orca*) populations, narwhal predators. Given these threats and ongoing harvest, effective population management requires the identification of stock structure. Due to their elusive nature and the logistical difficulties associated with tracking large numbers of individuals, stock structure identification is best identified by conducting spatial analyses of population genetic structure. To identify stock structure, narwhals from across their range in Canada were genotyped at 32 microsatellite markers. I will present a preliminary analysis of the spatial population genetic structure of Narwhals.

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Responses from acute exposure to increased aquatic pCO_2 in Lake Sturgeon (*Acipenser fulvescens*) / Réponses d'une exposition aigue à la pCO_2 aquatique augementée chez l'esturgeon jaune (*Acipenser fulvescens*)
Global climate change is expected to impact general health of aquatic organisms, however, it is unknown if species which have remained relatively unchanged for hundreds of millions of years would be robust to the rate of climate change currently experienced. It is assumed that natural rates of climate change progress over thousands of years with gradual increases or decreases of abiotic factors (e.g. temperature and CO_2) presumably allowing sufficient time for adaptation to the changing environment. In northern latitude rivers snow melt and rain between winter and spring can release land-derived acids and CO_2 into rivers and lakes, which results in sharp seasonal declines in pH and increases in pCO_2. Consequently, acute changes in the aquatic environment can occur over short time periods that are coincidental with periods when resources are scarce and thus are particularly challenging for survival in age-0 fish. Recent research on White Sturgeon, *Acipenser transmontanus*, suggests a physiological tolerance to acute increases in pCO_2. Here we investigate behavioural, metabolic and blood chemistry responses of Lake Sturgeon, *Acipenser fulvescens*, to acute exposure to increased pCO_2. Results will be discussed in the context of seasonal changes overlaying global increases of pCO_2 in freshwater aquatic environments.

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Upregulation of anti-viral and pro-inflammatory transcripts in response to poly (I:C) in two *Xenopus laevis* spleen cell lines / Régulation positive des transcrits antiviraux et pro-inflammatoires en réponse au poly (I:C) dans deux lignées de cellules de la rate de *Xenopus laevis*
The capacity of spleen fibroblast and mesothelial cells to function as accessory cells in the initiation of a pro-inflammatory immune response in amphibians is largely unknown. Using two previously established continuous cell lines from *Xenopus laevis* spleen tissue, termed Xela S5m (mesothelial-like morphology) and Xela S5f (fibroblast-like morphology), we examined the molecular signatures Xela S5m and Xela S5f and their ability to upregulate pro-inflammatory transcripts levels in response to poly (I:C). Transcripts for cytokeratin 19, fibronectin and vimentin were detected in both Xela S5m and Xela S5f, while only collagen1A2 could be detected in Xela S5m using RT-PCR. Upon stimulation with poly (I:C), Xela S5m and Xela S5f exhibited a change in cell morphology and an increase in mRNA levels for interleukin-1 beta, interferon type 1 and inhibitor of kappa beta in a dose- and time-dependent manner. Together, these data suggest that Xela S5m and Xela S5f possess unique molecular signatures, participate in the recognition of microbial associated molecular patterns, such as poly (I:C), and can upregulate the expression of key anti-viral and pro-inflammatory cytokines important in initiating an immune response.

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Sociality and heat stress in the mangrove rivulus, *Kryptolebias marmoratus* / La socialité et le stress thermique chez le killi des mangroves, *Kryptolebias marmoratus*

Changes in the physical environment elicit physiological, molecular and behavioural responses in animals; however, we know comparatively little regarding how the social environment affects an animal's response to environmental change. We used the self-fertilizing hermaphroditic fish, the mangrove rivulus (*Kryptolebias marmoratus)* to test the hypotheses that 1) social context will influence the phenotypic response to thermal stress and 2) thermal stress will affect social preferences. To determine if thermal physiology was influenced by social condition, we measured critical thermal maximum (CTmax) and heat shock protein (HSP70) levels after an acute heat shock event in fish living in pairs and fish living in isolation. Paired fish had higher expression of HSP70 than isolated fish, but there was no effect of social context on their CTmax. To determine if the thermal environment affected social preferences, we observed the amount of time fish spent alone as opposed to associating with conspecifics in control and heat-shocked conditions, and predicted that thermal stress would significantly affect social preference. However, fish did not change social preferences during acute heat shock compared to control conditions. We conclude that the social environment impacts thermal physiology at the cellular level but high temperatures do not affect social preferences.

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Thyroid hormone influences the molecular physiology of tight junctions in a primary cultured gill epithelium / L'hormone thyroïdienne influence la physiologie moléculaire des jonctions serrées dans une culture primaire de l'épithélium des branchies

Thyroid hormones (THs) are involved in the regulation of physiological functions including growth, metabolism, and metamorphosis. As a feature of vertebrates, TH producing glands and follicles and peripheral mechanisms of TH action have been widely investigated. Previous findings also suggest that THs play a strong supportive role in teleost fish osmoregulation. However, it is not known whether THs influence the molecular physiology of a central element in piscine salt and water balance, the epithelial tight junction (TJ) complex. Using a primary cultured trout gill epithelium model, we highlight the effects of 3,5',3'-triiodo-L-thyronine (T3) on teleost osmoregulation with an emphasize on the response of TJ proteins. T3 (10 and 100 ng/mL) supplemented media bathing trout double-seeded inserts (DSIs, composed of gill pavement cells and mitochondria-rich cells) caused a decrease in transepithelial resistance and increased paracellular permeability of [^{3}H]PEG-400. This increase in gill epithelium permeability was accompanied by changes in the abundance of select TJ proteins (i.e. *claudins -8d*, *-28b*, *tricellulin*) and an increase in the mRNA abundance of Na^+/K^+-ATPase α1b isoform. Our findings suggest that T3 is capable of altering the permeability of the gill epithelium at least in part by its actions on the molecular physiology of the TJ complex.

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Correlation between thermal tolerance, ROS production and omega-3 content in fish hearts / Corrélation entre la tolérance thermique, la production de ROS et la teneur en oméga-3 dans les cœurs de poisson

In the context of climate change, it is of paramount importance to investigate the thermal sensitivity of aquatic ectotherms. Heat challenge tests have recently been advanced as a good way to assess an individual's robustness and general fitness. In this context, the objective of this study is to assess individual

heat challenge performance of fish and shed light on the underlying physiological mechanisms. Previous results demonstrated that mitochondrial activity is impaired and reactive oxygen species production rates level off in the same temperature ranges as the whole organism loss equilibrium. Four strains of charr were used to determine individual heat stress performance. In addition to that, the individual reactive oxygen species (ROS) production of permeabilized heart fibres were measured and the fatty acid profiles of heart tissue were determined. Our results show; 1) that less heat tolerant individuals have higher rates of ROS production, 2) good performers have a higher omega 3 content and less omega 6 in heart tissue. This demonstrates that an organism's performance in heat challenge tests seems to be correlated with its heart's ability to cope with increased ROS production. Moreover, individuals with higher omega3/omega6 ratios seem to be more robust and show better overall performance.

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Examining the time-dependent responses of the Pacific spiny dogfish kidney to lowered salinity using comparative transcriptome profiling / Examiner les réponses dépendantes du temps du rein de l'aiguillat commun du Pacifique à la salinité abaissée en utilisant un profil de transcriptome comparatif

Salinity greatly dictates the environments that most aquatic organisms, including fishes, can inhabit. The majority of elasmobranchs are restricted to environments with minimal changes in salinity (stenohaline), while a few species are capable of surviving a wider range of salinities (euryhaline). Importantly, the underlying physiological and molecular mechanisms that impart euryhalinity in elasmobranches has not previously been fully investigated. The Pacific spiny dogfish, *Squalus suckleyi*, is a small, partially euryhaline elasmobranch that primarily inhabits ocean waters but has been found in brackish, estuarine waters to ~21 ppt. Previous studies have explored the temporal changes in physiology of these sharks after low salinity (21 ppt) exposure by measurement of plasma osmolytes, qPCR, and biochemical assays. Here, we applied a comprehensive, RNA-seq approach using Illumina HiSeq 4000 to characterize the temporal, large-scale changes occurring in the kidney following low salinity exposure. Dogfish were exposed to lowered salinity (21 ppt) for 0h, 12h, and 48h to capture short-term and long-term changes in gene expression. This is the first study to examine whole-transcriptome differential expression of an elasmobranch.

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Mitochondrial adaptations to high altitude in brown adipose tissue of highland deer mice / Adaptations mitochondriales à haute altitude dans le tissu adipeux brun de souris sylvestre en haute altitude

High altitude endotherms such as deer mice (*Peromyscus maniculatus*) must support high metabolic rates necessary to guard their body temperature against low ambient temperatures, despite a reduced O_2 availability for mitochondrial respiration. Non-shivering thermogenesis (NST) in deer mice primarily takes place in brown adipose tissue (BAT), an organ specialized to produce heat using uncoupled mitochondrial respiration following activation of uncoupling protein 1 (UCP1) by free fatty acids. Past work has shown that highland deer mice have a greater NST capacity than acclimated lowlanders but no difference in BAT size with acclimation to cold and hypoxia. This suggests that highland deer mice modify BAT mitochondrial function, to increase NST capacity in cold and hypoxia. No population differences in basal or coupled mitochondrial respiration were found before or after cold and hypoxia acclimation. When UCP1 uncoupled respiration was stimulated with palmitoyl-carnitine, both populations had equivalent rates of O_2-consumption before acclimation. After acclimation to cold and hypoxia, highland mice significantly increased uncoupled respiration to rates significantly higher than in acclimated lowland mice.

These findings suggest that the enhanced NST capacity in highland deer mice acclimated to cold and hypoxia is partially the result of a greater fatty acid-stimulated uncoupled respiration per BAT mitochondrion.

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Effects of social ascension on growth and energetics in a group-living fish / Effets de l'ascension sociale sur la croissance et l'énergétique d'un poisson vivant en groupe

Individuals in social groups often form hierarchies. Social rankings usually reflect the outcomes of past agonistic interactions between group members, and influence access to limiting resources, such as shelter, food, and mates. Dominant animals generally monopolize these resources—maintaining larger energy stores, and exhibiting higher rates of feeding and growth. However, following a perturbing event, such as predation, long-standing hierarchies can become unstable, especially when vacancies provide subordinates an opportunity to attain dominant status. Few studies have explored the behavioural and physiological changes associated with such periods of social instability and the ascension from subordinate to dominant status. Using a group-living African cichlid, *Neolamprologus pulcher*, we assessed the behavioural and physiological changes that accompany social ascension. Specifically, we focused on whether fish adjust their activity, feeding, energy storage, metabolism, and growth. Overall, these findings add to our understanding of the mechanisms facilitating changes in social rank.

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Tracking muscle reinnervation during regeneration after pre-treatment with an NO-donor drug / Suivi de la réintégration musculaire pendant la régénération après un prétraitement avec un médicament donneur de NO

Satellite cell (SC) activation underpins muscle repair from damage, but function requires reinnervation of new fibers (myotubes). SC activation is mediated by nitric oxide (NO, a signaling free-radical molecule) which can enhance muscle repair and growth. SCs also up-regulate expression of a neural chemorepellent, semaphorin 3A (Sema3A) 6 days after muscle injury; Sema3A is thought to mediate axon growth toward regenerating fibers. We hypothesized that premature SC activation NO-donor treatment (2days before injury) would disrupt myotube reinnervation. Neuromuscular junction (NMJ) formation was examined in regenerating tibialis anterior muscle of adult mice (n=8/group) after injury by cardiotoxin (CTX, damages only fibers) or trauma (crush) (protocol UM#F14-015). Fiber formation was faster in CTX- than crush-injured muscle and accelerated by NO-donor treatment. NMJ maturity was classified from staining for acetylcholinesterase (AchE, silver) and Ach receptors. NO-donor treatment shifted NMJs to more immature patterns of early nerve-terminal formation and fragmented AchE at post-injury days 4 and 10 (CTX) and day 8 (crush) compared to untreated controls (Chi-square, $p<0.05$). Premature SC activation therefore advanced myogenesis but disrupted NMJ development, consistent with disrupted Sema3A action to repel motor axons. Manipulation of the timing and/or amount of Sema3A has potential to improve reinnervation after muscle damage. Supported by NSERC Discovery grant (JEA) and University of Manitoba Graduate Fellowship (ND).

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Two potential treatments for white-nose syndrome in little brown bats (*Myotis lucifugus*) / Deux traitements potentiels pour le syndrome du nez blanc chez les petits chauves bruns (Myotis lucifugus)

Wildlife pathogens can cause extinctions and identifying potential treatments for such pathogens is increasingly important for conservation. White-nose syndrome (WNS) is a recently emerged fungal skin disease devastating populations of North American hibernating bats. Several treatments for WNS have been proposed but few have been tested on live bats. Treatments for WNS should target the pathogen (*Pseudogymnoascus destructans* (Pd)) with high specificity to avoid impacting delicate microbial communities in bat hibernacula. Our objective was to evaluate two treatments that should target Pd with high specificity: 1) Inhibitors targeting proteases secreted by Pd during skin invasion; and 2) Polyethylene glycol (PEG), which inhibits growth of fungi susceptible to water stress. We captured hibernating, WNS-negative little brown bats (*Myotis lucifugus*) from the wild. We matched bats for age and mass and then assigned individuals to one of four groups: inoculated with Pd and sham-treated; sham-inoculated with Pd and sham-treated; inoculated with Pd and treated with protease inhibitors; and inoculated with Pd and treated with PEG. Treatment groups are housed in separate cages within climate-controlled incubators to maintain hibernation conditions throughout winter. Our results will help identify, or rule out, potential treatments for a wildlife disease causing devastating impacts on North American bats.

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3D gastropods: a guided tour inside the soft and the slimy / Gastéropodes end 3D: un tour guidé à l'intérieur du doux et du visqueux

Taxonomical and morphological studies of gastropods traditionally rely on external characters such as the snail shell as it is a rigid and readily observable structure. In this regard, however, soft bodied organisms lacking shells, such as slugs, are problematic. In addition, many structures allowing for taxonomic discrimination within gastropods are internal soft tissue organs. Their observation thus necessitates lengthy dissection which, as well as being destructive, changes their topological organisation. Imaging technology such as µ-computed tomography allows for tissues of variable densities to be imaged without resorting to dissection. This method, allowing for the observation of structures *in situ* and in three dimensions, is increasingly popular in the study of vertebrates but remains seldom used in soft-bodied organisms such as molluscs. This project aims at developing a protocol for the acquisition of images and models of internal organs of gastropods, including the optimal acquisition parameters and the most-suitable means of contrast staining, with µ-computed tomographs. Preliminary results show that multiple organs are easily observable with this technique and it could prove a valuable tool in ecomorphological and taxonomical studies within gastropods.

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Characterization of an animal MEP/Amt ammonia transporter – like protein, *AeAmt2* in the anal papillae of the larval mosquito, *Aedes aegypti* / Caractérisation de transporteur d'ammoniac MEP / Amt, AeAmt2, dans les papilles anales du moustique larvaire, *Aedes aegypti*

The mosquito, *Aedes aegypti* inhabits ammonia rich septic tanks in tropical regions of the world that make extensive use of these systems, explaining the prevalence of disease during dry seasons. Since ammonia (NH_3/NH_4^+) is toxic to animals, an understanding of how *A. aegypti* larvae can survive in this high ammonia environment is important. Aquatic animals typically excrete ammonia directly into the aqueous environment and the anal papillae of larval *A. aegypti,* in part, serve this function. Previously, we have shown that two Rhesus-like ammonia transporter proteins, *AeRh50-1*, *AeRh50-2*, and a MEP/Amt ammonia transporter-like protein, *AeAmt1,* participate in ammonia excretion by the anal papillae. The present study demonstrates that a fourth ammonia transporter – like protein, *AeAmt2,* is expressed in the anal papillae epithelium where it co-localizes with V-type H^+-ATPase on the apical membrane. By feeding larvae *AeAmt2* dsRNA, protein abundance of this transporter was significantly reduced after two days. Currently, we are measuring the effects of *AeAmt2* knockdown on ammonia fluxes at the anal papillae and assessing effects on hemolymph ammonia levels and pH.

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Comparison of metabolic rate analysis and white muscle enzyme activities in lake trout (*Salvelinus namaycush*) subjected to daily acute heat challenges / Comparaison de l'analyse des taux métaboliques et des taux d'enzymes dans le muscle blanc du touladi (*Salvelinus namaychus*) soumis aux défis quotidiens de la chaleur aiguë

Cold-water piscivores have an optimum temperature range for growth well below the summer water temperatures found in nearshore regions of lakes, where they obtain most of their energy. Lake trout (*Salvelinus namaycush*), which grow optimally at ~10°C, make rapid forays into nearshore waters during summer to feed; however, temperatures in these habitats are well beyond their optimum range for growth. Given lake surface water temperatures are expected to increase with climate change, we sought to test the effects of acute temperature increases on juvenile lake trout. First, we examined the effects of increasing temperatures (10°C control and daily acute challenges of 17°C and 22°C for 5 min) on metabolic rate, feeding and growth. Metabolic rate, including standard metabolic rate (SMR), maximum metabolic rate (MMR), and aerobic scope (AS), was measured via intermittent respirometry. Lactate dehydrogenase, pyruvate kinase and cytochrome c oxidase enzyme activity were measured in white muscle to examine relationships between enzyme levels and MR estimates across treatments. Metabolic rates showed no significant difference across treatments for SMR, but higher MMR and AS in treatment fish versus control. Despite altered MMR, muscle enzyme activities were not different among treatments. Further testing is required to determine potential relationships and/or effects.

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New biomarkers of post-settlement growth in the sea urchin *Strongylocentrotus purpuratus* / Nouveaux biomarqueurs de la croissance post-établissement chez l'oursin *Strongylocentrotus purpuratus*

Sea urchins are a potentially important aquaculture species. Many sea urchin species develop via an indirect life history that is characterized by a drastic settlement process at the end of the larval period. Settlement is typically associated with high mortality rates of juvenile populations. Juveniles require several days to develop a functional mouth and digestive system. During this period, juveniles use up

larval resources transferred to the juvenile stage. This perimetamorphic period is relatively poorly understood and mechanistic insights into processes underlying the onset of juvenile feeding and metabolism have implications for the recruitment of natural population as well as aquaculture. The insulin/IGF signaling (IIS) pathway is well conserved among animal phyla and regulates system-wide functions, such as growth, reproduction, aging and nutritional status. We analyzed the expression of FoxO, TOR and ILPs in post-settlement juveniles and conjunction with their early growth trajectories. We also tested how pre-settlement starvation is affecting post-settlement expression of IIS. We found that FoxO provides a useful molecular marker in early juveniles as its expression is strongly correlated with juvenile growth. We also found that pre-settlement starvation affects juvenile growth trajectories and IIS. Our findings provide preliminary insights into the mechanisms underlying post-settlement growth and metabolism.

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Parasite transmission in a heterogenous habitat: Does final host activity predict the presence of trematode parasites? / Transmission par parasite dans un habitat hétérogène: L'activité d'hôte final prédit-elle la présence de parasites trématodes?
Parasites have evolved strategies to increase the likelihood of transmission from host to host. Some two-host life cycle parasites complete transmission when cercariae encyst in the abiotic environment to become metacercariae. Since parasite transmission depends on the host consuming metacercariae, we tested whether metacercariae were more likely to be found in areas of final host activity. We focused on the trematode *Quinqueserialis quinqueserialis* which uses a mollusc first host and a muskrat final host. Six wetlands were sampled that had high prevalence of infection in muskrats (80%, 106/133) to compare the presence and intensity of metacercariae near (experimental) and 10 m away (control) from muskrat activity. Metacercariae were only detected in 5 of 12 paired samples indicating that cysts were unevenly distributed even in areas where the final host was active (feeding or housing). In addition, we found no difference in snail, plant, or metacercaria density between the treatments. By sequencing the 28S gene region, we confirmed that *Q. quinqueserialis* is using a novel first intermediate host, *Promenetus* sp. Future experiments will determine if the metacercariae have any preferences for encysting on a particular substrate to better understand the predictability of transmission for this parasite.

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Enhancement of reproductive quality in Pacific white shrimp using algal terpenoids / Amélioration de la qualité de la reproduction dans les crevettes blanches du Pacifique à l'aide de terpénoïdes d'algues
Industry production of Pacific white shrimp relies on eyestalk ablation (ESA) to induce rapid ovarian maturation and spawning, however, ablated females frequently produce abnormal eggs, have reduced reproductive output and a significant decrease in hatching success due to a diminished transfer of acyglycerides to their eggs. We are testing whether terpenoids from algal sources can be used to shorten ovarian maturation and enhance reproduction in Pacific white shrimp. Using GC-MS, we identified the chemical nature of terpenoids produced and released by the mandibular organ (MO) of Pacific white shrimp as well as those produced in a taxonomically diverse set of microalgae. Preliminary injections of identified terpenoids in Pacific white shrimp promote changes in reproductive development. We also tested several biomarkers for shrimp reproduction, such as vitellogenin production, gonadosomatic index (GSI), reproductive output and offspring hatching success to assess the effects of exogenous terpenoids on the maturation of the shrimp reproductive axis. If terpenoids from algal food sources can be used to induce ovarian maturation at a faster or similar rate to ESA and enhance offspring quality, then this

approach can be implemented in shrimp aquaculture feeds and serve a valuable and completely non-invasive alternative to ESA.

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The role of mitochondria in hypoxia tolerance of hibernators / Le rôle des mitochondries dans la tolérance à l'hypoxie des hibernateurs
Small hibernators, such as the thirteen-lined ground squirrel, spend most of the winter season in a state of reduced metabolic rate (MR) and body temperature (T_b), called torpor. Torpor bouts are punctuated by spontaneous arousals, where MR and T_b return to euthermic levels for several hours, called interbout euthermia (IBE). This rapid increase in MR may result in transient hypoxia *in vivo,* and ground squirrel tissues are more tolerant of hypoxia and ischaemia than non-hibernating rats. This tolerance likely translates to the mitochondrial level, as mitochondria contribute significantly to energy status and reactive oxygen species (ROS) production. Mitochondrial changes that accompany hibernation, such as suppression of electron transport system complexes, may contribute to tissue-level hypoxia tolerance. I will compare anoxia tolerance of liver mitochondria isolated from hibernating ground squirrels to those of rats and summer-active squirrels. Preliminary data from ground squirrels suggests that maximal mitochondrial respiration rates decline following anoxic exposure, but there is no difference between torpor and IBE. Moreover, the magnitude of this decline is independent of the duration of anoxia. This pattern suggests a large contribution from ROS-mediated damage in anoxia, which I aim to investigate by measuring markers of oxidative damage and activity of mitochondria-specific proteases.

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Acute and chronic effects of multiple stressors on microRNA in zebrafish / Effets aigus et chroniques de multiples facteurs de stress sur les microARN dans le poisson zèbre
As the human population continues to grow, increased anthropogenic stress is placed on the aquatic environment. Pharmaceuticals, such as venlafaxine (VFX), a heavily prescribed and readily detectable antidepressant, are found downstream of wastewater treatment plants. As a result of climate change, increased surface water temperatures and decreased dissolved oxygen levels have been observed. In this study, a multi-stressor approach was used to determine the cumulative, sublethal effects of the aforementioned stressors on microRNA (miRNA) in adult zebrafish (*Danio rerio*). MiRNA are small, conserved, non-coding RNA which act by decreasing mRNA translation. This impacts the functional responses of downstream targets and is a method of environmental and epigenetic regulation of phenotypic response. Adult zebrafish were exposed to control (27°C, 100% O_2, 0 µg/L VFX) or stressed (32°C, 50% O_2, 1 µg/L VFX) conditions for 24 hours or 21 days. RNA was extracted from liver, gonad, and muscle tissue and RT-qPCR was performed on specific miRNA related to proteins that respond to hypoxia, heat stress, or contaminants. This comparison between lengths of exposure showed differences between initial and acclimated responses. Due to the conserved nature of miRNA, this will improve our understanding of the effects that environmental stressors have on epigenetic regulation.

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Examining dietary niche shifts of marine predators in response to capelin availability / Examen des changements de niche alimentaire des prédateurs marins en réponse à la disponibilité du capelan
Understanding complexities behind the structure and function of marine ecosystems are key challenges in marine ecology. In northeast Newfoundland, marine predators rely on capelin (*Mallotus villosus*), a dominant forage fish that migrates inshore to spawn in July, transforming prey biomass from low (pre-spawning) to high (spawning). During July-August, 2016, we investigated trophic shifts and dietary niche

breadth of marine predators including; non-breeding great (*Ardenna gravis*) and sooty shearwaters (*A. grisea*), breeding herring gulls (*Larus argentatus*) and great black-backed gulls (*L. marinus*), and transient humpback whales (*Megaptera novaeangliae*), using stable isotope analysis ($\delta^{15}N$, $\delta^{13}C$). We predicted that trophic position would change and niche breadth would narrow as capelin biomass shifted from low to high, reflecting higher capelin-reliance. Blood (birds) and skin (whales) samples were divided into early, mid, and late periods determined by sampling dates and tissue turnover rates. Isotopic niche breadth, quantified in *SIBER* and representing diets over 2-3 weeks, narrowed and trophic position shifted toward higher $\delta^{15}N$ and $\delta^{13}C$ for all species, though shifts occurred to varying degrees. These findings suggest the diet of marine predators shift with capelin biomass, indicating reliance and underpinning the importance of the resource.

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Characterization of the estrogen biosynthetic pathway and 17α-ethinylestradiol disruption across the ovarian maturation cycle in mummichog (*Fundulus heteroclitus*) / Caractérisation de la voie de biosynthèse des œstrogènes et de la perturbation du 17α-ethinylestradiol à travers le cycle de maturation de l'ovaire chez le choquemort (*Fundulus heteroclitus*)
17α-ethinylestradiol (EE2), an endocrine disrupting compound (EDC), is linked to organism-level (hormone physiology/development) and population-level (egg production) effects in fish. Compared to model freshwater teleosts, estuarine *Fundulus heteroclitus* (mummichog) egg production is less sensitive to EE2 exposure, which may be due to differences in ovarian physiology including 17β-estradiol (E2) regulation. Plasma and ovarian follicles from maturing mummichog were collected and grouped into five stages of maturation, where steroid production and/or gene expression in hormone signalling and steroidogenic pathways were assessed. Plasma and follicular production of E2, testosterone, and maturation inducing steroid (MIS) increased as the ovarian maturation cycle progressed, and dropped after maturation. Gene expression of selected steroidogenic enzymes and gonadotropin receptors increased throughout the cycle and dropped at late maturation; however, P450 c17 and follicle stimulating hormone receptor dropped earlier in the maturation cycle. Estrogen receptor expression showed no clear trends. Stages of follicles were exposed to 50 - 250 nM of EE2 *in vitro*; after 24 hours, P450 aromatase and luteinizing hormone receptor expression showed no exposure differences. The dissimilarity in mummichog from other model teleosts in E2 regulation plus EE2 insensitivity in maturing follicles may be partially responsible for egg production differences in estrogenic EDC exposure.

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Decoding Richardson's ground squirrel (*Urocitellus richardsonii*) alarm vocalizations / Décodage des vocalisations d'alarme de l'écureuil terrestre de Richarson (*Urocitellus richardsonii*)
Alarm calls provide neighbouring conspecifics with information regarding predatory threats, facilitating appropriate anti-predator behaviour among receivers. Among Richardson's ground squirrels (RGS), these signals are known to encode the nature of the presumptive threat (aerial versus terrestrial), response urgency, and the individual identity of the caller. Variation in call spectral structure, however, may also encode more fine-grained information regarding predator attributes and behaviour. To identify how alarm vocalizations vary in structure relative to the context surrounding predator encounters, we recorded ~300 alarm calls emitted by free-living RGS in conjunction with the appearance of 18 naturally-occurring predator and non-predator species at an established field site in Winnipeg, Manitoba. Multivariate analyses corroborate previous studies, demonstrating that RGS alarm calls fall into two main categories: "whistles" (longer-duration, stable frequency calls) and "chirps" (shorter duration, frequency-modulated calls), associated with terrestrial threats and with aerial threats respectively. Further analyses elucidate the degree to which frequency, power, and temporal characteristics within these vocalization classes vary with

predator attributes and behaviour, thus characterizing the degree of productional-specificity of RGS alarm vocalizations.

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Investigation of genes involved in testicular differentiation in the sea lamprey, *Petromyzon marinus* / Investigation des gènes impliqués dans la différenciation testiculaire chez la lamproie marine, *Petromyzon marinus*

Sex differentiation is the diversification of undifferentiated tissue into tissues and phenotypes associated with the male or female fate. In lampreys, ovarian differentiation occurs during the larval stage but testicular differentiation appears to be delayed until metamorphosis. Some of the genes involved in ovarian differentiation in lampreys have recently been identified, but nothing is known regarding the genetic factors involved in testicular differentiation. We therefore tested whether key Sertoli cell transcription factors involved in testicular differentiation and spermatogenesis in other vertebrates (e.g., *SOX9*, *DMRT1*, *WT1*, and *DAZAP1*) show differential gene expression prior to and during testicular differentiation in sea lamprey, *Petromyzon marinus*. Using qRT-PCR, we compared gene expression in ovaries and testes from larval, metamorphosing, and adult sea lamprey, and performed histological analysis on all testes. An increase in germ cells in the testes coincided with increased expression of *SOX9*, *DMRTA2* (*DMRT-family gene)* and *WT1*, and higher *DAZAP1* expression was observed during spermatogenesis and spermiogenesis. The increase in *SOX9* expression was followed by an increase in *DMRTA2*, with significantly higher expression in larval males relative to females. Thus, genes involved in testicular differentiation appear to be conserved across vertebrates, although the involvement of lamprey-specific genes cannot yet be ruled out.

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Did a million squirrels come from two? Examining inbreeding in an invasive African ground squirrel (*Atlantoxerus getulus*) / Un million d'écureuils sont-ils venus de deux? Examiner la consanguinité dans un écureuil terrestre Africain (*Atlantoxerus getulus*) envahissant

The founder effect is a phenomenon where a new population is established by a small number of individuals, resulting in a limited gene pool that is not representative of the more diverse source population. Nascent populations established by a few founders are genetically depauperate and prone to the detrimental effects of inbreeding and genetic drift. The population of Barbary ground squirrels on the island of Fuerteventura, thought to have been founded by a single breeding pair that was recently introduced from nearby Morocco, provides an opportunity to study founder effects. We predicted that a sample of the island population (N = 30) when compared to samples from the source location (N = 10) will reveal little to no variation in the mitochondrial control region. Any variation present may be indicative of a second founder event or mutation. Preliminary results show no variation in the mitochondrial DNA of the island population, but some variation within the source population. This study will give us greater insight into the effects of a single founder event on the genetic diversity of an invasive species of mammal.

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Let's break it down: Mitophagy as a mechanism for metabolic suppression during diapause in the Colorado potato beetle / Déconstruisons-le: la mitophagie comme mécanisme de suppression métabolique pendant la diapause chez le doryphore du Colorado

Temperate insects spend over half their lives overwintering, during which most enter diapause; a pre-programmed state of developmental arrest. During diapause, insects cease development and suppress their metabolism. Some diapausing insects degrade their muscles during the winter, however the role that such atrophy plays in metabolic suppression during diapause, especially at the mitochondrial level, remains unknown. In this study, we found that Colorado potato beetles (*Leptinotarsa decemlineata*) suppress their whole-animal metabolic rate by 88% in diapause. During diapause, the mitochondrial respiration rate of flight muscles is lower, and virtually undetectable compared with non-diapausing beetles. Using MitoTracker staining, transmission electron microscopy, and citrate synthase enzyme assays, we will confirm that beetle flight muscle contains fewer mitochondria during diapause, suggesting that mitophagy underlies the observed metabolic suppression, rather than active suppression of components of mitochondrial electron transport. Our comprehensive investigation of mitochondrial metabolism in a diapausing insect will provide novel insights into the physiological mechanisms of insect diapause and metabolic suppression.

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Growth and recovery of gene expression in embryonic zebrafish exposed to untreated and ozone-treated oil sands process-affected water / Croissance et récupération de l'expression des gènes chez le poisson zèbre embryonnaire exposé à l'eau non-traitée et l'eau affectée par les sables bitumineux traités à l'ozone

The extraction of bitumen from oil sands is based on a hot water alkaline extraction process. The water is commonly referred to as oil sands process-affected water (OSPW), and is stored in tailings containment structures to enable it to be recycled for various uses such as bitumen extraction, material hydro transport, and process cooling. Recent studies have focused on the use of ozonation as a tool to expedite remediation efforts, as it has previously been shown to minimize the effects of OSPW exposure on embryonic fishes. This study characterizes the effects of OSPW exposure on embryonic zebrafish by measuring gene expression and focuses on the effectiveness of ozonation as a remediation process. Zebrafish were exposed to both raw and ozone-treated treated OSPW from 0-7 days post fertilization (dpf). Embryos were transferred to clean water at 7dpf for a 4-day recovery period to monitor recovery post-exposure. Gene expression was measured immediately after exposure at 7dpf, as well as after two and four days of recovery (9 and 11dpf, respectively). Raw OSPW exposure significantly increased the expression of biotransformation enzymes cytochrome P450 1a and 1b as well as decreased the expression of genes involved in neurodevelopment and cardiac development. However, ozone-treated OSPW exposure did not significantly change expression levels of any target genes. Following two days of recovery from exposure to raw OSPW, gene expression levels were similar to control. This study shows that embryonic fish recover relatively quickly after raw OSPW exposure and that ozone-treatment aids in reducing the observed changes in gene expression. By characterizing embryonic OSPW exposure and studying recovery time we can determine the length of time that OSPW-induced effects might persist and the effectiveness of ozone-treatment as a tool for remediation.

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Use of beluga whale condition indices to meet objectives of the Tarium Niryutait Marine Protected Area in the Canadian Arctic / Utilisation des indices de condition de béluga pour atteindre les objectifs de la Zone Protégée Marine de Tarium Niryutait dans l'Arctique Canadien

The Tarium Niryutait Marine Protected Area (TNMPA) was the first Arctic MPA in Canada with the conservation objective to conserve and protect beluga whales and other marine species, their habitats, and

their supporting ecosystem in the Inuvialuit Settlement Region (ISR) of the Beaufort Sea. Indicators can be useful monitoring tools for marine management as they can represent changes in the larger ecosystem. While multiple indicators have been proposed to monitor the TNMPA, there is a gap in understanding what trends are captured by proposed indicators and how indicators can advise marine management decisions. This research evaluates the proposed health indicators of the focal species in the TNMPA, beluga whale (*Delphinapterus leucas*). The three research objectives are: (1) evaluate body condition indices by analysing data quality and identifying any significant body condition trends; (2) determine if body condition trends correlate with environmental drivers; (3) work alongside management agencies to incorporate findings into future monitoring activities. Two body condition indices were selected for analysis, blubber thickness and girth and data was collected from 1989-2016 at whaling camps in the ISR. Results will improve marine management practices in the Canadian Arctic by evaluating the effectiveness of proposed indicators to meet management objectives.

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Understanding host fish and habitat requirement helps to locate a vast population of the rare Hickorynut mussel (Unionidae) in the Ottawa River / Comprendre les poisson hôtes et les besoins d'habitat contribue à localiser une vaste population de moules Hickorynut (Unionidae) rare dans la rivière d'Ottawa
The Hickorynut mussel, *Obovaria olivaria*, is one of 55 Canadian native freshwater mussel species. It prefers deep-water habitats with strong water currents and occurs in only six rivers nationwide (status: Endangered). In Canada, the known host fish is the Lake Sturgeon, *Acipenser fulvescens*. The Ottawa River watershed has a rich freshwater mussel fauna with 21 species. Museum records point to this river as a prime location for Hickorynut populations. The goal of this study was to demonstrate that by locating the best host fish habitat, and aligning such information with habitat preferences of the Hickorynut, we would be able to find a healthy population of this rare freshwater mussel. The Finlay Island Ecological Reserve area, in the Lac Coulonge reach of the Ottawa River, was identified as ideal for sturgeon and presumably for the Hickorynut. SCUBA diving surveys revealed the presence of 5 species of mussels with the Hickorynut being the second most abundant species in the area (0.73 indiv. m^{-2}, and 22% of total live mussel counts). The Lac Coulonge reach favors the Lake Sturgeon and the Hickorynut mussel as it still a 'wild' sector of the Ottawa River that is unobstructed, with free-flowing water and no dams.

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Phenotypic plasticity in the skin of the amphibious mangrove rivulus (*Kryptolebias marmoratus*) / La plasticité phénotypique dans la peau du killi de la mangrove amphibie (*Kryptolebias marmoratus*)
We assessed the cellular effects of air exposure and salinity on the skin of the air-breathing mangrove rivulus, *K. marmoratus*. We hypothesised that rivulus survive dramatic changes in environmental salinity and air exposure because of phenotypically plastic changes in specialized ion transport cells (ionocytes) in their skin. We predicted that there would be significantly more ionocytes in the skin of fish in 1) high salinity conditions (45 ppt) and 2) during air exposure compared to when fish are in brackish water (15 ppt). We also predicted that fish in 45 ppt would have a distinctive ion signature in their skin mucous and that mucous composition would differ between air and water. Using scanning electron microscopy (SEM), we did not observe differences in ionocyte number, type or area with air exposure or salinity. Notably, fish in 45 ppt had more mucous coverage compared to fish in 15 ppt, independent of air exposure. Using SEM elemental analysis, fish in 15 ppt had distinctive skin/mucous elemental composition compared to fish at 45 ppt. Our results indicate that the skin of this amphibious mangrove fish exhibits phenotypic plasticity, critical for ionoregulation in its extreme habitat.

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The analysis of *in vivo* expression of genes that encode erythropoiesis growth factors in goldfish during *Trypanosoma carassii* infection / L'analyse *in vivo* de l'expression des gènes qui codent pour les facteurs de croissance de l'érythropoïèse pendant une infection *Trypanosoma carassii* chez le poisson-rouge

Trypanosoma carassii is a flagellated bloodstream parasite of cyprinid fish. Pathogenesis of *T. carassii* infection manifests primarily as severe anemia in experimentally infected fish. The anemia is due to a substantial decrease in the number of circulating red blood cells (RBCs) during peak parasitaemia, indicated by significant drop in the packed cell volume and total RBC counts. Erythropoietin (EPO) and its associated receptor (EPOR) are important regulators of RBC production, and have been implicated in the resolution of anemia in other model systems. We previously cloned, expressed and characterized goldfish EPO (rgEPO) and showed that the recombinant molecule increase proliferation, survival and differentiation of erythroid progenitor cells *in vitro.* In this study, we describe the changes in expression of genes predicted to be important in the resolution of the anemic state, as well as the in vivo effects of rgEPO administration, during T. carassii infection. [Funded by NSERC, Canada]

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The expression of the alternative oxidase protein in the copepod *Tigriopus californicus* in response to temperature / L'expression de la protéine oxydase alternative dans le copépode Tigriopus californicus en réponse à la température

Alternative oxidase (AOX) is a terminal quinol oxidase that is located in the mitochondrial electron transport systems of some animals. AOX is non-proton pumping and bypasses complexes III and IV and is therefore often viewed as energetically wasteful. The copepod *Tigriopus californicus* lives in intertidal rock pools along the western coast of North America and as such experiences extreme daily fluctuations in their environment. The objective of this research was to determine whether *T. californicus* expresses the AOX protein and whether this expression changes with 24 hour and 1 week exposures to a variety of temperatures (6, 15, 23, 28, and 32°C). Our results indicate that in *T. californicus*: i) AOX protein is expressed and is ~50 kDa; ii) prolonged exposure to temperatures >28°C are fatal; iii) increased AOX protein levels are seen after exposure to higher temperatures. *T. californicus* is the first animal species in which it has been demonstrated that an AOX gene is present, the expression of AOX mRNA occurs, and the expression of AOX protein has been experimentally confirmed. We therefore expect that *T. californicus* will be an excellent model system for gaining a deeper understanding of the physiological function of AOX in animals.

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Aerobic scope is significantly affected by environmentally relevant diel thermal cycles in wild Atlantic salmon / La portée aérobique est significativement affectée par les cycles thermiques journaliers pertinent à l'environnement dans le saumon Atlantique sauvage

Stable temperatures are rarely found in natural temperate ecosystems. Daily fluctuations in mean, maximum, and rate of temperature change can affect thermally sensitive ectothermic fish inhabiting these environments. Recent research suggests that physiological responses to stable temperatures are different from those of thermally cycled fish. We tested the hypothesis that environmentally relevant diel thermal cycles would influence metabolism and swim performance compared to fish acclimated to stable temperatures. We acclimated wild Atlantic salmon parr for 3 weeks at either 16°C, a daily thermal cycle of 16-21°C, or 18.5°C (the average of 16-21°C) and measured resting and maximum metabolic rate, aerobic scope, and U_{crit}. We found no differences in the resting metabolic rate among these thermal

treatments; however, there was a significant decrease in maximal metabolic rate and aerobic scope in thermally cycled fish (16-21°C). Despite this, we saw no difference in U_{crit} between groups. Our data show that, 1) aerobic metabolism in wild Atlantic salmon is significantly altered in natural diel thermal cycles, and 2) there is a disconnect between maximum metabolic rate and swimming performance. In the future, thermal laboratory experiments on wild temperate fish should incorporate diel thermal cycling to more accurately predict thermal effects in nature.

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Early growth in migratory and resident northern form Dolly Varden / Croissance précoce du Dolly Varden nordique migrante et résidentielle
Northern Dolly Varden char (Salvelinus malma malma) are listed as special concern by COSEWIC due to their limited distribution, population declines, and concerns over their ability to tolerate climate change. Research focus to date has been on the anadromous (migratory) life history form; information on resident (non-migratory) Dolly Varden and their overall role in populations is unknown, despite the fact that anadromous and resident Dolly Varden are genetically the same within rivers. Therefore, this research aims to compare resident and anadromous life histories and identify factors that contribute to the selection of different life history strategies, specifically looking at early growth rates and associated traits. Research will involve comparison of biological data collected in conjunction with ongoing stock assessment studies. Otoliths (ear-bones) will be analyzed to determine fish age and growth rates. Traits such as juvenile growth will be compared between resident and anadromous Dolly Varden within and among rivers to determine how growth influences life history selection. Results presented will include comparison of size-at-age of from three river systems. The results of this study will aid in management efforts for Dolly Varden and enhance the overall understanding of life history strategies within this species.

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High GLUT5 and GLUT1 transcript expression and capacity for rapid phosphorylation by hexokinase may facilitate rapid utilization of glucose and fructose in flight muscle of the ruby throated hummingbird (*Archilochus colubris*) / L'expression et la capacité de transcription GLUT5 et GLUT1 élevées pour une phosphorylation rapide par l'hexokinase peuvent faciliter l'utilisation rapide du glucose et du fructose dans le muscle volant du colibri à gorge rubis (Archilochus colubris)
Hummingbirds can oxidize both newly ingested glucose and fructose in flight muscle cells quickly enough to completely fuel energetically expensive hovering flight. To achieve this, hummingbirds must both transport the sugars into muscle fibers, and phosphorylate them, at exceptionally high rates. We hypothesized that hummingbird flight muscles have the highest densities of glucose and fructose transporters, as well as fructolytic enzymes, among vertebrates. We quantified sugar transporter and fructolytic enzyme transcript expression in multiple tissues of the ruby-throated hummingbird (*Archilochus colubris*), and further investigated aldolase B protein expression. We found that hummingbird flight muscle had among the highest relative transcript levels of the glucose transporter GLUT1 and the fructose transporter GLUT5 ever observed in vertebrate muscle, but low expression of ketohexokinase and aldolase B transcript. Protein levels of aldolase B were consistent with transcript density. Finally, we measured the maximal enzyme activity of hexokinase in muscle and found that fructose phosphorylation rates were among the highest ever observed. Based on these findings we formed the alternative hypothesis that hummingbird hexokinase may rapidly phosphorylate fructose *in vivo*. We find evidence supporting an unusual capacity for metabolic flexibility in carbohydrate oxidation in hummingbird flight muscle.

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Dietary overlap between ringed and harp seals in Cumberland Sound, Nunavut / Le chevauchement alimentaire entre les phoques annelés et les phoques du Groenland dans Cumberland Sound, Nunavut

As the ocean climate continues to warm, northward range expansions of subarctic species and increasing abundance of temperate species in Arctic regions are predicted. In the Cumberland Sound region, locals have reported unusually abundant subarctic forage fish, namely capelin, since 2000. Coincident with this have been increases in harp seal summer distribution in recent years, and Inuit knowledge suggests that resident ringed seal populations have been declining. We hypothesize that, when sympatric, harp seals occupy a similar ecological niche to that of ringed seals and that this may be a factor in population changes. To address this, we examined ringed and harp seal stomach contents and muscle and liver stable isotopes (SI) from tissues collected by Inuit hunters during the open-water period from 2008-2016. Stable isotope analyses suggest high dietary overlap (43% muscle SI, 56% liver SI), though there appears to be some niche partitioning based on stomach contents. A greater understanding of the impacts of range expansions on ecosystem structure and function can better inform management of subsistence- and commercially-harvested species.

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Transgenerational effects of elevated temperature on the upper thermal tolerance of *Salvelinus namaycush* and *S. fontinalis* / Effets transgénérationnels de la température élevée sur la tolérance thermique supérieure de *Salvelinus namaycush* et *S. fontinalis*

Global average temperatures are predicted to rise, however, the capacity of ectotherms to cope with climate change isn't thoroughly understood. Some can respond to long-term changes in temperature through transgenerational plasticity (i.e. thermal experiences can be passed on to offspring, improving their ability to tolerate warmer temperatures). Previous studies have seen this in fish that are warm-adapted or eurythermal, but it's unclear whether cold-adapted, stenothermal ectotherms are capable of the same response. My research examines transgenerational plasticity in *Salvelinus fontinalis* and *S. namaycush* to determine whether there's potential for these fish to cope with anticipated warming. I hypothesize that the thermal tolerance of cold-adapted, stenothermal ectotherms can be improved through transgenerational plasticity. Adult trout, acclimated to optimal and elevated temperatures, were crossed to produce offspring from parents of matched and mismatched temperatures. At the fry stage, the offspring were acclimated to an optimal or elevated temperature and their thermal tolerance was determined by measuring their critical thermal maximum and metabolic rate during an acute temperature challenge. In both species, offspring from elevated temperature parents had a higher thermal tolerance than those from optimal temperature parents. Future experiments will explore the influence of transgenerational plasticity on proximate mechanisms underlying thermal tolerance.

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The impact of raw and ozonated oil sands process-affected water exposure on prey capture and facial morphometrics in zebrafish larvae / L'impact de l'exposition de l'eau affectée par les sables

bitumineux brut et ozonisé sur la capture des proies et la morphométrie du visage chez les larves de poissons zèbres

Oil sands process affected water (OSPW) from bitumen extraction processes is stored in tailings containment facilities to enable water to be recycled for production uses including extraction, process cooling, and hydro-transport of materials. Tailings reclamation strategies include development of aquatic or terrestrial habitat that will function similar to habitat naturally found in the oil sands region. Ozone treatment, a tertiary treatment commonly applied to municipal wastewater, is being investigated in an effort to expedite remediation of OSPW to a quality acceptable for various reclamation scenarios. The impact of OSPW exposure on early developmental stages of fish has been well studied, however, the sublethal impacts of untreated and ozonated OSPW on the complex behaviors of developmentally exposed fish have yet to be determined. In this study, we examined the effect of embryological exposure to raw and ozonated OSPW on the prey capture behavior of juveniles and avoidance behavior of adults in response to predator avoidance cues. The study of complex behaviors, such as feeding behavior and predator avoidance behavior on a well characterized teleost model species, such as the zebrafish, will increase our understanding of the effectiveness of ozone treatment and further characterize the potential impacts of OSPW exposure.

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Reductions in mitochondrial reactive oxygen species mimic the anoxic response in goldfish neurons / Les réductions des espèces d'oxygène réactives mitochondriales imitent la réponse anoxique dans les neurones de poissons rouges

Although the anoxia intolerant mammalian brain undergoes neuronal death within minutes, the common goldfish *Carassius auratus*, is able to avoid cellular damage in anoxic environments. Due to the suppression of action potentials in excitatory glutamatergic neurons and the increased action potential frequency in inhibitory GABAergic neurons, the goldfish is able to decrease its overall energy expenditure and survive weeks under low oxygen conditions. In conjunction with the decreased oxygen availability complication, these animals also have to overcome the homeostatic imbalance of reactive oxygen species (ROS). ROS in low concentrations has been proposed to function as part of signal transduction pathways. Given that the cellular mechanism of anoxia tolerance in goldfish remains elusive, we proposed that low ROS contribute to the anoxic response. Using the whole-cell patch-clamp technique, we measured changes in electrophysiological parameters of cortical pyramidal goldfish neurons in response to ROS scavengers. We found that 125 uM NAC was sufficient to depolarize the membrane by 8mV, similar to the anoxic response. In addition, firing frequency decreased in pyramidal neurons by approximately 50% and whole cell conductance increased by 150%- mimicking anoxia. MitoTEMPO, a mitochondrial scavenger, exhibited similar results. Together, this implies that ROS plays a signaling role in anoxia.

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Filling in the gaps of the IMD Immune pathway of the kissing bug *Rhodnius prolixus* / Remplir les lacunes de l'IMD voie immunitaire des triatomes Rhodnius prolixus

Arthropod defenses against pathogens rely entirely on an innate immune system. Upon detection of pathogens three antimicrobial signal transduction immune pathways are activated: The toll pathway, the JAK/STAT pathway, and the immune deficiency pathway (IMD). The Toll and JAK/STAT pathways are conserved throughout all arthropods. The IMD pathway, however, is reduced and apparently absent in some hemimetabolous insects. This pathway is important in eliminating Gram-negative bacteria, and all the insects identified with “non-functional” IMD pathways rely on Gram-negative symbionts for survival. In the hematophagous hemipteran *Rhodnius prolixus*, a major vector of Chagas Disease, membrane

receptors and effector genes are present, but most signal transduction genes were not detected in the genome. Despite having a modified or absent IMD pathway, the effector immune genes normally regulated by the IMD pathway are expressed. Whether the IMD pathway functions through novel proteins linking existing IMD proteins or through a non-canonical pathway is unknown. We used HMMER, a tool to predict distant homologs, and found several genes that resemble the missing elements of the IMD pathway in *R. prolixus*. We have validated the expression of these genes and knocked down their expression using RNAi techniques, to determine where the classic IMD pathway is interrupted.

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Passive acoustic monitoring of beluga habitat use in the Mackenzie Estuary / Surveillance acoustique passive de l'utilisation de l'habitat du béluga dans l'estuaire du Mackenzie
Eastern Beaufort Sea beluga whales (*Delphinapterus leucas*) form large summering aggregations in the Mackenzie Estuary. The timing and location of beluga presence in the estuary is well documented; however, drivers for temporal and spatial patterns of occurrence are not understood. Recent research identified 'hotspots' within the estuary where belugas were likely to congregate year after year, providing a starting point to closely examine beluga habitat use. The objective of this study is to assess abiotic drivers for beluga occurrence in Kugmallit Bay (in the Mackenzie Estuary), by examining localized patterns of presence/absence alongside environmental (wind speed, wind direction) and oceanographic (temperature, depth, salinity) data. Passive acoustic monitoring has previously proven useful in determining localized presence/absence of belugas in the estuary. As such, five hydrophones will be moored with oceanographic sensors in Kugmallit Bay during the summer. Mooring placement will be based on beluga hotspots, unique oceanographic features, and traditional knowledge. A nearby weather station will record wind climatology. With rapid climate change, and increasing industrial activities, an understanding of drivers for habitat use within the estuary is needed. This knowledge will be used to assess climate change impacts, evaluate industrial proposals, and formulate management plans for Beaufort Sea beluga whales.

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The chromosomal inversion *In(3R)Payne* underlies clinal variation in body size among North American populations of *Drosophila melanogaster* / L'inversion chromosomique *In(3R)Payne* est à la base de variation clinale de la taille du corps chez les populations nord-américains de *Drosophila melanogaster*
Chromosomal inversions are thought to play an important role in adaptation. In *Drosophila melanogaster*, the widespread inversion polymorphism *In(3R)Payne* shows clinal variation on at least two continents, Australia and North America. The existence of parallel latitudinal clines suggests *In(3R)P* may be maintained by spatially varying selection. As several fitness-related traits likewise display latitudinal clinal variation, it is tempting to speculate that *In(3R)Payne* might underlie some of these traits. Here, we investigate whether *In(3R)P* affects body size, development time, chill coma recovery, and diapause incidence using homokaryon lines carrying *In(3R)P* or the standard arrangement. For the first time, we report that *In(3R)P* contributes to the body size cline along the North American east coast, consistent with previous findings from the parallel but evolutionarily independent Australian cline. Inversion lines are smaller than standard lines across both sexes. *In(3R)P* also potentially contributes to incidence of reproductive diapause. By contrast, development time and chill coma recovery were unaffected by karyotype. Our results provide compelling evidence that *In(3R)P* has parallel adaptive effects on size variation across two continental clines. In addition, the fact that *In(3RP)* might affect several clinal fitness traits may be consistent with the idea that inversions can function as life history "supergenes".

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Trout enterocyte-macrophage co-culture system using RTgut-GC and RTS11-GFP cell lines as in vitro models to study gut physiology and enteritis / Système de co-culture entérocyte-macrophage des truites utilisant les lignées cellulaires RTgut-GC et RTS11-GFP comme modèles in vitro pour étudier la physiologie intestinale et l'entérite

The development of a permanently transfected monocytic/macrophage cell line derived from Rainbow trout spleen, expressing GFP (RTS11-GFP) opens many possibilities for physiological studies of immune cell interactions with other cell types. RTS11-GFP was developed over 7 years ago through nucleofection of RTS11, an already established trout monocyte/macrophage cell line that has been well characterized over its lifespan of 20+ years. In the present study we explore enterocyte-macrophage interactions using co-cultures of the established trout gut cell line RTgut-GC with RTS11-GFP and investigate effects of antioxidants, pesticides and fish feed components on their ability to enhance or disrupt the model enteroid barrier set-up with the two cell lines. Intraepithelial macrophage projections, changes in phagocytic ability and stabilized enteroid barrier function measuring trans-epithelial resistance, could be monitored in these co-culture systems using trans-well epithelial-immune cell set-up. This co-culture system provides a practical and reproducible culture model to investigate suitability of novel fish feed components to enhance or disrupt fish intestinal physiology and host responses that could prevent development of enteritis in novel feed formulation trials.

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Responses of a locust motion sensitive visual interneuron to changes in approaching object velocity / Réponses d'un interneurone visuel sensible au mouvement acridien à des changements dans l'approche de la vélocité des objets

Locusta migratoria is an established neuroethological system for the study of sensory coding within a well-defined motion-sensitive visual neural pathway consisting of two identified interneurons, the Lobula Giant Movement Detector (LGMD) and its postsynaptic partner, the Descending Contralateral Movement Detector (DCMD). The DCMD connects to thoracic interneurons and motor neurons and is implicated in initiating avoidance behaviours. The present study aims to determine if the DCMD looming response differs when approaching objects change velocity. We presented locusts with looming stimuli that increased or decreased in speed during approach. We presented stimuli against simple (white) or flow field backgrounds. Preliminary results suggest that the DCMD firing rate, number of spikes and peak width at half height decreased with an increase in velocity and decreased further when velocity was reduced during approach. Interestingly, the presence of a flow field mitigated velocity change-dependent alterations of DCMD activity. The peak firing rate was delayed in response to stimuli altering their velocity. These results suggest that this motion-sensitive pathway is capable of actively adapting to objects that alter their velocity during approach.

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Unraveling a complex puzzle: cryptic trematode parasite diversity in birds from Manitoba wetlands / Se démêler d'un casse-tête complexe: diversité de parasites du trématode cryptique chez les oiseaux des zones humides du Manitoba

Recent reviews have found that there are more cryptic species complexes present in trematodes relative to other helminth parasites. The presence of cryptic species indicates that estimates of trematode species diversity and host specificity are inaccurate. These traits are fundamental characteristics that are critical to understanding the evolutionary ecology of parasites. Genetic sequencing has suggested several cryptic complexes in echinostome trematodes. Many species in this group have broad geographic distributions

and parasitize a wide array of vertebrate hosts such as birds and mammals. However, if cryptic species are present, each species within a complex may have a more restricted geographic and host range. To better understand the geographic and definitive host range of echinostomes, we surveyed 63 birds from 16 species in four Manitoba wetlands. Echinostomes were isolated from 12 infected hosts from four different species. Nineteen adult worms were sequenced at a nuclear and mitochondrial gene, which revealed three species considered to be part of cryptic complexes: *Echinostoma revolutum*, *Echinostoma trivolvis* lineage A and *Echinostoma robustum.* By integrating molecular analysis with morphological data and host use information, we will determine host specificity of echinostomes, which will allow us to better understand processes underlying parasite diversity and ecology.

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The relationship between life stage-dependent changes in ammonia excretion patterns and Rhesus glycoprotein distribution in the gills of an ancient vertebrate / La relation spécifique au stade de vie entre les modèles de changements d'excrétion de l'ammoniac et la distribution de glycoprotéines Rhésus dans les branchies d'un ancien vertébré

Sea lamprey (*Petromyzon marinus*) are jawless vertebrates that spend their first 3-7 years as filter-feeding larvae before metamorphosing into free swimming parasitic juveniles that migrate downstream to feed on the protein-rich blood of fishes. They then migrate back upstream to spawn and die. The increased protein intake during the parasitic phase is accompanied by increases in both amino acid catabolising capacity and nitrogenous waste (N-waste) excretion rates. However, it is not known if these changes in life stage, diet, and N-waste excretion rates are accompanied by changes in the abundance and distribution of Rhesus glycoproteins, transport proteins known to facilitate ammonia excretion in other fishes. Accordingly, we collected gills from larvae, metamorphosing (stages 1-7), and post-metamorphic juveniles, and used heterologous Rhesus glycoprotein antibodies for immunohistochemical localization. This analysis revealed Rhcg-like staining in the gills suggesting that, like other fish species, sea lamprey use Rhesus glycoproteins to excrete ammonia. Subsequent analysis will determine if these transporters are upregulated throughout metamorphosis, increasing the lamprey's capacity to excrete N-wastes during life stages where large amounts of protein rich blood are consumed. The information from my study will provide insight into the evolution of N-waste excretion mechanisms in the jawless and jawed fishes.

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Does acclimation temperature influence the cellular response to an acute heat shock in a basal chordate, the sea lamprey (*Petromyzon marinus*)? / Est-ce que la température d'acclimatation influence la réponse cellulaire à un choc thermique aigu chez un chordé primitif, la lamproie marine (*Petromyzon marinus*)?

Sea lamprey (Petromyzon marinus) are a basal craniate, and a successful invasive species in the Laurentian Great Lakes which, prior to an intensive international control effort, decimated the fisheries. A characteristic which likely facilitated their range expansion, and may enable future expansions under current warming trends, is their broad thermal tolerance. Recent sequencing of the sea lamprey transcriptome has allowed for a more comprehensive exploration of the genetic control of the heat shock response (HSR) in sea lamprey than was previously feasible. In the proposed study, ammocoetes will be acclimated to 5, 12, or 19^{o}C and subsequently exposed to one of three different heat shock treatments for one or four hours. Differential expression of specifically targeted genes associated with the HSR will be evaluated using qPCR. These will include heat shock proteins (hsps), immediate early genes, genes associated with apoptosis pathways (casps), cell cycle regulation (cdks), and proteolysis (ubs). Evaluating the genetic response to an acute stressor in this generalist may shed light on some of the physiological

characteristics of successful invasive species from a cellular perspective. Comparing the response to that of more derived teleosts will provide an evolutionary perspective of the HSR in vertebrates.

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Life on the land: Thermoregulatory decisions in the mangrove rivulus / La vie sur la terre: Les décisions thermorégulatrices chez le killi des mangroves

The Mangrove rivulus, *Kryptolebias marmoratus*, emerges onto land when encountering conditions such as elevated water temperature, decreased dissolved oxygen, or elevation in hydrogen sulphide. We previously suggested that this emergence behaviour was thermoregulatory in nature, since on land, the fish could utilize evaporative cooling. In the wild, these fish inhabit small, stagnant bodies of water that are prone to frequent flooding and drying, and during the dry season, oxygen levels decline, while noxious gases rise. The mangrove rivulus survives for weeks on land through their enhanced cutaneous respiration capacity. Whether they choose to emerge simply to cool down or or to avoid unfavourable aquatic conditions is unknown. Using a split-choice thermal gradient, providing fish with voluntary access to a range of temperatures in water and on land, we demonstrated that 25°C acclimated fish of two strains (Belize and Florida) preferred lower temperatures on land (~25°C) compared to water (~28°C). Both strains voluntarily emerged onto land; the Belize strain only did so ~2% of the time, the Florida strain ~10% of the time. A subsequent, short-term (1 week) 30°C water acclimation eliminated this land vs. water thermal preference difference, such that fish selected similarly warm temperatures (~28°C) when provided access to a land and water temperature gradient. We conclude that terrestrial emersion behaviour in the mangrove rivulus may serve thermoregulatory needs, but is itself a plastic behaviour.

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Characterization of the gills of the Louisiana red swamp crayfish (*Procambarus clarkii*) / Caractérisation des branchies de l'écrevisse des marais rouges de la Louisiane (Procambarus clarkii)

Procambarus clarkii is a freshwater crayfish species native to Louisiana in the Atchafalaya River Basin and contributes to 90% of Louisiana's crayfish export. This industry grosses 181 million US dollars annually. Previous research on this species has identified two different cell morphologies in the trichobranchiate gills. Inner filaments located towards the base of the gill, consist of a thicker epithelium, are more mitochondria rich and have more infolding than the outer filaments. Dissections of the inner filaments, outer filaments and lamella of 8 crayfish were conducted and RNA was isolated for transcript abundance comparisons of several osmoregulatory genes of interest. Whole animal ammonia excretion, an important function of the gills, in response to acute exposure to buffered water, and 7ppm S. NaCl was also investigated. There was a significant decrease in ammonia excretion when animals were placed in buffered solution (p-value = 0.0133, N=5) and a trend toward reduced excretion in slightly saline water (p-value= 0.06, N=5). Silver staining indicated that the inner filament regions showed higher Cl^- concentrations compared to the outer filament and lamella. Initial PCR results confirmed transcript expression of Na^+/K^+ -ATPase, H^+-ATPase, Rhesus protein, NHEs and AE in all three branchial regions.

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How do cuttlefish (*Sepia officinalis*) respond to a moderate hypoxia exposure? Insights from whole animals and isolated tissue / Comment la seiche (Sepia officinalis) répond-elle à une exposition modérée à l'hypoxie? Perspicacité des animaux entiers et des tissus isolés

Naturally occurring hypoxic conditions in warm coastal waters may increase in frequency and severity in the near future. Understanding how marine organisms respond to ecologically relevant hypoxia is therefore important. For sepioids like the common cuttlefish (*Sepia officinalis*) suboptimal dissolved oxygen content (DO_2) is thought to range from 65% to 35%. We challenged cuttlefish for one hour to 50% DO_2 and observed a decrease in oxygen consumption of 37% associated with an 85% increase in ventilation rate. Octopine levels, a marker of anaerobic metabolism, increased by a small but significant level in mantle, whereas there was no change in gill or heart levels. Similarly, the hypoxic period did not result in changes in HSP70 or polyubiquinated protein levels in mantle, gill, or heart. It seems that although metabolic rate decreases there is only a minor increase in anaerobic metabolism and no biochemical changes that are hallmarks of alterations in protein trafficking. Experiments with isolated preparations of mantle, gill, and heart suggest that pharmacological inhibition of protein synthesis could decrease oxygen consumption by 32% to 42% or Na^+/K^+ ATPase activity by 24% to 54% dependent upon tissue type. The decrease in whole animal oxygen consumption is potentially the result of a controlled decrease in the energy demanding processes of both protein synthesis and Na+/K+ ATPase activity.

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The interactive effect of digesting a meal and thermal acclimation on maximal enzyme activities in the gill, kidney, and intestine of goldfish (*Carassius auratus*) / L'effet interactif de la digestion d'un repas et de l'acclimatation thermique sur les activités enzymatiques maximales dans les branchies, les reins et l'intestin des poissons rouges (*Carassius auratus*)

Ectotherms can compensate for changes in environmental temperatures at one or more biological levels, or allow temperature to dictate processes such as enzyme activities. Digestion also alters enzyme activities, therefore the interacting effect of thermal acclimation (8°C and 20°C) and digesting a single meal on maximal enzyme activities in three tissues of the goldfish (*Carrassius auratus*) was investigated. Warm-acclimation reduced branchial Na^+, K^+, ATPase (NKA) activities, but did not affect renal NKA, nor glutamate synthetase (GS). Citrate synthase (CS) and pyruvate kinase (PK) activities were not altered in any tissue. An enhanced capacity for increasing post-prandial enzyme activities was observed in the intestines and gills for NKA, and in intestinal GS in warm-acclimated fish. Digestion had no impact on renal NKA nor GS activities. NKA and GS were the only enzymes investigated that showed intestinal zonation, with their activities increasing toward the distal intestine, with warm-acclimated animals demonstrating a more distinct zonation pattern for NKA than for GS. However, this amplified capacity was ameliorated by alterations in tissue protein content. Amplified NKA activity may ultimately have implications for ATP demand in these tissues, while increased GS activity may beneficially increase intestinal ammonia-detoxifying capacity. Funded by an NSERC Discovery Grant.

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Background trace element concentrations in Manitoba water bodies and their relationship to fish otolith chemistry / Concentration des éléments traces du fond dans les masses d'eau du Manitoba et leur relation avec la chimie des otolithes de poisson

The Coordinated Aquatic Monitoring Program (CAMP) is a long-term, system-wide water management program for much of Manitoba Hydro's impounded and many of Manitoba's non-impounded sub-basins.

Two main areas of monitoring in CAMP include water quality (e.g., trace element measures) and fish communities, which involves the archiving of fish age structures (e.g., otoliths). Fish otoliths (or ear bones) are metabolically-inert, calcified structures used to potentially determine trace element exposure history over time through studying otolith chemical signatures. The CAMP program presents a unique opportunity to test several hypotheses around trace elements in water and corresponding otolith trace element concentrations. In this study, CAMP water quality data from 2008-2014 (for the elements Ba, Mn, Sr, Mg and Na) was compared to otolith chemistry of two commercially relevant fish species, lake whitefish (*Coregonus clupeaformis*) and walleye (*Sander vitreus*) (caught in 2013-2014) from multiple CAMP water bodies. The effect of fish species, underlying water body geology, and water body impoundment status were analyzed for their influence on the observed otolith signature. Preliminary results indicate walleye take up Ba and lake whitefish take up Mn and Sr more so than each other in the same waterbody. Also that Na and Mg water concentrations correspond poorly to otolith concentrations.

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Man's best friend or an uneasy ally? Stress responses of domestic dogs (*Canis familiaris*) to human hugging / Le meilleur ami de l'homme ou un allié mal à l'aise? Les réponses de stress des chiens domestiques (*Canis familiaris*) aux étreintes humaines

Stanley Coren sampled 250 still photographs of humans hugging pet dogs from the internet, and, based on the fact that 81.6% of photographs were scored as showing at least one behavioral indicator of stress or anxiety, concluded that human hugging proves stressful for dogs. This result is surprising considering the intimate and long-standing evolutionary relationship between humans and dogs. Further, Coren's study did not account for the context in which the hug occurred or the dog's relationship to the human hugger. We thus tested whether hugging of dogs by either the dog's owner or a stranger activates the dog's physiological stress response (i.e. the hypothalamic-pituitary-adrenal axis) by collecting saliva and quantifying salivary cortisol concentrations. Saliva was collected from 20 dogs prior to hugging and after hugs administered by the dog's owner or a stranger in alternating order. Behavioural responses to hugs were video recorded and owners completed a pre-trial questionnaire to document the history, individual characteristics, and behavioral propensities of each subject dog. Our findings definitively address whether human hugging stresses dogs based on physiological and behavioural indicators of stress, elucidate whether owner- versus stranger-administered hugs differentially stress dogs, and reveal dog-specific correlates of stress responses to human hugging.

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Evaluating the effectiveness of headstarting for Wood Turtle (*Glyptemys insculpta*) recovery / Évaluation d'un programme d'élevage et réintroduction pour récupérer une population de Tortue de Bois (*Glyptemys insculpta*)

Headstarting is a conservation tool applied to turtles that includes collection of wild eggs, hatching and rearing the hatchlings in captivity for some period of time, and then releasing them back into the wild once they have reached a size that should increase survivorship. A population of endangered Wood Turtles (*Glyptemys insculpta*) declined by 70% after a suspected poaching event in the mid-1990s. A population viability analysis determined that extirpation was inevitable if no intervention was undertaken and so a headstarting project was initiated in 2003 and the first cohort was released in 2005. Our objective is to model population demographic parameters to evaluate recovery efforts that have occurred to date and determine the next phase of recovery. To meet our goal, we are conducting intensive mark-recapture surveys, along with radio telemetry of wild adult turtles (n=20), headstarted turtles (n=30), and wild

hatchlings (n=15). Given the growing number of headstarting projects globally, our study will aid in bettering the practice.

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Characterization of the ΔNHX3 knock-out mutant in *C. elegans*: How to create a zombie / Caractérisation du mutant ΔNHX3 dans *C. elegans*: comment créer un zombie

In order to evaluate the role of the hypodermally expressed cation-proton exchanger NHX-3 in *C. elegans*, hypodermal $H^+$and Na^+ fluxes (SIET) as well as whole body ammonia excretion rates were assessed in wild-type worms (N2) and a NHX-3 knock-out mutant (ΔNHX-3). Compared to N2 H^+ and ammonia excretion rates decreased by ca. 48% and 30%, respectively, while Na^+ uptake rates remained unchanged. ΔNHX-3 exhibited also significant reduced cytochrome c oxidase activity. More importantly, out of the 8 remaining other NHX proteins expressed in *C. elegans,* 7 showed vastly different mRNA expression levels when compared to the wild-type. Also, two out three cation proton antiporter from the CPA-2 family (NHA-1, NHA-3), as well as the V-ATPase showed reduced mRNA expression levels. More puzzling data: In contrast to findings in N2, exposure to EIPA caused a significant increase in H^+ and ammonia efflux rates. Application of amiloride, a non-specific blocker for Na^+ channels and NHEs caused an increase in hypodermal Na^+ up-take by ca. 200%. These data demonstrate clearly that extreme care must be taken when knock-out mutants are employed to evaluate the function of the target protein and its role in a physiological process.

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Characterisation of the HIF1a cellular pathway and its response to hypoxia during lake whitefish development / Caractérisation de la route cellulaire de HIF1a et sa réponse à l'hypoxie pendant le développement du grand corégone

Exposure to hypoxia during development has been shown to activate the hypoxia-inducible-factor 1(HIF-1) cellular pathway but little is known about the physiology of low oxygen tolerance in fish embryos. This study assessed the ontogeny of the HIF1a cellular pathway in embryonic lake whitefish (*Coregonus clupeaformis*) (LWF), and its response to hypoxia. Changes in gene expression were quantified for HIF1a and known HIF1a target genes: Insulin like growth factor binding protein 1 (IGFBP1), vascular endothelial growth factor A (VEGFa), erythropoietin (EPO) and lactate dehydrogenase A (LDHA), as well as heat shock proteins (HSP) 70, 90α and 90β. LWF embryos were exposed to one of three treatments: severe, mild and control for 6 hours at 21, 38, 63, 83 and 103 days post fertilization (dpf). Results indicate that HIF1a mRNA levels are stable throughout embryogenesis until 103dpf where they decline. In low oxygen environments, HIF1a mRNA is down-regulated compared to control until 103 dpf, where they increase significantly. IGFBP1 levels increase throughout embryogenesis and are first up-regulated in response to low oxygen at 38 dpf. HSP70 was significantly upregulated in response to low oxygen at all time-points studied during embryogenesis. Data on EPO, VEGFa, LDHa, HSP90α and HSP90β will also be presented.

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Population genetics analyses assist in fisheries management of Inconnu (*Stenodus leucichthys*) in Great Slave Lake, Northwest Territories / Les analyses de génétique de la population aident à la gestion des pêches d'Inconnu (*Stenodus leucichthys*) dans Great Slave Lake, Territoires du Nord-Ouest

Inconnu (*Stenodus leucichthys*) are important in commercial and subsistence fisheries in Great Slave Lake (GSL). Intense fishing pressure has caused some Inconnu stocks to decline while others are thought to be healthy and productive. However, areas experiencing higher catches could be caused by the expansion of productive stocks, effectively concealing a decline in a genetic stock. We hypothesized that each river with a population of Inconnu migrating into GSL represents a discrete genetic stock due to Inconnu philopatry. From 1992 to 2016, Inconnu tissue samples (muscle/finclips) were collected in GSL and eight lakes and surrounding river systems. Multilocus genotypes for >800 fishes were generated from 17 microsatellite loci. There was evidence for population structuring by sampling location according to pairwise genetic differentiation and Bayesian clustering analysis. The latter results indicated at least five genetic populations, and evidence of unsampled populations from unknown sources. Within the eight locations, most loci were in Hardy-Weinberg equilibrium (HWE) though overall four locations were not in overall HWE. This research will assist future management decisions for an important Canadian fishery by estimating the number of distinct genetic stocks and their geographic distributions, and help determine whether or not a genetic stock has declined.

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Stress and fitness implications of central versus peripheral territories in Richardson's ground squirrels (*Urocitellus richardsonii*) / Les implications du stress et de la condition physique des territoires centraux versus périphériques dans les écureuils terrestres de Richardson (*Urocitellus richardsonii*)

Selfish herd theory predicts that central individuals benefit disproportionately over individuals on the edge of a group. Higher predation pressure at a group's edge should decrease survivorship and reproductive output of peripheral group members through both direct and indirect effects predator encounters. Predation is a major source of mortality for ground-dwelling squirrels, while non-lethal encounters with predators have been proposed to affect prey through increased activation of the hypothalamic-pituitary-adrenal axis, resulting in lower reproductive output. Richardson's ground squirrels (*Urocitellus richardsonii*) defend territories within their colonies, and thus may experience differential fitness outcomes based on the location of their territory within the colony. To examine this, we recorded ground squirrel alarm vocalizations with Wildlife Acoustic SM3 audio recorders placed at centre and edge locations of a colony to estimate predation pressure and predator type (airborne vs. terrestrial), quantified faecal glucocorticoid metabolite concentration as a measure of stress, and tracked offspring production and survivorship of females and their young for a year. The results of this project quantify the indirect effects of predator presence on members of this social, group-living species, and provide insight into the factors promoting the evolution and maintenance of sociality.

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Glucose metabolism and adaptive sex allocation by Richardson's ground squirrels, *Urocitellus richardsonii* / Le métabolisme du glucose et l'allocation adaptative du sexe par les écureuils terrestres de Richardson, *Urocitellus richardsonii*

Circulating glucocorticoid and blood glucose levels during early gestation affect offspring sex ratio in many mammalian species. These findings are consistent with the glucose metabolism hypothesis as a mechanism promoting adaptive sex allocation, but are correlative. We experimentally manipulated blood glucose concentrations in otherwise free-living Richardson's ground squirrels, *Urocitellus richardsonii* by surgically implanting osmotic minipumps releasing controlled glucose doses. Subject squirrels received a high glucose dose (7.14 mg/kg/day; n = 4), moderate glucose dose (3.57mg/kg/day dose; n = 3), normal saline (n = 4), or no implant (n = 3). Blood glucose concentrations of subjects were measured every 4th day throughout gestation and lactation with a hand-held glucometer and fecal samples were collected to assess fecal glucocorticoid levels. While biased offspring sex ratios were detected for certain litters, offspring sex ratio was unrelated to glucose treatment. Further, no difference in the number of placental scars and the number of offspring weaned was detected. Our data thus fail to support the glucose metabolism hypothesis, though our negative results may be attributable to the squirrel's ability to regulate blood glucose levels rather than any failure of the mechanism itself. Pancreatic tissues were collected to examine this possibility, but analyses are presently incomplete.

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How *Drosophila* become winter warriors: Describing the ionoregulatory adjustments that underlie cold acclimation in *Drosophila* / Comment les *Drosophiles* deviennent des guerriers d'hiver: Décrivant les ajustements ionorégulateurs qui sous-tendent l'acclimatation à froid chez la drosophile

At low temperatures *Drosophila*, like most insects, lose the ability to regulate ion and water balance across the gut epithelia, which leads to a lethal accumulation of K^+ in the hemolymph (hyperkalemia). Cold-acclimation, prior to low temperature exposure, can mitigate or entirely prevent these ion imbalances, but the physiological mechanisms that facilitate this process are still not understood. Here, we investigate the potential modulation of Na^+/K^+-ATPase (NKA) and V-Type H^+-ATPase (VA) activities in the gut and the Malpighian tubules of *Drosophila* in cold acclimation. Upon adult emergence, *D. melanogaster* females were subjected to seven days at 25°C (warm acclimation) or 10°C (cold acclimation). Cold-acclimation reduced the critical thermal minimum (CT_{min}), sped up recovery from chill coma, improved survival following prolonged cold stress, and mitigated cold-induced hyperkalemia. NKA and VA activities were lower in the midgut and the Malpighian tubules of cold-acclimated flies. This coincided with increased Malpighian tubule secretion rates across a variety of thermal conditions and the maintenance of K^+ secretion at low temperatures. Our results suggest that the modification of Malpighian tubule activity mitigates cold-induced hyperkalemia in cold-acclimated flies and that this process is not driven by increased VA and NKA activities in the Malpighian tubules.