LIVING EARTH COLLABORATIVE
CENTER FOR BIODIVERSITY

December 14, 2021

Department of Integrative Biology
University of Colorado Denver
Denver, CO 80204

Dear Dr. Greene & members of the search committee,

I am writing to apply for the position of Assistant Professor in Physiology. I am an organismal biologist who studies physiological adaptation to historical and future environments. Currently, I am a Biodiversity Post-Doctoral Fellow with the Living Earth Collaborative at Washington University in St. Louis. Before obtaining this competitive fellowship, I earned a Ph.D. in Biology from Case Western Reserve University in 2019.

The research program that I will bring to CU Denver focuses on a long-standing question in biology: **how is adaptation in one life-cycle stage constrained by natural selection in other stages?** Through my research on this topic, I have studied many physiological processes in dragonflies and amphibians, including thermal physiology, immune defense, fat storage, and yolk allocation. By integrating experimental, comparative, and novel citizen-science approaches, my work reveals: 1) when life stages can adapt freely from each other; and 2) the consequences when life stages do not decouple. To support my eco-physiological research, I have been awarded **grants and competitive fellowships totaling >$310,000**. I have also published **15 first-author articles (21 total) in leading journals** such as *Proceedings of the National Academy of Sciences*, *Ecology Letters*, and *Biology Letters*. Furthermore, my research on thermal adaptation has garnered international press attention (e.g. CNN, The Guardian, Smithsonian Magazine) and has been adapted for teachers to use in K-12 classrooms (via *Science Journal for Kids*).

Building on the foundation of my prior research, my lab at CU Denver will be well positioned to become a **field leader in eco-physiological adaptation to historical and future environments.** My framework for integrating research on natural selection, physiology, development, and ecological diversification across the dragonfly life cycle will allow my lab to explore constraints on adaptation in ways that few other systems can. The implications of my group's work will further ensure that we can apply for grants from basic and applied funding sources, including NSF, NASA, and EPA. The focus of this program will complement the department's expertise in comparative physiology, behavioral ecology, molecular evolution, and global change biology. The local odonate richness and proximity to diverse natural and human-impacted habitats also make CU Denver well suited for establishing my lab's eco-physiological research.

My research program has already **provided experience for 18 students, including 12 from historically excluded groups**. Because my research uses many approaches that can be completed from anywhere or at any time, my lab at CU Denver will be able to offer more equitable opportunities to students whose schedules have precluded lab-based experiences. CU Denver's financial support for student research (e.g. Undergraduate Research Opportunity Program) will also be an asset as I work to ensure students from less-privileged backgrounds do not have to sacrifice income in order to gain research experience in my lab.

In my prior positions, I gained teaching experience in eco-physiology, biostatistics, and ecology. For biostatistics, I earned a departmental teaching award. I also worked as a substitute teacher in public schools across 4 years. Furthermore, to broaden my pedagogical impact, I am involved in a research project that examines learning retention of students in a physiology course. At CU Denver, I could **develop or contribute to courses in animal physiology, eco-physiology, evolution, biostatistics, and global change biology**.

Accompanying this letter, you will find my CV; research statement; DEI statement; teaching statement; and contact information for three professional references: Ryan Martin (ram225@case.edu), Kasey Fowler-Finn (kasey.fowlerfinn@slu.edu), and Howard Whiteman (hwhiteman@murraystate.edu).

I thank you for considering my application, and I look forward to your decision.

Michael P. Moore, Ph.D.
Biodiversity Post-Doctoral Fellow
Living Earth Collaborative, Washington University in St. Louis

MICHAEL P. MOORE, Ph.D.

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APPOINTMENTS

2019 - Present	**Biodiversity Post-Doctoral Fellow**	**Living Earth Collaborative** Washington University in St. Louis Tyson Research Center Saint Louis University

EDUCATION

2019	**Ph.D. Biology**	**Case Western Reserve University**
2014	**M.S. Watershed Science**	**Murray State University**
2011	**B.S. Biology *Cum Laude***	**Gonzaga University**

PEER-REVIEWED PUBLICATIONS (Links to representative media coverage below)

§ - equal contribution. 1 - high-school student. 2 – undergraduate student. ‡ - corresponding, but not first, author.

View articles on Google Scholar: https://scholar.google.com/citations?user=Na6MQ4QAAAAJ&hl=en&oi=ao

[21] **Moore MP**, Hersch K[2], Sricharoen C[2], Lee S[2], Reice C[2], Rice P[2], Kronick S[2], Medley KA, and Fowler-Finn KD. 2021. Sex-specific ornament evolution is a consistent feature of climatic adaptation across space and time in dragonflies. ***Proceedings of the National Academy of Sciences*** 118(28): e2101458118.

* Article chosen to be one of the issue's featured articles - https://www.pnas.org/content/118/28/eiti2821118
* Research highlighted by *Nature Climate Change* – https://rdcu.be/cvMaF
* Press coverage by CNN, The Guardian, The Hill, Environment & Energy News, Smithsonian Magazine, St. Louis Post-Dispatch, The Times of India, Natural History Magazine, New Scientist, Science News, and many other outlets
* Interviewed on public radio (KWMU – St. Louis) and the "Weather or Not" Podcast (WSVN – Miami)
* Adapted for K-12 classrooms by *Science Journal for Kids* - https://sciencejournalforkids.org/wp-content/uploads/2021/10/dragonfly_article.pdf

[20] **Moore MP**. 2021. Larval habitats impose trait-dependent limits on the direction and rate of adult evolution in dragonflies. ***Biology Letters*** 17(5): 20210023.

[19] **Moore MP** and Martin RA. 2021. Natural selection on adults has trait-dependent consequences for juvenile evolution in dragonflies. ***The American Naturalist*** 197(6): 677-689.

[18] Leith NT, Macchiano AT, **Moore MP**, and Fowler-Finn KD. 2021. Temperature impacts all behavioral interactions during insect and arachnid reproduction. ***Current Opinions in Insect Science*** 45: 106-114

[17] **Moore MP**, Pechmann JHK, and Whiteman HH. 2020. Relative size underlies alternative morph development in a salamander. ***Oecologia*** 193(4): 879-888.

[16] Lis C[1], **Moore MP**‡, and Martin RA. 2020. Warm development temperatures induce non-adaptive plasticity in the intrasexually selected colouration of a dragonfly. ***Ecological Entomology*** 45: 663-670.

[15] **Moore MP** and Martin RA. 2019. On the evolution of carry-over effects. ***Journal of Animal Ecology*** 88(12): 1832-1844.

* Finalist for the Sidnie Manton Award – A biennial competition for the best review paper by an early career researcher in *Journal of Animal Ecology*

[14] **Moore MP**, Whiteman HH, and Martin RA. 2019. A mother's legacy: the strength of maternal effects in animal populations. ***Ecology Letters*** 22(10): 1620-1628.

[13] Lackey ACR, **Moore MP**, Doyle J, Gerlanc N, Hagan A, Geile M, Eden C, and Whiteman HH. 2019. Lifetime fitness, sex-specific life history, and the maintenance of a polyphenism. ***The American Naturalist*** 194(2): 230-245.

[12] Khazan ES, Verstraaten T, **Moore MP**, and Dugas MB‡. 2019. Nursery crowding does not influence offspring, but might influence parental, fitness in a phytotelm-breeding frog. ***Behavioral Ecology and Sociobiology*** 73: 33.

[11] **Moore MP**, Lis C[1], Gherghel I, and Martin RA. 2019. Temperature shapes the costs, benefits, and geographic diversification of sexual coloration in a dragonfly. ***Ecology Letters*** 22(3): 437-446.

* Press coverage by MSN, the Daily Kos, ScienceDaily, the iNaturalist blog, Amore a Quattro Zampe (Italian), and several other outlets
* CWRU Department of Biology Outstanding Paper Award – 2nd Place – 2019
* Highlighted as an exciting new use of iNaturalist data on the citizen-science SciStarter Podcast (~26 minute mark)

[10] **Moore MP**, Lis C[1], and Martin RA. 2018. Immune deployment increases larval vulnerability to predators and inhibits adult life-history traits in a dragonfly. ***Journal of Evolutionary Biology*** 31(9): 1365-1376.

[9] **Moore MP** and Martin RA. 2018. Trade-offs between larval survival and adult ornament development depend on predator regime in a dragonfly. ***Oecologia*** 188(1): 97-106.

[8] **Moore MP**, Lis C[1], and Martin RA. 2018. Larval body condition regulates predator-induced life-history variation in a dragonfly. ***Ecology*** 99(1): 224-230.

* CWRU Department of Biology Outstanding Paper Award – Honorable Mention – 2018

[7] **Moore MP** and Martin RA. 2016. Intrasexual selection favours an immune-correlated colour ornament in a dragonfly. ***Journal of Evolutionary Biology*** 29(11): 2256-2265.

[6] Dugas MB[§], **Moore MP[§],** Martin RA, Richards-Zawacki CL, and Sprehn CG. 2016. The pay-offs of maternal care increase as offspring develop, favouring extended provisioning in an egg-feeding frog. ***Journal of Evolutionary Biology***. 29(10): 1977-1985.

[5] **Moore MP** and Whiteman HH. 2016. Natal philopatry varies with larval condition in salamanders. ***Behavioral Ecology and Sociobiology***. 70(8): 1247-1255.

[4] **Moore MP**, Riesch R, and Martin RA. 2016. The predictability and magnitude of life-history divergence to ecological agents of selection: a meta-analysis in livebearing fishes. ***Ecology Letters*** 19(4): 435-442.

* CWRU Department of Biology Outstanding Paper Award – 1st Place – 2016

[3] **Moore MP**, Landberg T, and Whiteman HH. 2015. Maternal investment mediates offspring life history variation with context-dependent fitness consequences. ***Ecology*** 96(9): 2499-2509. DOI: 10.1890/14-1602.1

* Research highlighted at Phys.org

[2] Dugas MB, **Moore MP**, Wamelink CN, Richards-Zawaki CL, and Martin RA. 2015. An experimental test for age-related improvements in reproductive performance in a frog that cares for its young. ***The Science of Nature*** 102: 48.

[1] **Moore MP**, Burt CR, Whitney TD, Hastings SA, and Chang GC[‡]. 2012. Does social feeding improve larval survival of the two-spotted lady beetle, *Adalia bipunctata?* ***Journal of Insect Science*** 12: 101.

MANUSCRIPTS IN REVIEW

(available upon request)

Moore MP. How citizen science is super-charging the study of evolutionary adaptation in the Anthropocene. *In Revision* for ***Proceedings of the American Philosophical Society***.

Leith NT, Fowler-Finn KD, and **Moore MP**. Co-adaptation of thermal ecology and sexual selection. *Invited* to ***Ecology Letters.***

OTHER PUBLICATIONS

Moore MP, Hersch K, Sricharoen C, Lee S, Reice C, Rice P, Kronick S, Medley KA, and Fowler-Finn KD. 2021. How will dragonflies adapt to a warmer Earth? ***Environmental Science Journal for Teens.*** https://sciencejournalforkids.org/wp-content/uploads/2021/10/dragonfly_article.pdf

Moore MP. 2021. Human activity imperils one of the Earth's great survivalists: dragonflies. ***The Hill (Opinion)***. https://thehill.com/opinion/energy-environment/562526-human-activity-imperils-one-of-the-earths-great-survivalists

Moore MP. 2020. There are no second acts in the lives of animals. ***Animal Ecology in Focus.*** https://animalecologyinfocus.com/2020/04/17/there-are-no-second-acts-in-animal-life-cycles/

GRANTS, AWARDS, AND FELLOWSHIPS

2020	Sidnie Manton Award Finalist from *Journal of Animal Ecology*
2019-2022	Living Earth Collaborative – Biodiversity Post-Doctoral Fellowship (salary & research budget $183,000)
2019-2021	University of Arizona – G.G. Simpson Post-Doctoral Fellowship (salary & research budget $105,318; *Offer Declined*)
2019	CWRU Department of Biology Outstanding Paper Award – 2nd Place
2018	CWRU Department of Biology Outstanding Paper Award – Honorable Mention
2018	Oglebay Grant Award ($1,500)
2017	Joanne Westin Distinguished Graduate Student Teaching Award
2017-2018	GAANN Fellowship
2017	Theodore Roosevelt Memorial Fund Award ($2,000)
2017	Oglebay Grant Award ($1,429)
2016	CWRU Department of Biology Outstanding Paper Award – 1st Place
2015	Murray State University Libraries #RacerScholars of the Week (Oct. 6)
2014	Watershed Research Grant ($1,000)
2013	Watershed Research Grant ($1,200)
2012-2014	Murray State University Innovation Research Assistantship ($15,300)

MENTORSHIP AND TEACHING

Mentorship

(1 – high-school student supervisor; 2 – undergraduate student supervisor; 3 – graduate thesis committee member)

2020-Present Karissa Coffield[3] Murray State University

Masters Thesis: Adaptive plasticity of coloration in response to environmental change

2019-2021 Kaitlyn Hersch[2] Washington University in St. Louis
Honor's Thesis: Ornaments evolved faster than eco-morphological traits among dragonflies
Project: Using citizen science to study climatic adaptation in dragonflies

2019-2021 Paul Rice[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2020-2021 Saanya Sharma[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2019-2021 Chanont Sricharoen[2] Washington University in St. Louis
Project: Using citizen science to unravel the origins of a reproductive innovation
Project: Using citizen science to study climatic adaptation in dragonflies

2019-2021 Caitlin Reice[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2019-2021 Sarah Lee[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2019-2021 Sophie Kronick[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2019-2020 Isabelle Ciaverelli[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2019-2020 Francis Serrano[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2019 Jonah Bernstein[2] Washington University in St. Louis
Project: Using citizen science to study climatic adaptation in dragonflies

2016-2019 Cassandra Lis[1] Hathaway Brown School
Senior Thesis: Rearing temperature and sexually selected color in dragonflies
Project: Thermal effects of sexually selected color in dragonflies
Project: Fitness costs of immune deployment in dragonflies
Project: Predator-induced life-history variation in dragonflies
* watch Cassandra on the local news: www.wkyc.com/video/home/cassandra-lis-farah-sayed-hathaway-browns-science-research-engineering-program-srep-101118/95-8278838

2018 Christian Prechtl[2] Case Western Reserve University
Project: Predator-mediated selection on a male weapon in fairy shrimp

2018 Kayla Harris[2] Case Western Reserve University
Honor's Thesis: Carotenoid-mediated maternal effects in fire-bellied toads

2016 Andrew Wiecek[2] Case Western Reserve University
Project: Adaptive decoupling and evolutionary trade-offs in dragonflies

2016 Lindsey Robinson[2] Case Western Reserve University
Project: Ontogenetic conflict over sexually selected coloration in dragonflies

2015 Jared Larson[2] Case Western Reserve University
Project: Fitness costs of immune deployment in dragonflies

2012	Katie Mount[2]	Murray State University
	Project: Maternal effects and adult life-history variation in salamanders	
2012	Emily Clouse[2]	Murray State University
	Project: Maternal effects and adult life-history variation in salamanders	

Graduate Teaching Assignments

2018	Quantitative Biology	Case Western Reserve University
2017	Ecophysiology of Global Change	Case Western Reserve University
2017	Quantitative Biology	Case Western Reserve University
2016	Ecophysiology of Global Change	Case Western Reserve University
2016	Quantitative Biology	Case Western Reserve University
2015	Genes, Ecology, and Evolution	Case Western Reserve University
2014	Genes, Ecology, and Evolution	Case Western Reserve University
2012	Ecology	Murray State University

Guest Lectures

2021	"Adaptation in a changing world"	Advanced Evolutionary Biology (SLU)
2020	"Sexual Selection"	Evolutionary Biology (SLU)
2020	"Mating Systems"	Sex, Evolution, and Behavior (SLU)
2020	"Evolution of reproductive modes"	Sex, Evolution, and Behavior (SLU)
2019	"Sexual vs Natural Selection"	Evolutionary Biology (SLU)
2018	"Sexual Selection"	Advanced Topics in Evolution (CWRU)
2018	"Multi-level models"	Quantitative Biology (CWRU)
2017	"Writing an introduction and discussion"	Ecophysiology of Global Change (CWRU)
2017	"Multi-level models"	Quantitative Biology (CWRU)
2017	"Evolutionary responses to global change"	Ecophysiology of Global Change (CWRU)
2013	"Reptiles and amphibians"	Field Biology (MSU)
2012	"Amphibian life-history variation"	Evolution (MSU)

Other Teaching Experience

2007-2011	Substitute Teacher	Weare Middle School, Weare, NH 03281

KEYNOTE ADDRESSES, INVITED SEMINARS, & PRESENTATIONS

(‡ -denotes upcoming seminar or presentation)

Keynote Addresses & Invited Panel Discussions

2021 American Philosophical Society — Invited Panelist
"The promise of citizen science"
* Watch: https://youtu.be/NEf3nAqXMxw

2020 Hefner Museum of Natural History — 46th Annual Lecture
"How your iNaturalist observations are supercharging evolutionary biology"
* Flyer: https://www.miamioh.edu/cas/about/news/2020/10/hefner-lecture.html
* Watch: https://youtu.be/9_jjU4HITik

2019 Ohio Odonate Conference — Keynote Address
"Too hot to trot? Climate & color adaptation in dragonflies"
* Flyer: https://u.osu.edu/ohioodonatasurvey/2019/02/

Invited Seminars

2021 Towson University

2021 Oakland University

2021 Eawag

2021 University of North Carolina - Chapel Hill

2021 Eastern Michigan University

2020 Miami (OH) University

2020 Murray State University

2020 Tyson Research Center
* watch replay here: https://youtu.be/nH5MfjPglr4

2019 Saint Louis University

2019 Washington University in St. Louis

2019 John Carroll University

2018 Case Western Reserve University

2018 University of California - Davis

Research Conferences

2022‡ Society for Integrative and Comparative Biology — Oral Presentation

2022‡	Society for Integrative and Comparative Biology	Poster Presentation
2019	Society for the Study of Evolution	Oral Presentation
2019	Society for the Study of Evolution	Poster Presentation
2018	American Society of Naturalists	Oral Presentation
2017	Society of Integrative & Comparative Biology	Oral Presentation
2015	Ecological Society of America	Oral Presentation
2014	Ecological Society of America	Oral Presentation
2014	Southeastern Ecology & Evolution Conference	Oral Presentation
2013	Ecological Society of America	Poster Presentation
2013	Society for Study of Evolution	Poster Presentation
2013	Midwestern Ecology & Evolution Conference	Oral Presentation
2012	Southeastern Population Ecology & Evolutionary Genetics	Oral Presentation
2010	Murdock College Science Research Conference	Poster Presentation

Institutional Symposia

2015	CWRU Biology Graduate Research Symposium	Oral Presentation
2014	Watershed Science Research Symposium	Oral Presentation
2013	Watershed Science Research Symposium	Oral Presentation
2012	Watershed Science Research Symposium	Oral Presentation

SERVICE & OUTREACH

2021 Science Journal for Kids – Adapted research article for use in K-12 classrooms
Role: Author & Editor
* View here: https://sciencejournalforkids.org/wp-content/uploads/2021/10/dragonfly_article.pdf

2021 Tyson Research Center Summer Fellows – Panel on Demystifying Grad School
Role: Organizer & Presenter

2021 Tyson Research Center Summer Fellows – Visiting Professional Presentation
Role: Presenter

2021 LEC Presents: A Panel on Environmental Racism & Biodiversity Conservation in St. Louis
Role: Co-organizer
* Watch here: https://youtu.be/820MDO8iHoM

2020-2021 LEC & Washington University EEPB Seminar Series
Role: Organizer & Host

2020 Tyson Research Center Summer Fellows – Career Panel
Role: Presenter

2020 LEC Biodivers-A-Palooza Scavenger Hunt
Role: Organizer

2020 Tyson Research Center Lunch & Learn Discussions
Role: Presenter *Title: iNaturalist in Ecology & Evolution Research*

2020 LEC Presents: Adventures in Biodiversity Summer Seminar Series
Role: Organizer & Host
* Watch here: https://www.youtube.com/channel/UCfLG3SSfA2BlKqb5mnm8-8Q

2020 LEC Graduate Student Research Grant Program
Role: Organizer

2020 Tyson Research Center Conservation Corps – Career Panel
Role: Presenter

2019 LEC Biodiversity Post-doctoral Fellowship Selection Committee
Role: Post-Doc Representative

2019 Bristol Elementary School (Webster Groves, Missouri) STEAM Night
Role: Exhibit *Title: Patterns of Biodiversity*

2017 Cleveland Museum of Natural History Think and Drink with the Extinct
Role: Exhibiter *Title: The Evolution of Insect Color*

2017 Case Western Reserve University Graduate Research Symposium
Role: Organizer

2017 Case Western Reserve University Graduate Student-Invited Speaker
Role: Host

2014 Murray State University Herpetological Society
Role: Presenter *Title: When mother knows best: adaptive maternal effects and amphibian life cycles*

2013 Hancock Biological Station - Murray High School AP Biology Trip
Role: Presenter *Title: Life Cycles and Adaptations of Amphibians*

2013 Weare, NH Middle School 5th Grade Science
Role: Presenter *Title: Life Cycles and Adaptations of Amphibians*

2012-2013 Murray State University Graduate Student Journal Club
Role: Organizer

2012 Weare, NH Middle School 5th Grade Science
Role: Presenter *Title: Life Cycles and Adaptations of Amphibians*

REPRESENTATIVE MEDIA COVERAGE

For responses to global change in dragonflies

- CNN (article): https://us.cnn.com/2021/07/06/us/dragonfly-wings-climate-change/index.html
- The Guardian (article): https://www.theguardian.com/environment/2021/jul/06/climate-crisis-causing-male-dragonflies-to-lose-wing-bling-study-finds
- St. Louis Public Radio (live interview – *St. Louis on the Air*): https://news.stlpublicradio.org/show/st-louis-on-the-air/2021-07-08/thursday-as-male-dragonflies-adapt-to-climate-change-females-might-be-less-attracted
- The Times of India (article): https://www.indiatimes.com/technology/science-and-future/climate-change-dragonfly-shine-loss-544430.html
- St. Louis Post-Dispatch (article): https://www.stltoday.com/news/local/metro/dragonflies-lose-wing-markings-in-warmer-climates-washu-and-slu-study-shows/article_487b4436-96da-5577-b502-e940018c77b3.html
- Smithsonian Magazine (article): https://www.smithsonianmag.com/smart-news/warmer-climate-may-cause-male-dragonflies-lose-their-patchy-wings-180978141/
- Science News (article): https://www.sciencenews.org/article/climate-change-dragonfly-wing-spots-biology
- New Scientist (article): https://www.newscientist.com/article/2283184-male-dragonflies-may-become-less-colourful-as-the-climate-warms/
- The Wildlife Society (article): https://wildlife.org/warmer-weather-means-duller-dragonflies/

For evolutionary conflict between life-cycle stages:

- Finalists for Sidnie Manton Early Career Researcher Award from Journal of Animal Ecology (blog post): https://animalecologyinfocus.com/2020/04/06/second-journal-of-animal-ecology-sidnie-manton-shortlisted-papers/
- Phys.org (article): *"When less is more: smaller offspring thrive in competitive environments"* - https://phys.org/news/2015-10-smaller-offspring-competitive-environments.html

For using citizen science to study adaptation

- Discover Magazine (podcast): *"Explore biodiversity with iNaturalist and the Appalachian Mountain Club"* (highlighted at 26 min mark) - https://blog.scistarter.com/2019/10/explore-biodiversity-with-inaturalist-and-the-appalachian-mountain-club/
- iNaturalist blog (interview): *"iNat photos used to study correlation between dragonfly wing coloration and temperature"* - https://www.inaturalist.org/blog/22029-inat-photos-used-to-study-correlation-between-dragonfly-wing-coloration-and-temperature
- Daily Kos (article): *"Daily bucket: for blue dasher dragonflies, every picture tells a story, and stories become science"* - https://www.dailykos.com/stories/2019/3/2/1838754/-Daily-Bucket-For-blue-dasher-dragonflies-every-picture-tells-a-story-and-stories-become-science

- Amore a quatro zampe (Italian article): *"Gli animali cambiano colore: colpa dei cambiamenti climatici"* - https://www.amoreaquattrozampe.it/news/animali-cambiano-colore-cambiamenti-climatici/37025/

OTHER PROFESSIONAL ACTIVITIES

Working Groups

2015 "Costs of phenotypic plasticity and adaptation to novel environments". National Evolutionary Synthesis Center. Feb. 22-24.

Workshops

2020 "Understanding and Analyzing Systematic Racism". Crossroads Antiracism Organizing & Training. St. Louis, MO USA. Feb. 26-28.

2019 "Get ahead of the game: writing effective proposals". Dr. Saran Twombly, NSF DEB program director. Saint Louis University. Dec. 13.

Ad Hoc Manuscript Referee

Biology Letters, The American Naturalist, Evolutionary Applications, Heredity, Functional Ecology, Journal of Animal Ecology, Journal of Experimental Zoology-Part A, Ecography, Oikos, Oecologia, Evolutionary Ecology, Ecological Entomology, Journal of Herpetology, Écoscience, International Journal of Odonatology, Amphibia-Reptillia, Insect Science, Ecosphere, Ecology & Evolution, BMC Ecology and Evolution, Royal Society Open Science, PeerJ, PLoS One

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MID-LIFE CRISES: TRADE-OFFS & CONFLICT BETWEEN LIFE-CYCLE STAGES

Plants and animals face a fundamental problem as they proceed through their life cycles: juveniles and adults face very different demands from each other. For some organisms, demands differ because life stages occur in radically different habitats (e.g. frogs, salmon). For many more organisms, however, demands differ simply because juveniles must maximize survival whereas adults must maximize reproduction. Although biologists have long wondered how organisms optimize their physiology and morphology for all of these contrasting demands, relatively little is known about how conflict between life stages has affected adaptation in the past or if it will handicap responses to future global change. Thus, my research program addresses **how physiological and morphological adaptation in one stage are constrained by natural selection in other stages**. By integrating experimental, comparative, and citizen-science approaches in a dragonfly system that I developed, my lab at CU Denver will explore the impact of "ontogenetic conflict" on historical and future adaptation.

WHEN CAN ONE LIFE STAGE ADAPT FREELY FROM SELECTION IN OTHERS? Theory dating back to Darwin posits that organisms will evolve mechanisms, like metamorphosis, that enable each life stage to adapt freely from others. In a recent review, however, I showed that developmental links can persist across even those life stages separated by metamorphosis (Moore & Martin 2019, *J Anim Ecol*). Since this work indicates that life stages may not be as decoupled as we long assumed, our models of physiological and morphological adaptation depend on learning when life stages can actually evolve independently.

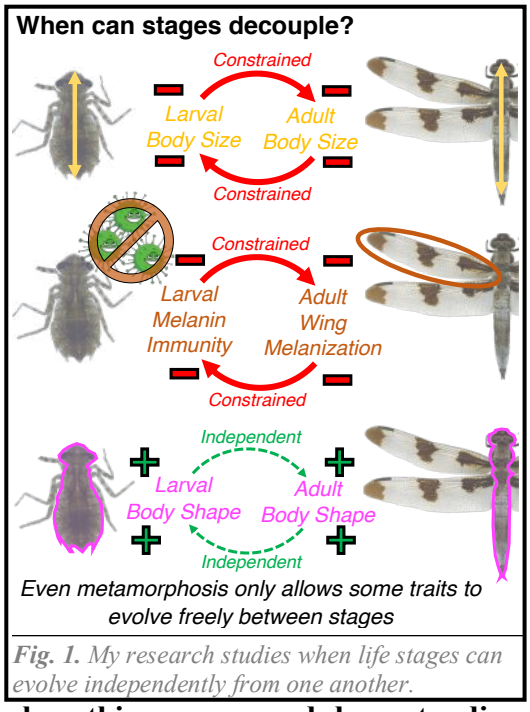

Fig. 1. My research studies when life stages can evolve independently from one another.

My lab at CU Denver will use dragonflies to study when life stages can and cannot be decoupled from one another. Dragonflies are well suited to this theme because theory predicts that metamorphosis completely unyokes juvenile and adult evolution by cleaving developmental links between the stages. However, **my work on this group upends long-standing expectations about when life stages can evolve freely from each other**. Using comparative studies, for example, I have uncovered that few physiological or morphological traits can actually evolve independently between life stages even in taxa that undergo a dramatic metamorphosis (Fig 1; Moore & Martin 2021, *Am Nat*; Moore 2021, *Biol Lett*). As many organisms do not have the benefit of a metamorphosis to cleave developmental links between stages, **my findings indicate that juvenile and adult evolution are unlikely to be independent from one another for most physiological and morphological traits**. My lab at CU Denver will next use field, meta-analytic, and comparative studies to explore the factors that allow only some physiological and morphological traits to decouple between stages.

Beyond the effects of its own genes, an individual's traits in each stage can be governed by the non-genetic physiological factors that the individual receives from its parents (e.g. nutrients, hormones). Such "parental effects" on an individual's development are often determined by how its parents responded to demands in their own lives. Thus, my lab at CU Denver will also study when juveniles and adults can evolve independently from these parental effects. Based on a meta-

analysis of all animals (Moore *et al.* 2019a, *Ecol Lett*), **my work shows that juvenile traits have little capacity to evolve freely from parental effects, but adult traits have more flexibility.** My lab at CU Denver will next use phenotypic engineering to examine which maternally transmitted physiological factors are most influential to juvenile vs adult development (e.g. yolk, hormones; see also Moore *et al.* 2015, *Ecology*).

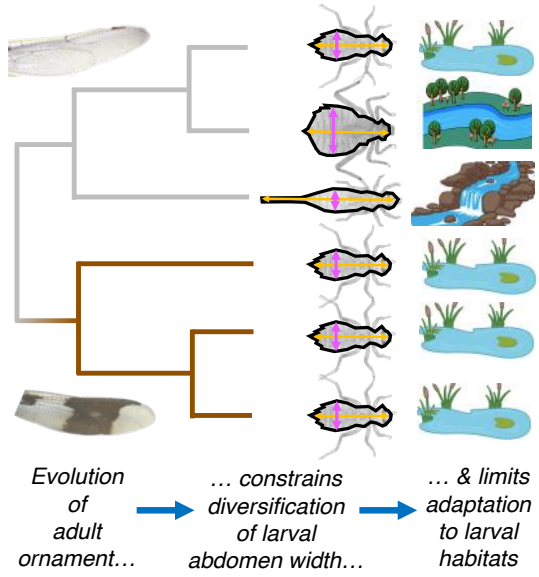

Fig. 2. *My research studies the costs of stages that do not decouple from each other.*

What Are the Consequences when Life Stages Do Not Decouple? Although biologists long assumed that organisms would evolve mechanisms to avoid costly trade-offs between life stages, my empirical and synthetic research shows that stages do not typically evolve freely even when separated by a dramatic metamorphosis (Moore & Martin 2019, *J Anim Ecol*). A widespread, but overlooked, constraint on physiological and morphological adaptation could therefore be the effects of natural selection in other stages. However, the extent to which adaptation is actually hindered by these links between life stages remains unknown.

My lab at CU Denver will use dragonflies to study how much adaptation and diversification in one stage are limited by natural selection in others. My prior experiments show that the demands of producing sexually attractive adult ornaments makes larvae vulnerable to parasites (Moore *et al.* 2018, *J Evol Biol*) and predators (Moore & Martin 2018, *Oecologia*). My comparative work has also uncovered that, because adult ornament production requires large larval fat stores, ornamented species have slower evolution of larval body shape and have been unable to adapt to some larval habitats over the last 200 million years (Fig 2; Moore, In Prep). **My research thus shows that adapting to selection in one stage is indeed a major constraint on physiological, morphological, and ecological adaptation in others**. My lab will next use citizen-science approaches to assess which larval niches are most restricted by the physiological requirements of adult ornament production. An exciting aspect of these methods is that they can be completed anywhere or anytime that works best for students, which offers more equitable research opportunities to students who cannot commit to working many hours in the lab (Moore, In Revision, *Proc Am Philos Soc*).

Future Research on Eco-Physiological Adaptation to Global Change. As my work shows that trade-offs between life-cycle stages have shaped historical adaptation, it is also likely that they will affect future responses to global change. In my competitive post-doctoral fellowship at WashU's Living Earth Collaborative ($183,000), I have further developed my dragonfly system to study physiological and morphological adaptation to global change. This work has uncovered ways that adult dragonflies predictably adapt to warmer climates and other anthropogenic threats (Moore *et al.* 2021, *PNAS;* Leith *et al.* Invited, *Ecol Lett*; Moore *et al.* In Prep). Armed with replicated patterns of adult evolution, my lab at CU Denver will be able to study how adaptation to global change in one stage affects physiological and ecological responses in other stages.

Many organisms will need to adapt to a warmer future. For those organisms that transition between habitats across ontogeny, however, the extent of warming in one stage may not align with the

extent of warming in others (cf. water vs air). Thus, my lab will **test if physiological adaptation to warmer climates in one stage limits adaptation in others** (to *NSF IOS: ORCC* or *NASA: ROSES*). Comparative studies will assess the extent to which the evolution of adult physiology (Fig 3A) is decoupled from larval physiology. Mesocosm experiments will test how climatic warming changes natural selection on larvae vs adults. Breeding and transcriptomic studies will quantify the genetic capacity for larval and adult stages to evolve independently in the future. Biogeographic analyses will assess how physiological adaptation to larval vs adult temperature affects species' ranges under climate change. CU Denver is well suited for this work due to the local odonate diversity and the potential for collaboration with experts in thermal adaptation.

Researchers and conservationists are now recognizing that evolutionary responses to global change can broadly affect many ecological processes. Another arm of my research at CU Denver will **explore how adult adaptation to warmer climates disrupts the physiological ecology of larvae** (to *NSF DEB: EP*). My previous research shows that: 1) dragonflies adapt to warmer climates by producing less melanin ornamentation over both historical and contemporary timescales (Fig 3B; Moore *et al.* 2021, *PNAS*); and 2) the loss of adult ornamentation unshackles the evolution of larval immune defense (Fig 1; Moore & Martin 2021, *Am Nat*). Thus, the host-parasite dynamics of larvae could be re-shaped by adult adaptation to global change. Landscape genomic analyses of blue dasher populations will test if larval immune defense evolves to be stronger in regions where warmer climates have reduced adult ornaments (see also Moore *et al.* 2019b, *Ecol Lett*). Mesocosm studies will assess if larvae from non-ornamented populations compete better against heterospecifics in high-parasite environments than do larvae from ornamented populations. Macro-physiological analyses will explore if selection on adults determines which species can occupy high-parasite larval habitats. CU Denver is nearly ideal for this work because of its proximity to many field sites as well as its experts in behavioral ecology and molecular evolution.

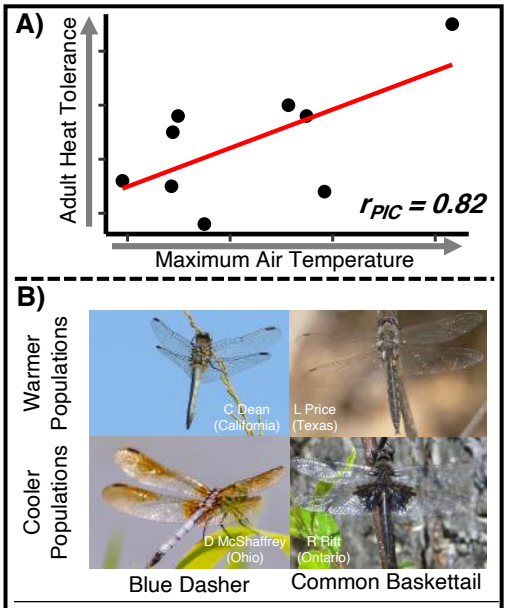

*Fig 3. **A)** Dragonfly species (circles) in warmer climates have higher adult heat tolerances. **B)** iNaturalist observations reveal that dragonflies consistently evolve less wing color in hotter areas.*

DETERMINING THE CAUSES & CONSEQUENCES OF ONTOGENETIC CONFLICT. Beyond these short-term goals, my lab at CU Denver will be well positioned over the next 10+ years to become a leader in physiological adaptation. My framework for integrating research of natural selection, physiology, development, and ecological diversification across the dragonfly life cycle will allow my lab to explore the impact of ontogenetic conflict in ways that few other systems can. The implications of my lab's work will also ensure that we can apply for grants from basic and applied funding sources, including NSF, NASA, and EPA. Lastly, as my lab's equitable and diverse approach to conducting research can align with the goals of most graduate students and post-docs, I will be able to establish a training environment where physiologists and evolutionary biologists of any background can flourish. Ultimately, by drawing on these collective strengths, my lab at CU Denver will seek to resolve a question that Darwin first grappled with in *On the Origin of Species:* how is adaptation in one stage constrained by natural selection in other stages?

I believe that educating is central to my role as a scientist. Accordingly, I have actively sought opportunities to work with the next generation of scientists and problem solvers throughout my career. I have gained graduate teaching experience in courses such as eco-physiology, biostatistics, ecology, and introductory biology. I also worked as a substitute teacher in public schools across 4 years. At CU Denver, I could contribute to or develop new courses in animal physiology, eco-physiology, evolution, biostatistics, and global change biology.

TEACHING PHILOSOPHY & APPROACH. As many of the students in my classes will not become comparative physiologists, I believe it is vital that they develop approaches to tackling problems that translate beyond biology. Fortunately, biological research requires a set of skills that can be used in many other professions and in every-day life. Practice is essential to honing these skills, and my courses therefore blend traditional lecturing with inquiry-based and active-learning techniques. Discussions of primary literature in my classes encourage students to read critically and deliberate on constructive ways to improve others' work. In-class activities facilitate collaborative thinking and allow students to polish their skills while receiving real-time feedback. Course-based undergraduate research experiences (CUREs) require my students to lay out a vision for a project, manage its day-to-day operation, and then report on its outcomes. Among the many skills that students have the ability to acquire and/or refine in my classes, I especially prioritize development in two: data literacy and written communication.

Because few things in biology or the world are deterministic, understanding probabilities and trends is a crucial skill. Consequently, I am dedicated to ***improving data literacy and quantitative reasoning***. This commitment is exemplified by my work in a biostatistics course at Case Western Reserve University (CWRU). Here, students completed weekly assignments where they chose appropriate analyses for assigned questions and datasets. Students also undertook projects where they answered their own research questions with data they gathered. I further illustrated the value of data literacy with non-biological examples, such as the consequences of non-independent datapoints in the 2016 U.S. Election forecasts from familiar news outlets (e.g. FiveThirtyEight, NY Times). For this work, I won the departmental award for excellence in teaching.

Whether it's in a manuscript for peer-review, a law brief, or even just an email to an employer, students will eventually need to write evidence-based arguments. I therefore emphasize practice of ***written communication***. To this end, my biostatistics students handed in weekly reports where they had to describe and justify the analyses they chose. In eco-physiology and ecology courses, my students completed proposals for term-length independent projects, giving them a chance to practice articulating a vision for larger studies. To provide a more conceptual approach to writing, I also lecture on ways to write scientific reports, including with exercises where students have to assemble a series of statements in an order that makes the most logical narrative.

EQUITY & INCLUSION IN THE CLASSROOM. As teachers, it is our duty to ensure that we provide an equitable and inviting educational experience. Research shows that active learning and CUREs are effective at improving educational outcomes and recruitment of less-privileged students. As the first member of my family to earn a college degree myself, I can attest that CUREs were the first time that I realized independent research was even an option. Accordingly, I have worked to provide meaningful CUREs in all of my lab courses, including exploring the physiological effects of global warming with outdoor warming chambers and testing predictions of island biogeography theory using insect assemblages in woodland ponds. At CU Denver, my goal would be for any lab course that I teach to include independent research projects.

Given the importance of diversity and representation to an inclusive learning environment, I also recognize that my status as a white man can reinforce harmful perceptions of who can and cannot be a scientist. One way that I try to offset this in my lectures is teaching with primary research examples by our colleagues from minoritized groups. I also always include their pictures on the slides, which visually indicates to the students that scientists do not need to look like me.

MENTORING PHILOSOPHY. While training future physiologists is among my proudest achievements, I recognize that students have diverse motivations for seeking research experience. I also appreciate that many students cannot commit to working in a lab setting for multiple hours each week. I therefore work to ensure that my research program offers hands-on experiences that can match nearly any availability or career goal (e.g. meta-analysis for data science; eco-immunology for pre-health; citizen science for community engagement).

My research has already afforded opportunities to a diverse group of ***18 undergraduate and high-school students, including 12 from historically disadvantaged communities***. Students often leave these experiences with a newfound appreciation for biology as a career path. For example, while studying salamanders with me, one Murray State student switched her major to biology after realizing that she could pursue her passion for amphibians professionally. For 3.5 years, a student from an all-girls high school assisted on my dragonfly research. Although initially hesitant about getting into the pond in chest waders, she ultimately co-authored three publications, published her own first-author article about thermal physiology (Lis *et al.* 2020, *Ecol Entomol*), and talked to reporters on the local news (www.wkyc.com/video/home/cassandra-lis-farah-sayed-hathaway-browns-science-research-engineering-program-srep-101118/95-8278838). Beyond these traditional research experiences, I maintain ongoing projects on which students can work at any time and from any location. I recently published an article on thermal adaptation in dragonflies with 6 undergraduates who worked from their homes to gather and process citizen-science observations (Moore *et al.* 2021, *PNAS*). As many students cannot work for several hours in the lab each week, projects like this offer equitable access to research experiences in my program (Moore, In Revision, *Proc Am Philos Soc*).

My ***graduate students*** at CU Denver will pursue projects dictated by their career goals and our shared interests. Students will be given the space to develop their own questions and will be encouraged to begin addressing them using citizen-science data and/or meta-analysis. My expertise in both areas is ideal for jumpstarting projects with readily acquirable data (e.g. Moore *et al.* 2016, *Ecol Lett*; Moore *et al.* 2019a, *Ecol Lett;* Moore *et al.* 2019b, *Ecol Lett*). For instance, I am working with a PhD student at St. Louis University on a meta-analysis about the co-evolution of sexual traits and thermal physiology (Leith *et al.* Invited, *Ecol Lett*). Such projects will allow my students to develop good habits in data collection, analysis, and writing at an early stage.

INTEGRATING TEACHING & RESEARCH. I have also conducted research to improve teaching approaches. I am collaborating with an instructor at CWRU on a project that examines how students retain course material from an introductory-level physiology class. Students took follow-up exams three and eleven months after completing either: 1) a semester-long version of the course or 2) a month-long summer version. This allowed us to test if information retention was greater when the material was learned over a longer period of time. Our team presented the results of this project at an institutional research conference, and we are preparing a manuscript for a pedagogy-focused journal. Beyond providing insight into how students retain course material, this work is helping instructors at CWRU structure the breadth and pacing of their physiology courses. If possible, I would be excited to participate in similar projects at CU Denver.

Biology has long been dominated by a single race, gender, and socio-economic group. As a member of that advantaged race and gender, one of my major career goals at CU Denver will be to promote a more equitable learning and training environment for students of all backgrounds.

DEI IN RESEARCH. While some students can volunteer for multiple hours each week in a lab setting, many others are not so fortunate—particularly those from minoritized and/or other disadvantaged groups. To alleviate these opportunity gaps, we must develop research programs that students from all backgrounds can actually take advantage of. A strength of my program is that I establish projects where students can participate at anywhere or anytime. On one ongoing project, ten students are exploring thermal adaptation in dragonflies using iNaturalist.org observations. After <1 hour of training, the students work on their own schedules and from wherever they choose. For several students, jobs and other life commitments had precluded in-person opportunities in other labs, and this project was the first time that they could participate in research. Six students recently co-authored portions of this project with me (Moore *et al.* 2021, *PNAS*). By blending in-person lab experiences with more flexible projects like this, ≥ 12 disadvantaged and/or first-generation students have already been able to participate in my research program, and eight of my published articles have students from such backgrounds as co-authors.

Even for students whose schedules permit research participation, it was my experience as the first member of my family to earn a college degree that many students do not know how to get involved in research. Filling our labs with only those students who know to approach us about opportunities poses an inherent disadvantage to the students that our society has conditioned to wait until they are called upon. I strive to offset these biases by working with programs that directly provide access to research opportunities to students from less-privileged backgrounds and by widely advertising all new opportunities in my lab. For instance, I worked with a program for 3.5 years in Cleveland that places high-school girls in research labs. Advertising all new opportunities in my research program has also helped me recruit students who did not realize research was even an option for them. One of my best undergraduates, for example, started as an accounting major at Murray State because she was unaware that she could get paid to work on amphibians. After her time with me, she changed her major to biology and is now a professional wildlife biologist.

My lab at CU Denver will strive to become an inclusive space for researchers from any background. Such an environment does not create itself, and I must work to ensure this outcome. To this end, I will participate in annual workshops on anti-racism, and my grant proposals will include funds for students to complete ≥1 similar session. CU Denver's financial support (e.g. UROP) will also help my students avoid sacrificing income for research experience.

DEI IN TEACHING & SERVICE. As a white man, I must find ways to emphasize to my students that biologists do not need to look like me. I therefore lecture using research examples from our colleagues from minoritized groups, and I always include their pictures on the slides, which hopefully somewhat offsets my presence at the front of the room. I also aim to diversify the scientists featured in seminars. In organizing WashU's series, I scheduled the most diverse line-up in the series' history, including seminars devoted to DEI in STEM (via Project Biodiversify).

Research shows that lecture-only courses with so-called "weed out" tests systematically harm learning outcomes for less-privileged students. I thus strive to teach using less-biased ways of delivering information and evaluating student progress. Accordingly, my classes at CU Denver will include active-learning approaches, such as group problem solving, evaluations based on science communication to a lay audience, and course-based undergraduate research experiences.

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