

Julie McDonald

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EDUCATION

Massachusetts Institute of Technology, Cambridge, MA September 2020–September 2025

Ph.D. Candidate, Department of Biology

- Thesis: “Engineering Biological CO₂ Fixation Via Directed Evolution and Machine Learning”
- Advisor: Professor Matthew D. Shoulders
- Relevant coursework: Quantitative Analysis of Biological Data, Biophysical Technique, Fundamentals in Chemical Biology, Graduate Biochemistry, Graduate Genetics, Introduction to Deep Learning

Wesleyan University, Middletown, CT

September 2014–May 2018

Bachelor of Arts, High Honors, Molecular Biology & Biochemistry

- Thesis: “Thermodynamic Characterization of the DNA Four-Way Junction Melting Process”
- Advisor: Professor Ishita Mukerji
- Relevant coursework: Biochemistry, Computer Science, Bioinformatics, Organic Chemistry, Physical Chemistry, Structural Biology Laboratory

RESEARCH EXPERIENCE

Shoulders Group, Dept. of Chemistry; MIT

June 2021–Present

Ph.D. Student

- Developed an *in vivo* directed evolution pipeline for the enzyme RuBisCO, leading to significant improvements in carboxylation efficiency.
- Applied state-of-the-art protein language models (pLMs) to enhance plant RuBisCO catalysis, uncovering sequence-function relationships with agricultural translatability.
- Collaborated with several subgroups, resulting in development of novel directed evolution technologies and an emergent class of PROTACs in mammalian cells.

Chao Group, Dept. of Mol. Biol.; Massachusetts General Hospital

July 2018–July 2020

Research Technician

- Established a protein production pipeline, optimizing fermentation of *Pichia pastoris* and membrane protein purification.
- Independently investigated mitochondrial protein structures using cryo-electron microscopy (cryo-EM), *in situ* cryo-electron tomography, and negative staining, contributing to multiple publications.

Mukerji Group, Dept. of Mol. Biol. & Biochem.; Wesleyan University

May 2017–May 2018

Undergraduate Research Assistant

- Designed and executed fluorescence spectroscopy experiments to study the thermodynamics of DNA structures linked to oncogenic instability, compiling findings into a senior thesis.

FELLOWSHIPS, AWARDS, & HONORS

Fellow, *MIT Martin Family Society of Fellows for Sustainability*, 2024

Graduate Research Fellowship Program Honorable Mention, *NSF*, 2021

Hawk Prize for Excellence in Biochemistry, *Wesleyan University*, 2018

High Honors in Molecular Biology and Biochemistry, *Wesleyan University*, 2018

PUBLICATIONS

McDonald, J.L.; Zhao, Y.; Kaines, S.; Whitney, S.M.; Wilson, R.H.; Shoulders, M.D. Machine learning-assisted directed evolution of plant RuBisCO. *In preparation* (2025).

- Engineering of tobacco RuBisCO using pLMs for enhanced carbon fixation efficiency *in vitro* and *in planta*.

McDonald, J.L.; Shapiro, N.P.; Whitney, S.M.; Wilson, R.H.; Shoulders, M.D. *In vivo* directed evolution of a natural, ultra-fast RuBisCO from a semi-anaerobic environment innovates on oxygen sensitivity. *bioRxiv*, in review (2025). DOI: 10.1101/2025.02.17.638297v3.

- Discovery of remarkably fast RuBisCO variants with high resistance to oxygenation, via the development of a fully integrated mutagenesis and selection platform for *in vivo* evolution.

McDonald, J.L. & Wilson, R.H. New molecular chaperone roles for CO₂ assimilation in early land plants. *Mol. Plant* **18**, 386–388 (2025).

- Perspective highlighting emerging research that empowers RuBisCO synthetic biology.

Mengiste, A.A.; **McDonald, J.L.;** Tran, M.T.N.; Plank, A.V.; Wilson, R.H.; Butty, V.L.; Shoulders, M.D. MutaT7^{GDE}: A Single chimera for the targeted, balanced, efficient, and processive installation of all possible transition mutations *in vivo*. *ACS Synth. Biol.* **13**, 2693–2701 (2024).

- Development and characterization of a new MutaT7-based technology for *in vivo* targeted mutagenesis that vastly simplifies the system while improving mutagenic properties.

Boopathy, S.; Luce, B.E.; Lugo, C.M.; Hakim, P.; **McDonald, J.L.;** Kim, H.L.; ... & Chao, L.H. Identification of SLC25A46 interaction interfaces with mitochondrial membrane fusogens Opa1 and Mfn2. *J. Biol. Chem.* **300**, 107740 (2024).

- Mapping of the interaction interfaces between mitochondrial proteins, providing new insights into the molecular regulation of mitochondrial dynamics.

Fry, M.Y.; Navarro, P.P.; ... **McDonald, J.L.;** ... & Chao, L.H. (2024). *In situ* architecture of Opa1-dependent mitochondrial cristae remodeling. *EMBO J.* **43**, 391–413 (2024).

- Discovery of the structural organization of Opa1-mediated mitochondrial cristae remodeling, uncovering ultrastructural insights into mitochondrial fusion.

Ge, Y.; Shi, X.; Boopathy, S.; **McDonald, J.L.;** Smith, A.W.; & Chao, L.H. (2020). Two forms of Opa1 cooperate to complete fusion of the mitochondrial inner-membrane. *eLife* **9**, e50973 (2020).

- Cooperation of Opa1 isoforms mediates complete fusion of the mitochondrial inner membrane.

PRESENTATIONS & CONFERENCES

- **Invited Seminar:** Engineering photosynthesis for higher crop yields. *MIT Climate & Sustainability Graduate Research Lunch Series* (April 2025, Cambridge, MA).
- **Poster:** Evolving RuBisCO for enhanced carboxylation efficiency. *Eastern Regional Photosynthesis Conference* (March 2025, Woods Hole, MA).
- **Poster:** Engineering the photosynthetic enzyme RuBisCO for enhanced carboxylation efficiency. *American Society of Plant Biologists Annual Meeting* (June 2024, Honolulu, HI).
- **Poster:** Engineering RuBisCO for enhanced carboxylation efficiency. *Eastern Regional Photosynthesis Conference* (March 2024, Woods Hole, MA).
- **Seminar:** Engineering RuBisCO. *MIT Structure & Function Supergroup* (March 2024, Cambridge, MA).
- **Invited seminar:** Technology for continuous directed evolution of RuBisCO. *Australian National University Plant Biology Seminar Series* (August 2023, Canberra, AU).

- **Poster:** A Versatile plasmid-based system for continuous evolution in bacterial hosts. *Boston Bacterial Meeting* (June 2023, Boston, MA).
- **Poster:** Continuous directed evolution of plant RuBisCO. *Gordon Research Conference: CO₂ Assimilation in Plants from Biome to Genome* (May 2023, Lucca, IT).
- **Poster:** Engineering photosynthetic enzymes towards increased crop yields. *MIT Climate and Sustainability Consortium (MCSC) Annual Symposium* (October 2022, Cambridge, MA).

TEACHING EXPERIENCE

MIT Dept. of Biology

Teaching assistant, Certificate in Pedagogy

September 2021–May 2024

5.08/7.08: Fundamentals of Chemical Biology (Spring 2024)

Profs. Barbara Imperiali & Ronald Raines

- Developed recitation, problem set, and exam materials for course of ~40 advanced undergraduate and graduate students. Led recitation section for ~20 students.
- Constructed new course modules on emergent chemical biology tools, such as the use of AlphaFold in experimental design.

7.015: Introductory Biology (Fall 2021)

Profs. Jing-Ke Weng & Seychelle Vos

- Led recitation sections and held office hours for ~30 undergraduate students, reinforcing fundamental biological concepts.
- Designed and taught bioethics modules related to coursework.

OUTREACH & MENTORSHIP

Shoulders Group

June 2022–Present

- For most of my graduate studies, I have mentored an undergraduate student through the completion of a research project, which is now under review for publication. This mentee presented at the Boston Bacterial Meeting in 2024 and is preparing applications to Ph.D. programs.

Genes in Space, miniPCR bio

March 2024–Present

- I mentored a pair of high school students in designing a molecular biology experiment to be conducted on the International Space Station (ISS). They presented their work to a panel of ISS-affiliated scientists and published an abstract in the *Journal of Emerging Investigators*. They are both pursuing biology summer programs and are preparing their college applications.

Biology Application Assistance Program (BAAP)

June 2022–Present

- I provide support to underrepresented students who are applying to Ph.D. programs. These students routinely receive offers to competitive Ph.D. programs in biological sciences.

Whitehead Institute HS Teacher's Program

August 2021–August 2022

- I assisted high school science teachers in designing their biology curriculums. I designed a lesson plan for agrobacterium-mediated transformation of GFP into tobacco plants.

Expedition:Bio, Whitehead Institute

August 2021–August 2022

- I led molecular biology experiments, such as DNA extraction from fruit, for high school students and younger during this summer program.