

## 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 CO<sub>2</sub> 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 2022–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.

**Weng Group**, Dept. of Biology; MIT (*now Northeastern U.*)

May 2021–May 2022

*Ph.D. Student*

- Developed multiple independent projects and collaborated with lab members to uncover the structure and functions of enzymes involved in plant secondary metabolism.

**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.**; 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. *Proc. Natl. Acad. Sci.*, in press (2025).

- 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 CO<sub>2</sub> 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<sup>GDE</sup>: 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

- **Poster:** Evolving enhanced CO<sub>2</sub>-fixation. *MIT J-WAFS 10<sup>th</sup> Anniversary Celebration Event* (May 2025, Cambridge, MA).
- **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).
- **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: CO<sub>2</sub> 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 2023–Present

- For most of my graduate studies, I have mentored an undergraduate student through the completion of a research project, which is now published with this mentee as second-author. This mentee presented also 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.