BIOGRAPHICAL SKETCH

NAME	POSITION TITLE
Shelley D. Copley	Professor, Department of Molecular, Cellular and Developmental Biology

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR(s)	FIELD OF STUDY
Harvard-Radcliffe	A.B.	1980	Biochemistry
Harvard Medical School		1980-82	Medicine
Harvard University	Ph. D.	1987	Biophysics
MIT		1987-1988	Molecular Biology
University of Colorado		1988-1990	Bioorganic chemistry

A. Personal Statement

The Copley laboratory studies the evolution of enzymes and metabolic pathways in the context of the complex metabolic and regulatory networks in cells using a combination of biochemistry, genetics, genomics and a deep understanding of enzyme mechanisms and microbial metabolism and physiology.

New enzymes often arise from physiologically irrelevant side-activities of existing enzymes. Although these “promiscuous” activities are usually inefficient, they are often orders of magnitude faster than uncatalyzed reactions. Thus, a promiscuous activity provides an excellent starting place for evolution of a new enzyme if that activity becomes important for growth or survival. We use experimental evolution to address fundamental questions about the processes by which new enzymes and metabolic pathways emerge, with an emphasis on identifying the molecular and cellular mechanisms by which mutations enhance fitness.

The initial stage of evolution of a new enzyme often involves gene amplification to provide higher levels of an inefficient enzyme, followed by mutations that improve the newly needed activity in some alleles while others continue to provide the ancestral function. We have examined the earliest stage of this process by characterizing the effect of segmental amplification on the levels of mRNAs and proteins produced from coamplified genes and amplicon remodeling that removes extra copies of coamplified genes that do not contribute to enhanced fitness.

The presence of hundreds of enzymes, each of which probably has a number of promiscuous activities, within a particular microbe provides the possibility of patching together multiple promiscuous activities to generate a novel metabolic pathway. We are identifying novel pathways that can reconstitute biosynthesis of the cofactor PLP in various bacteria when an essential gene is deleted. This model system allows us to address questions such as 1) how many novel pathways can be assembled from the resources in a given genome, and are some better than others?; 2) how do different bacteria solve this evolutionary challenge, and why do their solutions differ?; and 3) how do mutations enable assembly of a novel pathway?

We have recently turned our attention to the potential of genes acquired by horizontal gene transfer (HGT) to contribute to novel metabolic pathways. HGT is rampant among microbes and provides an additional source of catalytic capability that can be utilized to address an environmental challenge or opportunity. We are investigating the mechanisms by which horizontally transferred genes are “domesticated” when they arrive in a new host genome.

B. Positions and Honors

Positions Held

1990-1998 Assistant Professor of Chemistry and Biochemistry, University of Colorado at Boulder

1990 – present	Fellow, Cooperative Institute for Research in Environmental Sciences, University of Colorado at Boulder
1998-1999	Associate Professor of Chemistry and Biochemistry, University of Colorado at Boulder
2000-2004	Associate Professor of Molecular, Cellular, and Developmental Biology, University of Colorado at Boulder
2004-present	Professor of Molecular, Cellular, and Developmental Biology, University of Colorado at Boulder
2012-2015	Associate Chair of Molecular, Cellular, and Developmental Biology, University of Colorado at Boulder

Scientific Appointments

1999-2003	NSF Molecular Biochemistry Panel
2000	NIH Physical Biochemistry Study Section
2001	Nominating Committee, Biological Division of the American Chemical Society
2002-2004	Councilor, Biological Division of the American Chemical Society
2003-2004	Associate, Committee on Environmental Improvement, American Chemical Society
2003-2005	Editorial Board, Bioorganic Chemistry
2003	Co-Vice Chair, Gordon Conference on Enzymes, Coenzymes, and Metabolic Pathways
2003-2004	NIH Biochemistry study section
2003-2011	Member of Faculty of 1000
2004	Co-Chair, Gordon Conference on Enzymes, Coenzymes, and Metabolic Pathways
2004-2005	Member, Japanese-American Frontiers of Science Symposium Planning Committee
2004-2005	Member, National Research Council Space Studies Board Committee on Limits of Life in the solar System
2004-2007	NIH Genetic Variation and Evolution study section
2009	NIH MSFE study section, Special Emphasis Panel and Grand Opportunity grant study section
2010	NIH Genetic Variation and Evolution study section, EUREKA Review Panel
2010-2013	Biocatalysis Organizing Committee, Society for Industrial Microbiology Annual Meeting
2012	Chemical and Systems Biology Theme Organizer, ASBMB 2013 Annual Meeting
2012	NIH Biological Chemistry and Macromolecular Biophysics B special study section
2012	NSF Molecular Biochemistry Panel
2013	NIH Glue Grant study section, NIH U54 study section
2014	NIH Genetic Variation and Evolution study section
2014-2016	Editorial Review Board, *Journal of Biological Chemistry*
2017	AbSciCon 2017 Session organizer, Origin and Evolution of Life: Evolution/Genetics: Experimental Microbial Evolution
2018	NIH Genetic Variation and Evolution study section
2019	NIH R25 study section
2020	NIH R35 study section
2021	NIH R24 study section
2022	NIH Fellowship study section
2022-	co-Theme Organizer, American Society for Biochemistry and Molecular Biology 2024 Annual Meeting
2022-	External Advisory Board, Arizona State University BII: Mechanisms of Cellular Evolution Center
2022-	Steering Committee, NASA *LIFE* Research Coordination Network
2023	Co-Vice Chair, Gordon Research Conference on Molecular Mechanisms in Evolution

2024 Theme Leader, Cool and Novel Enzymes, ASBMB 2024
2025 Co-Chair, Gordon Research Conference on Molecular Mechanisms in Evolution

Honors

1980 A. B. *summa cum laude*, Harvard University
1980 Phi Beta Kappa
1987-1988 Anna Fuller Fund Fellow
1991 University of Colorado Junior Faculty Development Award
1998 Mortar Board National Honor Society Outstanding Professor

C. Publications

Yang, D-D, Rusch, LM, Widney, KA, Morgenthaler, AB and Copley, SD. "Synonymous edits in the *E. coli* genome have substantial and condition-dependent effects on fitness", *Proc. Natl. Acad. Sci. USA*, 121 (5) e2316834121, 2024.

Fritts, RK, Ebmeier, CC and Copley, SD. "The transcriptomic and proteomic ramifications of segmental amplification", BioRxiv [Preprint] Nov 21, 2023, available from https://doi.org/10.1101/2023.11.21.568005.

Copley, SD, Newton, MS and Widney, KA. "How to recruit a promiscuous enzyme to serve a new function", *Biochemistry*, (Special issue in honor of Professor Dan Tawfik), 2022.

Morgenthaler, AB, Fritts, RK and Copley, SD. "Amplicon remodeling and genomic mutations drive population dynamics after segmental amplification", *Mol. Biol. Evol.* msab289, 2021.

Copley, SD, Babbs, S and Losoff, B. "Science and society: Integrating historical science materials into an undergraduate biology course", *CourseSource*, 2021.

Copley, SD. "Setting the stage for evolution of a new enzyme", *Curr. Opin. Structural Biol*, **69**, 41-49, 2021.

Copley, SD. "Evolution of new enzymes by gene duplication and divergence", *FEBS J.* **287**, 1262-1283, 2020.

Copley, SD. "The physical basis and practical consequences of biological promiscuity", *Phys. Biol.***17**, 051001, 2020.

Choudhury, A, Fankhauser, RG, Freed, EF, Oh, EJ, Morgenthaler, AB, Bassalo, MC, Copley, SD, Kaar, JL and Gill, RT. "Determinants for efficient editing with Cas9-mediated recombineering in *Escherichia coli*", *ACS Synth. Biol.* **9**, 1083-1099, 2020. PMID 32298586

Morgenthaler, AB, Kinney, WR, Ebmeier, CC, Walsh, CM, Snyder, DJ, Cooper, VS, Old, WM and Copley, SD. "Mutations that improve the efficiency of a weak-link enzyme are rare compared to adaptive mutations elsewhere in the genome". *eLife* **8**:e53535, 2019. PMID: 31815667 DOI: 10.7554/eLife.53535.

Kim, J, Flood, JJ, Kristofich, M, Gidfar, C, Morgenthaler, AB, Fuhrer, T, Sauer, U, Snyder, D, Cooper, VS, Ebmeier, CC, Old, WM, and Copley, SD. "Hidden resources in the *E. coli* genome restore PLP synthesis and robust growth after deletion of the "essential" gene *pdxB*", *Proc. Natl. Acad. Sci. USA* **116**, 24164-24173, 2019. PMID 31712440

Flood, J.J. and Copley, S.D. "Genome-wide analysis of transcriptional changes and genes that contribute to fitness during degradation of the anthropogenic pollutant pentachlorophenol by *Sphingobium chlorophenolicum*", *mSystems* **3**, e00275-18, 2018. PMID: 30505947

Kristofich, J-C, Morgenthaler, AB, Kinney, WR, Snyder, DJ, Ebmeier, CC, Old, WM, Cooper, VS, and Copley, SD. "Synonymous mutations make dramatic contributions to fitness when growth is limited by a weak-link enzyme", *PLoS Genet.* **14**, e1007615, 2018. PMID 30148850

Mikkonen, A, Yläranta, K, Tiirola, M, Dutra, LAL, Salmi, P, Romantschuk, M, Copley, S, Ikäheimo, J, Sinkkonen, A, "Successful aerobic bioremediation of groundwater contaminated with higher chlorinated phenols by indigenous degrader bacteria". *Water Res.* **138**, 118-128, 2018.

Copley, SD. "Shining a light on enzyme promiscuity", *Curr. Opin. Struct. Biol.* **47**, 67-75, 2017.

Kershner, JP, Yu McLoughlin, S, Kim, J, Morgenthaler, A, Ebmeier, CC, Old, WM, Copley, SD. "A synonymous mutation upstream of the gene encoding a weak-link enzyme causes an ultrasensitive response in growth rate." *J. Bacteriol.* **198**, 2853-2863, 2016. PMID 27501982

Thiaville, J, Flood, J, Yurgel, S, Prunetti, L, Elbadawi-Sidhu, M, Hutinet, G, Forouhar, F, Zhang, X, Ganesan, V, Reddy, P, Fiehn, O, Gerlt, J, Hunt, J, Copley, SD, De Crecy-Lagard, V. "Members of a novel kinase family (DUF1537) can recycle toxic intermediates into an essential metabolite", *ACS Chem. Biol.* **11**, 2304-2011, 2016.

Copley, SD. "An evolutionary biochemist's perspective on promiscuity", *Trends Biochem. Sci.* **40**, 72-78, 2015.

Khanal, A, Yu McLoughlin, S, Kershner, JP and Copley, SD. "Differential effects of a mutation on the normal and promiscuous activities of orthologs: implications for natural and directed evolution", *Mol. Biol. Evol.* **32**, 100-108, 2015. PMID: 25246702

Copley, SD. "An evolutionary perspective on protein moonlighting", *Biochem. Soc. Trans.* **42**, 1684-1691, 2014.

Rudolph, J, Erbse, AH, Behlen, L and Copley, SD. "A radical intermediate in the conversion of pentachlorophenol to tetrachlorohydroquinone in *Sphingobium chlorophenolicum*". *Biochemistry* **56**, 6539-6549, 2014. PMID: 25238136

Kim, J, Webb, AM, Kershner, JP, Blaskowski, S and Copley, SD. "A versatile and highly efficient method for scarless genome editing in *Escherichia coli* and *Salmonella enterica*", *BMC Biotechnol.* **14**, 84, 2014.

Rokicki, J, Knox, D, Dowell, RD, and Copley, SD. "CodaChrome: a tool for the visualization of proteome conservation across all fully sequenced bacterial genomes", *BMC Genom.* **15**, 65, 2014.

Novikov, Y and Copley, SD. "Reactivity landscape of pyruvate under simulated hydrothermal vent conditions", *Proc. Natl. Acad. Sci. USA* **110,** 13283-13288, 2013. PMID: 23872841

Yadid, I, Rudolph, J, Hlouchova, K and Copley, SD. "Sequestration of a highly reactive intermediate in an evolving pathway for degradation of pentachlorophenol", *Proc. Natl. Acad. Sci. USA*, **110**, E2182-E2190, 2013. PMID: 11764999

Kim, J and Copley, SD. "The orphan protein bis-γ-glutamylcystine reductase joins the pyridine nucleotide-disulfide reductase family", *Biochemistry* **52**, 2905-2913, 2013. PMID: 23560638

Kim, J and Copley, SD. "Inhibitory cross-talk upon introducing a novel metabolic pathway into an existing metabolic network", *Proc. Natl. Acad. Sci. USA* **109**, E2856-E2864, 2012. PMID: 22984162

Hlouchova, K, Rudolph, J, Pietari, JMH, Behlen, LS, Shoemaker, RK and Copley, SD. "Pentachlorophenol hydroxylase, a poorly functioning enzyme required for degradation of pentachlorophenol by *Sphingobium chlorophenolicum*, *Biochemistry* **51**, 3848–3860, 2012. PMID: 22482720

Copley, SD. "Paradigm adjustment required: Moonlighting is mainstream", *Bioessays* **34**, 578-588, 2012. PMID: 22696112

Copley, SD. and Summons, RE. "Terran Metabolism: The First Billion Years", in Frontiers of Astrobiology, C. Impey, J. Lunine and J. Funes, Eds., Cambridge University Press, 2012.

Copley, SD. "Toward a systems biology perspective on enzyme evolution", *J. Biol. Chem.* **287**, 3-10. (Special issue on Enzyme Evolution), 2012. PMID: 22069330

Copley, SD, Rokicki, J, Turner, P, Daligault, H, Nolan, M and Land, M. "The whole genome sequence of *Sphingobium chlorophenolicum* L-1: insights into the evolution of the pentachlorophenol degradation pathway", *Genome Biol. Evol.* **4**, 184-198, 2012. PMID: 22179583

Chumachenko, N, Novikov, Y, Shoemaker, RK and Copley, SD. "A dimethyl ketal-protected benzoin-based linker suitable for photolytic release of unprotected peptides", *J. Org. Chem.* **76**, 9409-9416, 2011. PMID: 21950361

Novikov, Y, Copley, SD. and Eaton, BE. "A simple route for synthesis of 4-phospho-D-erythronate", *Tetrahedron Lett.* **52**, 1913-1915, 2011.

Kim, J, Kershner, JP, Novikov, Y, Shoemaker, RK and Copley, SD. "Three serendipitous pathways in *E. coli* can bypass a block in pyridoxal 5'-phosphate synthesis", *Mol. Sys. Biol.* **6**, 43, 2010. PMID: 21119630

Rudolph, J, Kim, J and Copley, SD. "Multiple turnovers of the nicotino-enzyme PdxB require α-keto acids as co-substrates", *Biochemistry* **49***,* 9249–9255, 2010. PMID: 20831184

Copley, SD. "Evolution and the Enzyme", in *Comprehensive Natural Products Chemistry,* vol. 8, (Enzymes and Enzyme Mechanisms), Elsevier, pp 9-46; L. Mander and H.-W. Liu, Eds., 2010.

Copley, SD, Smith, E and Morowitz, HJ. "How life began: The emergence of sparse metabolic networks", *J. Cosmol.* **10**, 3345-3361, 2010.

Copley, SD. "Prediction of function in enzyme superfamilies", *F1000 Biology Reports*, **1**, Report 91, 2009.

Copley, SD. "Evolution of efficient pathways for degradation of anthropogenic chemicals", *Nature Chem. Biol.* **5**, 559-566, 2009. PMID: 19620997

Smith, E, Morowitz, HJ, and Copley, SD. "Core metabolism as a self-organized system", in *Protocells: Bridging Nonliving and Living Matter*, edited by Rasmussen, S. et al., MIT Press, 2009.

Yu McLoughlin, S and Copley, SD. "A compromise required by gene sharing enables survival: Implications for evolution of new enzyme activities", *Proc. Natl. Acad. Sci. USA* **105**, 13497-502, 2008. PMID: 18757760

Hamady, M, Widmann, J, Copley, SD, and Knight, R. "MotifCluster: An interactive online tool for clustering and visualizing sequences using shared motifs", *Genome Biol.* **9**, R128, 2008. PMID: 18706079

Warner, JR, Behlen, LS and Copley, SD. "A trade-off between catalytic power and substrate inhibition in TCHQ dehalogenase", *Biochemistry* **47**, 3258-3265, 2008. PMID: 18275157

Kim, J and Copley, SD. "Why metabolic enzymes are essential or non-essential for growth of *Escherichia coli* K12 on glucose", *Biochemistry* **46**, 12501-12511, 2007. PMID: 17935357

Warner, JR and Copley, SD. "Pre-steady state kinetic studies of the reductive dehalogenation catalyzed by tetrachlorohydroquinone dehalogenase", *Biochemistry* **46**, 13211-13222, 2007. PMID: 17956123

Copley, SD, Smith, E and Morowitz, HJ. "The origin of the RNA world: Co-evolution of genes and metabolism", *Bioorg. Chem.* **35**, 430-443, 2007. PMID: 17897696

Warner, JR and Copley, SD. "Mechanism of the severe inhibition of tetrachlorohydroquinone dehalogenase by its aromatic substrates", *Biochemistry* **46**, 4438-4447, 2007. PMID:17355122

Copley, SD. "Glutathione transferases", in *Redox Biology*, R. Banarjee, Ed., Wiley, 2007.

Cleland, CE and Copley, SD. "The possibility of alternative microbial life on earth", *Int. J. Astrobiology* **4**, 165-173, 2005.

Warner, JR, Lawson, SL, and Copley, SD. "A mechanistic investigation of the thiol-disulfide exchange step in the reductive dehalogenation catalyzed by tetrachlorohydroquinone dehalogenase", *Biochemistry* **44**, 10360-10368, 2005.

Copley, SD, Smith, DE, and Morowitz, HG. "A mechanism for the association of amino acids with their codons and the origin of the genetic code", *Proc. Natl. Acad. Sci. USA* **102**, 4442-4447, 2005 (PMC555468).

Dai, MH, Gill, RT and Copley, SD. "Visualization of protoplast fusion and quantitation of recombination in fused protoplasts of auxotrophic strains of *Escherichia coli*", *Metab. Eng.* **7**, 45-52, 2005.

Copley, SD, Novak, W, and Babbitt, PC. "Divergence of function in the thioredoxin-fold suprafamily: Evidence for evolution of peroxiredoxins from thioredoxins", *Biochemistry* **43**, 13981-13995, 2004. PMID:15518547

Dai, M-H and Copley, SD. "Genome shuffling improves degradation of the anthropogenic pesticide pentachlorophenol by *Sphingobium chlorophenolicum* ATCC 39723", *Appl. Env. Microbiol.* **70**, 2391-2397, 2004.

Copley, SD. "Enzymes with extra talents: Moonlighting functions and catalytic promiscuity", *Curr. Opin. Chem. Biol.* **7**, 265-272, 2003.

Dai, M-H, Rogers, JB, Warner, JR, and Copley, SD. "A previously unrecognized step in pentachlorophenol degradation in *Sphingobium chlorophenolicum* is catalyzed by tetrachlorobenzoquinone reductase (PcpD)", *J. Bacteriol.* **185**, 302-310, 2003. PMID:12486067

Copley, SD. and Dhillon, JK. "Lateral gene transfer and parallel evolution in the history of glutathione biosynthesis genes", *Genome Biol.* **3**, research 0025.1-0025.16, 2002.

Kiefer, PM, Jr, McCarthy, DL, and Copley, SD. "The reaction catalyzed by tetrachlorohydroquinone dehalogenase does not involve nucleophilic aromatic substitution", *Biochemistry* **41**, 1308-1314, 2002.

Kiefer, PM, Jr and Copley, SD. "Characterization of the initial steps in the reductive dehalogenation catalyzed by tetrachlorohydroquinone dehalogenase", *Biochemistry* **41**, 1315-1322, 2002.

Copley, SD. "Aromatic dehalogenases: Insights into structures, mechanisms, and evolutionary origins", *In* Dehalogenation: Microbial Processes and Environmental Applications, Kluwer Academic Publishers, 2002.

Copley, SD, Anandarajah, K and Kiefer, PM, Jr. "A tale of two enzymes – tetrachlorohydroquinone dehalogenase and maleylacetoacetate isomerase", *Chem.-Biol. Interact*. **133**, 200-203, 2001.

Copley, SD. "Evolution of a metabolic pathway for degradation of a toxic xenobiotic: The patchwork approach", *Trends Biochem. Sci.* **26**, 261-265, 2000.

Anandarajah, K, Kiefer, PM, Donohoe, BS. and Copley, SD. "Recruitment of a double bond isomerase to serve as a reductive dehalogenase during biodegradation of pentachlorophenol", *Biochemistry* **39**, 5303-5311, 2000.

Fall, R and Copley, SD. "Bacterial sources and sinks of isoprene, a reactive atmospheric hydrocarbon", *Env. Microbiol.* **2**, 123-130, 2000.

Xu, L, Resing, K, Babbitt, PC, Lawson, SL and Copley, SD. "Evidence that *pcpA* Encodes dichlorohydroquinone dioxygenase, the ring-cleavage enzyme required for degradation of pentachlorophenol in *Sphingomonas chlorophenolica*", *Biochemistry* **38**, 7659-7669. 1999

Copley, SD. “Microbial dehalogenases”. *In* Enzymes, Enzyme Mechanisms, Proteins, and Aspects of NO Chemistry, C. D. Poulter, Ed., Vol. 5 of Comprehensive Natural Products Chemistry, D. Barton and K. Nakanishi, Eds., 1999.

Copley, SD. “Microbial dehalogenases: Enzymes recruited to convert xenobiotic substrates”, *Curr. Opin. Chem. Biol.* **2**, 613-617, 1998.

McCarthy, DL, Louie, DF and Copley, SD. “Identification of a covalent intermediate between glutathione and Cys13 formed during catalysis by tetrachlorohydroquinone dehalogenase.”*J. Am. Chem. Soc.* **119**, 11337-11338, 1997.

Copley, SD. “Diverse mechanistic approaches to difficult chemical transformations: Microbial dehalogenation of chlorinated aromatic compounds. *Chem. & Biol.* **4**, 169-174, 1997.

Plowman, DL, Claude, A and Copley, SD. “*In vivo* levels of chlorinated hydroquinones in a pentachlorophenol-degrading bacterium”, *Appl. Env. Microbiol.* **63**, 1883-1888, 1997.

McCarthy, D, Navarette, S, Willett, WS, Babbitt, PC. and Copley, SD. “Exploration of the relationship between tetrachlorohydroquinone dehalogenase and the glutathione *S*-transferase superfamily”, *Biochemistry* **35**, 14634-14642, 1996.

Willett, WS and Copley, SD. “Identification and localization of a stable sulfenic acid in peroxide-treated tetrachlorohydroquinone dehalogenase using electrospray mass spectrometry”, *Chem. & Biol.* **3**, 851-857, 1996.

Crooks, GP, Xu, L, Barkley, R and Copley, SD. "Exploration of possible mechanisms for 4-chloro-benzoyl CoA dehalogenase: Evidence for an aryl-enzyme intermediate." *J. Am. Chem. Soc.* **117**, 10791-10798, 1995.

Crooks, GP and Copley, SD. "Purification and characterization of 4-chlorobenzoyl CoA dehalogenase from *Arthrobacter* sp. 4CB-1" *Biochemistry* **33**, 11645-11649, 1994.

Crooks, GP and Copley, SD. "A surprising effect of leaving group on the nucleophilic aromatic substitution reaction catalyzed by 4-chlorobenzoyl CoA dehalogenase." *J. Am. Chem. Soc.* **115**, 6422-6423, 1993.

Copley, SD and Crooks, GP. "Enzymic dehalogenation of 4-chlorobenzoyl CoA in *Acinetobacter* sp. 4-CB1." *Appl. Env. Microbiol*. **58**, 1385-1387, 1992.

Copley, SD, Frank, E, Kirsch, WM and Koch, TH. "Aminomalonic acid: A constituent of proteins or an artifact of hydrolysis?" *Anal. Biochem.* **201**, 152-157, 1992.

Copley, SD. and Knowles, JR. "The conformational equilibrium of chorismate in solution: Implications for the mechanism of the non-enzymic and the enzyme-catalyzed rearrangement of chorismate to prephenate." *J. Am. Chem. Soc.* **109**, 5008- 5012, 1987.

Guilford, WJ, Copley, SD and Knowles, JR. "On the mechanism of the chorismate mutase reaction." *J. Am. Chem. Soc.* **109**, 5013-5019, 1987.

Copley, SD and Knowles, JR. "The uncatalyzed Claisen rearrangement of chorismate to prephenate prefers a transition state of chairlike geometry." *J. Am. Chem. Soc.* **107**, 5306-5308, 1985.

Grimshaw, CE, Sogo, SG, Copley, SD and Knowles, JR. "Synthesis of stereoselectively labeled [9-^{2}H,^{3}H] chorismate and the stereochemical course of 5-enolpyruvoyl shikimate-3-phosphate synthetase." *J. Am. Chem. Soc.* **106**, 2699-2700, 1984.

Kovachy, R. J, Copley, SD and Allen, RH. **“**Recognition, isolation, and characterization of rat liver D-methylmalonyl coenzyme A hydrolase.” *J. Biol. Chem.* **258**, 11415-21, 1983.

D. Funding

NASA Exobiology Copley (PI)

1/15/21-1/14/24
$555,750
Confronting a Conundrum: the Prevalence of Loss-of-function Mutations in Evolution

NIH/NIGMS R01GM134044 Copley (PI)
8/12/19 – 7/31/23, in no-cost extension
$1,420,133
Gene Duplication and Divergence: the Bigger Picture

NIH/NIGMS R01GM135364 Copley (PI)
5/1/20-2/29/24
$1,390,009
Promiscuity, Serendipity and Metabolic Innovation

National Aeronautics and Space Administration Interdisciplinary Consortia for Astrobiology Research
80NSSC23K1357 Rosenzweig, GA Tech (PI)
10/1/23 – 9/30/28
$803,483 to Copley lab
Engine of Innovation: How Compartmentalization Drives Evolution of Novelty and Efficiency Across Scales