

David L. Zechel

Associate Professor of Chemistry

Curriculum vitae

Department of Chemistry, Queen's University,
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Website: www.zechellab.com

Birthplace

Winnipeg, Manitoba, Canada, 1973

Personal

Married, 2 children

Research Interests

Enzyme mechanisms, organophosphonate degradation, enzymatic halogenation, natural product biosynthesis.

Research Experience

- 2010 – 2011 Sabbatical stay with Professor Andreas Bechthold, Institut für Pharmazeutische Wissenschaften, Albert-Ludwigs-Universität, Freiburg, Germany. Identification and genetic manipulation of natural product biosynthetic pathways in *Streptomyces* sp.
- 2010 – present Associate professor, Department of Chemistry, Queen's University, Kingston, Ontario, Canada
- 2004 – 2010 Assistant professor, Department of Chemistry, Queen's University
- 2002 – 2004 Post-doctoral fellow with Prof. Andreas Plückthun, Biochemisches Institut, Universität Zürich, Switzerland. Development of ribosome display for evolution of proteins. Selection of novel protein folds from random secondary-structure protein libraries.
- 2001 – 2002 Post-doctoral fellow with Prof. Gideon Davies, York Structural Biology Laboratory, University of York, UK. Study of glycosidase mechanism through X-ray crystallography, transition state analogue inhibitors, isothermal titration calorimetry and kinetic analysis.
- 1996 – 2001 Ph.D. student with Prof. Stephen Withers, Department of Chemistry, University of British Columbia, Canada. Study of glycosidase mechanism. Engineering mutant glycosidases (glycosynthases) for the synthesis of oligosaccharides and carbon fluorine bonds. Development of ESI-MS for the analysis of enzyme kinetics.

Education and Training

- 2013, 2016 Whitewater Rescue Technician, Level III certification
1996 – 2001 Ph.D. in chemistry and enzymology, Department of Chemistry, University of British Columbia
1991 – 1995 B.Sc. in chemistry and biochemistry, University of Toronto

Awards and Fellowships

- 2011 Ontario / Baden-Württemberg Faculty Exchange Award (held in Bechthold lab, Albert-Ludwigs Universität Freiburg).
2007 Ontario Early Researcher Award
2006 *Synlett* and *Synthesis* Journal Award
2004 Boehringer Ingelheim Award for Organic or Bioorganic Chemistry (Ph.D thesis)
2002–2004 Human Frontier Science Program Postdoctoral Fellow (Plückthun Lab)
2001 Arthur S. Hawkes Fellowship (UBC)
2000–2001 University of British Columbia Graduate Fellowship
1998–2000 Izaak Walton Killam Predoctoral Fellowship
1992–2000 Natural Sciences and Engineering Research Council of Canada (NSERC) scholar (undergraduate and graduate)
1991–1995 University of Toronto Arbor Scholar
1991–1995 Canada Science Scholar

Undergraduate Course Instruction

- 2013 – present Chem 311 Physical Organic Chemistry (50–70 students per year)
2009, 2011 – present Chem 281 Organic Chemistry (500 students each year)
2005 – 2008 Chem 212 Principles of Chemical Reactivity (250 to 300 students each year)
2007 – 2011, 2013 Chem 323 Biological Chemistry (35–50 students per year)
2004 – present Chem 417 Research Project (1 to 2 4th year students each year)
2004 – present BCHM 422 Advanced Biochemistry Laboratory II (supervised several students from this program in my lab since 2004)

Graduate Course Instruction

- 2013, 2015 Chem 915, Biosynthesis of Natural Products
2005, 2008 Chem 814, Carbohydrate Chemistry
2006 Chem 983, Solving Reaction Mechanisms
2010 Chem 915, Protein Engineering
2005, 2009, 2012, 2014, 2016, 2017 Chem 883, Bioorganic Chemistry

RESEARCH FUNDING (2010–present)

- 2017–2020, NSERC Strategic Grant, \$851,400 (\$179,100 to DLZ), Biodegradation of the most commonly used herbicide on earth. Trevor Charles (PI, U. Waterloo), Geoff Horsman (Wilfrid Laurier U.), Ze-Chun Yuan (U. Western Ontario), Keri Wang (A&L Canada Labs)
- 2016–2019, NSERC Directed Accelerator Supplement, **\$120,000**, From Genes to Molecules: Mining Bacterial Genomes for New Enzyme Reactions. Zechel (PI).
- 2016–2021, NSERC Discovery Grant, **\$300,000**, From Genes to Molecules: Mining Bacterial Genomes for New Enzyme Reactions. Zechel (PI).
- 2015–2016, NSERC RTI1, **\$99,274**, Shaker incubators for cultivation of bacteria, Zechel DL (PI), Jia Z, Ross A, Smith S.
- 2011–2016, NSERC Discovery Grant, **\$150,000**, From Genes to Molecules: Mining Bacterial Genomes for New Enzyme Reactions. Zechel (PI).
- 2013–2014, NSERC RTI1, **\$118,094**, Monitoring Biomolecular Interactions using Isothermal Titration Calorimetry, Jia Z (PI), Zechel DL, Plaxton W, Snedden W.
- 2012–2013, NSERC RTI1, **\$150,000**, HPLC–DAD–MS System, Zechel DL (PI), Crudden C, Jessop P, Oleschuk R, Petitjean A.
- 2012–2013, Queen's University Senate Advisory Committee–Principal's Development Fund, **\$10,000**, Waking the Dead: Revival of Cryptic Natural Product Biosynthesis in Streptomyces for Drug Discovery. Zechel (PI).
- 2007–2012, Early Researcher Award, Ministry of Research and Innovation Ontario, **\$100,000**, Harnessing Nature's Catalysts: Mechanistic and Engineering of Enzymes. Zechel (PI).
- 2005–2012, CFI – Infrastructure Operating Fund, **\$37,440**, Zechel (PI).
- 2010–2012, Green Centre Canada – Proof of Principle Fund, **\$35,000**, Turning a new leaf: synthesis of organohalogens with halogenases. Zechel (PI).
- 2010–2011, Queen's University Senate Advisory Committee–Principal's Development Fund, **\$10,000**, In pursuit of biological fluorination: deciphering the biosynthesis of nucleocidin. Zechel (PI).

Publications (2010–present)

(Zechel lab trainees in **bold**, [§]shared first authorship, *corresponding author)

49. Sarwar, A; Latif, Z; Zhang, S; Zhu, J; Zechel, D; *Bechthold, A. Biological control of potato common scab with rare Isatropolone C compound produced by plant growth promoting *Streptomyces* A1RT. *Front. Microbiol.* **2018**, 9, 1126.
48. Ulrich, EC; Kamat, SS*; Hove–Jensen, B*; Zechel DL*. Methylphosphonic Acid Biosynthesis and Catabolism in Pelagic Archaea and Bacteria. *Methods in Enzymology* **2018**, 605, 351–426. *Invited review for a special volume on marine enzymes and specialized metabolism (edited by Bradley Moore).*
47. Zhang, S.; Zhu, J.; Zechel, D. L.; Jessen–Trefzer, C.; Eastman, R. T.; Paululat, T.; Bechthold, A. New WS9326A Derivatives and One New Annimycin Derivative with Antimalarial Activity Are Produced by *Streptomyces asterosporus* DSM 41452 and Its Mutant. *ChemBioChem* **2017**, 19, 272–279.
46. Horsman G and Zechel DL*: Unusual Transformations in Phosphonate Biochemistry. *Chem. Rev.* **2017**, 118, 5704–5783. *Invited contribution for a special issue on unusual enzyme reactions (edited by Wilfred van der Donk).*
45. Zechel DL: PhnK: Another Piece of the Carbon–Phosphorus Lyase Puzzle. *Structure/Folding and Design* **2016**, 24, 3–4. *Invited commentary.*
44. Johnston CW, Skinnider MA, Wyatt MA, Li X, Ranieri MRM, Yang L, Zechel DL, Ma B, Magarvey NA*: An Automated Genomes–to–Natural Products Platform (GNP) for the Discovery of Modular Natural Products. *Nature Comms.* **2015**, 6, 1–11.
43. **Zhu XM**, Hackl S, Thaker MN, Kalan L, Weber C, Urgast DS, Krupp EM, **Brewer A**, **Vanner S**, **Szawiola A**, Yim G, Feldmann J, Bechthold A, Wright GD, Zechel DL*: Biosynthesis of the fluorinated natural product nucleocidin in *Streptomyces calvus* is dependent on the *bldA* specified Leu–tRNA^{UUA} molecule. *ChemBioChem* **2015**, 16, 2498–2506.
42. **Gessner A**, Heitzler T, Zhang S, **Klaus C**, Murillo R, **Zhao H**, **Vanner S**, **Zechel DL***, and **Bechthold A***. Changing biosynthetic profiles by expressing *bldA* in *Streptomyces* strains. *ChemBioChem* **2015**, 16, 2244–2252.
41. van Staalduinen LM, **McSorley FR**, Schiessl K, **Séguin J**, Wyatt PB, Hammerschmidt F, Zechel DL*, Jia J*: Crystal structure of PhnZ bound to substrate reveals a new di–iron oxygenase mechanism for catabolism of organophosphonates. *PNAS* **2014**, 111, 5171–5176.
40. Hove–Jensen, B., Zechel, D.L., and Jochimsen, B. Utilization of glyphosate as phosphate source: Biochemistry and genetics of bacterial carbon–phosphorus lyase. *Microbiol. Mol. Biol. Rev.* **2014**, 78, 176–197.
39. Kalan L[§]; **Gessner A**[§], Thaker MN, Waglechner N, **Zhu X**, **Szawiola A**, Bechthold A, Wright GD, Zechel DL*: A cryptic polyene biosynthetic gene cluster in *Streptomyces calvus* is expressed upon complementation with a functional *bldA* gene. *Chem. Biol.* **2013**, 20, 1214–1224. *Highlighted in a commentary by Keith Chater (Chem. Biol. 2013, 20, 1199–1200).*
38. Hove–Jensen B*, **McSorley FR**, Zechel DL*: Catabolism and detoxification of 1–aminoalkylphosphonic acids: *N*-acetylation by the *phnO* gene product. *PLoS One* **2012**, 7, e46416.
37. **McSorley FR**, Wyatt PB, Martinez A, DeLong EF, Hove–Jensen B, Zechel DL*: PhnY and PhnZ comprise a new oxidative pathway for enzymatic cleavage of a carbon–phosphorus bond. *J. Am. Chem. Soc.* **2012**, 134, 8364–7. *Selected as a “Spotlight” article (JACS, 2012, 134, 9830–9831)*
36. **He S–M**, **Wathier M**, Podzelinska K, **Wong M**, **McSorley F**, Asfaw, A, Hove–Jensen B, Jia Z, Zechel DL*: Structure and mechanism of PhnP, a phosphodiesterase of the carbon–phosphorus lyase pathway. *Biochemistry*, **2011**, 50, 8603–15.
35. Jochimsen B, Lolle S, **McSorely FR**, Nabi M, Stougaard J, Zechel DL, Hove–Jensen B*: Five *phn* gene products as components of a multi–subunit complex of the carbon–phosphorus lyase pathway for organophosphonate catabolism. *Proc. Natl. Acad. Sci. USA*, **2011**, 108, 11393–8.

34. Harle, J, Gunther S, Lauinger B, Weber M, Kammerer B, Zechel DL, Luzhetskyy A, Bechthold A*: Rational design of an aryl-C-glycoside catalyst from a natural product O-glycosyltransferase. *Chem. Biol.* **2011**, *18*, 520–30.
33. Hove-Jensen B*, **McSorley F**, Zechel DL*: Physiological role of *phnP*-specified phosphoribosyl cyclic phosphodiesterase in catabolism of organophosphonic acids by the carbon-phosphorus lyase pathway. *J. Am. Chem. Soc.* **2011**, *133*, 3617–24.
32. **Groom K**, **Bhattacharya A**, Zechel DL*: Rebeccamycin and staurosporine biosynthesis: Insight into the mechanisms of the flavin-dependent monooxygenases RebC and StaC. *ChemBioChem* **2011**, *12*, 396–400.
31. Podzelinska K, **Latimer R**, **Bhattacharya A**, Vining LC, Zechel DL*, Jia Z*: The structure of CmlS, a flavin-dependent halogenase involved in the biosynthesis of chloramphenicol. *J. Mol. Biol.* **2010**, *397*, 316–331.
30. Hove-Jensen B*, Rosenkrantz TJ, Zechel DL, Willemoës M: Accumulation of intermediates of the carbon-phosphorus lyase pathway for phosphonate degradation in *phn* mutants of *E. coli*. *J. Bacteriol.* **2010**, *192*, 370–4.
29. Nelson GW, **Perry M**, **He SM**, Zechel DL, Horton JH*: Characterization of covalently bonded proteins on poly(methyl methacrylate) by X-ray photoelectron spectroscopy. *Colloids. Surf. B Biointerfaces* **2010**, *78*, 61–68.
28. Suits MDL, Zhu Y, Taylor EJ, Walton J, Zechel DL, Gilbert HJ, Davies GJ*: Structure and kinetic investigation of *Streptococcus pyogenes* family GH38 alpha-mannosidase. *PLoS ONE* **2010**, *5*, e9006.

Book Chapters

- Kamat S, Singh S, Abinaya R, **Gama S**, Zechel DL, “Enzymatic Strategies for the Catabolism of Organophosphonates” in Comprehensive Natural Products III: Chemistry and Biology. In preparation. *Invited chapter for a volume on enzyme mechanisms (edited by Christian Whitman, Kenji Watanabe, and Paul Fitzpatrick).*
- Seguin J**, Zechel DL, “The Di-Iron Oxygenase PhnZ” in the Encyclopedia of Inorganic and Bioinorganic Chemistry, Messerschmidt A, Ed., Wiley (2016). *Invited contribution on the new CP-bond cleaving enzyme PhnZ discovered by my lab.*

Seminars (2010–present)

46. “A Short History of Methylphosphonate“.RTG1976 Co-factor Retreat, Felberg-Falkau, Germany, April **2018**. **Keynote speaker**.
45. “Activation of Molecular Oxygen for Microbial Biosynthesis and Catabolism“, RTG1976 Enzyme Co-factor Working Group, Albert-Ludwigs-Universität Freiburg, Freiburg, Germany, February, **2018**. **Invited seminar**.
44. “New enzyme mechanisms from microbial catabolism of organophosphonates“, DPhG seminar series, Institute for Pharmaceutical Sciences, Albert-Ludwigs-Universität Freiburg, November **2017**, Freiburg, Germany. **Invited seminar**.
43. “New chemistry from the sea: Enzymatic cleavage of phosphonate CP bonds via CH bond activation“, 100th Canadian Chemistry Conference and Exhibition, Symposium on Reactivity in Organic and Biological Chemistry, Toronto, June **2017**. **Invited seminar**.
42. “Biosynthesis of fluorometabolites and the perplexing case of a missing molecule“ 100th, Canadian Chemistry Conference and Exhibition, Symposium on Fluorinated Molecules: Syntheses, Analysis, and Applications, Toronto, June **2017**. **Invited seminar**.
41. “Follow the chemistry: making and breaking odd-bonds with enzymes“. Molecular and Cellular Biology group, Department of Biology, Queen’s University, March 28th, 2017. Invited seminar.
40. “Follow the chemistry: making and breaking odd-bonds with enzymes“. Department of Chemistry, University of Toronto, March 10th, 2017. **Invited seminar**.

39. "*Raising the dead: A cure for baldness and cryptic biosynthesis in Streptomyces calvus*", International VAAM–Workshop 2016, Biology of Bacteria Producing Natural Products, Freiburg, Germany, September 2016. **Plenary speaker.**
38. "*A cure for baldness and cryptic biosynthesis in Streptomyces calvus*", Maritimes Natural Products Conference, Dalhousie University, Halifax, August 2016. **Plenary speaker.**
37. "*Follow the chemistry: Making and breaking odd bonds with enzymes.*" Trent University, March 2nd, 2016.
36. "Follow the chemistry: Making and breaking odd bonds with enzymes." Wilfrid Laurier University Jan. 29th, 2016.
35. "*A cure for baldness and cryptic biosynthesis in Streptomyces calvus.*" Pacifichem 2015 – Biosynthesis of Natural Products symposium, Waikiki, USA, December 2015. **Invited seminar.**
34. "*A new oxidative pathway for enzymatic cleavage of phosphonate CP bonds.*" 250th American Chemical Society National Meeting, Symposium celebrating Gordon Hammes Award recipient Frank Raushel, Boston, August, 2015. **Invited seminar.**
33. "*A cure for baldness and cryptic biosynthesis in Streptomyces calvus*". American Society of Pharmacognosy Annual Meeting, Copper Mountain, Colorado, USA, July 2015. **Invited seminar.**
32. "*Eliminating bottlenecks in natural product discovery: the role of TTA codons in the expression of biosynthetic pathways in Streptomyces.*" Canadian Society for Chemistry national meeting, Natural Product Biosynthesis symposium, Ottawa, June 2015
31. "*Raising the dead: cryptic biosynthesis in Streptomyces calvus*". Cellular and Molecular Biology group meeting, Dept. of Biology, Queen's University, Kingston, Ontario, January 2015.
30. "*New chemistry from the sea: Enzymatic cleavage of phosphonate CP bonds via CH bond activation.*" 20th International Conference on Phosphorus Chemistry (ICPC), Dublin, Ireland, June 2014. **Invited seminar.**
29. "*Mechanistic and structural analysis of a new di-iron dependent oxygenase that cleaves carbon– phosphorus bonds.*" Canadian Society for Chemistry national meeting, Enzymology Session, Vancouver, June 2014
28. "*New enzyme mechanisms for the cleavage of carbon–phosphorus bonds.*" Canadian Society for Chemistry national meeting, Quebec, May, 2013.
27. "*Expression and analysis of cryptic biosynthetic genes in Streptomyces.*", Canadian Society for Chemistry national meeting, Quebec, May, 2013.
26. "*Advances in the structure and mechanisms of microbial enzymes that transform organophosphonates to phosphate*" Dept. of Chemistry, York University, October, 2012.
25. "*Necessity is the mother of invention: enzymatic cleavage of carbon–phosphorus bonds.*" BioMOLAR Network, Dept. of Chemistry, University of Ottawa, April 2012.
24. "*Waking the dead: Cryptic biosynthesis in Streptomyces calvus.*" Depts. of Biochemistry and Molecular Biology, Dalhousie University, September 2011.
23. "*Necessity is the mother of invention: enzymatic cleavage of carbon–phosphorus bonds.*" Dept. of Chemistry, McMaster University, September 2011.
22. "*Flavin–dependent enzymes in natural product biosynthesis.*" Helmholtz Institute for Pharmaceutical Sciences (HIPS), Saarbrücken University, Germany, May, 2011.
21. "*New frontiers in enzymatic organophosphonate degradation.*" Biochemisches Institut, Universität Zürich, Switzerland, March, 2011.
20. "*Breaking up is hard to do: Analysis of bacterial enzymes involved in the metabolism of organophosphonates.*" Albert–Ludwigs–Universität, Dept. of Pharmaceutical Sciences, Freiburg, Germany, November, 2010.
19. "*Halogenases: better living through ‘natural’ chemistry.*" Canadian Society for Chemistry national meeting, Toronto, June, 2010.
18. "*Oxidative Enzymes in Natural Product Biosynthesis.*" Dept. of Biochemistry, University of Victoria, April, 2010.

GRADUATE STUDENT SUPERVISION

MSc

2017–present	Suhayla Sequeira	Biosynthesis of nucleocidin
2015–2017	Kaitlyn Pinkett	Biosynthesis of the fluorinated natural product nucleocidin.
2013–2015	Alyssa Brewer	An analysis of the gene cluster encoding the biosynthesis of the fluorinated natural product nucleocidin by <i>Streptomyces calvus</i> . Present position: Pharmacy technician.
2013–2015	Jacqueline Seguin	Mechanistic analysis of the organophosphonate–degrading enzymes PhnY and PhnZ. Present Position: Scientist in protein expression group, Albany Molecular Research (Buffalo, USA)
2012–2014	Zhu, XiMing	Exploration of the cryptic biosynthetic pathways activated with a functional <i>bldA</i> gene in <i>Streptomyces calvus</i> . Present position: medical school, University of London, UK
2008–2010	Latimer, Ryan	Studies on the chloramphenicol halogenase CmlS. Present position: medical doctor resident, Canada
2008–2010	Hu, Di (co-supervised)	Computational studies of lipid autooxidation and solvent mediated antioxidant activity and a kinetic study of a halogenase in the pyrrolnitrin biosynthetic pathway. (co-supervised with Derek Pratt, now at U. of Ottawa). Present position: technologist at Sanofi Pasteur, Toronto
2006–2009	Perry, Meagan	Improving protein solubility via directed evolution. Present position: Clinical research project coordinator, Hospital for Sick Children.
2005–2008	He, Shu-Mei	Towards the structures and mechanisms of carbon-phosphorus lyase enzymes. Present position: lab technician, Queen's University.

PhD

2016–present	Ola Pasternak	Biosynthesis of fluorinated natural products.
2013–present	Simon, David (co-supervised)	Analysis of the influence of the <i>bldA</i> gene on the proteome and metabolome of <i>Streptomyces</i> sp. Co-supervised with Richard Oleschuk (Queen's).
2017–2018	Becky Lo	Mechanistic studies with the phosphonate degrading enzymes PhnY* and PhnZ
2013	Aftab, Usman	Discovery of anticancer compounds in <i>Streptomyces</i> isolated in Pakistan. Visiting PhD student (6 months).
2010–2012	Gessner, Arne (co-supervised)	The effect of the <i>bldA</i> gene on <i>Streptomyces</i> secondary metabolite production. Visiting student (2 months) and co-supervised with Andreas Bechthold, Albert-Ludwigs-Universität Freiburg. Present position: research scientist, Hoffmann La Roche Ltd., Switzerland.
2008–2013	McSorley, Fern	Enzymatic cleavage of carbon-phosphorus bonds. Present position: postdoctoral fellow with Chris Boddy, U. of Ottawa.

2005–2013 Groom, Katherine Studies in the biosynthesis and chemical synthesis of indolocarbazoles. Co-supervised with Victor Snieckus
Present position: intellectual property chemist, Apotex Pharmachem Inc., Toronto.

Postdoctoral

2018–present Manisha Patel Biosynthesis of cyanobactins.

2018–present Simanga Gama Mechanism of Pn catabolic enzymes.

2008–2009 Trofimova, Daria Generation of reactive oxygen species by antibodies. Co-supervised with Derek Pratt (now at U. of Ottawa)
(co-supervised) Present position: postdoctoral fellow, Queen's University.

2005–2007 Bhattacharya, Anupam Indolocarbazole biosynthesis and halogenases.
Present position: Assistant Professor, Dept. of Chemistry, Birla Institute of Technology and Science, Pilani, Hyderabad, India

2005–2008 Luo, Yan Mechanism of carbon-phosphorus lyase.
Present position: Biochemistry group leader, Caprotec Bioanalytics, Berlin, Germany.

Undergraduate

Supervised ca 40 undergraduates since 2004. This includes 4th year honours thesis projects, NSERC USRAs, co-op placements, volunteers, and visiting students.

COLLABORATIONS

National

Zongchao Jia, DBMS, Queen's University

Jia is a Canada Research Chair in Structural Biology. I have long collaborated with his lab to determine the X-ray crystal structures of our enzymes. We have published several papers together on CP-bond cleaving enzymes and halogenases (*PNAS* 2014, *Biochemistry* 2011, *J Mol Biol* 2010, *J Biol Chem* 2009, *J Bacteriol* 2008).

Nathan Magarvey, McMaster University

We work with the Magarvey lab to use his pioneering "Genes to Natural Products" methodology (GNP), a combination of bioinformatics, chemoinformatics, and MS/MS. GNP allows one to predict the structure of a natural product based on a microbial biosynthetic gene cluster. We share co-authorship on a recent paper describing the versatility of GNP (*Nature Comms* 2015).

Gerry Wright, McMaster University

We collaborated with the Wright lab to sequence the genome of *Streptomyces calvus*. It was through this collaboration that we discovered the role of *bldA* in the expression of cryptic biosynthetic pathways, including that of the rare fluorinated natural product, nucleocidin. We share co-authorship on our *Chem Biol* 2013 and *CheBioChem* 2015 papers.

International

Jorg Feldmann, University of Aberdeen, United Kingdom

Feldmann has developed a novel spectroscopic method called continuum source molecular absorption spectroscopy (CS-MAS) which can be coupled to HPLC for the detection of molecules that contain fluorine. We collaborate with his lab to analyze culture extracts from *Streptomyces calvus* for the presence of organofluorine secondary metabolites, including nucleocidin. He is a co-author on our *ChemBioChem* 2015 paper on nucleocidin.

Friedrich Hammerschmidt, University of Vienna, Austria

Analysis of the mechanisms of carbon-phosphorus bond cleavage by PhnY and PhnZ using substrate analogues synthesized by the Hammerschmidt lab. This is a very successful, ongoing collaboration that has so far led to co-authorship in our *PNAS* (2014) paper.

Andreas Bechthold, Albert-Ludwigs-Universität-Freiburg, Germany

Analysis of cryptic biosynthetic pathways in *Streptomyces*. This is a highly successful collaboration that began during my sabbatical in the Bechthold lab in 2010–2011. This collaboration initiated our studies into the biosynthesis of the annimycin and nucleocidin in *S. calvus*. We share co-authorship on our *Chem Biol* (2013) and *ChemBioChem* (2015) papers. We continue to collaborate on the effect of the *bldA* gene on expression of cryptic biosynthetic genes in *Streptomyces*. This has involved the exchange of students between our labs.

Edward F. DeLong, MIT, USA

Use of genetic screens to discover new organophosphonate catabolic pathways in microbes. The DeLong lab shared metagenomic data that contributed to our *JACS* (2012) paper on the novel oxidative PhnY / PhnZ pathway.

Bjarne Hove-Jensen, University of Copenhagen,

Analysis of the *E. coli* carbon-phosphorus (CP) lyase pathway for organophosphonate degradation. This is arguably my most successful collaboration involving a very complex and novel metabolic pathway. Since 2008 this collaboration has produced 11 co-authored papers concerning the CP-lyase pathway, including publications in *JACS* (2011, 2012) and *PNAS* (2011). Hove-Jensen provided brilliant expertise in microbiology that underpinned many of these publications. Our collaboration also involved Hove-Jensen visiting my lab on two occasions (Feb 2010 – Sept 2010, Apr 2011 – Sept 2011) for a total of 14 months which provided a unique opportunity for my students to work alongside an expert in *E. coli* genetics.