

**Serina L. Robinson**

## 1. PERSONAL INFORMATION

---

**Email:** [serina.robinson\[at\]eawag.ch](mailto:serina.robinson[at]eawag.ch), **Tel:** +41 58 765 6423

**OrcID:** [0000-0001-6947-7913](https://orcid.org/0000-0001-6947-7913); **Google Scholar:** [0bXdVF8AAAAJ&hl](https://scholar.google.com/citations?user=0bXdVF8AAAAJ&hl)

**DOB:** 18.08.1993, **Languages:** English: native, Norwegian: C1, German: B2

## 2. OVERVIEW

---

- Research areas: metagenome-guided discovery of microbial enzymes and pathways, machine learning, biotransformation of contaminants including pharmaceuticals, pesticides, food additives and packaging, current focus on per- and-polyfluoroalkyl substances (PFAS).
- Collaborative researcher working across disciplines including environmental biochemistry, microbiology and microbial ecology, computational biology, and cheminformatics.

## 3. PROFESSIONAL EXPERIENCE

---

Sept 2021 – Present | **Group leader, tenure-track**  
Department of Environmental Microbiology  
Swiss Federal Institute of Aquatic Science and Technology (Eawag)  
Dübendorf, CH

Aug 2020 – Aug 2021 | **ETH Postdoctoral research fellow**  
Advisor: Prof. Dr. Jörn Piel, Institute of Microbiology  
Eidgenössische Technische Hochschule (ETH) Zürich, Zürich, CH

Jun 2020 – Jul 2020 | **Postdoctoral researcher**, Advisor: Prof. Dr. Larry Wackett  
University of Minnesota – Twin Cities, Minneapolis, MN, USA

Jan 2019 – July 2019 | **National Science Foundation Ph.D. research fellow abroad**  
Dept. of Bioinformatics, Advisor: Prof. Dr. Marnix Medema  
Wageningen University & Research, Wageningen, the Netherlands

Aug 2015 – Aug 2016 | **Fulbright research fellow**, Advisor: Prof. Dr. Mette M. Svenning  
UiT: the Arctic University of Norway, Tromsø, Norway

Aug 2013 – May 2015 | **EPA GRO research Fellow**, Advisor: Dr. Carlie A. Lalone,  
U.S. Environ. Protection Agency Mid-continent Ecology Div., Duluth, USA

## 4. EDUCATION

---

Sept 2016 – May 2020 | **Ph.D., Microbiology**, defended May 27, 2020, Advisor: Prof. Dr. Larry Wackett, University of Minnesota – Twin Cities, Minneapolis, MN, USA

Sept 2018 – April 2020 | **M.Sc., Bioinformatics and Computational Biology (dual degree with Ph.D.)** University of Minnesota – Twin Cities, Minneapolis, USA

Sept 2011 – May 2015 | **B.A., Chemistry, B.A. Norwegian**, *summa cum laude*  
Saint Olaf College, Northfield, MN, USA

## 5. TEACHING & EDUCATIONAL ACTIVITIES

---

- Yearly, fall semesters: 752-4001-00L *Microbiology*, ETHZ, core D-USYS/D-HEST course
- Yearly, spring semesters: 701-0220-00L *Practical Course in Microbiology*, ETHZ, D-USYS
- February 2025: Workshop speaker for SCNAT Rigi course: 'Microbiome meets metabolism'
- June 2023: PEAK course lecturer, 'Transformationsprozesse von Spurenstoffen' (in German)
- June 2023: 'Applied Meta'omics' metagenomics workshop leader and lecturer, ETHZ
- Oct 2021: Lorentz Center scientific workshop co-organizer and leader, Leiden, NL
- March 2021: P GL Bio I *Microbiology Practicum* (D-BIOL), lab group leader, ETHZ
- Sept 2017 – Dec 2018: MicB 3301 *Biology of Microorganisms*, lab instructor, U of MN, USA
- Jan 2014 – May 2015: CSCI 125 *Computer Science for Scientists*, co-lecturer, designed new curriculum and group projects, St. Olaf College, Northfield, MN, USA

## 6. ORAL PRESENTATIONS

---

- Jan 2025, Invited conference session convener, session chair, and speaker, Society for Industrial Microbiology and Biotechnology NP Meeting, San Diego, CA, USA
- Nov 2024, Invited speaker, Swiss Society of Toxicology Annual Meeting, Basel, CH
- June 2024 Invited speaker, Institute of Biology, University of Leiden, Leiden, NL
- June 2024 Invited speaker, Microbial Secondary Metabolites in Microbiomes Symposium, (Major international symposium), Helsingør, DK
- May 2024 Invited speaker, 4<sup>th</sup> Synthetic Biology of Natural Products Meeting (Major international symposium), Yucatan, MX
- May 2024 Invited speaker, UK-Switzerland Synthetic Biology & Climate, Swiss Embassy, UK
- April 2024 Invited speaker, ETH Zürich departmental seminars (D-USYS/D-HEST), Zürich, CH
- Jan 2024 Swiss Microbiomes Forum, ETH Zürich, CH
- Jan 2024 Invited online speaker, Oregon State University, Corvallis, OR, USA
- Sept 2023 Invited speaker, ETH Zürich Genetic Diversity Center Symposium, Zürich, CH
- August 2023 Invited speaker, Swiss-UK Synthetic Biology Symposium. UNIL, CH
- August 2023 Invited speaker, Society for Industrial Microbiology and Biotechnology Annual Meeting (SIMB, Major international symposium), Minneapolis, MN, USA
- Dec 2022 Invited speaker, University of Applied Sciences (FHNW), Muttenz, CH
- August 2022 Speaker, International Society for Microbiology Ecology Conference, EPFL, CH
- May 2022 Invited Speaker, EPFL Environmental Engineering Seminar Series, Lausanne, CH
- April 2022 Speaker, Life Sciences Switzerland (LS<sup>2</sup>) Annual Meeting, UZH, CH
- February 2020 Nominated best talk from Gordon Research Seminar, invited speaking slot at the Gordon Research Conference in Marine Natural Products, Ventura, CA, USA
- May 2019 Selected talk, Novo Nordisk Bioscience Conference, Hillerød, DK

## 7. AWARDS, GRANTS, FELLOWSHIPS, AND SCHOLARSHIPS

---

- 2025 American Chemical Society (ACS) Environmental Rising Stars Award
- 2024 Uniscientia/World Food Systems Center grant (co-PIs, N. Bokulich, S. Sturla, ETHZ)
- 2024 ETH Research Domain Open Research Data (ORD) Track C Program Grant (solo-PI)
- 2023 ETH Research Grant recipient (co-PIs, N. Bokulich, S. Sturla, ETHZ)
- 2022 Swiss National Science Foundation Ambizione (solo-PI)
- 2022 Helmut Horten Foundation New Investigator Grant (solo-PI)
- 2022 Pierre Mercier Foundation funding (solo-PI)
- 2021 JGI Community Science Program (CSP) Functional Genomics Award
- 2021 ETH Zürich Postdoctoral Fellowship Award
- 2020 Dr. Marvin and Hadassah Bacaner Award for outstanding PhD research
- 2020 Beatrice Z. Milne and Theodore Brandenburg Award for outstanding PhD thesis

- 2019 National Academy of Sciences Cozzarelli Prize for outstanding paper (PNAS)
- 2016 U.S. Fulbright Fellowship
- 2016 National Science Foundation Graduate Research Fellowship (NSF GRFP)
- 2015 Arnold and Mabel Beckman Foundation Research Scholarship
- 2014 Environmental Protection Agency Greater Research Opportunities Fellow

## 8. OUTREACH & PROFESSIONAL ACTIVITIES

---

- 2025: Documentary interview on PFAS biodegradation, “Nano” 3sat/SRF1: <https://www.srf.ch/play/tv/-/video/-?urn=urn:srf:video:955314fa-a347-4f1c-aedb-c6c8bfaf69e6&startTime=1077>
- 2024 – Present: PI member of the World Food System Center (WFSC), ETHZ
- 2023 – Present: PI member, Microbiology and Immunology (MIM) Graduate Program, ETHZ
- Associate journal editor: *Federation of European Microbiology Societies (FEMS) Microbes*
- 2022 – 2023 memberships: Society for Industrial Microbiology and Biotechnology (SIMB), Life Sciences Switzerland (LS<sup>2</sup>) member, International Society for Microbial Ecology (ISME)
- Seminar organization committee for Environmental Microbiology & Eawag seminars

## 9. SELECTED PUBLICATION AND PATENTS

---

### Pre-prints and submitted manuscripts:

★denotes corresponding authorship

Probst, S.I., Felder, F., Poltorak, V., Mewalal, R., Blaby, I., ★**Robinson S.L.** (2024). Enzymatic carbon-fluorine bond cleavage by human gut microbes. *bioRxiv* doi: 10.1101/2024.07.15.601322.

Terlouw, B.R., Huang, C., Meijer, D., Cediél-Becerra, J.D., Rothe, M.L., Jenner, M., Zhou, S., Zhang, Y., Fage, C.D., Tsunematsu, Y., van Wezel, G.P., **Robinson, S.L.**, Alberti, F., Alkhalaf, L.M., Chevrette, M.G., Challis, G.L., Medema, M.H. (2025). PARAS: high-accuracy machine-learning of substrate specificities in nonribosomal peptide synthetases. *bioRxiv*, doi: 10.1101/2025.01.08.631717

Cavallaro, A., Probst, S., Duft, T., Rieder, M., El Fateh, O.A., Stricker, J., Gabrielli, M., **Robinson, S.L.**, Hammes, F. (2024). Variable inhibition of different *Legionella* species by antagonistic bacteria. *bioRxiv*, doi: 10.1101/2024.11.27.625680

### Selected peer-reviewed publications:

Publications written since starting at Eawag in September 2021:

1. Wackett, L.P. and **Robinson, S.L.** (2024). A prescription for engineering PFAS biodegradation. *Biochemical Journal*, 481(23), p.1757.
2. Zdouc, M. M., Blin, K., ...**Robinson, S.L.**...Weber, T., Medema, M.H. (2025). MIBiG 4.0: advancing biosynthetic gene cluster curation through global collaboration. *Nucleic acids research*, 53(D1), D678-D690.
3. Marti, T.D., Schweizer, D., Yu, Y., Schärer, M.R., Probst, S.I., ★**Robinson, S.L.** (2024). Machine learning reveals signatures of promiscuous microbial amidases for micropollutant biotransformations. *ACS Environmental Au*. 5(1), 114-127.
4. Attrah, M., Schärer, M., Esposito, M., Gionchetta, G., Bürgmann, H., Lens, P., Fenner, K.F., van de Vossenbergh, J., ★**Robinson, S.L.** (2024) Disentangling abiotic and biotic effects of

- treated wastewater on stream biofilm resistomes enables discovery of a new planctomycete beta-lactamase. *Microbiome*. 12, 164. doi: [10.1186/s40168-024-01879-w](https://doi.org/10.1186/s40168-024-01879-w).
5. Seller-Brison, C., Brison, A., Yu, Y., **Robinson, S.L.** and Fenner, K., (2024). Adaptation towards catabolic biodegradation of trace organic contaminants in activated sludge. *Water Research*, p.122431. doi: [10.1016/j.watres.2024.122431](https://doi.org/10.1016/j.watres.2024.122431).
  6. Feng, M., **Robinson, S.L.**, Qi, W., Edwards, A., Stierli, B., van der Heijden, M., Frey, B. and Varliero, G., (2024). Microbial genetic potential differs among cryospheric habitats of the Damma glacier. *Microbial Genomics*, 10(10), p.001301. doi: [10.1099/mgen.0.001301](https://doi.org/10.1099/mgen.0.001301).
  7. Bopp, C.E., Bernet, N.M., Meyer, F., Khan, R., **Robinson, S.L.**, Kohler, H.P.E., Buller, R. and Hofstetter, T., 2023. Elucidating the Role of O<sub>2</sub> Uncoupling for the Adaptation of Bacterial Biodegradation Reactions Catalyzed by Rieske Oxygenases. *ACS Environmental Au*. doi: [10.1021/acsenvironau.4c00016](https://doi.org/10.1021/acsenvironau.4c00016).
  8. Yu Y., Trottman, N.F., Schaerer, M.R., Fenner, K., **★Robinson, S.L.**, (2024) Substrate promiscuity of xenobiotic-transforming hydrolases from stream biofilms impacted by treated wastewater. *Water Research*. 256, 121593. doi: [10.1016/j.watres.2024.121593](https://doi.org/10.1016/j.watres.2024.121593).
  9. **★Robinson, S.L.** (2023) Structure-guided metagenome mining to tap microbial functional diversity. *Current Opinion in Microbiology*. doi: [10.1016/j.mib.2023.102382](https://doi.org/10.1016/j.mib.2023.102382)
  10. Mullaney, M.W., Duncan, K.R., Elsayed, S.S., Garg, N., van der Hooft, J.J.,...van Westen, G.J.P., Hirsch, A.K., Linington, R.G., **★Robinson, S.L.**, Medema, M.H. (2023) Artificial intelligence for natural product drug discovery. *Nature Reviews Drug Discovery*. doi: [10.1038/s41573-023-00774-7](https://doi.org/10.1038/s41573-023-00774-7).
  11. Feng, M., Varliero, G., Qi, W., Stierli, B., Edwards, A., **Robinson, S.L.**, van der Heijden, M., Frey, B. (2023) Microbial dynamics in soils of the Damma glacier forefield show succession in the microbial genetic potential. *Environmental Microbiology*. doi: [10.1111/1462-2920.16497](https://doi.org/10.1111/1462-2920.16497)
  12. Marti, T.D., Schärer, M.R., **★Robinson, S.L.** (2023) Microbial biocatalysis within us: the underexplored xenobiotic biotransformation potential of the urinary tract microbiota. *CHIMIA*, 77 (6), 424-431. doi: [10.2533/chimia.2023.424](https://doi.org/10.2533/chimia.2023.424).
  13. Fraley, A., **Robinson, S.L.**, and Piel, J., (2023) The versatile natural product enzymology of marine microbial communities. *Aldrichimica ACTA*. 55(3), 55-75.
  14. Terlouw, B. R., Blin, K., Navarro-Muñoz, J. C., Avalon, N. E., Chevrette, M. G., ... **Robinson S.L.**, ...Weber, T., Medema, M. H. (2023). MIBiG 3.0: a community-driven effort to annotate experimentally validated biosynthetic gene clusters. *Nucleic Acids Research*, 51(D1), D603-D610. doi: [10.1093/nar/gkac1049](https://doi.org/10.1093/nar/gkac1049).
  15. Paoli, L., Ruscheweyh, H.J., Forneris, C.C., Hubrich, F., Kautsar, S., Bhushan, A., Lotti, A., Clayssen, Q., Salazar, G., Milanese, A., Carlström, C.I., Papadopoulou, C., Gehrig, D., ...Sullivan, M.B., Wincker, P., Zeller, G., **★Robinson, S.L.**, **★Piel, J.P.**, **★Sunagawa, S.** (2022) Biosynthetic potential of the global ocean microbiome. *Nature*, 1-8. doi: [10.1038/s41586-022-04862-3](https://doi.org/10.1038/s41586-022-04862-3). **★co-corresponding**.

16. Scott, T.A., Verest, M., Farnung, J., Forneris, C.C., **Robinson, S.L.**, Ji, X., Hubrich, F., Chepkirui, C., Richter, D.U., Huber, S., Rust, P., Streiff, A.B., Zhang, Q., Bode, J.W., Piel, J.P. (2022) Widespread microbial utilization of ribosomal  $\beta$ -amino acid-containing peptides and proteins. *Chem*, 8(10), 2659-2677. doi: 10.1016/j.chempr.2022.09.017.
17. Hubrich, F., Bösch, N.M., Chepkirui, C., Morinaka, B.I., Rust, M., Gugger, M., **Robinson, S.L.**, Vagstad, A.L., Piel, J. (2022) Ribosomally derived lipopeptides containing distinct fatty acyl moieties. *Proceedings of the National Academy of Sciences (PNAS)*, 119(3). doi:10.1073/pnas.2113120119
18. Paoli, L. & **Robinson, S.L.**, (2022) A wealth of new biosynthetic pathways from the global ocean microbiome. *Nature*, doi: 10.1038/d41586-022-01545-x.
19. Guo, F., McAuliffe, J.C., Bongiorno, C. Latone, J.A., Pepsin, M.J., Chow, M.S., Dhaliwal, R.S., Hoffmann, K.M., Brazil, B.T., Heng, M.H., **Robinson, S.L.**, Wackett, L.P., Whited, G.M. A procedure for removal of cyanuric acid in swimming pools using a cell-free thermostable cyanuric acid hydrolase. (2022) *Journal of Industrial Microbiology and Biotechnology*, 49(2), kuab084. doi: <https://doi.org/10.1093/jimb/kuab084>.
20. Mason-Jones, K.M., **Robinson, S.L.**, Veen, G.F., Manzoni, S.M., van der Putten, W.H. (2022) Microbial storage and its implications for soil ecology. 16, 617–629. *The ISME Journal*, doi: 10.1038/s41396-021-01110-w.
21. ★**Robinson, S.L.**, (2021) Artificial intelligence for microbial biotechnology: beyond the hype. *Microbial Biotechnology*, 15(1), 65-69. doi: 10.1111/1751-7915.13943.

Publication record prior to starting at Eawag:

22. ★**Robinson, S.L.**, Piel, J., Sunagawa, S. A. (2021) A roadmap for metagenomic enzyme discovery. *Natural Product Reports*, 38(11), 1994-2023. doi: 10.1039/D1NP00006C.
23. **Robinson, S.L.**, Biernath, T., Rosenthal, C., Young, D., Wackett, L.P., Martinez-Vaz, B.M. (2021) Development of the organonitrogen biodegradation database: teaching bioinformatics and collaborative skills to undergraduates. *Journal of Biology & Microbiology Education*, 22(1), ev22i1.2351. doi: 10.1128/jmbe.v22i1.2351.
24. Tracanna, V., Ossowicki, A., Petrus, M.L.C., Overduin, S., Terlouw, B.R., George Lund, G., **Robinson, S.L.**, Warris, S., Schijlen, E.G.W.M., van Wezel, G.P., Raaijmakers, J.M., Garbeva, P. Medema, M.H. (2021) Dissecting disease-suppressive rhizosphere microbiomes by functional amplicon sequencing and 10X metagenomics. *mSystems*, 6(3), e01116-20. doi: 10.1128/mSystems.01116-20.
25. ★**Robinson, S.L.**, Terlouw, B.R., Smith, M.D., Pidot, S.J., Stinear, T.P., Medema, M.H., Wackett, L.P. (2020) Global analysis of adenylate-forming enzymes reveals  $\beta$ -lactone biosynthesis pathway in pathogenic *Nocardia*. *Journal of Biological Chemistry*. 295(44), 14826-14839. doi: 10.1074/jbc.RA120.013528.
26. Wackett, L.P. & **Robinson, S.L.** (2020) The ever-expanding limits of enzyme catalysis and biodegradation: polyaromatic, polychlorinated, polyfluorinated, and polymeric compounds. *Biochemical Journal*, 477(15), 2875–2891. doi: 10.1042/BCJ20190720.

27. ★**Robinson, S.L.**, Smith, M.D., Richman, J.E., Aukema, K.G., Wackett, L.P. (2020) Machine learning-based prediction of activity and substrate scope for OleA enzymes in the thiolase superfamily. *Synthetic Biology*, 5(1), ysaa004. doi: 10.1093/synbio/ysaa004.
28. Smith M.D., **Robinson S.L.**, Molomjamts M.M., Wackett L.P. (2020) *In vivo* assay reveals microbial OleA thiolases initiating hydrocarbon and  $\beta$ -lactone biosynthesis. *mBio*, 11(2), e00111-20. doi: 10.1128/mBio.00111-20.
29. Aukema, K.G., Tassoulas, L.J., **Robinson, S. L.**, Konopatski, J.F., Bygd, M.D., Wackett, L.P. (2020) Cyanuric acid biodegradation via biuret: physiology, taxonomy, and geospatial distribution. *Applied and Environmental Microbiology*, 86(2), e01964-19. doi: 10.1128/AEM.01964-19.
30. Kautsar, S.A., Blin, K., Shaw, S., Navarro-Muñoz, J.C., Terlouw, B.R., van der Hooft, J.J., van Santen, J., Tracanna, V., Suarez Duran, H.G., Andreu, V.P., Selem-Mojica, N., Alanjary, M., **Robinson, S.L.**, Lund, G., Epstein, S.C., Sisto, A.C., Charkoudian, L.K., Collemare, J., Linington, R., Weber, T., Medema, M.H. (2019) MIBiG 2.0: A repository for biosynthetic gene clusters of known function. *Nucleic Acids Research*, 48(D1), D454–D458. doi: 10.1093/nar/gkz882.
31. **Robinson, S.L.**, Christenson, J.K., Richman, J.E., Jenkins, D.J., Neres, J., Fonseca, D.R., Aldrich, C.C., Wackett, L.P. (2019) Mechanism of a standalone  $\beta$ -lactone synthetase: new continuous assay for a widespread ANL superfamily enzyme. *ChemBioChem*, 20, 1701-1711. doi: 10.1002/cbic.201800821.
32. Tveit, A.T., Hestnes A.G., **Robinson, S.L.**, Schintlmeister, A., Dedysh, S., Jehmlich, N., von Bergen, M., Herbold, C., Wagner, M., Richter A., Svenning M.M. (2019) Widespread soil bacterium that oxidizes atmospheric methane. *Proceedings of the National Academy of Sciences*, 116(17), 8515-8524. doi: 10.1073/pnas.1817812116. \*Winner of the 2019 Cozzarelli Prize in Biomedical Sciences
33. **Robinson, S.L.** & Wackett, L.P. Rings of power: enzymatic routes to  $\beta$ -lactones. (2019) In *Comprehensive Natural Products III: Chemistry and Biology, Enzymes and Enzyme Mechanisms*.
34. **Robinson, S.L.**, Christenson, J.K., Wackett, L.P. (2018) Biosynthesis and chemical diversity of  $\beta$ -lactone natural products. *Natural Product Reports* 36(3), 458-475. doi: 10.1039/C8NP00052B.
35. **Robinson, S. L.**, Badalamenti, J. P., Dodge, A.G., Tassoulas, L.J., Wackett, L.P. (2018) Microbial biodegradation of biuret: defining biuret hydrolases within the isochorismatase superfamily. *Environmental Microbiology* 20(6), 2099-2111. doi: 10.1111/1462-2920.14094.
36. **Robinson, S.L.** & Wackett, L.P. (2018) Diversity and taxonomy of aliphatic hydrocarbon producers. *Handbook of Hydrocarbon and Lipid Microbiology Series*, Springer-Nature, 1-20.
37. Wackett, L.P. & **Robinson, S.L.** (2018) The future of environmental microbiology. *Environmental Microbiology* 20(6), 1988–1990. doi: 10.1111/1462-2920.14256.
38. Vergauwen, L., Cavallin, J.E., Ankley, G.T., Bars, C., Gabriëls, I.J., Michiels, E.D.G., Fitzpatrick, K.R., Periz-Stanacev, J., Randolph, E.C., **Robinson, S.L.**, Saari, T.W., Schroeder, A.S., Stinckens, E., Swintek, J., Van Crutchen, S.J., Verbeuken E., Villeneuve,

- D.L., Knapen, D. (2018) Gene transcription ontogeny of hypothalamic-pituitary-thyroid axis development in early-life stage fathead minnow and zebrafish. *Gen. Comp. Endocrinology* 266, 87-100. doi: 10.1016/j.ygcen.2018.05.001
39. Christenson, J.K., **Robinson, S.L.**, Engel, T.A., Richman, J.E., Wackett, L.P. (2017)  $\beta$ -Lactone decarboxylase: function, mechanism, and linkage to class III haloalkane dehalogenases. *Biochemistry* 56(40), 5278–5287. doi: 10.1021/acs.biochem.7b00667. \*Highlighted in *Science* as an Editor's Choice, 358(6367), 1144. doi: 10.1126/science.358.6367.1144.
40. Schulfer, A.F., Battaglia T., Alvarez, Y., Bijnens, L., Ruiz, V. E., Ho, M., **Robinson, S.L.**, Ward, T.W., Cox, L.M., Rogers, A.B., Knights, D., Blaser, M.J. (2017) Intergenerational transfer of antibiotic-perturbed microbiota enhances colitis in susceptible mice. *Nature Microbiology* 3(2), 234. doi: 10.1038/s41564-017-0075-5.
41. LaLone, C.A., Villeneuve, D.L., Lyons, D., Helgen, H.W., **Robinson, S.L.**, Swintek, J.A., Saari, T.W., Ankley, G.T. (2016) Sequence alignment to predict across species susceptibility (SeqAPASS): a web-based tool for addressing the challenges of cross-species extrapolation of chemical toxicity. *Toxicological Sciences* 153(2), 228-245. doi: 10.1093/toxsci/kfw119.