

# Richard A. Eisenberg

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## Research Interests

Programming languages, functional programming, dependent type theory, Haskell. I want to make programs correct and elegant by construction.

## Appointments

2020–pres. Principal Researcher, Tweag  
 2016–20 Assistant Professor of Computer Science, Bryn Mawr College

## Education

Sep 2016 PhD in Computer & Information Science, University of Pennsylvania, Philadelphia, PA  
 Dissertation: *Dependent Types in Haskell: Theory and Practice*  
 Advisor: Stephanie Weirich  
 Harvard University, Cambridge, MA  
 June 2003 M.S., Computer Science  
 June 2003 B.A., Physics, *magna cum laude* with highest honors

## Publications

- POPL'22 27) F. Krawiec, S. Peyton Jones, N. Krishnaswami, T. Ellis, **R. A. Eisenberg**, and A. Fitzgibbon. *Provably Correct, Asymptotically Efficient, Higher-Order Reverse-Mode Automatic Differentiation*. In *Proceedings of the ACM on Programming Languages*, Vol. 6, Issue POPL (POPL '22), ACM, 2022. Article 48, 30 pages.  
 (acceptance rate: 23%)
- ICFP'21 26) **R. A. Eisenberg**, G. Duboc, S. Weirich, and D. Lee. *An Existential Crisis Resolved: Type Inference for First-Class Existential Types*. In *Proceedings of the ACM on Programming Languages*, Vol. 5, Issue ICFP (ICFP '21), ACM, 2021. Article 64, 29 pages.  
 (33%)
- Haskell'21 25) G.-J. Bottu and **R. A. Eisenberg**. *Seeking Stability by Being Lazy and Shallow: Lazy and Shallow Instantiation is User Friendly*. In *Proceedings of the 2021 ACM SIGPLAN Symposium on Haskell* (Haskell '21), ACM, 2021. pp. 85-97.  
 (40%)
- POPL'21 24) P. Choudhury, H. Eades III, **R. A. Eisenberg**, and S. Weirich. *A Graded Dependent Type System with a Usage-Aware Semantics*. In *Proceedings of the ACM on Programming Languages*, Vol. 5, Issue POPL (POPL '21), ACM, 2021. Article 50, 32 pages.  
 (24%)
- ICFP'20 23) P. Downen, Z. M. Ariola, S. Peyton Jones, **R. A. Eisenberg**. *Kinds are Calling Conventions*. In *Proceedings of the ACM on Programming Languages*, Vol. 4, Issue ICFP (ICFP '20), ACM, 2020. Article 104, 29 pages.  
 (37%)
- Haskell'20 22) **R. A. Eisenberg**. *Stitch: The Sound Type-Indexed Type Checker (Functional Pearl)*. In *Proceedings of the 2020 ACM SIGPLAN Symposium on Haskell* (Haskell '20), ACM, 2020. pp. 39-53.  
 (50%)
- Haskell'20 21) Y. Parès, J.-P. Bernardy, **R. A. Eisenberg**. *Composing Effects into Tasks and Workflows*. In *Proceedings of the 2020 ACM SIGPLAN Symposium on Haskell* (Haskell '20), ACM, 2020. pp. 80-94.  
 (50%)
- POPL'20 20) N. Xie, **R. A. Eisenberg**, B. C. d. S. Oliveira. *Kind Inference for Datatypes*. In *Proceedings of the ACM on Programming Languages*, Vol. 4, Issue POPL (POPL '20), ACM, 2020. Article  
 (29%)

53, 28 pages.

- POPL'20 (29%) 19) M. P. Jones, J. G. Morris, **R. A. Eisenberg**. *Partial Type Constructors; Or, Making ad hoc datatypes less ad hoc*. In *Proceedings of the ACM on Programming Languages*, Vol. 4, Issue POPL (POPL '20), ACM, 2020. Article 40, 28 pages.
- ICFP'19 (32%) 18) S. Weirich, P. Choudhury, A. Voizard, **R. A. Eisenberg**. *A Role for Dependent Types in Haskell*. In *Proceedings of the ACM on Programming Languages*, Vol. 3, Issue ICFP (ICFP '19), ACM, 2019. Article 101, 29 pages.
- Haskell'18 (43%) 17) **R. A. Eisenberg**, J. Breitner, and S. Peyton Jones. *Type Variables in Patterns*. In *Proceedings of the 2018 ACM SIGPLAN Symposium on Haskell (Haskell '18)*, ACM, 2018, pp. 94-105.
- Haskell'18 (43%) 16) D. Otmani and **R. A. Eisenberg**. *The Thoralf Plugin: For Your Fancy Type Needs*. In *Proceedings of the 2018 ACM SIGPLAN Symposium on Haskell (Haskell '18)*, ACM, 2018, pp. 106-118.
- ICFP'17 (35%) 15) J. G. Morris and **R. A. Eisenberg**. *Constrained Type Families*. In *Proceedings of the ACM on Programming Languages*, Vol. 1, Issue ICFP (ICFP '17), ACM, 2017. Article 42, 28 pages.
- ICFP'17 (35%) 14) S. Weirich, A. Voizard, P. H. Azevedo de Amorim, **R. A. Eisenberg**. *A Specification for Dependently-Typed Haskell*. In *Proceedings of the 22nd ACM SIGPLAN International Conference on Functional Programming (ICFP '17)*, ACM, 2017. Article 31, 29 pages.
- PLDI'17 (14%) 13) **R. A. Eisenberg**, S. Peyton Jones. *Levity Polymorphism*. In *Proceedings of the 2017 ACM SIGPLAN Conference on Programming Language Design and Implementation (PLDI '17)*. ACM, 2017. pp. 525-539.
- Haskell'16 12) M. Pickering, G. Érdi, S. Peyton Jones, **R. A. Eisenberg**. *Pattern Synonyms*. In *Proceedings of the 2016 ACM SIGPLAN Symposium on Haskell (Haskell '16)*, ACM, 2016. pp. 80-91.
- JFP'16 11) J. Breitner, **R. A. Eisenberg**, S. Peyton Jones, S. Weirich. *Safe Zero-cost Coercions for Haskell*. In *Journal of Functional Programming*, Vol. 26. Cambridge University Press, 2016. 79 pages.
- ESOP'16 (33%) 10) **R. A. Eisenberg**, S. Weirich, H. Ahmed. *Visible Type Application*. In *Programming Languages and Systems: 25th European Symposium on Programming (ESOP '16)*. LNCS 9632, Springer, 2016. pp. 229-254.
- Wadlerfest '16 9) S. Peyton Jones, S. Weirich, **R. A. Eisenberg**, D. Vytiniotis. *A reflection on types*. In *A List of Successes that Can Change the World*, a festschrift in honor of Phil Wadler. LNCS 9600, Springer, 2016. pp. 292-317.
- Haskell'15 (39%) 8) J. Stolarek, S. Peyton Jones, **R. A. Eisenberg**. *Injective Type Families for Haskell*. In *Proceedings of the 2015 ACM SIGPLAN Symposium on Haskell (Haskell '15)*, ACM, 2015. pp. 118-128.
- Haskell'14 (43%) 7) T. Muranushi, **R. A. Eisenberg**. *Experience Report: Type-checking Polymorphic Units for Astrophysics Research in Haskell*. In *Proceedings of the 2014 ACM SIGPLAN Symposium on Haskell (Haskell '14)*, ACM, 2014. pp. 31-38.
- Haskell'14 (43%) 6) **R. A. Eisenberg**, J. Stolarek. *Promoting Functions to Type Families in Haskell*. In *Proceedings of the 2014 ACM SIGPLAN Symposium on Haskell (Haskell '14)*, ACM, 2014. pp. 95-106.
- ICFP'14 (33%) 5) J. Breitner, **R. A. Eisenberg**, S. Peyton Jones, S. Weirich. *Safe Zero-cost Coercions for Haskell*. In *Proceedings of the 19th ACM SIGPLAN International Conference on Functional Programming (ICFP '14)*, ACM, 2014. pp. 189-202.
- POPL'14 4) **R. A. Eisenberg**, D. Vytiniotis, S. Peyton Jones, S. Weirich. *Closed Type Families with*

- (23%) *Overlapping Equations*. In *Proceedings of the 41st ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages* (POPL '14), ACM, 2014. pp. 671-683.
- OOPSLA'13 3) C. DeLozier, **R. A. Eisenberg**, S. Nagarakatte, P.-M. Osera, M. M. K. Martin, and S. (26%) Zdancewic. *Ironclad C++: A Library-Augmented Type-Safe Subset of C++*. In *Proceedings of the 2013 ACM SIGPLAN International Conference on Object Oriented Programming, Systems, Languages, & Applications* (OOPSLA '13), ACM, 2013. pp. 287-304.
- ICFP'13 2) S. Weirich, J. Hsu, and **R. A. Eisenberg**. *System FC with Explicit Kind Equality*. In (30%) (2) *Proceedings of the 18th ACM SIGPLAN International Conference on Functional Programming* (ICFP '13), ACM, 2013. pp. 275-286.
- Haskell'12 1) **R. A. Eisenberg** and S. Weirich. *Dependently Typed Programming with Singletons*. In (41%) *Proceedings of the 2012 Haskell Symposium* (Haskell '12), ACM, 2012. pp. 117-130.

### Technical Reports

- 2017 **R. A. Eisenberg** and S. Peyton Jones. *Levity Polymorphism (extended version)*. Bryn Mawr Technical Report MS-1079, 2017.
- 2015 **R. A. Eisenberg**. *System FC, as implemented in GHC*. University of Pennsylvania Technical Report MS-CIS-15-09, 2015.
- 2015 **R. A. Eisenberg**. *An Overabundance of Equality: Implementing Kind Equalities into Haskell*. University of Pennsylvania Technical Report MS-CIS-15-10, 2015.
- 2015 J. Stolarek, S. Peyton Jones, **R. A. Eisenberg**. *Injective Type Families for Haskell (extended version)*. Politechnika Łódzka Technical Report, 2015.
- 2014 **R. A. Eisenberg**, J. Stolarek. *Promoting Functions to Type Families in Haskell (extended version)*. University of Pennsylvania Technical Report MS-CIS-14-09, 2014.
- 2014 J. Breitner, **R. A. Eisenberg**, S. Peyton Jones, S. Weirich. *Safe Zero-cost Coercions for Haskell (extended version)*. University of Pennsylvania Technical Report MS-CIS-14-07, 2014.
- 2013 **R. A. Eisenberg**, D. Vytiniotis, S. Peyton Jones, S. Weirich. *Closed Type Families with Overlapping Equations (extended version)*. University of Pennsylvania Technical Report MS-CIS-13-10, 2013.
- 2013 P.-M. Osera, **R. A. Eisenberg**, C. DeLozier, S. Nagarakatte, M. M. K. Martin, S. Zdancewic. *Core Ironclad*. University of Pennsylvania Technical Report MS-CIS-13-06, 2013.
- 2013 S. Weirich, J. Hsu, **R. A. Eisenberg**. *System FC with Explicit Kind Equality (extended version)*, University of Pennsylvania Technical Report MS-CIS-15-11, 2013.

### Research-related open-source contributions

GHC core developer Core developer for the [Glasgow Haskell Compiler](#) (GHC), the main compiler for the [Haskell](#) functional programming language. Principal contributions:

- Levity polymorphism, based on *Levity Polymorphism* (PLDI'17)
- Kind equalities, based on *Kind Equalities* (ICFP'13)
- Visible type application, based on *Visible Type Applications* (ESOP'16)
- New solver for type equality, based on *Safe Zero-cost Coercions* (JFP'16)
- Roles, based on *Safe Zero-cost Coercions* (ICFP'14)
- Closed type families, based on *Closed Type Families* (POPL'14)

Haskell The *singletons* package, described in the Haskell'12 and Haskell'14 papers.

packages The *units* package, described in the Haskell'14 experience report.  
 The *stitch* package, described in the Haskell'20 functional pearl.

## Presentations

- Oct 2020 - @rae's *Thoughts on Haskell*. Weekly YouTube series, [online](#).  
 present
- May 2022 *What Automatic Differentiation Really Means*. IFIP Working Group 2.8, New York, USA
- Dec 2021 *First-class existential types and their application to ergonomic programming with linear types*. Invited lecture, University of Iowa, online
- Aug 2021 *An Existential Crisis Resolved*. ICFP, online
- Feb 2021 *An Existential Crisis Resolved*. IFIP Working Group 2.8, online
- Nov 2020 *Simplifying Constraint Solving in GHC*. Haskell eXchange, online
- Sep 2020 *Partial Type Constructors*. Invited talk, MuniHac, online
- Aug 2020 *Stitch: the Type-Indexed Type Checker (Functional Pearl)*. Haskell Symp., online
- Aug 2020 *Parameters of Many Flavors*. Invited talk, Haskell Love, online
- June 2020 *How to Extend GHC*. GHC Track talk, ZuriHac, online
- May 2020 *Partial Type Constructors*. Invited lecture, University of Nottingham, online
- Nov 2019 *Partial Type Constructors*. Invited lecture, University of Cambridge, Cambridge, UK
- Oct 2019 *Stitch: the Type Indexed Type-Checker*. Haskell eXchange, London, UK
- June 2019 *Stitch: the Type Indexed Type-Checker*. Invited keynote, ZuriHac, Zürich, Switzerland
- June 2019 *Tour of the GHC Front End*. GHC Track talk, ZuriHac, Zürich, Switzerland
- May 2019 *Generalized Newtype Compiling: Don't let you types slow you down*. IFIP Working Group 2.8, Bordeaux, France
- Sep 2018 *Type Variables in Patterns*. Haskell Symp., St. Louis, MO, USA
- Apr 2018 *Stitch: the Type Indexed Type-Checker*. New York Haskell Users' Group, USA
- Sep 2017 *Constrained Type Families*. ICFP, Oxford, UK
- Jun 2017 *Levity Polymorphism*. PLDI, Barcelona, Spain
- Sep 2016 *A Dependent Haskell Triptych*. Haskell Implementors' Workshop, Nara, Japan
- Apr 2016 *Visible Type Application*. European Symposium on Programming, Eindhoven, Netherlands
- Aug 2015 *Levity Polymorphism in Dependent Haskell*. Haskell Implementors' Workshop, Vancouver, Canada
- May 2015 *A Practical Introduction to Haskell GADTs*. Invited speaker, LambdaConf, Boulder, CO, USA
- Oct 2014 *Dependent Types for Haskell*. Invited speaker, New York City Haskell Users' Group, USA
- Sep 2014 *Dependent Haskell*. Haskell Implementors' Workshop, Gothenburg, Sweden
- Sep 2014 *Safe Zero-cost Coercions for Haskell*. ICFP, Gothenburg, Sweden
- Jan 2014 *Closed Type Families with Overlapping Equations*. POPL, San Diego, CA, USA
- Sep 2013 *System FC with Explicit Kind Equality*. ICFP, Boston, MA, USA
- Sep 2013 *GeneralizedNewtypeDeriving is now Type-safe: How Roles Save the Day*. Haskell Implementors' Workshop, Boston, MA, USA
- Sep 2012 *Dependently Typed Programming with Singletons*. Haskell Symp., Copenhagen, Denmark

## Funding

- 2017 *SHF: MEDIUM: Collaborative Research: The Theory and Practice of Dependent Types in Haskell*. R. A. Eisenberg and S. Weirich (PIs). NSF 1704041, \$949,964, 7/2017-7/2021.

## Honors and Awards

- 2021 Distinguished Paper Award for *An Existential Crisis Resolved*, ICFP'21  
*Awarded by an additional peer-review process to fewer than 10% of papers accepted at the conference*
- 2020 Full Member, Sigma Xi Honor Society
- 2020 Distinguished Paper Award for *Kind Inference for Datatypes*, POPL'20  
*Awarded by an additional peer-review process to fewer than 10% of papers accepted at the conference*
- 2017 Morris and Dorothy Rubinoff Award, U. of Penn.  
*Awarded to a doctoral candidate whose dissertation may lead to innovative applications of computer technology*
- 2016 Penn Prize for Excellence in Teaching by Graduate Students, U. of Penn.  
*One of 10 graduate students across the university recognized for our teaching, nominated by undergraduates*
- 2014-16 Graduate Student Fellowship, Microsoft Research  
*One of 12 doctoral students chosen among candidates from U.S. and Canada.*
- 2013-14 Fellowship for Teaching Excellence, U. of Penn. Center for Teaching and Learning  
*Nominated & selected as the graduate student departmental advocate for teaching.*
- 2011-12 John Henry Towne Fellowship, U. of Penn. School of Engineering & Applied Science  
*Awarded to exceptionally qualified first-year doctoral students.*
- 2002, 2003 John Harvard Scholarship  
*Awarded to undergraduates in the top 5% of their class*
- 2001 Harvard College Scholarship  
*Awarded to undergraduates in the top 10% of their class*

## Non-profit Work

- Feb 2021 - present Chair of the Board of Directors: Haskell Foundation  
*The Haskell Foundation is a non-profit entity working to promote Haskell and functional programming, by attracting donations and funding projects of need in core Haskell infrastructure.*

## Professional Experience

- Dec 2015 – Mar 2016 Consultant, Awake Networks, Mountain View, CA. My task was to help design an efficient domain-specific language embedded in Haskell to be used in a networking security product.
- Summer '13 Research Intern, Microsoft Research, Cambridge, UK. Mentored by Simon Peyton Jones.
- Summer '02 Software Design Engineer Intern, Microsoft, Redmond, WA
- Summer '01 Software Engineer Intern, Actuality Systems, Inc., Reading, MA

## Research Advising

- Tweag G. Duboc. *Existential Quantification*. Tweag Internship, 2020-21.  
 G. Rudoy. *Compiling Refinement Types to Idris*. Tweag Open Source Fellow, 2020.  
 G.-J. Bottu. *Type Instantiation*. Tweag Internship, 2020.
- Undergrad thesis advisor E. Feng. *Verification of Dijkstra's Algorithm in Idris*. Bryn Mawr College, 2019.  
 S. Depew. *Visualizing Algorithms with Android*. Bryn Mawr College, 2019.  
 K. J.-C. Liao. *I Am The Senate: Introducing Palpatine, a Vote Counter for Australian Senate*

*Ballots written in Idris with Verification of Totality and Cardinality*. Haverford College, 2018.

R. Xu. *Comparison Between Program Verification Techniques in Dependent Haskell and Liquid Haskell*. Bryn Mawr College, 2018.

X. Zhang. *A Tale of Two Provers: A Comparison of Dependent Haskell and F\**. Bryn Mawr College, 2018.

J. Henck. *A Supercompiler for an Object-Oriented Language*. Bryn Mawr College, 2017.

Undergrad M. Nguyen. *Types and Programming Languages / Type System Implementation*. Fall 2018.

Ind. Study M. Yacavone. *Cubical Type Theories*. Fall 2018.

advisor E. Feng. *Verifying Functional Algorithms in Idris*. Fall 2018.

D. Otwani. *Type-Level Finite Maps*. Fall 2017 – Spring 2018.

R. Xu and X. Zhang. *Verification Languages*. Fall 2017.

R. Xu and X. Zhang. *Types and Programming Languages*. Spring 2017.

M. Yacavone. Ind. Study: *Homotopy Type Theory in Coq*. Spring 2017.

Summer M. Nguyen. *Visible Kind Application*. Summer 2018.

science N. Adnane. *Improving GHC Error Messages*. Summer 2018.

research E. Feng and P. Thiel. *Merging Term and Type Parsers*. Summer 2018.

advisor M. Yacavone. *Explicit Variable Quantification*. Summer 2018.

## Teaching

### Higher Education

Instructor, CMSC 110: Introduction to Computing (27 undergrads), fall 2016  
Bryn Mawr College

CMSC 113: Computer Science I (avg. 26 undergrads), fall 2017, spring 2018

CMSC 206: Introduction to Data Structures (26 undergrads), spring 2018

CMSC 231: Discrete Mathematics (21 undergrads), fall 2017

CMSC 245: Principles of Programming Languages (avg. 25 undergrads), fall 2018 (x2)

CMSC 246: Programming Paradigms (32 undergrads), spring 2017

CMSC 350: Compiler Design (16 undergrads), spring 2019

CMSC 380: Modern Functional Programming (24 undergrads), spring 2017

CMSC 399: Senior Conference (11 seniors), spring 2019

Instructor, CIS194: Haskell Programming (12 students, mostly undergrad), fall 2014  
U. of Penn.

CIS190: C++ Programming (19 students, mostly undergrad), fall 2012

Head TA CS50: Introduction to Computer Science (~100 undergrads), fall 2002, Harvard U.

TA CIS552: Advanced Programming (~40 students, grad & undergrad), fall 2013, U. of Penn.

CIS120: Programming Languages & Techniques (~100 undergrads), spring 2013, U. of Penn.

CS50: Introduction to Computer Science (~200 undergrads), fall 2001, Harvard U.

CS50: Introduction to Computer Science (~300 undergrads), fall 2000, Harvard U.

### High school

2008-11 The American School in London, London, UK

*The American School in London is a private, co-educational K-12 school with an American curriculum.*

Taught computer science and math, including AP Computer Science in Java  
Mentored high-school and middle-school FIRST robotics teams  
Created new Digital Electronics course from scratch, including outfitting the lab

2003-08 Northfield Mount Hermon School, Mount Hermon, MA

*Northfield Mount Hermon is a private, co-educational boarding high school.*

Taught computer science and math, including AP Computer Science in Java  
Dorm parent (3 years) and director (2 years), overseeing 40 students. Received the Parents Council Award for Excellence in Residential Life (2005).

## Professional Activities

Jan 2023 Program Committee member: POPL

Jan 2022 Co-organizer: Workshop on the Implementation of Type Systems

*This new workshop was co-located with POPL'22 and attracted roughly 60 participants. It is expected to run yearly going forward.*

Aug 2021 Program Committee member: ML Family Workshop

Nov 2020 Member: Haskell Foundation Working Group

Nov 2020 Program Committee member: Haskell eXchange

Aug 2020 Program Committee member: Int'l Conference on Functional Programming (ICFP)

Aug 2019 Program Committee chair: Haskell Symposium

Aug 2019 External Review Committee member: ICFP

Jun 2019 Invited speaker: ZuriHac, Zurich, Switzerland.

May 2019 Invited guest/speaker: IFIP Working Group 2.8, Bordeaux, France

Sep 2018 Program Committee co-chair: Workshop on Type-Directed Development (TyDe)

Sep 2018 Distinguished Papers Committee member: ICFP

Sep 2018 External Review Committee member: ICFP

Sep 2018 Program Committee member: Implementation of Functional Languages (IFL)

Sep 2017 Invited Panelist: *Careers in Programming Languages*, Prog. Lang. Mentoring Workshop

Sep 2017 Program Chair: Haskell Implementors' Workshop

May 2017 Organizer: GHC implementation workshop, a 2-week gathering of compiler writers

Jan 2017 - present Member: GHC Steering Committee, for reviewing proposals for updates to GHC

Sep 2016 Program Committee member: Haskell Symposium

Sep 2016 Program Committee member: TyDe

Mar 2016 Invited participant: Dagstuhl Seminar *Language Based Verification Tools for Functional Programs*, Wadern, Germany

Nov 2015 - present Member: Haskell Prime Committee, for updating the standard for the Haskell language

Nov 2015, Oct 2014 Organizer: Hac Phi, a yearly weekend-long Haskell exchange, Philadelphia, PA

Oct 2015 Awardee: Center for Teaching & Learning Teaching Certificate, U. of Penn.

*Earning this certificate requires participation in ongoing conversations about teaching and participating in a teaching observation & reflection.*

Aug 2015 Program Committee member: Haskell Implementors' Workshop, Vancouver, Canada

## Outreach

- Mar 2020 - Co-organize twice-yearly Tweag Fellowship program, accepting applications from global  
present contributors to open-source projects for full-time funding
- Summer Google Summer of Code mentor, supervising the start of implementation of a dependently-  
2018 typed core language in GHC, performed by Ningning Xie of the University of Hong Kong
- Aug 2015 Organized and ran *Stencyl Boot Camp*, an introduction to programming for middle- and  
high-school students, West Tisbury, MA
- Apr 2014 Led workshop to high school students on introduction to programming with Scratch for  
Women in Computer Science Day, U. of Penn.
- Nov 2013 Presented introduction to Haskell at the Charter School of Wilmington, Wilmington, DE
- Feb 2013 Consulted with educators at Merion Mercy Academy, a Catholic girls' high school, about  
starting a computer science program, Merion Station, PA
- Feb 2013 Volunteered as Pit Coordinator at FIRST LEGO League regional championship,  
Philadelphia, PA