

# Elizabeth E. Hunter

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## EDUCATION

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**University of Pennsylvania, School of Engineering and Applied Science** Philadelphia, PA  
*PhD*, Mechanical Engineering and Applied Mechanics *Expected* Apr. 2020  
Thesis: “Microscale Robotic Wetware for Synthetic Biology,” Advisor: Dr. Vijay Kumar  
*Master of Science in Engineering*, Robotics May 2017  
*Bachelor of Science in Engineering*, Mechanical Engineering and Applied Mechanics Aug. 2013

## RESEARCH INTERESTS

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Micro/nano robotics; soft robotics; advanced manufacturing; synthetic biology; soft matter; medical devices

## RESEARCH EXPERIENCE

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**University of Pennsylvania, General Robotics, Automation, Sensing and Perception Lab**  
*PhD Researcher, Advisor: Dr. Vijay Kumar* Aug. 2013–Present

- Researched fabrication, actuation, control, sensing, and information processing methods for small-scale robots that can safely and reliably interface with biological systems
- Experimentally demonstrated transport of multiple microstructures using active bacterial baths, delivery of biochemicals to biological substrates using diamagnetically levitated microrobot pipettors, and closed-loop control of soft micro bio robots harboring sensors and processors produced with genetic engineering
- Established cross-functional collaborations among multiple departments, universities, and industry partners
- Explored market potential and developed MVP for early-stage technologies as part of the NSF Penn I-Corps Accelerator and Penn Health-Tech Pilot Program

**University of Pennsylvania, McKay Orthopaedic Research Laboratory**

*Undergraduate Researcher, Advisor: Dr. Dawn Elliott* Jan. 2010–Aug. 2012

- Investigated spine biomechanics and structure-function relationships of the intervertebral disc
- Developed techniques in histology, microscopy, and image processing to examine the micro-scale fiber architecture of the intervertebral disc including cartilage endplate thickness
- Executed electromechanical testing to quantify mechanical properties of native intervertebral discs and tissue engineered implants
- Developed small animal models of intervertebral disc degeneration and therapy and formulated animal care and use protocols

**Cleveland Clinic, Spine Research Laboratory**

*Research Assistant, Advisor: Dr. Lars Gilbertson* May–Aug. 2008 & 2009

- Explored the kinematic response of spinal ligaments under altered loading conditions
- Performed *in vitro* experiments on human cadaveric samples and developed a computational model to study spine kinematics before, during, and after altered loading
- Received training in cadaver surgeries and dissections as part of the Cleveland Spine Review

## AWARDS AND HONORS

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IEEE MARSS Best Student Paper Award Finalist July 2018  
National Inventors Hall of Fame Women in Innovation Mar. 2017  
IEEE ICRA Best Automation Paper Award Finalist May 2016  
Edison Award Winner, Therapeutic Category, Gold Apr. 2015  
Forbes’ 30 Under 30 in Science Jan. 2015  
IROS Micro-Nano Robotic Swarms Workshop, Best Poster Award Sept. 2014  
The CNN 10 Inventions of 2014 July 2014  
Popular Science Invention Award May 2014

James Dyson International Design Award, First Place International Winner	Nov. 2013
Collegiate Inventors Competition, Undergraduate Finalist	Nov. 2013
James F. Lincoln Arc Welding Foundation Division V, Bronze Award	Jan. 2014
NIH Design by Biomedical Undergraduate Teams (DEBUT), First runner up	Aug. 2013
McNair Graduate Scholarship	Aug. 2013
William Fontaine Graduate Fellowship	Aug. 2013
Intel Corporation Cornell Cup, First Place	May 2013
UPenn School of Engineering Senior Design Competition, Second Place	May 2013
UPenn Mechanical Engineering Senior Design Competition, Overall Project Excellence	Apr. 2013
National Science Foundation Graduate Research Fellowship	Mar. 2013
McNair Scholar	Apr. 2011

## SKILLS

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**Languages:** MATLAB-Simulink, Python, C++

**Applications:** Robot Operating System (ROS), OpenCV, SolidWorks, COMSOL Multiphysics, L<sup>A</sup>T<sub>E</sub>X/ B<sub>I</sub>B<sub>T</sub>E<sub>X</sub>

**Fabrication:** Laser-cutting, 3D-printing, manual & CNC milling, manual lathe, photolithography, soldering

**Laboratory:** Cell culture, brightfield & fluorescence microscopy, DNA sequencing, PCR, molecular cloning, histology, tissue dissection

## JOURNAL ARTICLES

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An arrow ^ marks papers for which I delivered the conference presentation. Previously published as Elizabeth E. Beattie.

- [J1] Sambeta Das, **Elizabeth E. Hunter**, Nicholas A. DeLateur, Edward B. Steager, Ron Weiss, and Vijay Kumar, “Cellular expression through morphogen delivery by light activated magnetic microrobots, *J. Micro-Bio Robot.*, pp. 112, Jun. 2019.
- [J2] Geelsu Hwang\*, Amauri J. Paula\*, **Elizabeth E. Hunter**, Yuan Liu, Kathleen Stebe, Vijay Kumar, Edward Steager, and Hyun Koo, “Catalytic antimicrobial robots for biofilm eradication, *Sci. Robot.*, vol. 4, no. 29, p. eaaw2388, Apr. 2019. \*Equal contribution.
- [J3] **Elizabeth E. Hunter**^, Edward B. Steager, Allen Hsu, Annjoe Wong-Foy, Ron Pelrine, and Vijay Kumar, “Nanoliter Fluid Handling for Microbiology via Levitated Magnetic Microrobots,” *IEEE Robotics and Automation Letters*, vol. 4, no. 2, pp. 9971004, Apr. 2019.  
  
Presented at the *IEEE International Conference on Robotics and Automation (ICRA)*, Montreal, Canada, May 2019. [Acceptance rate 44.0%].
- [J4] **Elizabeth E. Hunter**^, Evan W. Brink, Edward B. Steager, and Vijay Kumar, “Toward Soft Micro Bio Robots for Cellular and Chemical Delivery,” *IEEE Robotics and Automation Letters*, vol. 3, no. 3, pp. 1592-1599, Jul. 2018.  
  
Presented at the *IEEE International Conference on Robotics and Automation (ICRA)*, Brisbane, Australia, May 2018. [Acceptance rate 40.6%].
- [J5] Lachlan J. Smith, Deborah J. Gorth, Brent L. Showalter, Joseph A. Chiaro, **Elizabeth E. Beattie**, Dawn M. Elliott, Robert L. Mauck, Weiliam Chen, and Neil R. Malhotra, “In vitro characterization of a stem-cell-seeded triple-interpenetrating-network hydrogel for functional regeneration of the nucleus pulposus,” *Tissue Engineering. Part A.*, vol. 20, no. 13-14, pp. 1841-1849, Jul. 2014.
- [J6] Denise Wong, **Elizabeth E. Beattie**, Edward B. Steager, and Vijay Kumar, “Effect of surface interactions and geometry on the motion of micro bio robots,” *Applied Physics Letters*, vol. 103, no. 15, p. 153707, Oct. 2013.
- [J7] John T. Martin, Deborah J. Gorth, **Elizabeth E. Beattie**, Brian D. Harfe, Lachlan J. Smith, Dawn M. Elliott, “Needle puncture injury causes acute and long-term mechanical deficiency in a mouse model of intervertebral disc degeneration,” *Journal of Orthopaedic Research*, vol. 31, no. 8, pp. 1276-1282, Aug. 2013.
- [J8] Brent L. Showalter, Jesse C. Beckstein, John T. Martin, **Elizabeth E. Beattie**, Alejandro A. Espinoza Orías, Thomas P. Schaer, Edward J. Vresilovic, and Dawn M. Elliott, “Comparison of Animal Discs Used in Disc Research to Human Lumbar Disc: Torsion Mechanics and Collagen Content,” *Spine*, vol. 37, no. 15, pp. E900-E907, Jul. 2012.

## CONFERENCE PROCEEDINGS

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An arrow ^ marks papers for which I delivered the conference presentation. Previously published as Elizabeth E. Beattie.

- [C1] **Elizabeth E. Hunter**^, Evan W. Brink, Edward B. Steager, and Vijay Kumar, “3D Micromolding of Small-Scale Biological Robots,” in *2018 IEEE International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS)*, Nagoya, Japan, 2018, pp. 1-6. [**Best Student Paper Finalist**].
- [C2] Sambaeta Das, **Elizabeth E. Hunter**^, Nicholas A. Delateur, Edward B. Steager, Ron Weiss, and Vijay Kumar, “Controlled Delivery of Signaling Molecules using Magnetic Microrobots,” in *2018 International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS)*, Nagoya, Japan, 2018, pp. 1-5.
- [C3] David E. Hernandez, Steven W. Chen, **Elizabeth E. Hunter**, Edward B. Steager, and Vijay Kumar, “Cell Tracking with Deep Learning and the Viterbi Algorithm,” in *2018 International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS)*, Nagoya, Japan, 2018, pp. 1-6.
- [C4] **Elizabeth E. Hunter**^, Nathaniel Chodosh, Edward B. Steager, and Vijay Kumar, “Control of microstructures propelled via bacterial baths,” in *2016 IEEE International Conference on Robotics and Automation (ICRA)*, Stockholm, Sweden, 2016, pp. 1693-1700. [Acceptance rate 34.7%]. [**Best Automation Paper Finalist**].
- [C5] **Elizabeth E. Beattie**^, Jonathon H. Yoder, Sung M. Moon, Edward J. Vresilovic, Dawn M. Elliott, and Alexander C. Wright, “Quantification of intervertebral disc cartilaginous endplate morphology using MRI,” in *2012 38th Annual Northeast Bioengineering Conference (NEBEC)*, 2012, pp. 103-104.
- [C6] John T. Martin, **Elizabeth E. Beattie**, Deborah J. Gorth, Lachlan J. Smith, and Dawn M. Elliott, “Mechanical and Biochemical Consequences of Needle Puncture Injury in the Mouse Caudal Disc,” in *58th Annual Meeting of the Orthopaedic Research Society*, 2012.
- [C7] John T. Martin, **Elizabeth E. Beattie**, Deborah J. Gorth, Lachlan J. Smith, and Dawn M. Elliott, “Mechanical Consequences of Needle Puncture Injury in the Mouse Caudal Spine,” in *ASME 2012 Summer Bioengineering Conference, Parts A and B*, 2012, p. 501.
- [C8] Brent L. Showalter, Jesse C. Beckstein, John T. Martin, **Elizabeth E. Beattie**, Alejandro A. Espinoza Orías, Thomas P. Schaer, Edward J. Vresilovic, and Dawn M. Elliott, “Disc Torsion Mechanics: Comparison of Animal Models to Human,” in *ASME 2011 Summer Bioengineering Conference, Parts A and B*, 2011, p. 1285.

## REFEREED WORKSHOP PRESENTATIONS

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- [W1] **Elizabeth E. Hunter**, Denise Wong, Edward B. Steager, and Vijay Kumar, “Toward Fully Functional Micro Robots: Actuation, Control, and Sensing,” *International Conference on Robotics and Automation (ICRA), Workshop on 30 Years of Small-Scale Robotics: from Nano-, to Millimeter-Sized Robotic Systems and Applications*. Brisbane, Australia. May 25, 2018. Poster Presentation.
- [W2] **Elizabeth E. Beattie**, Denise Wong, Edward B. Steager, and Vijay Kumar, “Effect of Surface Interactions on the Motion of Micro Bio Robots,” *International Conference on Intelligent Robots and Systems (IROS) Workshop on Micro-Nano Robotic Swarms for Biomedical Applications*. Chicago, Illinois. September 14, 2014. Poster Presentation. [**Best Poster Award Recipient**].
- [W3] **Elizabeth E. Beattie**, Edward B. Steager, and Vijay Kumar, “Effect of Geometry and Bacterial Collisions on the Motion of Micro Bio Robots,” *Robotics: Science and Systems (RSS), Workshop on Robotics Methods for Structural and Dynamic Modeling of Molecular Systems*. Berkeley, California. July 12, 2014. Oral Presentation.
- [W4] **Elizabeth E. Beattie**, Edward B. Steager, and Vijay Kumar, “Effect of Geometry and Bacterial Collisions on the Motion of Micro Bio Robots,” *Robotics: Science and Systems (RSS), Workshop on Women in Robotics*. Berkeley, California. July 12, 2014. Poster Presentation.
- [W5] John T. Martin, **Elizabeth E. Beattie**, Lachlan J. Smith, and Dawn M. Elliott, “Mechanical Consequences of Needle Puncture Injury in the Mouse Caudal Disc,” *Spine Research Symposium: New Horizons in Intervertebral Disc Research*. Philadelphia, Pennsylvania, 2011. Poster Presentation.

## INVITED PRESENTATIONS

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- [T1] “Multifunctional Soft Micro Bio Robots Enabled Through Biofabrication,” Invited talk, Special Session on Bio-hybrid Microrobotic Systems, International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS), Toronto, Canada, July 13-17, 2020. *MARSS has been postponed for one year due to COVID-19.*
- [T2] “Phototactic Control of Bacterial Actuators and Sensors,” Invited talk, Special Session on Light-Based Control of Microsystems: From Reactive Agents to Swarms, International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS), Toronto, Canada, July 13-17, 2020. *MARSS has been postponed for one year due to COVID-19.*
- [T3] “Tracking Swimming Microorganisms with Deep Learning,” Invited talk, Special Session on Machine Learning for Small-Scale Robotics, International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS), Toronto, Canada, July 13-17, 2020. *MARSS has been postponed for one year due to COVID-19.*
- [T4] “Multifunctional Magnetic Micro Robots for Synthetic Biology,” Invited seminar, Department of Electrical and Computer Engineering, United States Naval Academy, Annapolis, MD, April 16, 2020.
- [T5] “Microscale Robotic Wetware: Synthetic and Biological Mechanisms for Actuation, Control, and Sensing,” Invited seminar, School of Electrical and Computer Engineering & School of Mechanical and Aerospace Engineering, Cornell University, Ithaca, NY, March 19, 2020.
- [T6] “Robotics for Synthetic Biology,” Invited talk, Automation Team - Ginkgo Bioworks, Boston, MA, November 21, 2019.
- [T7] “Building Robots Using Biology: Microscale Robotic Wetware,” Invited spotlight talk, GRASP Impact & Innovation: Celebrating 40 Years, Philadelphia, PA, September 29, 2019.
- [T8] “Toward Fully Functional Micro Robots: Actuation, Control, and Sensing,” Invited seminar, Department of Chemical and Biomolecular Engineering, Johns Hopkins University, Baltimore, MD, September 6, 2018.
- [T9] “Developing Robots to Enable Superhuman Feats,” Co-keynote speaker (with Adwoa Boakye), Great Lakes Science Center Girls Go! Program, Cleveland, OH, November 14, 2015.
- [T10] “Breaking Barriers: Successes and Challenges of a Young Robotician,” Invited speaker, Magnificat High School, Rocky River, OH, November 12, 2015.
- [T11] “Multi-Scale Robotics: Enabling the Superhuman,” Invited speaker, Forbes’ 30 Under 30 Summit Inventor Showcase, Philadelphia, PA, October 6, 2015.
- [T12] “Micro Bio Robots”, Invited speaker (with Denise Wong), Nanotechnology Engineering Summer Program at Penn, University of Pennsylvania, July 13, 2015.
- [T13] “Titan Arm: A Powered Upper-Body Exoskeleton”, Co-keynote speaker (with Nick McGill), Undergraduate Research Symposium, University of Pennsylvania, February 27, 2014.
- [T14] “Titan Arm: Idea to Final Prototype”, Co-keynote speaker (with Nick McGill), Y-Prize, University of Pennsylvania, January 27, 2014.

## PATENTS

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- [P1] Hyun Koo, Edward Steager, **Elizabeth Hunter**, and Alaa Babeer. *Automated and Precise Device for Dental Plaque Detection, Monitoring and Removal*. United States provisional patent pending under application #62/927,414, filed October 29, 2019.
- [P2] Hyun Koo, Kathleen Stebe, Vijay Kumar, **Elizabeth Hunter**, and Evan Brink. *Small-Scale Robots for Biofilm Eradication*. United States provisional patent pending under application #62/772,306, filed November 28, 2018.

## PROFESSIONAL SERVICE

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[S1] “Multifunctional Microrobots: Emerging Methods for Design & Fabrication at Small-Scales.” Full-Day Workshop. *International Conference on Intelligent Robots and Systems (IROS) 2020*. David Cappelleri, Cédric Clévy, M. Ani Hsieh, **Elizabeth Hunter**. Under Review.

## CONFERENCE TRAVEL GRANTS

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BIOFABRICATE Summit –Selected Student Attendee	2018
Penn President Gutmann Leadership Award	2018
ICRA, Robotics and Automation Systems (RAS) Travel Grant	2018, 2019
Penn Fontaine Society Travel Award	2016, 2018
RSS, Women in Robotics Travel Award	2014

## REFEREE SERVICE

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Journal of Micro Bio Robots (JMBR)	2019
IEEE Robotics and Automation Letters (RA-L)	2018–2019
IEEE International Conference on Robotics and Automation (ICRA)	2015–2018
IEEE International Conference on Manipulation, Automation, and Robotics at Small Scales	2018
IEEE RAS/EMBS International Conference on Biomedical Robotics and Biomechanics (BioRob)	2014

## RESEARCH ADVISING

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**Evan W. Brink**, Undergraduate student, University of Pennsylvania  
*Undergraduate Researcher* May 2017–May 2019  
Research project: “Design and fabrication of 3D micromolded soft micro bio robots”

**Spencer Fox**, Undergraduate student, University of Pennsylvania  
*Undergraduate Researcher* May 2018–August 2018  
Summer project: “Design of tri-axial nested Helmholtz coils”

**David E. Hernandez** (co-mentored with Steven Chen), Masters student, University of Pennsylvania  
*Graduate Student Researcher* August 2017–May 2018  
Research project: “Cell Tracking with Deep Learning and the Viterbi Algorithm”

## TEACHING

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**Penn Center for Teaching and Learning (CTL)**, Teaching Certificate Program Completed Dec. 2017

- Pedagogical discussion and training, teaching experience, professional development through teaching observations and reviews, and formulation of a teaching philosophy

**University of Pennsylvania**, MEAM 110: Introduction to Mechanics  
*Teaching Assistant* Aug.–Dec. 2014 & 2015

- Led interactive recitation classes for 52 students (2014) and 45 students (2015) twice per week on the fundamentals of classical mechanics
- Delivered guest lectures on the work-energy theorem (October 26, 2015) and on conservation of energy (October 28, 2015)
- Created supplementary curriculum for problem-solving focused recitation classes and counseled students on their academic progress

**University of Pennsylvania**, MEAM 211: Engineering Mechanics–Dynamics  
*Teaching Assistant* Jan.–May 2015

- Lectured 105 students twice per week on the fundamentals of dynamics in small group recitations
- Delivered a guest lecture on Newton-Euler equations of motion and moments of inertia (April 3, 2015)
- Developed supplementary curriculum for recitation peer-instruction style classes

## OUTREACH AND CIVIC ENGAGEMENT ACTIVITIES

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Penn Open Labs Science Café, Director	Jan. 2016–May 2018
Mechanical Engineering Senior Design Day Judge, SEAS UPenn	Apr. 2015
Penn NSF Graduate Research Fellowship Presentation, Panelist	Oct. 2013, 2014
General Robotics, Automation, Sensing, and Perception Lab, Tour Guide	Oct. 2014–present
Camp Invention, Innovation Mentor	July 2014
Women in Computer Science High School Day for Girls, SEAS UPenn	Apr. 2013
Hexagon Senior Society, Penn Engineering student ambassador	Mar. 2012–May 2013
Penn Engineering Research Peer Advisor, Undergraduate mentor	May 2011–May 2013
Penn Girls in Engineering, Math, and Science, Program volunteer	June 2010, 2011
The Perry Initiative, Volunteer for Philadelphia, PA outreach program	Nov. 19, 2011

## SCIENTIFIC AND PROFESSIONAL SOCIETIES

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IEEE, Institute for Electrical and Electronic Engineers, Robotics and Automation Society  
APS, American Physical Society  
AWE, Penn Advancing Women in Engineering  
MEGA, Penn Mechanical Engineering Graduate Association, *Served as President during 2015–2016.*

## GRANTS

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Penn Health-Tech Pilot Grant  
***Small-scale robots for biofilm removal***  
Role: Co-Principal Investigator  
Funding: \$25,000  
Dates: January 1, 2019–December 31, 2019  
[Penn Health-Tech Project Website](#)