DEREK E. MOULTON

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1. Employment history

Professor of Applied Mathematics, University of Oxford — August 2022 - present
Wolfson Centre for Mathematical Biology, Mathematical Institute
Tutorial Fellow, Balliol College

Associate Professor, University of Oxford — April 2013 - August 2022
Wolfson Centre for Mathematical Biology, Mathematical Institute
Tutorial Fellow, Balliol College

Postdoctoral Researcher, University of Oxford — June 2010 - March 2013
OCCAM, Mathematical Institute
Millard and Lee Alexander Postdoctoral Fellow, Christ Church

Hanno Rund Postdoctoral Fellow, University of Arizona — 2008 - 2010
Department of Mathematics

Ph.D. Applied Mathematics, University of Delaware — May 2008
Dissertation: Mathematical modeling of Field Driven Mean Curvature Surfaces
Advisor: John A. Pelesko

M.S. Applied Mathematics, University of Delaware — January 2006
GPA 3.95

B.A. Mathematics, University of Denver — June 2003
Magna Cum Laude, minor in Computer Science and English

2. Research

PUBLICATIONS

Published work – Top 6 publications are indicated by **
Papers for which I am corresponding author are indicated by †

- † DE Moulton, H. Oliveri, A. Goriely & C Thorogood, "Mechanics reveals the role of peristome geometry in prey capture in carnivorous pitcher plants (Nepenthes)" *PNAS – accepted* (2023)
- † H Reynolds, BW Turney, SL Waters, DE Moulton, "Harnessing oscillatory fluid behaviour to improve debris wash-out in ureteroscopy", *Frontiers in Urology* **Vol 3** (2023).
- CR Constante-Amores, L. Kahouadji, JG Williams, DE Moulton, BW Turney, S Shin, J Chergui, D Juric, & SL Waters, "The role of kidney stones in renal pelvic flow" *J Biomech Eng* **145.5** (2023): 051007
- B Walker, GL Celora, A Goriely, DE Moulton &H Byrne, "Minimal Morphoelastic Models of Solid Tumour Spheroids: A Tutorial." *Bulletin math bio* **85.5** (2023): 38.
- † B Kaczmarski, A Goriely, E Kuhl & DE Moulton, "A simulation tool for physics-informed control of biomimetic soft robotic arms." *IEEE Robotics and Automation Letters* **8.2** (2023): 936-943.

- DE Moulton, B Kaczmarski, E Kuhl & A Goriely, "Active Filaments I: curvature and torsion generation" *J Mech Phys Solids* **164** (2022) 104918.
- A Goriely, DE Moulton, A Mihai, "A rod theory for liquid crystalline elastomers" *J. Elasticity* **153.4-5** (2023): 509-532.
- ** R Chirat, A Goriely & DE Moulton, "The physical basis of mollusk shell chiral coiling" *PNAS* **118**:48 (2021) e2109210118.
  (A detailed and innovative model that explains the physical origin of coiling patterns in mollusk shells. A landmark study that uncovers a simple mechanism for a diversity of shell forms, including the startling meandering form of *Nipponites mirabilis*, and provides insight into how mechanics can generate symmetry breaking during development. Though not corresponding author, my contribution was principal scientist in development and analysis of the mathematical model.)

- JG Williams, F Wechsung, BW Turney, SL Waters & DE Moulton, "Shape optimisation for faster washout in recirculating flows" *J. Fluid Mechanics* **914**:A37 (2021).
- JG Williams, L Goldsmith, DE Moulton, SL Waters & BW Turney, "A temperature model for laser lithotripsy" *World Journal of Urology* **39**:6 (2021), 1707-1716.
- ** † DE Moulton, H Oliveri, & A Goriely, "Multiscale integration of environmental stimuli in plant tropism produces complex behaviors" *PNAS* **117**:51 (2020), 32226-32237.
  (A multi-scale mathematical framework that connects for the first time information at cell, tissue, and organ scales for modelling the response of plants to environmental stimuli; capable of simulating in a straightforward manner complex and dynamic 3D morphologies never before investigated.)

- † A Almet, HM Byrne, PK Maini, & DE Moulton, "The role of mechanics in the growth and homeostasis of the intestinal crypt" *Biomech and Modeling in Mechanobiology* **20**:2 (2020), 585-608.
- † DE Moulton, T Lessinnes, & A Goriely, "Morphoelastic Rods III: Differential Growth and Curvature Generation in Elastic Filaments" *J Mech Phys Solids* **142** (2020), 104022.
- ** † DE Moulton, A Goriely & R Chirat, "Mechanics unlocks the morphogenetic puzzle of interlocking bivalved shells" *PNAS* **117**:1 (2020), 43-51.
  (This paper won the 2019 Cozzarelli Prize for top scientific research. We uncovered 'simple' mechanical rules that explain how two separate growing fronts of a bivalved shell naturally interlock. From evolutionary perspective, this work explains how the same interlocking pattern independently appeared in both brachiopods and bivalved mollusks.)

- A Erlich, GW Jones, F Tisseur, DE Moulton & A Goriely, "The role of topology and mechanics in uniaxially growing cell networks" *Proceedings Royal Society A* **476**:2233 (2020), 20190523.
- JG Williams, AA Castrejon-Pita, BW Turney, PE Farrell, SJ Tavener, DE Moulton & SL Waters, "Cavity flow characteristics and applications to kidney stone removal" *J. Fluid Mechanics* **902**:A16 (2020).
- † JG Williams, L Rouse, BW Turney, SL Waters , & DE Moulton, "A lumped parameter model for kidney pressure during stone removal" *IMA J. Applied Math* **85**:5 (2020), 703-723.
- JG Williams, BW Turney, DE Moulton, & SL Waters, "Effect of geometry on resistance in elliptical coaxial pipe flows" *J. Fluid Mechanics* **891**:A4 (2020).
- S Rudraraju, DE Moulton, R Chirat, A Goriely & K Garikipati, "Seashell morphogenesis: A computational framework for the three-dimensional evolution of surface and volumetric growth in gastropods" *PLOS* **15**:7 (2019), e1007213.
- † JG Williams, BW Turney, NJ Rauniyar, TP Harrah, SL Waters, & DE Moulton, "The Fluid Mechanics of Ureteroscope Irrigation" *J. Endourology* **33**:1 (2019), 28-34.
- M Gomez, DE Moulton, & D Vella, "Dynamics of viscoelastic snap-through" *Journal of the Mechanics and Physics of Solids* **124** (2019), 781-813.

- A Erlich, DE Moulton, & A Goriely, "Are homeostatic states stable? Dynamical stability in morphoelasticity" *Bulletin Math Bio* **81**:8 (2019), 3219-3244.
- † AA Almet, HM Byrne, PK Maini, & DE Moulton, "Post-buckling behaviour of a growing elastic rod" *J Theor Biology* **78**:3 (2018), 777-814.
- † M Gomez, D Vella, & DE Moulton, "Pull-in dynamics of overdamped microbeams" *J Micromech and Microeng*, (2018).
- † DE Moulton, A Goriely, & R Chirat, "How seashells take shape" *Scientific American* **318**:4, (2018), 68.
- DE Moulton, P Grandgeorge, & S Neukirch, "Stable elastic knots with no self-contact" *J Mech Phys Solids* **116** (2018), 33-53.
- † A Erlich, R Howell, A Goriely, R Chirat, & DE Moulton, "Mechanical feedback in seashell growth and form" *The ANZIAM Journal*, **59** (2018), 581-606.
- M Gomez, DE Moulton, & D Vella, "Delayed pull-in transitions in overdamped MEMS devices" *J Micromech and Microeng*, **28**:1 (2018), 015006.
- M Gomez, DE Moulton, D Vella, "Passive control of viscous flow via elastic snap-through" *Physical review letters* **119**:14, (2017), 144502.
- B Blonder, DE Moulton, J Blois, BJ Enquist, BJ Graae, M Macias-Fauria,..., "Predictability in community dynamics" *Ecology letters* **20**:3 (2017) 293-306.
- T Lessinnes, DE Moulton, & A Goriely, "Morphoelastic rods: Part II: Growing birods". *J Mech Phys Solids*, **100** (2017), 147-196.
- ** M Gomez, DE Moulton, & D Vella, "Critical slowing down in purely elastic snap-through instabilities" *Nature Physics* **13**:2 (2017) 142.
  (This paper analysed both mathematically and experimentally a generic phenomenon in which a bistable elastic object, when snapping from one state to another, can be drastically slowed. This work provided both new insight and a mathematical tool for a phenomenon with relevance in a number of engineering systems. I was co-senior author with D Vella on this paper.)

- † DE Moulton, V Sulzer, G Apodaca, HM Byrne, & SL Waters, "Mathematical modelling of stretch-induced membrane traffic in bladder umbrella cells" *J Theor Biol* **409** (2016), 115-132.
- A Erlich, DE Moulton, A Goriely, & R Chirat, "Morphomechanics and developmental constraints in the evolution of ammonites shell form" *J Exper Zoology Part B* **326**:7 (2016), 437-450.
- ** H Hofhuis, DE Moulton, T Lessinnes, AL Routier-Kierzkowska, ... A Hay, "Morphomechanical innovation drives explosive seed dispersal" *Cell* **166**:1 (2016) 222-233.
  (I was co-first author, and principal driver of the mathematical modelling, for this hugely interdisciplinary and thorough study of the mechanism underlying the explosive catapulting by which the plant *Cardamine hirsuta* disperses its seeds. Our analysis, which included developing a suite of mathematical models, uncovered a sequence of key developmental changes, linking genetic, cellular, tissue, and whole plant scales.)

- † DE Moulton, T Lessinnes, S OKeeffe, L Dorfmann, & A Goriely, "The elastic secrets of the chameleon tongue" *Proc R Soc A* **472**:2188 (2016), 20160030.
- M Gomez, DE Moulton, & D Vella, "The shallow shell approach to Pogorelov's problem and the breakdown of 'mirror buckling"' *Proc R Soc A* **472**:2187 (2016), 20150732.
- † LG Bowden, HM Byrne, PK Maini, & DE Moulton "A morphoelastic model for dermal wound closure". *Biomech and Modeling in Mechanobiology*, **15**:3 (2016), 663-681.
- † DE Moulton, A Goriely, & R Chirat, "The morpho-mechanical basis of ammonite form" *J Theor Biology*, **364(C)** (2015), 220-230.
- A Erlich, T Lessinnes, DE Moulton, & A Goriely, "A short introduction to morphoelasticity: the mechanics of growing elastic tissues", *Extremely Deformable Structures*, (2015) 269-297.

- LG Bowden, PK Maini, DE Moulton, JB Tang, XT Wang, PY Liu, & HM Byrne, "An ordinary differential equation model for full thickness wounds and the effects of diabetes", *J Theor Biology* **361**:C (2014), 87-100.
- A Pandey, DE Moulton, D Vella, & DP Holmes, "Dynamics of snapping beams and jumping poppers," *Euro Phys Lett* **105**:2, (2014) 24001.
- † DE Moulton, A Goriely, "Surface growth kinematics via local curve evolution," *J Math Biol*, **68**:1-2 (2014) 81-108.
- † R Chirat, DE Moulton, and A Goriely, "Mechanical basis of morphogenesis and convergent evolution of spiny seashells," *PNAS*, **110**:15 (2013), 6015-6020.
- S O'Keefe, DE Moulton, S Waters, and A Goriely, "Growth-induced axial buckling of a slender elastic filament embedded in an isotropic elastic matrix", *Int J Nonlinear Mech* **56** (2013), 94-104.
- DE Moulton, T Lessinnes, and A Goriely, "Morphoelastic rods Part I: A single growing elastic rod," *J Mech Phys Solids*, **61**:2 (2013) 398–427.
- † DE Moulton, J Lega, "Effect of disjoining pressure in thin film equations with non-uniform forcing," *Eur J Appl Math*, **24**, (2013) 887-920.
- † DE Moulton, A Goriely, "Mechanical growth and morphogenesis of seashells," *J Theor Biol*, **311** (2012), 69–79.
- † DE Moulton, A Goriely, "Possible role of differential growth in airway wall remodeling in asthma," *J Appl Physiology*, **110**:4 (2011) 1003-12.
- ** † DE Moulton, A Goriely, "Circumferential buckling instability of a growing cylindrical tube," *J Mech Phys Solids*, **59** (2011) 525–537.
  (This highly cited study was one of the first papers that demonstrated the role of growth in mechanical buckling instabilities, providing a new biological perspective on a classic aspect of elasticity and material stability, and paving the way for many follow-up studies examining growth and pattern formation in biology.)

- JM Restrepo, DE Moulton, and H Uys, "Precessive Sand Ripples in Intense Steady Shear Flows," *Phys Rev E*, **83** (2011), 031305.
- † DE Moulton, A Goriely, "Anticavitation and differential growth in elastic shells," *J Elasticity*, **102**:2, (2011), 117–132.
- A Goriely, DE Moulton, and R Vandiver, "Elastic cavitation, tube hollowing, and differential growth in plants and biological tissues," *Euro Phys Lett*, **91** (2010), 18001.
- A Goriely, DE Moulton, New Trends in the Physics and Mechanics of Biological Systems: Lecture Notes of the Les Houches Summer Schools, volume 92, chapter *Morphoelasticity - A theory of elastic growth* (M Ben Amar, A Goriely, M Mueller, Editors) Oxford University Press (2010).
- † DE Moulton, JA Pelesko, "Reverse Draining of a Magnetic Soap-Film," *Phys Rev E*, **81** (2010), 046320.
- † DE Moulton, J Lega, "Reverse draining of a magnetic soap film - Analysis and simulation of thin film equation with non-uniform forcing," *Physica D*, **238** (2009), 2153–2165.
- † DE Moulton, JA Pelesko, "Catenoid in an Electric Field," *SIAM J Appl Math*, **70** No. 1 (2009), 212–232.
- † DE Moulton, JA Pelesko, "Theory and Experiment for Soap-Film Bridge in an Electric Field," *J Colloid Interface Sci*, **322** No. 1 (2008), 252–62.
- † DE Moulton, JA Pelesko, "Thermal Boundary Condition - an Asymptotic Analysis," *Heat and Mass Transfer* **44** No. 7 (2008), 795–803.

AWARDS AND HONOURS

- Recipient of 2019 Cozzarelli Prize awarded to top scientific research published in PNAS in the category 'Engineering and Applied Science', for the paper *Mechanics unlocks the morphogenetic puzzle of interlocking bivalved shells*.
- 2010: Travel award, US Congress on Theoretical and Applied Mechanics, Penn State University.

FUNDING

- Royal Society International Exchanges Cost Share Travel Grant, PI, £12,000 for project *Mathematical modelling and transcriptomics of horned mollusc seashells*, ref IEC\R3\193090, awarded March 2020.
- EPSRC Doctoral Prize, £20,000, to retain for 6 months supervised PhD student J. Williams, awarded 2019.
- EPSRC Doctoral Prize, £20,000, to retain for 6 months supervised PhD student M. Gomez, awarded 2018.
- John Fell Fund OUP Research Fund, PI, £7500 for project: *High speed camera for Mathematical Observatory*, 2013.

PATENTS

Patent on ureteroscope access sheath design for use in kidney stone removal. U.S. Application No. 62/552,819. Patent Application: Access device methods of using the same.

MEDIA

- Article in PNAS, "The physical basis of mollusk shell chiral coiling", featured in articles in the New York Times (`https://www.nytimes.com/2021/12/10/science/mollusk-shells-mathematics.html`), and "Pour la Science".
- Cozzarelli prize winning paper, *Mechanics unlocks the morphogenetic puzzle of interlocking bivalved shells*, featured in numerous media outlets. Also interviewed for podcast by PNAS: `https://open.spotify.com/episode/1ZzwX3riB8q9GwCT8VM9Nn`
- Interviewed in podcast titled, *Math and the shape of shells* by American Mathematical Society about work on seashells, 2018, `https://www.ams.org/publicoutreach/mathmoments/mm138-shells-podcast`.
- Produced popular science article for Scientific American, *How seashells take shape*, April 2018.
- Article in PNAS on spine morphogenesis in seashells (2013) was covered by numerous popular science news outlets, including ScienceDaily, Nature Highlights, CNRS Press Release, and a feature article in The Scientist Magazine.
- Article in *Proc Roy Soc A* on elasticity and chameleon's tongue (2016) was covered by numerous popular science news outlets, including BBC Science. `https://www.bbc.co.uk/news/science-environment-36082277`
- Have produced popular science research videos about work on seashells and also on seed dispersal article featured on the cover of *Cell*. These are available on Youtube, with links on my webpage.

INTERNATIONAL/INTERDISCIPLINARY COLLABORATION

- R Chirat, paleontologist, Univ Lyon 1, France collaborators since 2011, have published 8 papers together.
- Boston Scientific Corporation – have fostered industrial collaboration on modelling physical aspects of ureteroscope biomedical device since 2016 – collaboration has involved co-supervision of 3 PhD students, and has generated one patent, 6 publications, and 3 mini-workshops.
- A Sato, developmental biologist, Ochanomizu Univ, Japan, collaborator on current Royal Society Travel grant.

- M Davis, marine biologist, Florida Atlantic Univ, USA, co-supervisors of summer project, active collaboration on Queen conch conservation.
- E Kuhl, mechanical engineer, Stanford, USA, co-supervisors of PhD student since 2020 on activation of filaments for soft robotics.
- B Turney, clinical urologist, Nuffield Department of Surgical Sciences, Oxford, co-supervisors of 3 PhD students on modelling biomedical device ureteroscope, have published 6 papers together.
- R Cleveland, biomedical engineer, Oxford, co-supervising a PhD student since 2020.
- G Apodaca, cell biologist, Univ Pittsburgh, USA, published 1 paper together on bladder epithelium.
- A Hay, plant scientist, Max Planck Institute for Plant Breeding Research, Germany, published 1 paper together on seed dispersal.
- B Blonder, ecologist, Univ California Berkeley, USA, published 1 paper together on ecological dynamics.
- S Neukirch, mechanical engineer, UPMC, France, published 1 paper together on elastic knots.
- K Garikipati, mechanical engineer, Univ Michigan, USA, published 1 paper together on seashell ornamentation.
- L Dorfmann, mechanical engineer, Tufts Univ, USA, published 1 paper together on chameleon tongue mechanism.
- P Liu, plastic surgeon, Brown Univ, USA, published 1 paper together on modelling wound healing.

SCIENTIFIC ACTIVITES

- Co-founder of the Mathematical Observatory, an experimental space in the Mathematical Institute
- Have given invited seminars at over 10 different universities spanning 6 countries.
- I have presented talks at over 20 international conferences or workshops. This includes an invited talk at major international conference – American Physical Society March Meeting (2019), and presentation at major biological conference – Euro Evo Devo (2014).
- Contributed to mathematical modelling study groups for industry in Moscow (2010), Malaysia (2011), and MBI Ohio State (2012).

3. University lectures and classes

COURSES LECTURED, CLASSES TUTORED (IN DEPARTMENT)

- Lecturer for M4: Geometry, 2020-present, 15 lecture hours course
- Lecturer for C5.9: Mathematical Mechanical Biology, 2020-present, 16 lecture hours course
- Lecturer for B5.2: Applied Partial Differential Equations, 2015-2019, 16 lecture hours course
- Lecturer for A6: Differential Equations 2, 2015-2018, 16 lecture hours course – had significant involvement in syllabus development following restructuring of differential equations courses.
- Lecturer for B5.A: Techniques of Applied Mathematics, 2013-2015, 16 lecture hours course
- Intercollegiate class tutor for 3rd and 4th year courses:
  – 3rd year: Applied Partial Differential Equations, Further mathematical biology, Nonlinear systems
  – 4th year: Solid mechanics, Elasticity and plasticity, Mathematical Mechanical Biology

AWARDS, STUDENT FEEDBACK

- Received Departmental teaching award, Mathematical Institute, 2015.

- In student feedback questionnaires, taken across across all of departmental teaching and lecturing, 93% of students responded to the queries 'The lecturer explained the material well' or 'The class tutor made the subject understandable' with 'Strongly agree', or 'Agree', with 61% responding with 'Strongly agree'.
- Direct quotes from students in feedback questionnaires include:
  - Dr Moulton is the best lecturer I've had at Oxford by a considerable margin
  - Really enjoyed the course-lectures were great!
  - he's a really good lecturer and tries to answer all the questions raised by the students.
  - Excellent lecturer.
  - If only everyone could explain the material that well
  - Class was excellent!

4. Graduate supervision

PhD Supervision

- Sophie Abrahams, *Modelling of laser-induced cavitation bubbles for ureteroscopy*, 2020 – present.
- Isabelle Scott, *Mechanics of tendonopathy*, 2018 – present (thesis due to be submitted March 2022)
- Harry Reynolds, *Time dependent flows in ureteroscopy*, 2018 – present (thesis due to be submitted March 2022)
- Bartek Kaczmarski, *Simulating muscular contraction to inform actuation in bio-inspired soft robots*, 2020 – present (joint supervisor of student based at University of Stanford)
- Jessica Williams, *Mathematical modelling of fluid flows during ureteroscopic kidney stone removal*, PhD completed 2019
- Michael Gomez, *Ghosts and bottlenecks in elastic snap-through*, PhD completed 2018
- Axel Almet, *Biomechanics of intestinal crypt morphogenesis*, PhD completed 2019
- Alex Erlich, *Growth laws in morphoelasticity*, PhD completed 2017
- Lucie Bowden, *Mathematical modelling of full thickness wounds and the effects of diabetes*, PhD completed 2015
- Stephen O'Keeffe, *The mechanics of growth and muscle contraction in soft tissues*, PhD completed 2014

Postdoc Supervision

- Jessica Williams, *Shape optimisaton for ureteroscopic kidney stone removal*, 2019 – 2020
- Michael Gomez, *Crumpling dynamics*, 2018

5. University Examination

- Part A Examiner 2017-2018, 2018-2019, 2021-2022
- PhD Examiner for A Melnik (U Oxford, 2015), D Humphries (U Oxford, 2018), J Kwiekcinski (U Oxford, 2018), H Alawiye (U Oxford, 2020)
- Have served as Transfer and/or Confirmation Examiner in the Mathematical Institute usually for a couple of students each year
- Set and marked examinations for lecture courses in Mathematical Institute, U Oxford: B5.A (Techniques of Applied Mathematics), A6 (Differential equations 2), B5,2 (Applied PDEs), and C5.9 (Mathematical Mechanical Biology)

6. Service

Roles in Mathematical Institute

- Part A Examiner, 2017-2018, 2018-2019, 2021-2022
- Mathematical Modelling and Scientific Computing MSc Advisory Committee, 2020-present
- Mathematical Modelling and Scientific Computing MSc Admissions Committee, 2015-2018
- Member of Department Workload working group, 2020.
- REF representative, Mathematical Biology Group, 2018-present.
- Regular volunteer at open days, course option fairs

Scientific organisation

- Co-organiser of conference: *On growth and pattern formation: a celebration of Philip Maini's 60th birthday*, 18-19 September 2019, ∼150 attendees.
- Organised mini-symposium: *Frontiers in Mathematical Mechanical Biology*, at British Applied Mathematics Colloquium, U. Cardiff, 2014.
- Co-founder of Mathematical Observatory, experimental laboratory in Mathematical Institute, U. Oxford.
- Supervisor in European Summer School in Industrial Mathematics Modelling Week, Milan Italy, 2011.
- Organised Modeling and Computation Seminar, Applied Mathematics, U. Arizona, 2009-2010.

Outreach

- Annually demonstrated experiments and describe underlying mathematics for visiting Frost Scholars, Sep, 2014-2018.
- Mathematical Biology lecture to students at London International Youth Science Forum, 2017.
- Talk on Mathematical Biology to school students, 2015.
- Presented public lecture at Mathematical Institute Garden Party, 2012.

Non-PhD research supervision

- T Strube, *Mathematical model of Nepenthes pitcher plants*, MSc thesis, 2021.
- M Monks, *Modelling Queen conch shell growth*, Undergraduate summer project, 2021.
- J Rahman, *Mathematical modelling of plant tropisms*, MSc thesis, 2018.
- S Rose, *Modelling the growth of spines on seashells*, Undergraduate thesis, 2017-18.
- L Hadley, *A model of elastic tongue dynamics*, Undergraduate summer project, 2016.
- A Bassett, *Mathematical modelling of oscillating bubbles*, Undergraduate thesis, 2015-16.
- R Howell, *A model of seashell ornamentation*, Undergraduate thesis, 2014-15.
- J Wang, *Mathematical model of prey capture in spiders*, MSc thesis, 2015.
- C Antonovici, *Modelling the growth of tumour spheroids*, MSc thesis, 2014.
- M Gomez, *Flow induced snap-through*, MSc thesis, 2014.
- K Enoyoshi, *Modelling spine formation in seashells*, Summer internship 2015.
- V Sulzer, *Modelling umbrella cells in bladder*, Undergraduate thesis, 2014-15.
- V Brunck, *Modelling the optimal geometry of seashells*, Summer internship 2014.

Other

- Created mathematical equations design (pro bono) for use as wallpaper and notebook cover.
- Worked as mathematical consultant on the Warner Bros. major motion picture 'Sherlock Holmes 2: A Game of Shadows'. Numerous media sources featured stories on our contribution. Also produced an article for SIAM News and a chapter for the popular-science book '50 Visions of Mathematics'.
- Reviewer for over a dozen different scientific journals.

- Panel speaker at 'Research careers' event for Wolfson Centre for Mathematical Biology, 2018, and speaker during 'Research Careers' session of Careers Event, Mathematical Institute, U. Oxford, 2013.

7. Undergraduate teaching for College

- Tutor for 1st and 2nd year applied mathematics courses, Balliol College:
  – 1st year courses: Geometry, Fourier Series and PDEs, Dynamics
  – 2nd year courses: Differential Equations 1, Differential Equations 2, Fluids and Waves, Integral transforms, Calculus of variations, Mathematical biology.

8. College Administration

Roles in Balliol College

- Climate Fellow – creator and inaugural holder of this role, initiated in November 2021 – will generate and drive forward the College's initiatives on reducing environmental impact, also chairing a newly created Climate and Biodiversity Subcommittee.
- Buildings Fellow, active since October 2016 – representative of the fellowship on buildings matters
- Sports Committee, active since October 2016
- Housing Policy Implementation Committee, active since October 2020
- Executive Committee, 2014-2016
- Member of Governing Body, active since 2013.
- Hiring panel for Early Career Research Fellowships, 2014, 2018, 2019

9. Future plans for research

Seashells and mechanisms of development

- I have a well-established collaboration with paleontologist R. Chirat, which has led to a number of high impact publications, uncovering physical mechanisms underlying the development of shell forms. We have outlined several areas of future investigation; the long-term goal of a unified mathematical framework and physical understanding of the second largest phylum in the animal kingdom is within sight. We also have plans to turn our results into a book in the near future.
- While the work with Dr Chirat focusses primarily on comparisons with the fossil record, I have also recently established collaborations with developmental biologist A. Sato and marine biologist M. Davis to investigate shell form at lower scales and driven by experiments on living species.
  - With Dr Sato, I intend to uncover molecular cues underlying the formation of spines in the species *T Cornutus*. These shells show dramatic phenotypic plasticity, and we will aim to link a multiscale mathematical model with transcriptome analysis conducted by Dr Sato's lab.
  - Dr Davis is a world-leader in the conservation and restoration of Queen Conch, which includes the active development of conch hatcheries throughout the Caribbean. Our goal is to develop a mathematical framework that enables to link the precise environmental conditions of the hatchery to the growth and form of the conch shells, with the ultimate aim of optimising the survival rate of hatchery-raised conch.

Filamentary mechanics

- A key thread in my research to date has been the development of mathematical tools to study filamentary objects. This work takes as a starting point the classic Kirchhoff equations for elastic rods, and integrates features of growth, remodelling, and activation, leading to a mathematical suite ideally suited for studying a number of biological applications. My future work will continue to develop this tool kit, including:

  - Control of 3D filamentary structures via prescribed activation of fibres. This thread is motivated by the fascinating abilities of the elephant trunk, which displays tremendous dexterity through activation of a complex muscular structure. We are developing a mathematical framework that can model with sophisticated mechanical precision the morphology of such a structure for any given muscular activation pattern. The next step will be to formulate a control problem, in which a desired goal (e.g. grabbing a ball) is achieved via finding the appropriate activation pattern. This will require incorporating mathematical tools from optimisation and machine learning in the mechanical framework we have developed. This work has the goal of design principles for soft robotics, and will involve collaboration with robotics engineers at Stanford University.

  - In a recent PNAS paper, we constructed a mathematical framework for tropic growth of plants, which can naturally be modelled as growing filamentary elastic structures. Tropism is the growth response of a plant to external or internal stimulus, such as gravity or light, and is a ubiquitous phenomenon of fundamental importance in plant science. Our PNAS model was the first ever to link explicitly plant growth due to concentration of growth hormone with complex 3D morphologies. A key future step is designing and linking explicitly with tropic experiments, for which I have engaged in discussion with several experimental plant scientists; a Banff workshop on modelling plant growth to which I have been invited in October 2022 will serve as a perfect platform to further this work.

Ureteroscopy

- Along with Prof S Waters (Mathematical Institute, Oxford), and Dr B Turney (Nuffield Dept of Surgical Sciences, Oxford), I have fostered since 2016 a fruitful collaboration with industrial partner Boston Scientific, with the general aim of developing mathematical tools for ureteroscopy, a medical procedure using a device called a ureteroscope for the removal of kidney stones. This procedure includes features of complex fluid dynamics (due to the continuous irrigation of saline solution during the procedure), fluid-solid interaction (motion of the kidney stone and/or fragments), and laser physics. This collaboration has produced a number of publications, as well as a patent, and I have made a number of contacts at Boston Scientific who are all enthusiastic to continue this thread of research; I intend to continue this work in the following areas:

  - Fluid-solid structure and 3D fluid mechanics. The geometry of the renal-pelvic cavity is complex, and the wall itself is deformable. Most of our modelling to date has considered an idealised 2D geometry for this cavity; a key step going forward will be to consider a more realistic geometry. For this purpose we have established a collaboration with a team of researchers with expertise in 3D computational fluid mechanics.

  - I am currently co-supervising a 3rd PhD student in this area, with focus on the laser physics (a laser embedded in the ureteroscope is used by the clinician to break up the kidney stone). This is an extremely rich field, and in particular when fluid flow and kidney stone motion is included, it is an area that is effectively untouched in existing literature. We are taking initial steps with our current PhD student, but there will be both a strong potential and a clinical need to investigate much beyond the work that is planned for the PhD. This area will benefit from experimental work undertaken either at Boston Scientific or in experimental labs under the supervision of Dr Turney.