MATTEO TAFFETANI

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RESEARCH INTERESTS

My research focuses on the mathematical modeling and analysis of continuum systems influenced by non-mechanical stimuli, with emphasis on differential geometry for slender approximation, asymptotics analysis in dynamics, and PDE-based approaches for numerical analysis.

- Mathematical modeling of continuum systems with non-mechanical stimuli.
- Analysis of elasticity–stimuli coupling to analyze novel constitutive laws.
- Asymptotic methods and slender-body approximations in PDE systems.
- Geometric and variational approaches to shape adaptation and morphing.

ACADEMIC RECORD

Lecturer in Structures (fixed-term contract) 23/10/2023 -- present
Institute of Infrastructure and Environment, University of Edinburgh, Edinburgh (United Kingdom)

- Research:
  - Topic: Slow-fast systems. Dynamic-induced morphing in morpho-elastic thin structures.
    Supervisor of PhD student William Simpkins.
    Paper submitted: Simpkins W., Hennessy M., **Taffetani M.** (2025) Snap-through time of arches is controlled by slenderness and imperfections, *Physical Review Letters*
  - Topic: Geometrical and physical non-linearities in morphoelastic shells.
    Paper submitted: Pezzulla M., **Taffetani M.** (2025) Nonlinear morpholeastic energy based theory for curvature controlled shells, *Journal of Elasticity*
  - Topic: Multiphysics morphing in biology. Coupling elasticity with reaction-diffusion-advection equations for morphing in chemical controlled growth of biological organoids.
- Teaching:
  - Introduction to Ordinary and Partial Differential Equations, in Engineering Mathematics 2A; Introduction to Rational Mechanics in Structural Mechanics 2A.

Lecturer in Engineering Mathematics 22/09/2020 -- 19/10/2023
Department of Engineering Mathematics, University of Bristol, Bristol (United Kingdom)

- Research in mathematical modelling in continuum mechanics and slender approximation.
- Teaching:
  - Mathematics and Data Modelling for MSc Engineering Mathematics.
  - Partial Differential Equations / Continuum Mathematics; Introduction to Probability in Engineering Mathematics 1.
- Admin:
  - Programme Director MSc Engineering Mathematics. Senior Year 1 undergraduate tutor. Staff Student Liaison Committee.

Postdoctoral Research Assistant 01/10/2018 -- 21/09/2020
Mathematical Institute, University of Oxford, Oxford (United Kingdom)
Scientific supervisor: Professor Sarah Waters

- 'Postdoctoral Research Assistant in the Mathematical Modelling of Engineered Tissues'.
  - I developed multiphase models to understand the growth in biological tissues for tissue engineering applications, focusing on the mechanics of the interfacial zone between a fluid domain and a poroelastic domain.
  - The project was highly interdisciplinary and I led the interactions between the postdoctoral researchers at the three institutions involved: beyond myself being in a mathematical department, the group involved an electronic engineer and a biologist.

Postdoctoral Research Assistant 01/10/2015 -- 30/09/2018
Mathematical Institute, University of Oxford, Oxford (United Kingdom)
Scientific supervisor: Professor Dominic Vella

- 'Postdoctoral Research Assistant in the Simulation of Thin Elastic Shells' as part of the ERC-funded project 'Geometry and Anomalous Dynamic Growth of Elastic Instabilities'.
  - Numerical and analytical investigation of the stability and morphological emergence of patterns in shell-like structures.
  - I used a combination of asymptotic analysis and numerical simulations to derive the universal role of the intrinsic curvature on the emergence of radial dependent radially symmetric wrinkling in indented pressurized spherical shells
  - I showed the validity of the shallow shell theory in describing the static bistability in spherical caps, studying the morphologies that caps accommodate when connecting the two self-equilibrated states via indentation.

Postdoctoral Research Assistant 01/05/2013 -- 30/09/2015
MOX Laboratory, Department of Mathematics, Politecnico di Milano, Milano (Italy)
Scientific supervisor: Professor Pasquale Ciarletta

- Mathematical modelling of nanoscale therapeutic systems. Mathematical evaluation of the stability conditions in stretched fibers with surface energies.
  - I proposed a novel theoretical and numerical approach for studying the onset and the fully nonlinear development of the elastocapillary beading in soft cylinders subjected to axial stretch.
  - I learnt how to bridge the formal aspects of concepts in nonlinear elasticity for solid mechanics to their potential applications. The collaboration with my supervisor has been fundamental to improving my use of mathematical modelling rigorously.

EDUCATION

Doctor of Philosophy
in **Structural, Geotechnical and Earthquake Engineering** 01/01/2010 -- 28/02/2013
Politecnico di Milano, Milano (Italy)
PhD thesis: *Frequency and time domain analysis on fiber reinforced poroviscoelastic tissue: study on articular cartilage through nanoindentation tests at micrometric characteristic lengths*
Supervisor: Professor Pasquale Vena

Master of Science in **Biomedical Engineering** 09/2007 -- 12/2009
Politecnico di Milano, Milano (Italy)
Mark: 110/110 summa cum laude
Master thesis: *Shape optimization through multi-objective approach for the design of coronary stents*

Bachelor of Science in **Biomedical Engineering** 09/2004 -- 07/2007
Politecnico di Milano, Milano (Italy)

Mark: 110/110 summa cum laude
Bachelor thesis: *Active exoskeletons for lower limbs support*

QUALIFICATIONS

- **Italian qualification (Abilitazione Scientifica Nazionale - II fascia)**
  in the sector 01/A4 - Fisica Mathematica. 11/2020
- **Fellowship of the Higher Education Academy**
  with Merit 05/2022

MEMBERSHIPS

- Gruppo Nazionale di Fisica Matematica (GNFM) of the Istituto Nazionale di Alta Matematica (INdAM) 'Francesco Severi'.
- Committee member of the Nonlinear and Complex Physics Group (NCPG) of the Institute of Physics (IOP)

GRANTS and AWARDS

As *Principal Investigator*

Duration	Funder and Project	Funding
31/03/2023 -- 30/03/2025	**Royal Society International Exchanges Third Round 2022** Curvature-induced morphing of thin objects: application to biological membranes Co-I: Dr. M. Pezzulla (Aarhus)	£5,000
2022	**QJMAM Fund for Applied Mathematics First Round 2022** Participation 11th European Solid Mechanics Conference in Galway (Ireland)	£1,300
2018	**QJMAM Fund for Applied Mathematics First Round 2018** Enhance collaborations with Prof. Benjamin Davidovitch at UMass Amhrest and Prof. Douglas Holmes at Boston University	£900
2015	**'Giovani Ricercatori 2015' Grant from National Group of Mathematical Physics of Istituto Nazionale di Alta Matematica (INdAM)** Mathematical models and numerical simulation of morphogenesis of nonlinear elastic solids	€5,000
01/02/2011 -- 31/12/2012	**Scholarship** from the **'Scuola Interpolitecnica di Dottorato (SIPD)'** Funds to support my PhD research	€10,000

As *Co-Investigator*

Duration	Funder and Project	Funding
2025	**UKMMN Pump Prime** Collaborations across Edinburgh and Manchester Metamaterials ride the waves!	£40,200
2019	**UKMMN Small Grants** Collaborations across Edinburgh, Durham and Bath Elastic-Plastic Localisation in Metamaterial Manufacturing	£1,000
2018	**'Giovani Ricercatori 2015' Grant from National Group of Mathematical Physics of Istituto Nazionale di Alta Matematica (INdAM)** Mechanical modelling for the growth of glioblastoma	€4,000
2016	**'Giovani Ricercatori 2015' Grant from National Group of Mathematical Physics of Istituto Nazionale di Alta Matematica (INdAM)** Fracture and instability phenomena in active soft materials	€4,500
2014	**'Giovani Ricercatori 2015' Grant from National Group of Mathematical Physics of Istituto Nazionale di Alta Matematica (INdAM)** Multiscale models in nanomedicine	€4,000

EXTERNAL RECOGNITION

- Invitation to participate in the 'KITP Program Active Solids: From Metamaterials to Biological Tissue' at the **Kavli Institute for Theoretical Physics**, Santa Barbara (USA) 12/2024
- External reviewer: **Shresht Jain**, MSc by Research at University of Manchester 02/2023
- External reviewer: Research project grant submitted to **Leverhulme Trust** 05/2023
- Invitation to participate in the workshop 'The Mathematics of Mechanobiology and Cell Signaling' at the **MFO (Oberwolfach Research Institute for Mathematics)**, Oberwolfach (Germany) 02/2018
- I have refereed articles for a number of journals, including: *Proceedings of the Royal Society A*, *Physical Review E*, *Physical Review Fluids*, *Mathematics and Mechanics of Solids*, *Journal of Elasticity*, *Journal of the Mechanics and Physics of Solids*, *International Journal of Nonlinear Mechanics*, *The European Physical Journal E*, *Zeitschrift fur angewandte Mathematik und Physik, ZAMP*, *SIAM Journal on Applied Mathematics*, *Soft Matters*

SYMPOSIA ORGANIZATION

- 1-day workshop in ''Slender and Active: Mechanics of Emerging Material Systems' supported by Institute of Physics 12/2025
- 'Mechanics controls the behaviour of biological and active materials'. Symposium (six speakers) at British Applied Mathematics Colloquium (BAMC) 2024, Newcastle upon Tyne, (UK) 04/2024
- 'Morphing in Soft and Biological Solids'. Symposium (six speakers) at British Applied Mathematics Colloquium (BAMC) 2019, Bath, (UK) 04/2019

INVITED PRESENTATIONS

- **Slender non-linear elasticy**
  - 12th European Solid Mechanics Conference, Lyon (France) 07/2025
- **Instabilities in Shells**
  - International Symposium on the Mathematics and Mechanics of Emerging Materials and Structures, Tianjin (China) 06/2025
  - Seminar at School of Mathematics at the University of Manchester, Manchester (UK) 03/2023
  - 11th European Solid Mechanics Conference, Galway (Ireland) 07/2022
  - RAM3 - Recent Advances in Mechanics and Mathematics of Materials, Roma, (Italy) 09/2021
  - SIAM Conference on Mathematical Aspects of Materials Science, Bilbao, (Spain) 05/2021
  - Seminar at School of Mathematics and Statistics of the University of Glasgow, Glasgow (UK) 11/2016
- **Morphing in Soft and Biological Solids**
  - Seminar at School of Mathematics at the University of Strathclyde, Glasgow (UK) 04/2023
  - British Applied Mathematics Colloquium (BAMC) 2023, Bristol, (UK) 04/2023
  - 25th International Congress of Theoretical and Applied Mechanics, Milano (Italy) 08/2021
  - International Workshop on Modelling across the Biology/ Mechanics Interface, Castro Urdiales (Spain) 09/2015
  - International Workshop on Pattern Formation in Soft Materials, Tianjin (China) 06/2015

TEACHING

Lecturing - Design and Delivery

- *Fourier Series and Partial Differential Equations for Engineering Courses, Structural Mechanics* 10/2023 - 12/2023
  (Undergraduate) Engineering, University of Edinburgh, Edinburgh (UK)
- *Continuum Mathematics / Partial Differential Equations (50%), Engineering Mathematics 1 (13%), Group projects for Mathematics and Data Modelling, Final Year Projects* 10/2021 - 05/2023
  (Undergraduate and MSc) Engineering Mathematics, University of Bristol, Bristol (UK)
- *Engineering Physics 1 (50%), Engineering Mathematics 1 (13%), Mathematics and Data Modelling 2 (4%)* 02/2021 - 05/2021
  (Undergraduate) Engineering Mathematics, University of Bristol, Bristol (UK)
- *Mechanics of Solids* (25 hours) 03/2015 - 07/2015
  (Master) Scuola di Architettura Civile, Politecnico di Milano, Milano (Italy)
- *Structural Mechanics* (30 hours) 03/2014 - 07/2014 & 03/2013 - 07/2013
  (Master) Material Engineering and Nanotechnology, Politecnico di Milano, Milano (Italy)

Tutoring

- *Engineering Physics 1* 10/2020 - 05/2021
  (Workshop Undergraduate) Engineering Mathematics, University of Bristol, Bristol (UK)
- *Fluids and Waves* (8 hours) 02/2020 (Hilary Term)
  (Undergraduate) St Anne's College, University of Oxford, Oxford (UK)
- *Differential Equations 2* (16 hours) 02/2020 (Hilary Term)
  (Undergraduate) St Anne's College, University of Oxford, Oxford (UK)
- *Elasticity and Plasticity* (16 hours) 02/2016 - 04/2016 (Hilary Term)
  (Undergraduate) Mathematical Institute, University of Oxford, Oxford (UK)

MENTORING

PhD students

- **William Simpkins**, 'Dynamic-induced morphing in elastic thin structures'
  PhD in Engineering Mathematics at University of Bristol, Bristol (UK) 12/2022 — present
- **Daniel Marris**, second supervisor 'Dynamics of lattice random walks'
  PhD in Engineering Mathematics at University of Bristol, Bristol (UK) 09/2021 — present
  Principal advisor: Prof. Luca Giuggioli

MSc students

- **Owen Bradfield**, 'Cellular growth in a deformable scaffold'
  MSc in Engineering Mathematics, University of Bristol, Bristol (UK) 09/2023
- **William Simpkins**, 'Bistability of arches'
  MSc in Engineering Mathematics, University of Bristol, Bristol (UK) 09/2022
- **Shanshan Li**, 'Sequential buckling in compressed beams on foundation'
  MSc in Engineering Mathematics, University of Bristol, Bristol (UK) 09/2022
- **Ninguan Chen** 'Computing numerical solutions for models of developmental growth'
  MSc in Mathematical Modelling and Scientific Computing, University of Oxford, Oxford (UK) 09/2019
  Principal advisor: Dr. Ricardo Ruiz Baier
- **Stefania Lunardi**, 'Microscale simulation of the absorption efficiency of nanoparticles'
  Master degree in Mathematical Engineering at Politecnico di Milano, Milano (Italy) 07/2015
  Principal advisor: Dr. Carlo de Falco
- **Elena Bulgarello** and **Sara Frizziero**, 'Isogeometric simulation of the characteristic perfusion in the liver tissue'

Master degree in Mathematical Engineering at Politecnico di Milano, Milano (Italy) 04/2015
Principal advisor: Dr. Carlo de Falco

- **Giovanni Gandolfi**, 'Poroelastic characterization of articular cartilage in nanoindentation creep tests'
  Master degree in Biomedical Engineering at Politecnico di Milano, Milano (Italy) 04/2014
  Principal advisor: Prof. Pasquale Vena

Internships

- **Arthur Neveu**, 'Curvature Induced Rigidity'
  University of Oxford, Oxford (UK) 09/2017
  Principal advisor: Prof. Dominic Vella

MATTEO TAFFETANI

PUBLICATIONS

- Personal metrics. Total contributions: 26 works.
  Total citations: 440 & h-index: 13 (Scopus); Total citations: 580 & h-index: 13 & h10-index: 13 (Google Scholar).

SELECTED PUBLICATIONS

This list contains the most relevant publications, in term of my personal contribution and the theoretical results / impact to the academic community that they show.

1. Simpkins W., Hennessy M., **Taffetani M.** (submitted) Snap-through time of arches is controlled by slenderness and imperfections, *Phys. Rev. Letters*
   → We shows how symmetries control the snap-through time of a slender arch induced by the presence of a pitchfork bifurcation, by a combination of multiple scale analysis and matched asymptotic.
2. Pezzulla M., **Taffetani M.** (submitted) Nonlinear morpholeastic energy based theory for curvature controlled shells, *J. Elas.*
   → By rewriting the energy of a non-linear morphoelastic systems by using the fundamental forms to describe the mid-surface and a suitable through-the-thickness function, we derive the effective two-dimensional energy for an elastic curved shell with prescribed non-mechanical stimuli.. I developped the formal analysis.
3. **Taffetani M.**, Hennessy M. (2024) Curvature controls beading in soft coated elastic cylinders: Finite wavemode instability and localized modulations, *J. Mech. Phys. Solids*, 187, 105606.
   → We included the effect of the Helfrich-type bending functional on the axisymmetric beading of soft elastic coated cylinders. I perform the modelling, the rigorous linear stability, weakly non-linear analysis and numerical simulations, showing the characteristic of the emergent finite wavemode instability.
4. **Taffetani M.**, Walker M. (2022) Axisymmetric ridges and circumferential buckling of indented shells of revolution, *Phys. Rev. E*, 105, 065003.
   → We present an analytical model of the circular ridge that forms in shells with general non-negative Gaussian curvature, and I derive the universal scaling relations for its circumferential buckling in the near threshold regime.
5. **Taffetani M.**, Ruiz-Baier R., Waters S. (2021) Stokes flow coupled with non homogenous poroelasticity, *Q. J. Mech. Appl. Math.*, 74(4), 411–439.
   → We investigate how a poroelastic domain deforms because of the interaction with a Stokes domain. I provide fundamental insights into the mechanical behaviour of these multiregion systems by developing: (i) a formal asymptotic analysis in the limit of a thin channel; (ii) the full characterization of the mechanics in the interface (inner) domains; (iii) the derivation of the effective elastic transmission conditions across the outer domains.
6. P. Ciarletta, H. Dai, **Taffetani M.** (2020) Elastic fingering of a bonded soft disc in traction: interplay of geometric and physical nonlinearities. *SIAM J. Appl. Math.* 80(2), 690–705.
   → We investigate the pattern dictated by the interplay between physical and geometrical non linearities and how buckling is favoured by the curvature of the meniscus in disk under traction. I contributed to the theory based on the Stroh formulation and I performed the simulations.
7. **Taffetani M.**, Jiang X., Holmes D., Vella D. (2018) Static bi-stability of spherical caps, *Proc. Royal Soc. A*, 474: 20170910.
   → I discuss the existence of bistability in spherical caps, also showing the plethora of buckled morphologies that emerge when connecting quasi-statically the two equilibria. By a combination of linear stability analysis and numerical simulations, I demonstrate the validity and the limitations of using shallow shell theory in studying the morphing of constrained curved objects.
8. **Taffetani M.**, Vella D. (2017) Regimes of wrinkling in pressurized elastic shells, *Phil. Trans. R. Soc. A*, 375: 20160330.
   → I use a combination of asymptotic analysis and numerical simulations to derive the universal role that the intrinsic curvature has on the emergence of radial dependent radially symmetric wrinkling in indented

pressurized spherical shells. The analytical approach is based on linear stability analysis and far from threshold analysis, this latter employing tension field theory.

9. Ciarletta P., Destrade M., Gower A.L., **Taffetani M.** (2016) Morphology of residually stressed tubular tissues: Beyond the elastic multiplicative decomposition, *J. Mech. Phys. Solids*, 90: 242-253.
→ We consider how the build-up of residual stress can cause a solid to buckle. I contributed to the definition of the model that and allows the prescription of any residual stress field and I performed the numerical simulations.
10. **Taffetani M.**, Ciarletta P. (2015) Beading instability in soft cylindrical gels with capillary energy: weakly non-linear analysis and numerical simulations, *J. Mech. Phys. Solids*, 81: 91-120.
→ We propose a novel theoretical and numerical approach for studying the onset and the fully non-linear development of the beading induced by elastocapillarity in soft cylinders subjected to axial stretch. I derive the equilibrium equations by minimizing the energy functional associated to the problem when rewritten by making use of a suitable stream function. A rigorous balance is performed order by order around the critical condition to look at the behaviour in the weakly non-linear regime.

OTHER PUBLICATIONS

1. Moore A.C., Hennessy M.G., Nogueira L.P., Franks S.J, **Taffetani M.**, Seong H., Kang Y.K, Tan W.S., Miklosic G., El Laham R., Zhou K., Zharova L., King J.R., Wagner B., Haugen H.J., Münch A., Stevens M.M. (2023) Fiber Reinforced Hydrated Networks Recapitulate the Poroelastic Mechanics of Articular Cartilage, *Acta Biomaterialia*, 167, 69-82.
2. Mason J.H., Luo L., Reinwald Y., **Taffetani M.**, Hallas-Potts A., Herrington C.S., Srsen V., Lin, C.-J., Barroso I.A., Zhang Z., Zhang Z., Ghag A.K., Yang Y., Waters S., El Haj, A.J., Bagnaninchi P.O. (2023) Debiased ambient vibrations optical coherence elastography to profile cell, organoid and tissue mechanical properties, *Communications Biology*, 6(1), 543.
3. Liu M., Domino L., Dupont de Dinechin I. , **Taffetani M.**, Vella D. (2023) Snap-induced morphing: From a single bistable shell to the origin of shape bifurcation in interacting shells, *J. Mech. Phys. Solids*, 170, 105116.
4. Ruiz-Baier R., **Taffetani M.**, Westermeyer H.D., Yotov I. (2022) The Biot-Stokes coupling using total pressure: formulation, analysis and application to interfacial flow in the eye, *Comput. Methods Appl. Mech. Eng.*, 389, 114384.
5. Luo L., Mason J., **Taffetani M.**, Waters S., Reinwald Y., Yang Y., Bagnaninchi P., El Haj A. (2022) e\MECHASCAN: a novel online monitoring tool for assessing mechanical properties of tissue engineered grafts, *Tissue Engineering Part A*, 28, S71-S72.
6. **Taffetani M.**, Box F., Neveu A., Vella D. (2019) Limitations of curvature-induced rigidity: How a curved strip buckles under gravity, *Europhys. Lett.* 127(1): 14001.
7. Gastaldi D., **Taffetani M.**, Raiteri R., Vena P. (2018) Effect of the anisotropic permeability in the frequency dependent properties of the superficial layer of articular cartilage, *Comput. Methods Biomech. Biomed. Engin.* 21 (11): 635-644.
8. **Taffetani M.**, Ciarletta P. (2015) Elastocapillarity can control the formation and the morphology of beads-on-string structures in solid fibers, *Phys. Rev. E*, 91(3):032413.
9. **Taffetani M.**, Raiteri R., Gottardi R., Gastaldi D., Vena P. (2015) A quantitative interpretation of the response of articular cartilage to atomic force microscopy-based dynamic nanoindentation tests, *J. Biomech. Eng.*, 137(7): 071005.
10. de Girolamo L., Niada S., Arrigoni E., Di Giancamillo A., Domeneghini C., Dadsetan M., Yaszemski M., Gastaldi D., Vena P., **Taffetani M.**, Zerbi A., Sansone V., Peretti G.M., Brini A.T. (2015) Repair of osteochondral defect in a large animal model by oligo(polyethyleneglycol)fumarate hydrogel loaded with adipose-derived mesenchymal stem cells, *Regen. Med.* 10(2): 135-151.
11. **Taffetani M.**, Griebel M., Gastaldi D., Klisch S. M., Vena P. (2014) Poroviscoelastic finite element model including continuous fiber distribution for the simulation of nanoindentation tests on articular cartilage, *J. Mech. Behav. Biomed. Mater.*, 32: 17-30.

12. **Taffetani M.**, de Falco C., Penta R., Ambrosi D., Ciarletta P. (2014) Biomechanical modelling in nanomedicine: multiscale modeling and future challenges, *Arch. Appl. Mech.*, 84(9-11): 1627-1645.
13. **Taffetani M.**, Gottardi R., Gastaldi D., Raiteri R., Vena P. (2014) Poroelastic response of articular cartilage by nanoindentation creep tests with different characteristic sizes, *Med. Eng. Phys.*, 36(7): 850-858.
14. **Taffetani M.**, Bertarelli E., Gottardi R., Raiteri R., Vena P. (2012) Modelling of the frequency response to dynamic nanoindentation of soft hydrated anisotropic materials: application to articular cartilage, *Comput. Model. Eng. Sci.*, 87(5): 433-460.
15. (book chapter) Ruiz Baier R., Boon W.M., Hornkjøl M., Kuchta M., Mardal K.-A., **Taffetani M.**, Westermeyer H.D., Yotov I. (2022) Mixed formulations for poroelasticity/free-flow using total pressure. In Peszynska M., Pop S., Wohlmuth B., Yosibash Z. (eds) *Multiscale Coupled Models for Complex Media* , Mathematisches Forschungsinstitut Oberwolfach, Oberwolfach.
16. (book chapter) Ambrosi D., Ciarletta P., Danesi E., Falco C., **Taffetani M.**, Zunino P. (2017) A Multiscale Modeling Approach to Transport of Nano-Constructs in Biological Tissues. In: Gerisch A., Penta R., Lang J. (eds) *Multiscale Models in Mechano and Tumor Biology. Lecture Notes in Computational Science and Engineering*, vol 122. Springer, Cham.

MANUSCRIPTS IN PREPARATION

1. Ruiz-Baier R., **Taffetani M.** (in preparation) Mechanochemical model for digit selection in developmental limb growth.
2. Binysh J., Soulsov A., **Taffetani M.** (in preparation) Novel mechanics from odd elastic plates.