Luca Deseri, Ph.D. - Biosketch

Luca is a tenured ***Full Professor of Solid Mechanics and Structural Engineering*** **in the Dep.t of Mechanical, Civil & Environmental Engineering at the *University of Trento*, in Italy**, where he is the ***Head of the Ph.D. School*** in Mechanical, Civil & Environmental Engineering, since 2019. He has also been re-appointed as Adjunct Research Professor in MEMS-Mechanical Engineering and Materials Science Dept. in the Swanson School of Engineering at the University of Pittsburgh in 2018. Luca is also Adjunct Professor in both the Dept. of Mechanical Engineering and in the one of Civil and Environmental Engineering at Carnegie Mellon University, Pittsburgh PA, USA. In September 2017 Luca stepped down from his position as permanent Full Professor and Division lead of Mechanical and Aerospace Engineering at Brunel University London, with the permanent role of Full Professor of Solid and Structural Mechanics and Aerospace Engineering.

Within the last year and a half, Luca started a scientific collaboration at the University of Chicago with the Dept of Surgery and with the Dept. of Physics, though Sr. L. Pocivavsek and Prof. K. Yee Lee, Provost for research at UC.

Furthermore, Luca also started a collaboration at the University of Colorado-Denver, with the Medicine-Pulmonary Sciences Dept., together with Dr. D. E. Winnica.

Luca earned his MS in Structural Engineering from the University of Bologna (Italy) with Magna cum Lauda. Subsequently, he got his Ph.D. in Theoretical Mechanics from the University of Pisa, while spending a year at Carnegie Mellon at the Dept. of *Mathematical Sciences* and at the *Center for Nonlinear Analysis*, where he subsequently did his *post-doc in Theoretical and Applied Mechanics*. He was then appointed assistant and then associate professor at the University of Ferrara. After eight years, he moved to the University of Molise (Italy) as permanent Full Professor of Solid Mechanics and deputy dean of Engineering. Shortly after he left to become Dept. Head of Mechanical & Structural Engineering at the University of Trento, in Italy. The School of Engineering in Trento was ranked first nationwide 12 times in the last 16 years.

In 2012 Luca completed his term (4 years) at the Italian directorate of Solid Mechanics and Structural Engineering and three terms (9 years) as the leader of the local IUTAM society of Mechanics of Materials. He is a member of the ISDIMM-Intercations between Mechanics and Mathematics, panel member of the SNP, Society for Natural Philosophy. Furthermore, Luca is the only non US scientist nominated for the election of the new Board of Director of the SES-Society for Engineering Sciences.

He is associate editor of Frontiers, sect. of Mechanics of Materials (Nature publisher, Lausanne), and he is on the editorial board of the Int. J. of Medical Nano Research. He is reviewer for several major journals, such as Int. J. Solids & Structures, J. Mech. Phys. Solids, Proc. of the Royal Soc., Int. J. Non-Linear Mech., J. Elasticity, Nature Comm., Biomech. Modeling Mechanobiol., J. Nanomech. Micromech.-ASCE, J. Eur. Ceramic Soc., Math. Models Methods Appl. Sciences, Math. And Mech. of Solids, etc.

Luca has held several visiting professorships at Cornell, the University of Kentucky and Carnegie Mellon. He has been invited to visit multiple universities, including Berkeley, Caltech, Columbia NYC, Wisconsin-Madison, Nebraska-Lincoln, Ecole Polytechnique-Paris, Durham UK, Jiao Tong, Univ. Tech. Sidney, Univ. Auckland, among many others and to many specialized workshops held in major international conferences, such as WCCM, ECCM, ESMC, ASME, SES, SIAM, etc.

Luca's research ranges from topics of interest in Mechanical Engineering and also to ones that push the boundaries of Theoretical Mechanics to foundational aspects of such Discipline.

Recent interests had been in the area of multiscale modeling and multiphysics of the dynamics of structured media, including applications to granular materials, rhelogy of concrete, mechanobiology, cell mechanics and multiphysics, hierarchical structures. In this respect, most of the recent papers apply principles of Solid Mechanics to interdisciplinary and emerging fields in Mathematical Biology, Biomechanics and Engineering Sciences in general. An example of such research is the mechanobiology of receptors involved in second messenger activity across the cell membrane. The principles governing such dynamics lead to a paradigm with the potential of explaining the entry mechanism of COVID 19 inside human cells. Indeed, a very recent contributionfrom Dr. Deseri, together with his students and other coauthors, deal with the dynamic response of the cell membrane under G-proteins Coupled Receptors. For the very frst time it has been proved that mechanobiology predicts raft formations triggered by ligand-receptor activity across the cell membrane. This has been published in august 2020 on the J. MECHANICS & PHYSICS of SOLIDS and, especially because of its potential for understanding how SARS CoV-2 hijacks cells, it generated the interest of the national and International press. For instance, this can be found in https://www.eurekalert.org/pub_releases/2020-06/uop-art061520.php?fbclid=IwAR2Q9bycOVCTmUgpdOlmsSc-3ePhKbAFXGdAWUr5Hhb4BQv4jy-vFand2EI. In this work, it is highlighted how clustering of ligand-binding receptors of different types on thickened isles of the cell membrane, namely lipid rafts, is an experimentally observed phenomenon. Although its influence on cell's response is deeply investigated, the role of the coupling between mechanical processes and multiphysics involving the active receptors and the surrounding lipid membrane during ligand-binding has not yet been understood. Specifically, the fo- cus of this work is on G-protein-coupled receptors (GPCRs), the widest group of transmembrane proteins in animals, which regulate specific cell processes through chemical sig- nalling pathways involving a synergistic balance between the cyclic Adenosine Monophos- phate (cAMP) produced by active GPCRs in the intracellular environment and its efflux, mediated by the Multidrug Resistance Proteins (MRPs) transporters. This paper develops a multiphysics approach based on the interplay among energetics, multiscale geometrical changes and mass balance of species, i.e. active GPCRs and MRPs, including diffusion and kinetics of binding and unbinding. Because the obtained energy depends upon both the kinematics and the changes of species densities, balance of mass and of linear momentum are coupled and govern the space-time evolution of the cell membrane. The mechanobi- ology involving remodelling and change of lipid ordering of the cell membrane allows to predict dynamics of transporters and active receptors –in full agreement with experimentally observed cAMP levels–and how the latter trigger rafts formation and cluster on such sites. Within the current scientific debate on Severe Acute Respiratory Syndrome CoronaVirus 2 (SARS-CoV-2) and on the basis of the ascertained fact that lipid rafts often serve as an entry port for viruses, it is felt that approaches accounting for strong cou- pling among mechanobiological aspects could even turn helpful in better understanding membrane-mediated phenomena such as COVID-19 virus-cell interaction.

Other recent papers deal with human cells under mechanical and/or acoustic stimuli, where the latter are suitable to target and detect cancerous cells.

The very latest papers are published on the J. MECHANICS & PHYSICS of SOLIDS, INT. J. NONLIN. MECH. In the former, the standard (though unrealistic) hypothesis of rigid struts in tensegrity structures when used to idealize the cell cytoskeleton mechanical response has been removed for the first time. Both compressibility and bendability of the struts have then been removed and predictions on the mechanical behavior of the 30-elements modified tensegrity have been obtaines. This permits to simultaneously account for geometrical nonlinearity (i.e. large deformations) and hyper-elasticity of both tendons and bars, so abandoning the classical linear stress-strain constitutive assumptions. By relaxing the hypothesis of rigidity of the struts, we demonstrate that some quantitative confirmations and many related extreme and somehow counter-intuitive mechanical behaviors exploited by cells for storing/releasing energy, resist to applied loads and deform by modulating their overall elasticity and shape through pre-stress changes and instability-guided configurational switching, can be all theoretically found. The new soft-strut tensegrity model could pave the way for a wider use of engineering models in cell mechanobiology and in designing bio-inspired materials and soft robots. The latter article provides a mathematically detailed analysis of the model just mentioned, thereby finally showing that constitutive properties, instability and bar deformability cooperate to determine unusual form-finding results, providing peculiar overall mechanical responses as external forces are applied.

Another very recent contribution is going to appear on the PROC. ROYAL SOCIETY-A, and it has to do with the effective behavior of nonlinear elastic 1D multi-modular submacroscopic structures undergoing tension or compression. The model is built up through the repetition of n units, each one comprising two rigid rods having equal lengths, linked by means of pointwise constraints capable to elastically limit motions in terms of relative translations (sliders) and rotations (hinges). The mechanical response of the structure is analyzed by varying the number n of the elemental moduli, as well as in the limiting case of infinite number of infinitesimal constituents. This is done in the light of the theory of (first order) Structured Deformations (SDs), that interprets the deformation of any continuum body as the projection, at the macroscopic scale, of geometrical changes occurring at the level of its sub-macroscopic elements. In this way, a wide family of nonlinear elastic behaviors is generated by tuning internal microstructural parameters, the tensile buckling and the classical Euler's Elastica under compressive loads resulting as special cases in the so called continuum limit –say when $n \to \infty$. Possible imperfections at the discrete (micro-scale) level are incorporated in the analysis, is derived with respect to both tensile and compressive applied loads. Finally, the outcomes of the resulting continua are displayed of the in terms of first Piola-Kirchhoff stress versus macroscopic stretch, it is for the first time

demonstrated that such SDs-based 1D models can be helpfully used to generalize some standard hyperelastic behaviors by additionally taking into account instability phenomena and concealed defects.
Another model of cells suitable for investigating their dynamics response to ultrasounds is proposed in a series of two papers, appeared on the J. ENGINEERING MECHANICS of and on the J. ROYAL SOC.-INTERFACE. With the aim of investigating the effect of the prestress–for instance induced in protein filaments during cell adhesion–on the overall cell stiffness and, in turn, on its in-frequency response, a simple multiscale scheme is here proposed to bottom-up enrich the spring-pot-based viscoelastic single-cell models, by incorporating finite elasticity and in this way determining, through sensitivity analyses, the role played by the stretched state of the cytoskeletal elements on the cell vibration. The insights provided by a Theoretical Mechanics approach has been crucial for such an high impact problem like, at least conceptually, the targeting and the consequent selective attack of tumor cells.
In a similar fashion, it has been only applying the principle of (nonlinear) structural engineering that successful recent studies on the response of lipid membranes have been published on JMBBM- J. MECH. BEHAVIOR OF BIOMEDICAL MATERIALS (the editor is actually Dept. Head of Civil Eng. At MIT), on BMMB-BIOMECH. MODELING IN MECHANOBIOLOGY and on the Bioph. J. In both cases, nonlinear plates with "active" elastic moduli allow for explaining both the experiences structural and material instabilities. This is both in the nonlinearly elastic and viscoelastic regimes. Structural analysis in finite strains and accounting for power law viscoelasticity (actually motivated by experiments) allowed the full carachterization of the lipid membrane response.
The theory of Structured Deformations, obtained by the candidate ten-some years ago together with D.R. Owen, and applied by them to no-tension and then granular materials, comes from the way of thinking of Structural Engineering scientists. This provides a mathematically consistent and general multiscale framework allowing for investigating phenomena involving irreversibilities like fractures, faults, structural damage, plasticity, etc. The work is summarized in papers published on the INT. J. ENGINEERING SCIENCES, J. ELASTICITY, MECCANICA, INT. J. PLASTICITY, etc. Structural Engineering also guides the understanding of the viscoelastic response of hierarchical structures like bone: this has been published on INT. J. NUM. METH. BIOMEDICAL ENG. New and better performing architectures of prototype electroactive actuators have also been recently treated in the light of nonlinear structural engineering.
More traditional issues, such as which Representaitve Volume Element size should be taken for a random composite in the presence of residual stresses, have been treated in a 2013 paper on MECCANICA. This may have an impact o tne actual effective model that one should use for in Structural Engineering aplications of such a kind of composite.
Foundational and new aspects of viscoelasticity, viscoplasticity, nonlinear elasticity and anomalous viscoelasticity are also parts of his current scientific interests. Some of the arising issues may have an influence in Structural Engineering models. Examples are "New Insights on Free Energies and Saint-Venant's Principle in Viscoelasticity" recently appeared on the INT. J. OF SOLIDS AND STRUCTURES and "Free Energy and States of Fractional- Order Hereditariness" appeared in the same journal.

Luca's teaching and consulting activities had been in the broad field of Solid and Structural Mechanics. At the undergraduate level he taught primarily Solid Mechanics, Rigid Body Dynamics, Engineering Mechanics, etc., while at the graduale level he taught Nonlinear Solid Mechanics and related courses.

He primarily consulted for TRW Automotive, now ZF, for several years. During his time in Molise, Luca had an experience of tutor and consultant at ESA-ESTEC for the structural engineering aspects of a concept design for a new launcher. He also taught cross-Engineering foundational disciplines like Applied Linear Algebra, Differential Equations and Applications and, extensively, basic-to graduate-to Ph.D. Solid Mechanics and Structural Enginering.

LUCA DESERI, PH.D.,
CURRICULUM VITAE

INDEX OF THE CURRICULUM VITAE

-Nationality and citizenship: Italian

-Major employments and achieved ranks

--Current appointments and affiliations

September 2017-present Tenured full professor of Solid and Structural Mechanics and Head of the Ph.D. School, Dept. of Civil, Environmental and Mechanical Engineering, University of Trento, Italy.
January 2019-present Adjunct Research Professor in the Dept. of Mechanical Engineering and Material Science-MEMS, University of Pittsburgh USA.
July 2015-present Adjunct Professor of Solid and Structural Mechanics in the Dept. of Mechanical Engineering, Carnegie Mellon University, Pittsburgh PA, USA.
November 2013-present Full affiliate member at the Department of Nanomedicine, Houston Methodist Research Institute, 6565 Fannin St., MS B- 490 Houston, TX 77030 TX-USA.
January 2016-January 2019 Adjunct Research professor in the Dept. of Mechanical Engineering and Material Science-MEMS, University of Pittsburgh USA.
February 2017-August 2017 Division Lead of Mechanical and Aerospace Engineering, and tenured Full Professor Solid and Structural Mechanics, Department of Mechanical, Aerospace and Civil Engineering-MACE, Brunel University London, UK.
The purpose of the role is (1) to lead, manage and provide strategic direction to the Divisions of Mechanical and Aerospace Engineering and to provide visionary leadership in research and education activities of the Division; (2) to increase and improve research income and impact in the fields of Mechanical and Aerospace Engineering (3) to contribute to enhancing the external profile of Mechanical and Aerospace Engineering at Brunel University London.
The main duties are the following:
Leadership
- To provide strong leadership for the Mechanical and Aerospace Engineering Divisions
- To enhance the Divisions national and international reputation
- To provide a supportive environment and foster the development of staff and students
- To ensure the Divisions are both well-managed and well-run
- To sit on the Department's Academic and Management Committees.
- To contribute to the management of the Department

Research
- To publish high quality papers with impact in internationally recognized journals.
- To obtain research grants and other forms of external funding to build and support a research group
- To maintain a national and international research profile and to collaborate with other HEIs, industry and the not for profit sector.
- To establish new inter-disciplinary and inter-sectoral research opportunities with other Institute members, colleagues from other Universities and end-users from Industry/Business, as appropriate.

Teaching
- To promote further recruitment of high quality UG & PG students within Aerospace Engineering Division.
- To take an active role in using and developing new teaching methods/e-learning approaches.
- To direct new teaching initiatives and courses as appropriate

PhD Students
- To successfully supervise and train PhD students to timely completion of their studies
- To provide support, guidance and mentorship to new supervisors of PhD students.
- To actively assist in the recruitment of high quality PhD students.

Collegiality
- To support the Head of MACE in leadership and management of the Department and the Vice-Dean Education & Research.
- To attend meetings and events as required.
- To represent the Head of MACE at external events, as and when requested
- To mentor and support junior academics and post-doctoral fellows in their career development.
- To maintain a high external profile at an individual and divisional level.

July 2016-January 2017 Division Lead of Aerospace Engineering, and Full Professor Solid and Structural Mechanics, Department of Mechanical, Aerospace and Civil Engineering-MACE, Brunel University London, UK.
November 2012-June 2016 Tenured full professor of Solid and Structural Mechanics, Dept. of Civil, Environmental and Mechanical Engineering, University of Trento, Italy.

--Previous appointments and positions

January-July 2014 Visiting professor of Solid and Structural Mechanics in the CIT-Dept.s of Civil and Environmental Engineering and Mechanical Engineering, Carnegie Mellon University USA.

Sept. 2012-Aug. 2013 Visiting professorship at the Center for Nonlinear Analysis- Carnegie-Mellon University USA**.**

April 2009-November 2012 Head of the Dept. of Mechanical and Structural Engineering, University of Trento.

Supervisor of the following laboratories:

Materials, Structural Testing and Dynamics, Geotehcnica and Earthquake Engineering

Mechanics and Automatics

Computational Solid and Structural Mechanics

Turbomachinery

Geotechnics

Laboratory for physical modeling of structures and photoelasticity

Calibration of Force Devices (Laboratory of the "University Centre of Metrology" - C.U.M.)

Wind Turbine Test Field (CEST).

April 2008-Nov.2012 Tenured Full professor of Solid Mechanics and Strength of materials, Dept. of Mechanical and Structural Engineering, University of Trento.

August 28-September 5 2009 Visiting at the Department of Mathematical Sciences - Carnegie-Mellon University, Pittsburgh PA 15213.

April 15-May 14 2009 Visiting at: Dept. of Mechanical Engineering, McGill University, Montreal, Canada.

August-Sept. 2008 Rheology Research Center and Dept of Engineering Physics, University of Wisconsin-Madison, USA.

August-Sept. 2007 Dept of Engineering Physics, University of Wisconsin- Madison, USA.

July-August 2006 Co-op endowed Visiting Professor, College of Engineering and Department of Theoretical and Applied Mechanics (TAM), Cornell University, New York 14853.

January-June 2005 Visiting Professor at the Center for Nonlinear Analysis and Department of Mathematical Sciences - Carnegie-Mellon University, Pittsburgh PA 15213.

January-June 2004 Visiting Professor at the Department of Theoretical and Applied Mechanics (TAM), Cornell University, 212 Kimball Hall, Ithaca, New York 14853.

January-June 2002 Visiting professor at the University of Kentucky, Department of Mathematics, Group of Continuum Mechanics (coordinated by Dr. Chi-Sing Man), Lexington KY.

January 2005-March 2008 Associate Dean of Engineering and Tenured Full professor of Solid Mechanics and Structural Engineering, S.A.V.A. Dept. University of Molise, Campobasso.

November 2001–December 2004 Tenured Associate Professor of Solid Mechanics, Strength of Materials and Structural Analysis, Dept. of Engineering, University of Ferrara.

1999 Rank of Associate Professor- Tenure track.

1996-1999 Tenure track Assistant professor of Solid and Structural Mechanics, Dept. of Engineering, University of Ferrara, Italy

-Education

- 1998 *Postdoctoral Associate* at the Center for Nonlinear Analysis-Carnegie-Mellon University, Pittsburgh-PA-USA.

- 1995 Ph.D. in Solid Mechanics, Strength of Materials, Structural Analysis and Applied Mathematics. Consortium among the Universities of Pisa, Florence, Bari, Genova, Udine-Italy.

- 1992 *Visiting graduate student at the Center for Nonlinear Analysis and Department of Mathematical Sciences-Carnegie-Mellon University, Pittsburgh-PA-USA.*

-Memberships

- September 2013-present Panel member of the SNP, Society for Natural Philosophy;
- September 2014-present member of the SES, Society for Engineering Sciences;
- Dec.2013-present Full Affiliate member at *HMRI-Nanomedicine Research Institute, Houston Methodist Hospital*
- Sept. 2009-Dec. 2013: Member of the board of five coordinators of the Italian academic area of "Solid and Structural Mechanics", disciplinary sector ICAR/08-Structural and Geotechnical Engineering;
- March 2008-Dec. 2013 Group of Mechanics of Materials, Italian Association of Theoretical and Applied Mechanics (IUTAM-AIMETA), national coordinator since March 2008;
- Dec, 2011-present ASME American Society of Mechanical Engineering;
- June 2000-present Italian Group of Fracture, IGF member;
- June 1996-present National Group of Applied Mathematics-Section of Engineering Mechanics, GNFM-ITALY, member.
- January 2010-present ISIMM, International Society for the Interaction between Mechanics and Mathematics, member.
- February 2005-December 2006 member of the panel of reviewer of the project X-Fast, Advanced Space Transportation, European Space Agency (ESA), ESTEC, AB-Technologies. Project Manager: Dr. Eng. Biagio Ancarola.

-Scientific interests

My research interests are in the broad area of dynamical and evolutionary phenomena involving Multiscale Solid and Structural Mechanics and related areas of Engineering and Applied Sciences. Often times this goes beyond the boundaries of the traditional Solid Mechanics to branch out to new and challenging fields such as, but not limited to, mechano-biology and, very recently, to deformable polymeric dielectric actuators. In particular, studies towards the achievement of a new mathematical framework suitable to obtain multiscale constitutive equations for modelling the behaviour of classical and novel materials are active part of my current and future research. Obviously, a close and interdisciplinary collaboration with experimentalists will become essential to validate the obtained models.

-Recent talks and scientific activity

Spring 2021 Invited seminars at the Graduate Program of the Swanson School of Engineering, University of Pittsburgh;

Invited seminar at the Center for Nonlinear Analysis-Carnegie Mellon University

January-June 2020 Invited seminars at the Graduate Program of the Swanson School of Engineering, University of Pittsburgh;

Invited seminar at the Center for Nonlinear Analysis-Carnegie Mellon University

September 2019

-Invited seminar at the Graduate Program in Applied Mathematics and Engineering at the National University of Galway, Ireland

-Invited seminar at CEE-Carnegie Mellon University

April 2019 Invited seminar at the Graduate Program of the Swanson School of Engineering, University of Pittsburgh

January 2019 Invited joint seminar at the Department of Mechanical Engineering & Department of Civil & Environm. Eng., Carnegie Mellon University: Invited talk at the CAN seminar series, Carnegie Mellon University

November 2018 Invited talk at the Department of Structural Engineering-University of Naples "Federico II"
July 2018 WCCM 2018-NYC, Invited talk at the special session "Mechanics of biological structures"
April 2018 CNA-Center for Nonlinear Analysis-Carnegie Mellon University-seminar
May 2017 Cambridge UK, Dept. of Engineering-seminar
April 2017 Organizer of the minisymposium "Mathematical models in Biomechanics across the scales: from cells to biological tissues" within "5th International Conference on Computational and Mathematical Biomedical Engineering", to be held at the University of Pittsburgh, Pennsylvania, 10 - 12 April 2017
March 2016 University of Bristol UK, Engineering and Applied Math. Seminar series
September 2016 ESB Conference, Palermo Sept. 2-8 2016, invited talk.
July 2016 International Center of Mechanics-CISM-course "*The Role of Mechanics in the Study of Lipid Bilayers*", together with D.J.Steigmann (Berkeley), M. Deserno (Carnegie Mellon), M. Arroyo (Polytechnic University of Cataluna, ESP), J. Guven, (Univ. Mexico), R. Sauer (RWTH Aachen University).
May 2016 Invited talk at the Civil Engineering and mechanics seminar series, Carnegie Mellon University
November 2015 ASME-IMECE World Conf. workshop 52622, Houston TX
September 2015 Brunel University of London, Mechanical, Aerospace and Civil Eng.-seminars Aalto University-Espoo, Finland, Mechanics seminars
July 2015 Invited speaker at:
-ESMC-EUROMECH 2015-workshopon Cell Mechanics, talk on "Frequency-Based Mechanical Targeting of Healthy and Cancer Single-Cell Systems", Madrid;
-CERMODEL- conf. Talk on "Mechanics of hierarchical ceramics", Europ. J of Ceramics conf. series;
June 2015 Invited speaker at the Special Session #36 at the AMS-EMS-SPM, Porto
February 2015 Invited keynote at EUROMECH Colloquium 560: "Mechanics of Biological Membranes", Ascona (Switzerland), ETH Zurich facility;
October 2014
SES-ASME annual meeting (Purdue IN):
- invited talk at the mini-symposium on Mechanobiology of cells and tissues (ref. A Agrawal UHouston, M Taher A Saif IL,T Lele U FL);
- invited talk at the mini symposium Soft Materials and Structures (ref. P. Reis, K Bertoldi, Harvard);
August 2014 Invited speaker at the UTA_CMU/MAT/0005/2009 workshop, Instituto Superior Técnico-Lisbon
July 2014 WCCM-ECCM-IACM-Eccomas 2014 Invited talk at the MMCM5-Multiscale and Multiphysics Modelling for Complex Materials
June 2014 Invited lecture at the ICFDA-International Conference on Fractional Differentiation and its Applications, Catania-Italy
January-April 2014 Invited talks at
- University of Pittsburgh, Dept. of Civil Engineering;
- Carnegie Mellon, Dept. of Mechanical Engineering;
- Carnegie Mellon, Civil and Environmental Engineering;
- Carnegie Mellon, Center for Nonlinear Analysis;
-Department of Nanomedicine, Houston Methodist, Health Science Center, Houston TX-USA;
Sept. 2012-Nov. 2013: Invited talks at:
-Durham University UK, School of Engineering and Computing Sciences;
-University of Michigan Joint Institute Jong Tong Shanghai (ref. O. A. Bauchau) ;

-SES meeting at Brown University, workshops on (i) nano-biomechanics, (ii) in honor of the SES medalist D. J. Steigmann;
-Columbia University, Dept. Mechanical Engineering (ref. J. Kysar);
-APS Workshop 'Soft-Matter, Biology, & Bioinspiration' Baltimore, March 2013 (ref: C. Majidi)
-University of Lincoln Nebraska, Mechanical Engineering, Group of Solid Mechanics (ref. E. Baesu)
-Department of Nanomedicine at the University of Texas Health Science Center, Houston TX-USA;
- Department of Mathematical Sciences, Indiana University and Purdue University (ref. G. Guidoboni);
-Civil Engineering and Mechanics, Columbia University NYC (Ref. R. Betti);
-Caltech, California Institute of Technology, Graduate Aerospace Laboratories (ref. C. Daraio;
-University of Pittsburgh, Mechanical Engineering and Applied Mathematics (ref. A. Vainchtein);
-CNA-Center for Nonlinear Analysis-Carnegie-Mellon University (ref. D. R. Owen and I. Fonseca).
May 2012 Invited talks at University of Naples and University of Bologna, Italy
July 2012 8th European Solid Mechanics Conference, Graz: TU Graz
Aug 2011 Invited seminar at the Department of Engineering Sciences and Auckland Bioengineering Institute, University of Auckland
Nov 2010 Invited talk at the CNA seminar series, Center for Nonlinear Analysis- Carnegie-Mellon University USA
July 2010 Eccm 2010-Invited talk Workshop on Modeling of Complex Materials
Apr 2010 Invited talk at the Canadian Research Math. workshop on biovesicles, Montreal-Quebec-Canada
Febr 2010 Ecole Polytechnique Paris-LMS, France (talk)
2009
September AIMETA 09-Ancona (talk)
August visit at the CNA-CMU Pittsburgh PA
July ISDMM09-Trento (talk)
January GMA09-Polytechnic School-Milan, Italy (talk)
2008
September
Opening colloquium at the RRC (Rehology Research Center) University of Wisconsin-Madison-WI-USA (reference: Prof. Dr. Eng. A. J. Giacomin, Chair, RRC).
July Invited speaker at the symposium on "Recent Developments in the theory and applications of Structured Deformations, Canada (reference: Prof. Dr. D. R. Owen);
May Invited speaker at the Workshop on "Modelling biomembranes and biological structures", USA (reference: Prof. Dr. Eng. T. J. Healey.
February Visiting professor at the Department of Mechanical, Aerospace and Structural Engineering, Washington University in St. Louis, MO, USA;
2007
October Invited speaker at the 44th Society of Engineering Sciences Conference- Bernard Coleman symposium, Texas A. & M., College Station TX, USA.
July-September Visiting professor at the:
-Department of Mathematical Sciences and Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh PA 15213-3890 USA;
-Department of Engineering Physics, University of Wisconsin, Madison,
USA.
January-February Invited lectures from the following institutions:
Dept. of Mechanical Engineering, University of Wisconsin, Madison, WI, USA;
Dept. of Mathematical Sciences, Carnegie-Mellon University, Pittsburgh, PA, USA;

Dept. of Mechanical Engineering, Washington University, St. Louis, MI, USA.
2006
July-August Co-op endowed Visiting Professor, College of Engineering and Department of Theoretical and Applied Mechanics (TAM), Cornell University, 212 Kimball Hall, Ithaca, New York 14853, USA.
March-April Invited lectures from the following institutions:
Department of Mathematical Sciences and Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh PA Aerospace and Mechanics Dept., University of Minnesota, Minneapolis MN, USA (Host: Prof. Dr. Eng. R. D. James),
Dept. of Mechanical and Aerospace Engineering, Washington University, Saint Louis MO, USA, Theoretical and Applied Mechanics Dept., Cornell University, Ithaca NY, USA.
2005
January-June Invited Visting University Professor, Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh-PA, USA.
2004
June-September Visiting professor, Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh-PA, USA;
January-June Invited seminars in the following institutions:
-Aerospace Engineering and Mechanics, University of Minnesota, MNUSA;
-Theoretical and Applied Mechanics Department (TAM), Cornell University, Ithaca, NY, USA;
-Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh- PA, USA;
-University of Kentucky, Department of Mathematics (Group of Solid Mechanics), Lexington KY-USA.
2003
December Invited speaker at the Cofin 2002 Meeting, conference of the national grant "MMSM", national coordinator Prof. P. Podio- Guidugli, Bressanone, ITALY;
November Invited speaker at the international conf. Colloquium Lagrangianum 2003, Montpellier, France;
September Invited speaker at the SNP Meeting/IMA PI Conference: MultiscaleEffects in Material Microstructures and Defects, University of Kentucky, Lexington KY-USA.
August Visiting at the Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh-PA, USA. Invited seminar, A new approach to texture and plasticity of polycrystals.
February-March Visiting at the Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh-PA, USA.
2002
August-September Visiting at the Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh-PA, USA.
July Invited lecturer at the CISM Course: Multiscale Modeling in Continuum Mechanics and Structured Deformations, International Center for Mechanical Sciences, Udine-Italy, July 15-19, 2002.
Lecturers: D.R. Owen (USA), F. Marigo (FRA), M. Silhavi (Ceck Rep.), Le (D), G. Del Piero and R. Paroni, Italy.
2001
August Visiting at the Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh-PA, USA. Invited seminar, A new approach to texture and plasticity of polycrystals.
February-March Visiting at the Center for Nonlinear Analysis, Carnegie-Mellon University, Pittsburgh-PA, USA.
2000
September Invited speaker c/o Meeting on Dissipative Effects in Mechanics", Society for Natural Philosophy Meeting, University of California-Berkeley, USA (ref. Prof. Dr. D. J. Steigman)

June Invited speaker c/o Euromech2000, minisymposia “Strain localization and phase transitions”, Metz, FRA (ref. Prof. Dr. C. Faciu, Cristian.Faciu@imar.ro).
February Invited seminar c/o Graduate Aerospace Laboratories, California Institute of Technology, Pasadena-CA- USA (host: Prof. Dr. Eng. M. Ortiz).

-Recent grants

External senior scientists* in the “NIH-PITT bridge grant” 2018: “Engineering Biologic Topography into Vascular Grafts”, PI Dr. Edith Tzeng (UPMC), Dr. S. Velankar, Dr. L. Pocivavsek (UChicago)

*Luca’s status does not allow him to either PI or coPI grant proposals within the US system

FROM INDUSTRY

2018-2019 L.T.E.-Toyota Group-Italy: Investigation of failure mechanisms for handling devices (190 K€/year).
2006-present: S.A.C.M.I. Imola S. C. Ceramics grant on "Modelling for cold and dry compaction of ceramic powders", joint grant with D.I.M.S.-Trento (45 K€/year)
2007-2012: TRW Automotive grant. The subject of the work remains classified. (35K€/year).

FROM PUBLIC SOURCES

2018 (Dec.)-2021 ARS01-01384-PROSCAN, PON-UE-Foundational aspects in cancer medicine-In collaboration with University of Naples-Federico II (250 k€/year)
2019-2021 PRIN2017 20177TTP3S grant, Italian Ministry of University and Research
2017-2020 European Commission (EC) FET Proactive (Neurofibres) grant No. 732344.
2016-2019 Mathematical modeling of the biomechanics regulation and pharmacologic antagonism of the minimal persistent flogosis in respiratory epithelial cells, (50K€/year)-in collaboration with Campania Bioscience- University of Naples-Federico II-Horizon2020.
2009-2013 PRIN-competitive research funding program from the MIUR-Italian Ministry of University and Research (46 K€/year per each unit)
2012-2015 FP7project INTERCER2 - Modelling and optimal design of ceramic structures with defects and imperfect interfaces ", FP7-PEOPLE-2011-IAPP (2,5 M€)- member
2013-2018 "HOTBRICKS - Mechanics of refractory materials at high-temperature for advanced industrial technologies" FP7-PEOPLE-2013-IAPP; total funding 1.1 MEuro (funding to the research unit: 678 kEuro)-member
2014-2019 Admin. coordinator of “INSTABILITIES”, ERC Adv. Grant-Prof. D. Bigoni.
2011-2012 NANOSENSE, from the Italian Ministry of Foreign Affairs and the Italian Ministry of University, Research and Education (55 K€)-member
2007-2008: Chair and coordinator of INTERREG-Card-Phare `Meetigation of Seismisk Risk and Modelling’, Croatia-Molise program (1,5 M€/year)
2003-2006: Member of the National Grant "Modeling of Polycristalline Materials", in Applied Mathematics, Solid Mechanics, Mechanical Engineering and Material Science and Engineering (32 K€/year) 150K€/year, 3 years
2016-2019: Mathematical modeling of the biomechanics regulation and pharmacologic antagonism of the minimal persistent flogosis in respiratory epithelial cells, 250K€/year, Campania Bioscience Horizon2020.

-Leadership and managing skills

Fifteen years ago, a couple of years after winning a national competition to become full professor in Italy, the University of Molise hired me under the strategic plan to build the brand new College of Engineering. Immediately after, I led the start-up process, with the tasks of writing the

proposal for the College under construction, including the hiring strategy, the frame for the students plan at all levels and the growth plan.
During my permanence there, I was acting associate dean, delegate of the rector for the relationships with industries and I was also in charge of representing the College at the "COPI" (Union of the Italian Engineering Colleges) in Rome instead of the Dean. During that time I led an INTERREG project (EU funded) of the order of six hundred thousand euros involving the areas of Seismic Engineering, Solid and Soil Mechanics (Molise was the coordinator).
In 2008 I was invited to be appointed by the College of Engineering at the University of Trento, the n°1 college of engineering in Italy in ten years out of the last twelve, where I joined the DIMS-Dept. of Mechanical and Structural Engineering. Less than a year later, he was elected as head of this institution. Given the troubles suffered by such a department in the previous years, my plan was to push forward issues like (i) outsourcing coming from scientific and industrial grants and (ii) increasing international visibility in terms of publications and international relationships.
Organizational skills may be deduced by the fact that a particularly cohesive environment for faculties and students was built in Trento over the last year and a half. Although the department did have an average balance of seven hundred thousand euros/year, the first full year balance after my guidance jumped up to 3 millions euros/year. It is worth noting that the funding from the central government remained constant through the years (of the order of fifteen percent of the total). I think I gave strong motivations to the members of my department that led to a rapid improvement in both strategic directions and they seem to have the same trend for the upcoming year.
A good indication of having motivated colleagues is that after twenty five years from the foundation of the department, I was able to organize the first departmental conference ever held. This which was open to academicians, students and industries.
Leadership and management skills were of help while managing the following laboratories;
Materials and Structural Testing;
Mechanics and Automatics;
Computational Solid and Structural Mechanics;
Turbomachinery;
Geotechnics;
Laboratory for physical modeling of structures and photoelasticity;
Calibration of Force Devices (Laboratory of the "University Centre of Metrology" - C.U.M.);
Wind Turbine Test Field (CEST).
This has been a challenging and successful work. Particular emphasis may be put on laboratories which are more related to my scientific interests, such as Materials and Structural Testing, lab. for physical modeling of structures and photo-elasticity and Computational Solid and Structural Mechanics, which are leaders across Italy and top notch across Europe.
Among the issues I pursued during my term there has been a successful improvement of the graduate program and the increase of interdisciplinary research which also tied together academia and industries from Italy and foreign countries.
Interpersonal relationships are and have been also very important for me. In particular, good relationships with colleagues, students and people from industries and public administrations are key features that I pursued from the beginning of my career.
Faculties normally get along very well with me. For instance, the main reason why I have been elected as head of a department in Italy relies upon good personal relationships as well as the capability to compromise and let people to agree about general principles.
Leading teams, getting to the goals by keeping a good atmosphere represents a high gain for an academic environment.

-Networking

A few years after my Ph.D., which included a period of time at Carnegie-Mellon University, where I also spent a Postdoc, I established a long-standing network of international connections which actually is evolving year after year.
The academic network, mainly includes prestigious scientists and institutions in the USA, where I had a few visiting positions and systematic collaborations though the years; Canada and Europe are also part of my network. Aside from this, I also have good relationships with international industries in the field of automotive, production of machines for pressing ceramics, etc.

-Teaching and relationships with students

My long-standing experience (over 25 years) in teaching ranges from the Italian to the American system, where I taught with success at both levels. I was essentially in charge of courses in basic and advanced (including special topics) Solid Mechanics, Statics, basic and advanced Elasticity, Structural Mechanics, Structural Design, Structural Dynamics, Prestressed Concrete Structures, Linear Algebra and Applications, Differential Equations and Applications. Many undergraduate and Master degree students were supervised in Italy with good success, as well as a few graduate ones, who now are research fellows in Italian universities.
Skills to build up relationships with students is that I recently encouraged the ASI, Engineering Students association in Trento to apply to the EU network BEST, the famous European organization of students in technology; the reaction of ASI was enthusiastic. BEST was funded by many important international industries, with over thirty countries involved and over eighty clubs (right now there are only five partners in Italy).

Selected courses taught during the last 5 years.

At the University of Pittsburgh
Academic Year 2019-2020
- MEMS3090: Special Topics in Continuum Mechanics

Academic Year 2015-2016
- Rigid Body Mechanics: Dynamics, Undergrad.-Mechanical Engineering & Materials Science.

At Carnegie Mellon University
Academic Year 2015-2016
- Solid Mechanics II: soft matter, electroactive and biological systems and large deformations, Spring 2016 graduate course in Civil and Mechanical Eng.;
- Academic Year 2013-2014
- Solid Mechanics II: Spring 2014 graduate course in Civil, Mechanical Engineering, Materials Science, Physics.

At Brunel University London, UK
Academic Year 2016-2017
- Rigid Body Mechanics: Dynamics, Undergrad.-Mechanical & Aerospace Engineering.

At the University of Trento, Italy
- Academic Year 2018-2019
- Foundation of Structural Engineering, Undergraduate-Civil & Mechanical Engineering, Professional Curriculum;
- Nonlinear Solid Mechanics, Graduate Course in Engineering;

Academic Year 2017-2018
- Foundation of Structural Engineering, Undergraduate-Civil & Mechanical Engineering, Professional Curriculum;
- Nonlinear Solid Mechanics, Graduate Course in Engineering;

Academic Year 2015-2016
- Structural Engineering II, Undergraduate-Civil & Mechanical Engineering;

Academic Year 2014-2015

- Mechanics of biological membranes, Graduate Course in Engineering;
- Solid and Structural Mechanics I, Undergraduate course in Civil & Mechanical Engineering.

-Recent graduate students

Giuseppe Zurlo, (2007), now senior lecturer (associate professor) at NUI Galway (Ireland), Marco Dalla Torre (2009), Andrea Caserotti (2010), Laura Galuppi (2011), now assistant professor at the University of Parma (Italy), Andrea Ershbammer (2012), Daniele Maturi (2013), Pietro Pollaci (2015), Andrea Cugno (2017), now postdoctoral associate at the UC-San Diego (USA), Valentina Piccolo and Stefania Palumbo (2019) ongoing graduation, Riccardo Cavuoto (expected 2020), Matteo Gaibotti (expected 2021), Andrea Mirandola.

-Experience as a professional engineer

My experience in this field is primarily based in Italy and it can be be summarized as follows.
-Registered MS Civil and Mechanical Engineer since 1990-Italy;
-Co-founder of "Sinapsy Engineering s.a.s." 1995 (quit in 1997 to undertake the Postdoc in the US);
-Professional testing of monumental structures, e.g. churches for the Archdioceses of Ravenna: improvement of structures with a cultural heritage against earthquakes, 2010-2014;
-Professional testing structures in seismic zones: public buildings, such as schools, for local municipalities 2009-2013;
-Consultant for SACMI Imola, 2008-2010, Mechanical Engineering Design consultancy;
-Consultant for TRW Automotive Italy (now ZF), 2007-present, Mechanical Engineering Design consultancy.

-Recent editorial activity

The most recent activity has involved the nomination as Associate Editor of Frontiers in Materials, sect. of Mechanics of Materials, a Nature publisher group (EPFL, Switzerland). Editorial board member of: Journal of Nanomaterials, International Journal of Medical Nano Research, Journal of Nanomedicine and Applications, Mathematical Problems in Engineering.
Furthermore, service as reviewer is provided for the following journals:
-Journal of the Mechanics and Physics of Solids,
-Proceedings of the Royal Society-A,
-CMAME-Computer Methods in Applied Mechanics,
-International Journal of Solids and Structures,
-Journal of Engineering Mechanics, ASCE
-Journal of Elasticity,
-Mathematics and Mechanics of Solids,
-Meccanica,
-Composites B,
-Journal of Nanomechanics and Micromechanics,
-ZAMM- Zeitschrift fuer Angewandte Mathematik und Physik,
-Nature Communications,
-Biomechanics and Modeling in Mechanobiology,
-Communications in Nonlinear Science and Numerical Simulation
-Journal of the European Ceramic Society,
-Physics of fluids,
-Mathematical Models and Methods in Applied Sciences,
-Evolution Equations and Control Theory (EECT).

-Publications

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-Description of some selected publications and of the included main results

In this section a selection of published papers is presented. In particular, it emerges that very many of them contain several original results, each of which could have been published separately form the others. This choice has led to fewer, yet qualitatively higher level publications.

- AR Carotenuto, L Lunghi, V Piccolo, M Babaei, K Dayal, N Pugno, M Zingales, L Deseri*, M Fraldi (2020). J. MECH. PHYSICS SOLIDS. *Corresponding author.

In this work, it is highlighted how clustering of ligand-binding receptors of different types on thickened isles of the cell membrane, namely lipid rafts, is an experimentally observed phenomenon. Although its influence on cell's response is deeply investigated, the role of the coupling between me- chanical processes and multiphysics involving the active receptors and the surrounding lipid membrane during ligand-binding has not yet been understood. Specifically, the fo- cus of this work is on G-protein-coupled receptors (GPCRs), the widest group of transmembrane proteins in animals, which regulate specific cell processes through chemical sig- nalling pathways involving a synergistic balance between the cyclic Adenosine Monophos- phate (cAMP) produced by active GPCRs in the intracellular environment and its efflux, mediated by the Multidrug Resistance Proteins (MRPs) transporters. This paper develops a multiphysics approach based on the interplay among energetics, multiscale geometrical changes and mass balance of species, i.e. active GPCRs and MRPs, including diffusion and kinetics of binding and unbinding. Because the obtained energy depends upon both the kinematics and the changes of species densities, balance of mass and of linear momentum are coupled and govern the space-time evolution of the cell membrane. The mechanobi- ology involving remodelling and change of lipid ordering of the cell membrane allows to predict dynamics of transporters and active receptors –in full agreement with exper- imentally observed cAMP levels–and how the latter trigger rafts formation and cluster on such sites. Within the current scientific debate on Severe Acute Respiratory Syndrome CoronaVirus 2 (SARS-CoV-2) and on the basis of the ascertained fact that lipid rafts often serve as an entry port for viruses, it is felt that approaches accounting for strong cou- pling among mechanobiological aspects could even turn helpful in better understanding membrane-mediated phenomena such as COVID-19 virus-cell interaction.

- A. R. Carotenuto, N. M. Pugno, L. DESERI, S. Palumbo, A. Cutolo, M. Fraldi (2019). J. MECH. PHYSICS SOLIDS. Tensegrity structures are special architectures made by floating compressed struts kept together by a continuous system of tensioned cables. Their existence in a mechanically stable form is decided by the possibility of finding geometrical configurations such that pre-stressed tendons and bars can ensure self-equilibrium of the forces transmitted through the elastic network, the overall stiffness of which finally depends on both the rigidity of the compressed elements and the cables' pre-stress. The multiplicity of shapes that tensegrity structures can assume and their intrinsic capability to be deployable and assembled, so storing (and releasing) elastic energy, have motivated their success as paradigm –pioneeringly proposed three decades ago by the intuition of Donald E. Ingber– to explain some underlying mechanisms regulating dynamics of living cells. The interlaced structure of the cell cytoskeleton, constituted by actin microfilaments, intermediate filaments and microtubules which continuously change their spatial organization and pre-stresses through polymerization/depolymerization processes, seems in fact to steer migration, adhesion and cell division by obeying the tensegrity construct. Even though rough calculations lead to estimate discrepancies of less than one order of magnitude when comparing axial stiffness of actin filaments (cables) and microtubules (struts) and recent works have shown bent microtubules among stretched filaments, no one has yet tried to remove the standard hypothesis of rigid struts in tensegrity structures when used to idealize the cell cytoskeleton mechanical response. With reference to the 30-element tensegrity cell paradigm, we thus introduce both compressibility and bendability of the struts and accordingly rewrite the theory to simultaneously take into account geometrical non-linearity (i.e. large deformations) and hyper-elasticity of both tendons and bars, so abandoning the classical linear stress-strain constitutive assumptions. By relaxing the hypothesis of rigidity of the struts, we demonstrate that some quantitative confirmations and many related extreme and somehow counter-intuitive mechanical behaviors actually exploited by cells for storing/ releasing energy, resisting to applied loads and deforming by modulating their overall elasticity and shape through pre-stress changes and instability-guided configurational switching, can be all theoretically found. It is felt that the proposed new soft-strut tensegrity model could pave the way for a wider use of engineering models in cell mechanobiology and in designing bio-inspired materials and soft robots.

- E. Bologna, L. DESERI, F. Graziano, M. Zingales (2019) INT. J. NONLINEAR MECH. In this paper the authors deals with the heredity behavior of hydroxyapatite-based composite used for cranioplastic surgery. It is shown that biomimetic prostheses, for their microstructural morphology, have a mechanical behavior that can be well described by an isotropic fractional-order hereditary model. The three-axial isotropic behavior is framed in the context of fractional-order calculus and same details about thermodynamical restrictions of memory functions used in the formulation of the three-axial isotropic constitutive equations. A mechanical model that corresponds, exactly, to the three-axial isotropic hereditariness is also introduced in the paper.

- S. Palumbo, L. Deseri, D.R. Owen, M. Fraldi (2018). PROC. ROYAL SOC. A. In the present work, the overall nonlinear elastic behavior of a 1D multi-modular structure incorporating possible imperfections at the discrete (micro-scale) level, is derived with respect to both tensile and compressive applied loads. The model is built up through the repetition of n units, each one comprising two rigid rods having equal lengths, linked by means of pointwise constraints capable to elastically limit motions in terms of relative translations (sliders) and rotations (hinges). The mechanical response of the structure is analyzed by varying the number n of the elemental moduli, as well as in the limit case of infinite number of infinitesimal constituents, in light of the theory of (first order) ***Structured Deformations*** (SDs), that interprets the deformation of any continuum body as the projection, at the macroscopic scale, of geometrical changes occurring at the level of its sub-macroscopic elements. In this way, a wide family of nonlinear elastic behaviors is generated by tuning internal microstructural parameters, the tensile buckling and the classical Euler's Elastica under compressive loads resulting as special cases in the socalled continuum limit – say when $n \rightarrow \infty$. Finally, by plotting the results in terms of first Piola-Kirchhoff stress versus macroscopic stretch, it is for the first time demonstrated that such SDs-based 1D models can be helpfully used to generalize some standard hyperelastic behaviors by additionally taking into account instability phenomena and concealed defects.

-S. Palumbo, A.R. Carotenuto, A. Cutolo, L. Deseri, M. Fraldi (2018) INT. J. NONLINEAR MECH. Tensegrity systems occur when self-equilibrated states are achieved through the interplay of pretensed (cables) and precompressed (struts) elements. The principles that govern these types of structures have been widely observed in many living systems across the scales and recently recognized, with soft or buckling bars, in the cytoskeleton as well as within single protein architectures as associated with key cellular and subcellular processes. To properly model these mechanical phenomena, some limitations dictated by the mostly linear approaches –used in literature when dealing with tensegrity structures – needto be overcome. To this aim, the present work provides a novel 2-element soft-tensegrity paradigm that includes, for the first time, (neo-Hookean) finite hyperelasticity for cable and strut, the latter potentially undergoing both contraction and buckling at each prestressed equilibrium stage. It is finally shown that constitutive properties, instability and bar deformability cooperate to determine unusual form-finding results, providing peculiar overall mechanical responses as external forces are applied.

-A. Beltempo, M. Zingales, O. S. Bursi, L. Deseri (2018) INT J. SOLIDS & STRUCTURES. In this paper, the hereditariness of aging materials is modeled within the framework of fractional calculus of variable order. A relevant application is made for the long-term behavior of concrete, for which the creep function is evaluated with the aid of Model B3. The corresponding relaxation function is derived through the Volterra iterated kernels and a comparison with the numerically-obtained relaxation function of Model B3 is also reported. The proposed fractional hereditary aging model (FHAM) for concretes leads to a relaxation function that fully agrees with the well-established Model B3. Furthermore, the FHAM takes full advantage of the formalism of fractional-order calculus to yield semi-analytic expressions in terms of material parameters.

-G. Alaimo, V. Piccolo, A. Chiappini, M. Ferrari, D. Zonta, L. Deseri, M. Zingales (2017)-PART II- J. ENG. MECH. This work aims to shed light on the "thermally-anomalous" coupled behavior of slightly deformable bodies, in which the strain is additively decomposed in an elastic contribution and in a thermal part. The macroscopic heat flux turns out to depend upon the time history of the corresponding temperature gradient, and this is the result of a multiscale rheological model developed in Part I of the present study, thereby resembling a long-tail memory behavior governed by a Caputo's fractional operator. The macroscopic constitutive equation between the heat flux and the time history of the temperature gradient does involve a power law kernel, resulting in the "anomaly" mentioned previously. The interplay between such a thermal flux and elastic and thermal deformability are investigated for a pinned-pinned truss. This allows a focus on the effects of the deviation from Fourier's law on the thermoelastic coupling. Indeed, the interactions in the presented system are fully coupled because the temperature and displacement field mutually influence one another.

-G. Alaimo, V. Piccolo, A. Chiappini, M. Ferrari, D. Zonta, L. Deseri, M. Zingales (2017)-PART I- J. ENG. MECH. The paper deals with the generalization of Fourier-type relations in the context of fractional-order calculus. The instantaneous temperature-flux equation of the Fourier-type diffusion is generalized, introducing a self-similar, fractal-type mass clustering at the micro scale. In this setting, the resulting conduction equation at the macro scale yields a Caputo's fractional derivative with order of temperature gradient that generalizes the Fourier conduction equation. The order of the fractional-derivative has been related to the fractal assembly of the microstructure and some preliminary observations about the thermodynamical restrictions of the coefficients and the state functions related to the fractional-order Fourier equation have been introduced. The distribution and temperature increase in simple rigid conductors have also been reported to investigate the influence of the derivation order in the temperature field.

-M. Fraldi, A. Cugno, Cutolo, N. Pugno, A Carotenuto L. DESERI (2016) J ENG. MECH. In the last years, experimental evidences have suggested important direct implications of viscoelasticity of human cells and cell cytoskeleton dynamics on some relevant collective and at single cell behaviors such as migration, adhesion and morphogenesis. As a consequence, the mechanical properties of single cells as well as how cells respond to mechanical stimuli have been –and currently are– at the center of a vivid debate in the scientific community. By making reference to important experimental findings from the literature which have shown that human metastatic tumor cells are about 70% softer than benign cells, independently from the cell lines examined, the present authors have very recently theoretically demonstrated that these differences in stiffness might be exploited to mechanically discriminate healthy and cancer cells, for example through low intensity therapeutic ultrasound. In particular, by means of a generalized viscoelastic paradigm combining classical and fractional derivative-based models, it has been found that selected frequencies (from tens to hundreds kHz) are associated to resonance-like phenomena that are prevailing on thermal fluctuations and that could be hence, at least in principle, helpfully utilized for both targeting and selectively attacking tumor cells.
With the aim of investigating the effect of the prestress –for instance induced in protein filaments during cell adhesion– on the overall cell stiffness and, in turn, on its in-frequency response, a simple multiscale scheme is here proposed to bottom-up enrich the spring-pot-based viscoelastic single-cell models, by incorporating finite elasticity and in this way determining, through sensitivity analyses, the role played by the stretched state of the cytoskeletal elements on the cell vibration.

-L. DESERI, P. Pollaci, M. Zingales, K. Dayal (2016) JMBBM. Lipid ordering phase changes arising in planar membrane bilayers is investigated both accounting for elasticity alone and for effective viscoelastic response of such assemblies. Their mechanical response is studied by minimizing the Gibbs free energy which penalizes perturbations of the changes of areal stretch and their gradients only (see Deseri and Zurlo, 2013). Instabilities arise whenever areal stretches characterizing homogeneous configurations lie inside the spinoidal zone of the free energy density. Indeed, bifurcations from such configurations are shown to occur as oscillatory perturbations of the in-plane displacement. Experimental observations (Espinosa et al., 2011) show a power-law in-plane viscous behavior of lipid structures allowing for an effective viscoelastic behavior of lipid membranes, which falls in the framework of Fractional Hereditariness. A suitable generalization of the variational principle invoked for the elasticity is applied in this case, and the corresponding Euler–Lagrange equation is found together with a set of boundary and initial conditions. Separation of variables allows for showing how Fractional Hereditariness owes bifurcated modes with a larger number of spatial oscillations than the corresponding elastic analog. Indeed, the available range of areal stretches for material instabilities is found to increase with respect to the purely elastic case. The time-dependent part of the problem leads to a non-classical fractional eigenvalue problem. Although in bifurcated modes a significantly higher number of oscillations is expected than in the limiting case of the equilibrium elastic response of the bilayer, the transfer function, namely the time dependence of bifurcated solution, exhibits a slow decay, thereby indicating a relaxation of the number of the oscillations mentioned above.

-M. Fraldi, A. Cugno, L. Deseri, K. Dayal and N. Pugno (2015) J ROYAL SOC-INTERFACE.
Experimental studies recently performed on single cancer and healthy cells have demonstrated that the first ones are about 70% softer than the latter, regardless of the cell lines and the measurement technique used for determining the mechanical properties. At least in principle, the above mentioned differences in cell stiffness might be thus ad hoc exploited to build up mechanical based targeting strategies for discriminating neoplastic transformations within human cell populations and designing innovative complementary tools to cell-specific molecular tumor markers, leading to envisage possible applications in diagnoses and therapies for cancer diseases.
With the aim of characterizing and gaining insights into the frequency overall response of single cell systems to mechanical stimuli (typically Low Intensity Therapeutic Ultrasounds), a generalized viscoelastic paradigm, combining classical and spring-pot based models, is introduced for modeling the problem at hand, by neglecting details on the cascade of mechanobiological events involving cell nucleus, cytoskeleton, elastic membrane and cytosol. Theoretical results show that differences in stiffness, actually ex vivo and in vitro experimentally observed, allow to mechanically discriminate healthy and cancer cells, by highlighting frequencies (from tens to hundreds kHz) associated to resonance-like phenomena - prevailing on thermal fluctuations - that could be helpfully utilized for targeting and to selectively attack tumor cells.

-S S Soumya, A. Gupta, A. Cugno, L. DESERI, K. Dayal, D. Das, S. Sen, M. M. Inamdar (2015) PLOS ONE. Coherent angular rotation of epithelial cells is thought to contribute to many vital physiological processes including tissue morphogenesis and glandular formation. However, factors regulating this motion, and the implications of this motion if perturbed, remain incompletely understood. In the current study, we address these questions using a cell center based model in which cells are polarized, motile, and interact with the neighboring cells via harmonic forces. We demonstrate that, a simple evolution rule in which the polarization of any cell tends to orient with its velocity vector can induce coherent motion in geometrically confined nvironments. In addition to recapitulating coherent rotational motion observed in experiments, our results also show the presence of radial movements and tissue behavior that can vary between solid-like and fluid-like. We show that the pattern of coherent motion is dictated by the combination of different physical parameters including number density, cell motility, system size, bulk cell stiffness and stiffness of cell cell adhesions. We further observe that perturbations in the form of cell division can induce a reversal in the direction of motion when cell division occurs synchronously. Moreover, when the confinement is removed, we see that the existing coherent motion leads to cell scattering, with bulk cell stiffness and stiffness of cell-cell contacts dictating the invasion pattern. In summary, our study provides an in-depth understanding of the origin of coherent rotation in confined tissues, and extracts useful insights into the influence of various physical parameters on the pattern of such movements.

-L. DESERI, G. Gentili, J.M. Golden (2014). INT J. SOLIDS & STRUCTURES. In this paper the authors discuss the free energy function for fractional hereditary materials in terms of a recently proposed mechanical model. Indeed the specific expression of the free energy for a given relaxation/creep function is not unique. This problem is well-known and several expression of the free energy have been provided satisfying the thermodynamic restrictions about the minimum energy rate or the maximum entropy function. However for relaxation function, characterized by a single exponential (corresponding to an arrangement of elastic spring and a viscous dashpot) the expressions of the free energy coincides. In these cases it has been proved, that the expression of the free energy in (24) is the elastic potential energy stored in the solid phase of the the material. In case of other expressions of the relaxation function, however, no information about the physics beyond the free energy expressions have been presented in scientific literature.
The authors showed that a physical context to the free energy in (24) may be withdrawn, also, for the case of power-law relaxation function possessed by fractional hereditary materials. This equivalence has been obtained by means of the exact mechanical description of power-laws provided in previous papers involving either the case of Elasto-Viscous material models or the Visco-Elastic material models. Indeed, as the equivalence among a power-law relaxation and a mechanical model represented by a proper setting of linear elastic springs (solid phase) and linear

viscous dashpots (fluid phase) has been established then the evaluation of the stored and dissipated energy is unique. In this paper we showed that the dissipation rate of the material must be evaluated by means of the overall dissipation of the viscous dashpots of the rheological model. Hence the energy rate dissipated during any strain/stress history is provided, only, by the overall dissipation rate of the viscous elements of the fluid phase. Therefore, the rheological model equivalent to power-law creep/relaxation functions is a crucial point to evaluate the mechanical energy stored and dissipated in the material during any strain/stress history. It has been shown that the energy rate of FHM coincides with the energy rate in (24) for the power-law relaxation function. The free energy function corresponding to FHM has also been formulated in terms of the material state that represents the residual stress in non-virgin materials.

-DESERI L., and G. Zurlo (2013) BMMB. In this work, some implications of a recent model for the mechanical behavior of biological membranes (Deseri et al. in Continuum Mech Thermodyn 20(5):255–273, 2008) are exploited by means of a prototypical one-dimensional problem. We show that the knowledge of the membrane stretching elasticity permits to establish a precise connection among surface tension, bending rigidities and line tension during phase transition phenomena. For a specific choice of the stretching energy density, we evaluate these quantities in a membrane with coexistent fluid phases, showing a satisfactory comparison with the available experimental measurements. Finally, we determine the thickness profile inside the boundary layer where the order–disorder transition is observed.

-DESERI L., Di Paola M., Zingales M., Pollaci P. (2013), INT. J. NUM. METH. BIOMEDICAL ENG. In this paper the authors introduce a hierarchic fractal model to describe bone hereditariness. Indeed, experimental data of stress relaxation or creep functions obtained by compressive/tensile tests have been proved to be fit by power-law with real exponent included in the interval zero-one. The rheological behavior of the material has therefore been obtained, using the Boltzmann-Volterra superposition principle, in terms of real order integrals and derivatives (fractional-order calculus). It is shown that the power-laws describing creep/relaxation of bone tissue may be obtained introducing a fractal description of bone cross-section and the Hausdorff dimension of the fractal geometry is then related to the exponent of the power-law.

-Dal Corso, F. AND DESERI, L., (2013) MECCANICA. Random elastic composites with residual stresses are examined in this paper with the aim of understanding how the prestress may influence the overall mechanical properties of the composite. A fully non-local effective response is found in perfect analogy with the un-prestressed case examined in (Drugan and Willis, J. Mech. Phys. Solids 44(4):497–524, 1996). The second gradient approximation is considered and the impact of the residual stresses on the estimate of the RVE size is studied whenever the local response is used to describe the mechanical properties of the heterogeneous medium. To this aim, total and incremental formulations are worked out in this paper and the influence of both uniform and spatially varying prestresses are studied. Among other results, it is shown how rapid oscillations of relatively "small"residual stresses in most cases may result in the impossibility of describing the overall behavior of the composite with a local constitutive equation. On the other hand, prestresses with relatively high amplitudes and slow spatial oscillations may even reduce the RVE.

-DESERI L. and Owen, D. R. (2012). CONT. MECHANICS & THERMODYNAMICS. This paper encompasses some of the new features of the approach now available to study the mechanics of materials through the field theory of Structured Deformations. In particular here our attention is devoted to granular materials. For instance s in sand of powdered ceramics the material may be viewed as a continuum composed of much smaller elastic bodies. The multiscale geometry of structured deformations captures the contribution at the macrolevel of the smooth deformation of each small body in the aggregate (deformation without disarrangements) as well as the contribution at the macrolevel of the non-smooth deformations such as slips and separations between the small bodies in the aggregate (deformation due to disarrangements). When the free energy response of the aggregate depends only upon the deformation without disarrangements, is isotropic, and possesses standard growth and semi-convexity properties, we establish: (i) the existence of a compact phase in which every small elastic body deforms in the same way as the aggregate and, when the volume change of macroscopic deformation is sufficiently large, (ii) the existence of a loose phase in which every small elastic body expands and rotates to achieve a stress-free state with accompanying disarrangements in the aggregate. We show that a broad class of elastic aggregates can admit moving surfaces that transform material in the compact phase into the loose phase and vice versa and that such transformations entail drastic changes in the level of deformation of transforming material points.

-E. Puntel, DESERI L., E. Fried (2011) J. ELASTICITY. This paper represents one of the first analytic studies for the investigation of the occurrence and the development of wrinkling in thin sheets undergoing tension. When a thin rectangular sheet is clamped along two opposing edges and stretched, its inability to accommodate the Poisson contraction near the clamps may lead to the formation of wrinkles with crests and troughs parallel to the axis of stretch. The proposed energy functional includes bending and membranal contributions, the latter depending explicitly on the applied stretch. Motivated by work of Cerda, Ravi-Chandar, and Mahadevan, the functional is minimized subject to a global kinematical constraint on the area of the mid-surface of the sheet. Analysis of a boundary-value problem for the ensuing Euler–Lagrange equation shows that:

-wrinkled solutions exist only above a threshold of the applied stretch, which is actually quite small;

-there exists a sequence of critical values of the applied stretch, which is determined for the first time in the literature, displaying modes with many wrinkles.

The items above predict for the first time the experimental fact that many wrinkles in thin polymeric sheets are observed almost immediately under very small applied stretches.

Although previously proposed scaling relations for the wrinkle wavelength and root-mean-square amplitude are confirmed, in contrast to the scaling relations for the wrinkle wavelength and amplitude, the applied stretch required to induce any number of wrinkles depends on the in-plane aspect ratio of the sheet. When the sheet is significantly longer than it is wide, the critical stretch scales with the fourth power of the length-to-width. With some efforts the same procedure may be extended to account for:

-viscoelasticity of the membrane, leading to studies of wrinkling relaxation and creep; this may be relevant for corrugated layered composite sensor (e.g. polymeric films alternated with deposited gold, etc.), for which the ridges and troughs must be kept in their original shape and hence relaxation must be limited/prevented;

-biomembranes, for which the evolving elastic/viscoelastic properties of the lipid bilayer may in fact exhibit undesired wrinkling; as well as other cases and applications.

-DESERI L. and Owen, D. R. (2010) MATH. & MECH. of SOLIDS. This paper is a step forward towards elucidating the behaviour of continua with microstructure undergoing disarrangements (e.g. slips, voids, micro fractures, etc.) initiated in (8) and continued in (7) (and other papers) within the specific context of the plasticity of metallic single crystals. The new and general field theory for bodies with microstructure provided in (6) sets the basis of all the further developments.

In this framework, the notion of a submacroscopically stable equilibrium configuration of a body and the procedure introduced here for the determination of submacroscopically stable equilibria provide the basis for selecting in a systematic way preferred submacroscopic geometrical states of bodies in equilibrium. The augmented energy underlies this methodology and provides a functional of the macroscopic deformation and the *discrepancy* (Δ=G-M) between the deformation gradient without disarrangements and the diffused measure M of such quantities that is stationary for fixed Δ at equilibrium configurations. This augmented energy is proved not to increase under purely submacroscopic, quasistatic processes in time-independent environments.

These ideas were developed in Section 3 for arbitrary elastic bodies undergoing disarrangements and dissipation and were illustrated for specific bodies in Sections 4 and 5. In particular, polymers and other ductile materials could be described as the bodies studied in Section 4; the latter have biquadratic free energy response, and their submacroscopically stable equilibria arise only for submacroscopic geometries associated with the spherical phase, the classical phase, or the prolate phase, depending upon the value of the ratio of the two response moduli. For a specific range of the parameter, the formula (70) obtained in Section 4 for the minimum Helmholtz free energy density within the prolate phase is reminiscent of the formula (71) obtained by Bladon, Tarentiev and Warner [PRE, 47, 1993] by a different method, one based on a bottom-up, statistical calculation. Another class of rheological interesting materials, called here near-sighted fluids, are discussed in Section 5 possess universal spherical and universal prolate phases] that generally are not stress-free, but the submacroscopically stable equilibria that are available to such fluids all are stress-free.

-DESERI L., Piccioni M. D., G. Zurlo (2008), CONTINUUM MECHANICS AND THERMODYNAMICS A new free energy for quasi-incompressible and "in-plane fluid" thin biomembranes depending on chemical composition, temperature, degree of order and membranal-bending deformations is derived in this paper for the first time in the literature. The identification of the membranal contribution to the energy, which is the first order term of it, is done on the basis of a bottom-up approach: this relies upon statistical mechanics calculations. The main result is an expression of the biomembrane free energy density, whose local and non-local counterparts turn out to be weighted by different powers of the reference thickness of the bilayer. The resulting energy exhibits three striking aspects:

(i) the local (purely membranal) energy counterpart turns out to be completely determined through the bottom-up approach mentioned above, which is based on experimentally available information on the nature of the constituents;

(ii) the non-local energy terms, that spontaneously arise from the 3D–2D dimension reduction procedure, account for both bending and non-local membranal effects, the latter being proportional to the magnitude of the gradient of the thinning/thickening measure of strain;

(iii) such terms turn out to be uniquely determined by the knowledge of the membranal energy term, which in essence represents the only needed constitutive information of the model;

(iv) the "line tension" between different phases is recovered through the membrane non-local term, arising in boundary layers between thick and thin zones;
(v) the classical Helfrich model, which neither accounts for chemical composition and temperature nor for the membrane part of the energy (and hence for the switching of phases), is recovered as particular case of the obtained energy.
It is worth noting that the coupling among the fields appearing as independent variables of the model is not heuristically forced, but it is rather consistently delivered through the adopted procedure.
Applications to studies of elastic bifurcations of planar and curved biomembranes may be suitable, as well as extensions to account for the viscoelasticity of liposomes. Studies on bio-inspired nano-strusctured artificial materials may also be pursued by extending the obtained energy. Applications to more complex biological situations are also under investigations.

-DESERI L., Golden J. M. (2007). SIAM J. APPLIED MATH. A general closed expression is given for the isothermal minimum free energy of a linear viscoelastic material with continuous spectrum response.
Two quite distinct approaches are adopted, which give the same final result. The first involves expressing a positive quantity, closely related to the loss modulus of the material, defined on the frequency domain, as a product of two factors with specified analyticity properties.
The second is the non-trivial generalization of the continuous spectrum version of a method used by Breuer and Onat for materials with relaxation function given by sums of exponentials. It is further shown that under the assumed properties of the continuum spectrum materials envisaged in this work, minimal energy states, obtained by Del Piero and Deseri (see e.g. ref. (10) of this list) are uniquely related to histories and the work function is the maximum free energy with the property that it is a function of state.
Further developments may be devoted to examine materials with less restrictive properties on its relaxation, such as "power law polymers", so that the new spectra may determine a non-trivial equivalence class of histories leading to the same minimal state. In such a case the methods (a) and (b) must be revisited for a non-trivial extension.

-DESERI L., Golden M. J. AND M. Fabrizio (2006), ARCH. RATIONAL MECHANICS & ANALYSIS. This is a modern and key work on fundamental aspects of viscoelasticity, which may have practical impacts whenever mechanical components and structures are employed after experiencing unknown and recent past strains. The same issue arises if specimen are subject to treatments resulting in the presence of relaxing prestresses. Indeed, in this paper the impact on the initial-boundary value problem, and on the evolution of viscoelastic systems of the use of a new definition of state based on the stress-response. Comparisons are made between this new approach and the traditional one, which is based on the identification of histories and states. We shall refer to a stress-response definition of state as the minimal state, introduced by Del Piero and Deseri in 1997.
The energetics of linear viscoelastic materials is revisited and new free energies, expressed in terms of the minimal state descriptor, are derived together with the related dissipations. Furthermore, both the minimum and the maximum free energy are recast in terms of the minimal state variable and the current strain. The initial-boundary value problem governing the motion of a linear viscoelastic body is re-stated in terms of the minimal state and the velocity field through the principle of virtual power. The advantages are:
-the elimination of the need to know the past-strain history at each point of the body, and
-the fact that initial and boundary data can now be prescribed on a broader space than resulting from the classical approach based on histories.
These advantages are shown to lead to natural results about well-posedness and stability of the motion. Finally, we show how the evolution of a linear viscoelastic system can be described through a strongly continuous semigroup of (linear) contraction operators on an appropriate Hilbert space. The family of all solutions of the evolutionary system, obtained by varying the initial data in such a space, is shown to have exponentially decaying energy. Further striking developments are foreseen in the field of Computational Mechanics, because of new and open possibilities of getting new variational principles for viscoelastic mechanical components and structures whenever they are subject to unknown pre-existing strains.

-DESERI L., D. R. Owen. (2003). J. ELASTICITY. The vast scope of elasticity as a continuum field theory includes the description at the macrolevel of the dynamical evolution of bodies that undergo large deformations, that respond to smooth changes in geometry by storing mechanical energy, and that experience internal dissipation in isothermal motions only during nonsmooth macroscopic changes in geometry such as shock waves.
Nevertheless, the needs of bridging closer relationships between the mechanical behaviour at the submacroscopic level and its influence at the macrolevel push forward ideas to deriving multiscale theories, physically-based, which may generalize the classical "one-scale" nonlinear elasticity.
The research described in this paper leads to employing structured deformations of micro/nano-structured continua to obtain a field theory capable of describing such bodies, in the context of dynamics and large isothermal deformations. In other words, an approach owing the evolution of bodies that:

-undergo smooth deformations at the macroscopic length scale, that
-can experience piecewise smooth deformations (disarrangements) at submacroscopic length scales, and that
-can not only store energy but can also dissipate energy during such multiscale geometrical changes, is fully worked out in this paper.
The constitutive assumptions employed in this derivation permit the body to store energy as well as to dissipate energy in smooth dynamical processes. Only one non-classical field G, the deformation without disarrangements, appears in the field equations, and a consistency relation based on a decomposition of the Piola–Kirchhoff stress circumvents the use of additional balance laws or phenomenological evolution laws to restrict G. The field equations are applied to an elastic body whose free energy depends only upon the volume fraction for the structured deformation. Existence is established of two universal phases, a spherical phase and an elongated phase, whose volume fractions are $(1 - \gamma_0)^3$ and $(1 - \gamma_0)$ respectively, with $\gamma_0 := (\sqrt{5} - 1)/2$ the "golden mean".
Applications of such a theory are vitually infinite, as well as specialization to problems of plasticity, damage and other inelastic phenomena involving ductile, as well as granular, materials. Dimensionally reduced theories for beams, plates and shells made of ductile materials undergoing dissipative disarrangements look a fertile and very promising perspective for such an approach.

-DESERI L., D.R.Owen. (2002) MATH. & MECHANICS OF SOLIDS. With the aim of showing he impact of a new energetic description of the hardening behavior of single crystals undergoing single slip derived by Deseri and Owen (IJP 2000) is analyzed in this work by examining and modelling experiments of Sir. G.I. Taylor and Elam on the distortion of metallic single crystals. Simultaneous macroscopic simple shear and mesoscopic slips are described by means of a class of structured deformations called "two-level shears," along with measures of separation of active slip-bands proposed by the authors in (8) and the number of lattice cells traversed during slip. The multiscale energetics of two-level shears deduced in (8) is shown to give rise to a response consistent with the experimentally observed loading and unloading behavior of a single crystal in G. I. Taylor's soft device, as well as with the Portevin–le Chatelier effect.
Such behaviour is predicted through the occurrence of elastic material instabilities at the level of active slip planes.
The manifestation of such phenomenon occurs thanks to the snap-through of the loading point on a stress-strain plot from one stable branch of a constitutive locus, namely a stress-strain plot derived by the energy through simple differentiation, to another one, resulting in jumps of the loading point. The tunnelling of such a point through one or more stable branches of the locus is shown to occur with dissipation. In summary, since such jumps occur at a smaller length scale they predict an irreversible behaviour whenever loading occur beyond a certain stress level and subsequent unloading is considered, actually reproducing the observed plastic response for such crystals. The jagged shape of the curve caused by the mentioned snap-through is consistent with Portevin–le Chatelier effect. In particular, the initial critical resolved shear stress, the flow stress, and the hardening response are obtained, and an application to aluminium single crystals is displayed.
This paper gives justice to a famous sentence of J. Ericksen who foresaw that plasticity may be explained with elastic material instabilities at a smaller length scale. Henceforth this work puts solid and encouraging bases for a more robust and general nonlinear theory of elasticity for nano/microstructured bodies undergoing disarrangements such as slips, voids, etc.

-DESERI L., D. R. Owen. (2000). INT. J. PLASTICITY. This research supports recent efforts to provide an energetic approach to the prediction of stress-strain relations for single crystals undergoing single slip and to give precise formulations of experimentally observed connections between hardening of single crystals and separation of active slip-bands. Non-classical, structured deformations in the form of two-level shears permit the formulation of new measures of the active slip-band separation and of the number of lattice cells traversed during slip.
A new and revealing formula is obtained for the Helmholtz free energy per unit volume as a function of the shear without slip, the shear due to slip, and the relative separation of active slip-bands in a single crystal. This formula is the basis for a model, under preparation by the authors, of hardening of single crystals in single slip that is consistent with the Portevin-Le Chatelier effect and the existence of a critical resolved shear stress. The approach adopted in this paper may be generalized to more complex kinematical changes of the submacroscopic structure of metallic materials under general states of stress.

-DESERI L., R. Mares. (2000). MECHANICS OF MATERIALS. In this paper, a class of viscoelastoplastic constitutive models, deduced from a thermodynamically consistent formulation is presented. In particular, the exploitation of a penalty version of the maximum dissipation principle leads to a class of non-linear viscoelastoplastic equations which contains the ones developed by Krempl and Yao (1987) on the one hand, and Haupt and Korzen (1987), Haupt and Lion (1993) among others. Unlike the model discussed in Haupt and Lion (1993), for the class of models derived in this paper the concept of intrinsic time developed by Valanis (1971) is not used. History and rate dependencies are incorporated through the constitutive model by the concepts of equilibrium stress and overstress, respectively. In the previous sections, it is shown that either in the limiting cases of high viscosity or for extremely slow motions the constitutive model reduces to the one of the equilibrium stress as expected. Further, a numerical analysis of the differential equations describing the viscoelastoplastic behavior in the uniaxial case is investigated. The theoretical predictions obtained in this case turn out to well describe the most important effects of the variation of strain rate for stainless steels, such as abrupt changes during monotonic loading programs, monotonic repeated relaxations, and cyclic loading programs at different strain rates. Applications to the viscoplasticity of metals and the extension of this approach to severe strains may be fruitfully considered.

-DESERI L., G. Gentili AND M. J. Golden. (1999). J. ELASTICITY. Dealing with viscoelastic materials, the problem of finding the explicit form of the maximum recoverable work from a given state for all classes of such materials has been an open problem from the late fifties, late sixties. The importance of giving an answer to this question is easily understood if one qualitatively refers to what is a physically the least available energy for the material which is in a given state. Mathematically, this tantamount to saying that the free energy for the material is not unique and that the minimum possible one has a lot of relevance.
The problem above was only characterized at the beginning of the seventies, although it was not yet solved. This paper fully provides the sought answer. Indeed, a general expression for the isothermal minimum free energy of a linear viscoelastic material is given in the frequency domain for the full general tensorial case.
The method used here resides on a variational technique. However, the choice of functional to maximize is motivated by showing the equivalence of some alternative definitions of the maximum recoverable work.
Moreover such a maximization in the tensorial case relies crucially on certain results due to Gohberg and Kre˘ın concerning the factorizability of Hermitean matrices. The resultant expression is shown to be a function of state in the sense of Noll, formulated in the context of linear viscoelasticity by Del Piero and Deseri (1997). Moreover, it turns out to satisfy both the above cited definitions of the free energy.
The paper contains several and fundamental results which could have led to several papers. Nevertheless, they have been collected in this work and will be summarized below. Detailed, explicit formulae are given for the material responses associated with particular classes of tensorial discrete spectrum models. In Section 3 the constitutive relationship of the material is discussed, together with the concept of state. In Section 4 the maximum recoverable work from a given state is considered in detail. Factorization of a quantity closely related to the tensorial loss modulus is considered in Section 5, which allows the determination of a general expression for the maximum recoverable work in terms of Fourier transformed quantities in Section 6, from a variational argument. A result on the characterization of states in the sense of Noll for viscoelastic materials in the frequency domain is proved in Section 7, with the aid of which the maximum recoverable work is shown to be a function of the state. Since the minimum free energy m is identified with the maximum recoverable work, the results of Sections 6 and 7 refer to m as well. In Section 8, the expression found in Section 6 is shown to have the properties of a free energy according to Graffi's definition. In Section 9, such an expression is shown to be a free energy in the sense of Coleman and Owen, by using a suitable norm on the space of the states. Various choices of norm, including the free energy itself, are compared. Explicit results for particular relaxation functions are presented in Section 10.

-Del Piero G., DESERI L. (1997). ARCH. RAT. MECHANICS & ANALYSIS. The analysis of the response of viscoelastic solids is a very classical subject and a keystone of Solid Mechanics. As usual, the constitutive law of linear viscoelasticity is the Boltzmann-Volterra equation. Nevertheless, long term hereditary materials, such as many classes of polymers, are used to make components and structures. Such items are then subject to loading in a time interval of observability, i.e. from a certain time on; very often though the past strain history experienced by each point of the structure is obviously not known. Obvsiouly the latter influences on the overall response of the material, shielding its intrinsic relaxation properties and, in turn, of the structure. The impossibility of knowing past histories suggests that stress relaxation tests with no further loading may reveal if long memory effects are present in the mechanical component under exam. In other words, residual stresses are expected to relax while measured for further and increasing times. Roughly speaking a physical way to detect the effects of past histories would be to characterize such residual stresses. Henceforth, separating the contributions of the effects of the past history and of the actual loading becomes crucial to predict and verify their overall response.
Henceforth, while using the Boltzmann-Volterra equation, such a separation may then be of great interest.
In this respect, an existing framework introduced by Noll in its context of 'simple materials' (roughly speaking materials with local response) helps on going towards that way to treat past and future information. Noll states that ``if two states are different . . . then there must be some process which produces different stresses with the two states as initial states". If we accept this axiom, and if we agree that in our case the processes are the continuations, we may conclude that two histories whose difference produces zero residual stress for all future times must correspond to the same state. If we assume that the current deformation is independent of the past history, then we are led to define a state as a pair whose entries are an equivalence class of histories and a deformation. The deformation is the current deformation, and two histories are equivalent if their difference produce the same residual stress for all times.
With these definitions of process and state, we identify a system, and we use the general results of that theory to study some basic questions of linear viscoelasticity which have long been debated by several authors. One of such

question is the characterization of the state space. Unlike the usual choice of history-deformation pair there is, however, an important exception, that of the viscoelastic materials of rate type, for which the relaxation function is a linear combination of exponentials. For such materials, a state is usually identified with a finite array of internal variables. Before this paper it was not clear, however, whether this choice is a matter of convenience or is dictated by some sort of general requirements. In the approach that we present here, the possible definitions of a state are strictly limited by the structure of the solution set of equation: Indeed, a state can be represented by a history-deformation pair if and only if the solution set reduces to the null history alone, so that the equivalence classes which constitute the first entry of a state reduce to singletons. For a relaxation function of exponential type, we show in Section 6 that the finite dimensional characterization of a state is compatible with our definition, while the characterization as a history-deformation pair is not. This result can be easily extended to all viscoelastic materials of rate type. We also produce an example of a class of completely monotonic relaxation functions for which the equivalence classes are singletons, and therefore the states are correctly described by history-deformation pairs.
Another question which we consider here is that of the topology of the state space. When a state is defined as a history-deformation pair, it is natural to define the state space as the product of the space of histories and the space of deformations, and to endow it with the product norm of the two spaces. The norm chosen for the space of histories is usually the fading memory norm of Coleman and Noll suggested by the physical consideration that the response of a material with memory is more influenced by the deformations undergone in the recent past than by those that occurred in the far past. In effect, as shown by the weaker fading memory assumptions made by Volterra, Graffi and Day, a fading memory effect is implicit in the constitutive equation (1.1), provided that the relaxation function decays to its equilibrium value sufficiently fast. The main reason for the success of the approach of Coleman lies in the far reaching consequences of *the principle of the fading memory*, which is an assumption of continuity of the constitutive functionals in the topology induced by the fading memory norm. Under this assumption, many general properties of materials with memory have been proved, such as some restrictions and interrelations for the constitutive functionals, and the minimality of the equilibrium free energy in the set of all states having the same current deformation. In this paper, in the more limited context of linear viscoelasticity, we obtain the same results in a more direct way. We endow the space of histories with a seminorm, which is a norm for the set of the equivalence classes determined by the histories solving the equation obtained by setting the residual stress to zero for all times. The sum of this seminorm and the norm of the space of deformations is a norm for the state space, and we use the topology induced by that norm. This choice plays an important role in the definition of the free energy, which is the central subject of the paper. Among the definitions present in the literature, we focus our attention on the definition given by Coleman and Owen, who define the free energy as a lower potential for the work.
The general results of their theory are then used to prove the existence of a maximal and of a minimal free energy, characterized as the minimum work done to approach a state starting from the natural state, and as the maximum work which can be recovered from a given state, respectively. In the special case of linear viscoelasticity, we found two additional properties beyond those shared by all systems and by all free energies. Namely, we prove that every state can be approached from every other state by a sequence of processes with the property that the sequence of the works done in these processes is convergent, and we prove that the minimal free energy is lower semicontinuous with respect to the topology that we have adopted for the state space. The last two sections are devoted to the study of two particular classes of viscoelastic material elements, characterized by relaxation functions of exponential type and by completely monotonic relaxation functions, respectively. For the first class, we generalize a result of Graffi and Fabrizio, asserting that there is just one free energy, whose explicit expression was determined by Breuer and Onate. We also show that some other functions, which are usually considered as appropriate to describe the free energy, are indeed not acceptable because they do not define a function of state for this specific class of relaxation functions.

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