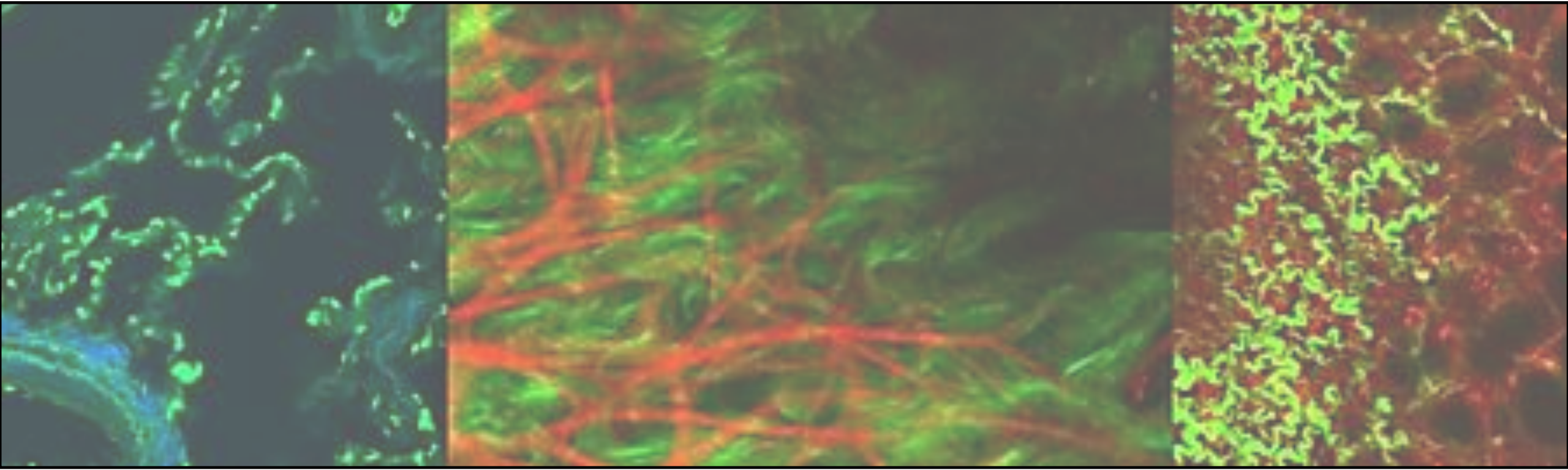
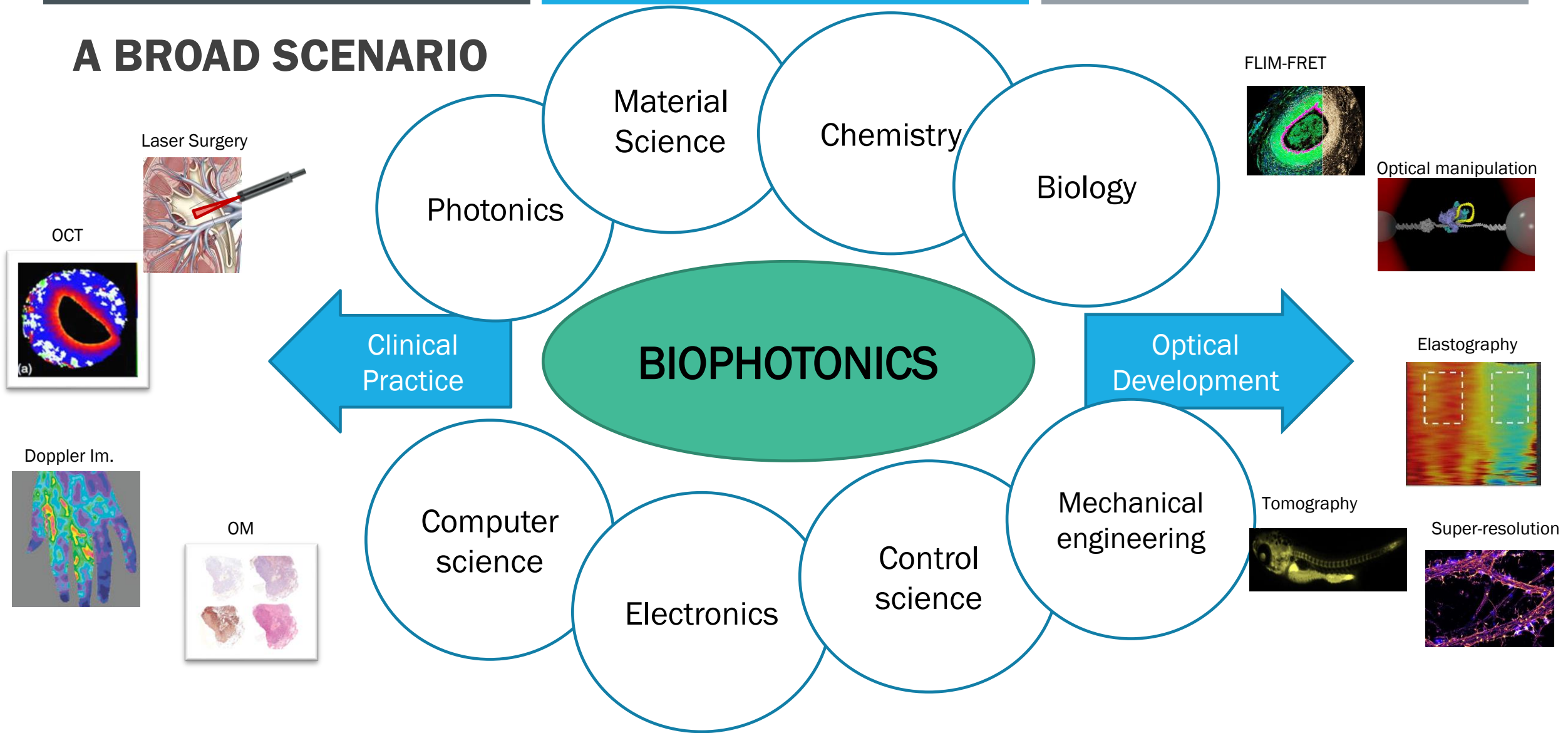

BIOFOTONICA ALLA NANO E MICRO-SCALA

MAURIZIO MATTARELLI, MARTINA ALUNNI CARDINALI, DANIELE FIORETTO (UNIPG)

SILVIA CAPONI (CNR)



A BROAD SCENARIO

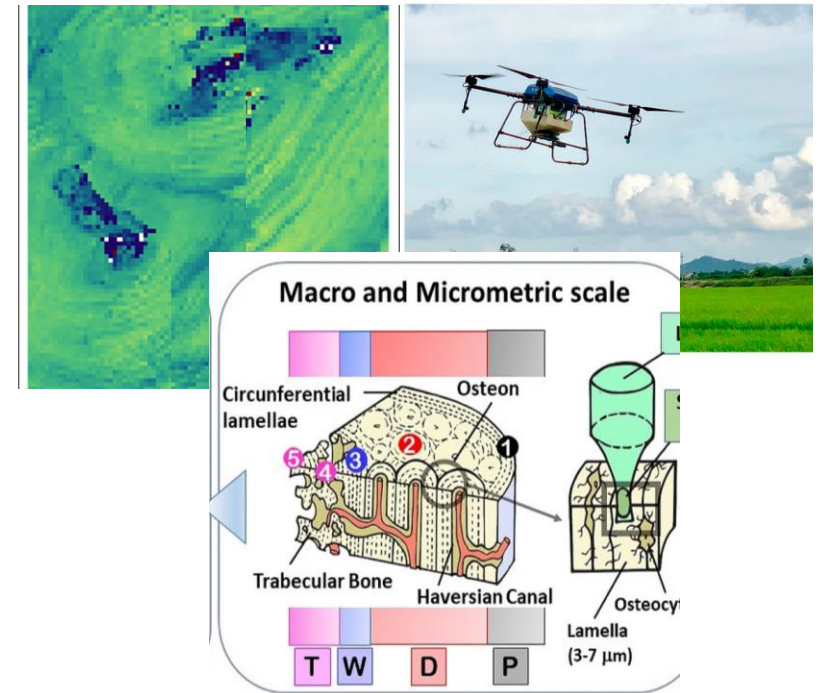
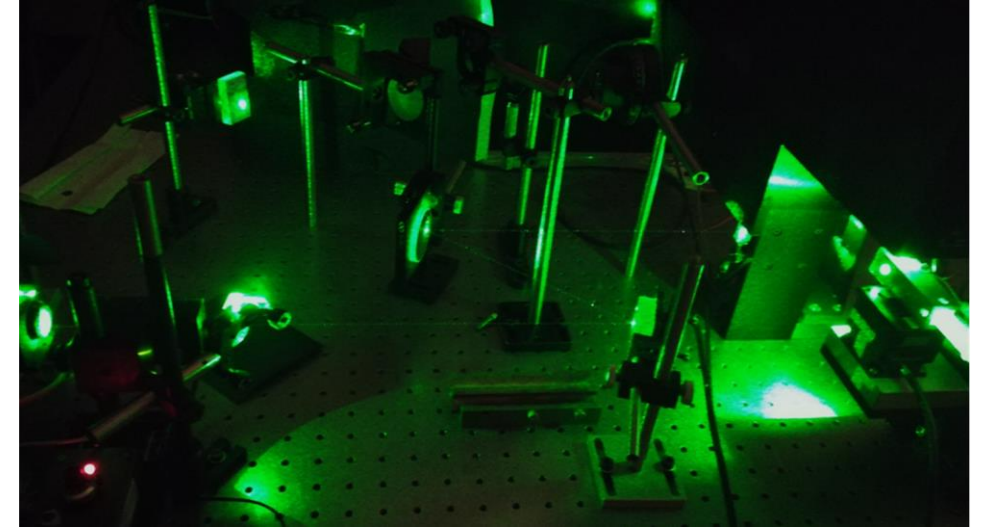


Physics touches many different aspects of this field:

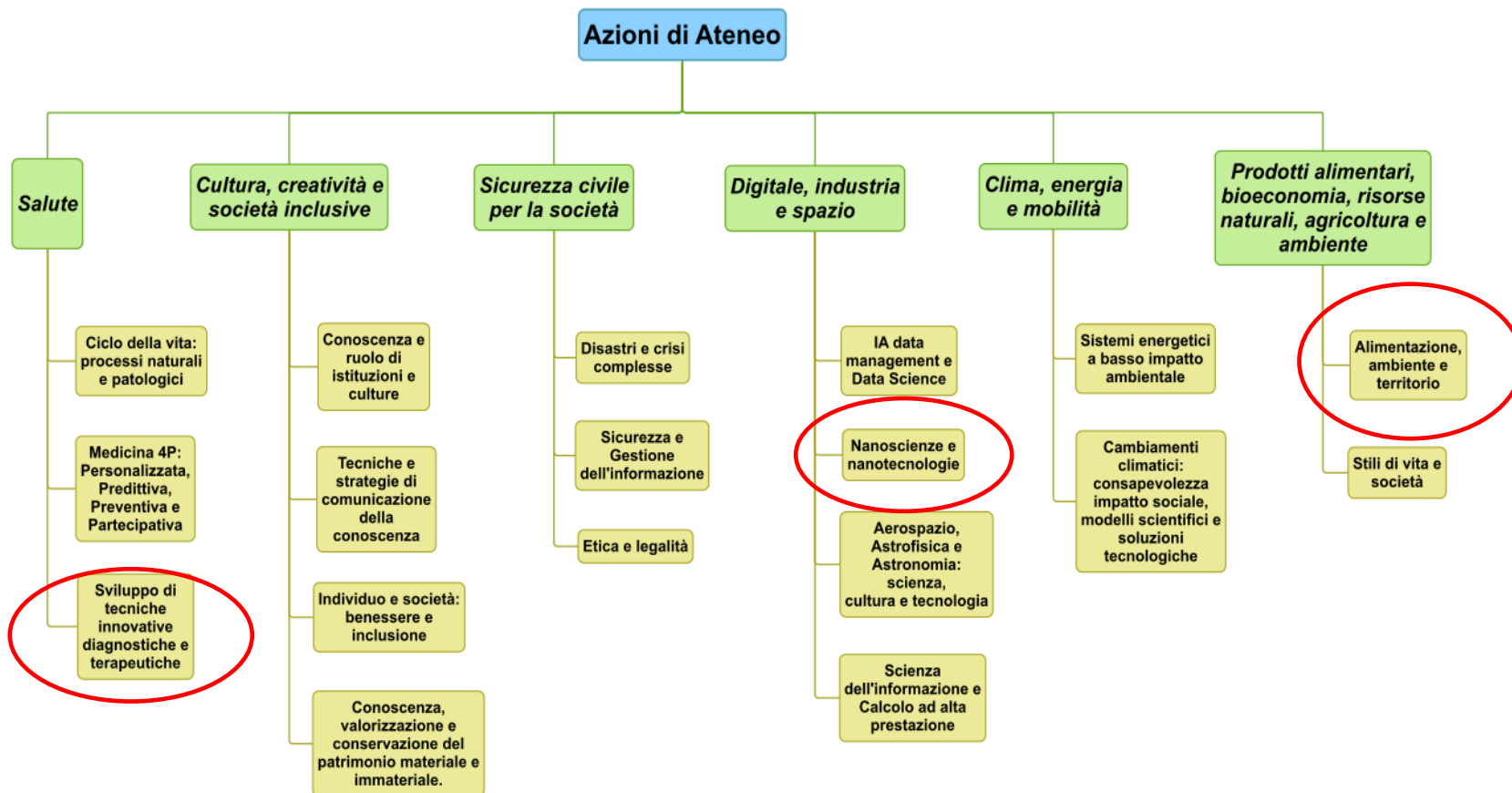
from the optics of the instrument design, to the interaction mechanism of light and matter, to biophysics (fundamental and diagnostics), to the design and characterization of biomimetic materials

BIOPHOTONICS

- Disegno e realizzazione di **strumenti per la spettroscopia ottica e per l'imaging spettroscopico**.
- Studio, anche a scopo diagnostico, delle **proprietà meccaniche e molecolari in cellule e tessuti** quali colture microbiche, tessuti ossei, placche di Alzheimer, tessuti epiteliali sani e tumorali.
- Spettroscopia e Imaging per **l'Agricoltura di precisione**
- Proprietà elastiche di sistemi nanostrutturati per applicazioni di interesse biologico – **Bio materiali**



E IN ATENEO



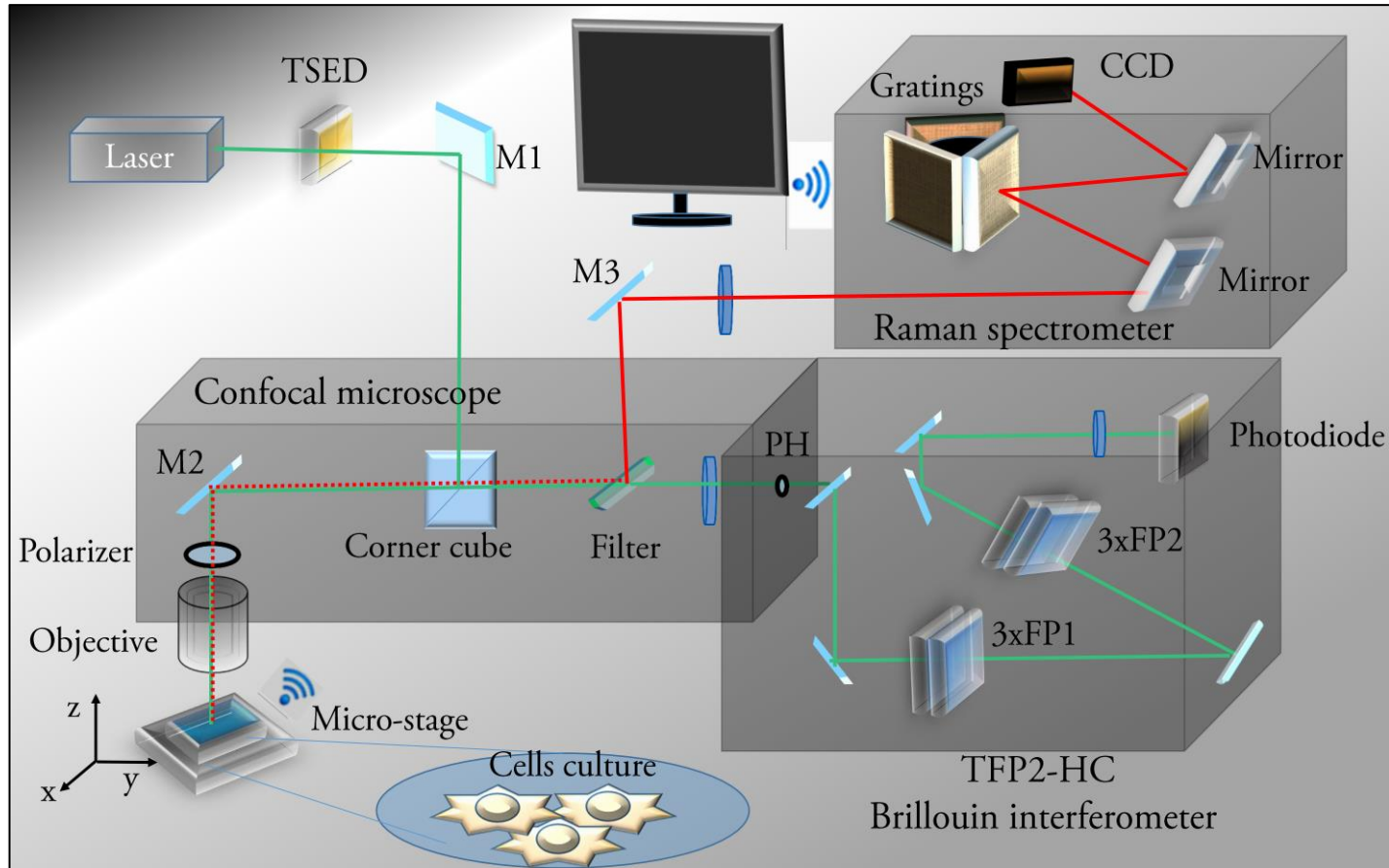
C-labs:

- 1) Imaging & Spettrometria
- 2) Computing & Data Management
- 3) Meccatronica

Didattica:

- 1) Tecnologie di Imaging (Biotecn.)
- 2) Caratterizzazione Chimica e fisica dei materiali (Ing. Industr.)
- 3) Laboratorio di ottica geom./avanzata (Ottica - Optometria.)
- 4) Metodologie spettroscopiche e di imaging per la caratterizzazione dei materiali (Ottica.-Optometria)

NEW SETUP FOR SIMULTANEOUS μ -BRILLOUIN AND μ -RAMAN SPECTROSCOPY



F. Scarponi et al. PRX 7, 031015 (2017);

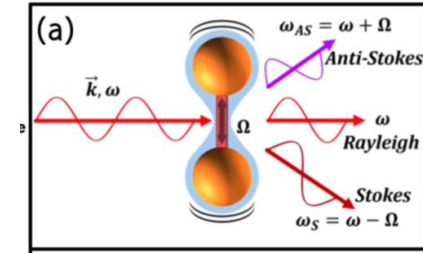
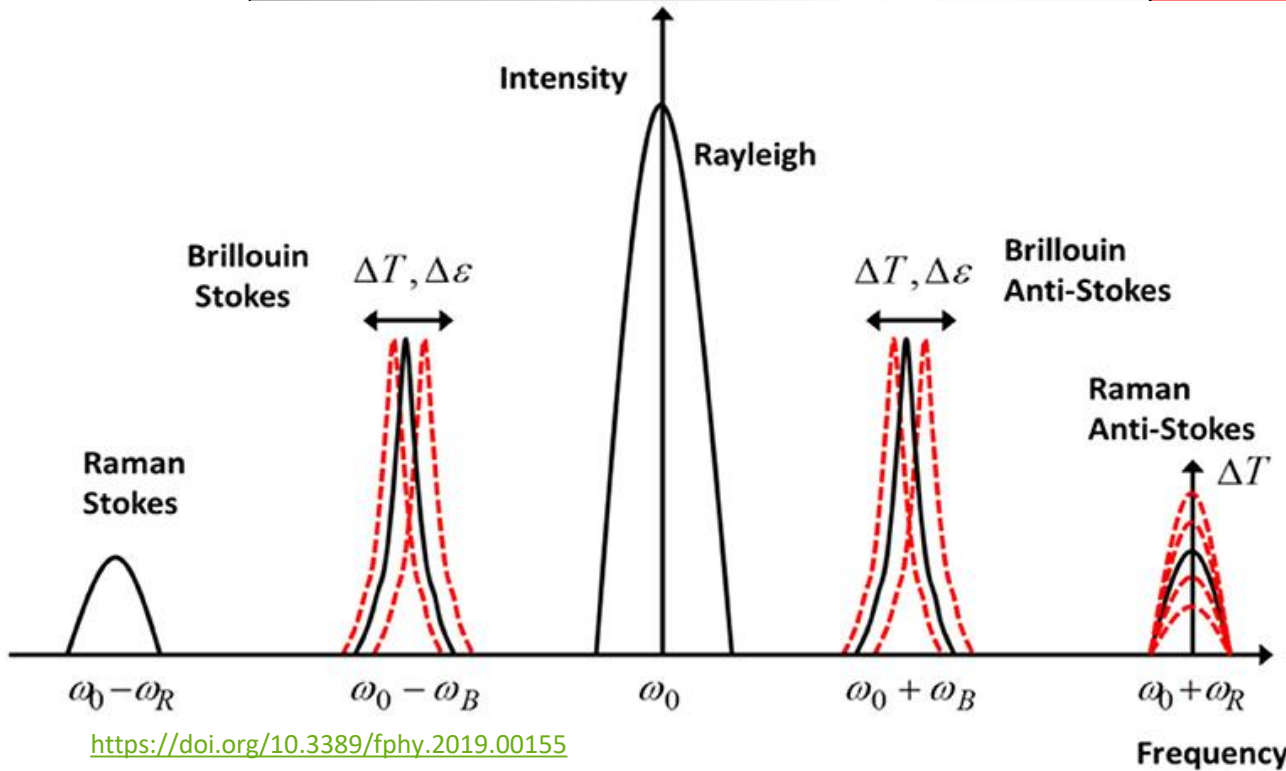
S. Mattana et al. Nature Light: Science & Applications 7, 17139 (2018);

R. Mercatelli et al. Nature: Comms Biology 2 117 (2019).

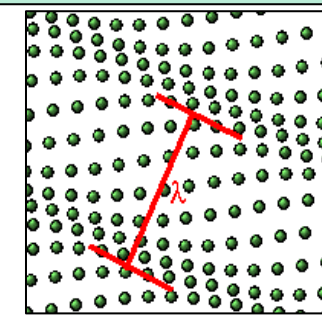
NEW SETUP FOR SIMULTANEOUS μ -BRILLOUIN AND μ -RAMAN SPECTROSCOPY

vibrational modes of molecules

Optical properties - composition, structure

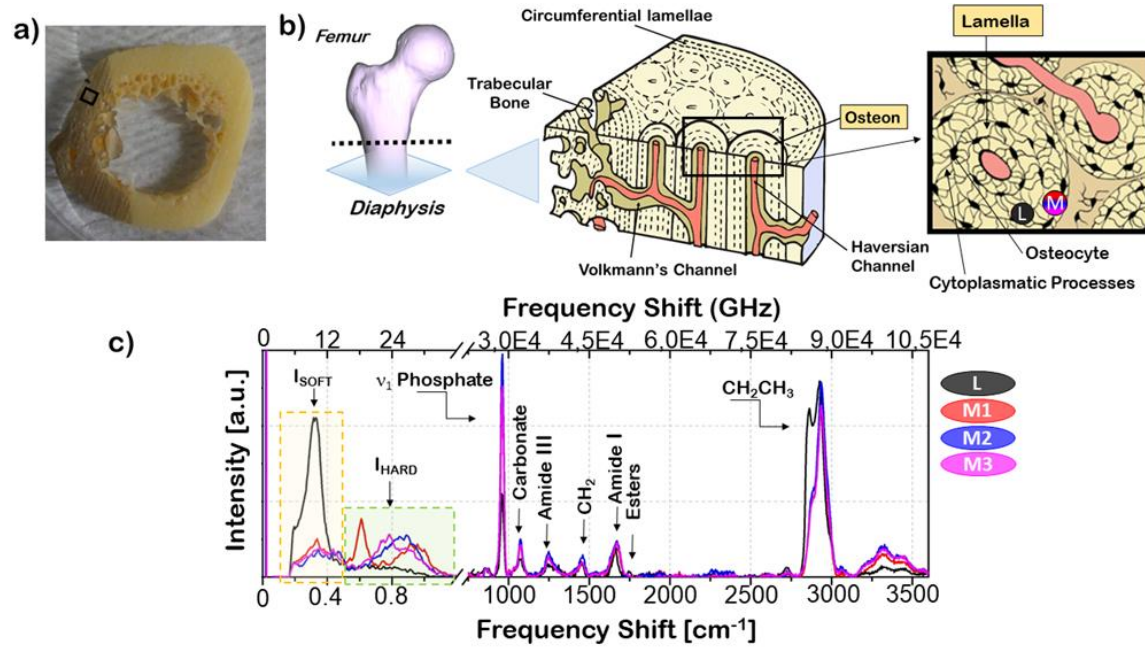


thermally activated acoustic waves
 Mechanical properties
 In the continuum description

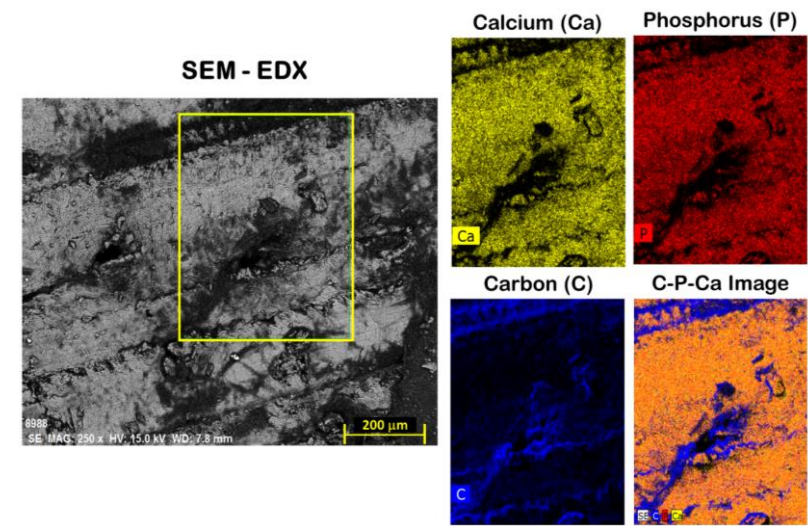
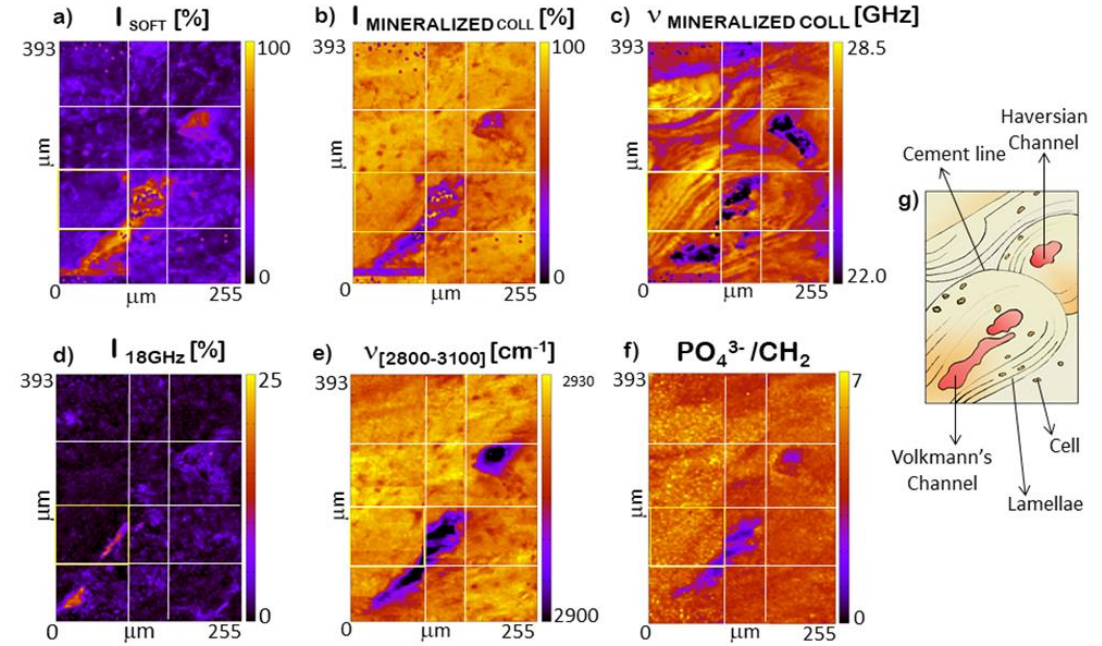


F. Scarponi et al. PRX 7, 031015 (2017);
 S. Mattana et al. Nature Light: Science & Applications 7, 17139 (2018);
 R. Mercatelli et al. Nature: Comms Biology 2 117 (2019).

MICRO IMAGING OF BONE TISSUES



L'osso ha un'architettura sofisticata caratterizzata da un'organizzazione gerarchica, a partire dal livello sub-micrometrico. L'imaging iperspettrale Raman e Brillouin, accompagnato dal SEM, è molto adatto ad evidenziare le proprietà chimico meccaniche su diverse scale. Il risultato è una migliore comprensione del rapporto tra struttura e funzionalità, utile sia per studiare l'insorgenza di patologie che per sviluppare biomateriali compatibili.

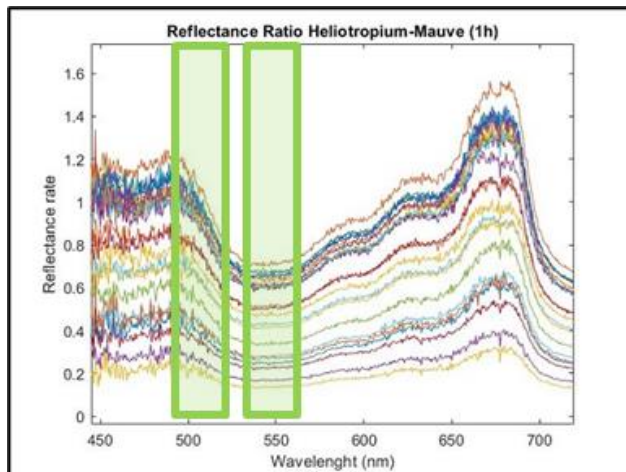
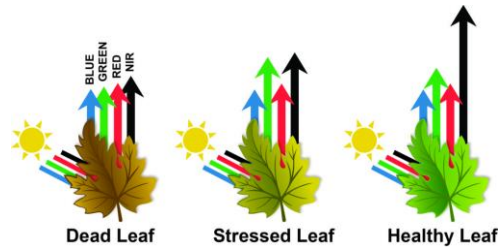


M Alunni Cardinali et al, Journal of the Royal Society Interface 19 (187), 20210642 (2021)
M Alunni Cardinali et al., Materials 14 (22), 6869 (2021)
M Alunni Cardinali et al., Scientific Reports 10 (1), 1-11 (2020)
M Alunni Cardinali et al., Biomedical optics express 10 (5), 2606-2611 (2019)

AGRICOLTURA DI PRECISIONE

Imaging di riflettanza.

- Comparazione risultati per piante officinali ed infestanti (o sane/malate)
- Individuazione tramite machine learning delle regioni spettrali in cui le piante officinali e infestanti (sane/malate) sono maggiormente distinguibili.
- Sviluppo di strumentazione per l'acquisizione delle immagini
- Determinazione di un protocollo di riconoscimento tramite fotogrammetria (drone aereo o terrestre).



Eliotropio



Malva



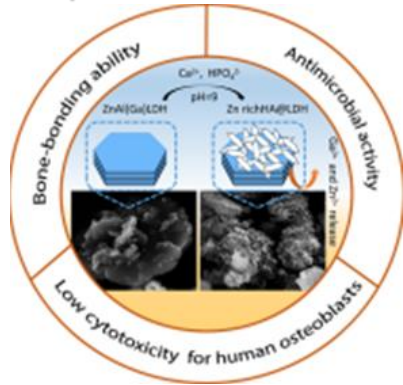
Malattia

20 m



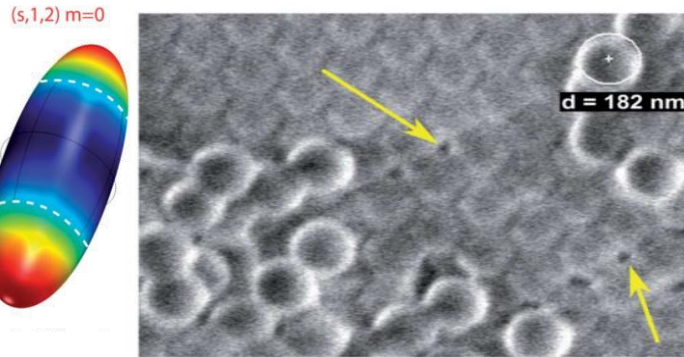
BIO MATERIALI

Biocompatible materials



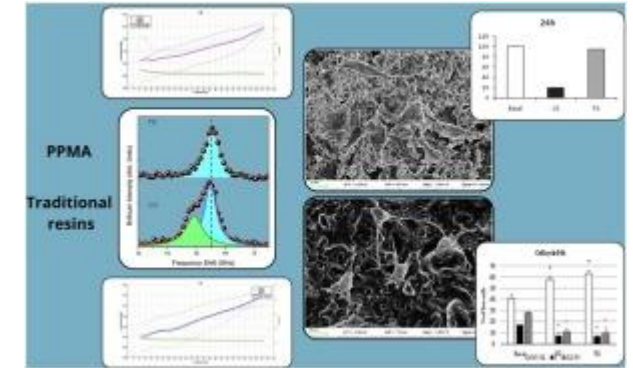
Donnadio et al., ACS Biomaterials Sci. Eng (2021)

Functionalized Nano-particles



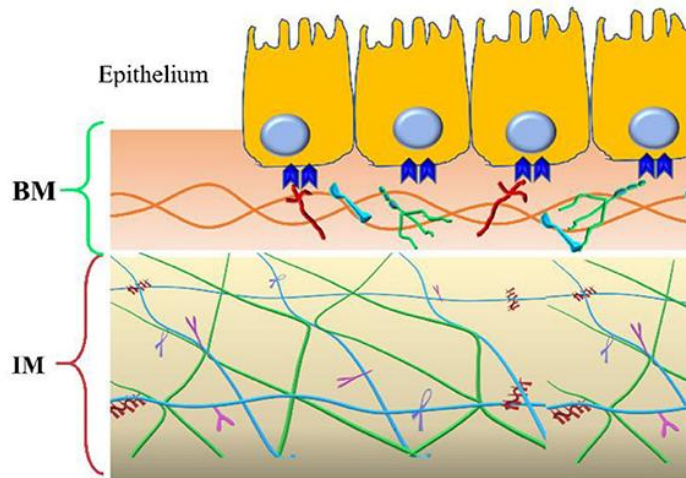
Mattarelli et al., Soft Matter (2012)

Dental resins

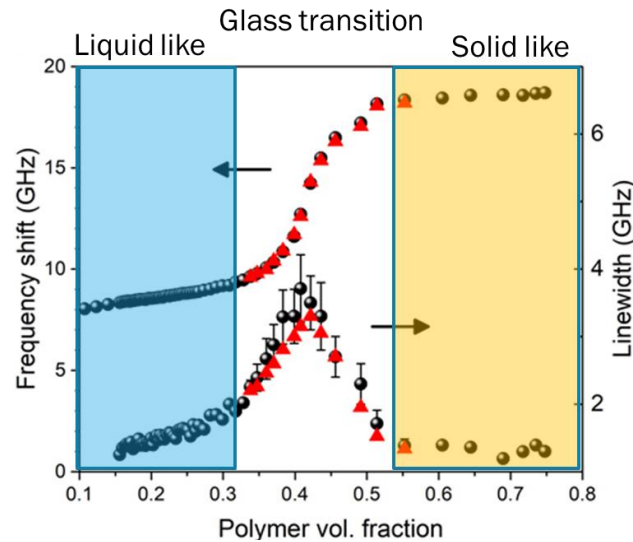


Pagano et al., Dental Materials 37 (2021) e118–e130

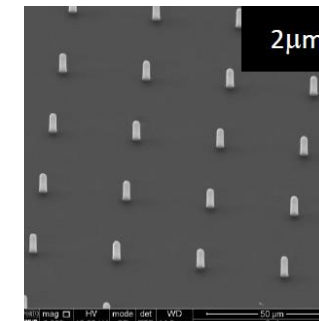
Biomimetic materials : ECM



<https://doi.org/10.3389/fmed.2021.610189>

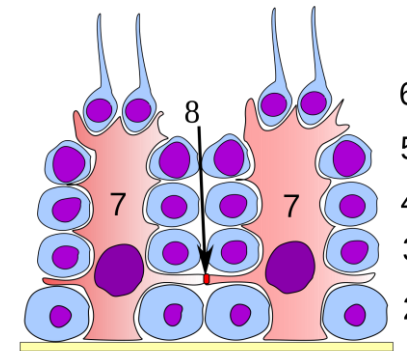


M Bailey et al., Science advances (2020)



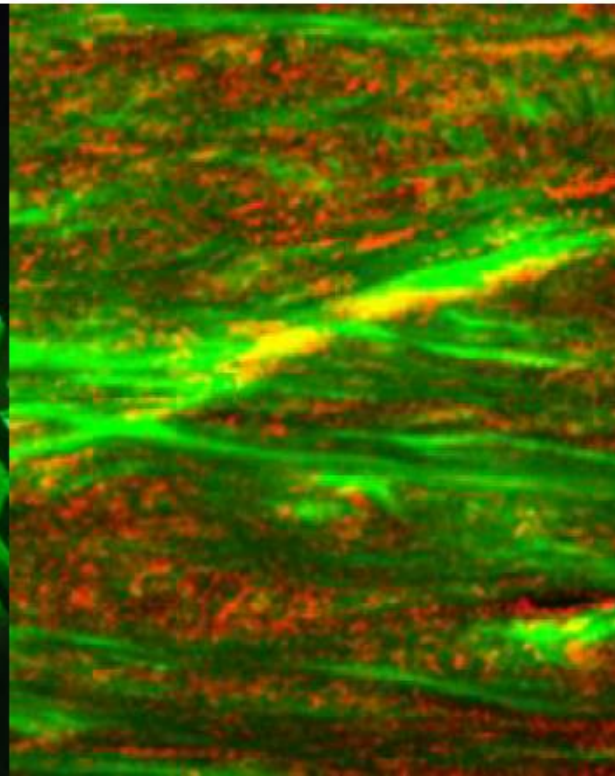
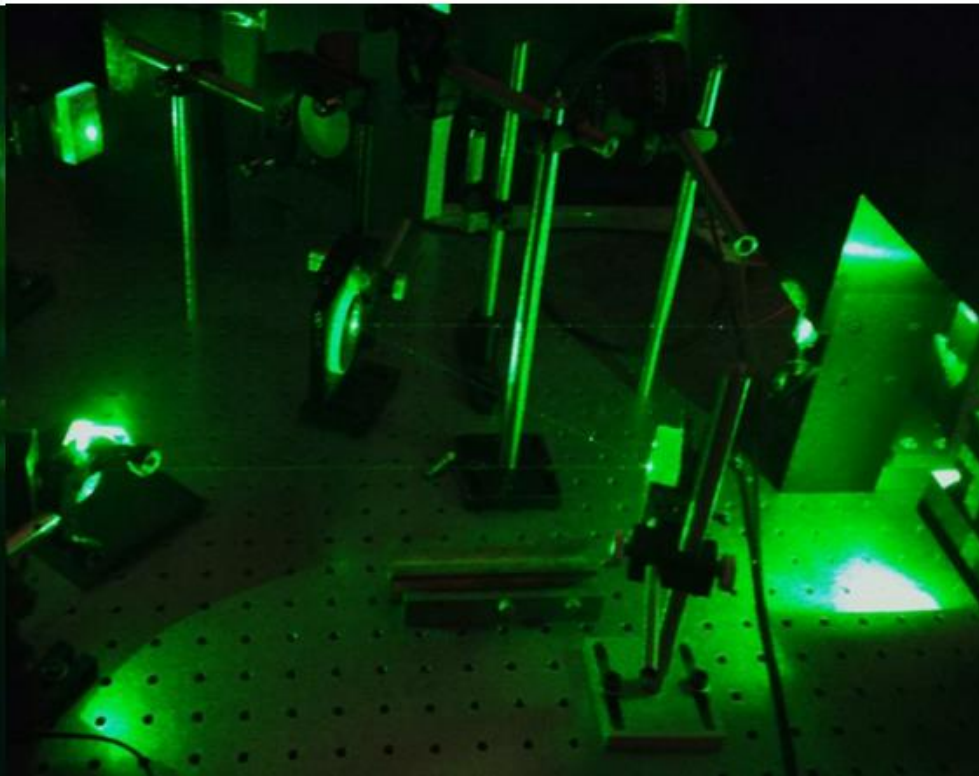
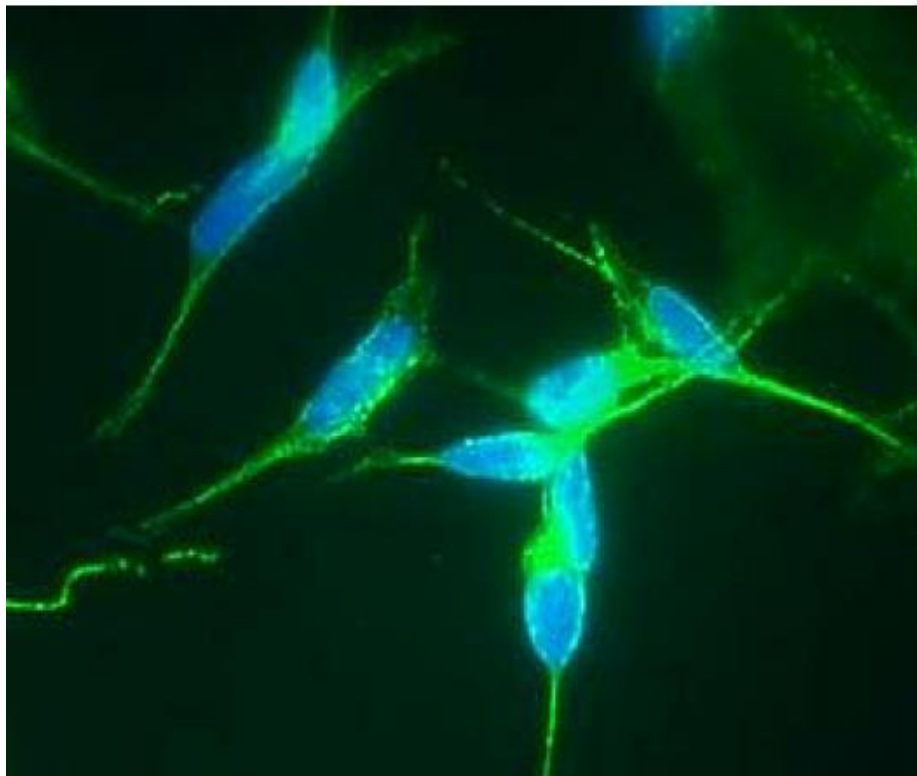
PDMS
Micropillars

Organoids Sertoli Cells



FOTONICA APPLICATA A MATERIALI DI INTERESSE BIOLOGICO

silvia.caponi@cnr.it
CNR-IOM Perugia- ITALY

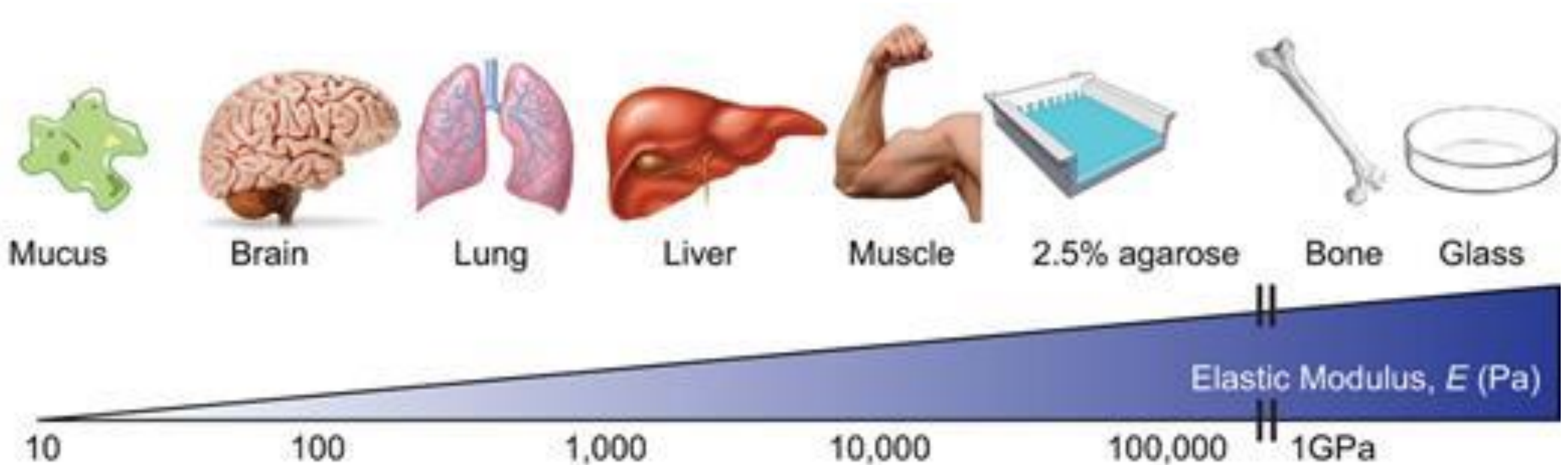


USING LIGHT TO PROBE AND IMAGE THE MATERIALS PROPERTIES:

BIOMECHANICS AND BIOCHEMISTRY

Mechanics in biology:

Tissues and cells shape, size and also mechanical properties strongly depend on their function

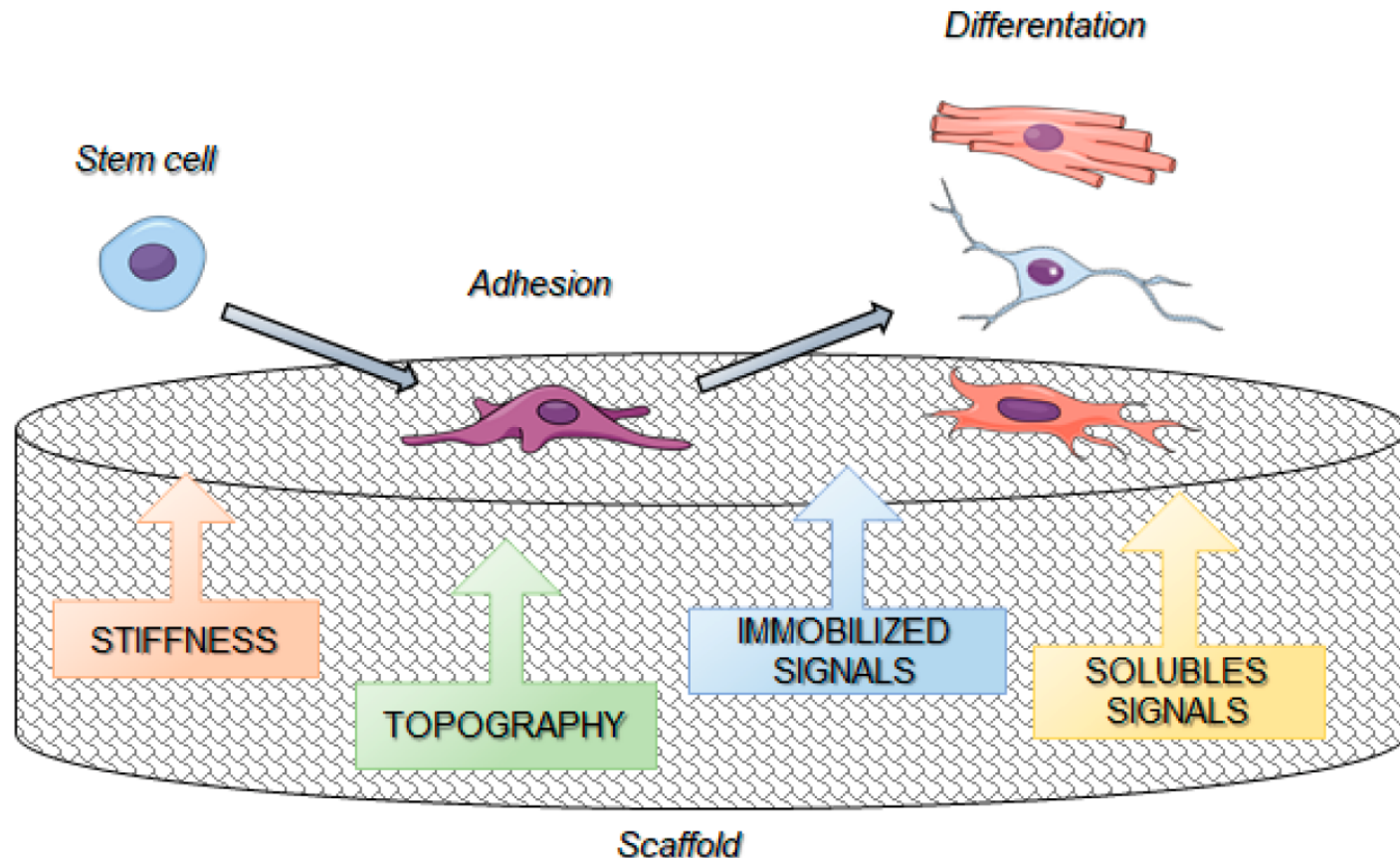


USING LIGHT TO PROBE AND IMAGE THE MATERIALS PROPERTIES:

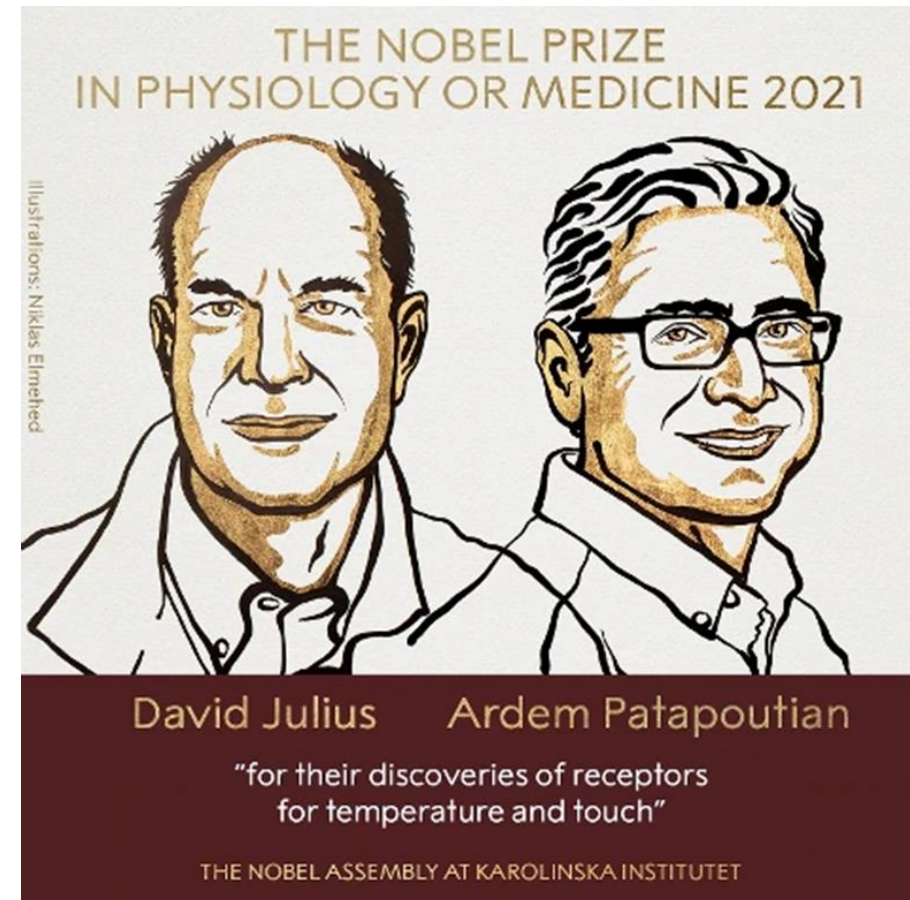
BIOMECHANICS AND BIOCHEMISTRY

Mechanics in biology:

Tissues and cells shape, size and also mechanical properties strongly depend on their function



Cells 2019, 8, 1036; doi:10.3390/cells8091036



Simultaneous μ -Brillouin and μ -Raman spectroscopy

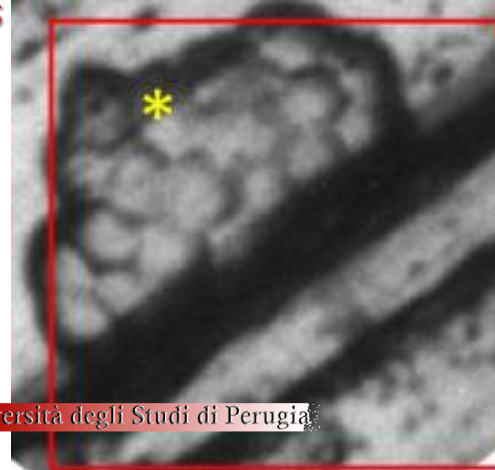
Living cells



Università degli Studi di Perugia

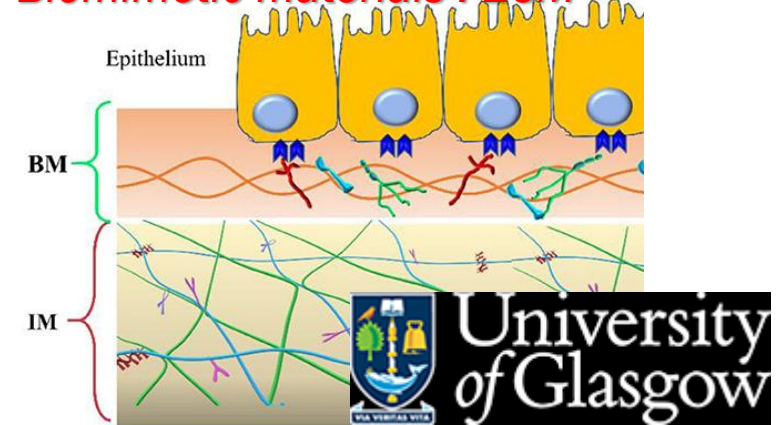


Biofilms



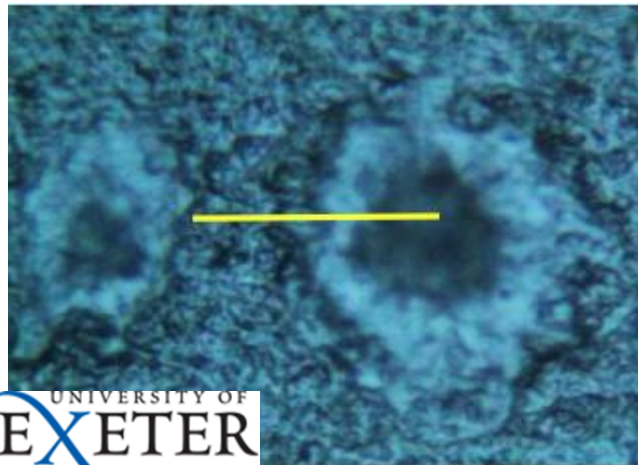
Università degli Studi di Perugia

Biomimetic materials : ECM

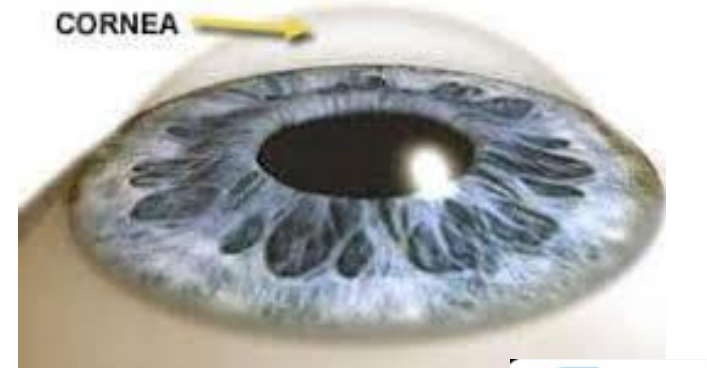


<https://doi.org/10.3389/fmed.2021.610189>

Amyloid Plaques in Transgenic Mouse Brain



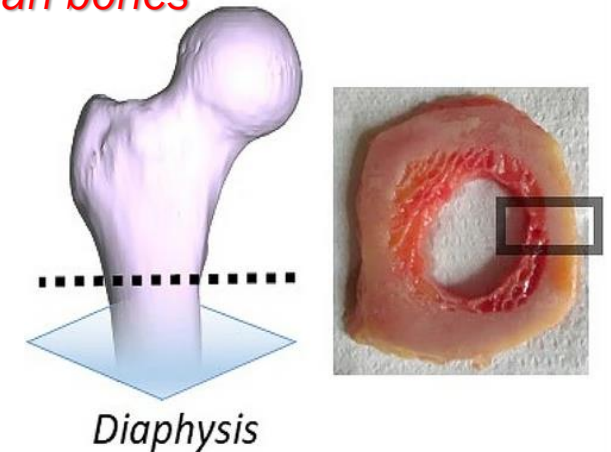
Human cornea



INO-CNR
ISTITUTO
NAZIONALE DI
OTTICA



Human bones



Istituto Ortopedico Rizzoli di Bologna
Istituto di Ricovero e Cura a Carattere Scientifico

BIOMECHANICS AT SUBCELLULAR SPATIAL RESOLUTION

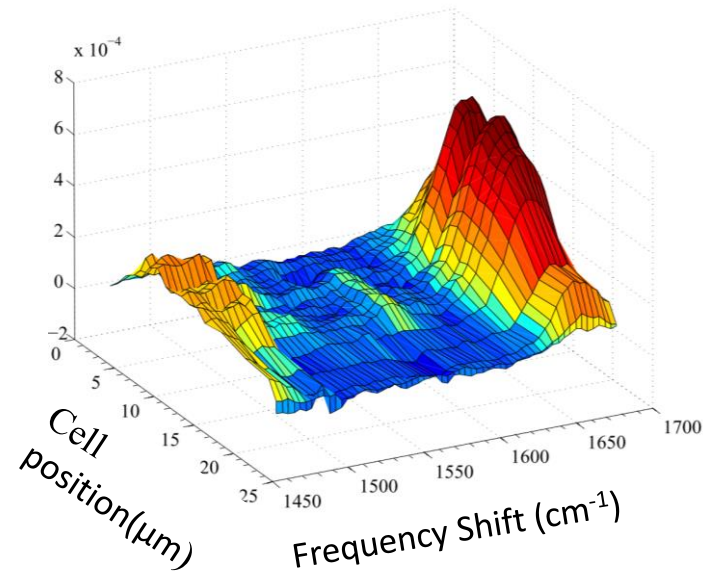
Living cells



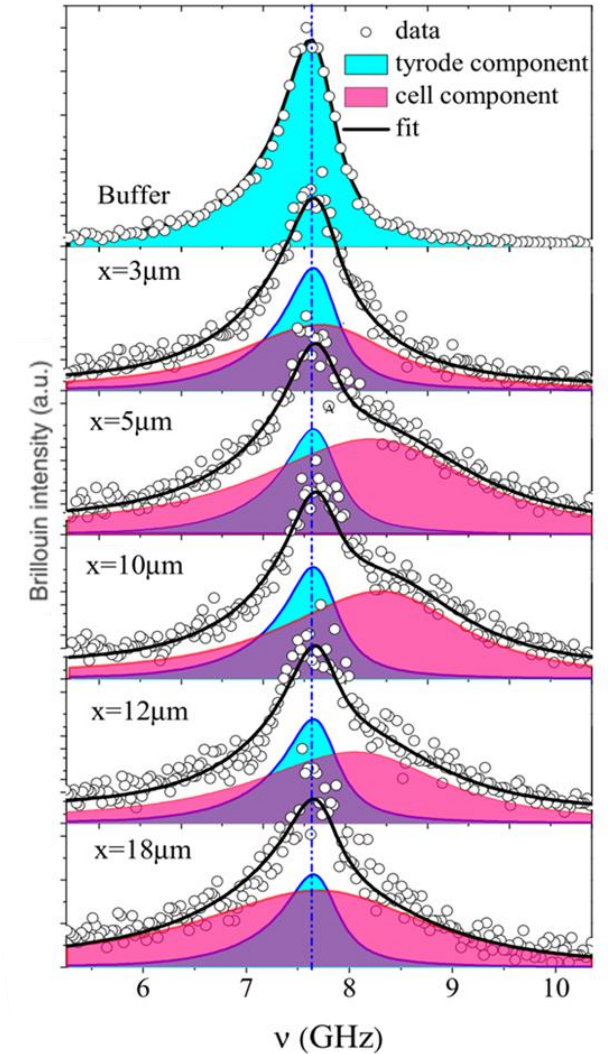
Università degli Studi di Perugia



Raman data



Brillouin data



$T=37^\circ\text{C}$

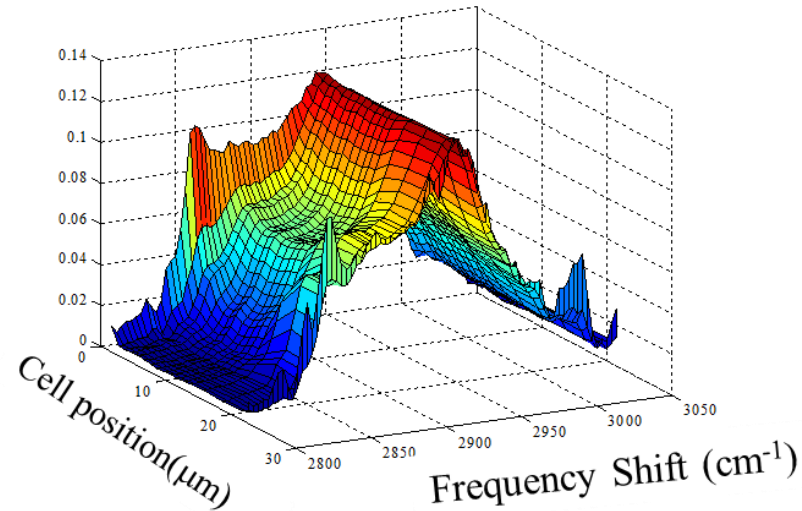
NIH 3T3 fibroblasts



$10\ \mu\text{m}$

nature.com > light: science & applications

Light Science & Applications



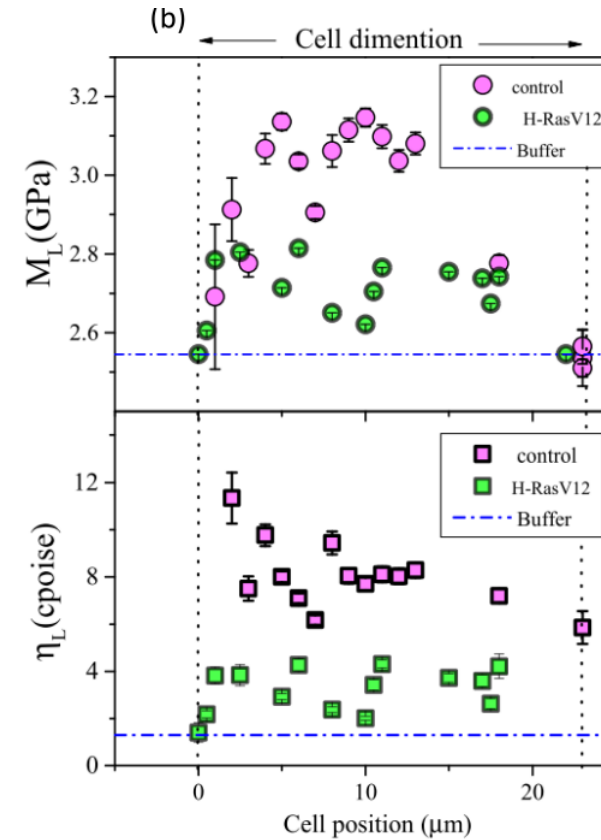
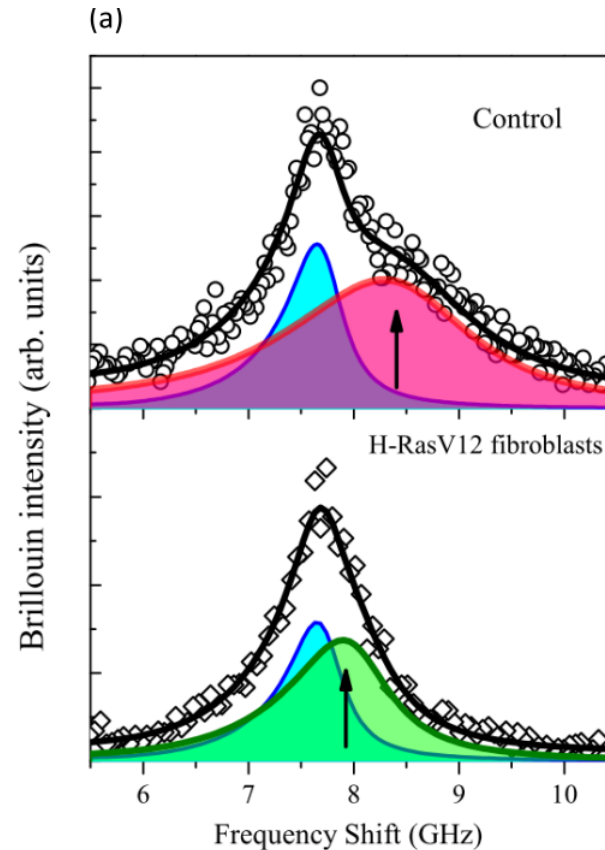
BIOMECHANICS AT SUBCELLULAR SPATIAL RESOLUTION

Diagnostic potential of cells after oncogene expression

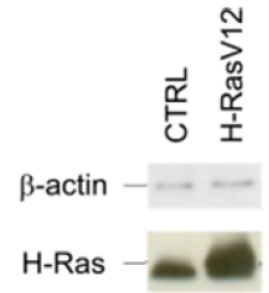
nature.com > light: science & applications

Light Science & Applications

Living cells



(c)



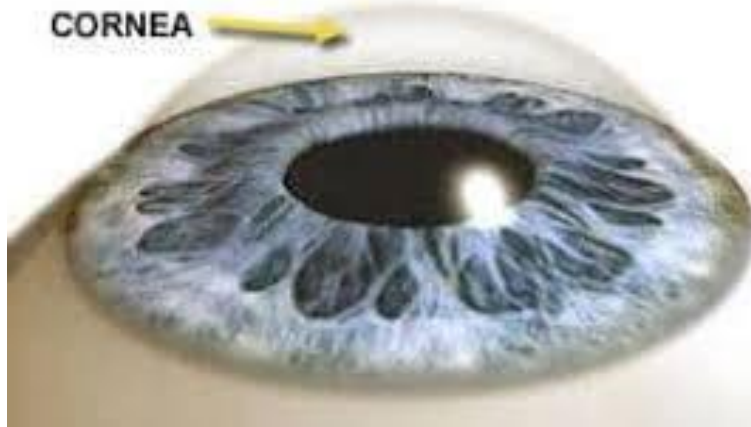
HUMAN TECHNOPOLE

NATIONAL PLATFORM ON "CELLULAR & MOLECULAR IMAGING" realizzazione di infrastrutture di ricerca presso lo Human Technopole a Milano (IT)

Nature- Light: Science and Applications **7**, 17139 (2018)

BIOMECHANICS AT SUBCELLULAR SPATIAL RESOLUTION ON TISSUES

Human cornea



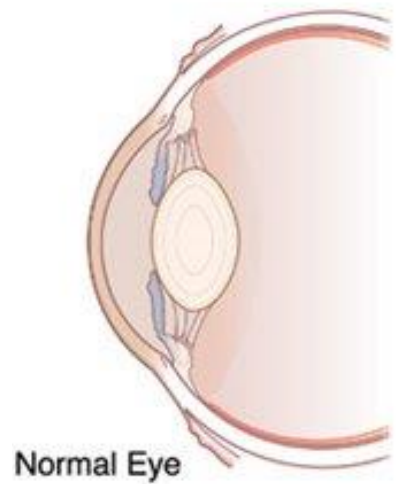
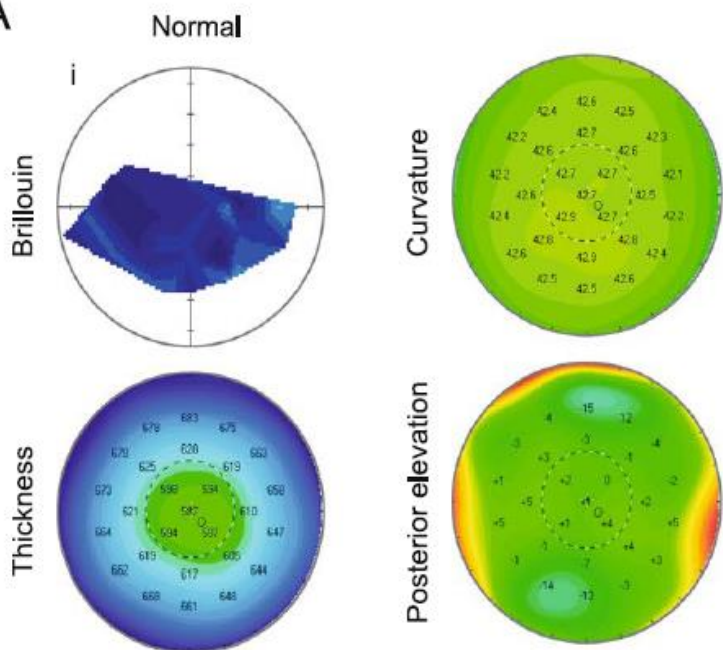
The first in vivo Brillouin imaging effort was reported by a team at Harvard Medical School, aiming at evaluating biomechanical properties of cornea and crystalline lens in animal models, and then in human in 2012.

JAMA Ophthalmology April 2015 Volume 133, Number 4

healthy cornea

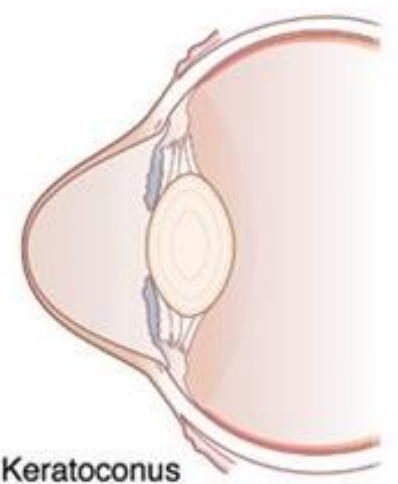
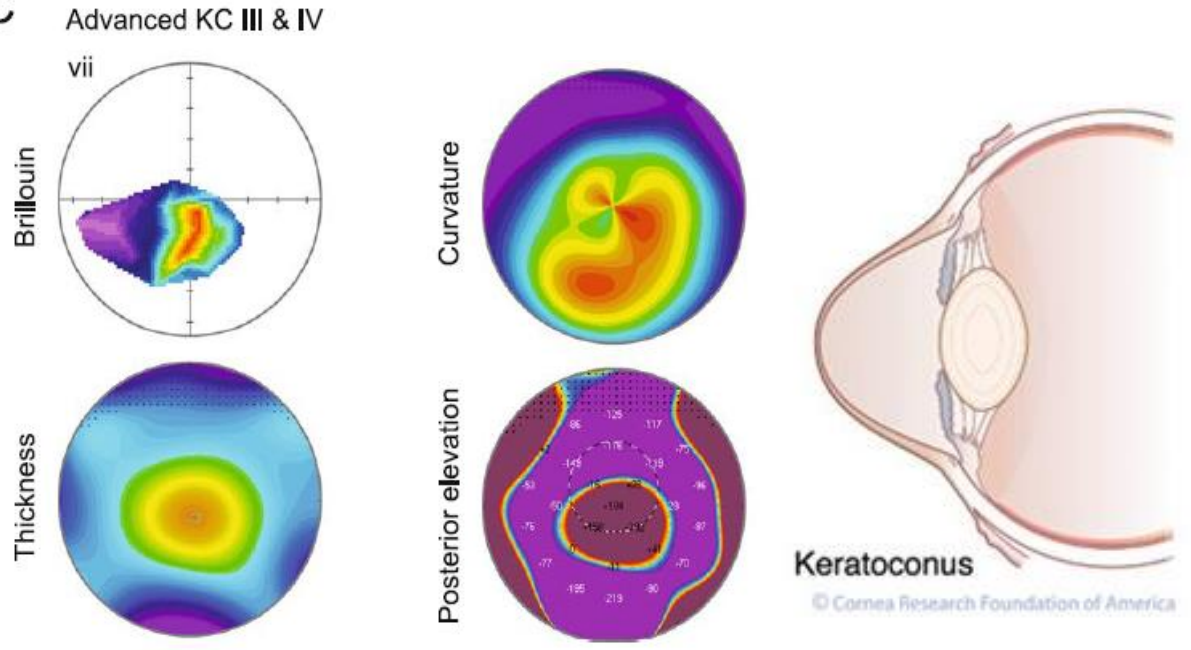
cornea with advanced keratoconus

A



Normal Eye

C

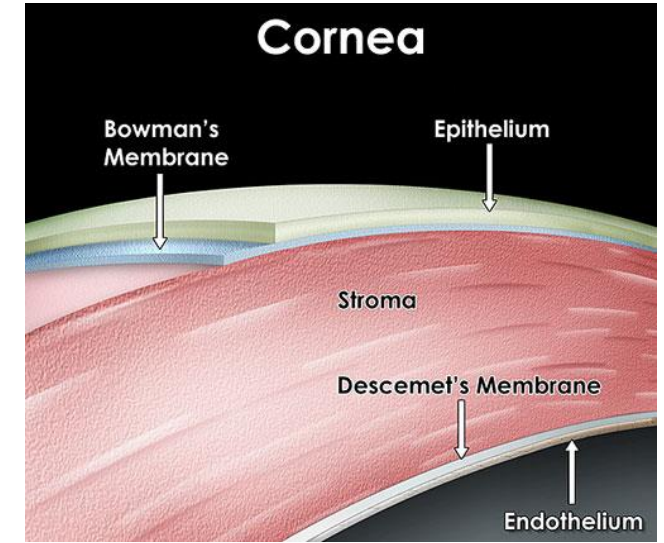
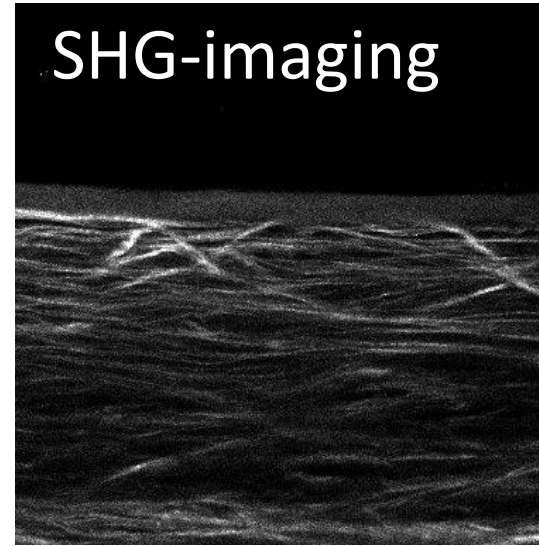
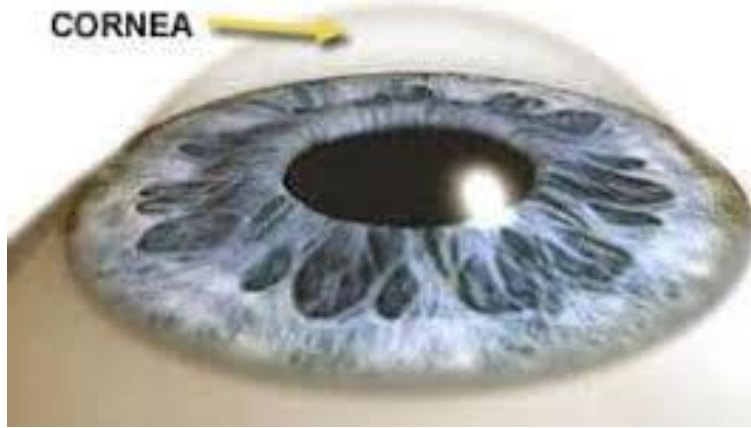


Keratoconus

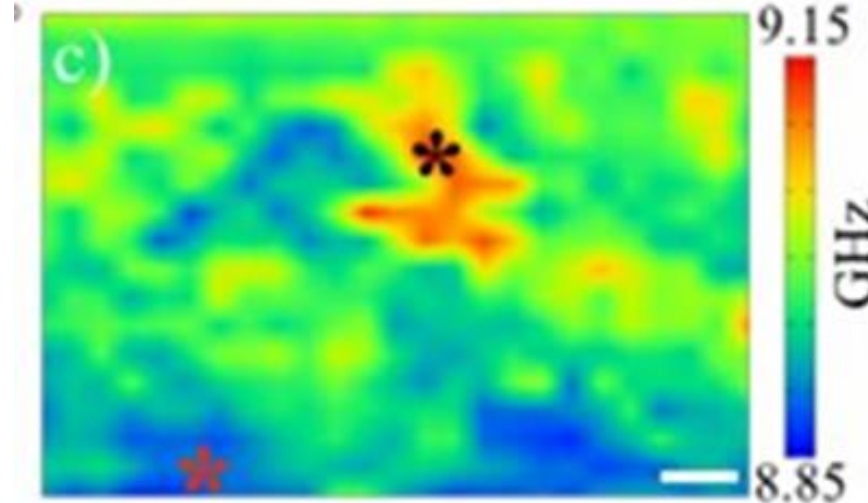
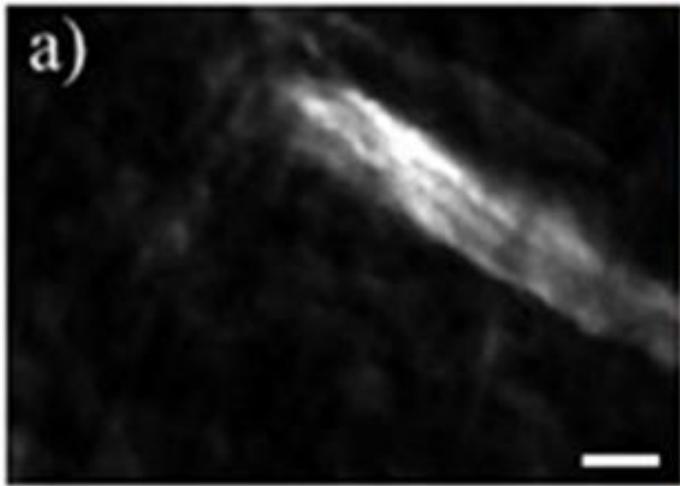
© Cornea Research Foundation of America

Biomechanics at subcellular spatial resolution on tissues

Human cornea



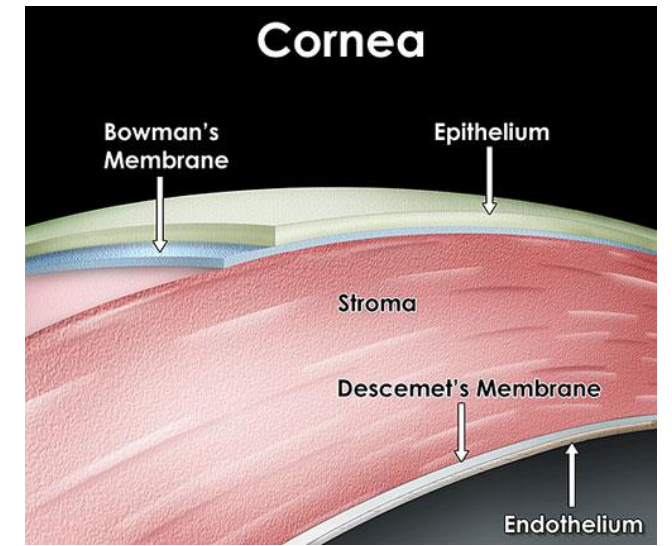
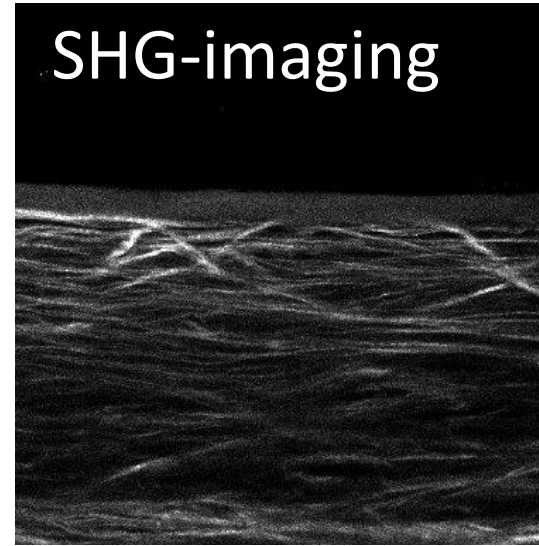
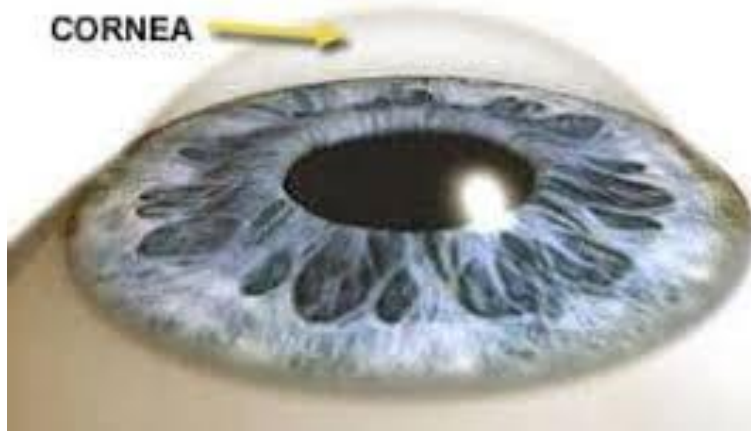
The **sutural lamellae**, immediately below Bowman's



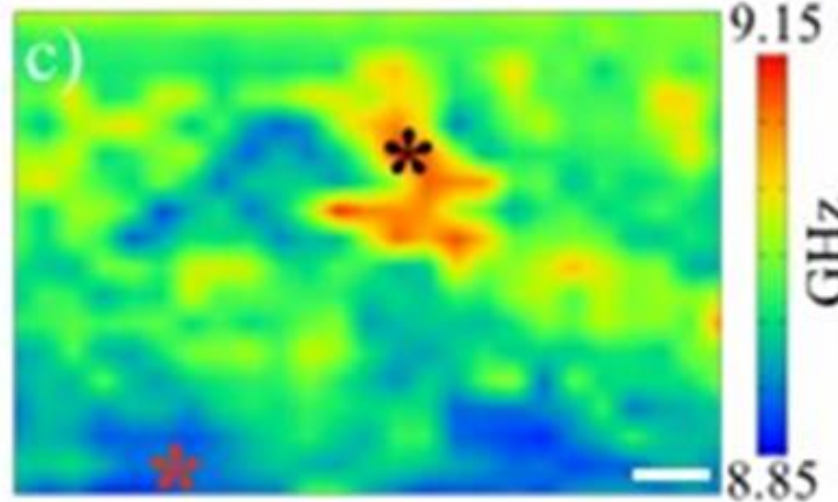
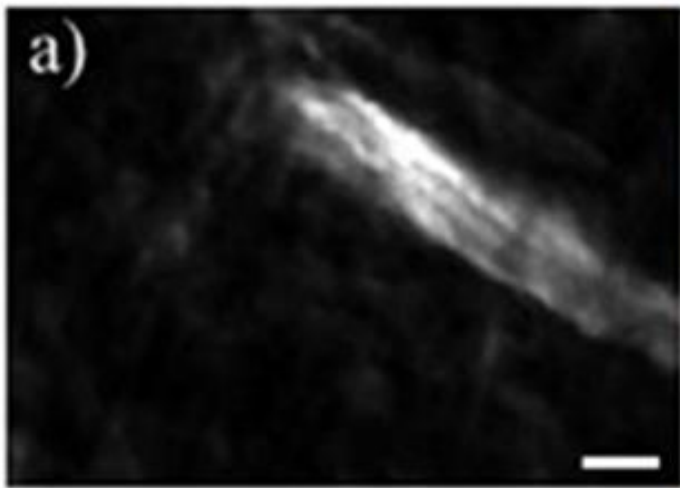
The use of a correlative approach was the key to achieve a deeper morphological interpretation of the mechanical properties, otherwise inaccessible to ordinary methods based on a single mechanism of optical contrast.

Biomechanics at subcellular spatial resolution on tissues

Human cornea



The sutural lamellae, immediately below Bowman's



A.D. 1308
unipg
UNIVERSITÀ DEGLI STUDI
DI PERUGIA

Formazione:

Corso di laurea in Ottica e optometria

Progettualità:

Sviluppo di strumentazione
diagnostica per misurazioni in vivo

COLLABORAZIONI

UNIPG :

**Chimica Biologia Biotecnologie
Scienze Farmaceutiche
Medicina e Chirurgia
Ingegneria dei materiali**

Nazionali:

**Lens
Istituto Rizzoli (BO)
UniGe
CNR-IBF (Trento, Genova)
CNR-INO (Firenze)
IFOM (Milano)
CREA (Roma)**

Internazionali:

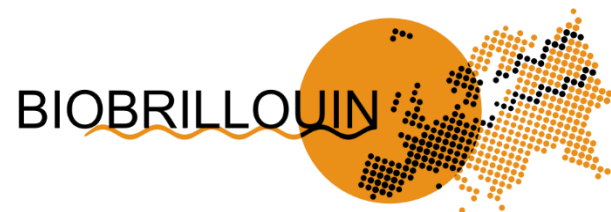
**Società BioBrillouin (board members)
University of Glasgow
University of Exeter
Università di Porto**

SVILUPPI FUTURI

Sviluppo di strumentazione

- **Human Technopole Milano**
- **Oculistica**
- **Sensori per droni (CREA)**

**PNRR: Centro Nazionale Agritech (NA)
Ecosistema per l'innovazione (UNIPG)**



THE ROYAL SOCIETY

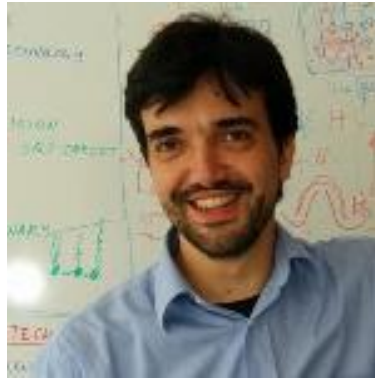
IL GRUPPO DI RICERCA IN BIO-FOTONICA



S. Caponi



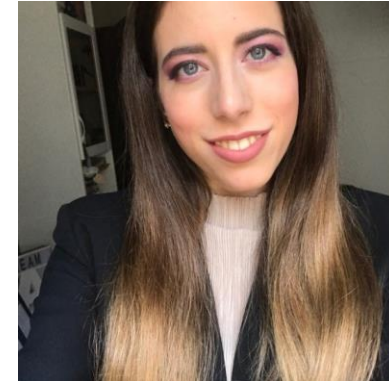
D. Fioretto



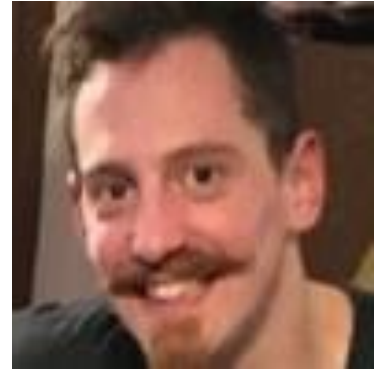
M. Mattarelli



M.A. Cardinali



A.A. Passeri



G. Capponi

