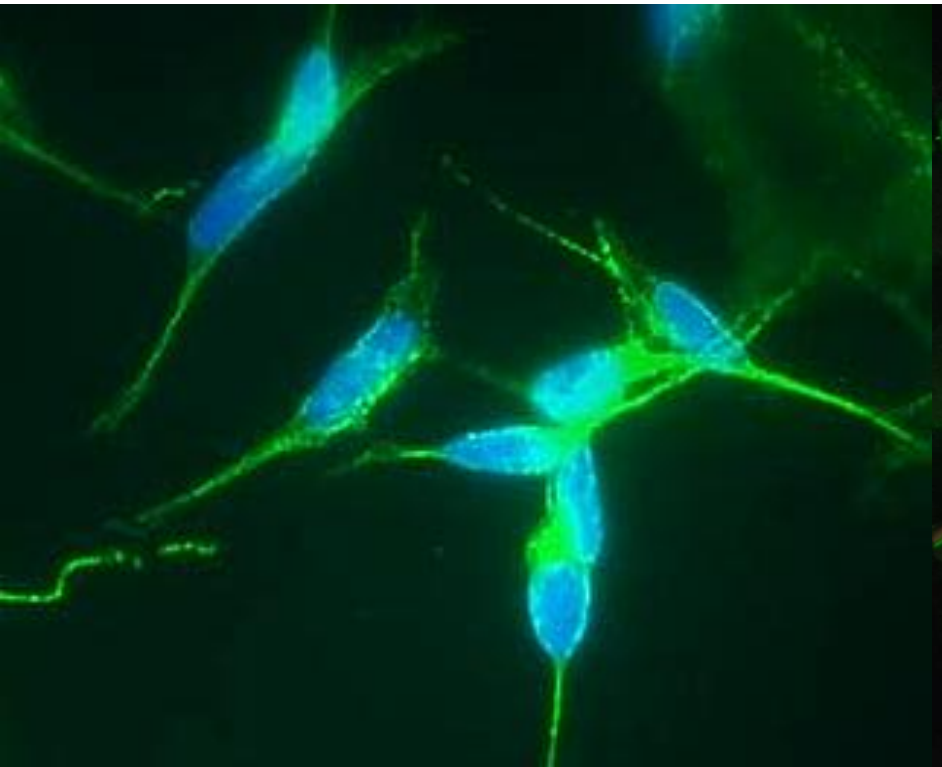
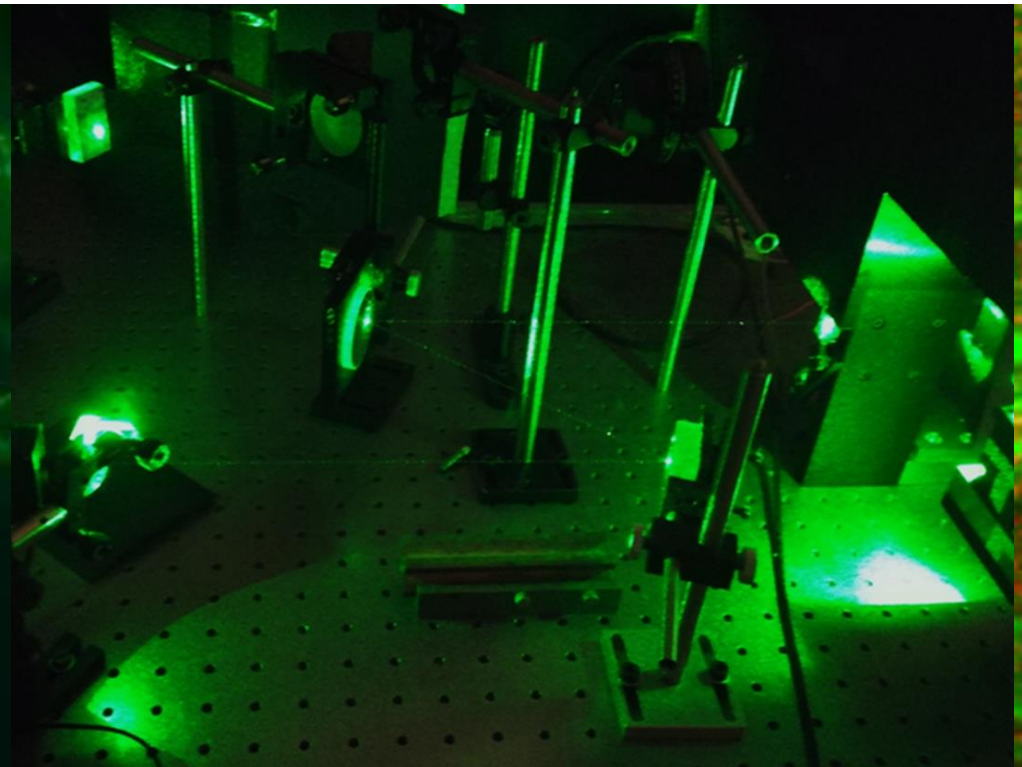
BIOPHOTONICS: BRINGING LIGHT INTO LIFE SCIENCES

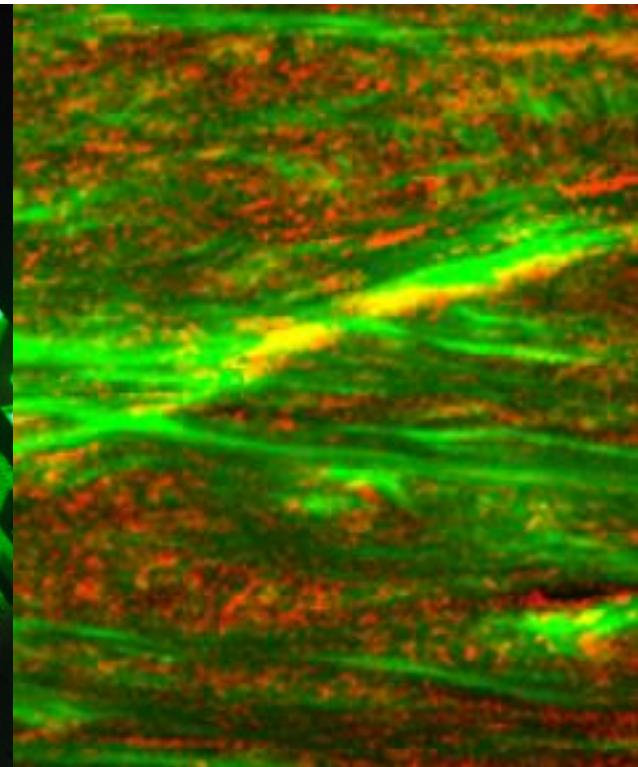
MAURIZIO MATTARELLI, DANIELE FIORETTO (UNIPG)

SILVIA CAPONI (CNR) caponi@iom.cnr.it

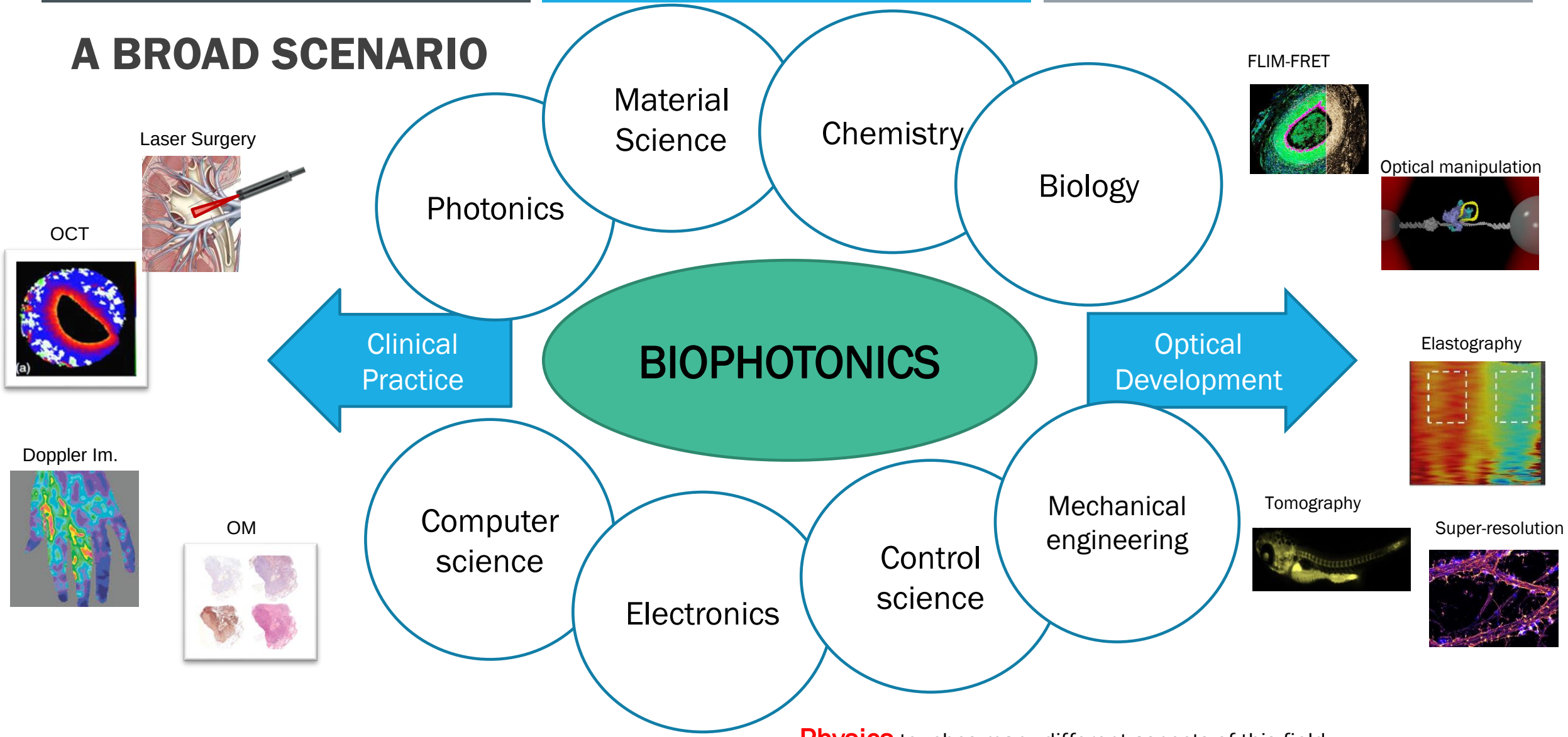
An emerging multidisciplinary research area, embracing all light-based technologies applied to the life sciences and medicine





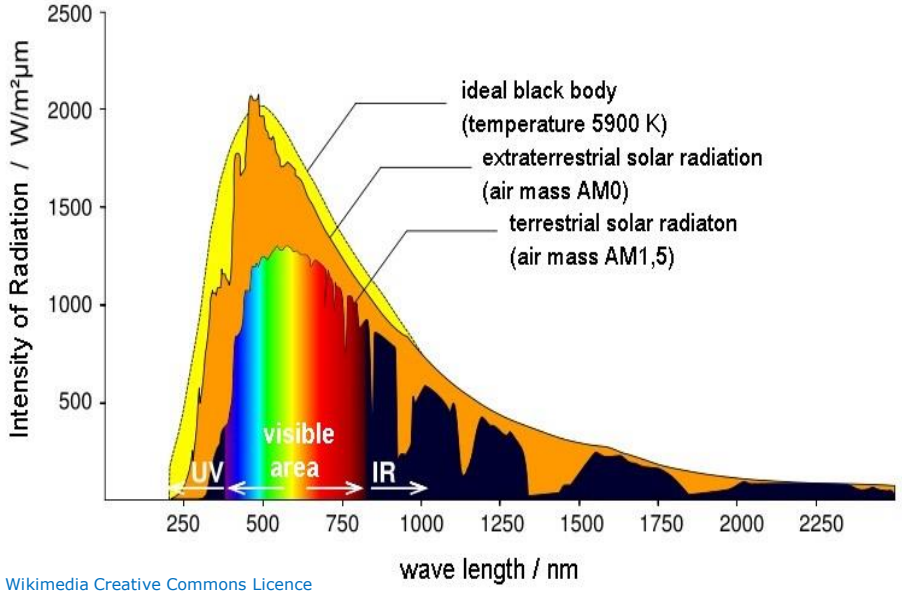


A BROAD SCENARIO

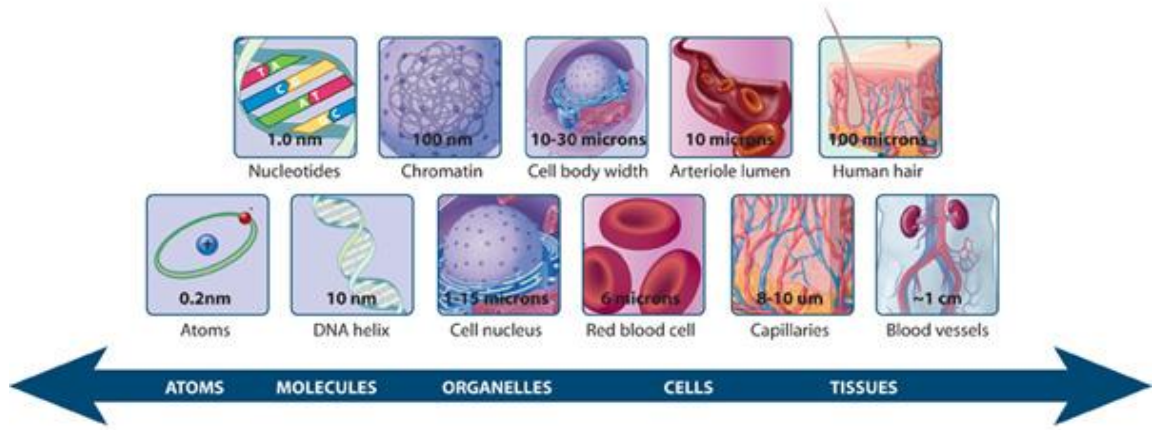


Physics touches many different aspects of this field:
from the optics of the instrument design, to the interaction mechanism of light and matter, to biophysics, to the design of biomimetic materials

WHY THE LIGHT TO STUDY BIOLOGICAL MATTER?



ONE FUNDAMENTAL REASON:
It can interact with biological matter,
without distructing it



https://www.nature.com/scitable

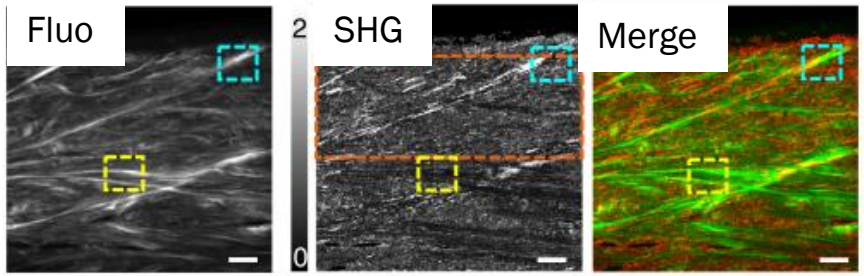
MANY PRACTICAL ONES:

Wide temporal and spatial scales

Multifunctional (morphology, chemistry, structure)

Compatibility (simultaneous use of several techniques)

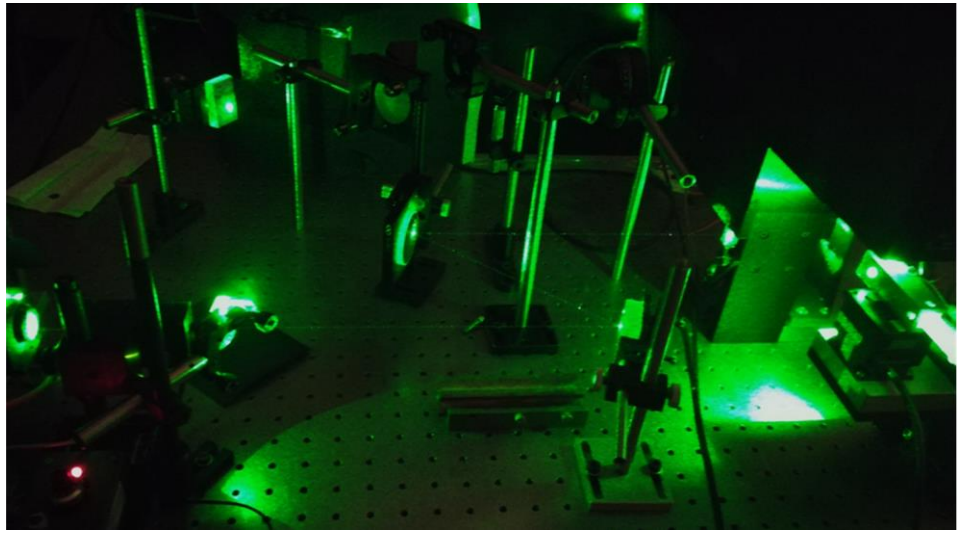
Practicity (low price, reduced invasiveness)

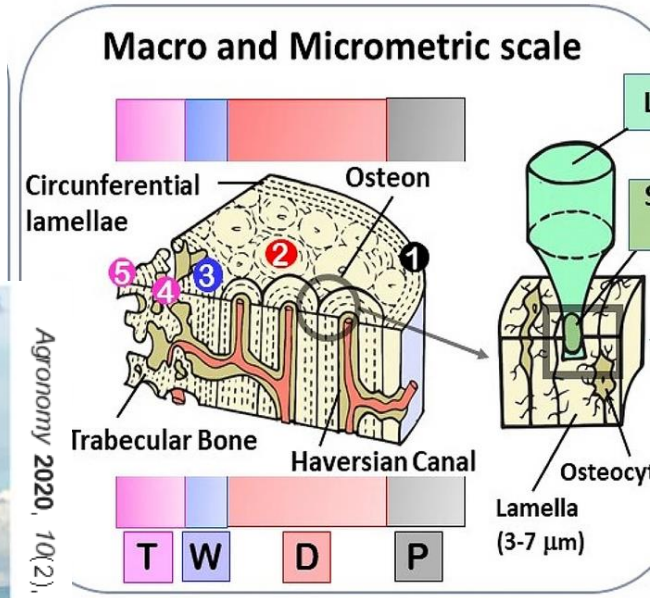


Mercatelli *et al., Commun Biol* **2,** 117 (2019).

BIOPHOTONICS IN PERUGIA

- 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
- Proprietà elastiche di sistemi nanostrutturati– biomateriali e nanomateriali
- Spettroscopia e Imaging per l'Agricoltura di precisione e monitoraggio ambientale





Agronomy 2020, 10(2), 303;

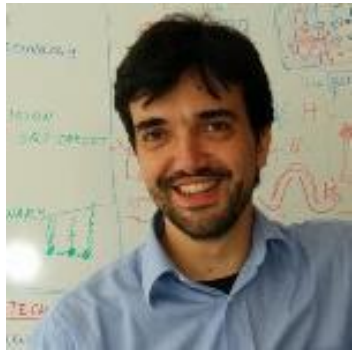
Cardinali, M.A.et al. Sci Rep 10, 17341 (2020).

Dal AA: 2022-2023 nuovo insegnamento di **Bio-fotonica** (6 cfu) nel corso di Laurea magistrale in Fisica Curriculum di Fisica della Materia e di Fisica medica.

IL GRUPPO DI RICERCA IN BIO-FOTONICA

S. Caponi

D.Fioretto

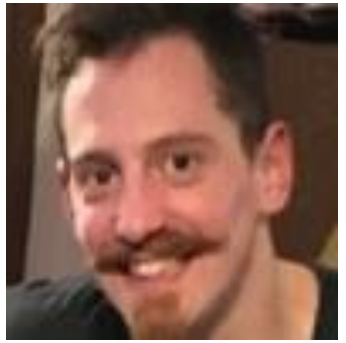


M. Mattarelli

F. Bonacci

I. Neri

A.A.Passeri

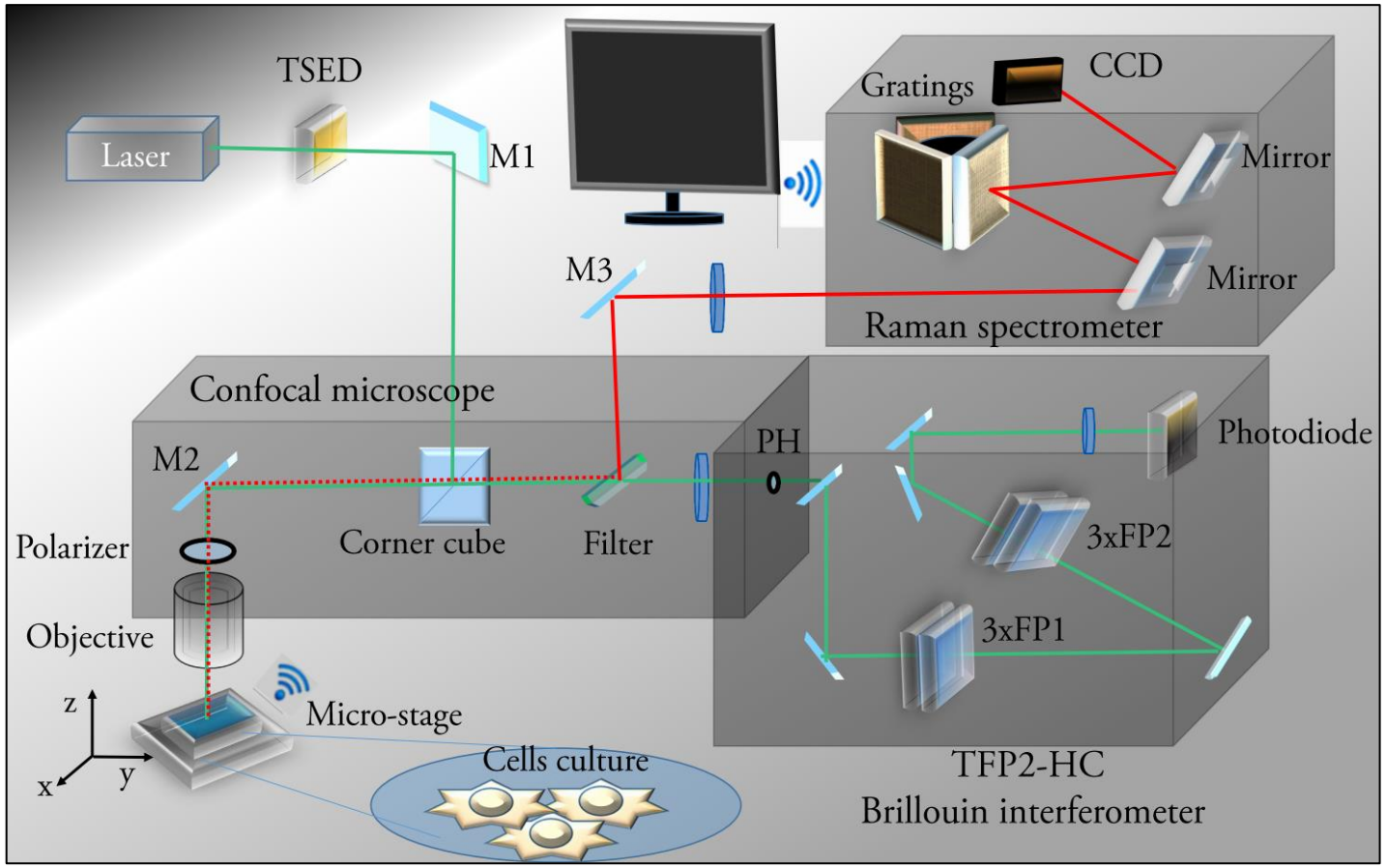


G.Capponi

V. D. Paccoia

https://sites.google.com/view/ghost-laboratory/

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

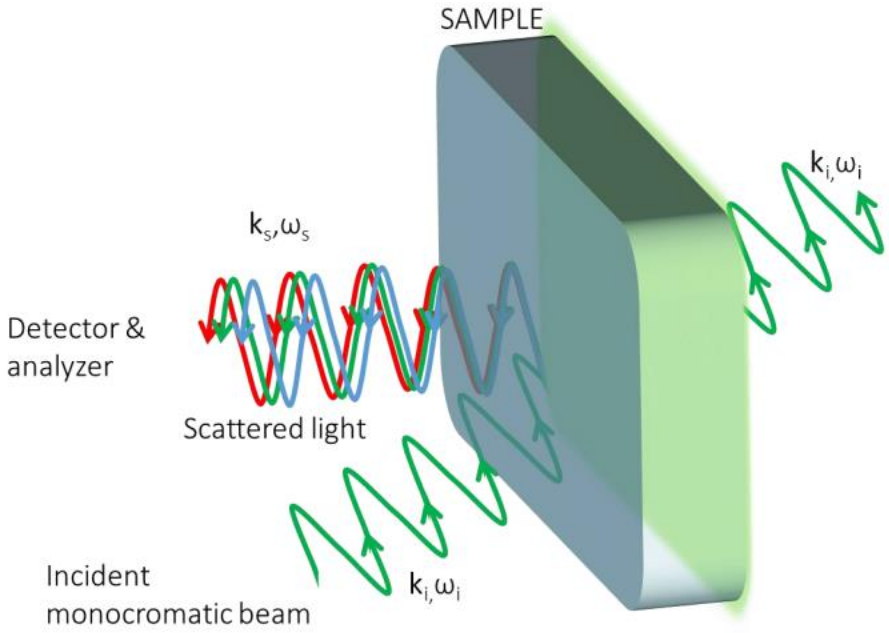


vibrational modes of molecules
Chemical properties - composition, structure

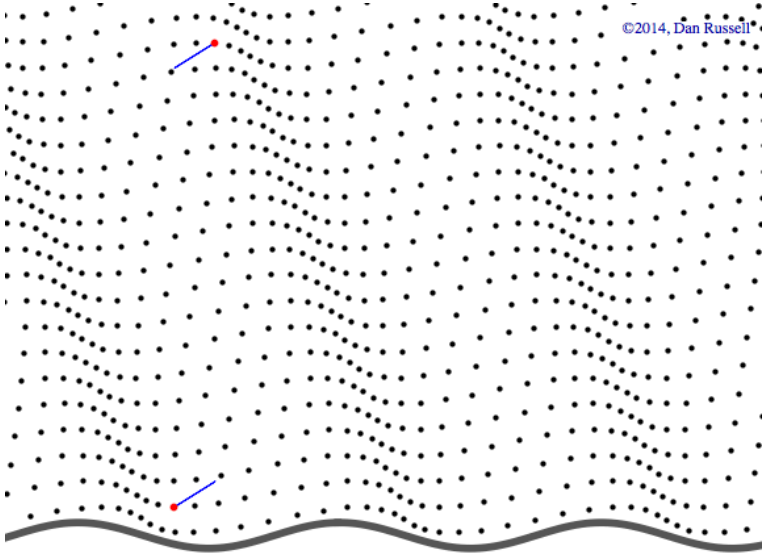
thermally activated acoustic waves
Mechanical properties
In the continuum description

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).

MISURA DELLE PROPRIETÀ ELASTICHE E CHIMICHE …USANDO UN LASER

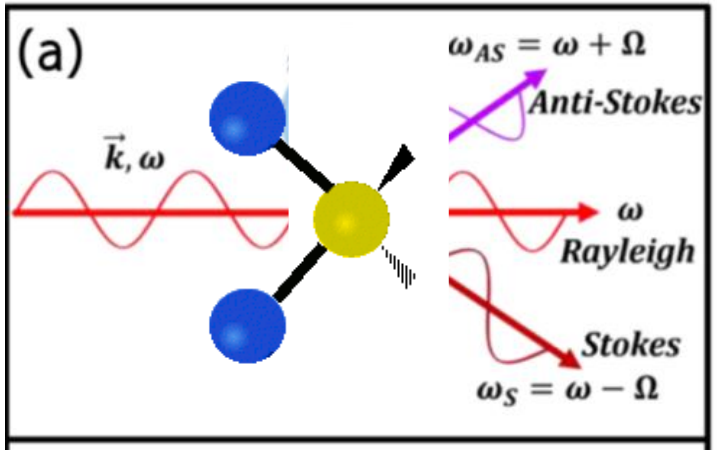


Spettroscopia Brillouin



Animation courtesy of Dr. Dan Russell,
Grad. Prog. Acoustics, Penn State

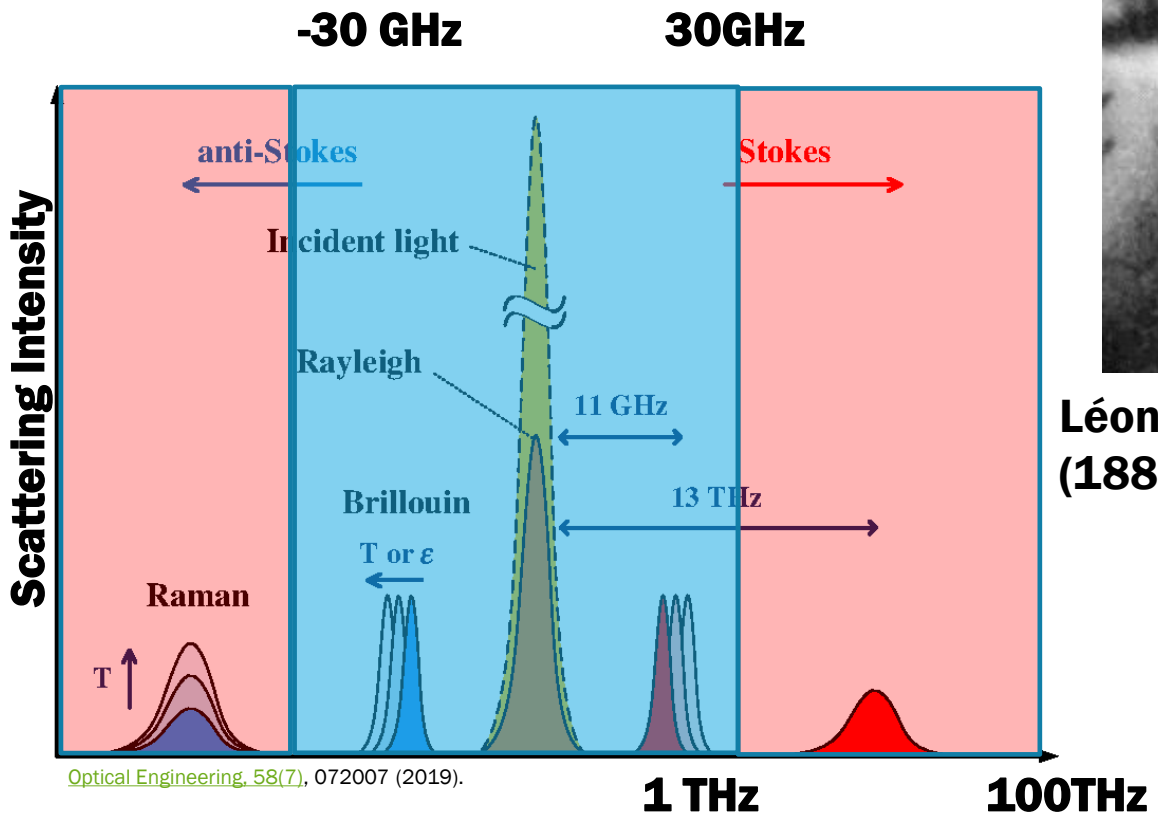
Spettroscopia Raman



S. Caponi, C. Canale, O. Cavalleri, M.Vassalli
«Characterization tools for mechanical probing of biomimetic materials" SPRINGER book (2019)

BRILLOUIN AND RAMAN SPECTROSCOPY

Sir C. V. Raman
(1888 –1970)



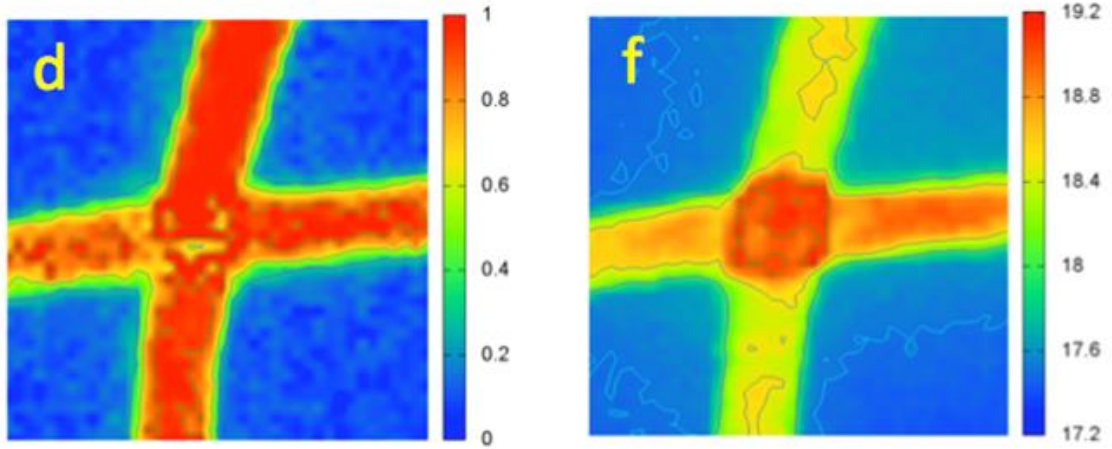
Optical Engineering, 58(7), 072007 (2019).

Léon Nicolas Brillouin
(1889–1969)

BRILLOUIN AND RAMAN MAPPING

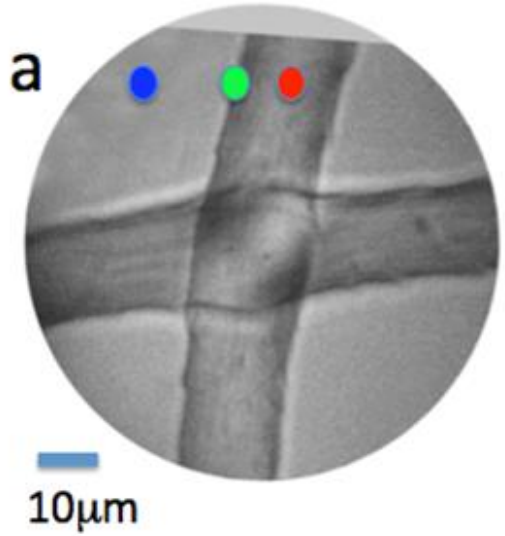
Two wool fibers embedded into epoxy film

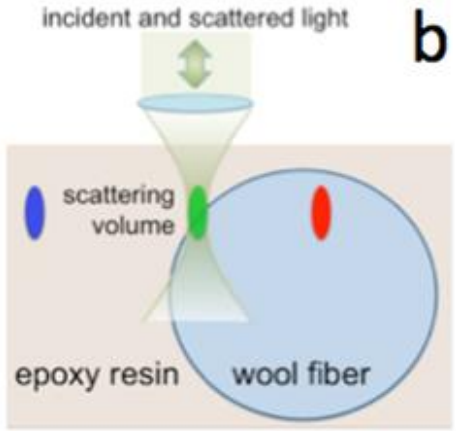
2μm step, 40×40 points
10 s
P=5mW

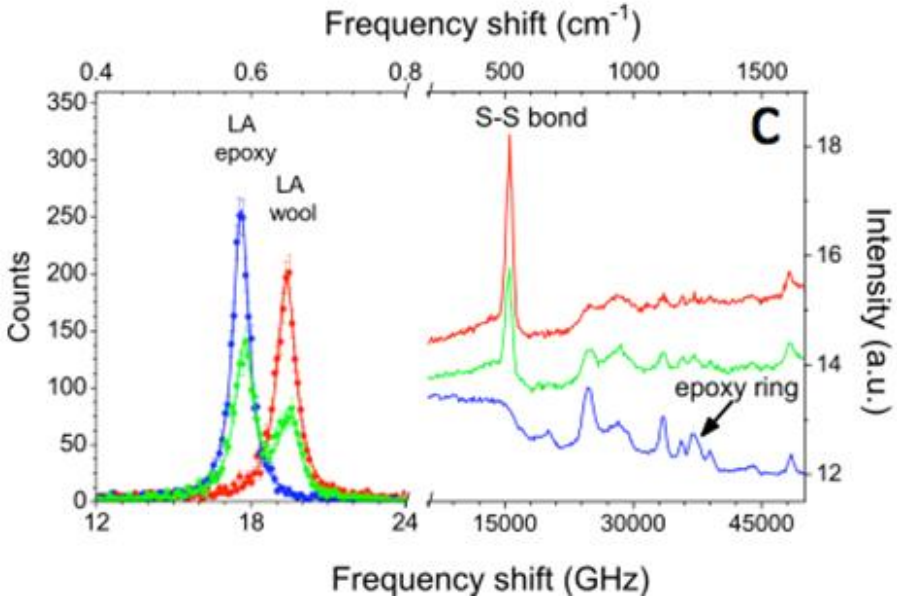


Chemical mapping

Mechanical mapping





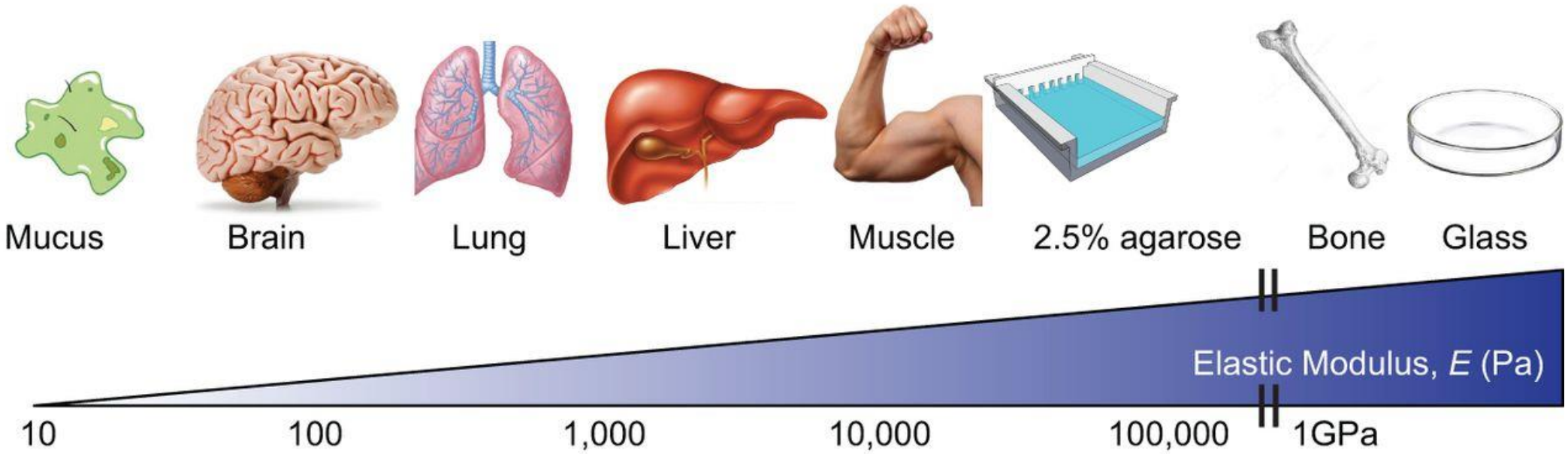


Fioretto et al. Biomedical Optics Express (2019)

USING LIGHT TO PROBE AND IMAGE THE MATERIALS PROPERTIES

Mechanics in biology

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



Barnes et al., Journal of Cell Science 2017 130: 71-82; doi: 10.1242/jcs.191742

USING LIGHT TO PROBE AND IMAGE THE MATERIALS PROPERTIES

Mechanics in biology

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The Guardian

More

The Observer
Science

The 10 biggest science stories of 2022 – chosen by scientists

7. Soft cell, hard cell…

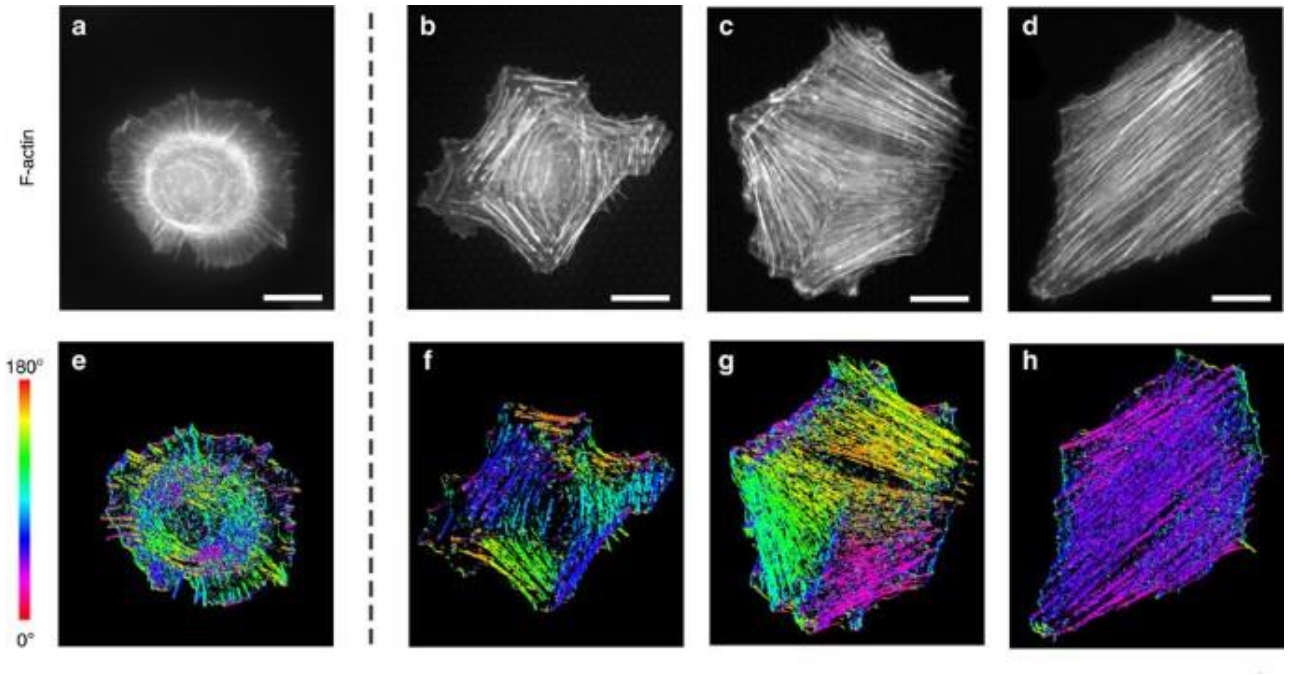
- https://www.theguardian.com/science/2022/dec/18/the-10-biggest-science-stories-of-2022-chosen-by-scientists

USING LIGHT TO PROBE AND IMAGE THE MATERIALS PROPERTIES:

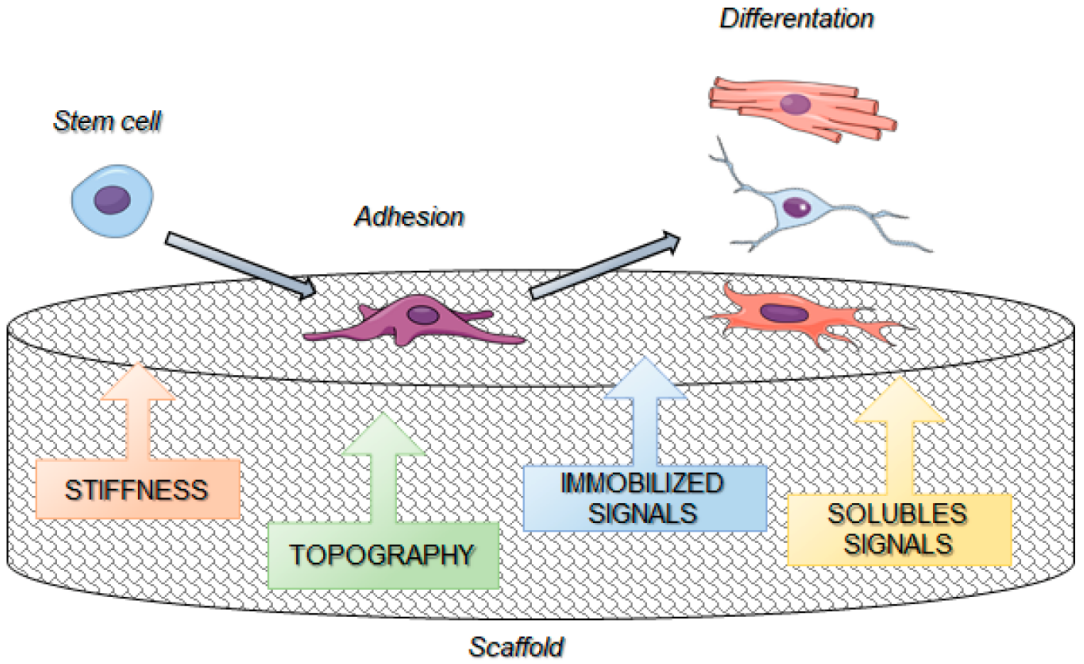
BIOMECHANICS AND BIOCHEMISTRY

Mechanics in biology:

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



Nature Communications **volume 6**, Article number: 7525 (2015)



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

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BIOMECHANICS AND BIOCHEMISTRY

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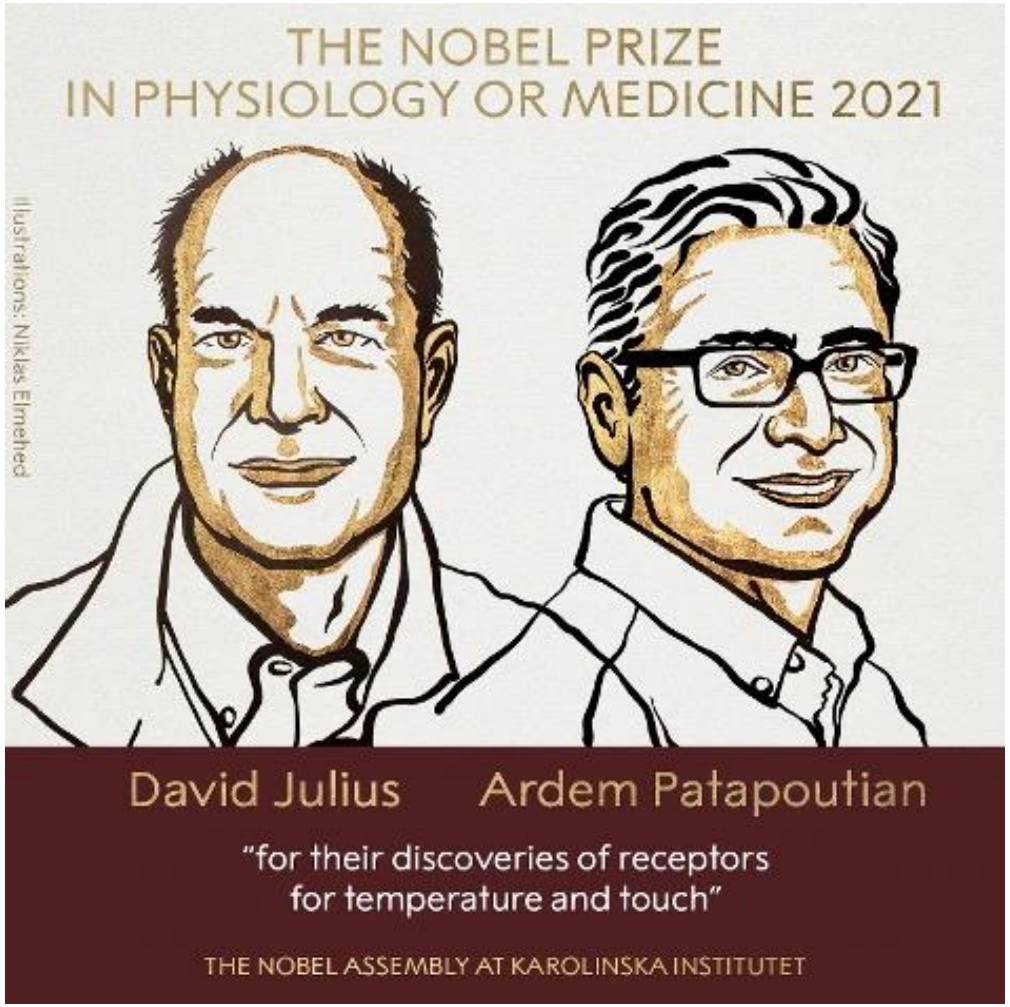

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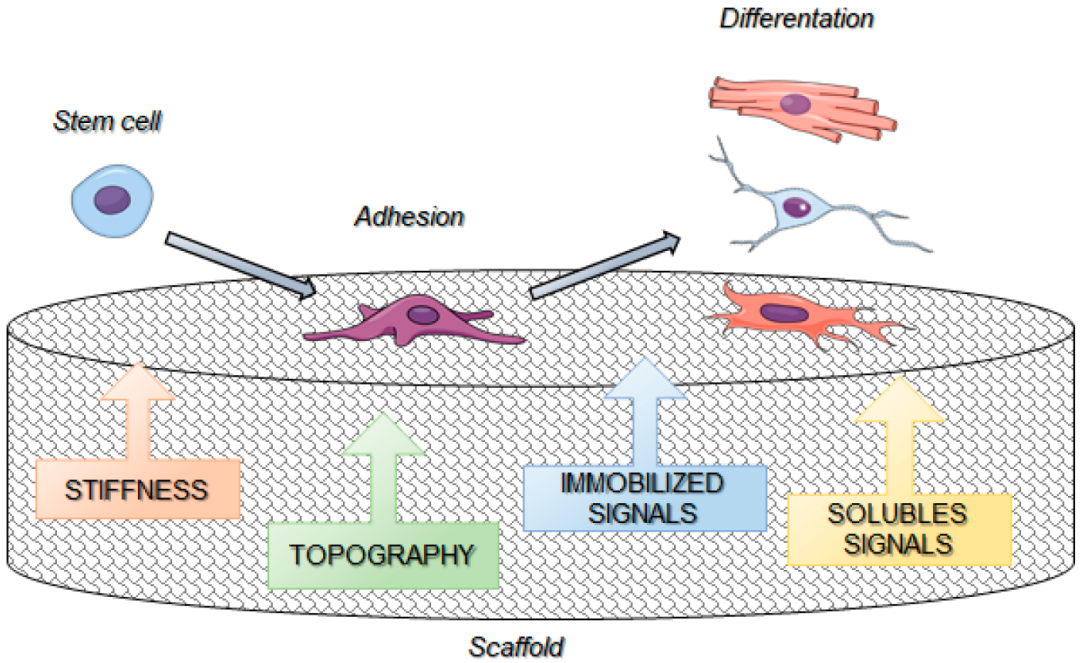
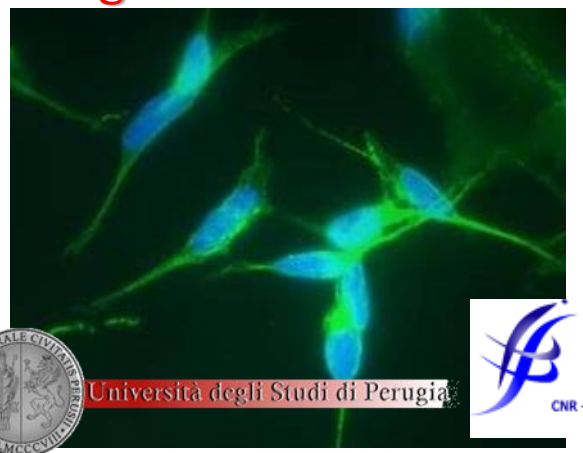


Cells 2019, 8, 1036; doi:10.3390/cells8091036

MICROSCOPIA CHIMICA E MECCANICA DI MATERIALI BIO

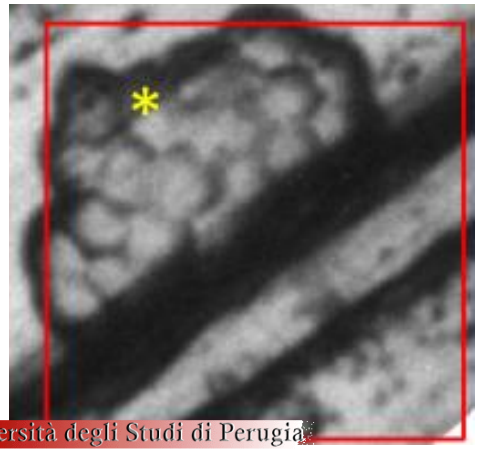
Living cells



Università degli Studi di Perugia

ibf
CNR - Istituto di Biofisica

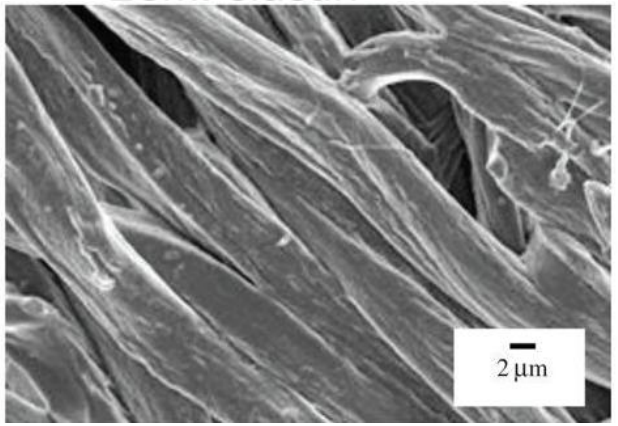
Biofilms



Università degli Studi di Perugia

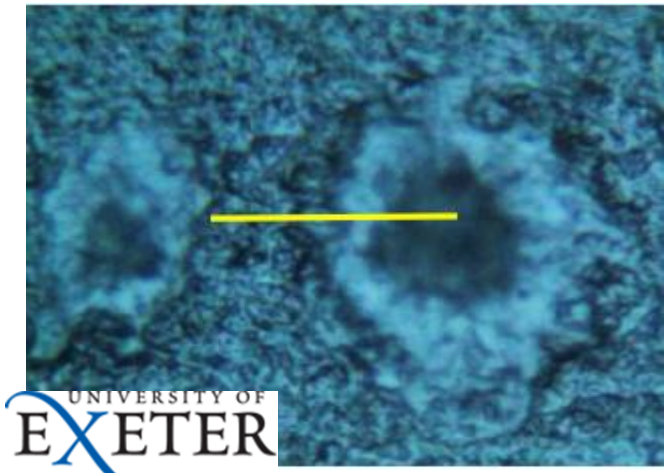
F. Scarponi et al. PRX 7, 031015 (2017)

ECM: elastin



10.1098/rsif.2014.0739

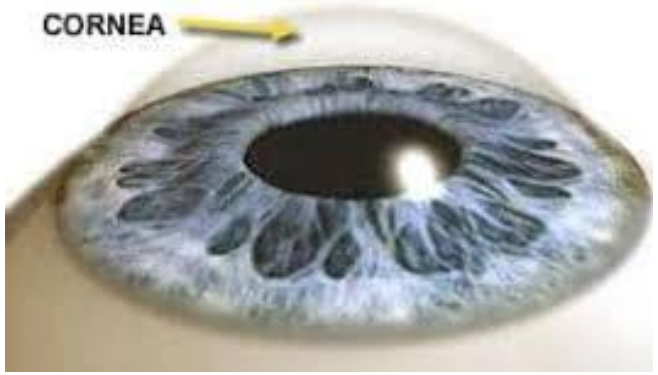
Amyloid Plaques in Transgenic Mouse Brain



UNIVERSITY OF EXETER

10.1142/S1793545817420019174200l-1

Human cornea

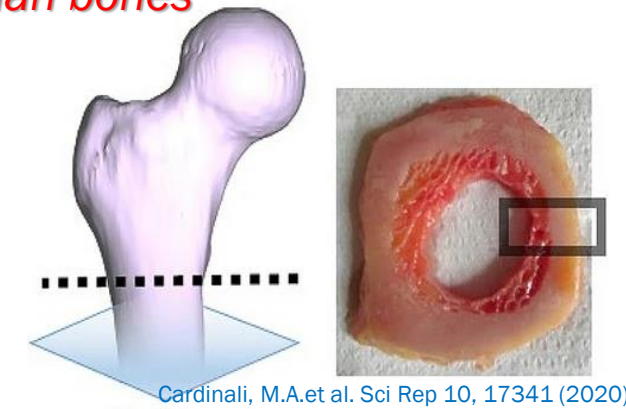


How the Human Eye Works | Cornea Layers/Role | Light Rays (nkcf.org)

INO-CNR
ISTITUTO NAZIONALE DI OTTICA

IFAC

Human bones



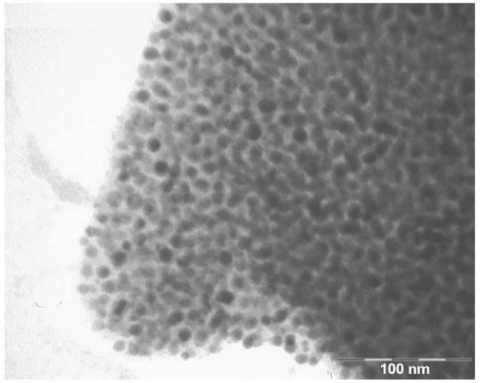
Cardinali, M.A.et al. Sci Rep 10, 17341 (2020).

Diaphysis

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

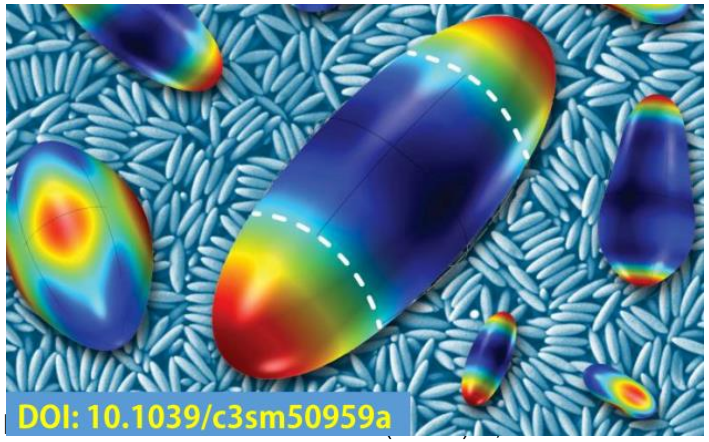
MICROSCOPIA CHIMICA E MECCANICA DI MATERIALI NANO

Vetri nanstrutturati



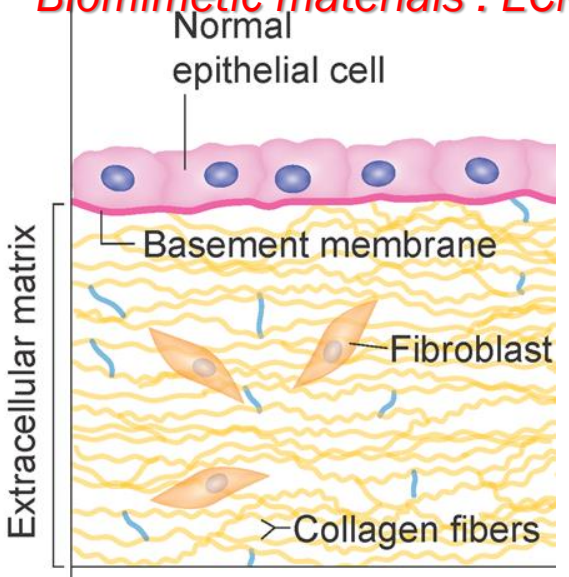
Mattarelli et al., Optical Materials 31 1362 (2009)

Nano-particles



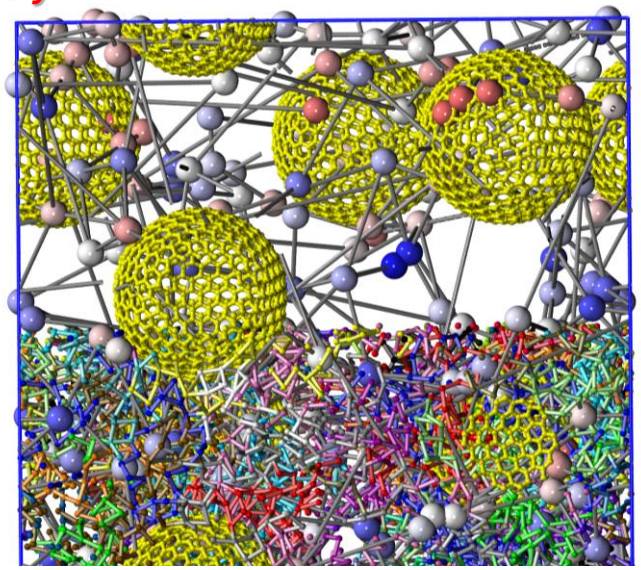
Thin films

Biomimetic materials : ECM



10.3390/cancers14122887

Polymer



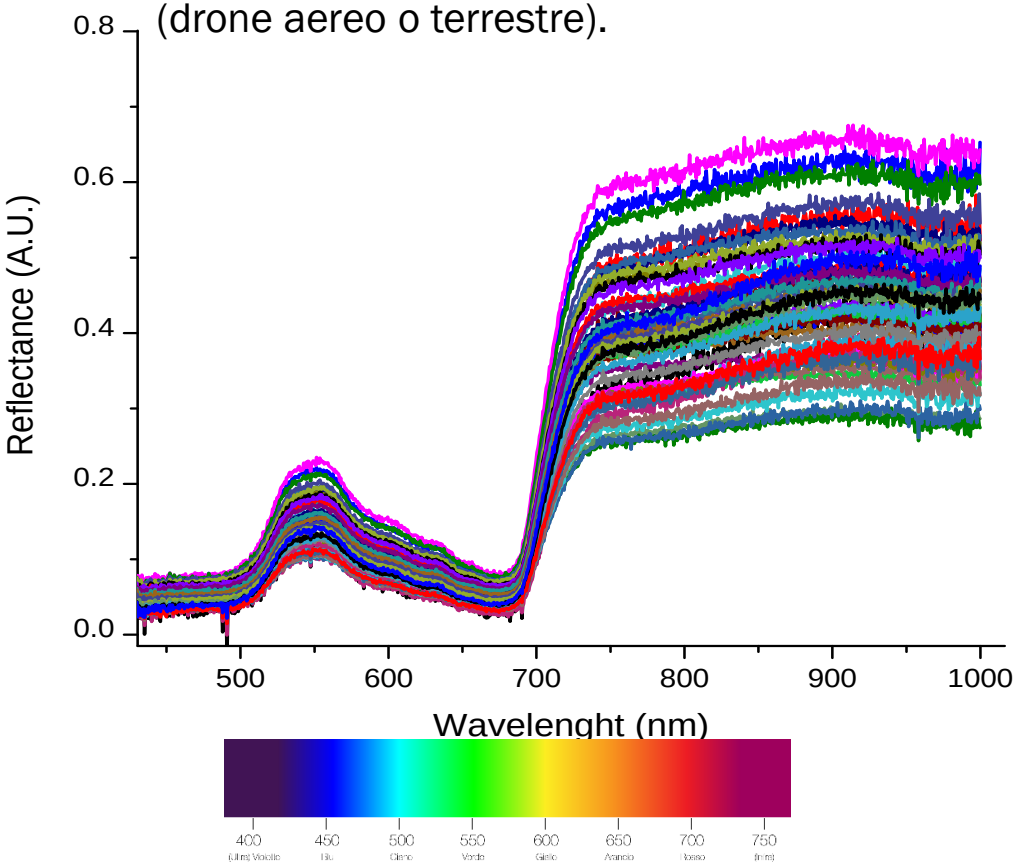
10.3390/polym12112591

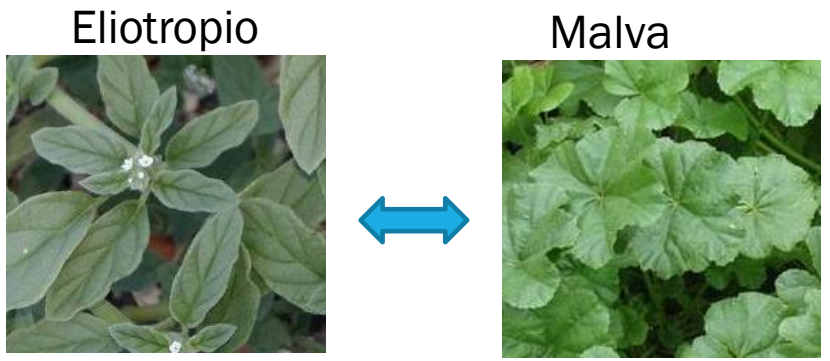
Film metallici, ceramici, polimerici con applicazioni in campo energetico/acustico, Isolamento termico/acustico, filtri ottici/acustici, coating protettivi

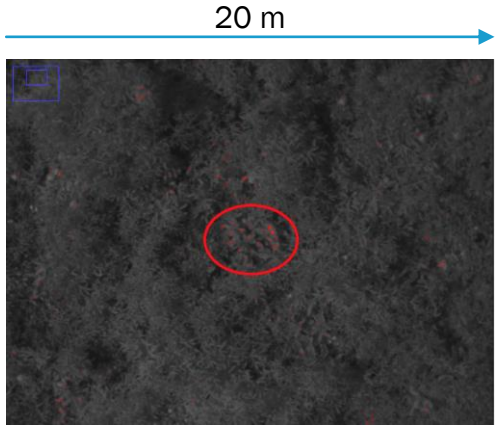
AGRICOLTURA DI PRECISIONE

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).







Agronomy **2020**, *10*(2), 303;

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: VITALITY Ecosistema per l'innovazione (UNIPG-CNR)

nffa.eu research infrastructure

crea Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

FONDAZIONE CASSA DI RISPARMIO DI TERNI E NARNI

BIOBRILLOUIN

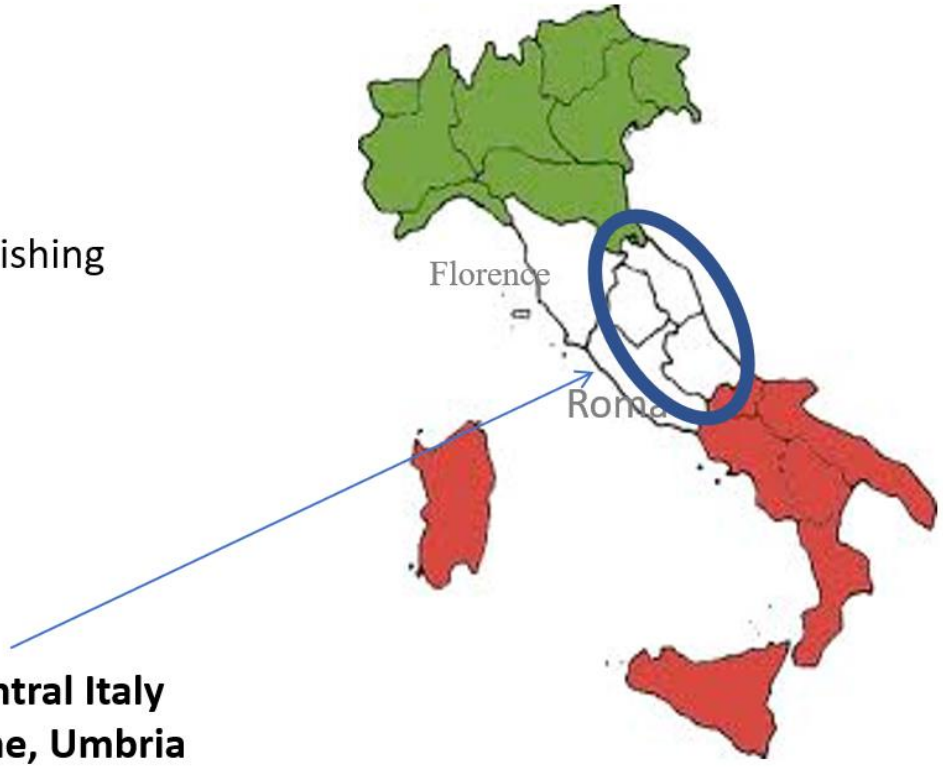
THE ROYAL SOCIETY

Innovation, digitalisation and sustainability for the diffused economy in Central Italy

What is it?

It is the NextGenerationEU funded project aimed at establishing an **INNOVATION ECOSYSTEM** in CENTRAL ITALY

2022-2026



3 Regioni in Central Italy
Abruzzo, Marche, Umbria

Focus on MATERIALS

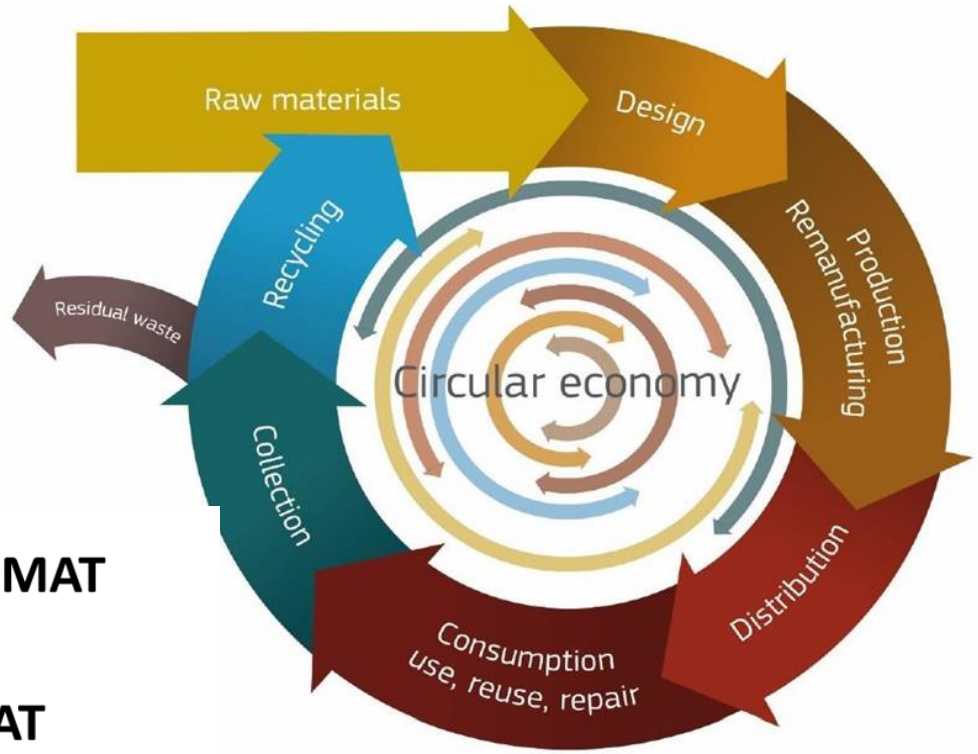
Innovation, digitalisation and sustainability for the diffused economy in Central Italy

What is it?

It is the NextGenerationEU funded project aimed at establishing an **INNOVATION ECOSYSTEM** in CENTRAL ITALY

2022-2026 Umbria

Nanostructured material and devices	Università di Perugia
Bio based and bio compatible materials and devices	Università di Perugia

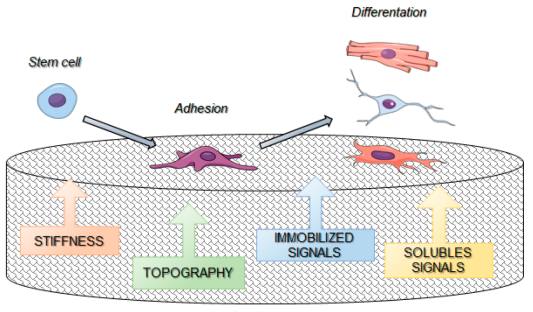


POLO NANOMAT
Nocera Umbra

POLO BIOMAT
Terni

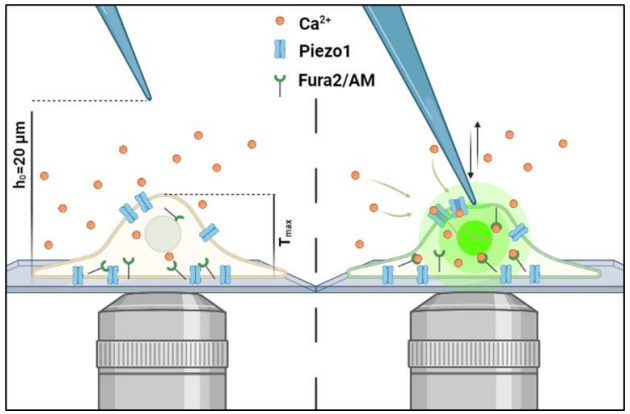
TESI

- Caratterizzazione meccanica e chimica di sistemi biomimetici

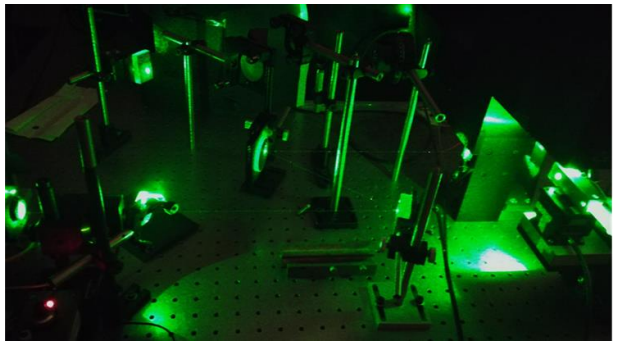


Cells 2019, 8, 1036; doi:10.3390/cells8091036

- Meccanobiologia in cellule e tessuti



10.3390/nano12152691

- 

  Ottimizzazione e sviluppo di strumentazione innovativa per analisi spettroscopica di materiali biologici

CONCLUSIONE

- Utilizzare la luce per investigare la materia biologica: un ampio spettro di attività.

- Tesi, Curiosità → maurizio.mattarelli@unipg.it

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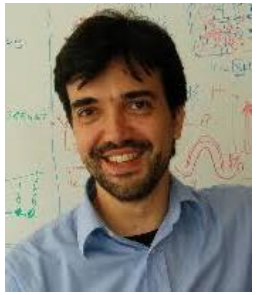

ISTITUTO OFFICINA DEI MATERIALI

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