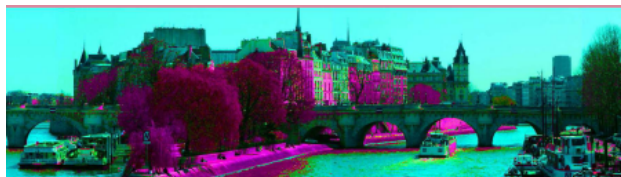
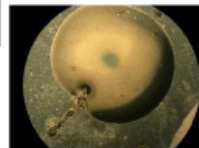
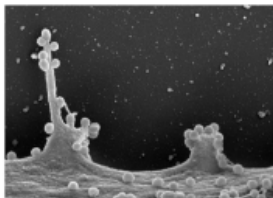
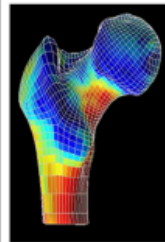
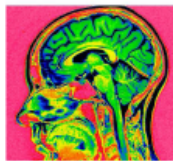


BioMedical Engineering

Master's Degree Program



bme Paris
BioMedical Engineering
MASTER PROGRAM



<http://www.bme-paris.org>

BiImaging Track (BIM)

Track chairs:

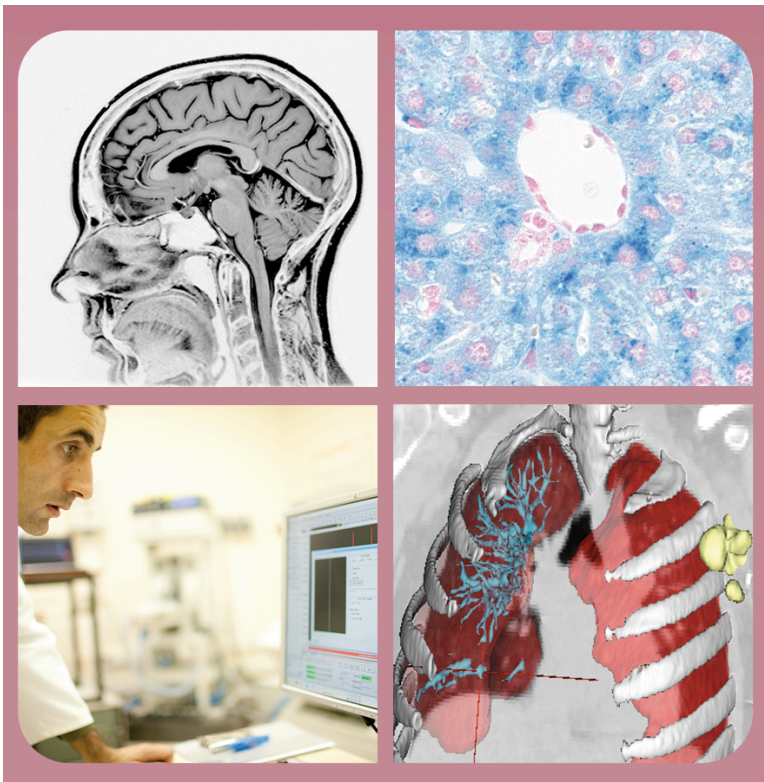
- E. Angelini , PhD (Telecom ParisTech)
- F. Cloppet , PhD (Univ. Paris Descartes)
- C. Oppenheim , MD (Univ. Paris Descartes)

BioImaging Track

Catherine Oppenheim
Medicine
Université Paris Descartes

Florence Cloppet
Computer Science
Université Paris Descartes

Elsa Angelini
Computer Science
Telecom ParisTech



Bioimaging is an exciting **field** at the interface between Mathematics, computer science, chemistry, physics, life science, biology and medicine.

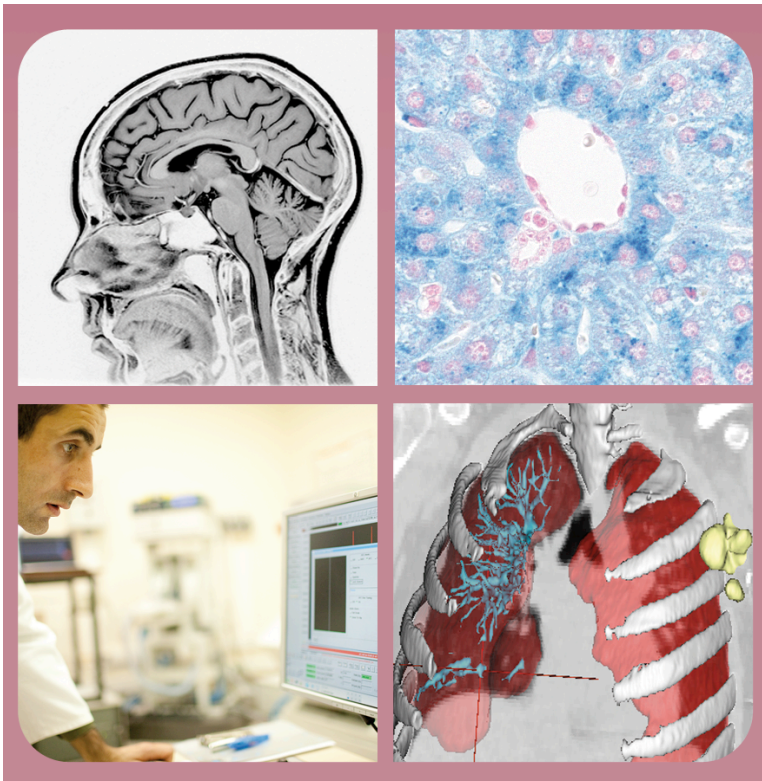
The main **goal** of **Bioimaging** is to improve human health using imaging modalities to advance diagnosis, treatment and prevention of human disease.

BioImaging Track

Catherine Oppenheim
Medicine
Université Paris Descartes

Florence Cloppet
Computer Science
Université Paris Descartes

Elsa Angelini
Computer Science
Telecom ParisTech



► SUB-TRACK Imaging from Molecule to Human (IMH)



► IMH@bme-paris.org

► SUB-TRACK Imaging Modalities and Processing (IMP)



► IMP@bme-paris.org

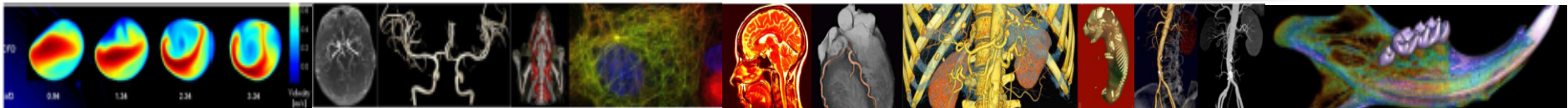
BioImaging Track

- Complementary skills from:
 - University Paris Descartes,
 - Paris Diderot
 - Engineering schools of ParisTech
- BIM program:
 - 15 courses (UE) at the M2 level.
 - Co-organized by faculty members experts in the field.

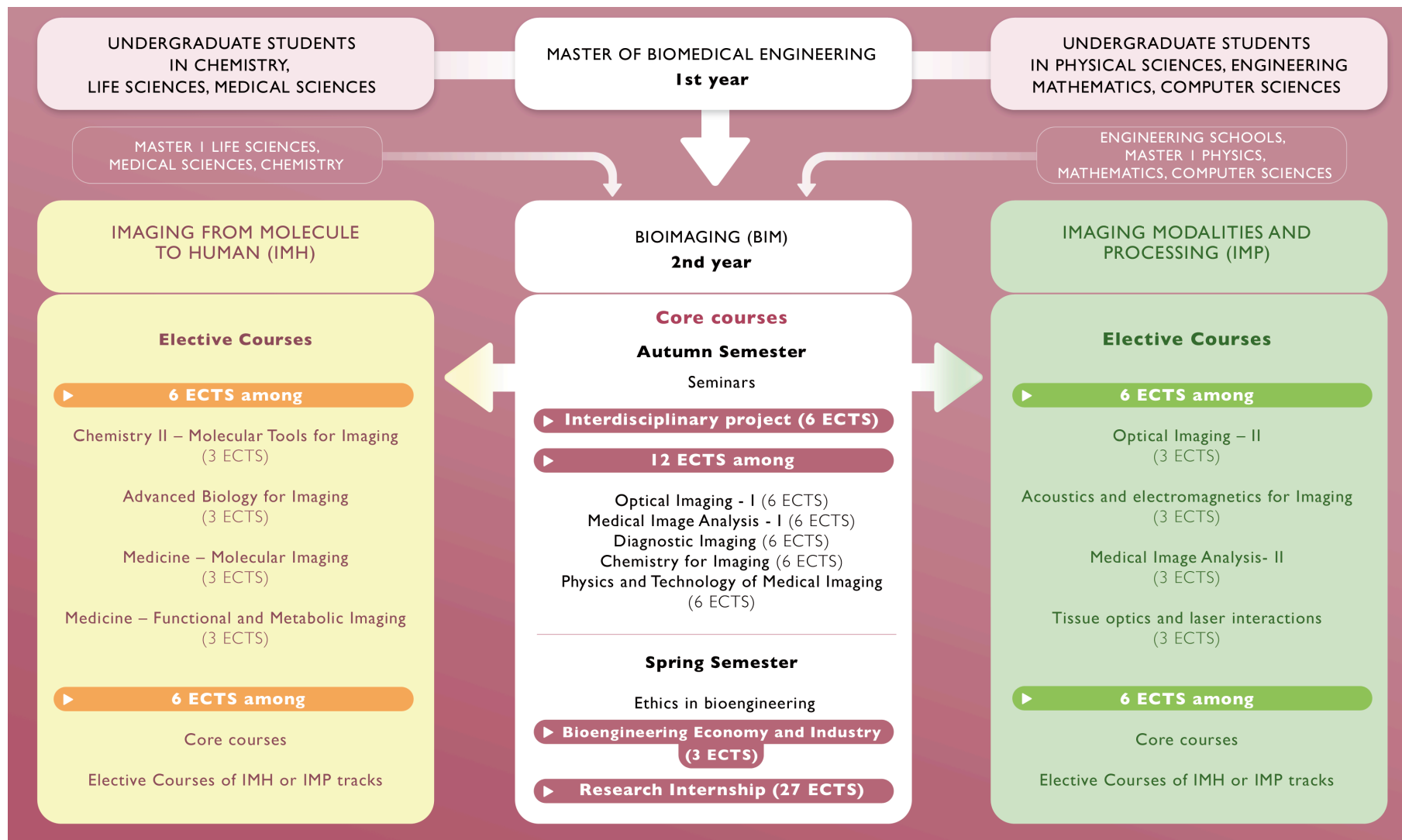
Basic sciences:
mathematics, physics,
chemistry

Applied mathematics:
signal & image processing,
numerical analysis.

Biology and Medicine:
diagnostic tools, innovative
screening, contrast agents,
biomarkers, image-based
modeling



BioImaging Track Program



BIM Research Labs

- **Image Processing Labs:**
 - **Telecom ParisTech:** Medical image processing group
 - **Paris Descartes** – UFR Mathematics-Computer Sciences
 - **Mines ParisTech:** Biological image processing
 - **Arts et Métier ParisTech:** musculo-skeletal imaging
- **Radiology Labs:**
 - **Hospitals** Ste Anne, HEGP, Lariboisière,....
 - **PARCC** Paris Cardiovascular Center of Research
- **Optical Imaging Labs:**
 - **Animal imaging platform:** Microscopy, Spectroscopy via Electronic Paramagnetic Resonance,
 - **Institut d'Optique** Graduate School ParisTech
 - **ENSTA ParisTech:** Laser-tissue interactions
 - **ESPCI:** novel elastography ultrasound imaging
- **Chemistry Labs:**
 - **Chimie ParisTech:** bio photonics, scintillators, luminescence nano-chemistry
 - **University Paris Descartes:** molecular imaging

ParisTech

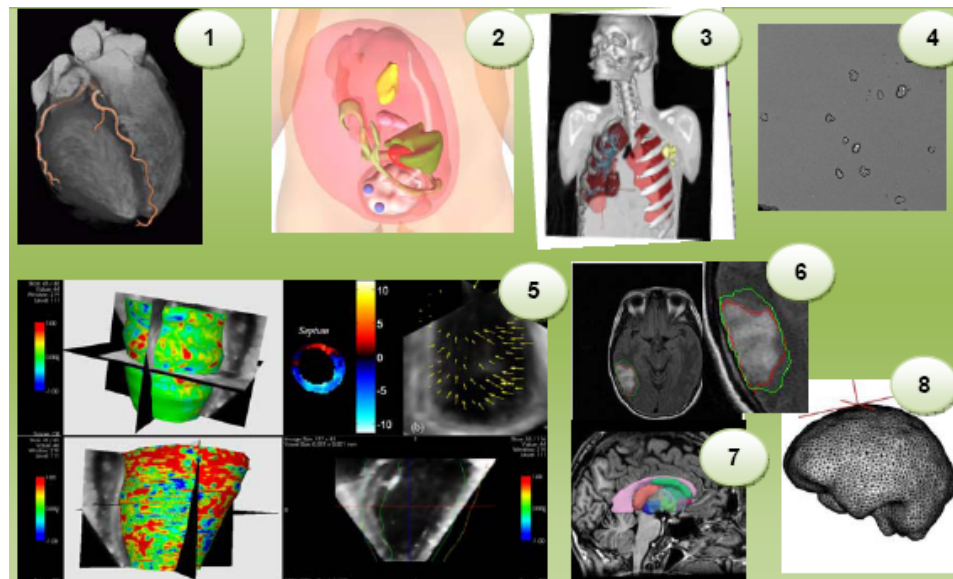
8 schools involved in Biolmaging



Telecom ParisTech

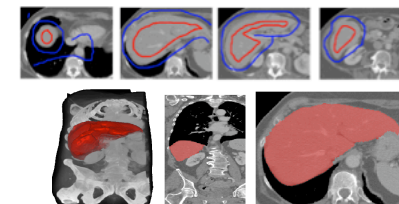
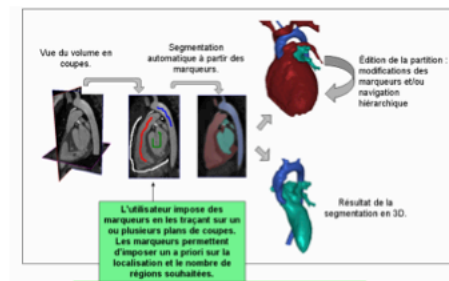
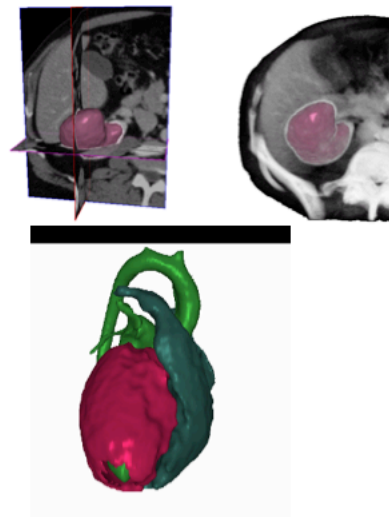
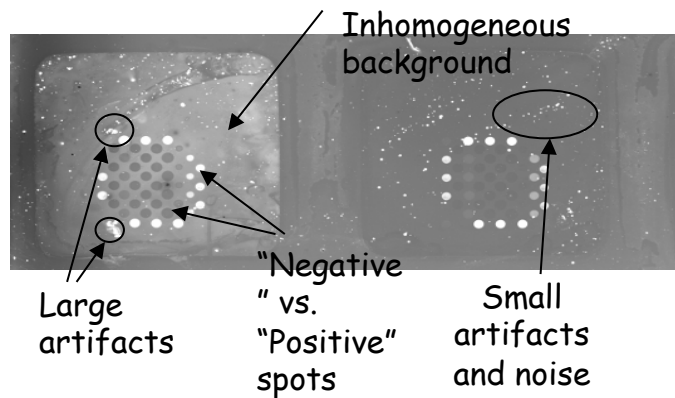
Department of Signal and Image Processing

- **Faculty :**
 - Elsa Angelini (elsa.angelini@telecom-paristech.fr)
 - Isabelle Bloch (isabelle.bloch@telecom-paristech.fr)
- **Specialty :** medical image processing (denoising, segmentation, registration, anatomical modeling,..)
- **Imaging modalities :** MRI, CT, PET-SPECT, ultrasound, retinal imaging, microscopy
- **Clinical applications:** brain, cardiac, thorax, obstetric, mammography, optical imaging
- **Academic collaborators :** CNRS, INSERM, INRIA, Institut Pasteur, several hospitals, Columbia University
- **Industrial partners :** Philips Healthcare, GE Healthcare, Siemens Corporate Research, Dosisoft, Echosens , ...



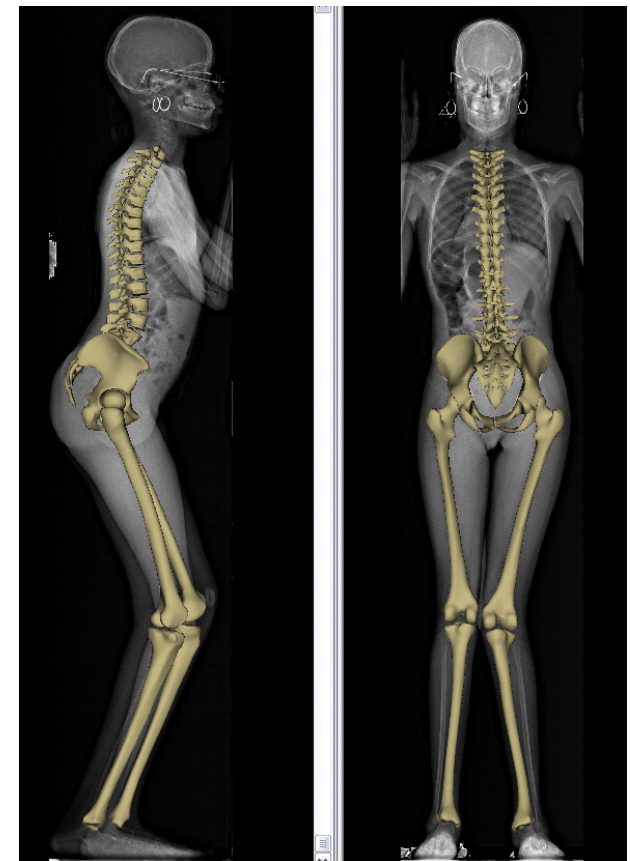
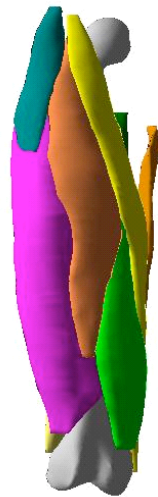
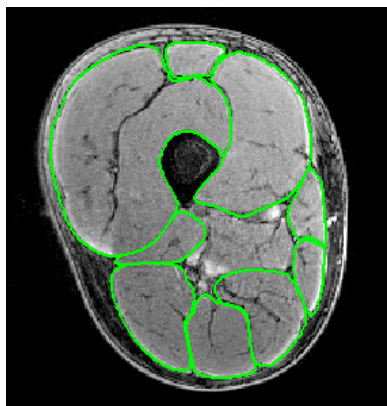
Centre de Morphologie Mathématique

- **Faculty :**
 - Etienne Decenciere (etienne.decenciere@ensmp.fr)
- **Specialty :** biomedical image processing (interactive 3D segmentation, quantification, dynamic analysis), mathematical morphology
- **Imaging modalities:** DNA and cells microarrays, MRI, CT, retinal imaging, microscopy
- **Clinical applications:** quantitative cytology and histology, angiogenesis quantification, cancerology
- **Academic collaborators :** Institut Gustave Roussy, Institut Curie
- **Industrial partners :** GE Healthcare, sanofi, l'Oréal



Laboratoire de Biomécanique

- **Faculty:**
 - Sébastien Laporte (sebastien.laporte@paris.ensam.fr)
 - Wafa Skalli (wafa.skalli@paris.ensam.fr)
- **Specialty :** anatomical modeling
- **Imaging modalities:** X-ray, MRI, musculo-skeletal imaging
- **Clinical applications:** numerical simulations, prosthesis design, surgery planning
- **Academic collaborators :** University of Montreal, several hospitals
- **Industrial partners :** EOS Imaging, Renault,...

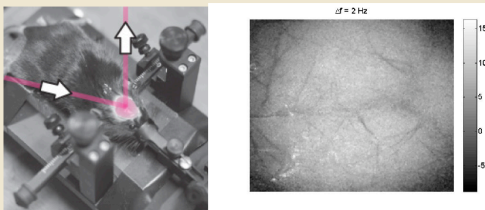


ESPCI ParisTech

Institut Langevin

- **Faculty:**
 - Emmanuel Bossy (emmanuel.bossy@espci.fr)
 - Remi Carminati (remi.carminati@espci.fr)
- **Specialty :** imaging of complex media, imaging devices, nanophysics, nanostructures, nanomaterials
- **Imaging modalities:** laser, ultrasound, photo-acoustic, elastography, holography, adaptive optics, thermal imaging
- **Clinical applications:** cell imaging, biology, vessels, tissue characterization,
- **Academic collaborators :** Institut Langevin, University P5, Institut Pasteur
- **Industrial partners :** l'Oréal

Imagerie laser Doppler plein champ en conditions peu invasives



Mesure quantitative de l'effet Doppler.
Limite : diffusion de la lumière.
Améliorer la résolution en profondeur

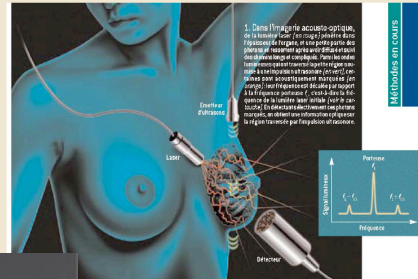
M. Atlan, M. Gross, T. Vitalis, A. Rancillac, B. Forget, A. Dunn. "Frequency-domain imaging," *Optics Letters*, 31, 2762-2764 (2006)

Imagerie par couplage lumière - ultrasons

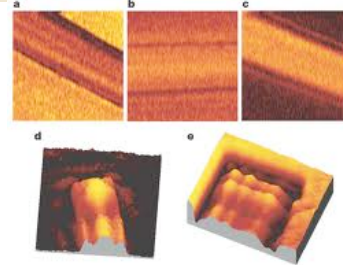
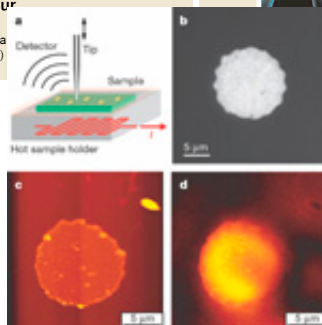
M. Atlan, C. Boccara, E. Bossy, K. Douadi, B. Forget, A. Funke, M. Gross, F. Jean, M. Lesaffre, F. Ramaz, P. Santos



- Explorer des milieux épais (cm)
- Révéler des contrastes optiques locaux (tumeurs)
- Méthode non invasive
- Traitement par hyperthermie
- Résolution mm³



F. Ramaz, M. Gross, B. Forget, C. Boccara. *Pour la Science*, décembre 2005

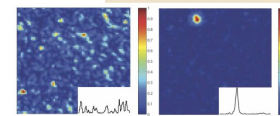
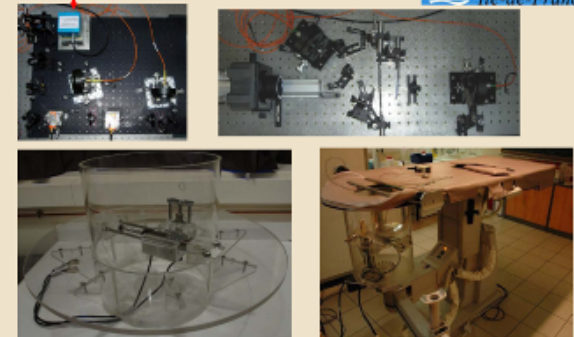


Projet Cancéropôle Ile-de-France Elastographie et acousto-optique

Co-Dir. Fink, M. Tantalat, LO4-ESPCI

Projet Européen demandé en 2007 (en attente)

Laser 800nm (G. Paulliat - IOTA)



Thermal radiation scanning tunneling microscopy

Polytechnique

Laboratoire d'Optique et Biosciences (LOB)

- **Faculty:**
 - Emmanuel Beaufrepaire (Emmanuel.Beaufrepaire@polytechnique.fr)
- **Specialty :** multiphotonic microscopy, design of imaging devices
- **Imaging modalities:** laser, SHG, THG, spectroscopy
- Biological applications: nanoparticles tracking, embryonic development, extracellular matrix imaging
- **Academic collaborators** DGA, INRIA, Institut Curie (Paris), Hospitals Bichat-Lariboisière (Paris), Centre rech. Cardiovasculaire (Paris), ESPCI, ENS-Paris, Institut Neurobiol. Alfred Fessard (Gif), ENS Lyon, UPMC (Paris)
- **Industrial partners :** Imagine Optics ; Fastlite

Imagerie non linéaire dynamique de la morphogénèse embryonnaire
Emmanuel Beaufrepaire (contact), Delphine Débarre (2009)

Photoablation/biomécanique

Imagerie des déformations tissulaires pendant la morphogénèse embryonnaire (Drosophile).

Modulation de la morphogénèse par ablations intravitales en régime femto.

Mise en forme spatiale de la lumière

Correction des aberrations
Ingénierie du front d'onde pour la microscopie

Collaborations: ESPCI, ENS (Paris), Imagine Optic (Orsay)
Soutien ANR/RIB 2008

Microscopie THG

Étude des mécanismes de contraste
Imagerie multimodale
2PEF-SHG-THG

Application 1: Imagerie structurale sans marquage (embryons)

Application 2: Une source de contraste majeure: les gouttelettes lipidiques (diabète, stéatose)

Tissu non marqué: THG / SHG / 2PEF

Publications
> Opt. Express 15, 8913 (2007)
> Biophys. J. 92 (2007)
> Nature Methods 3, 47 (2006)
> Opt. Lett. 30, 2134 (2005)
> PNAS 102, 1047 (2005)
> Med. Laser, April 20, 20 / (2005)
> Opt. Lett. 29, 2681 (2004)

LOB POLYTECHNIQUE

Expertise: étude des sources de contraste endogène pour la microscopie NL + microscopie multimodale (2PEF/SHG/THG...)

SHG Myocytes (cœur de grenouille)

2PEF SHG THG

LOB Polytechnique

Boulesteix *et al.*, OL 2004

2PEF / THG embryon de Drosophile

LOB Polytechnique

Débarre *et al.*, OL 2004

Artère carotide ex vivo (Rat)

Adventitia : SHG collagène
Media : 2PEF Elastine

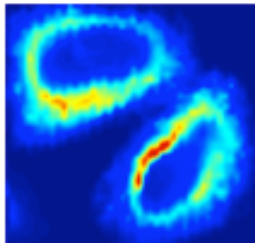
LOB Polytechnique

Boulesteix *et al.*, Cytometry 2006

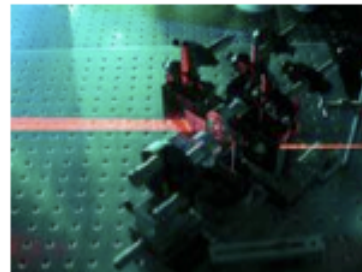
Institut d'Optique

Group Lasers & Biophotonics

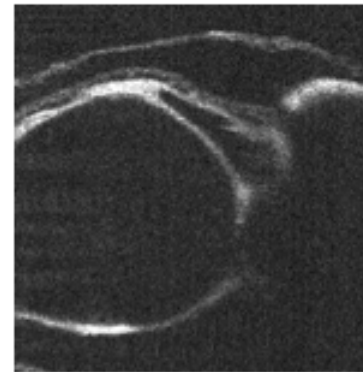
- **Faculty:**
 - Arnaud Dubois (arnaud.dubois@institutoptique.fr)
- **Specialty :** fluorescence microscopy, OCT, biochips, device design
- **Imaging modalities:** laser, microscopy,
- **Bio-Clinical applications:** imaging in diffusing media, retinal imaging, prostate, genetic diagnosis
- **Academic collaborators :** CNRS, INSERM, LPPM et Centre de Photonique Biomédicale (UPSud), IEF (Orsay), CGM (Gif/Yvette) LOA (ENSTA), Hotel Dieu (Paris), CEA LETI (Grenoble), CHU Bordeaux, ESPCI.....
- **Industrial partners :** Genoptics, Imagine Eyes, Amplitude Systèmes,



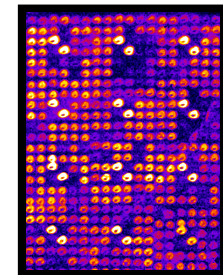
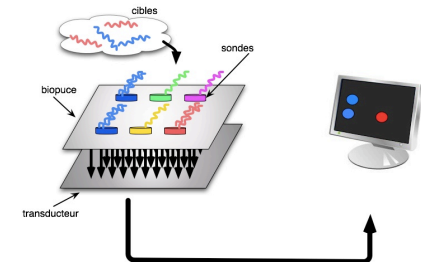
Total Internal Reflexion Fluorescence
Lifetime Imaging Microscopy



Multifocal Two-Photon
Fluorescence Lifetime
Microscopy



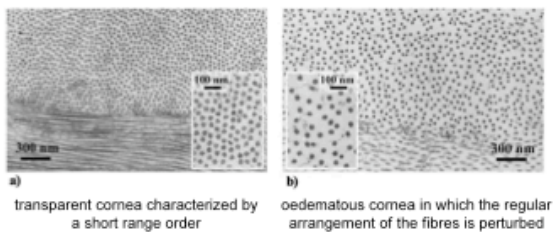
Full Field Optical Coherence
Tomography



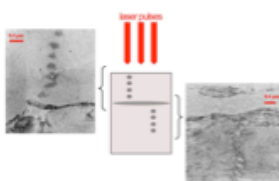
Laboratoire d'Optique Appliquée (Palaiseau)

- **Faculty:**
 - Karsten Plamann (karsten.plamann@ensta-paristech.fr)
- **Specialty** : laser eye surgery, OCT interventional imaging
- **Imaging modalities:** laser, microscopy,
- **Bio-Clinical applications:** imaging in diffusing media, retinal imaging, prostate, genetic diagnosis
- **Academic collaborators** : Laboratoire Biotechnologie et Œil (hôpital Hôtel Dieu / université Paris V), Banque Française des Yeux, Institut d'Optique Graduate School, École Polytechnique, University Paris Descartes
- **Industrial partners** : Imagine Eyes, Amplitude Systèmes

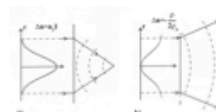
Optical properties of the cornea



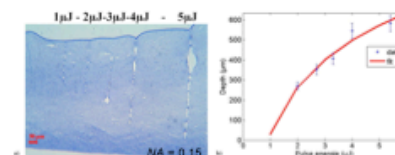
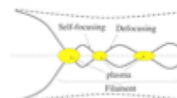
Human cornea obtained from the *Banque Française des Yeux* (French Eye Bank)



TEM photographs of a periodic structure below and above the lamellar plane in which the incision was performed

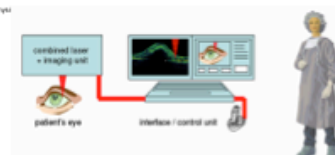
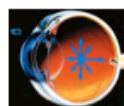


Focusing-defocusing cycles undergone by the intense core of a laser beam.



Penetration depths for different pulse energies


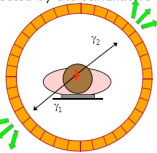
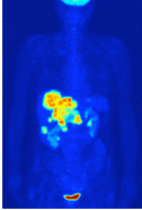

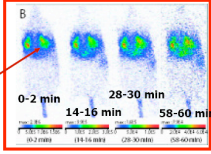
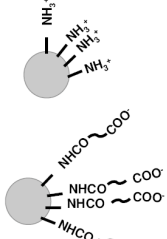
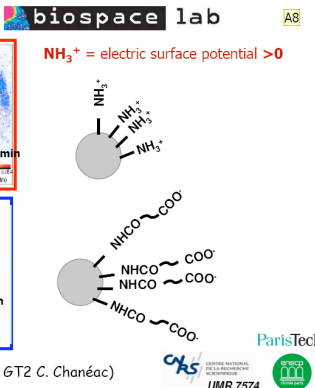
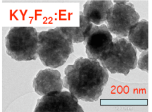
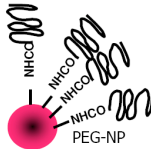
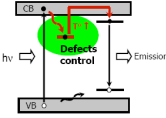

Penetration depths vs. pulse energy



(K. Caubron and A. Mylonidis, nonlinear side effects of fs pulses inside corneal tissue during photorefractive surgery)

Laboratoire de Chimie de la Matière Condensée de Paris

- **Faculty:**
 - Bruno Viana (bruno-viana@enscp.fr)
- **Specialty :** chemical agents for imaging, biophotonics, scintillation material, luminescence material, nanoparticles,
- **Imaging modalities:** PET, SPECT,
- **Bio-Clinical applications:** cancer imaging, small animal imaging
- **Academic collaborators :** CNRS, Paris 6, Collège de France
- **Industrial partners:** Saint-Gobain, Biospace

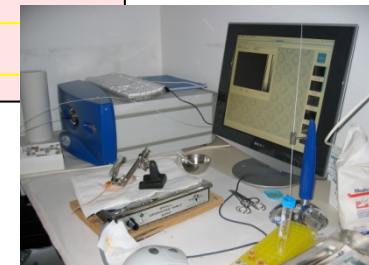
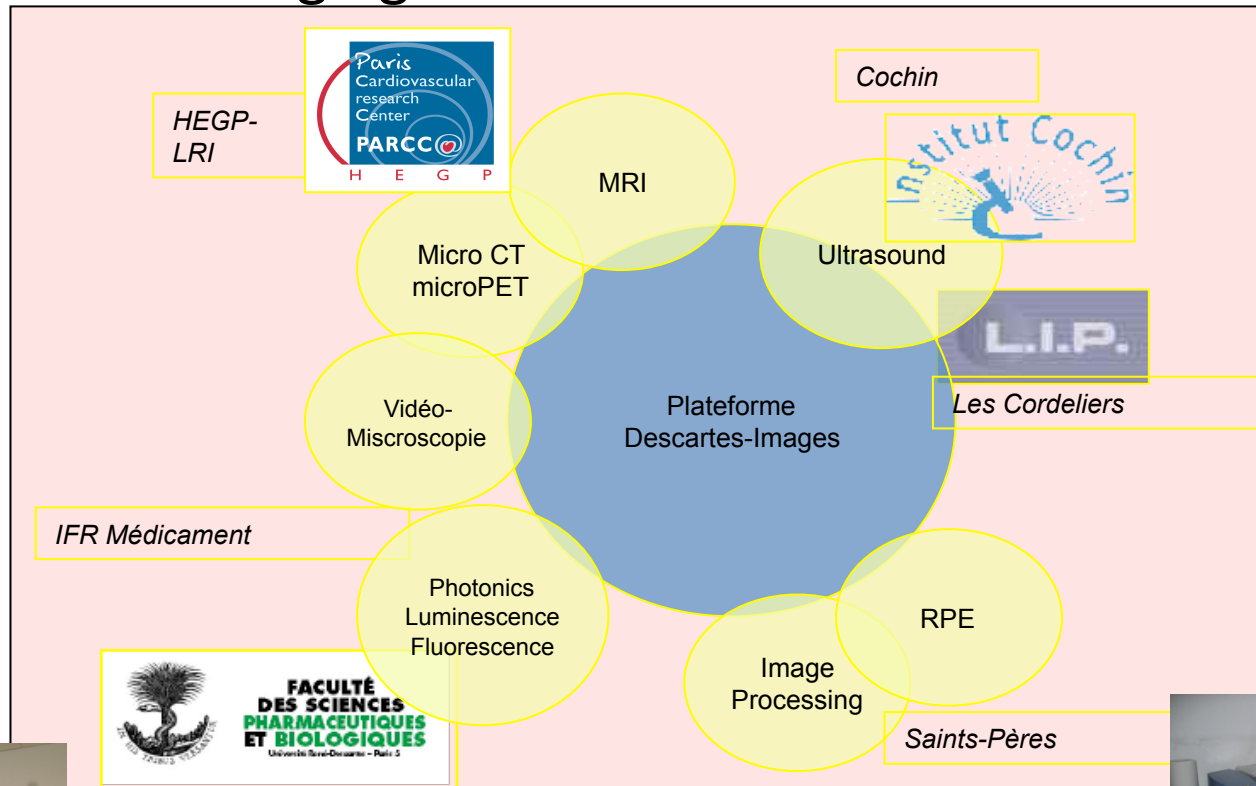
UMR-7574-ENSCP-ParisTech Scintillation Small Animal Imaging	UMR-7574-ENSCP-ParisTech Scintillation Small Animal Imaging	GT6 Group Imaging	Scintillation Small Animal Imaging
<p>Tomography imaging</p>  <p>SAINT-GOBAIN CRYSTALS</p> <p>=> early detection of tumours</p> <p>(PET scan)</p> <p>The patient absorbs molecules marked with positrons (β^+) emitting elements (^{18}F, ^{15}O, ^{13}N, ^{11}C...): $\beta^+ + e^- \Rightarrow \gamma_1 + \gamma_2$ (511 keV) γ rays are detected by the scintillators</p>   <p>Scintillators with : High density, fast decay, high LY</p> 	<p>Small Animal Imaging</p> <p>Collaboration D. Scherman et al. UPCG & ENSCP-ParisTech</p>  <p>lungs</p> <p>NH_3^+ = electric surface potential >0</p>  <p>COO^- = electric surface potential <0</p> <p>=> better circulation, then liver uptake</p> <p>(close interaction with GT2 C. Chanéac)</p> 	<p>Outlook</p> <p>New Materials for optical imaging</p> <ul style="list-style-type: none"> • Control of the size (ceramic scintillators precursors, and nanoparticles for small animal imaging) • Increase of the luminescence yield • Mechanisms study • New concepts and new applications    	<p>Scintillation Small Animal Imaging</p>

University Paris Descartes

Faculty:

Charles André Cuenod (ca@cuenod.net)

Imaging Platforms and Resources

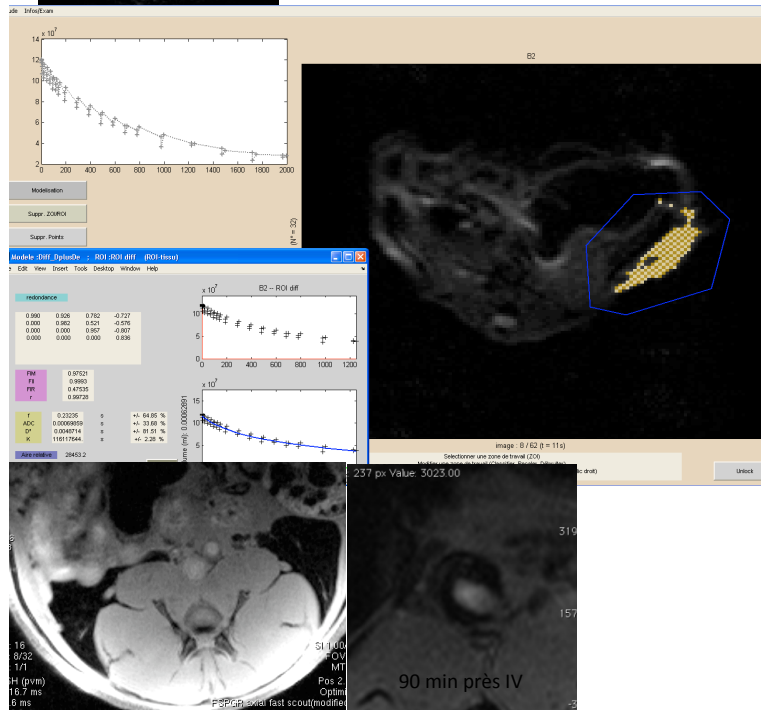
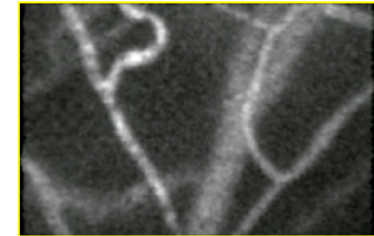
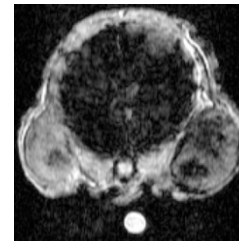
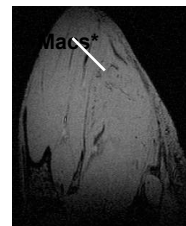
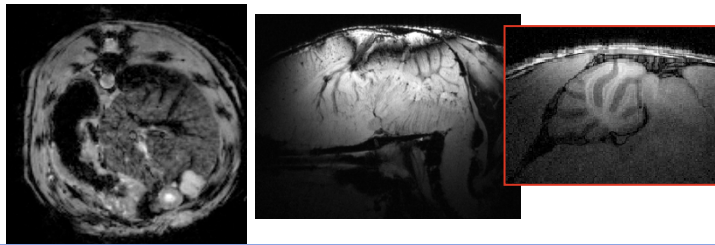


University Paris Descartes

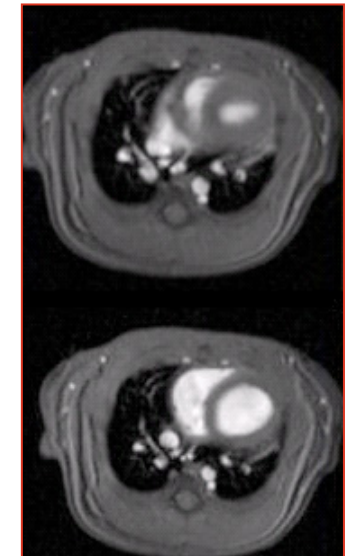
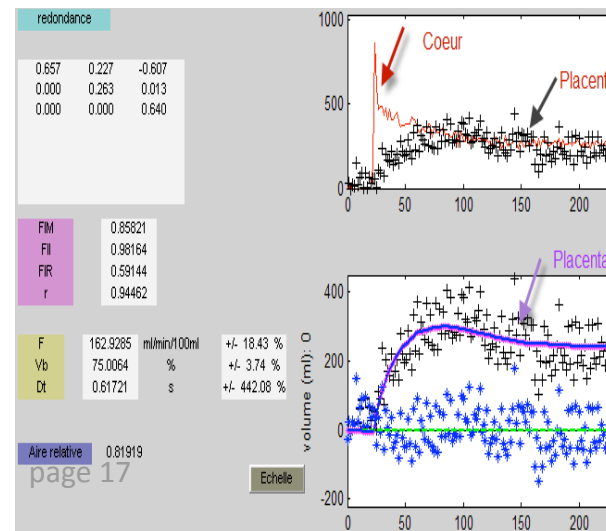
Faculty:

- Charles André Cuenod (ca@cuenod.net)
- Olivier Clément (olivier.clement@inserm.fr)

Anatomic, Functional and Molecular Imaging



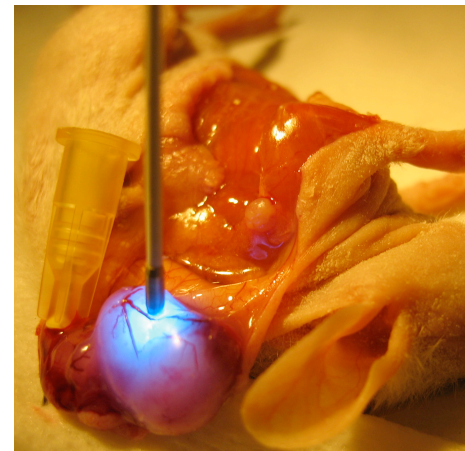
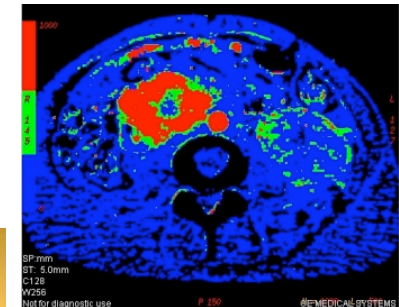
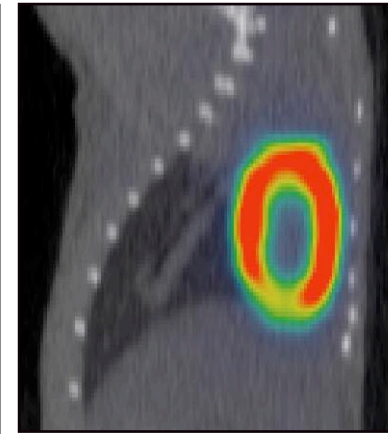
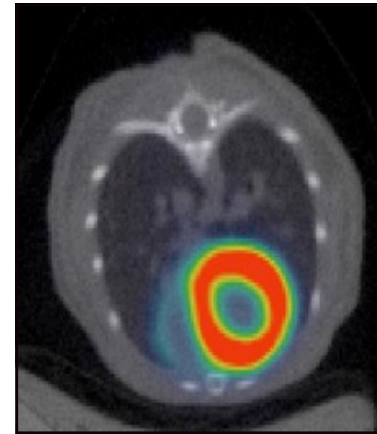
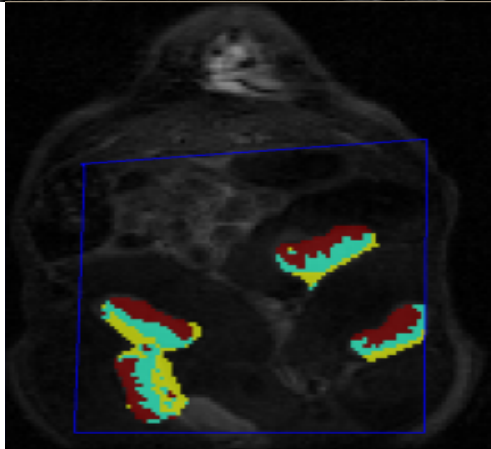
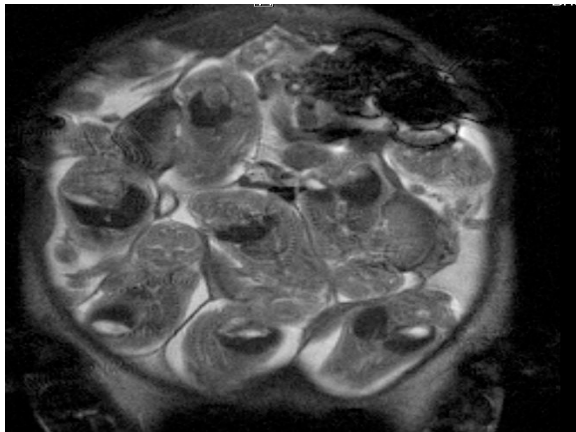
Human and small animals



University Paris Descartes

Faculty:

- Charles André Cuenod (ca@cuenod.net)
- Olivier Clément (olivier.clement@inserm.fr)



University Paris Descartes

Faculty:

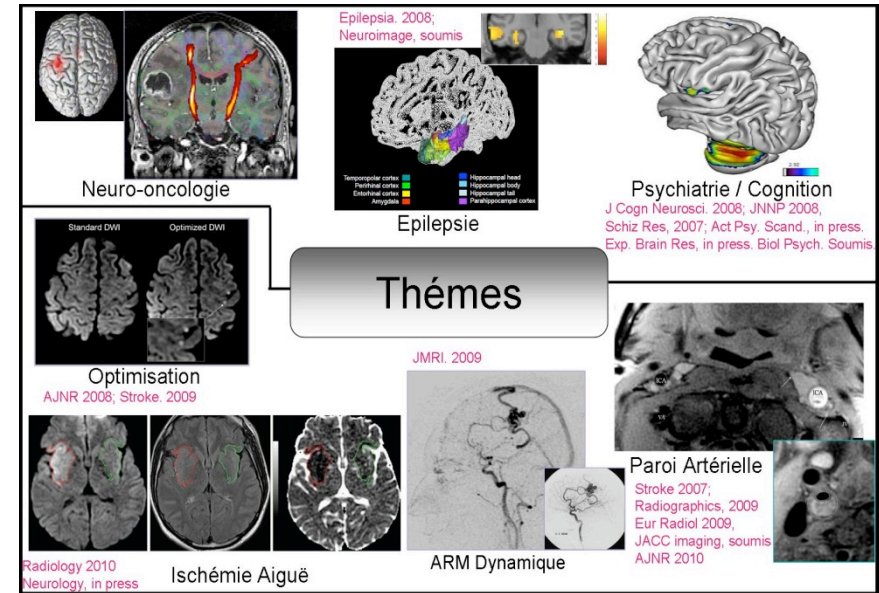
- Catherine Oppenheim (C.OPPENHEIM@ch-sainte-anne.fr)

Centre Hospitalier Sainte-Anne

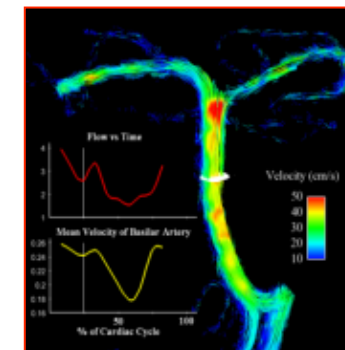
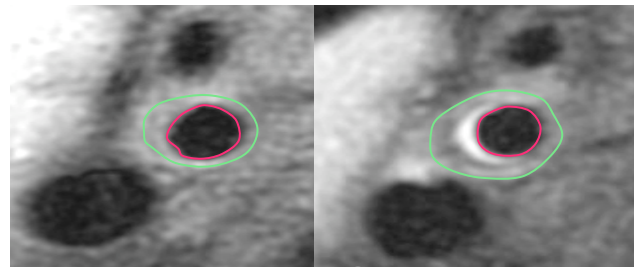
Département of Morphological and Functional Imaging

❖ Imaging Resources

- CT 64 detectors (2008)
- Interventional radiology
- Ultrasound
- MRI 1.5 T (2008) and **3T (2010)**



❖ INSERM UMR 894. Stroke Unit



University Paris Descartes



5 fields of research: Medicine, Biology,
Chemistry-Pharmacology, Physics,
Mathematics et Computer Science

Laboratory MAP 5

Image processing

Faculty:

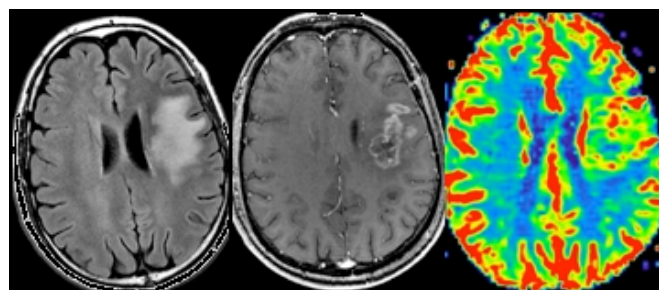
- Lionel Moisan (Lionel.Moisan@parisdescartes.fr)

Laboratory LIPADE

Image processing

Faculty:

- Florence Cloppet (florence.cloppet@mi.parisdescartes.fr)

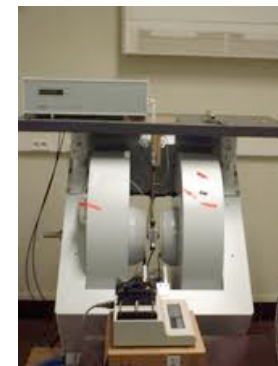
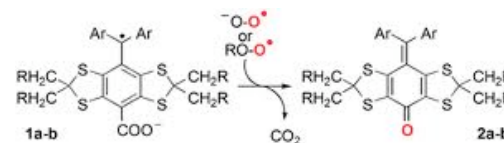


Laboratory UMR CNRS 8601

Faculty:

-Yves Frappart (yves.frapart@parisdescartes.fr)

Platform EPR imaging



BIM: after the M2....

- R&D engineer:
 - Main industrials of whole body screening: GE, Philips, Siemens
 - Startups in medical imaging: Supersonic, Echosens,...
 - Biological imaging: Biospace Lab, Leica,...
 - Pharmaceutical companies: Sanofi Aventis, Guerbet, ...
 - Medical Imaging Software: Dosisoft,
 - Additional: L'oreal,....
- PhD :
 - Medical image processing
 - Medical imaging and Chemistry for imaging
 - Biological and optical imaging