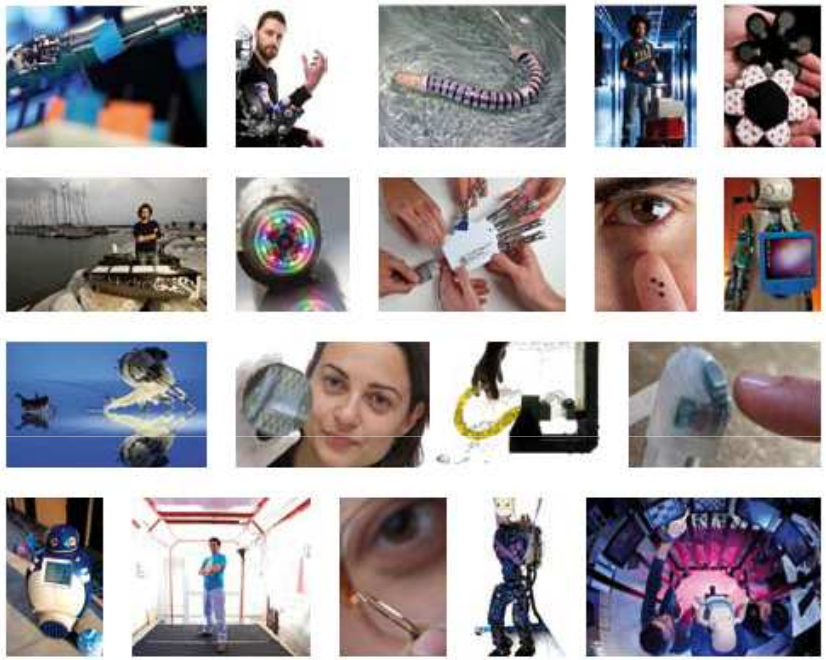
the BioRobotics Institute



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BIOSTEC 2014

7TH INTERNATIONAL JOINT CONFERENCE ON BIOMEDICAL ENGINEERING SYSTEMS AND TECHNOLOGIES

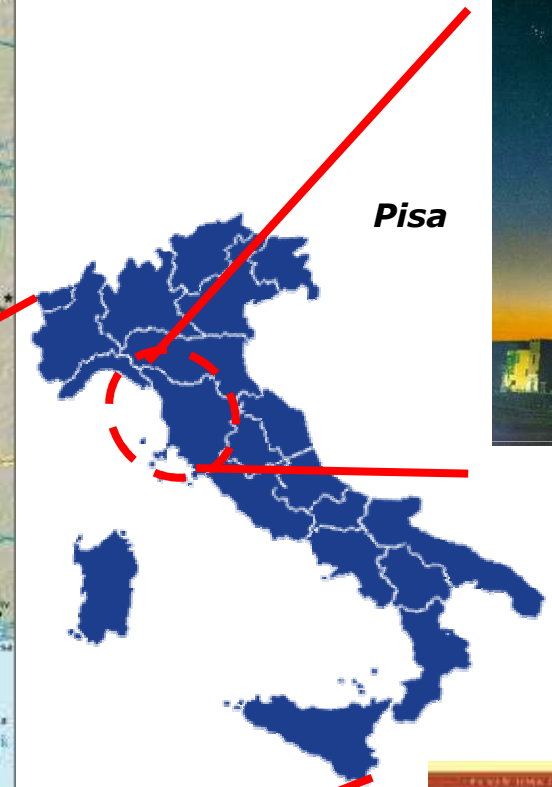
**Angers, France**
**March 4, 2014**

# FRONTIERS OF SURGICAL ROBOTICS


## Cesare Stefanini

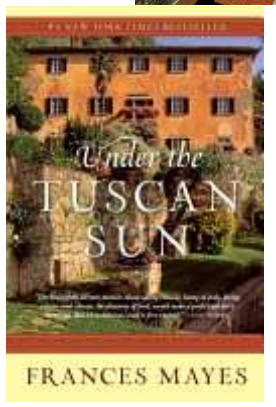
**The BioRobotics Institute**
**Scuola Superiore Sant'Anna**
**Pisa, Italy**

# Italy, Tuscany and Pisa in Europe

***Pisa***

***Firenze***



# The University and Research System in Pisa

Sistema Universitario Pisano

**Scuola Normale Superiore**
Established 1810
150 professors
283 students

**University of Pisa**
Established in 1343
2.100 professors
50.000+ students

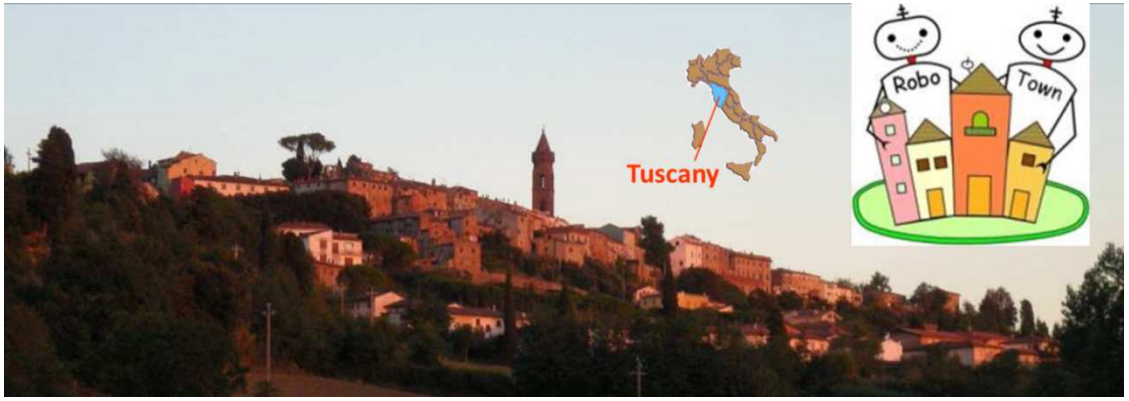
**Scuola Superiore Sant'Anna**
Established in 1987
100 professors
220 students

**CNR**
**National Research Council**
15 Research Institutes
About 1.500 researchers

National Enterprise for nanoScience and nanoTechnology

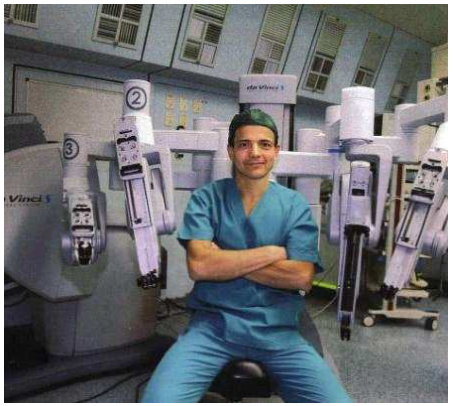
**National Institute of Nuclear Physics**
About 300 researchers

# Tuscany: the Land of Robot(ic)s

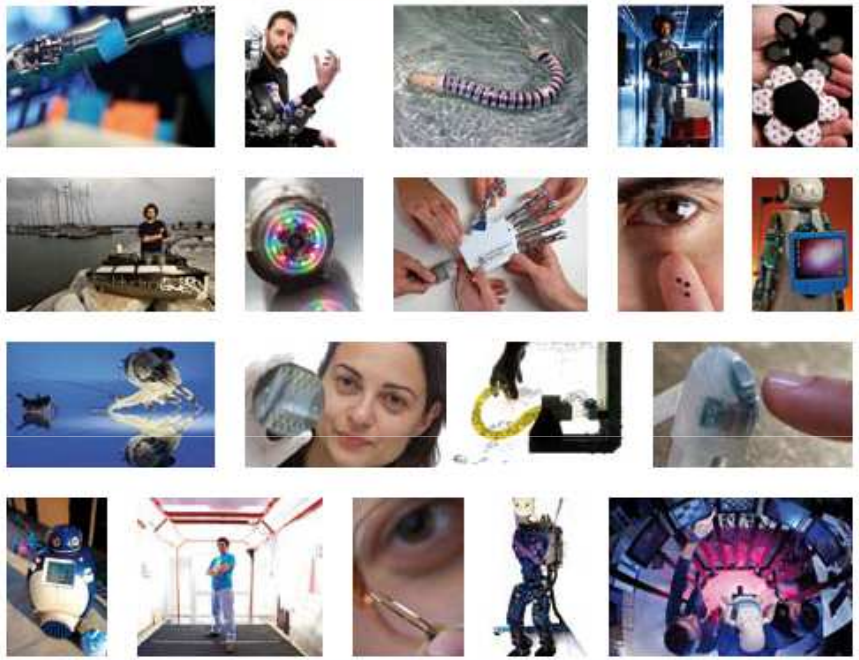








# the BioRobotics Institute



**12 Faculty**

**75 PostDocs**

**88 PhD Students**



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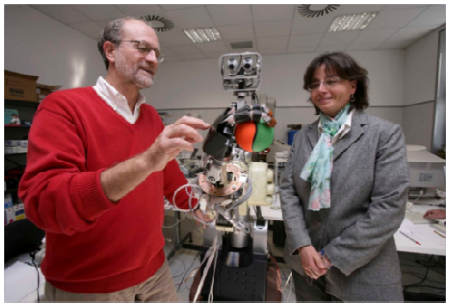
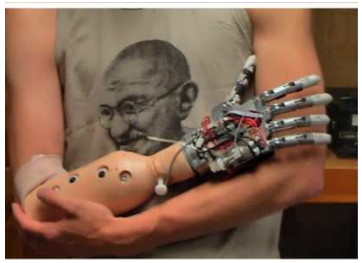
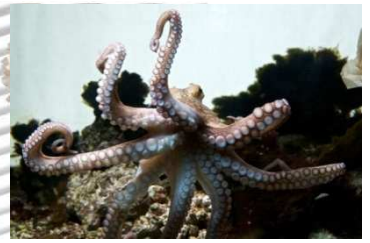
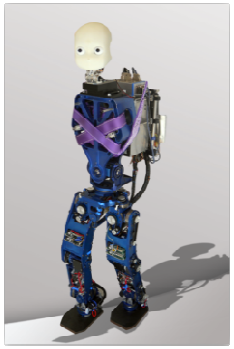
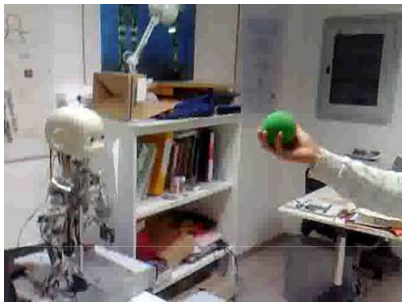
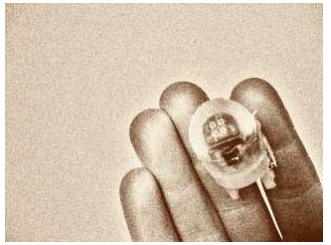
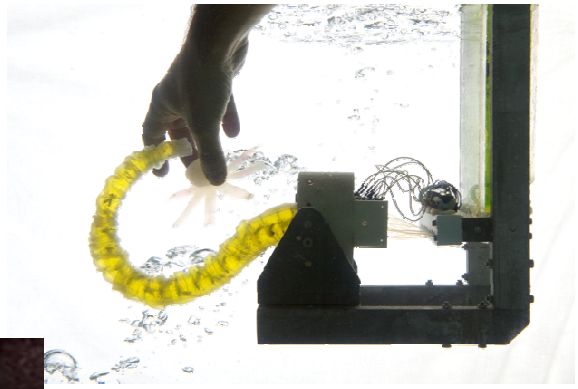
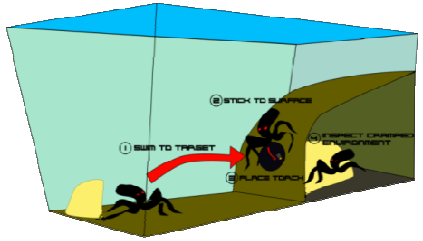
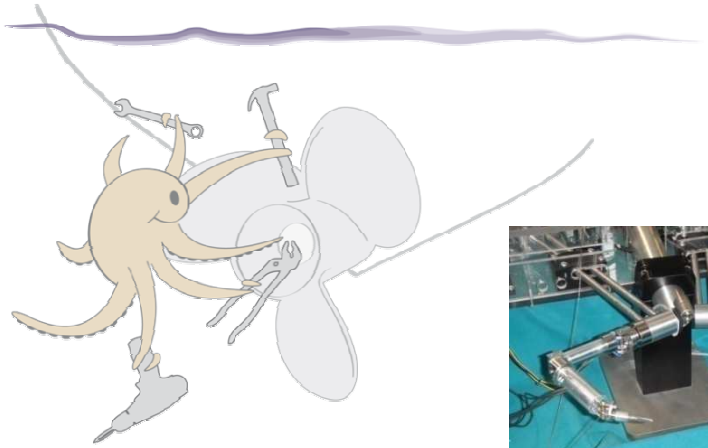
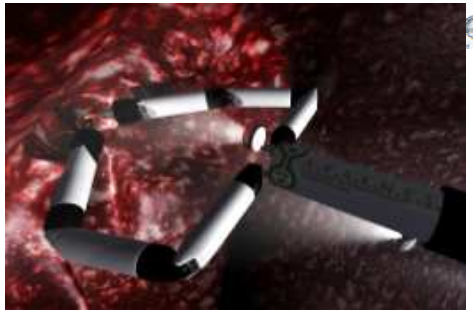
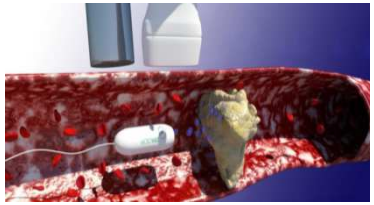


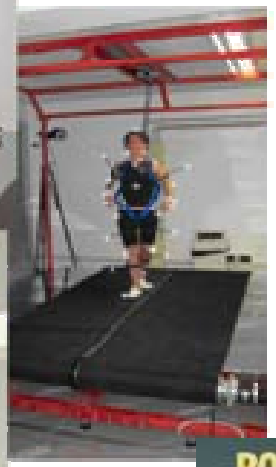
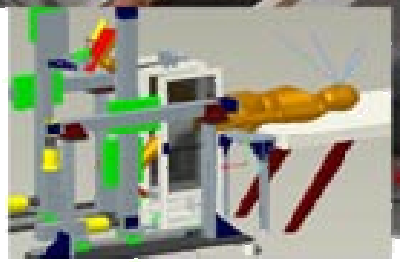
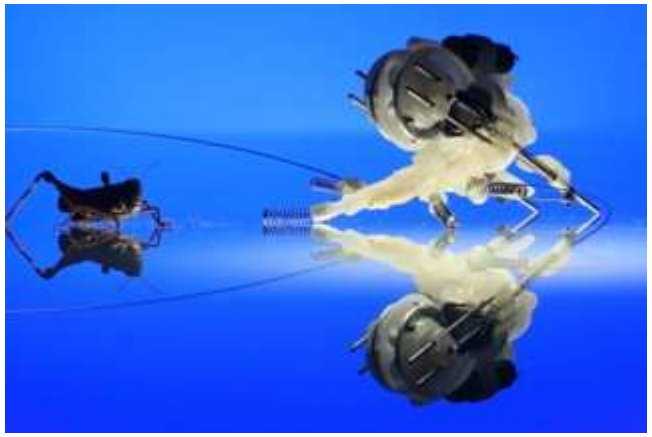
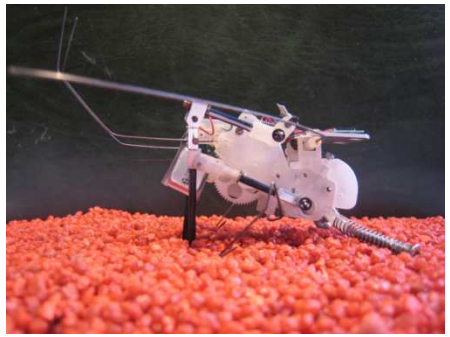


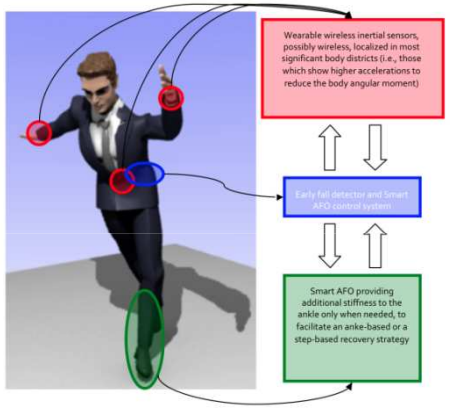





**This and more at: www.bioroboticsinstitute.eu**





**This and more at: www.bioroboticsinstitute.eu**




**This and more at: www.bioroboticsinstitute.eu**

# BioRobotics: quest for fundamental understanding (science) **and** consideration of use (engineering)

Biological system

Engineering analysis and modeling

Validation

Development of a physical model

Development of a biomedical robot

Bio-mimetic robot

Bio-inspired robot

# Lamprey and Salamander Robots and the Central Nervous System

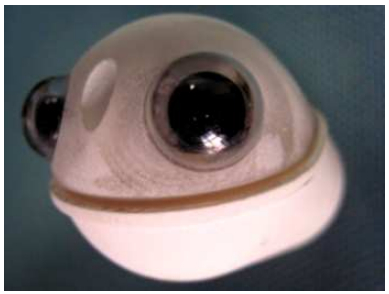

Biol Cybern (2013) 107:495–496
DOI 10.1007/s00422-013-0570-6

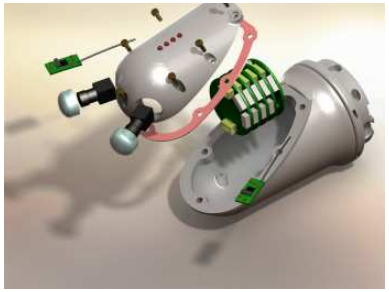
EDITORIAL

Biological Cybernetics

## Foreword for the special issue on Lamprey and Salamander Robots and the Central Nervous System

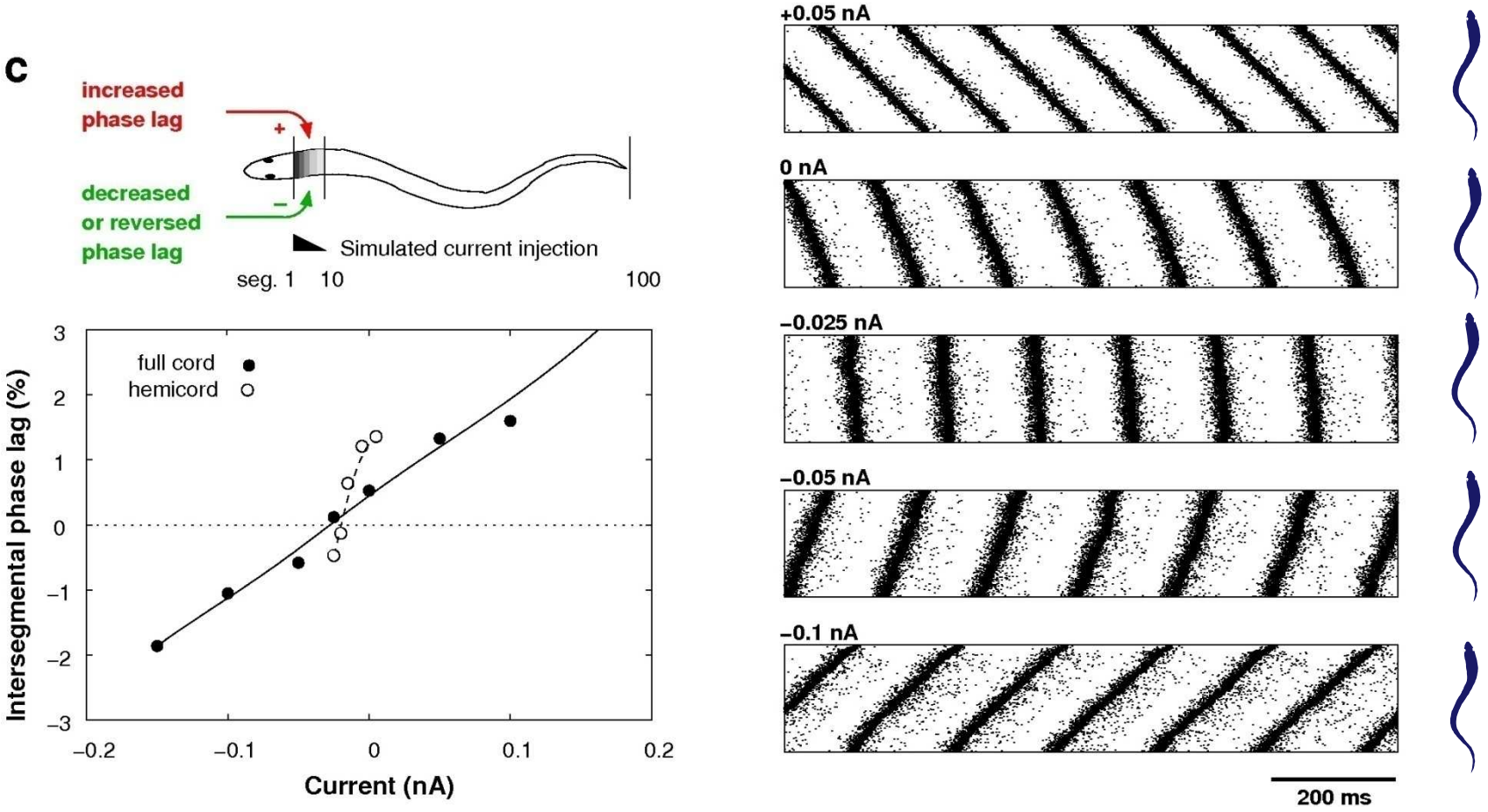
Auke Jan Ijspeert · Sten Grillner · Paolo Dario





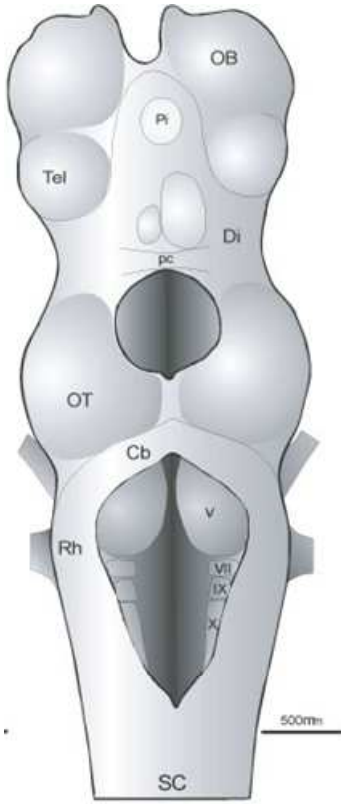
# Spinal neuromuscular machinery

## The intersegmental phase-lag - graded modification by action on a few rostral segments

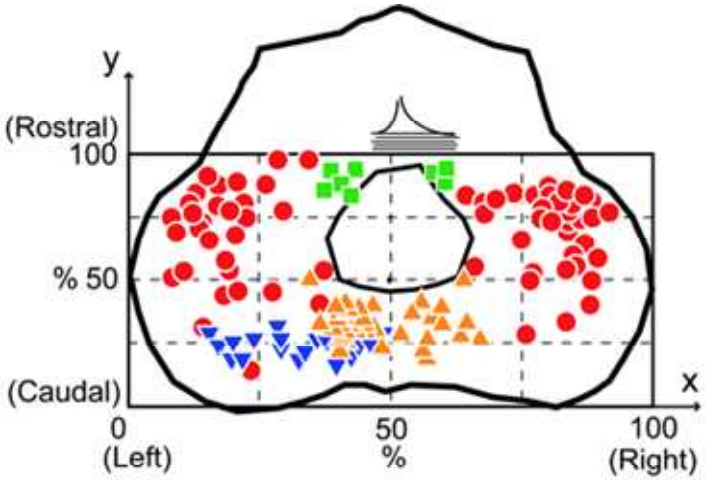



Kozlov et al, PNAS, 106:20027-32, 2009

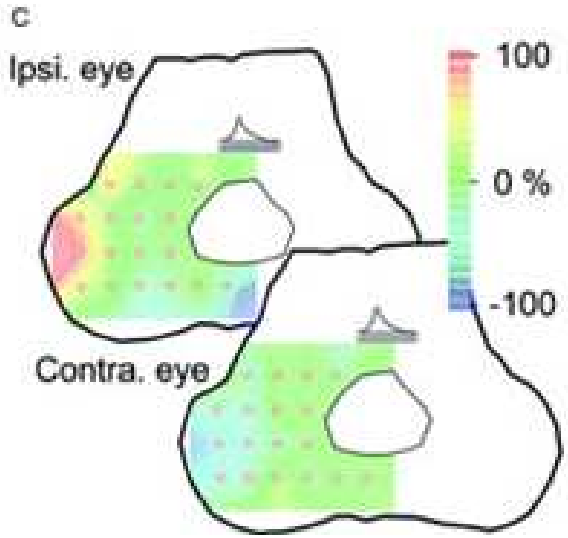
# Brain circuitry




Transformée




- Type I — Orienting response (eye, trunk, locomotion)
- Type II — Rhythmic eye and neck movements
- Type III — Downward shift of both eyes, body bending
- Type IV — Forward swimming, no eye and neck movements




**Tectal Control of Locomotion, Steering, and Eye Movements in Lamprey**

**Kazuya Saitoh, Ariane Ménard and Sten Grillner**

*J Neurophysiol* 97:3093-3108, 2007. First published Feb 15, 2007; doi:10.1152/jn.00639.2006

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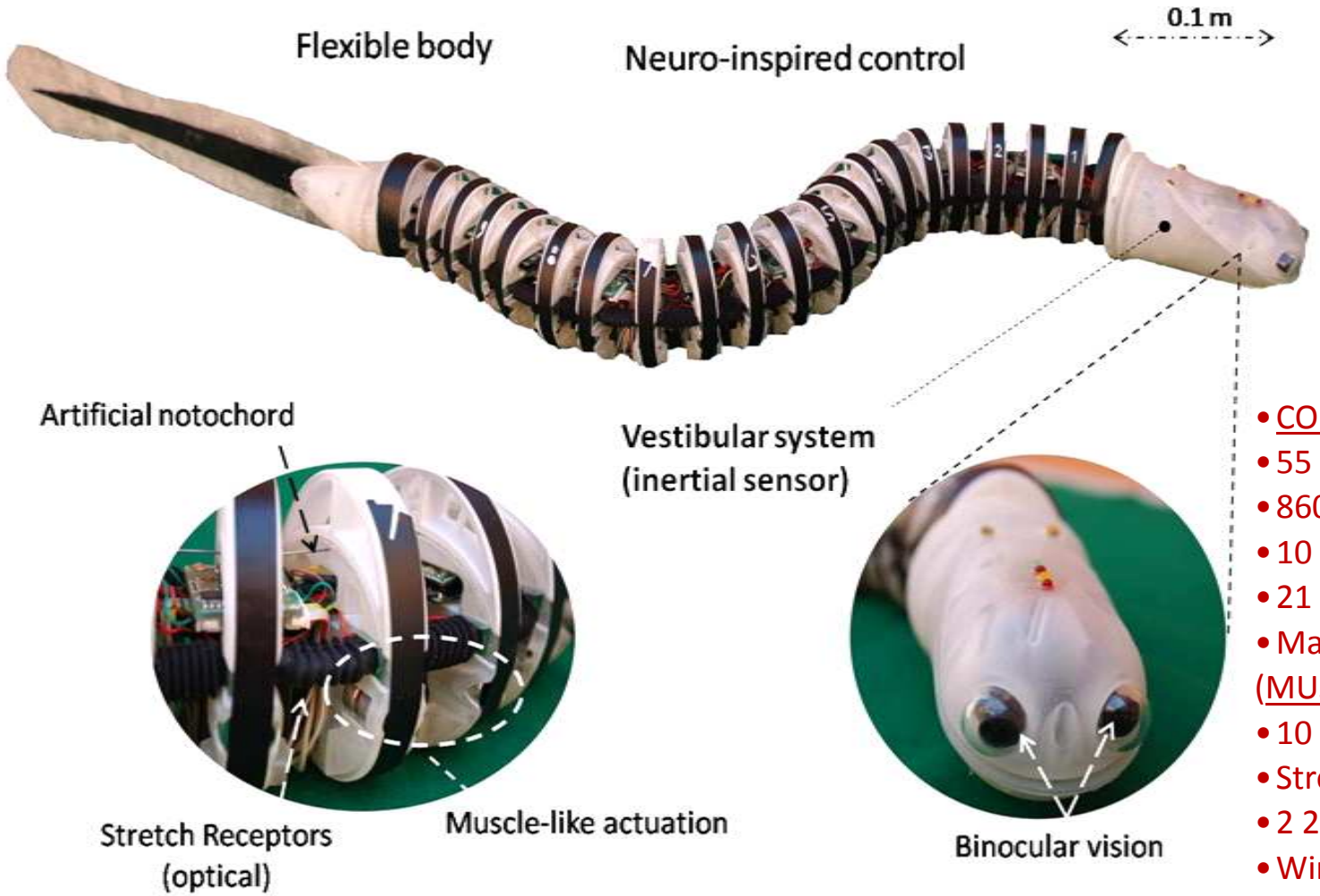
# The biomimetic artefact




- COMPLIANT BODY
- 55 mm in diameter
- 860mm in length
- 10 motors
- 21 vertebras
- Magnetic actuators (MUSCLE -LIKE)
- 10 battery packs
- Stretch sensors
- 2 2D cameras
- Wireless communication
- Gyros and accelerometers

***Results published on Bioinspiration and Biomimetics (vol. 7, p. 1-8, 2012)***

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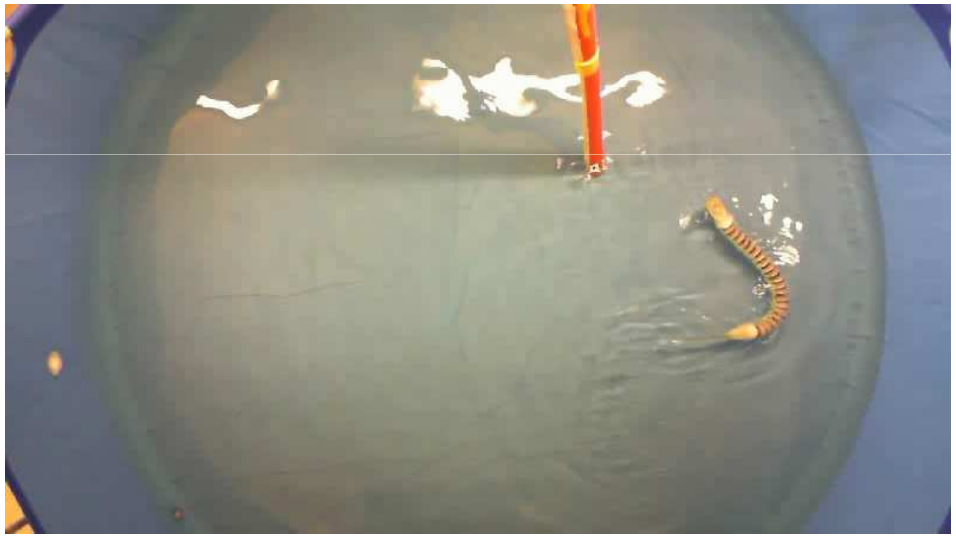
# Goal driven locomotion through vision

## Colour tracking

Continue targeting



Random spot targeting

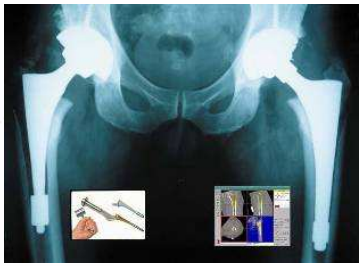
***Results in press on Biological Cybernetics***

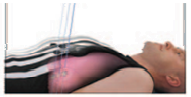
# Medical Robotics: an increasingly successful clinical and industrial field

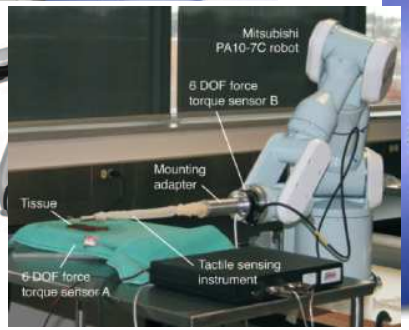














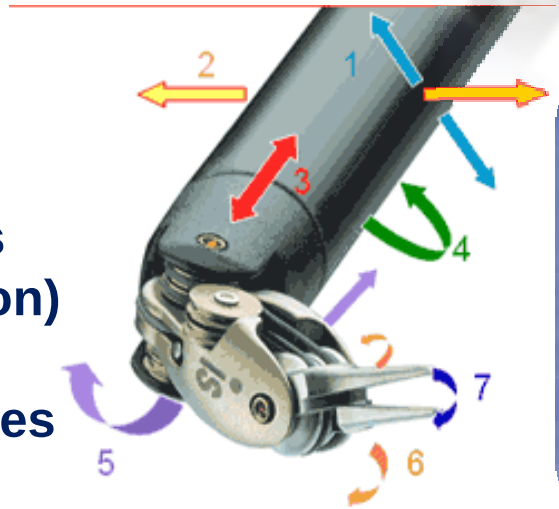


# Achievements of Robotics Surgery

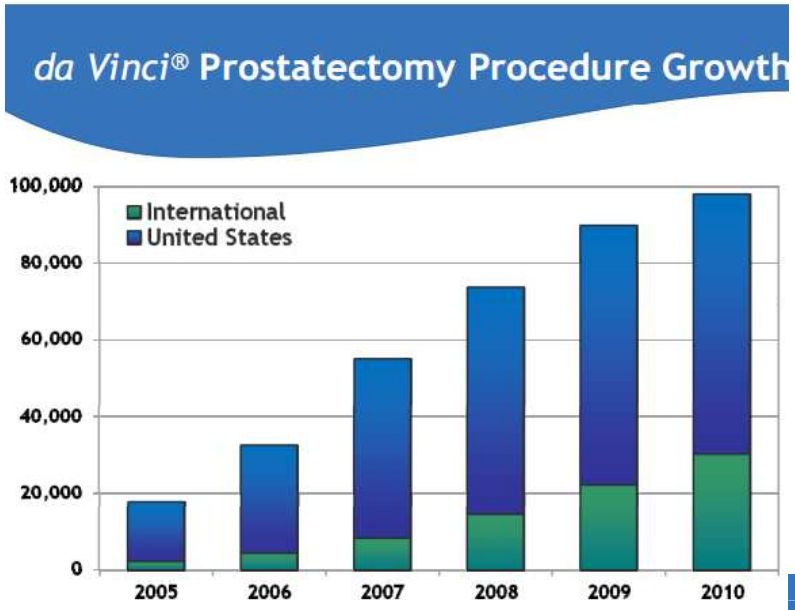
- Game-changing applications
- Technically advanced and dependable systems
- Widely accepted and used in clinical practice by surgeons, by patients and by hospital administrations: 450.000+ surgical interventions worldwide in 2012
- Real IMPACT on health, and on economy (real products, real jobs)

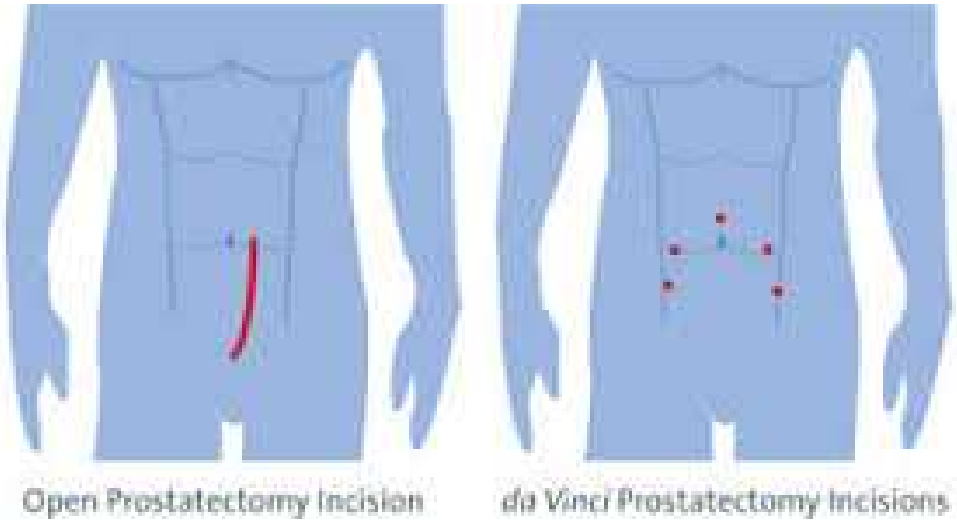
# The "Secrets" of the DaVinci Robot Success: Accuracy, Dexterity, Intuitiveness

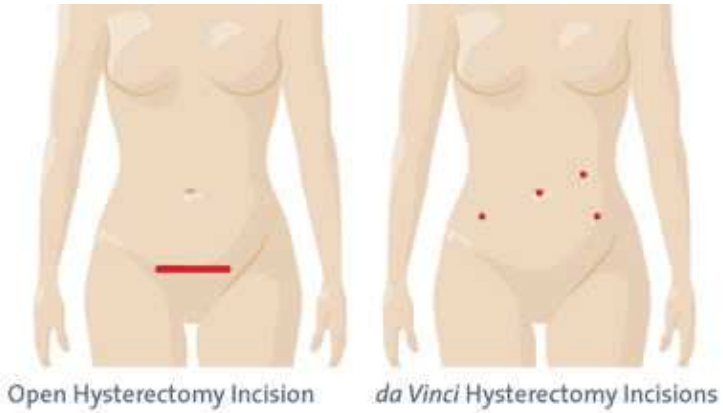

- Outstanding mechanical design
- Excellent optics (2D and 3D vision)
- Smart and friendly interfaces

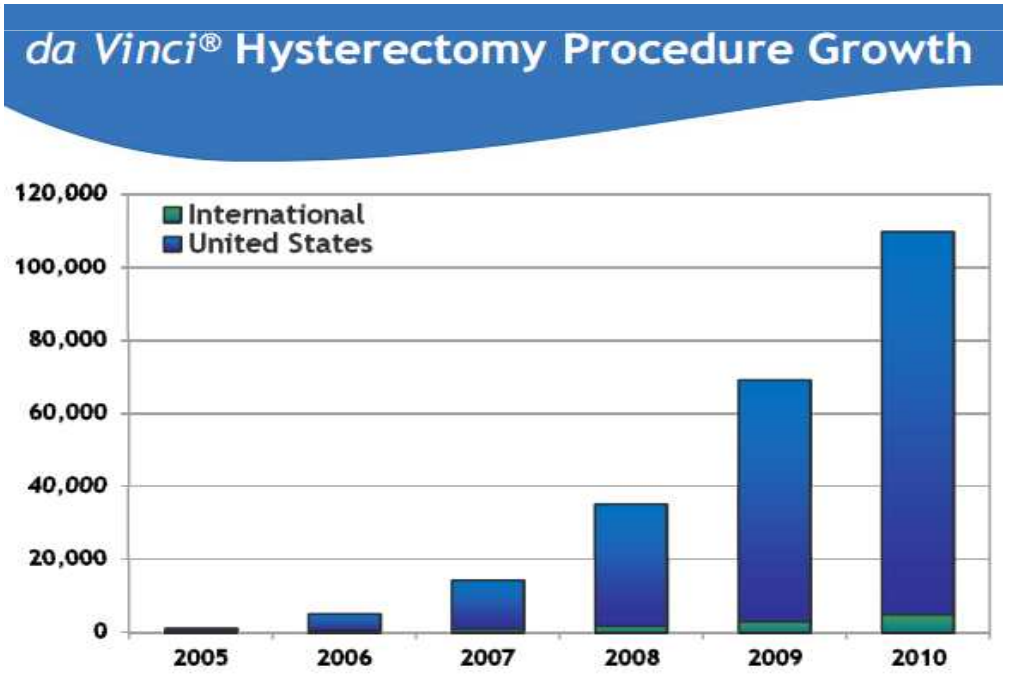



# Successful daVinci applications in surgery

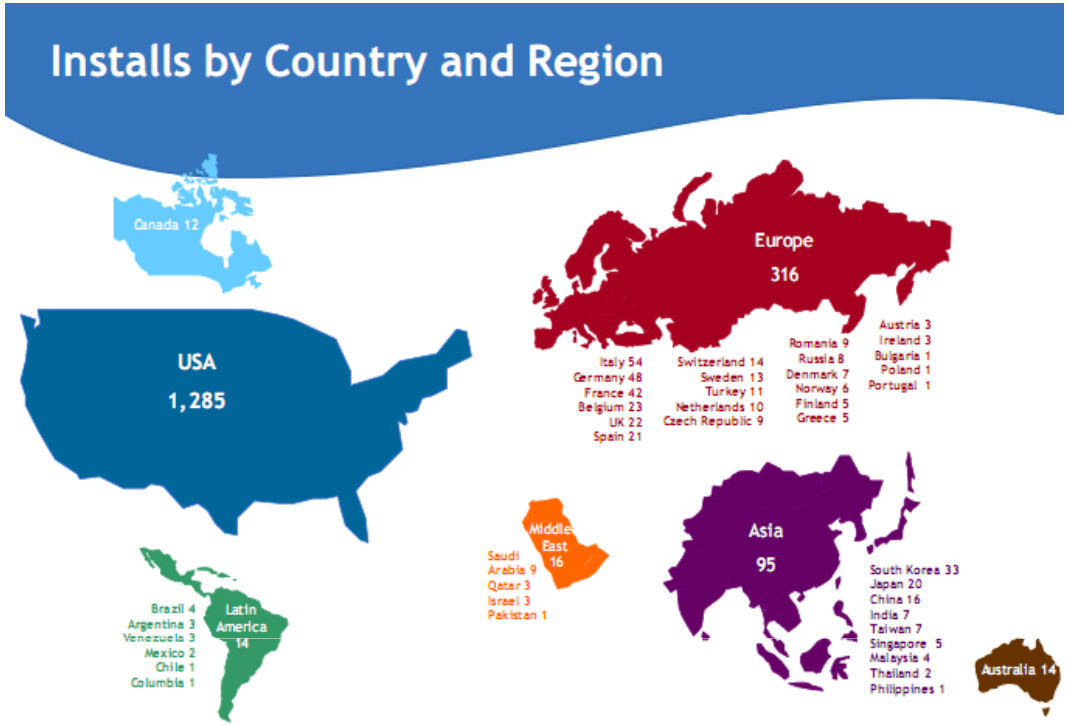



# Da Vinci Robot and Intuitive Surgical at-a-glance




**DaVinci Worldwide Installations**

**2.700+ systems installed in 30 Countries and in 1800+ hospitals**

**1700+ employees**

Revenue

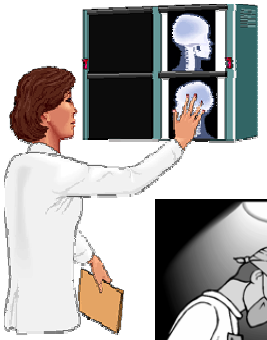
| Year Ended December 31, | | | |
|---|---|---|---|
| 2011 | 2010 | 2009 | 2008 |
| (In millions, except per share amounts and headcount) | | | |
| $1,757.3 | $1,413.0 | $1,052.2 | $ 874.9 |

**In 2012, 450.000 surgical procedures** were performed with the da Vinci Surgical System. **1.500.000 procedures in total so far.**

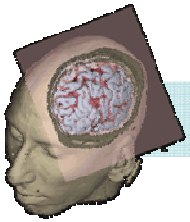
SOURCE:
www.intuitivesurgical.com

# The Evolution of Surgery

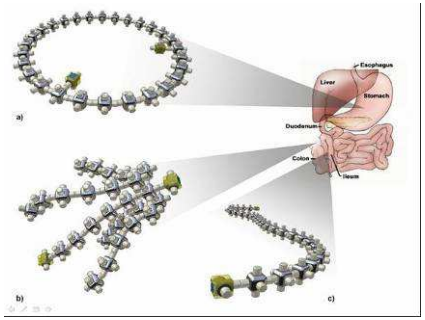
## TRADITIONAL SURGERY



## MINIMALLY INVASIVE SURGERY

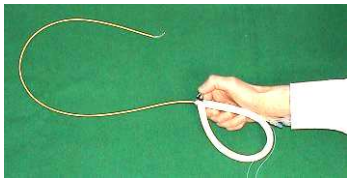


*Da Vinci CAS system*



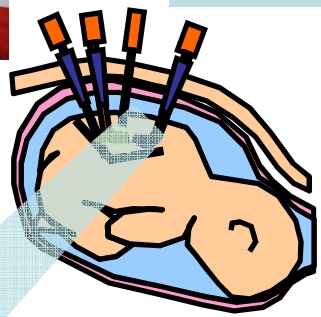
*Endoscopic capsules*
*Reconfigurable surgical systems*

## ENDOLUMINAL SURGERY

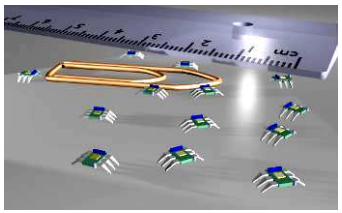


*Micro-endoscope for spinal cord*

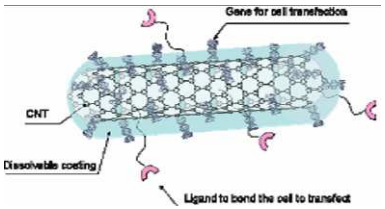
## FETAL SURGERY



## CELL SURGERY



*Force-feedback scissor for fetal surgery*




*Artificial virus for cell therapy*

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# Why a Change of Paradigm is INEVITABLE

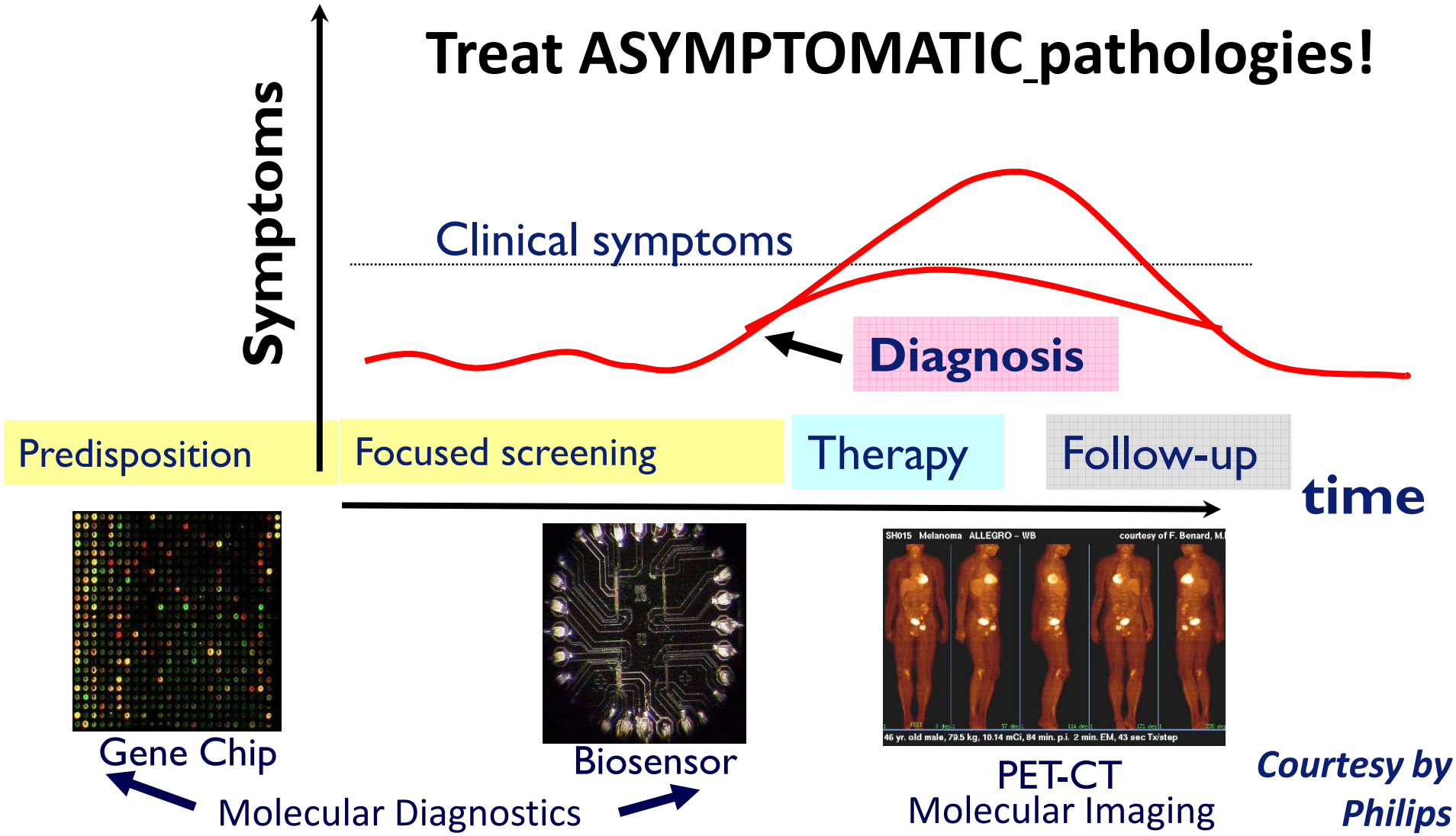
**Professor Sir Alfred Cuschieri, MD**
Director of the Institute of Medical Science and Technology in Dundee and St Andrew's Universities. Pioneer of endoscopic surgery

***The operating room of the year 2030 will be a totally different environment than today***

***MASS Screening and EARLY diagnosis will have a major impact on the type and invasiveness of required surgical procedures***

**The combination of micro/nano/bio technologies, molecular biology, chemistry, physics, robotics/microrobotics, etc. will be key technologies enabling future high quality (accurate and repeatable), early and minimal invasive surgery**

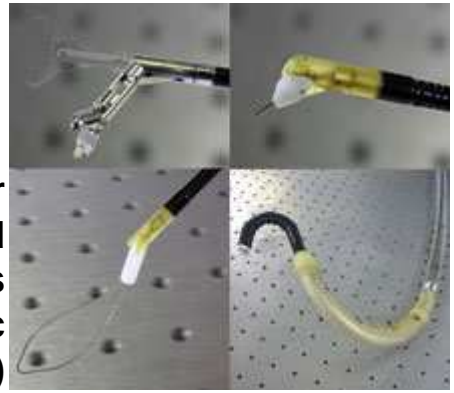
# Prevention: the challenge of modern medicine



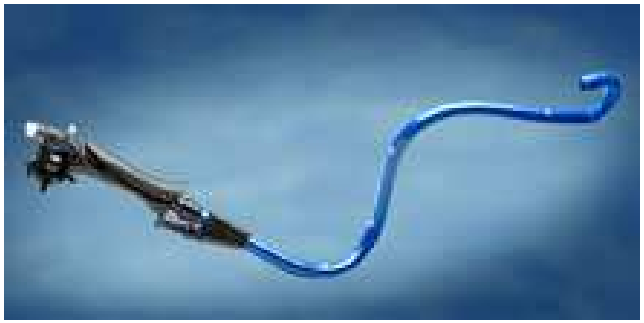
# What is Endoluminal Surgery?

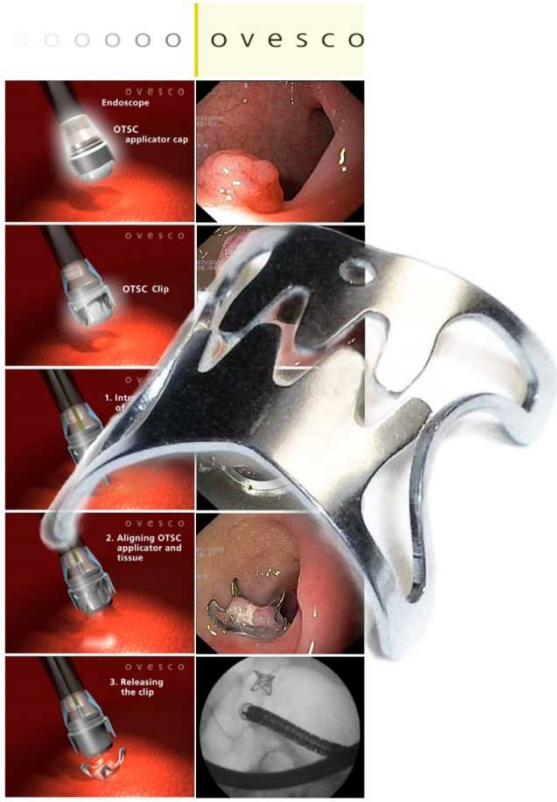
Endoluminal procedures consist of bringing a set of advanced therapeutic and surgical tools to the area of interest by navigating in the *lumina* of the human body, such as the gastrointestinal tract, the urinary apparatus, the circulatory system, etc., with a scarless or minimally invasive access

**PillCam for GI tract endoscopy**



**Instrumentation for endoscopic surgery and NOTES (Natural Orifices Transgastric Endoscopic Surgery)**





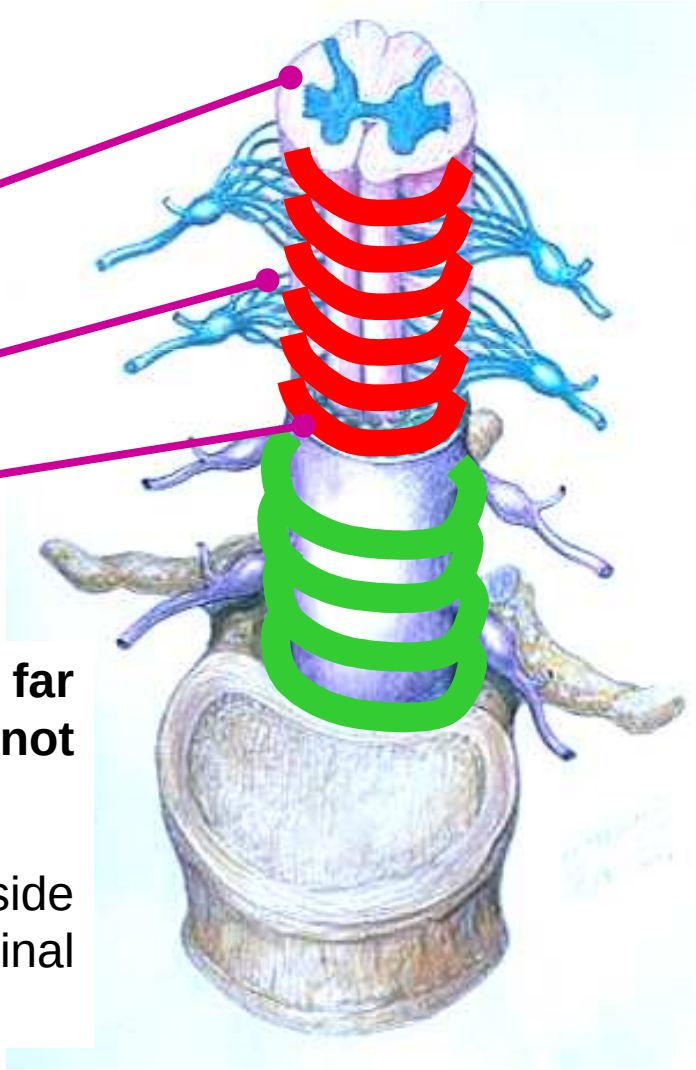

**Clip for endoscopic surgery**

# The Neuroendoscope: an example of new endoluminal ultraminiature tool

# NeuroEndoscopy of the spinal cord
# the Problem

## There is a need for:

- Precise and early diagnosis of spinal cord lesions (300.000 paralyzed persons in Europe)
- Possibility to intervene directly on pathologies:
  - Injection of neurotransmitters and pumping of haematomas in **traumatic lesions**
  - Electro-coagulation of the afferences to the posterior horn in case of **intractable pain**
  - Cleaning of fibrous adherences in case of **arachnoid proliferation**



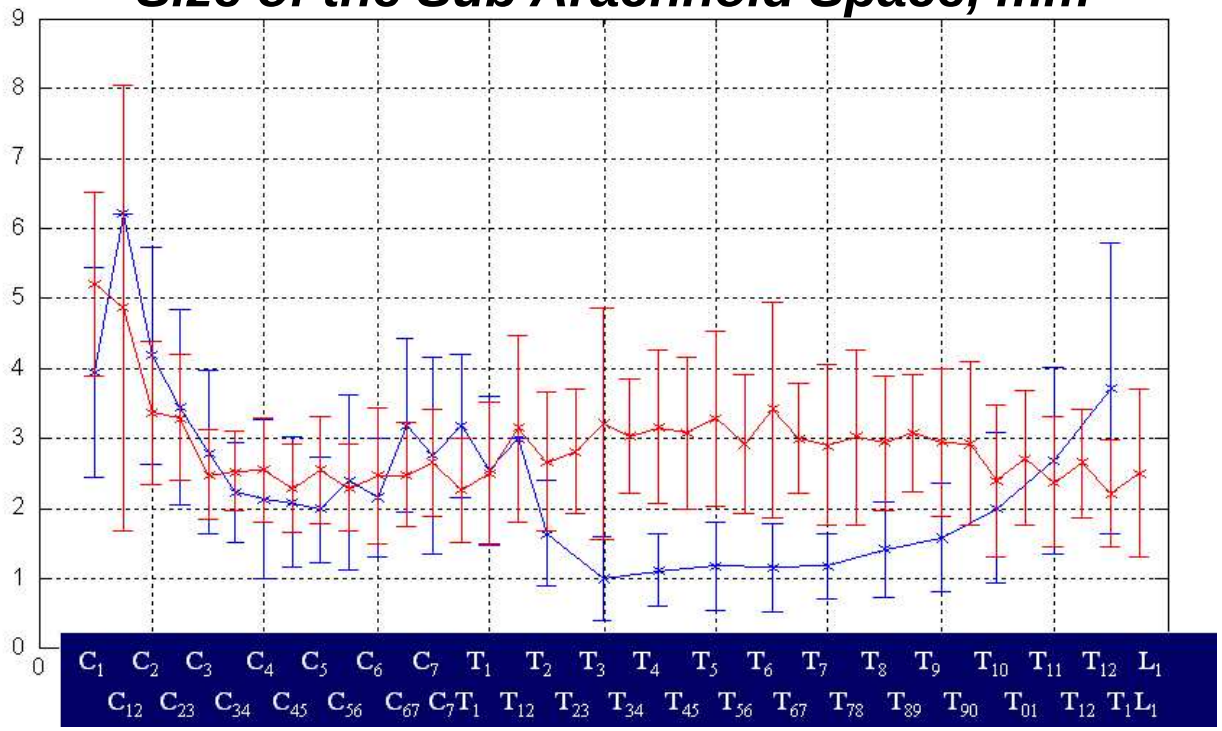
Current procedures are limited to the **epidural space**, **far** from the spinal cord and filled by semiliquid, **not transparent** fat.

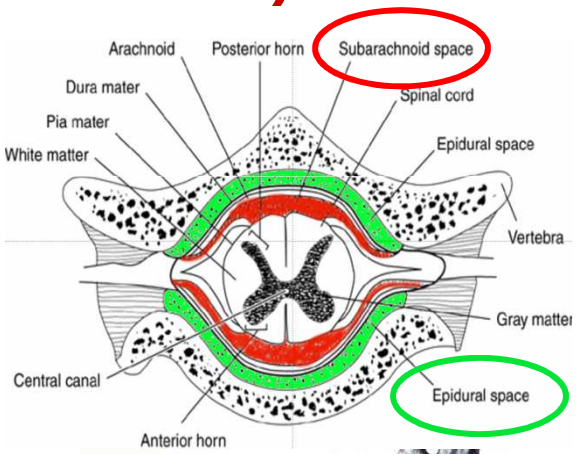
An Endoscopic System is needed for the **navigation** inside the **subarachnoid space** (filled by the Cerebro Spinal Fluid), for diagnosis and intervention.

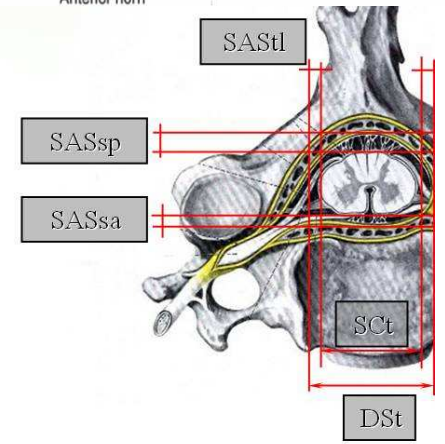
# Neuroendoscopy of Spinal Cord
# The environment

- The mean is suitable for navigation (Cerebro-Spinal Fluid, water-like liquid)
- The **workspace is extremely small (few millimeters)**

***Size of the Sub Arachnoid Space, mm***

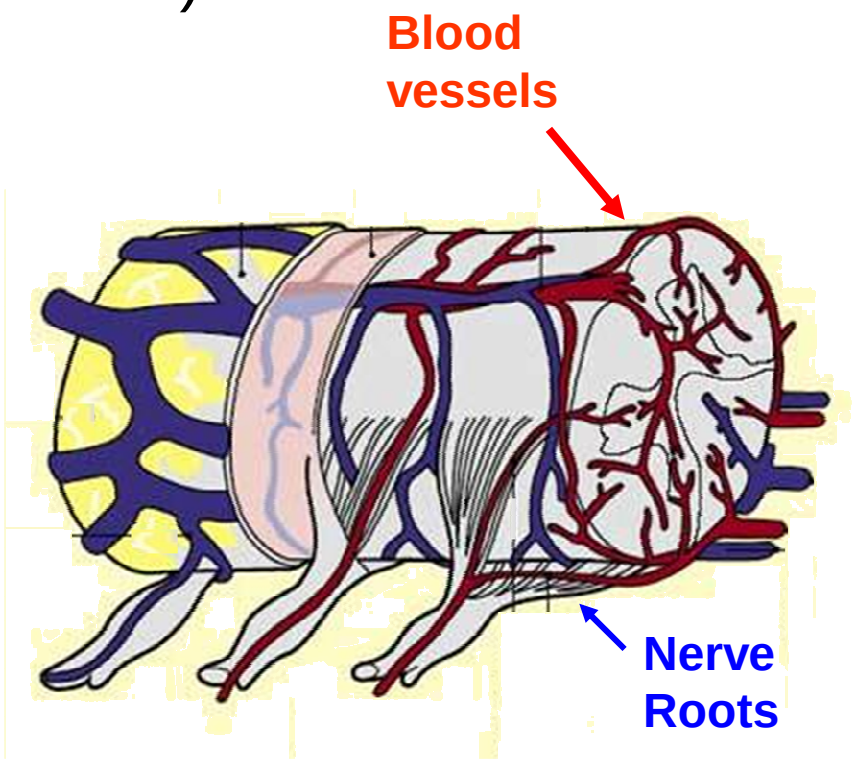


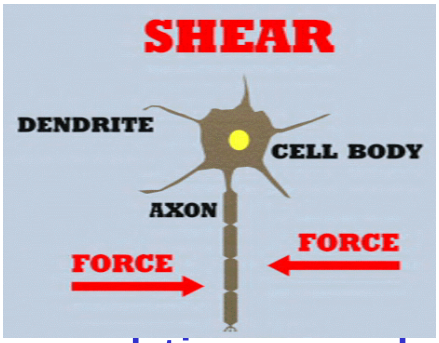



# Neuroendoscopy of Spinal Cord
# The environment

- The mean is very suiable for navigation (Cerebro-Spinal Fluid, water-like liquid)
- The workspace is extremely small
- Anatomical **structures are very DELICATE** (vessels, nerve roots)

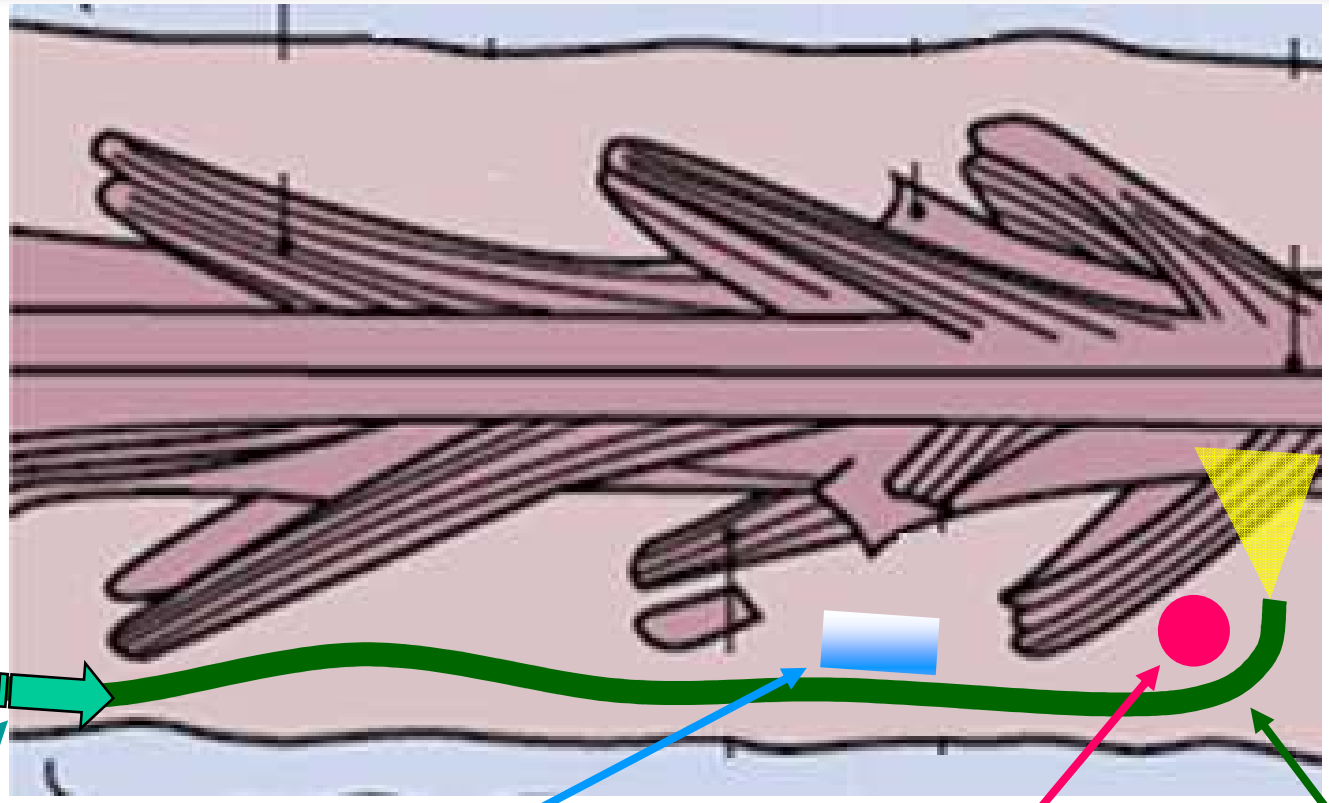



## AXONAL DAMAGE




For cord tissue, shear **strains** above 15% represent severe injury.

# Functions required for navigation



Vision and illumination

Flexible body

Advancement control

Soft contact means

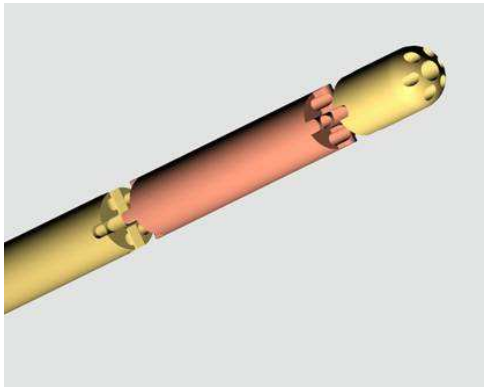
Awareness of delicate structures out of the viewfield

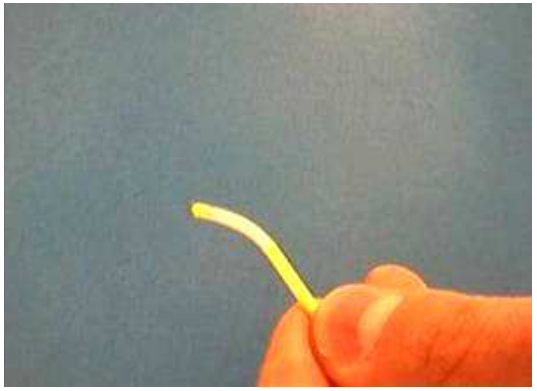
Steering with multiple degrees of freedom

# MINOSC – The **Actuated Catheter**

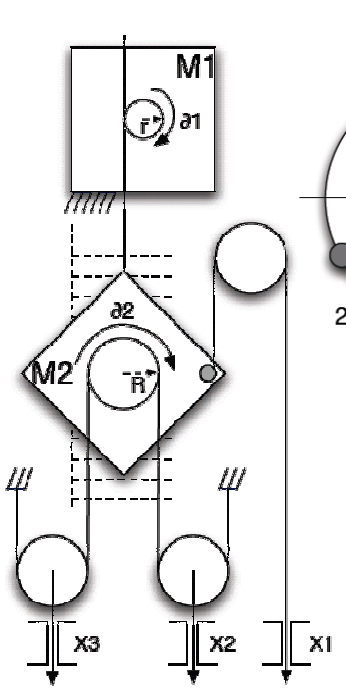
**The concept:**

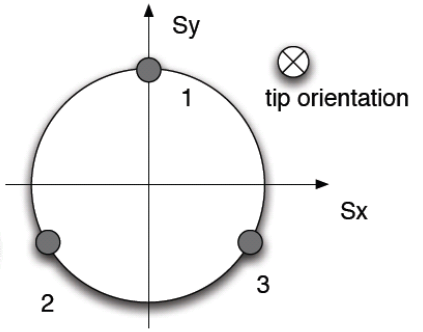
- **Mechanical Steering** of the endoscope using *flexure joints* fabricated via Graded Material Technology and Injection Molding.

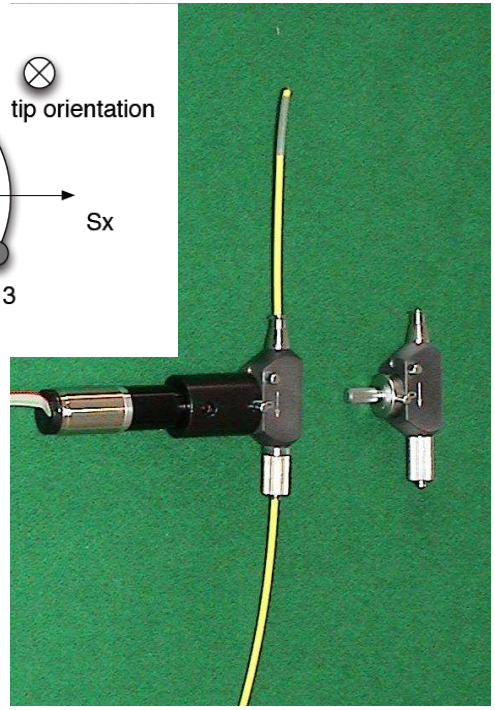




- **Servoassisted actuation** for fine and controlled advancement of the endoscope and steering. Servomotor actuating a STORZ micromanipulator.

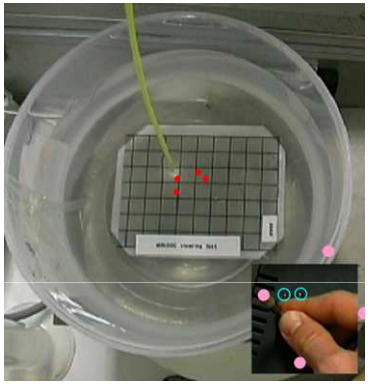


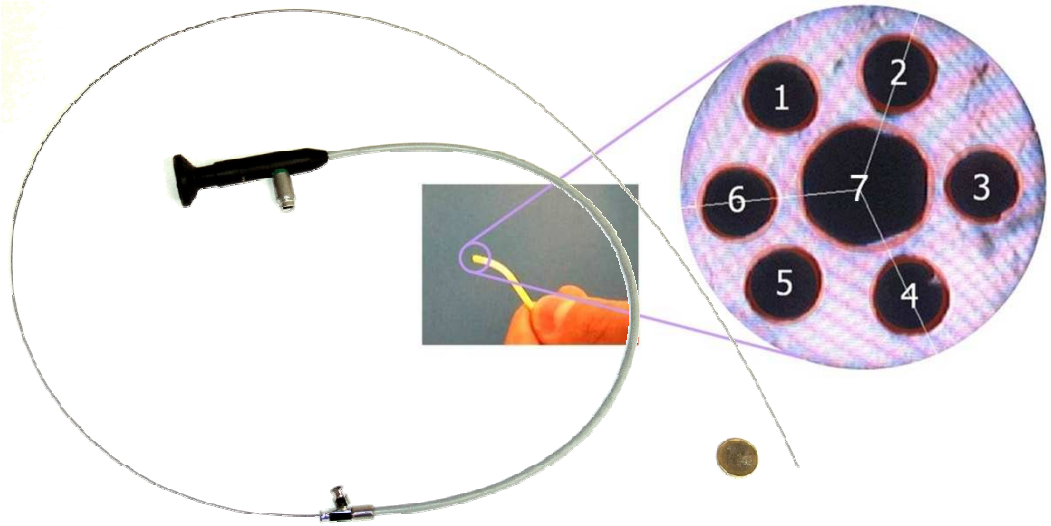
# MINOSC – The **Fluidic System**

**Fluidic navigation system** of a microendoscope exploiting *microjets*, in order **not to touch** the tissue



**Vision system:**

**0.5 mm OD** endoscope, 6000 pixels + illumination



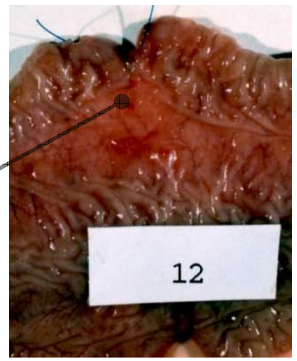
# Fluidic Configuration

Pump

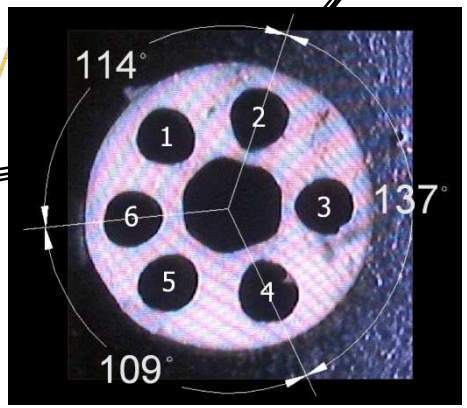

Elastic, external ducts for pulsation reduction

On/Off valves driven in PWM Pulsed mode

Catheter ducts




Compressive action (p)



# Automatic segmentation of lumen images

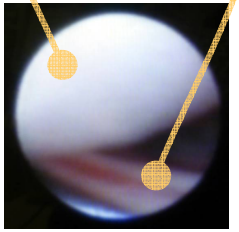
Nerve root

Pia Mater with blood vessel

Lumen

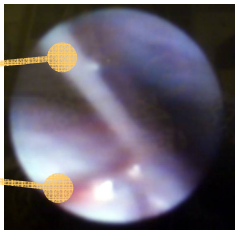
Pia Mater

nerve root with blood vessel

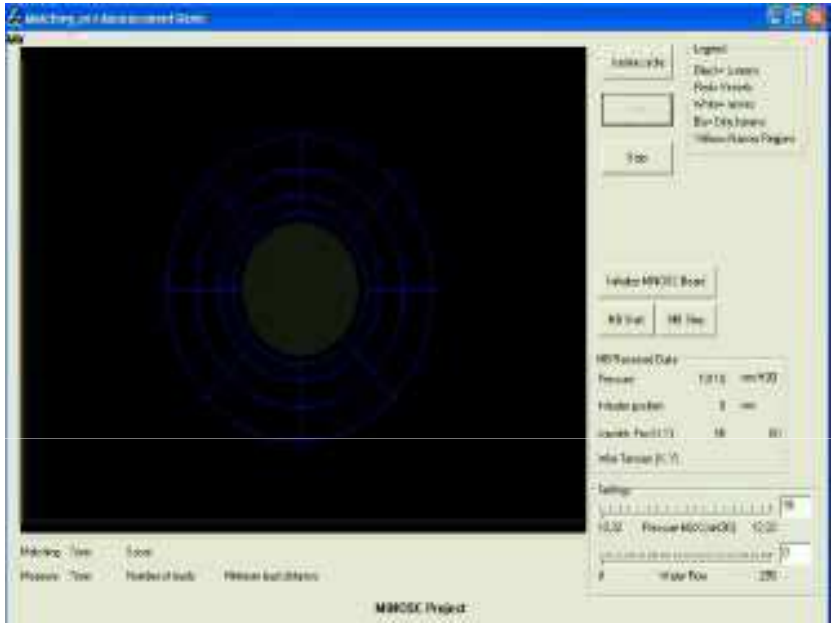


Nerve root

Pia Mater with blood vessel



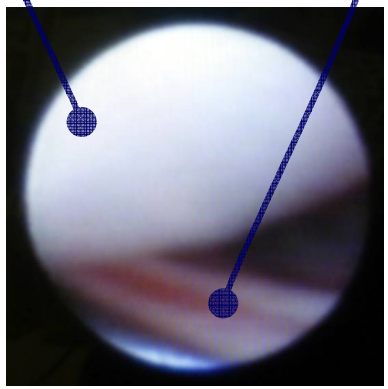
# In vivo navigation

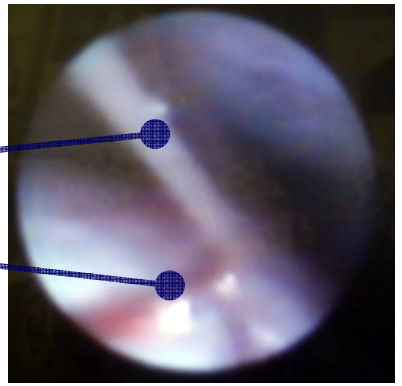


# In-vivo validation

**In vivo experiments in pigs in Ozzano (Bologna).**

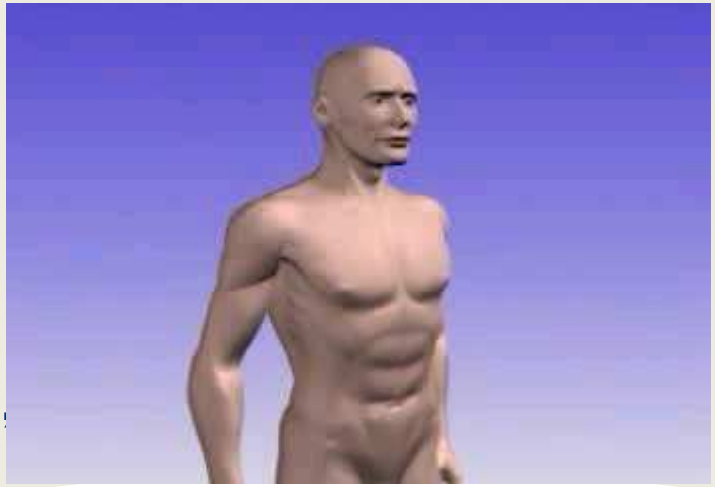
Successful endoscopy (see images below) of the whole spinal cord, from lumbar access up to cervical tract, with **direct nerve stimulation through endoluminal electrode**

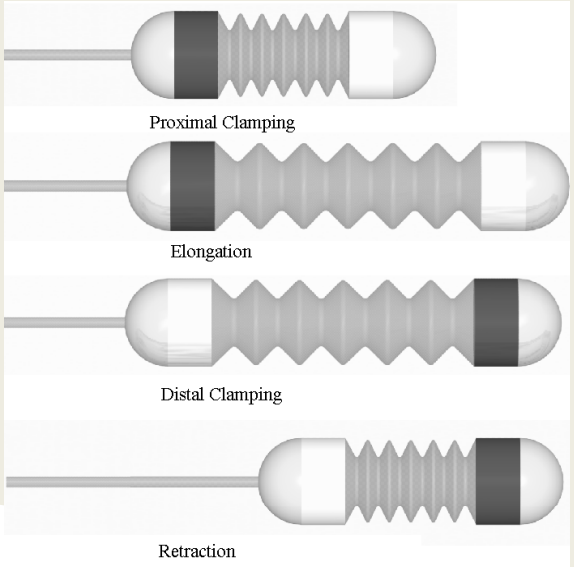


# From **bio-inspiration** to **bio-application**
## (the EU FET BIOLOCH and the EMIL IMC Projects)

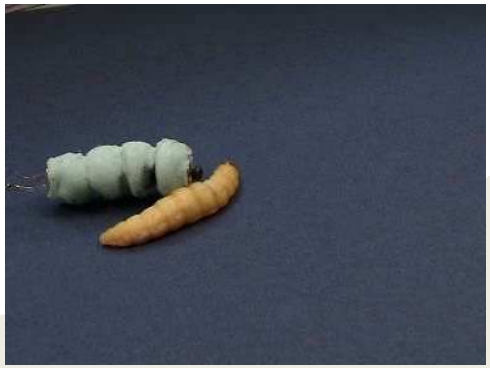
**Problems in colonoscopy: pain, difficult maneuverability…**

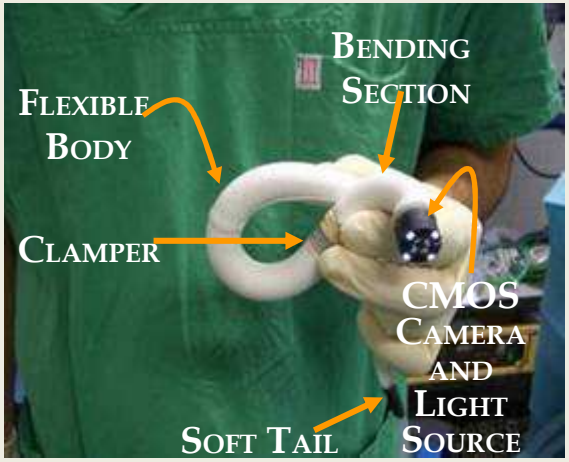





**Semi-autonomous inchworm-like locomotion**

**…like a worm in the gut…**






# The E-WORM Painless Colonoscopy System

Int J Artif Organs. 2009 Oct 21;32(8):517-527. [Epub ahead of print]

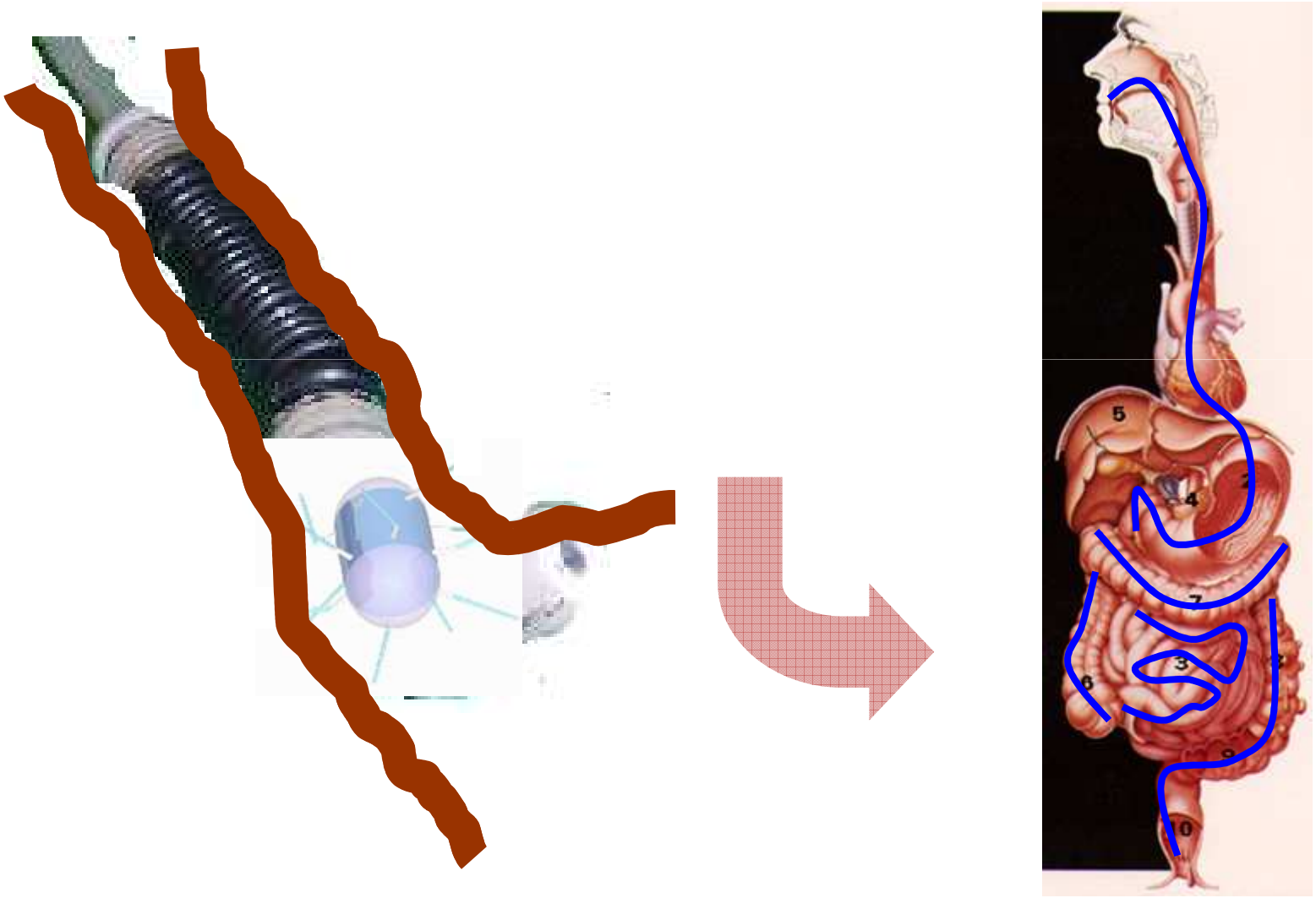
**Functional evaluation of the Endotics System, a new disposable self-propelled robotic colonoscope: in vitro tests and clinical trial.**

Cosentino F, Tumino E, Rubis Passoni G, Morandi E, Capria A.
Gastroenterology and Digestive Endoscopy, San Giuseppe Hospital, Milan - Italy.

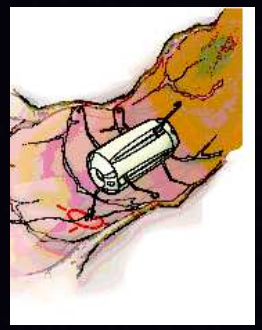
**Abstract**

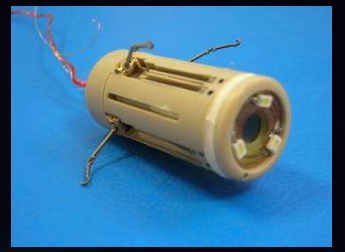
Objective: Currently, the best method for CRC screening is colonoscopy, which ideally (where possible) is performed under partial or deep sedation. This study aims to evaluate the efficacy of the Endotics System, a new robotic device composed of a workstation and a disposable probe, in performing accurate and well-tolerated colonoscopies. This new system could also be considered a precursor of other innovating vectors for atraumatic locomotion through natural orifices such as the bowel. The flexible probe adapts its shape to the complex contours of the colon, thereby exerting **low strenuous forces during its movement**. These novel characteristics allow for a painless and safe colonoscopy, thus eliminating all major associated risks such as infection, cardiopulmonary complications and colon perforation. Methods: An experimental study was devised to investigate stress pattern differences between traditional and robotic colonoscopy, in which **40 enrolled patients underwent both robotic and standard colonoscopy within the same day**. Results: The stress pattern related to robotic colonoscopy was **90% lower than that of standard colonoscopy**. Additionally, the robotic colonoscopy demonstrated a **higher diagnostic accuracy**, since, due to the lower insufflation rate, it was able to visualize small polyps and angiodysplasias not seen during the standard colonoscopy. **All patients rated the robotic colonoscopy as virtually painless compared to the standard colonoscopy, ranking pain and discomfort as 0.9 and 1.1 respectively, on a scale of 0 to 10, versus 6.9 and 6.8 respectively for the standard device**. Conclusions: The new Endotics System demonstrates efficacy in the diagnosis of colonic pathologies using a procedure nearly completely devoid of pain. Therefore, this system can also be looked upon as the first step toward developing and implementing colonoscopy with atraumatic locomotion through the bowel while maintaining a high level of diagnostic accuracy.

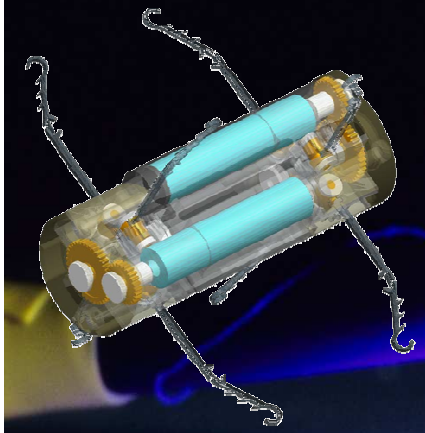
# From "**wired**"painless colonoscopy to "**wireless**" GI endoscopy

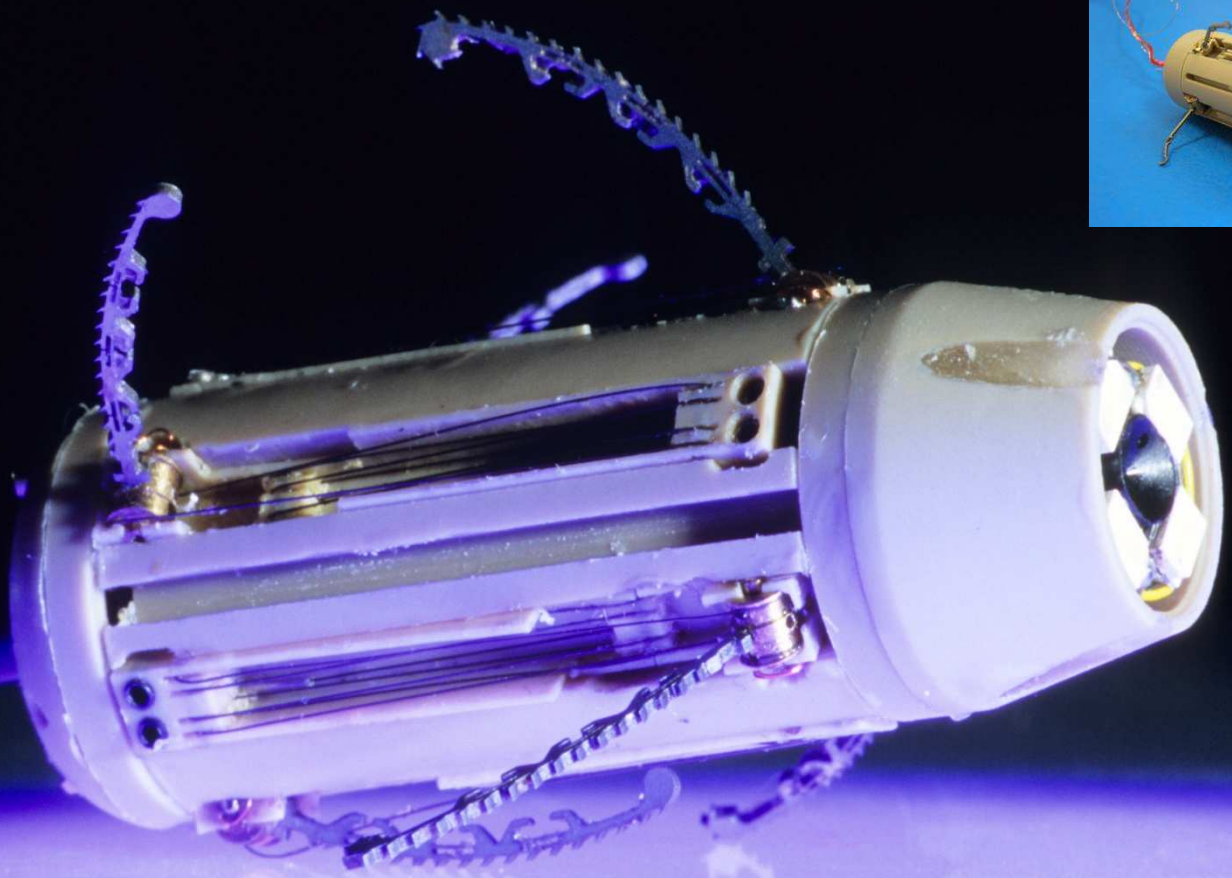


# ***Wireless*** *endoscopic capsules with active locomotion system for the* ***entire GI tract***





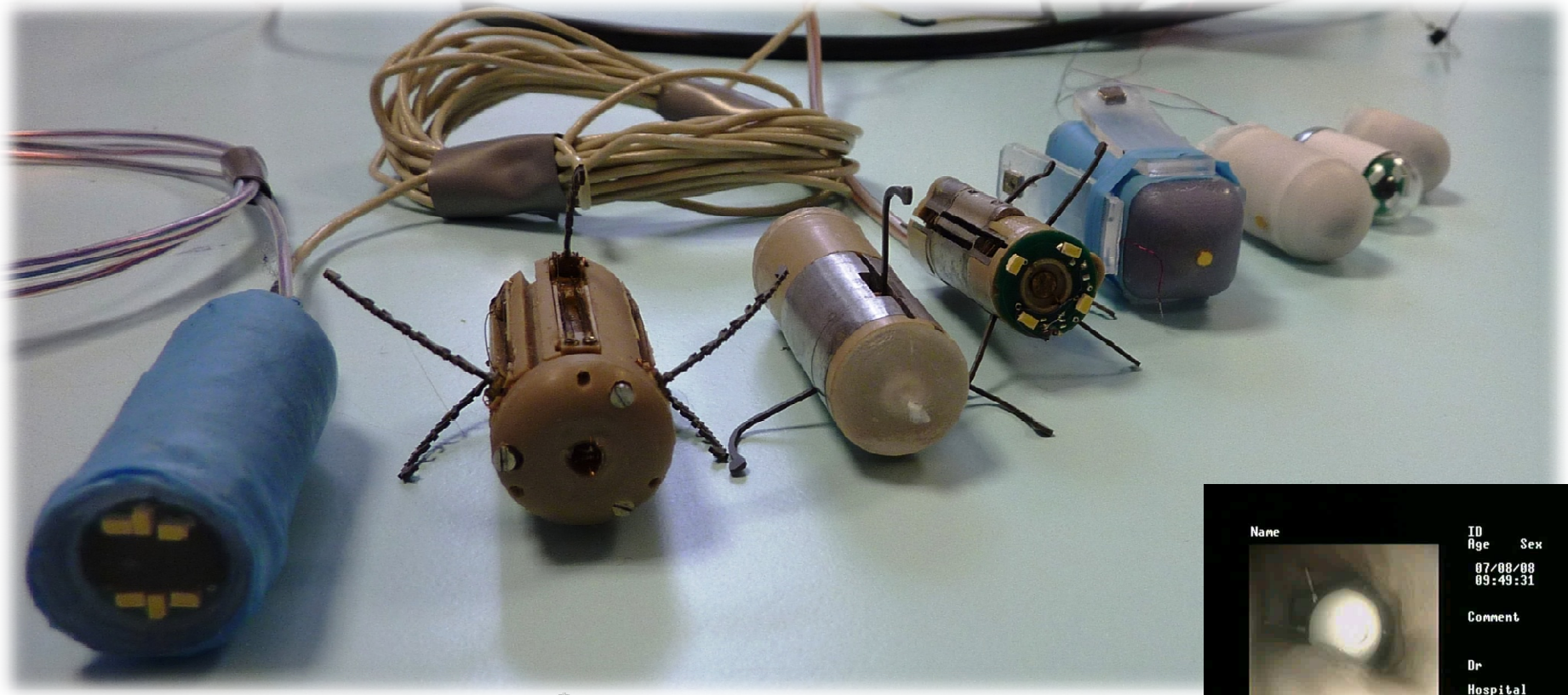




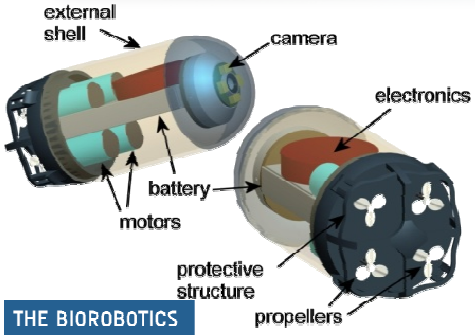

**A. Moglia, A. Menciassi, P. Dario, A. Cuschieri, "Clinical update: endoscopy for small-bowel tumours", THE LANCET, Vol 370 July 14, 2007, pp. 114-116**

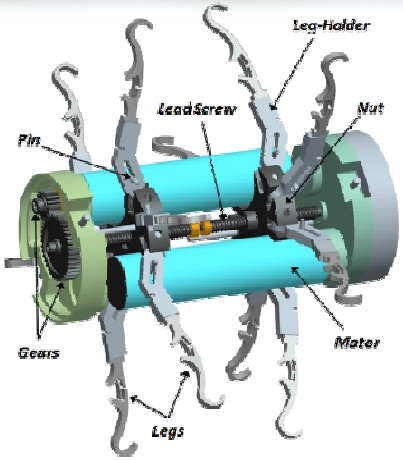
**M. Quirini, S. Scapellato, A. Menciassi, P. Dario, F. Rieber, C.-N. Ho, S. Schostek, M.O. Schurr, "Feasibility proof of a legged locomotion capsule for the GI tract", GASTROINTESTINAL ENDOSCOPY Vol. 67, No. 7, 2008**

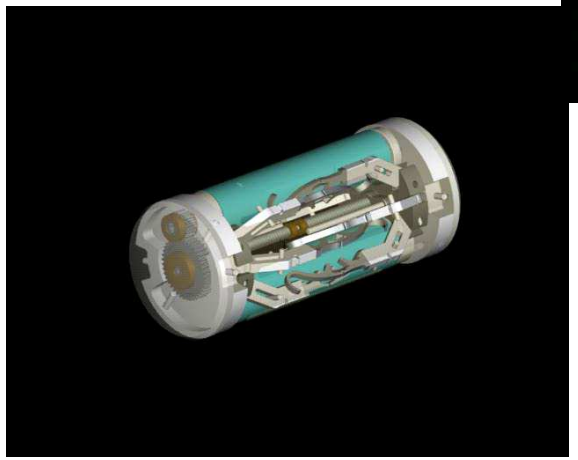
# ACTIVE capsules developed at The BioRobotics Institute





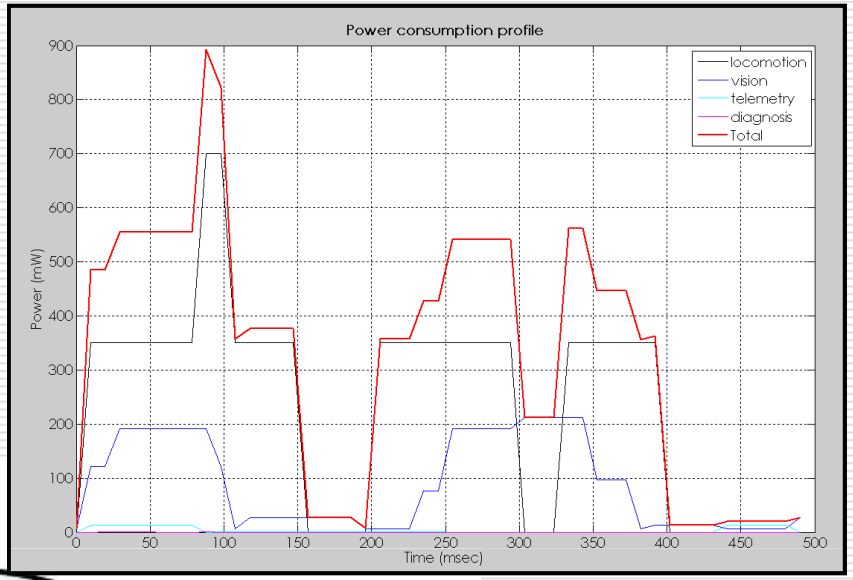



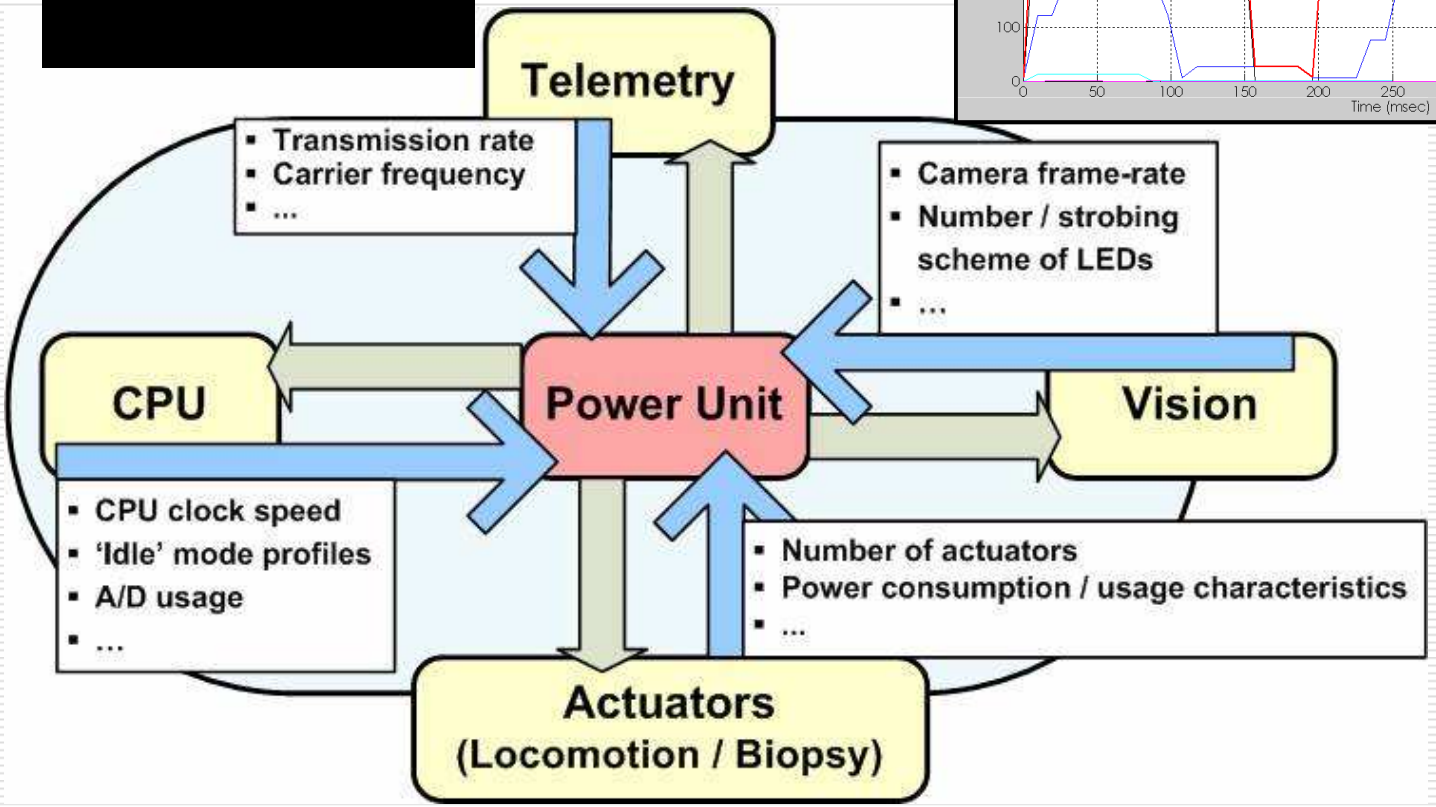
THE BIOROBOTICS INSTITUTE

Scuola Superiore Sant'Anna

# The MAJOR problem for active, legged endoscopic capsules

# POWER!

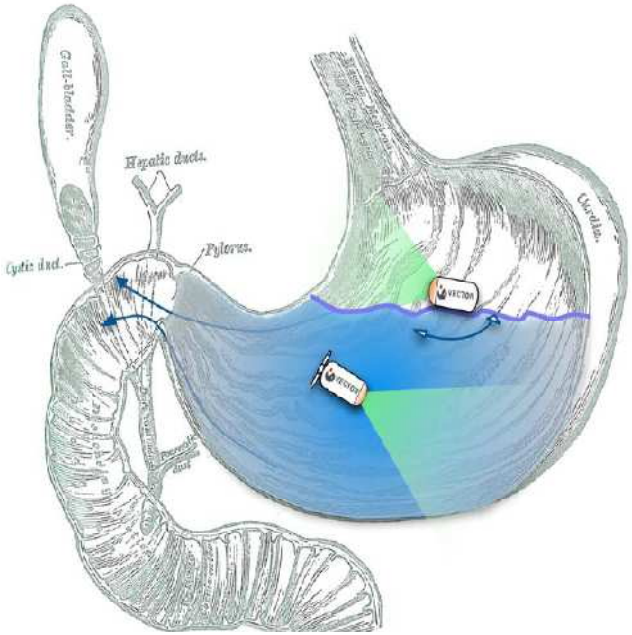


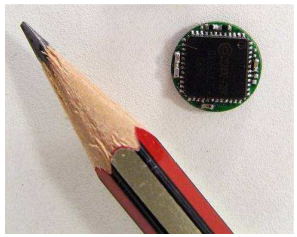



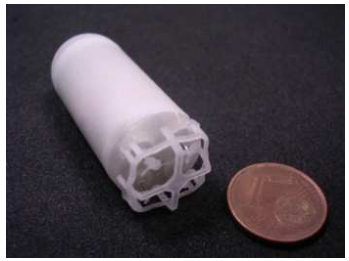

**A legged capsule incorporating state-of-art batteries could only walk for less than 30 minutes along the GI tract**

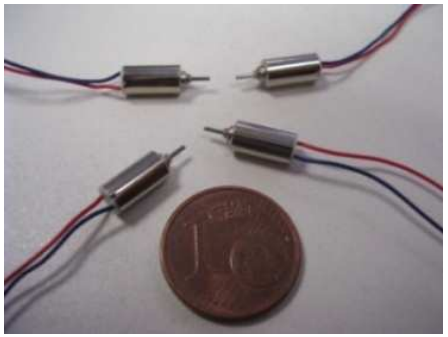
# Wireless Capsule for PAINLESS GASTROSCOPY

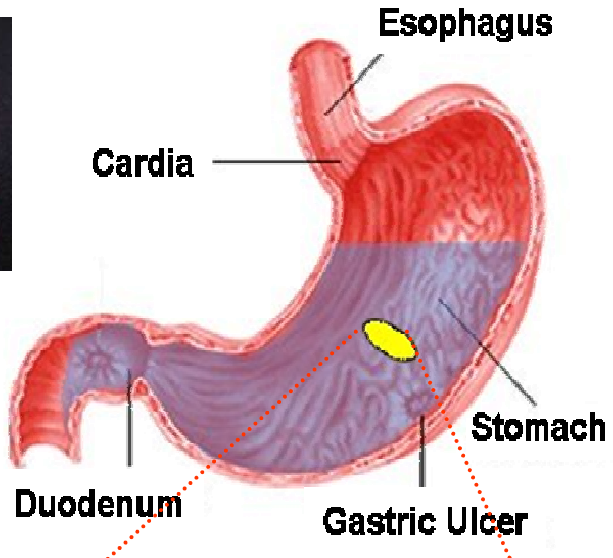
Ingestion of liquid in context with the examination allows to obtain organ distension, thus making possible a low power 3D locomotion in the stomach

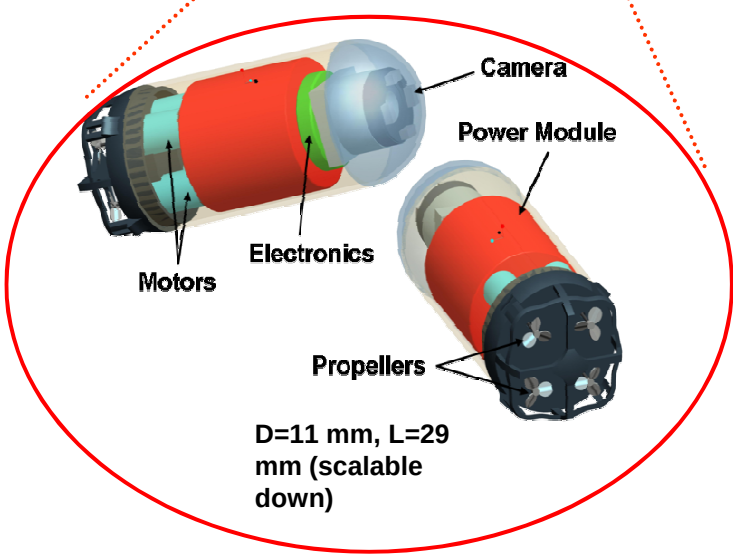




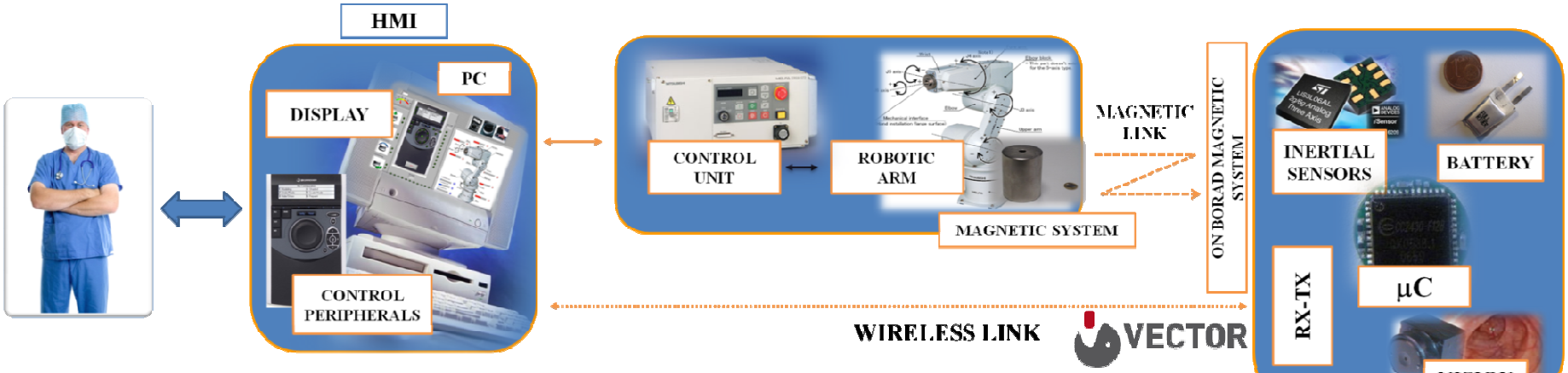




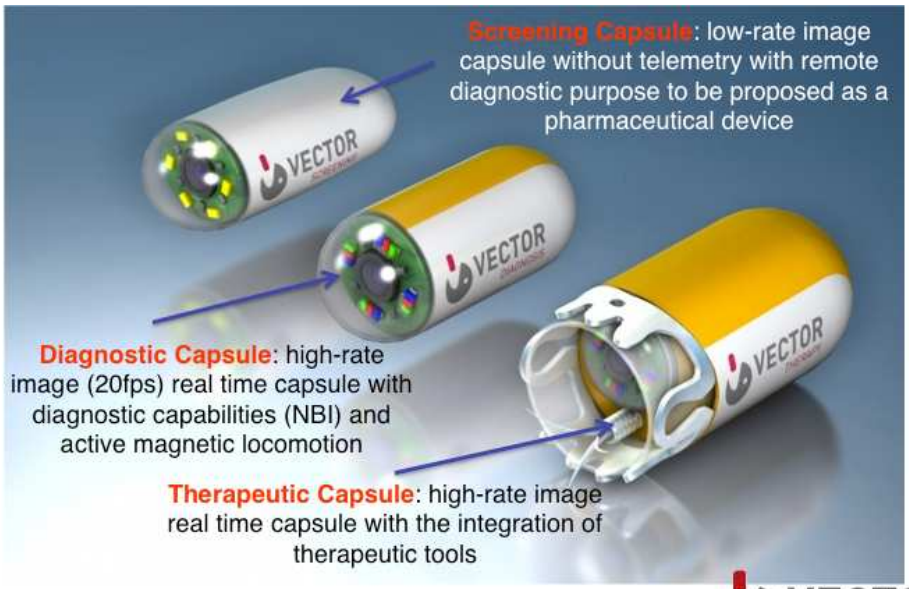



# Wireless Capsule for PAINLESS GASTROSCOPY

# How to overcome the energy problem in active capsular endoscopy: magnetic assisted locomotion




**Endoluminal magnetic locomotion can be extremely precise when the external magnet (s) is/are moved by means of high precision robot(s)**

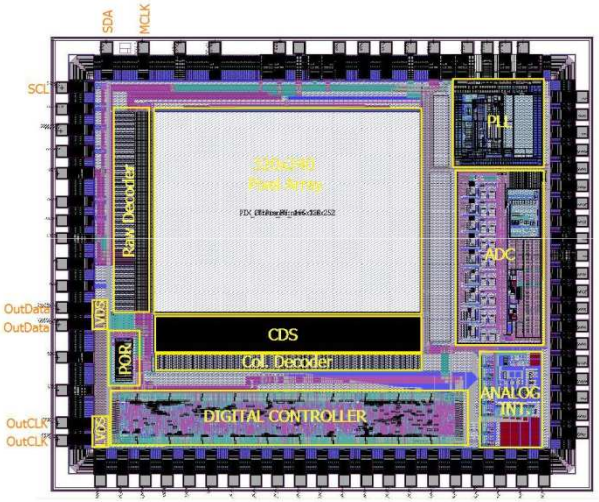


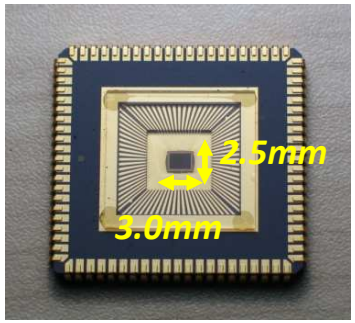

FP6 European Project VECTOR – "Versatile Endoscopic Capsule for gastrointestinal Tumor Recognition and Therapy" (EU/IST-2006-033970) (http://www.vector-project.com/)

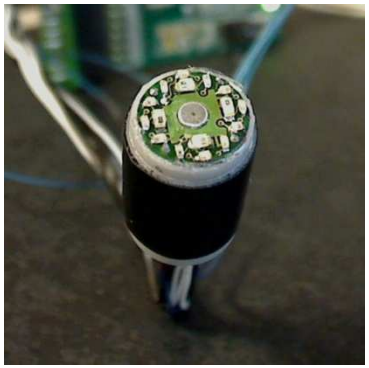
VECTOR

# Camera on Chip

## Custom image sensor



| | | |
|---|---|---|
| Resolution | | QVGA |
| Active area | | 320×240 |
| Optical format | inch | 1/11 |
| Pixel Pitch | μm² | 4.4×4.4 |
| Shutter type | | rolling |
| Die dimension | mm² | 2.5×3.0 |

| | | |
|---|---|---|
| Sensitivity | lux | 0.1@555nm,27° C, 30msec. |
| | W/m² | $1.7\times10^{-4}$@27° C, 30msec. |
| Responsivity | V/lux*sec. | 0.52@555nm, 27° C |
| | V/W/m²*sec. | 360@@27° C |
| Dynamic range | dB | 50 |
| SNR | dB | 46(max) |
| Pixel Noise | % | 0.70 |
| Fixed Pattern Noise | % | 0.86 |

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# A Novel Concept: Magnetically-Controllable Insulin-Filled Capsules as Carriers for Diabetes Treatment

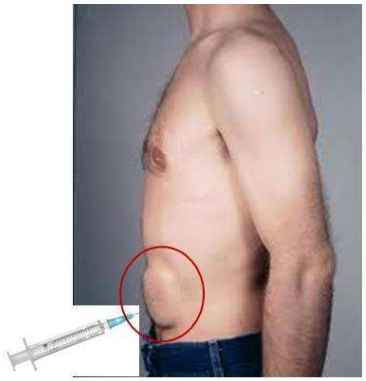
- 347 million people worldwide suffer from diabetes
- diabetes deaths are expected to double between 2005 and 2030
- worldwide diabetes market: from $ 14.9 billion in 2009 to $ 55 billion in 2019
- lifestyle strongly affected by traditional therapy

Multiple daily insulin injections

- The patient is slave of his/her pathology
- Long-term complications
- Non-physiologic insulin profile

Implanted artificial pancreas

- Limited lifetime
- Need of complicated periodical refilling procedures (surgical operations needed every 3 months)
- Low insulin stability in the implanted device



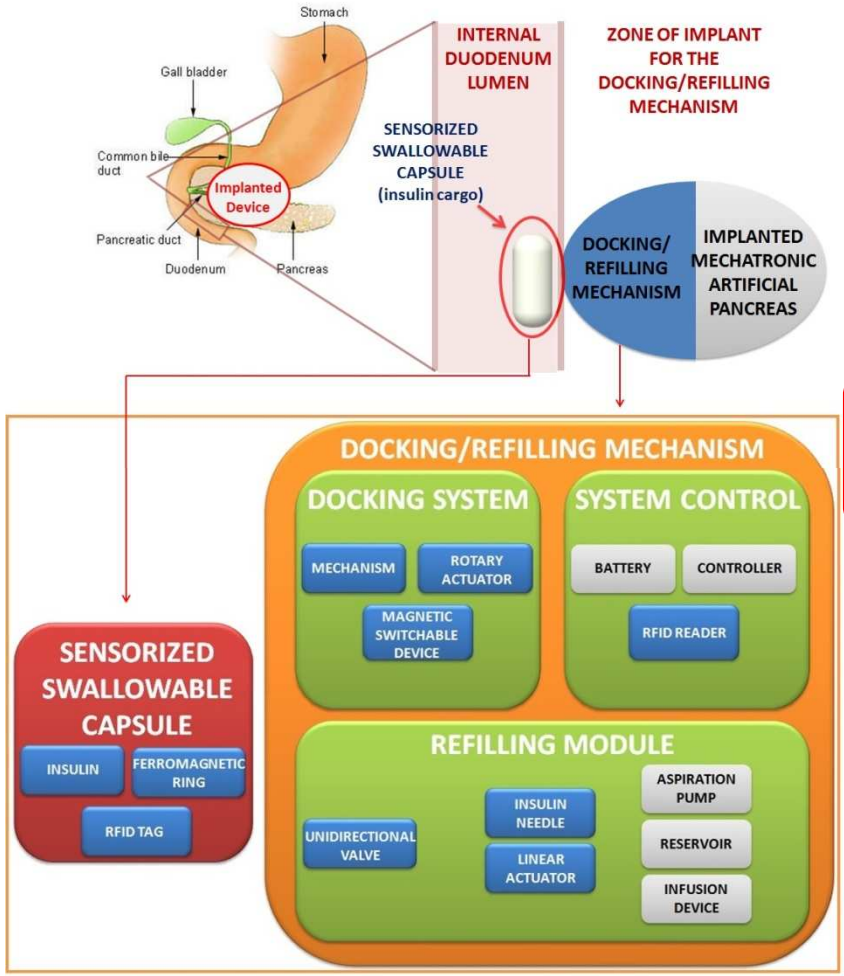
Wearable artificial pancreas

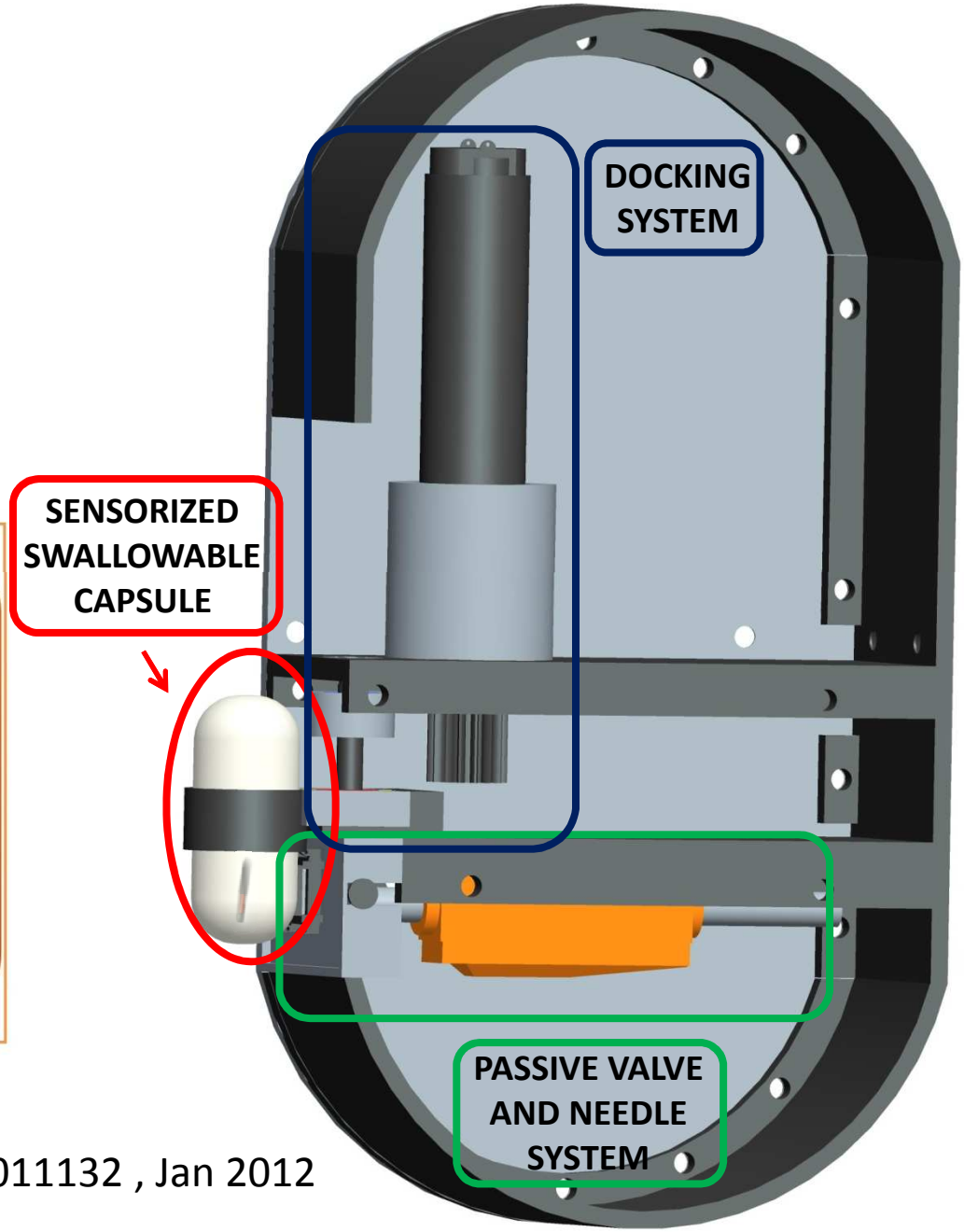
- Delays in insulin adsorption
- Common daily activities strongly affected

Holy Grail of diabetes treatment

**Long-term totally implantable AP refillable through insulin pills**

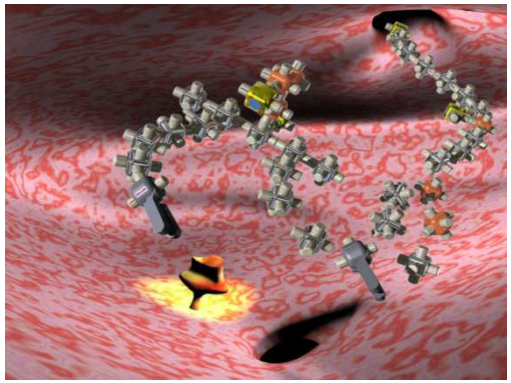
# Novel implantable artificial pancreas *

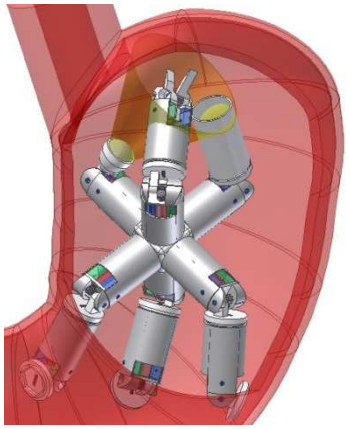


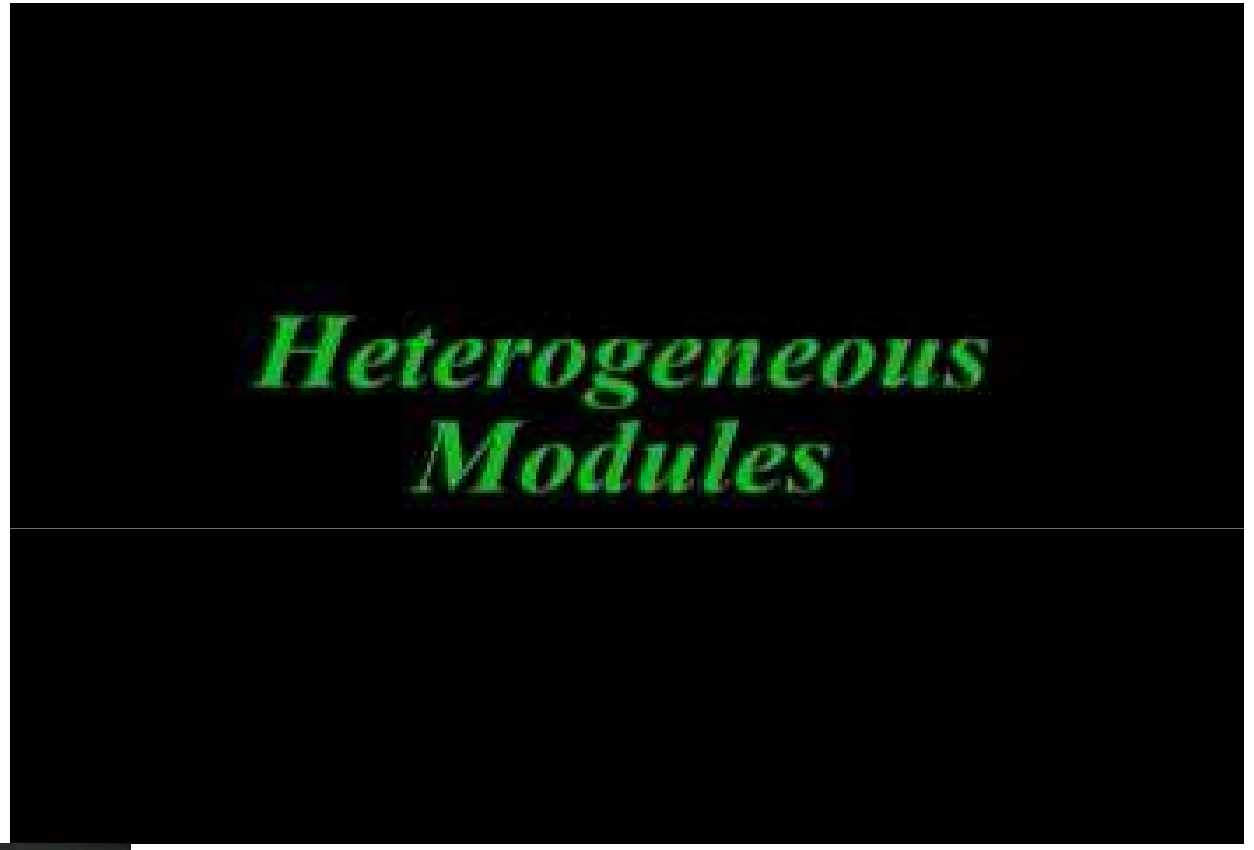



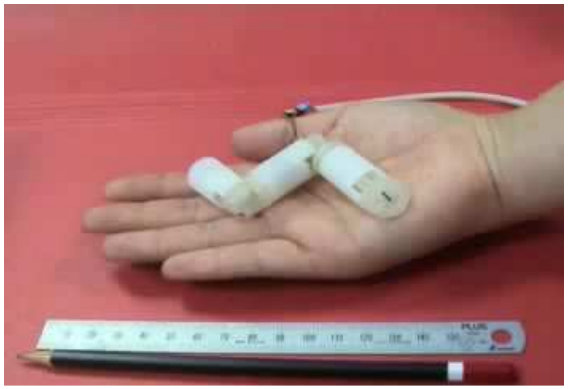

- Ricotti et al. PCT Patent - WO/2012/011132 , Jan 2012

# From **Single** Capsules to a **Molteplicity** of Capsules: **Modular** and **Reconfigurable** Surgical Instruments







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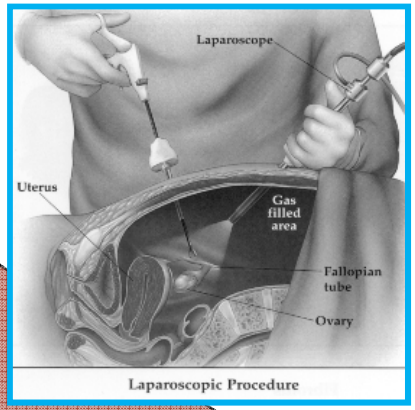
# Scarless Robotic Surgery

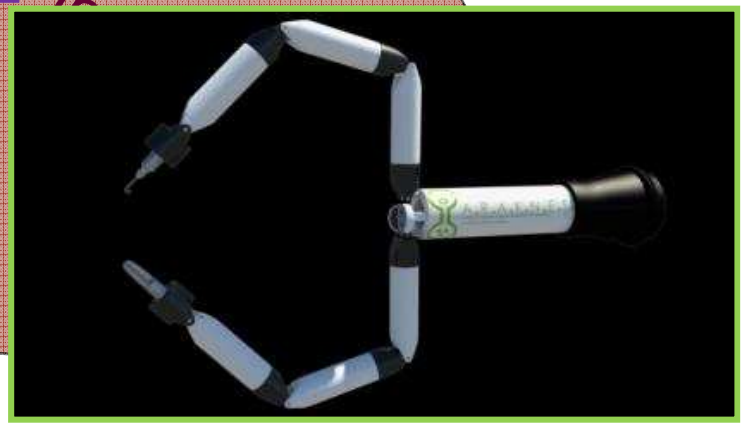
**TRADITIONAL TECHNIQUES**




**LAPAROSCOPIC SURGERY**

**ROBOTIC SURGERY**

**SCARLESS ROBOTIC SURGERY**



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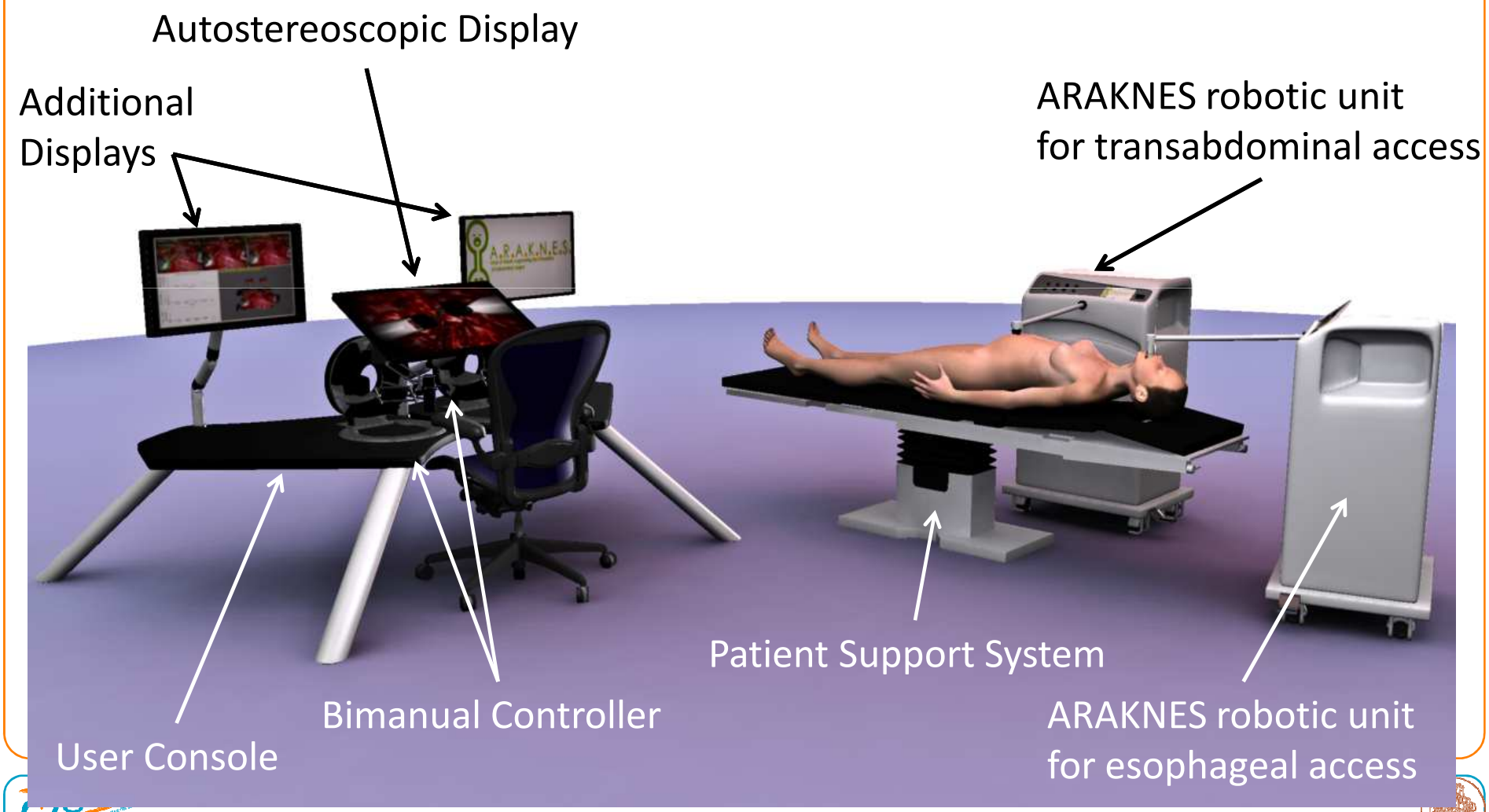
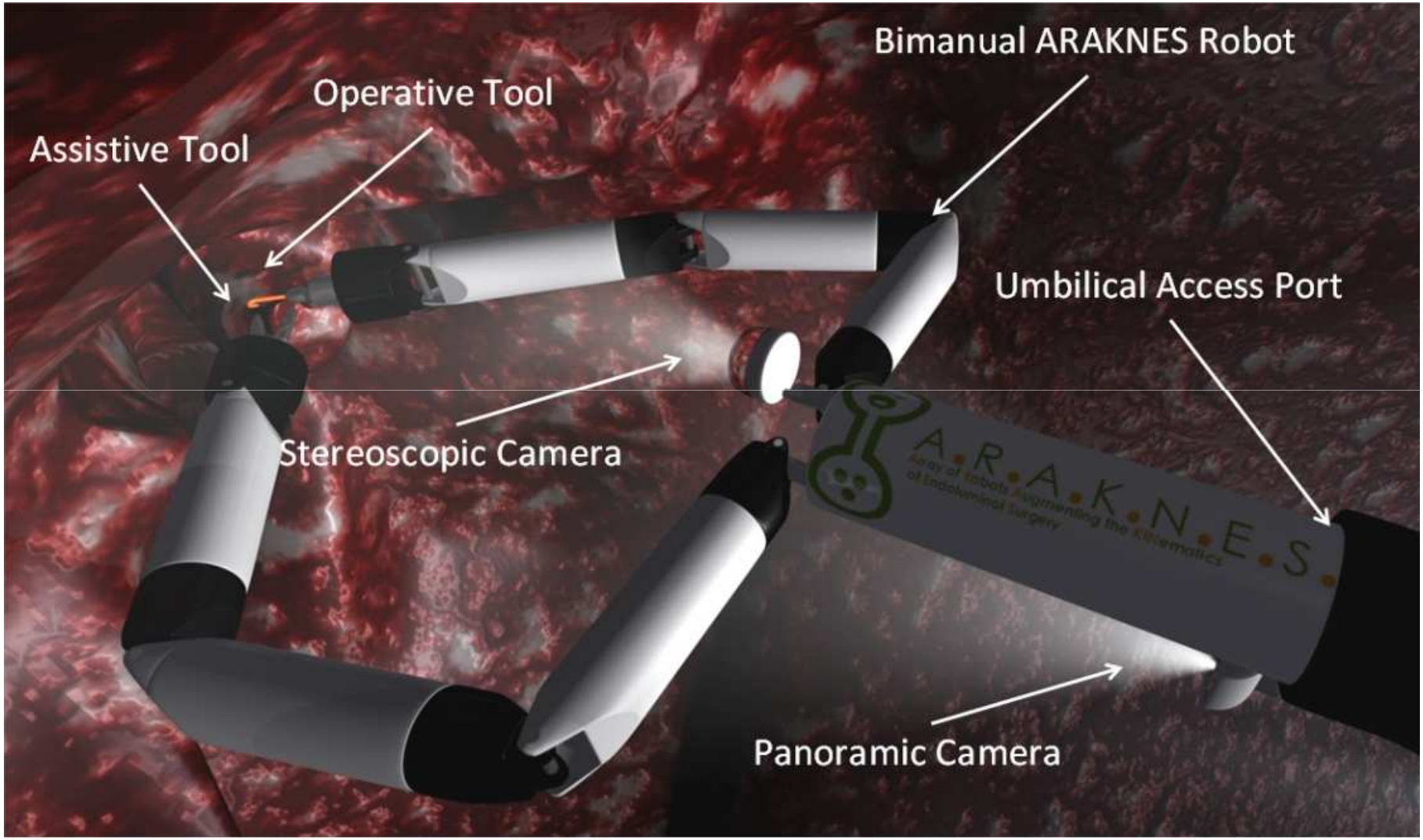
# The EU ARAKNES Project: www.araknes.org

## The ARAKNES System Architecture

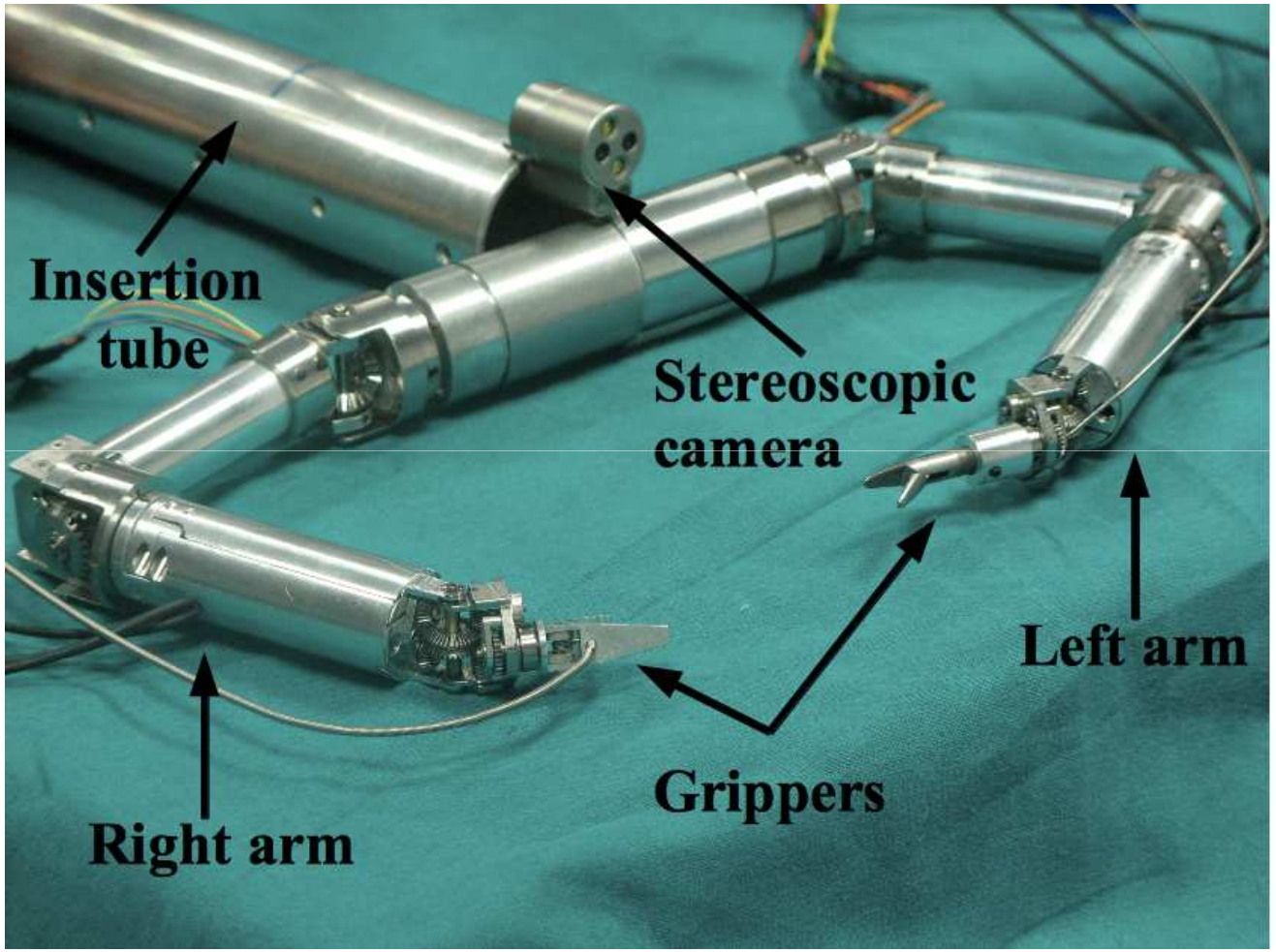


# SPRINT: Single-Port lapaRoscopy bImaNual roboT




The ARAKNES Project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement num. 224565.

# The SPRINT robot



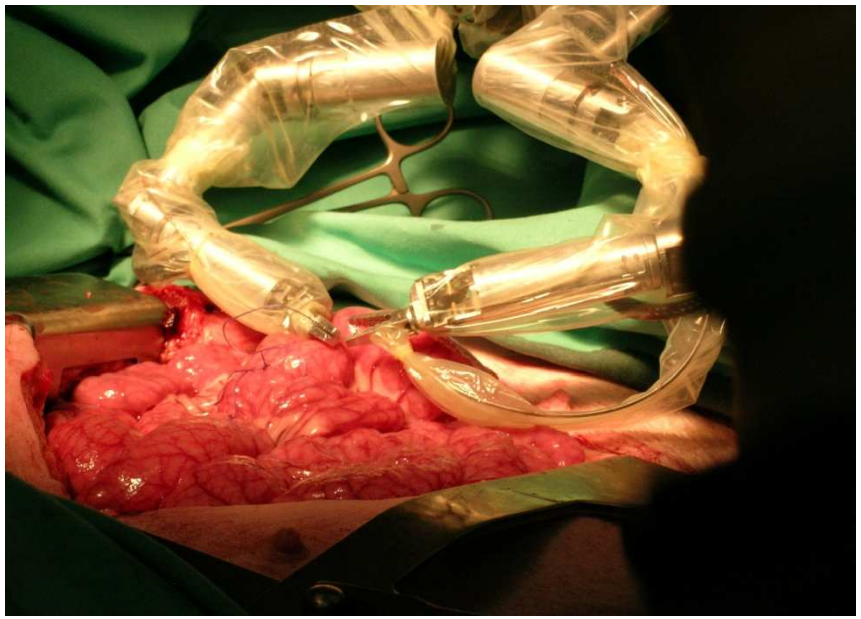

Single Port External Diameter: 30 mm

External Diameter of the robot arms: less than 20 mm

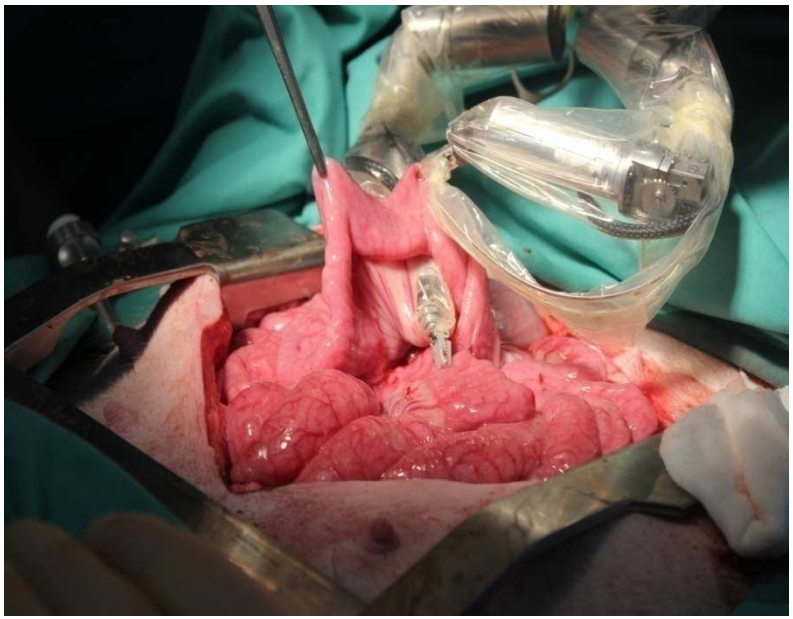
The ARAKNES Project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement num. 224565.

# In-Vivo Tests: Results

**Small bowel entero-enterostomy**



**Ligation of a mesenteric vessel bundle**



Results of In-Vivo Tests presented at **SAGES** Annual Meeting:

***A New Robotic System for Single-Incision Laparoscopic Surgery: Preliminary Experience.***

G. Basili, G. Pietroni, A. Menciassi, D. Pietrasanta, M. Niccolini, O. Goletti

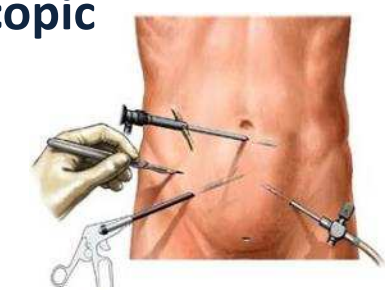
The ARAKNES Project has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement num. 224565.

# Minimally Invasive Surgery

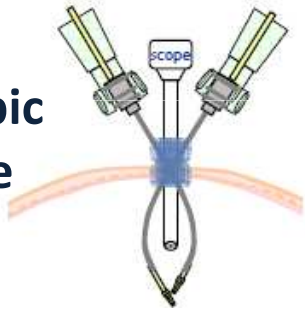

Vitiello et al., *Biomedical Engineering, IEEE Reviews,* 2013

- **Open surgery**

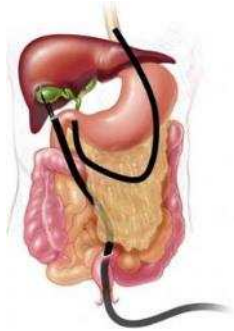
- **Laparoscopic surgery**



- **Laparo-endoscopic single site surgery**

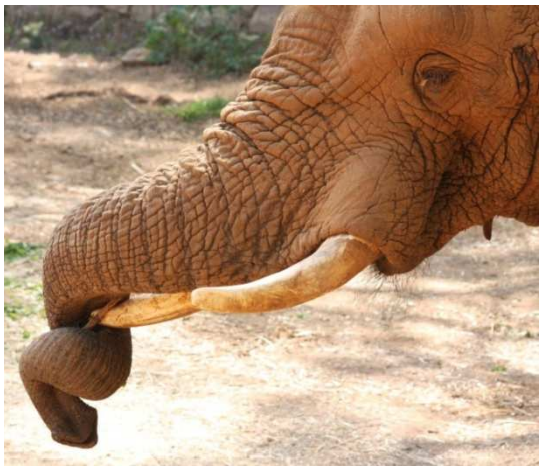



- **Natural Orifice translumenal endoscopic surgery**



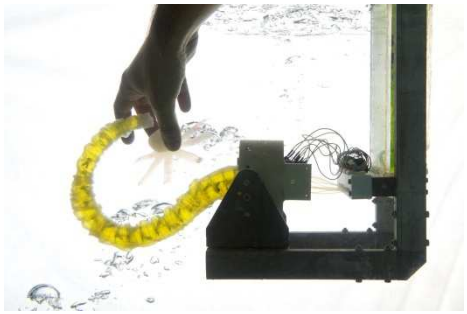
INVASIVENESS

# Biological and bioinspired manipulators



**The key aspect:**
to manipulate objects while **controlling the stiffness** of selected body parts and being **inherently compliant** when interacting with objects

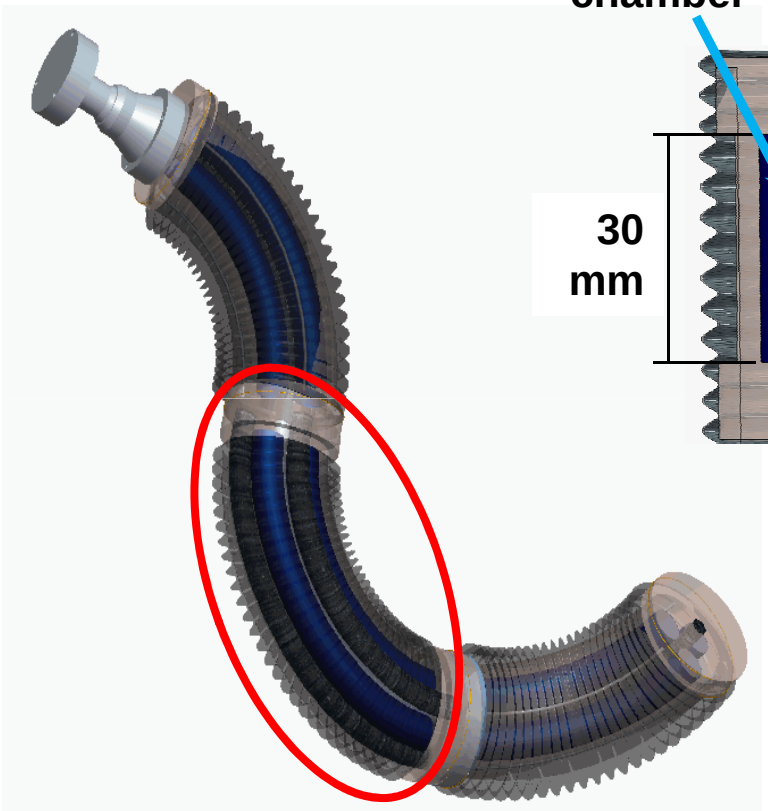
Muscular Hydrostat of tentacles, trunks, and tongues: **modifiable skeleton** which allows the transformation of force into motion

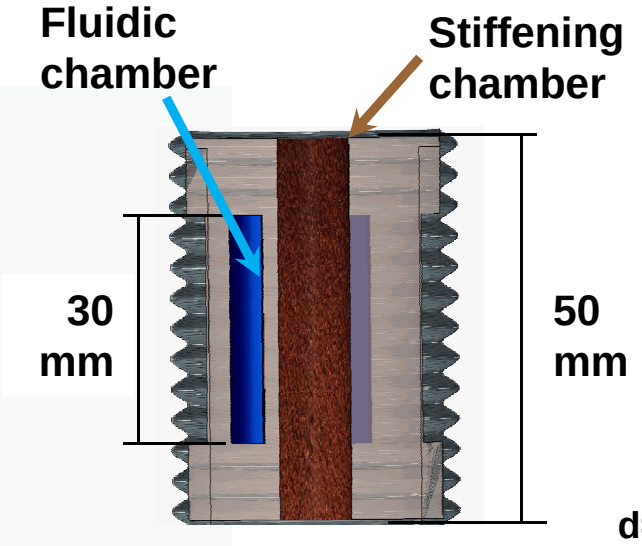


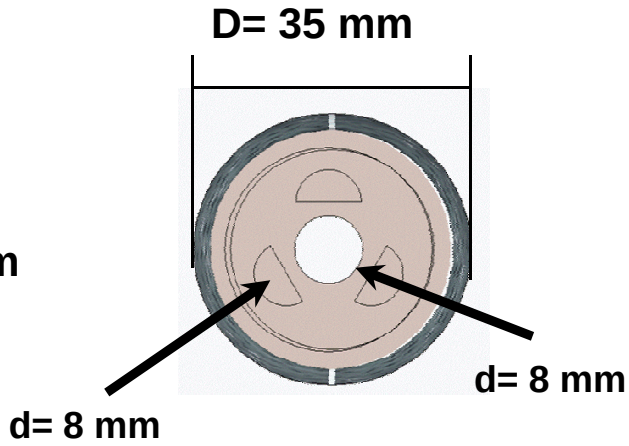
***OCTOPUS arm***
18 SMA modules
12 tendons
No rigid parts

# The STIFF-FLOP modular arm

## Overall






- Flexible fluidic actuation
- Stiffness modulation
- Driving system
- Characterization

Architecture consisting of connected modules

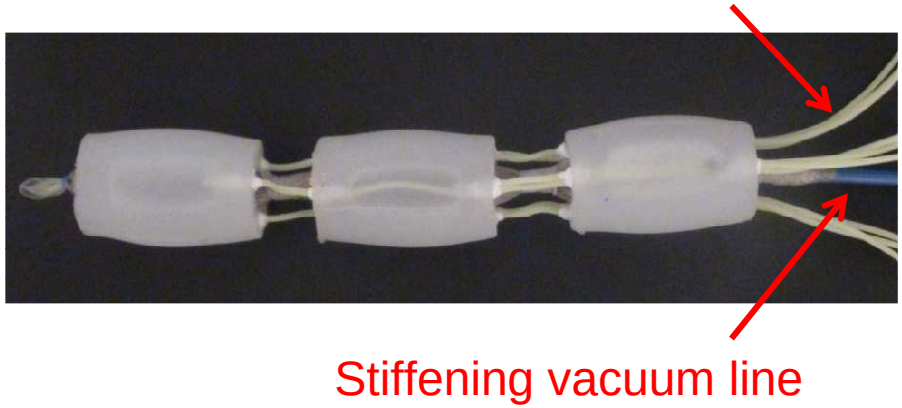
# Overall performance

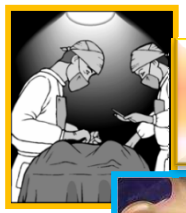
**The concept design of a new modular manipulator for MIS has been presented**

**One single module was fabricated and characterized, which can:**

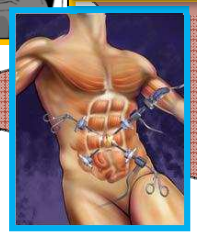
- **Bend** in any direction — up to 120°
- **Elongate** — up to 86.3%
- **Stiffen** locally — up to 36%
- **Produce force** — 47N of force at tip
- **Squeeze** for fitting into small diameter holes — up to -40%

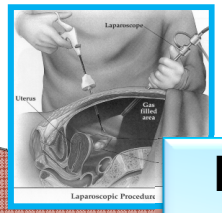
**…towards the modular manipulator with 3+ modules**





**TRADITIONAL TECHNIQUES**






**LAPAROSCOPIC SURGERY**

**Access Trauma Reduction in Surgery**

**SURGICAL ROBOTICS**

**Size: in the ≤ 1 mm range**

**Interventional platforms in the meso scale**

Combining **robotic technologies**, "wireless" actuation and biotech **for** transforming **systemic** therapeutic approaches into **targeted, local and precise** therapeutic approaches

**An endoluminal robot could also be seen as a carrier of micro/nano therapy agents (i.e. a SHUTTLE)**

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# Some examples of nanotechnologies contributing to endoluminal and cell surgery

# Exploitation of chemical and physical properties of nanomaterials in endoluminal and cell surgery

**Carbon nanotubes (CNTs):** blending physical and chemical properties for electroporation, localized hyperthermia, magnetic guided drug delivery, DNA transfection

**Boron nitride nanotubes (BNNTs):** from nanotubes to nanotransducers! Enhanced physical properties with the same chemical properties of CNTs

**Magnetic nanofilms:** merging the magnetic control with the therapeutic abilities of nanofilms in endoluminal surgery

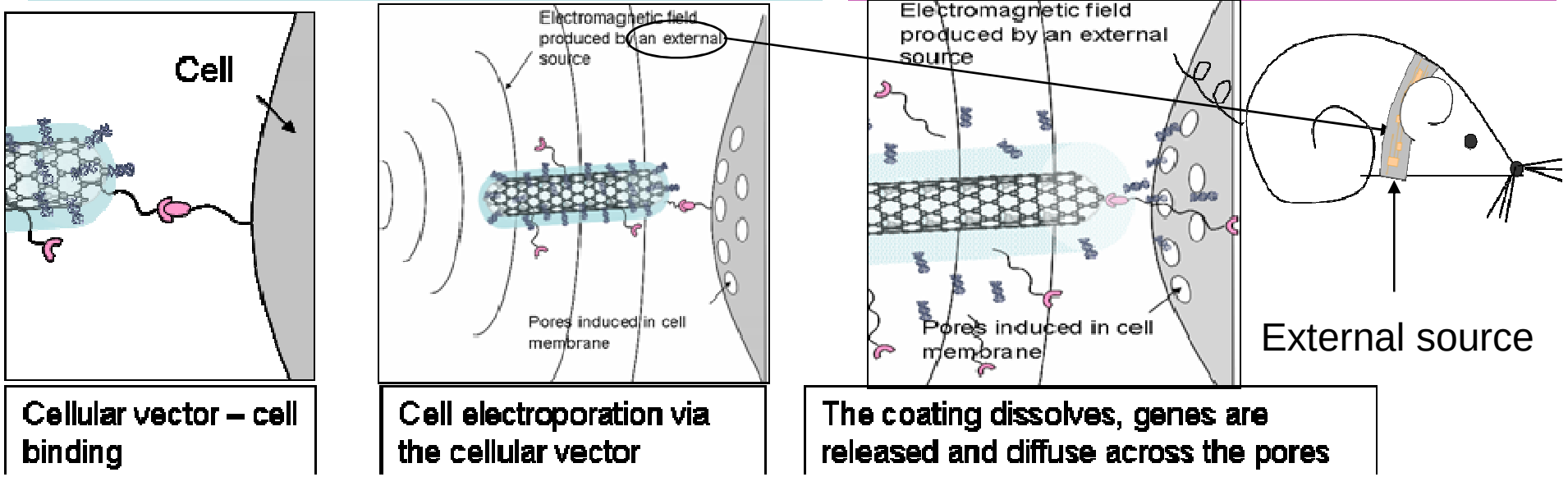
# Nano-machines for cell therapy: the NINIVE project (www.niniveproject.org, 6FP NMP 033378)

**OBJECTIVE and NOVEL CONVERGING APPROACH:**

**combining physical and chemical properties of CNTs holds great promise for the development of a new class of CNT-based drugs and therapies extremely controlled (i.e. much more controlled that methodologies based on diffusion, phagocytosis, endocytosis)**

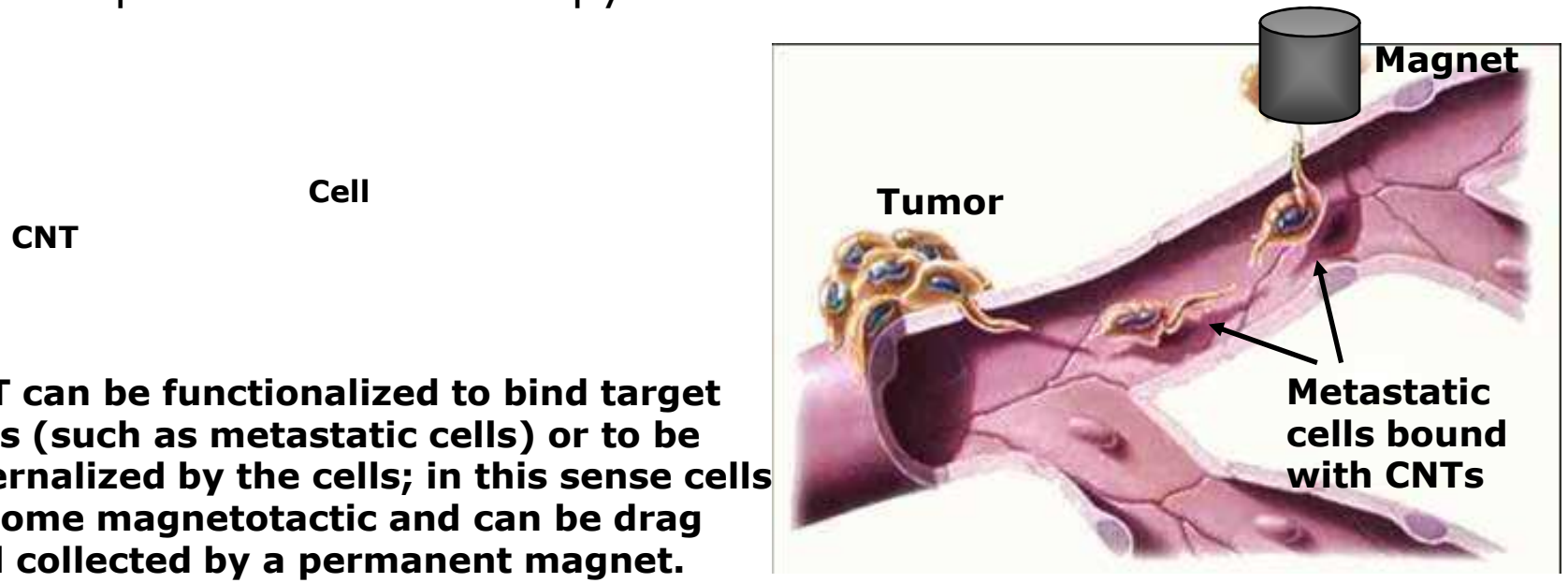
**Electrical properties (conductive and semi-conductive CNTs); optical properties; strong anisotropy; etc.**

**Covalent bonding of CNT surface; non-covalent absorption on the CNT surface; etc.**



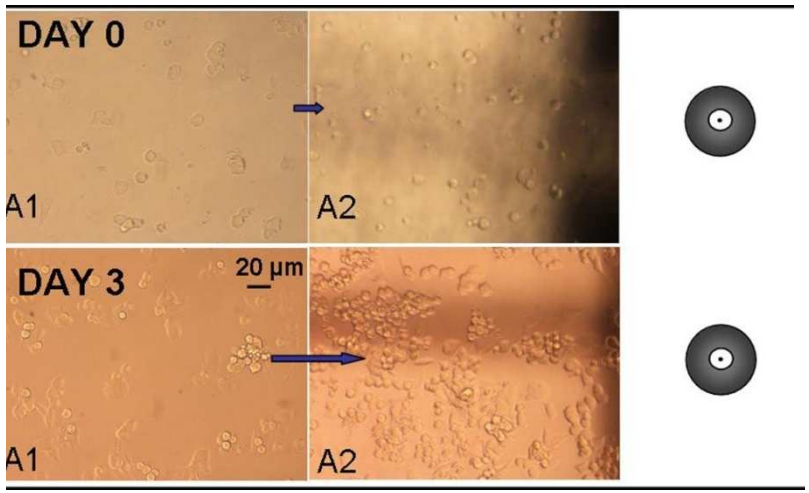
# Cell manipulation with magnetic carbon nanotubes

Once the CNTs (naturally magnetic thanks to residuals) are attached or internalized, cells can be concentrated in a desired compartment for subsequent localized therapy.




**CNT can be functionalized to bind target cells (such as metastatic cells) or to be internalized by the cells; in this sense cells become magnetotactic and can be drag and collected by a permanent magnet.**

**Human Neuroblastoma cells (SH-SY5Y) displacement after 3 days in culture with MWNTs-modified medium. Control sample not showed (with Nikon TE2000U inverted optical microscope, magnifications 20x).**

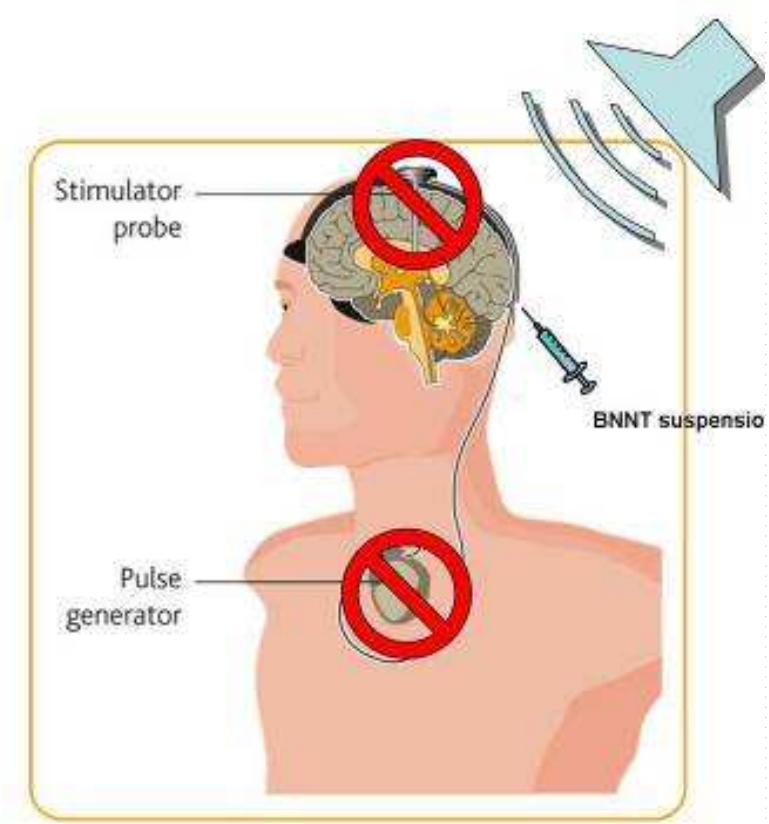


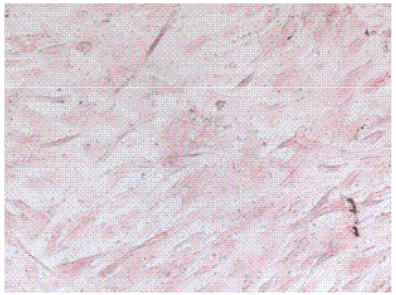

***V. Pensabene, O. Vittorio, S. Raffa, A. Menciassi, P. Dario, "Neuroblastoma cells displacement by magnetic carbon nanotubes", IEEE Trans. On NanoBioScience, 2008.***

# Perspectives related to PZT properties

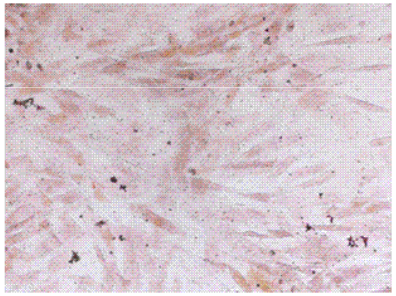
The piezoelectric properties of BNNTs make them attractive candidates as **bionanotransducers**. If stimulated with non-invasive ultrasounds, they should be able to generate electrical field.

We are carrying out experiments on cells sensible to electrical field (neurons, osteoblasts, muscle cells, etc.) and **preliminary results on primary human osteoblasts show a significant increment of osteocalcine and calcium content after incubation with BNNTs and stimulation with US**.



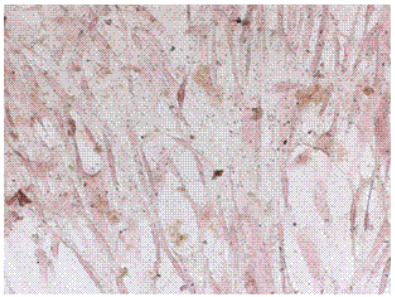



HOBs

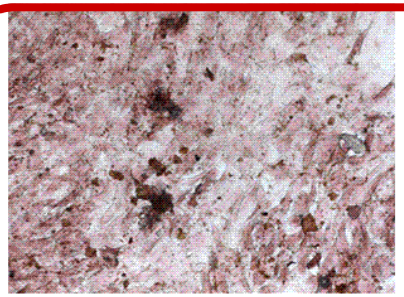


HOBs + US

*Von Kossa staining for calcium salts (in black)*



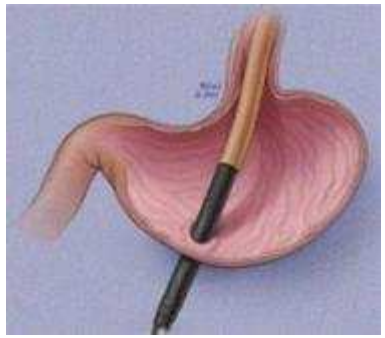
HOBs + BNNTs

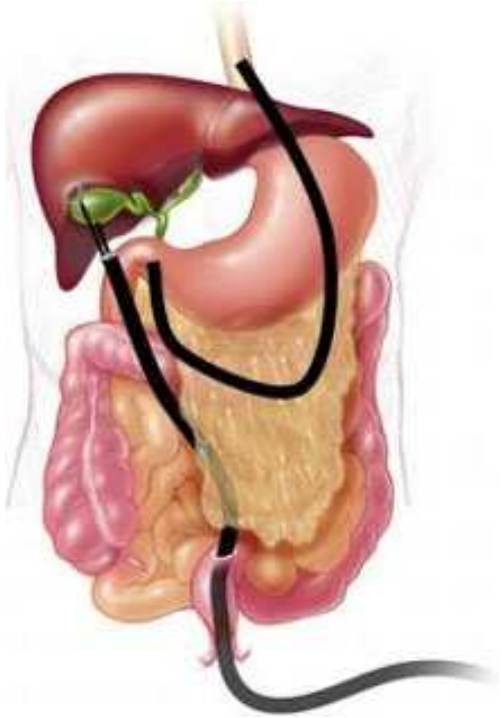


HOBs + BNNTs + US

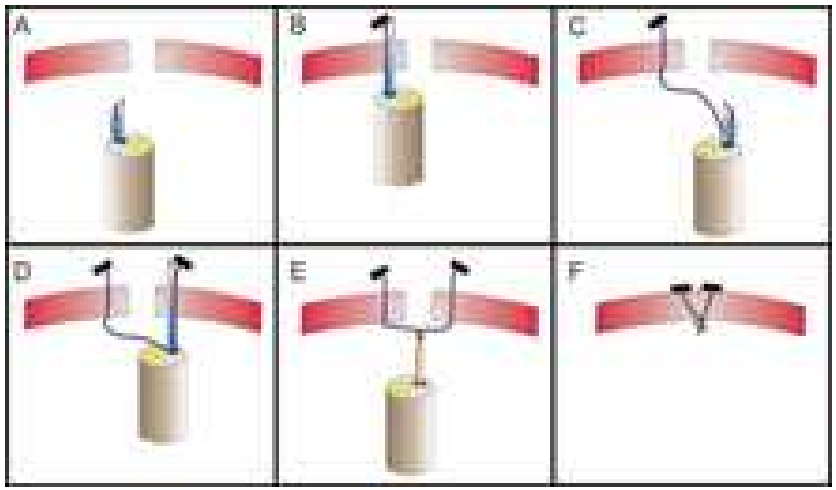
# Polymer ultra-thin nanosheet for endoluminal surgery

In **NOTES** (Natural Orifice Transluminal Endoscopic Surgery), access to the target organs is obtained through holes made in stomach/female reproductive/lung wall.

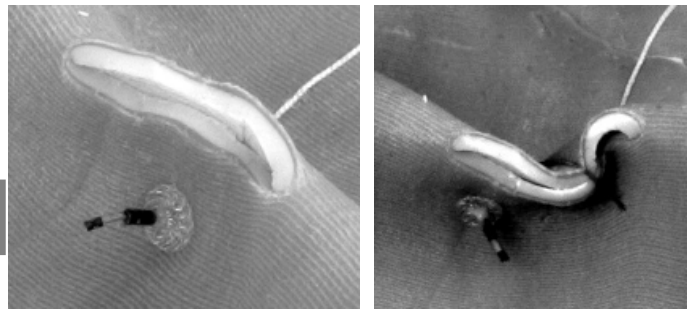




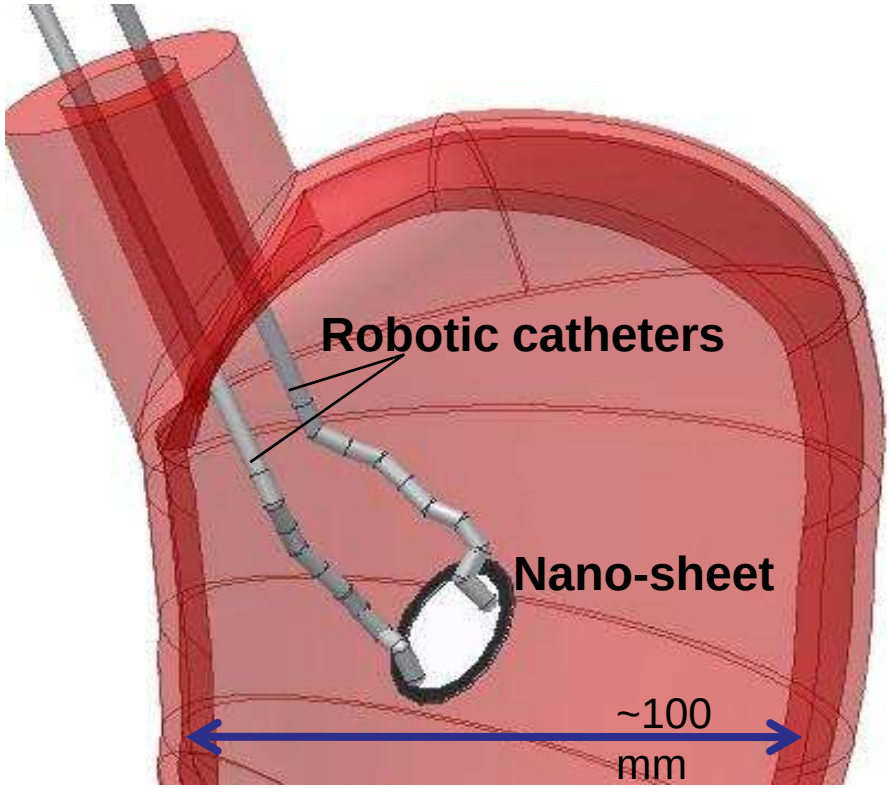
**Conventional technique to close a hole using endoluminal devices**



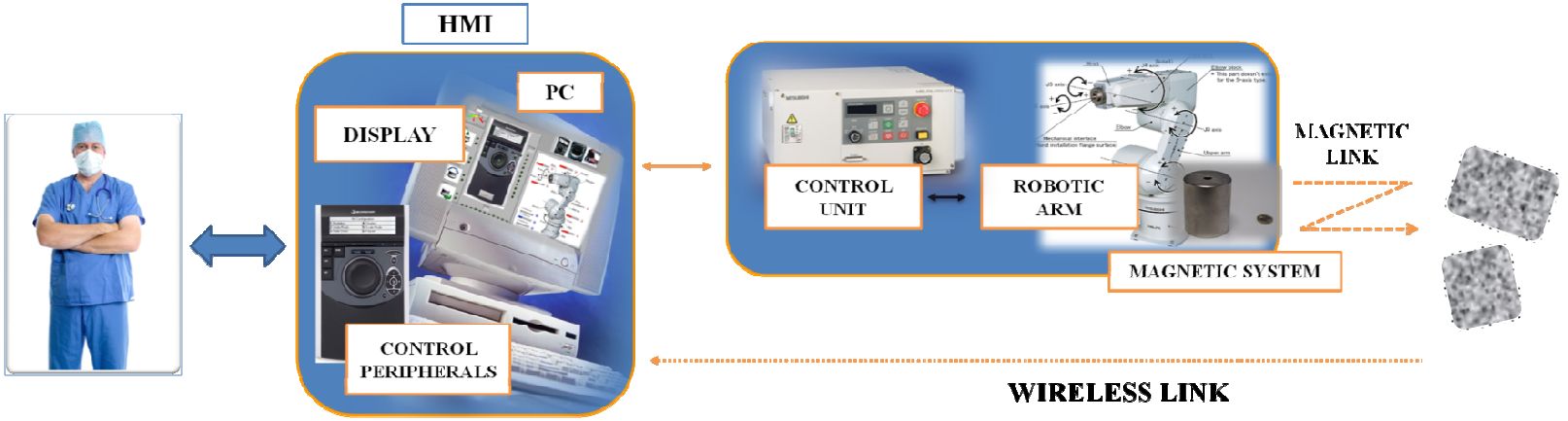

**Non invasive, flexible, efficient methods for hole closing are deeply investigated because current techniques show many limitations**



•Thanks to their flexibility, these nanofilms can be proposed as <u>nanoplasters</u> for closing incisions and wounding in endoluminal surgery procedures.
•They can be stored in small channels of endoscope and can be delivered without loosing their flexibility.

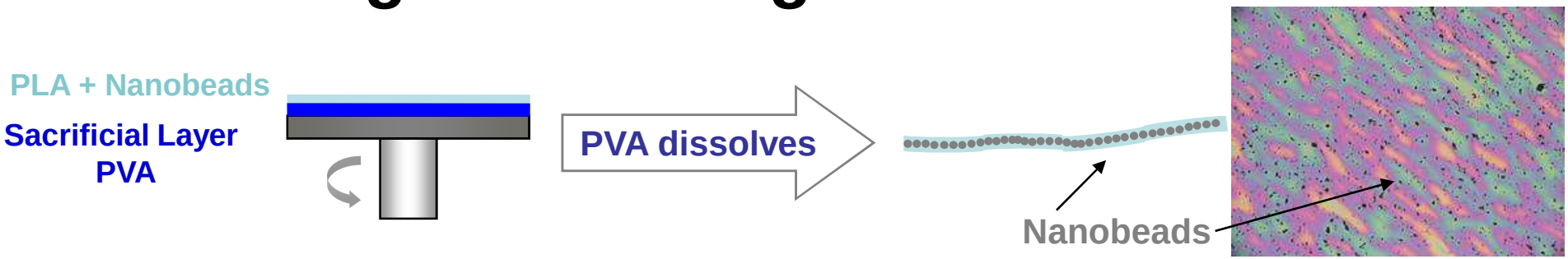



Adding magnetic properties to the film, nanosheets can be precisely positioned in situ with catheters or robotic modules inside the stomach or other orifices.




Magnetic nanosheet

# Homogeneous Magnetic Nanosheets

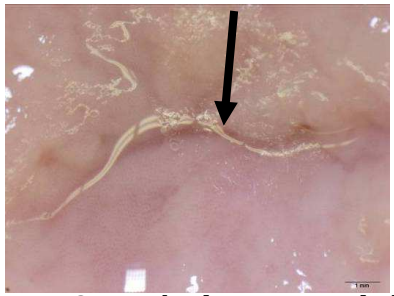



# Manipulation test

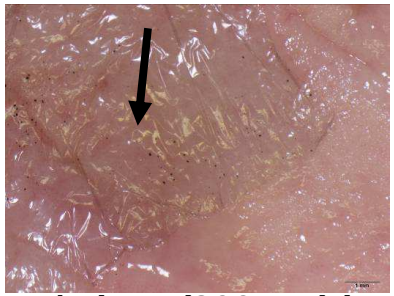
**A Neodymium Iron Boron permanent magnet (Br= 350 mT) is used to move the film in saline solution and finally the film is controlled and attached on the tissue.**

**Video-magnetic manipulation**

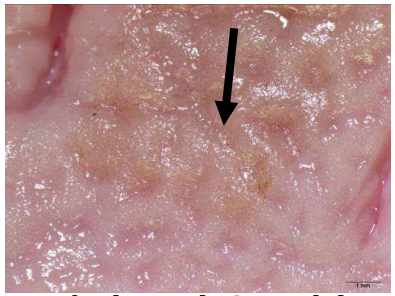
# Attachment of nanofilms on stomach tissue



**PLA 10 mg/ml, no particles**



**10 mg/ml NP (200 nm) in PLA 10 mg/ml**

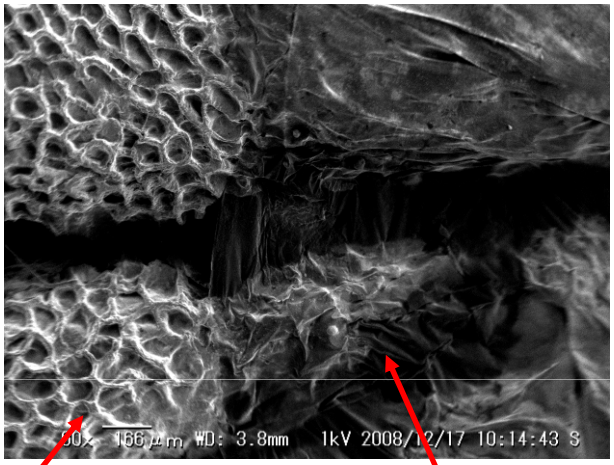


**10 mg/ml NP (40 nm) in PLA 10 mg/ml**

**After the removal of the liquid, the film adhere on the surface and, thanks to the nanometric thickness, it precisely fits the morphology of the tissue.**

# Magnetic nanofilms as nanoplaster for endoluminal surgery

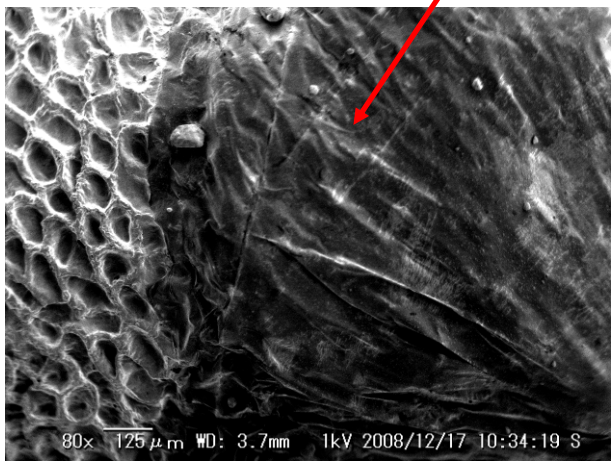
**10 mg/ml NP (200 nm) in PLA 20 mg/ml**



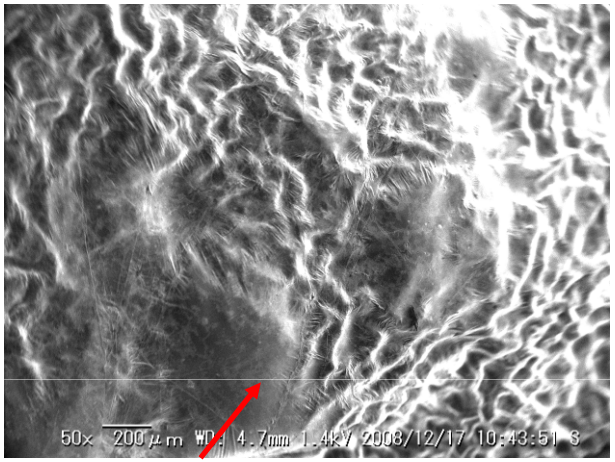

**Film covering an incision on the mucosal wall**

**gastric wall**

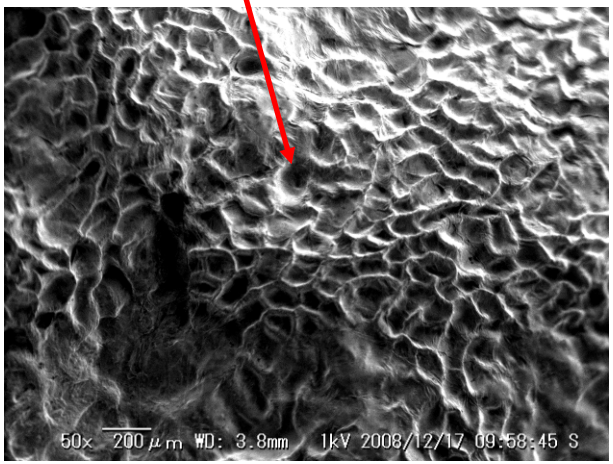
**magnetic nanofilm**




**10 mg/ml NP (40 nm) in PLA 10 mg/ml**




**The film follows the folds of the mucosal wall, completely covering it.**



# Concluding remarks

- Robots have a place in the modern operating room, because of their established ability – in a growing number of different fields - to exploit the **increasing power of planning, imaging, diagnostics and teleoperation techniques to improve surgical outcome**

- The new frontier of medical robotics: **miniaturization** and **integration of different functions**

- Enabling approach: the **convergence of many disciplines**, basically life science, physics, chemistry, neuroscience, nanotechnology, etc.

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