ICRA'07
2007 IEEE International Conference
on Robotics and Automation
10-14 April 2007, Roma, Italy

IEEE

Full Day Workshop on Roboethics
Rome, 14 April 2007

Roboethics in Biorobotics: Discussion of Case Studies

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Scuola Superiore
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di Studi Universitari e di Perfezionamento

Milestones in the history of roboethics

2003 Paper by José Maria Galvan "On technoethics" published on IEEE Robotics & Automation Magazine, December

2006 EURON ROBOETHICS ATELIER Genova, Italy

2006 BioRob Mini Symposium on Roboethics

2001 Italy-Japan 2001 Workshop HUMANOIDS A Techno-Ontological Approach, Waseda University, Tokyo, Japan

2004 IEEE RAS TC on Robo-Ethics founded

2006 ETHICBOTS First International Workshop, Naples, Italy

2000

2005

2010

2003 NEUROBOTICS FP-6-IST Ethical events

2005 ICRA Workshop on Roboethics, Barcelona, Spain

2007 ICRA 07 Workshop on Roboethics, Rome, Italy

2005 ETHICBOTS EU Project

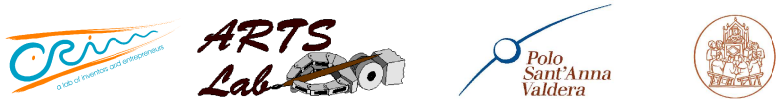
2007 ICORR 07 Workshop on Roboethics, Noordwjik, The Netherland

2001 Seminars by prof. José Maria Galván on "The relationship between human beings and technology: theological issues",at SSSA and University of Pisa, Italy

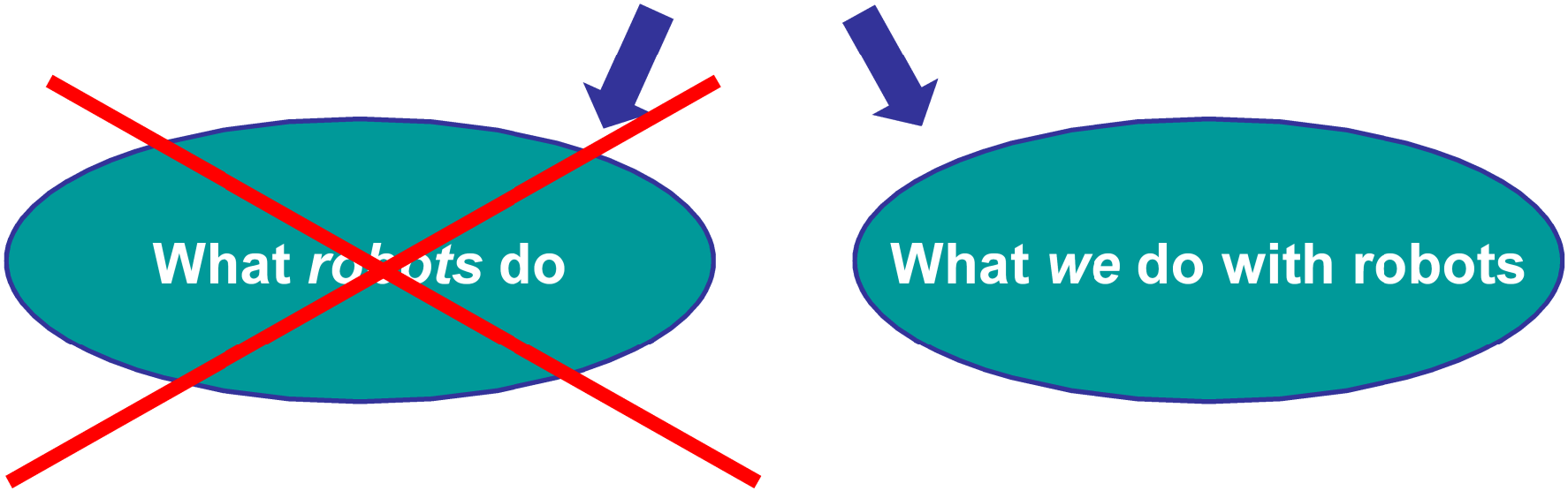
2004 First International Symposium on Roboethics, Sanremo, Italy

Many …ethics

- Bioethics deals with the ethical implications of biomedical research and applications especially in medicine (Webster dictionary).
- Technoethics can be defined as a sum of ideas that bring into evidence a system of ethical evidence that justifies that profund dimension of technology as a central element in the attainment of “finalized” perfection of men (Galvan, 2003)
- Computer ethics is concerned with ethical issues arising from the use of information technologies (Bynum, 2001)
- Philosophy of technology aims at making engineers aware of the values they bring to any design process).
- Neuroethics is concerned with ethical, legal and social policy implications of neuroscience, and with aspects of neuroscience research itself (Illes and Bird 2006).
- Machine ethics seeks to build ethical decision-making capacities directly into the machine (Allen, Wallach and Smit, 2006)
- What about Roboethics?

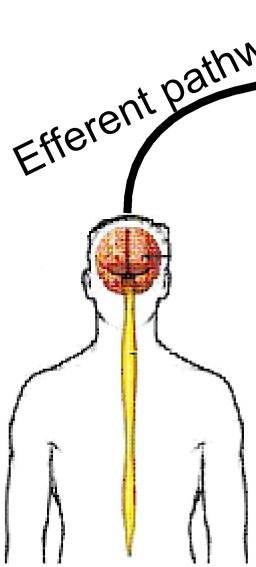


Roboethics



Roboethics is not only concerned with the cons of using robotics technologies and systems, but it points out also the benefits

From Autonomous Robots…



Human being

Efferent pathways

NATURAL EFFECTORS

Afferent pathways

NATURAL SENSORS

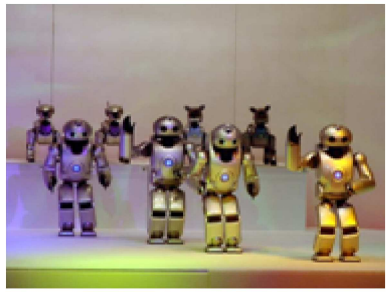
WORLD

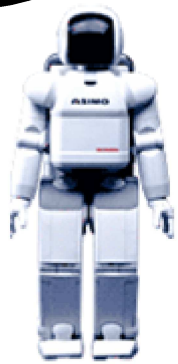
ARTIFICIAL EFFECTORS

Humanoid

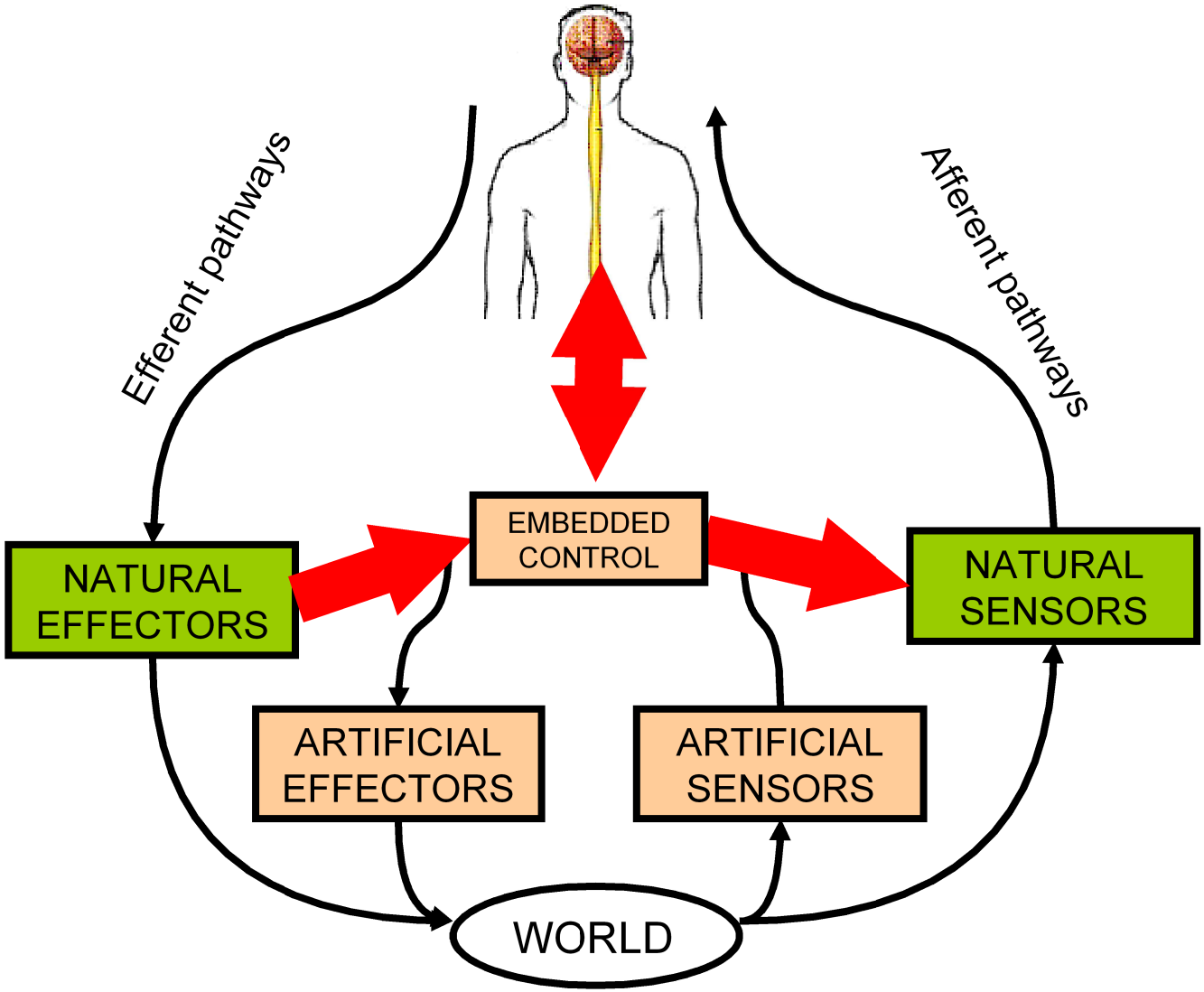
ARTIFICIAL BRAIN

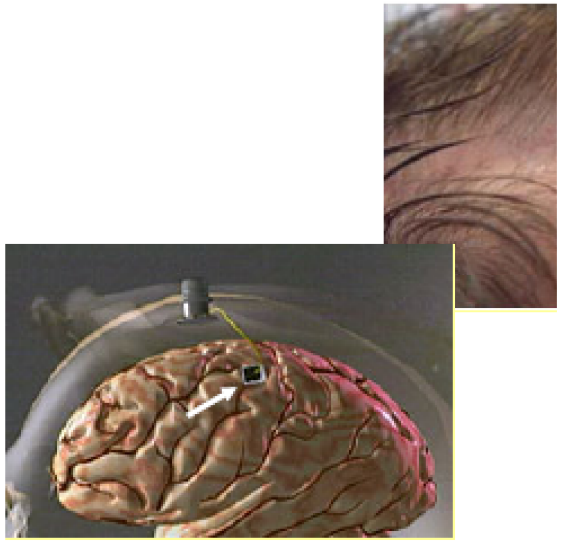
ARTIFICIAL SENSORS



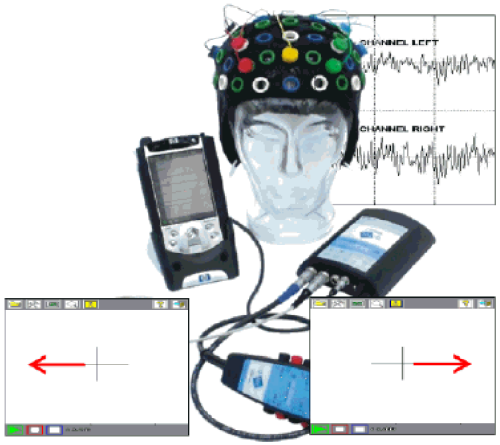


to Hybrid Bionic Systems





Hybrid Bionic Systems



ARTS Lab

Polo Sant'Anna Valdera

"Connecting" Man and Robot

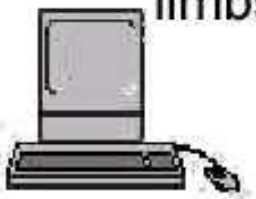
Brain — *Nerves* — Limbs

Bionic prostheses

Brain — *Nerves* — Artificial limbs

Interface

Artificially controlled limbs



Artificial Brain — *Electric wires* — Limbs

Robot

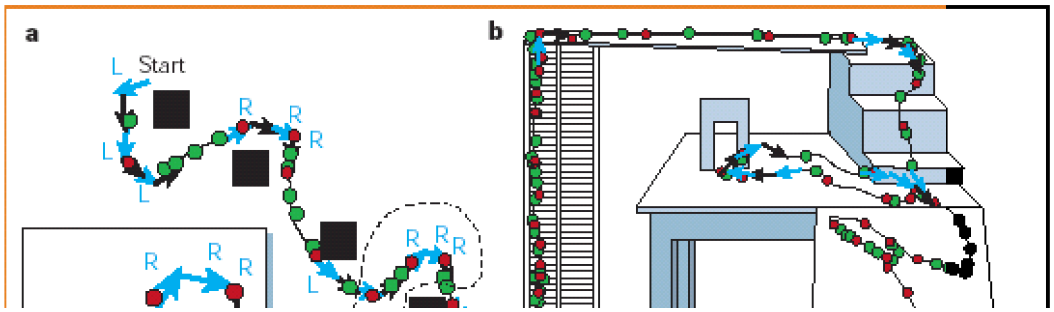
Artificial Brain — *Electric wires* — Artificial limbs

Implants currently available …on the market!

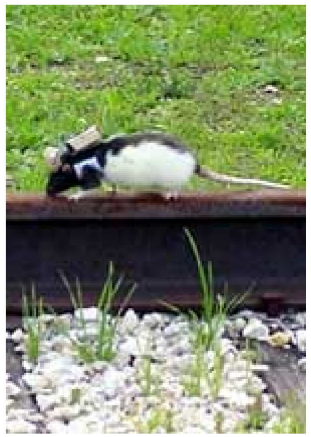
- Active medical devices
  - Pacemakers
  - Cochlear implants
  - Programmable drug delivery pumps (insulin pump for Diabetes, administration of Baclofen for patients with Multiple Sclerosis)
  - Neurostimulation devices
    - Spinal cord stimulation
    - Sacral nerve stimulation
    - Vagus nerve stimulation
  - Deep brain stimulation
    - For tremor control in patients with Parkinson's disease
    - For essential tremor
  - Artificial chip-controlled leg (by Otto Bock Healthcare GmbH)
- Identification and location devices
  - Read-Only (VeriChip)
  - Read-Write
  - Devices with tracking capabilities (RFID)

(From EGE (2005) Ethical aspects of ict implants in the human body)

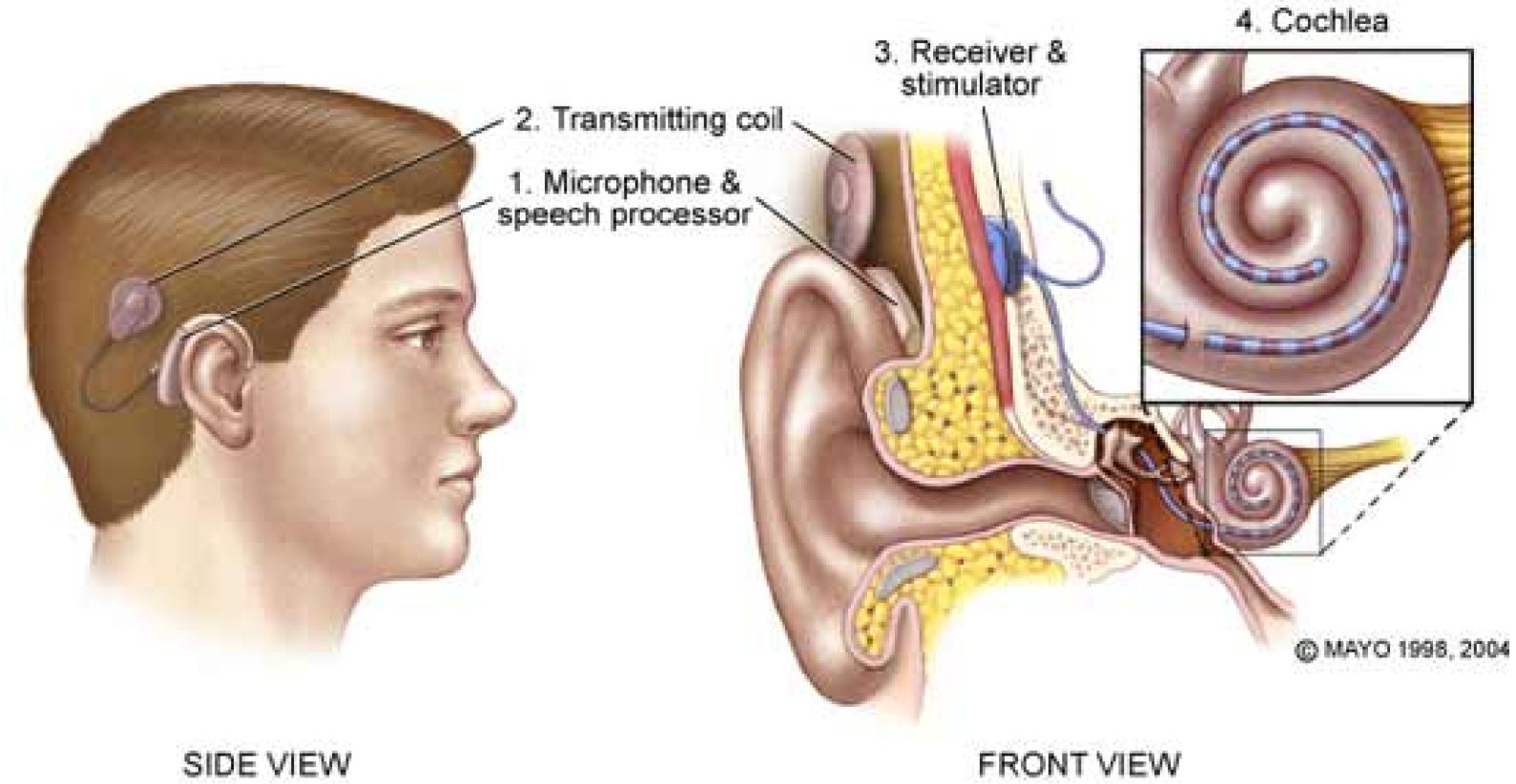
Controlling biological systems by artificial stimulation



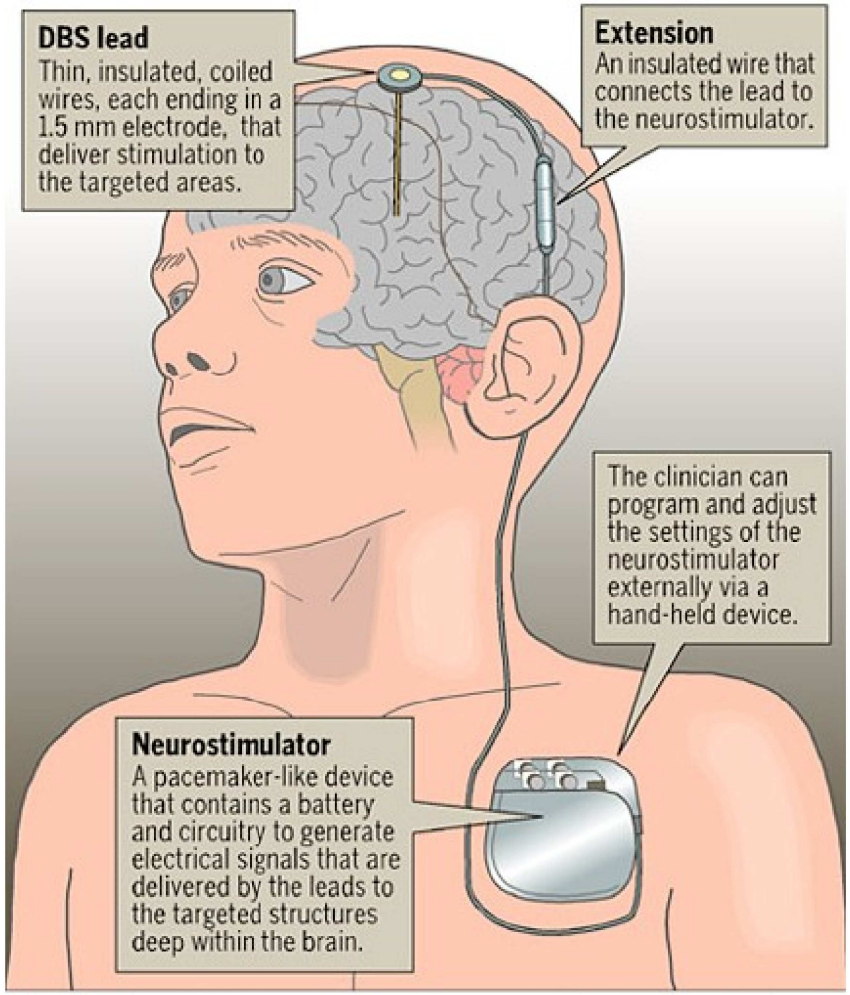
S. K. Talwar, S. Xu, E.S. Hawley, S. A. Weiss, K. A. Moxon, J. K. Chapin, "Behavioural neuroscience: Rat navigation guided by remote control" Nature 417, 37 - 38 (2002)



Cochlear implant: how it works



Deep brain stimulation



- DBS is used to help control tremors and chronic movement disorders. Tiny electrodes are surgically implanted in the brain and connected via a subcutaneous wire to a neurostimulator implanted under the skin near the clavicle

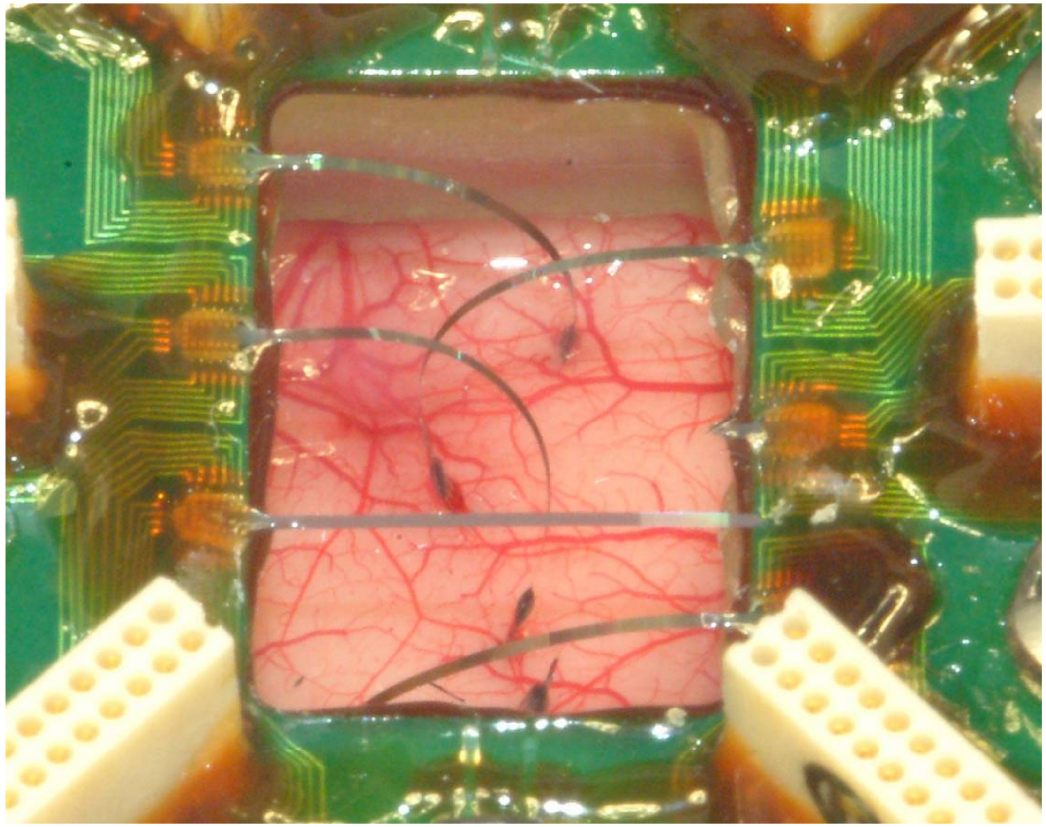
Source Medtronic Inc.

José Delgado pioneering experiments with brain implants in 1930

- Scientist Dr. José Delgado controlled an angry bull by electrical stimulation of the brain
- In 1974, Delgado stated: “We need a program of psychosurgery for political control of our society. The purpose is physical control of the mind. Everyone who deviates from the given norm can be surgically mutilated.”

“‘Matador’ with a Radio Stops Wired Bull Modified Behaviour in Animals the Subject of Brain Study” by John A. Osmundsen, *New York Times,* 17 May, 1965

Brain-Machine Interfaces

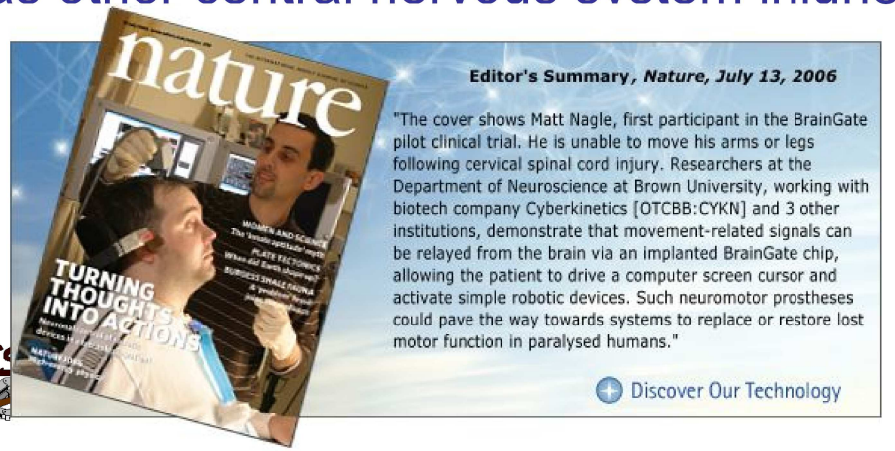


"Brain to Computer Interface is one of the 10 Emerging Technologies that will change the world"

Technology Review, January/February, 2001

BrainGate™

Cyberkinetics Neurotechnology Systems, Inc. presented some preliminary findings of **the BrainGate(TM) Neural Interface System pilot clinical study in humans** at the annual meeting of the Society for Neuroscience in San Diego, California in 2005.
The BrainGate™ System is being developed to provide novel communication interfaces, the ability to control devices and to potentially restore limb movement to those with spinal cord injury, stroke, ALS (Lou Gehrig's disease), as well as other central nervous system injuries.

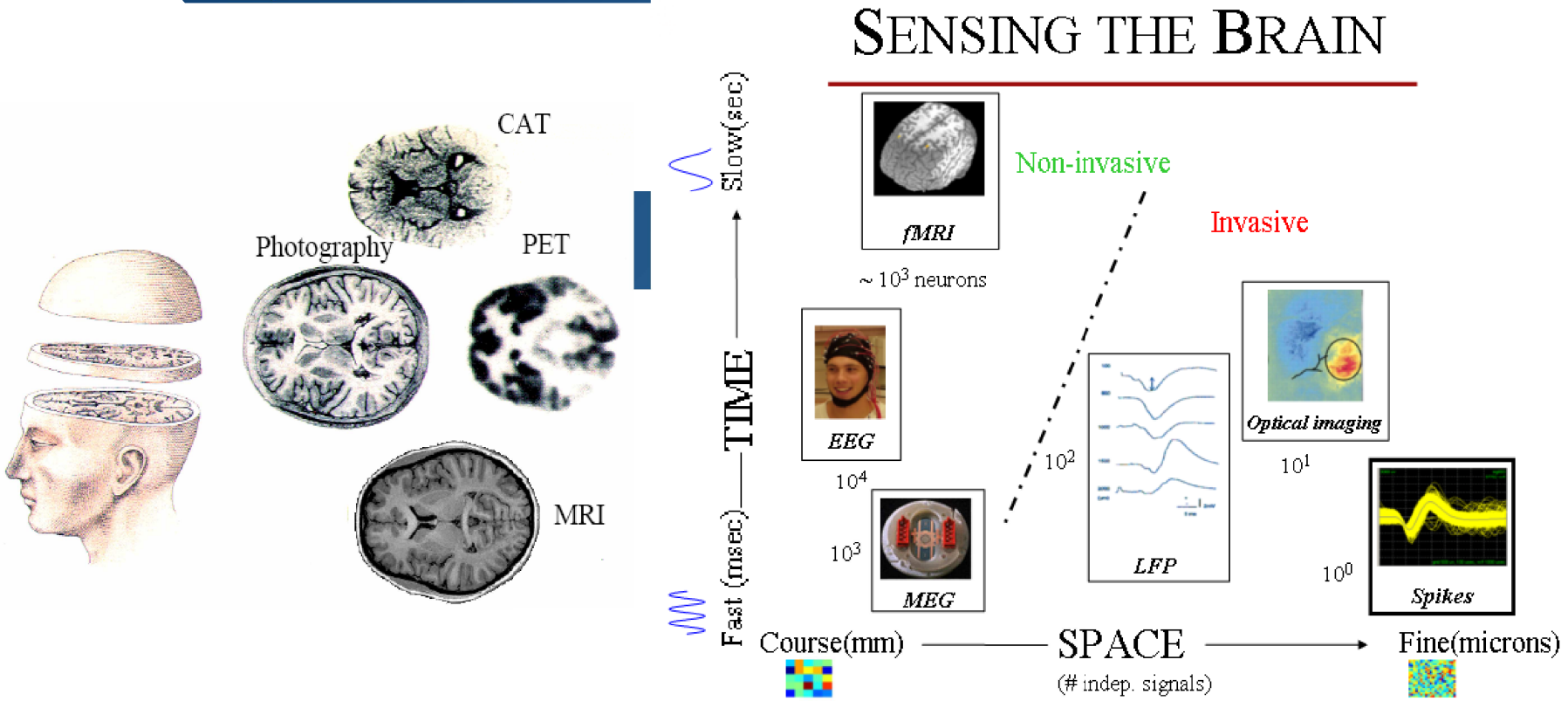


Cyberkinetics Neurotechnology Systems, Inc. presented some preliminary findings of **the BrainGate(TM) Neural Interface System pilot clinical study in humans** at the annual meeting of the Society for Neuroscience in San Diego, California.

The presentation included a discussion of the scientific, mathematical and practical observations that lead to **the first demonstration of a person with quadriplegia** using signals recorded from **motor cortex** and the BrainGate System to control a computer, environmental controls and a robotic limb.

Neuro-imaging

- Sensing technologies that can be used to observe neural activity, divided by invasiveness and classified by spatial and temporal resolution.



From From M. Black

CyberHand Project

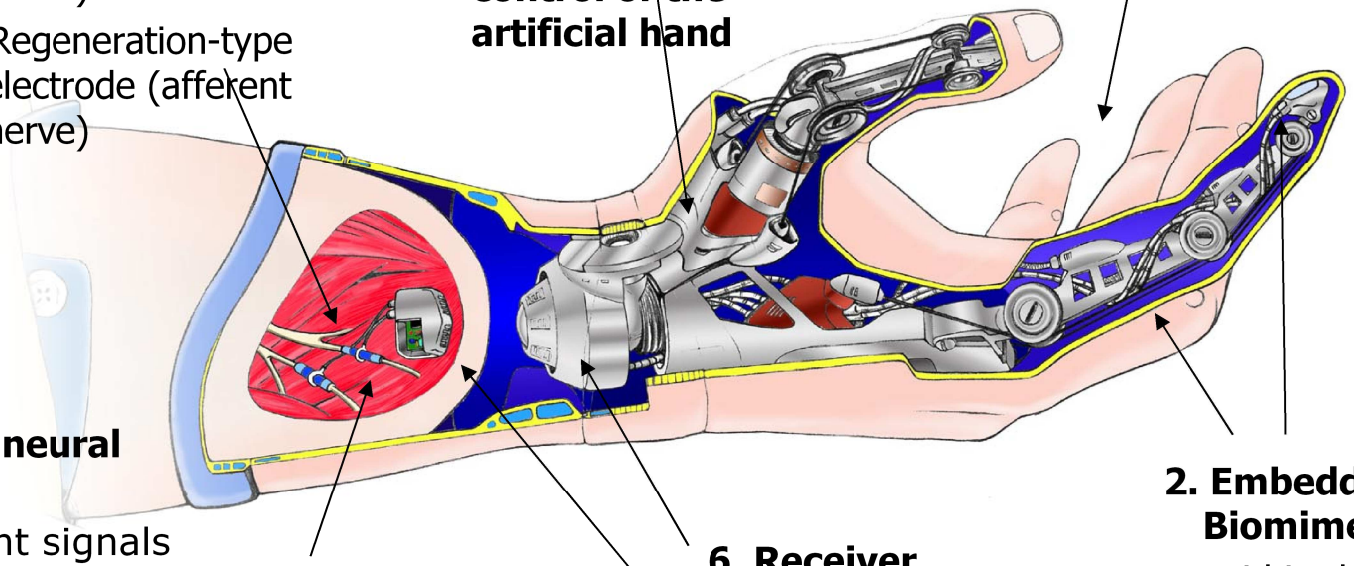
(01/05/2002 – 30/04/2005) IST-FET Project #2001-35094

Regeneration-type electrodes:

3. Regeneration-type electrode (efferent nerve)
4. Regeneration-type electrode (afferent nerve)

8. Decoding patient's intentions and **Embedded closed-loop control of the artificial hand**

1. Biomechatronic Hand



Stump

5. Implanted neural interface:

- ENG efferent signals recording (patient's intention detection)
- Afferent nerves stimulation (to provide sensory feedback to the patient)

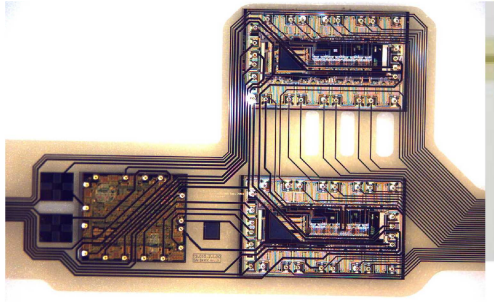
6. Receiver

7. Transmitter

2. Embedded Biomimetic sensors:

- within the structure
- within the glove

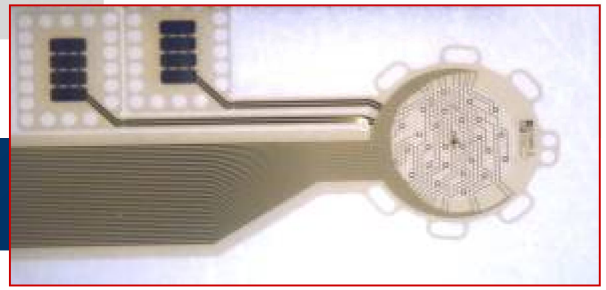
Electrodes for Recording and Stimulation in the PNS



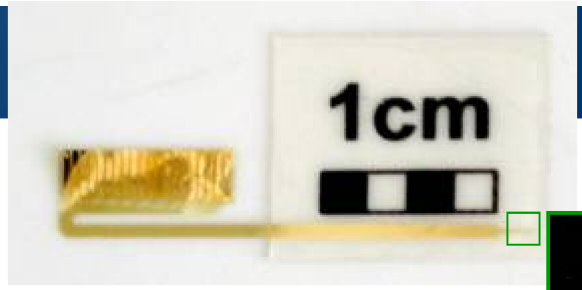
Integrated Electronics for Active Sieve Electrode

Sieve Electrode

Sieve silicon electrode

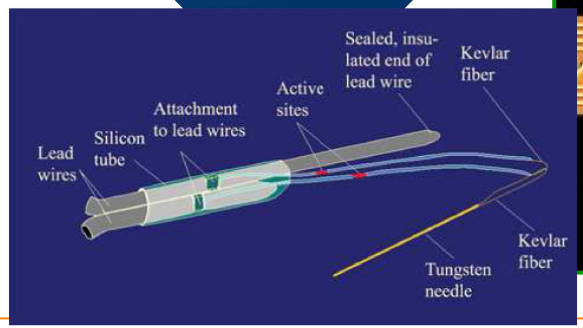


Sieve Head with Counter Electrodes

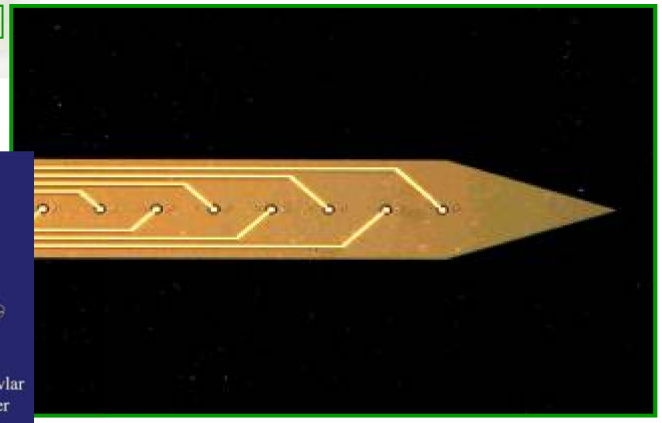


Shaft Electrode

Tripolar Cuff Electrodes



LIFE Electrodes



Platinum Electrodes on the Shaft

ARTS Lab

Short-term implant of intraneural electrodes in humans

Kevin Warwick, U. of Reading (UK)

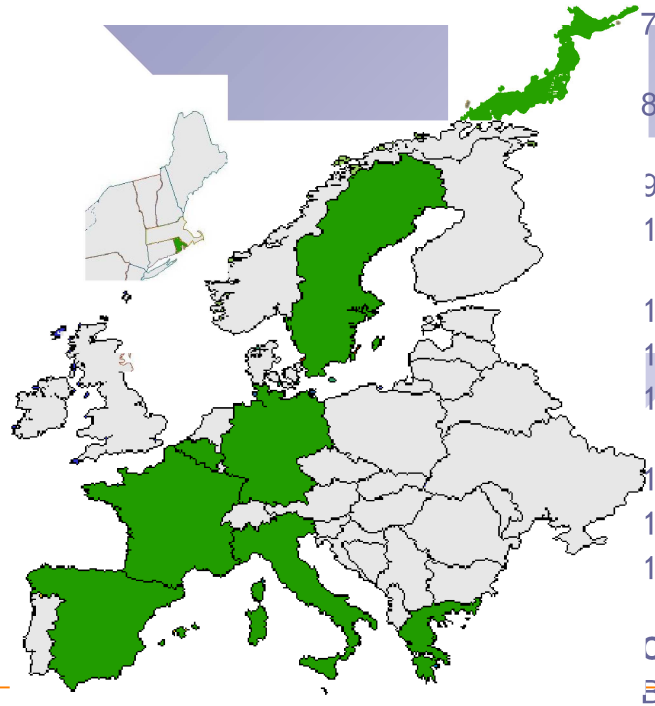
NEUROBOTICS

Sixth Framework Programme

Future and Emerging Technologies

Started: 01/01/2004 Duration: 48 months
Funding: 5.640 k€

The fusion of NEUROscience and roBOTICS



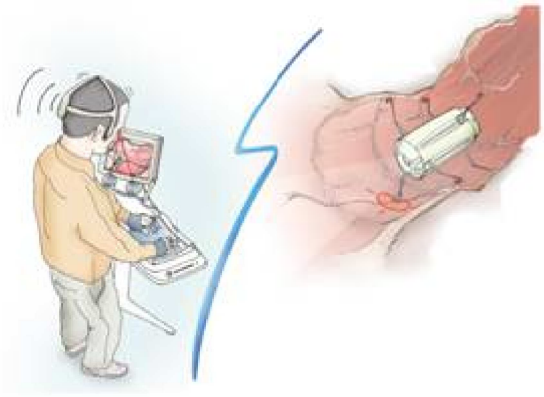
List of partners

1. Scuola Superiore Sant'Anna, Italy (prof. Paolo Dario) – Project Coordinator
2. Collège de France, CNRS, France (prof. Alain Berthoz)
3. Deutsches Zentrum fur Luft und Raumfahrt, Germany (prof. Gerd Hirzinger)
4. Fraunhofer Institute for Biomedical Engineering, Germany (dr. Thomas Stieglitz)
5. Karolinska Institutet, Sweden (prof. Sten Grillner)
6. KU Leuven, Belgium (prof. Guy Orban)
7. Kungl Tekniska Högskolan, Sweden (prof. Henrik Christensen)
8. National Technical University of Athens, Greece (prof. Kostas Kyriakopoulos)
9. Umea Universitet, Sweden (prof. Roland Johansson)
10. Universitat Autònoma de Barcelona, Spain (prof. Xavier Navarro)
11. University of Genova, Italy (prof. Giulio Sandini)
12. University of Parma, Italy (prof. Giacomo Rizzolatti)
13. Université P. et M. Curie / INSERM U483, France (prof. Yves Burnod)
14. Università di Ferrara (prof. Luciano Fadiga)
15. Pont-Tech (dr. Fabrizio Vecchi) – Project Manager
16. Università Campus Biomedico (prof. Paolo Maria Rossini)

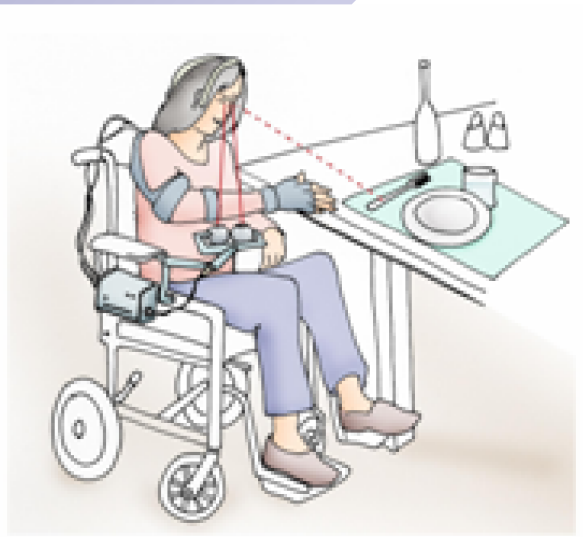
Collaboration with non-EU research groups

Brown University, USA (prof. John Donoghue)
Waseda University, Japan (prof. Atsuo Takanishi)

The goals: “hybrid bionic systems”



“Beyond Tele-operation”: robotic aliases for explorations in remote and/or difficult to access environments



“Beyond Ortheses”: a smart exoskeleton for improving accuracy, endurance and strength of human arm and hand movements

“Beyond Prostheses”: a novel highly anthropomorphic arm/hand system, for limb substitution or for adoption of additional limbs

Information Society Technologies

NEUROBOTICS ethical events

Neurobotics

NEUROBOTICS proposal

(ethical aspects covered in section B.9)

NEUROBOTICS proposal submission (April 24, 2003)

Request of an **ethical review** by the Unit C3, Ethics and Science of EU (August 6, 2003)

Ethical

- Resp
- Resp prima
- Poter

Recom

- Identification of countries where research will be carried out
- identification of any important national regulations relating to the research and confirmation that the national regulations in those countries will be observed
- confirmation that the Commission will be informed of local or national ethics approval being obtained before relevant research is carried out.
- identification of relevant EU and International legislation and confirmation that this will be observed.
- identification of research on humans or their tissues for which informed consent will be required together with details of the information that will be provided to those taking part and any provision made for their support and welfare.
- indication of how data storage and handling processes will ensure patient data protection and confidentiality
- justification for use of animals especially where this relates to non-human primates and transgenic animals - this should include justification of numbers and species and indicate clearly how the principles of reduction, refinement and replacement have been employed.
- further information on any ethics component in the proposal, including details of those involved and clarification of the role, remit and integration of that element.

(www.neu
Technolog

NEUROBOTICS Annex 1

Future and Emerging Technologies

The case of NEUROBOTICS

- The title of the origianal proposal: The fusion of NEUROscience and roBOTICS (for *augmenting* human capabilities);
- **EU Ethical Panel** raised a number of ethical issues concerning the objectives and methodology of the project:
  - **Research on human beings**
  - **Human dignity**
  - **Research on animals**
  - **Research on non-human primates**
  - **Dual use**
  - **Ethical and societal implications of research results**

NEUROBOTICS ethical replies

- **Dual use.** NEUROBOTICS research is not intended for developing military devices of any kind, but on the contrary its only purpose is for scientific and medical applications. The NEUROBOTICS consortium will identify legal routes to prevent military uses of patens and scientific results of the project.
- **Identity, privacy and control** NEUROBOTICS implants are not part of surveillance systems, and users are not part of any network; the implant can only be used locally for communicating with the prosthesis. As to identity, the implantation of electrodes in the brain cortex in order to record cortical activity does not produce effects on the brain and it does not affect human awareness of identity.
- **Autonomy** In NEUROBOTICS no artificial intelligent system is used to make decisions. Only the user's brain is in control of the robotic artefact. NEUROBOTICS objective is to restore the limited capabilities of the patient, thus contributing to enhance the autonomy of the person (and not of the robot).

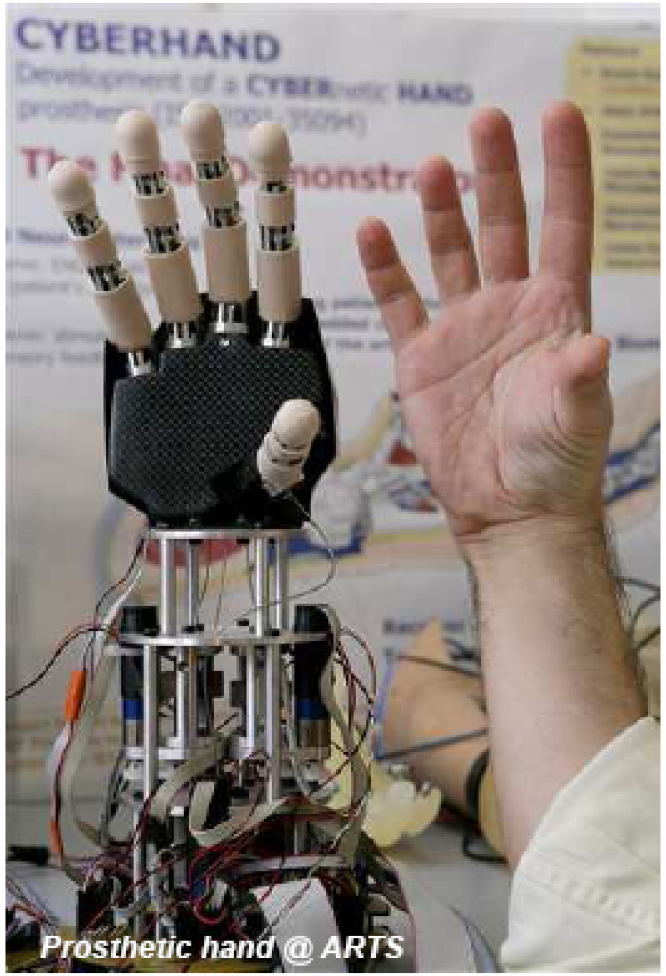
NEUROBOTICS ethical replies

- **Augmentation** The objective of NEUROBOTICS, however, is to restore lost functions in disable patients and improve their quality and right to life. The project is not intended for healthy individuals, but only for people which have experienced serious damages to bodily functions.
- **Dignity** As to NEUROBOTICS, researchers are aware of the risk of engendering false expectations in patients and people participating in clinical trials. Moreover, informed consent will be asked to the people willing to participate in new experiments. NEUROBOTICS is also concerned in avoiding physical, mental and economic harm as a result of participation in the research. Implantable interfaces used in NEUROBOTICS can be removed without risks as proved by experiments on animal models.
- **Discriminations and accessibility** NEUROBOTICS is intended to reduce the gap between healthy individuals and physically disable people.

The case of NEUROBOTICS (D.15.1)

- To address the ethical issues raised by the Ethical Panel a new Work Package (WP15) was added in the NEUROBOTICS Annex 1, to be specifically devoted to the analyses of the bioethical, technoethical and societal issues arising in the framework of the project.
- The main objectives of WP15 are:
  - To analyze the ethical impact of human augmentation
  - To monitor the experimental protocols and methodologies according to the European and national regulations
  - To investigate and define an appropriate ethical and methodological framework for exploring the relationships between robotics, neuroscience, and ethics in a broad sense.

CyberHand as one of the NEUROBOTICS platforms

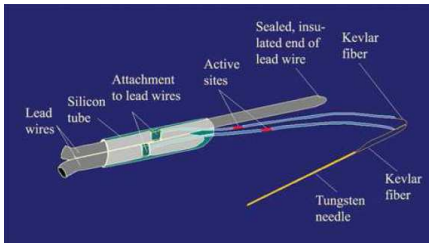


Prosthetic hand @ ARTS

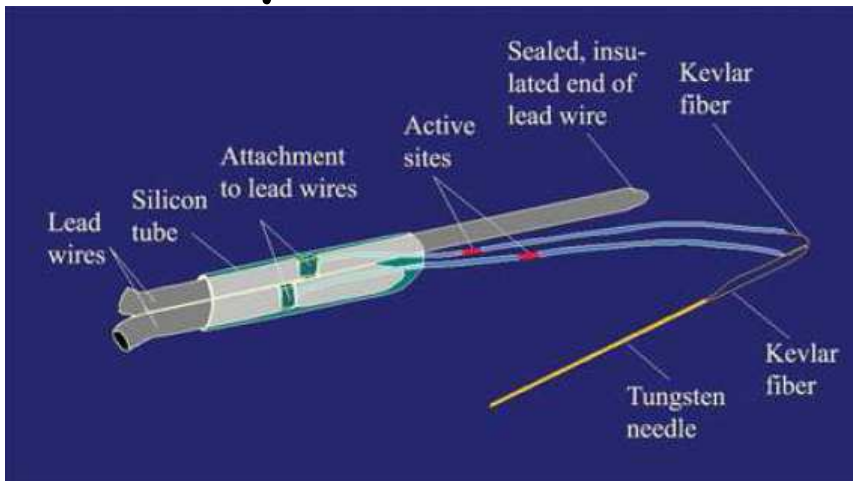
- **The Ethical Committee in Rome**
  - *In vivo* experiments on human beings…
    - Peripheral implants; not cronical.
  - Providing both researchers and doctors with knowledge on how to interface themselves with patients (epecially from psychological point of view).
- **The role of media: pros and cons**
  - Pros: critical mass; fundings.
  - Cons: creating false expectations on patients and people…
- **Trade-off benefits/functionalitis**

CyberHand

- Clinical trials will be performed in two steps:
  - ✓ Phase 1: Acute implant of new generation (8-contact) tf-LIFE interfaces
  - ✓ Phase 2: Chronic implant of the full CyberHand/Beyond Prostheses platform

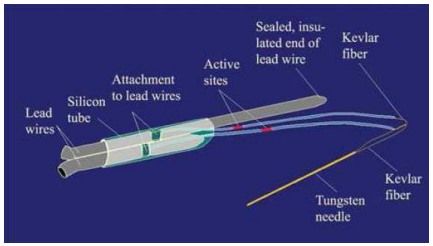


CyberHand



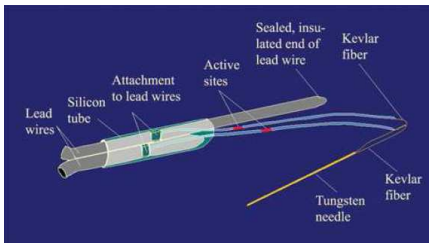
- **Phase 1: Acute implant of new generation (8-contact) tf-LIFE interfaces:**
  - ✓ 2 patients, to start in **JUNE 2007**
  - ✓ UCBM multi-disciplinary equipe including neurologists, orthopaedic surgery, hand microsurgery, neurorehabilitation, radiology, brain imaging, neuropsychology, bioengineering:
    - o *Prof. Paolo Maria Rossini, Prof. Vincenzo Denaro, Prof.ssa Silvia Sterzi, Prof. Bruno Beomonte Zobel, Dr. Luca Denaro, Dr. Mario Tombini, Dr. Franca Tecchio, Dr. Paola Chiovenda, Dr. Giuseppe Curcio*
    - o *Eugenio Guglielmelli, Loredana Zollo, Giovanni Di Pino*

CyberHand Phase 1 Trials



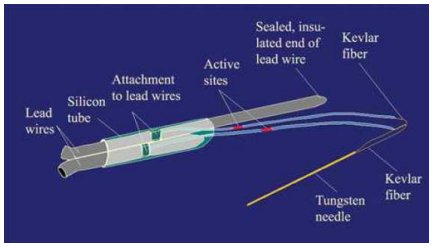
- Patient selection criteria:
  - ✓ Up to 2 chronic subjects (>2 years from the amputation); volunteers
  - ✓ Both subjects clearly unsatisfied from the previous clinical application of cosmetic and/or myoelectric hand prostheses
  - ✓ Strong motivation
  - ✓ No other significant cognitive or physical problems (WAIS-R, MMPI-2)

CyberHand Phase 1 Trials



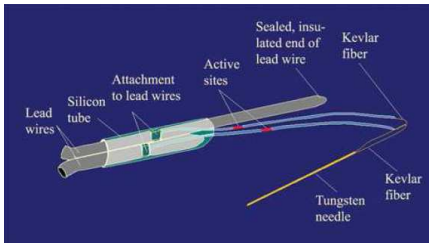
- In order to preliminarly assess the cortical response during imagination of movements of the missing limb and the level of cortical representation of the distal upper limb areas close to the amputation, both recruited subjects will undergo:
  - high resolution electroencephalogram = hrEEG
  - magnetoencephalography = MEG
  - fuctional Magnetic Resonance Imaging = fMRI
  - Transcranial Magnetic Stimulation = TMS
- In monolateral amputees comparative analysis with the controlateral limb will be also carried out

CyberHand Phase 1 Trials



- Two tf-LIFE electrodes will be implanted in the distal part of the median and ulnar nerve (30 – 80 mm from the amputation)
- Local anesthesia
- Transcutaneous connector
- Typical duration of the implant before surgical removal of the electrodes: 2 months

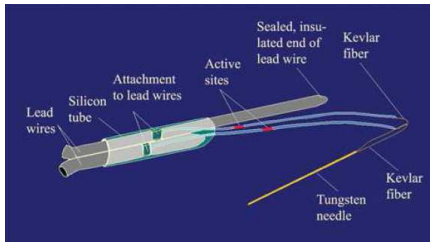
CyberHand Phase 1 Trials



- **<u>3-step incremental approach for clinical trials</u>**:
  - ✓ Initial verification and basic training of the patient for characterization of the interfaces:
    - o efferent signals classification
    - o afferent channels stimulation with programmable signals for evoking tactile sensations
    - o afferent channels stimulation with artificial tactile sensors
  - ✓ Trials for controlling a virtual hand set-up
  - ✓ Trials for controlling a real prosthetic hand desktop set-up (not implanted)

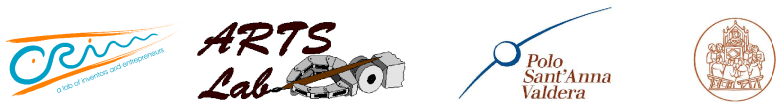
BEYOND PROSTHESES

CyberHand Phase 1 Trials



- New assessment of the cortical response during control of movements of the desktop prosthetic set-up and of the level of cortical representation of the distal upper limb areas close to the amputation:
  - high resolution electroencephalogram = hrEEG
  - magnetoencephalography = MEG
  - fuctional Magnetic Resonance Imaging = fMRI
  - Transcranial Magnetic Stimulation = TMS
- Comparative analysis with the preliminary assessment results

The CYBERHAND project got a great coverage by the media all over the world: from RAI, BBC, TSR to Disney Channel…



The Press...

- Article in **New Scientist** vol 181 issue 2436, Feb 28 2004, “The technology to build the world's first bionic limbs is almost within our grasp"
- Article on the **Economist** journal Science Technology Quarterly section, June 10°, 2004, “Once again with feeling"
- Article to appear on **Fraunhofer-Gesellschaft** 2005.4 (German version – next October; English version November)
- Articles in various Italian national newspapers and weekly magazines like **Corriere della Sera**, **la Repubblica, Sole 24 Ore, Secolo XIX**, **Secolo d’Italia**, **Libero, Panorama**
- Articles in Italian national scientific magazines like **Macchina del Tempo** and **Newton**
- ARTICLES ISSUED IN MANY OTHER COUNTRIES LIKE: **Poland**, **France**, **England**, **Spain**, **Portugal**