

# **A**dvanced **T**echnologies **B**eyond the **H**orizon: **C**onsiderations for **S**trategic **P**lanning



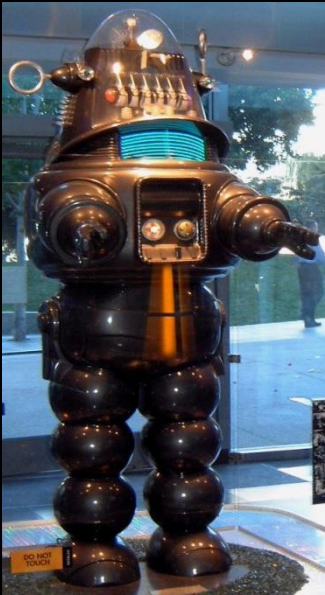
Research Frontiers in Medical Cyber-Physical Systems  
Washington, DC  
6 February, 2014



Richard M. Satava, MD FACS  
Professor Emeritus of Surgery  
University of Washington

# Disruptive Visions

“The Future is not what it used to be”



....Yogi Berra

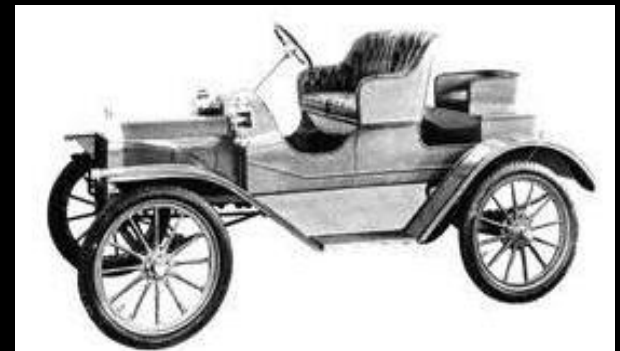
# What is a Disruptive Vision ?

## Rethinking Healthcare

“ If I had asked people what they wanted . . .  
 . . . they would have said a faster horse . ”



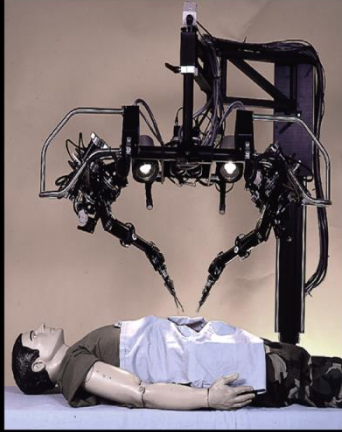
HENRY FORD



**E**xpectations are high . . .  
. . . **c**hallenges are **B**igger



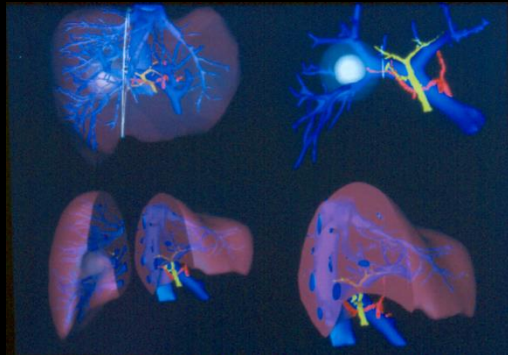
# Total Integration of Surgical Care



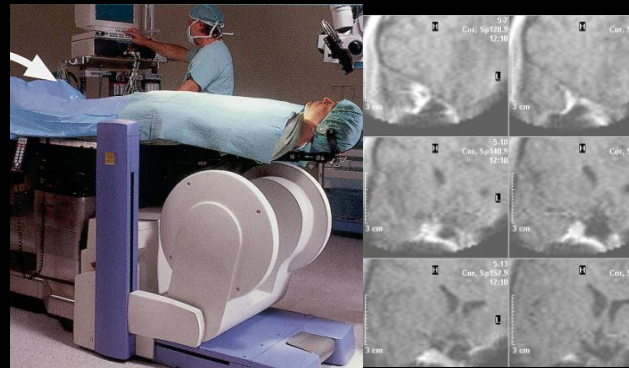
Remote Surgery



Minimally Invasive  
& Open Surgery



Pre-operative planning  
Surgical Rehearsal



Intra-operative navigation



Simulation & Training  
Pre-operative Warmup

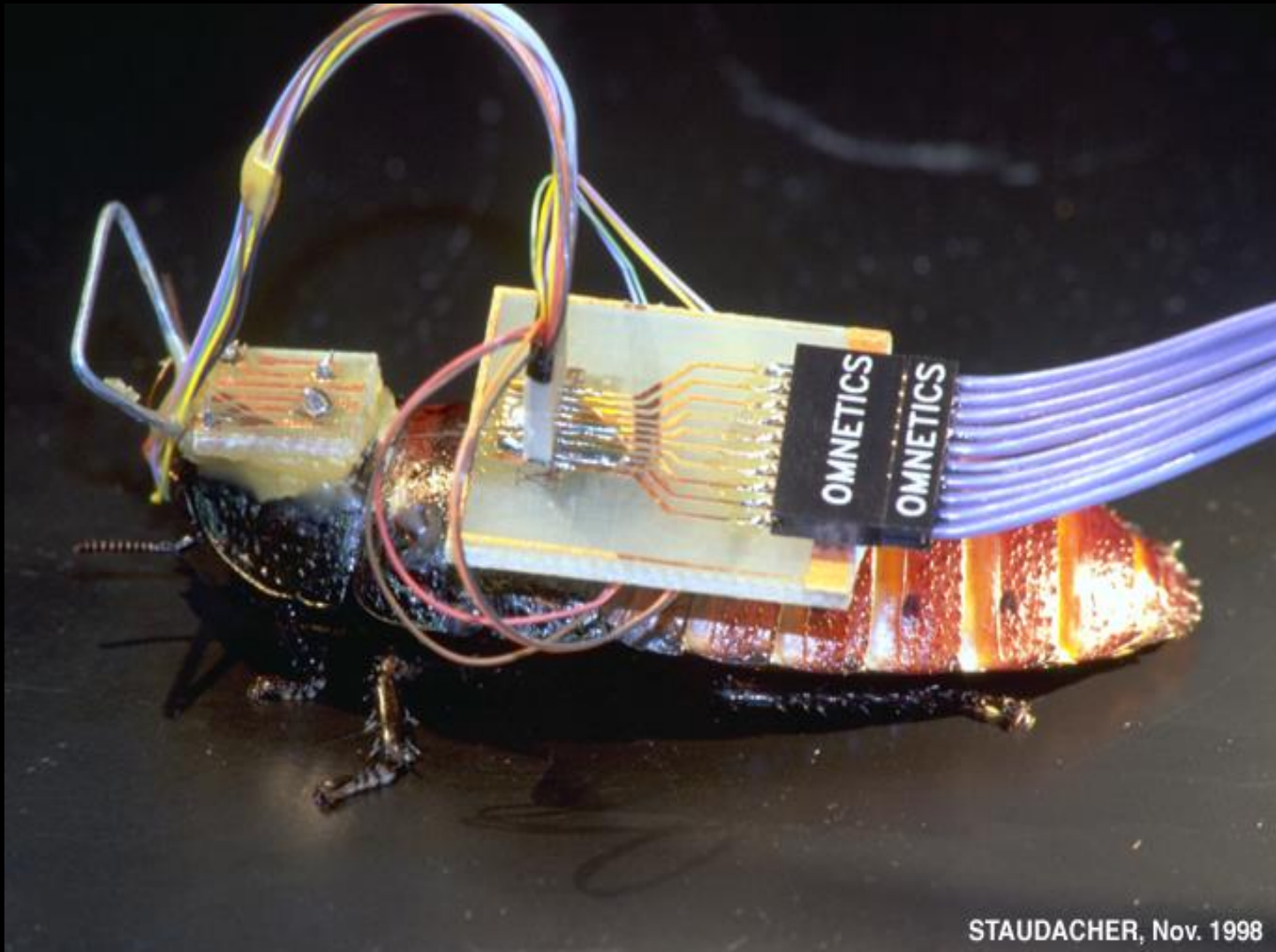
# Demonstration of Phase 1 Operating Room with No People



# Demonstration of Phase 1 Operating Room with No People



# Controlling Intervention

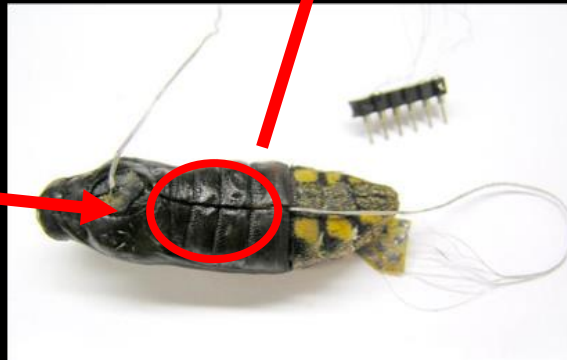
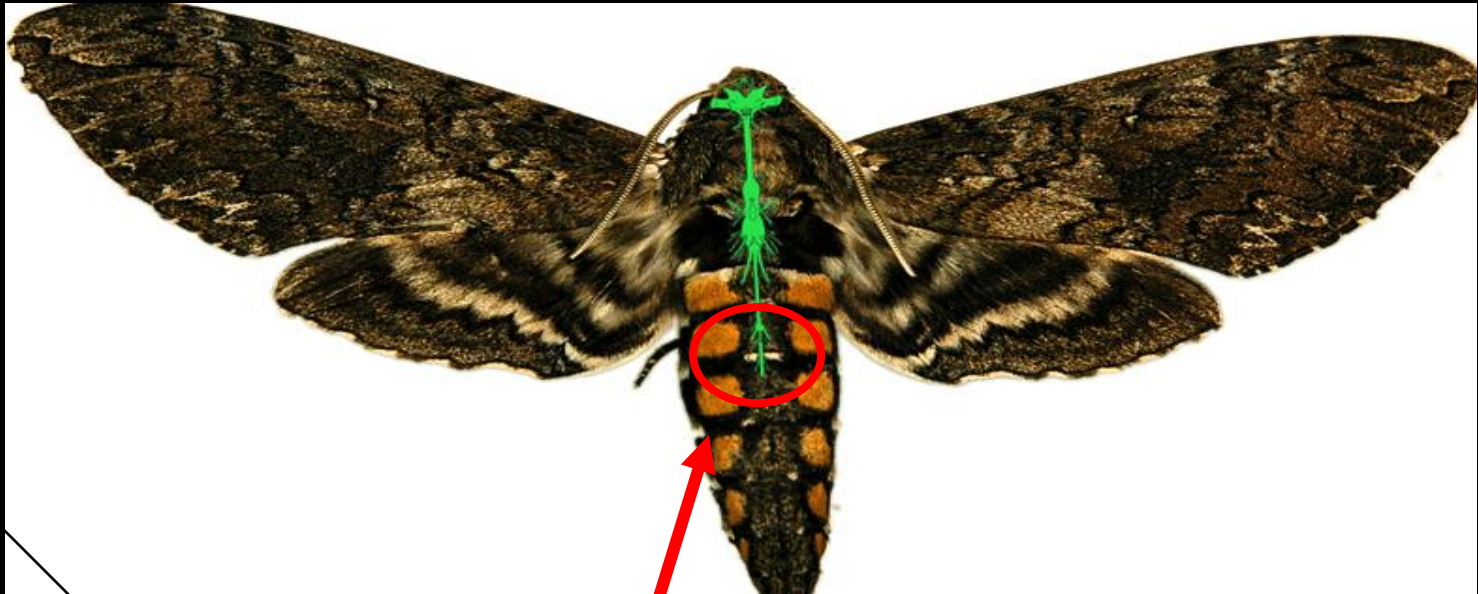


Catch me  
if you can!



STAUDACHER, Nov. 1998

# Direct Control of Muscles



# Biomimetic Micro-robot



Courtesy Sandia National Labs



Courtesy Danny Scott  
Texas Southwestern  
Dallas, TX



Capsule camera for gastrointestinal endoscopy

Courtesy Paul Swain, London, England



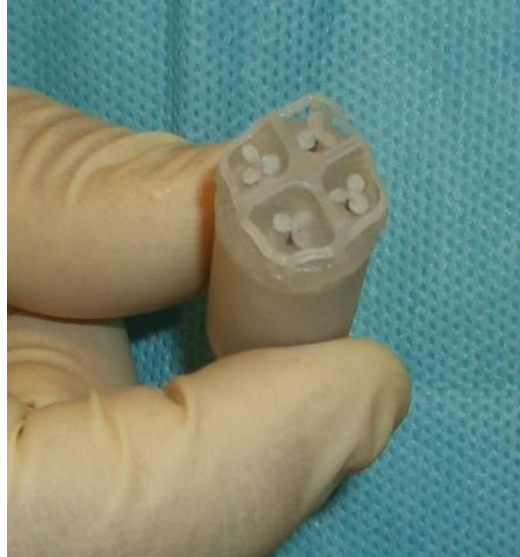
Courtesy D. Oleynikov, Univ Nebraska

# Internal Locomotion Actuators Currently Investigated

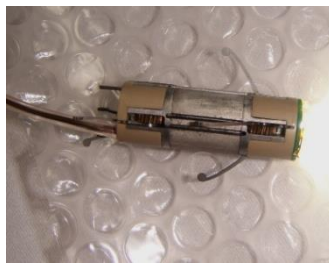
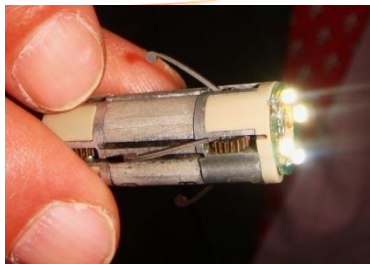
*Walking robot with legs*



*Submarine*



*Vibratory locomotion*



Source : A Menciassi et al., CRIM, Scuola Sant'Anna, Pisa

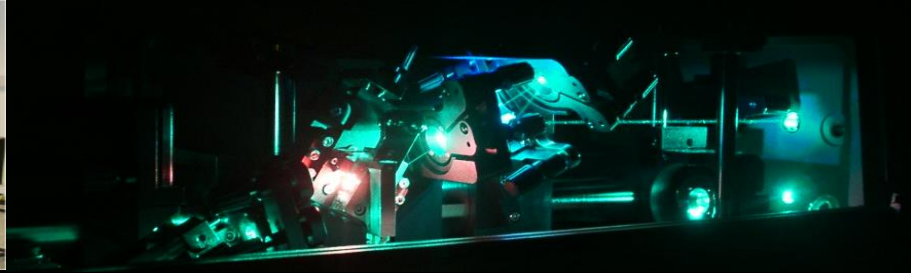
Source: M. Sfakiotakis et al., FORTH, Heraklion

Supported by the European Union as an Integrated Project  
Information Society Technologies - Contract Number 033970  
[www.vector-project.com](http://www.vector-project.com)

 **VECTOR**  
Courtesy Marc O. Schurr &  
The VECTOR consortium - 2008

# Femtosecond Laser

( $1 \times 10^{-15}$  sec)



Los Alamos National Labs, Los Alamos NM

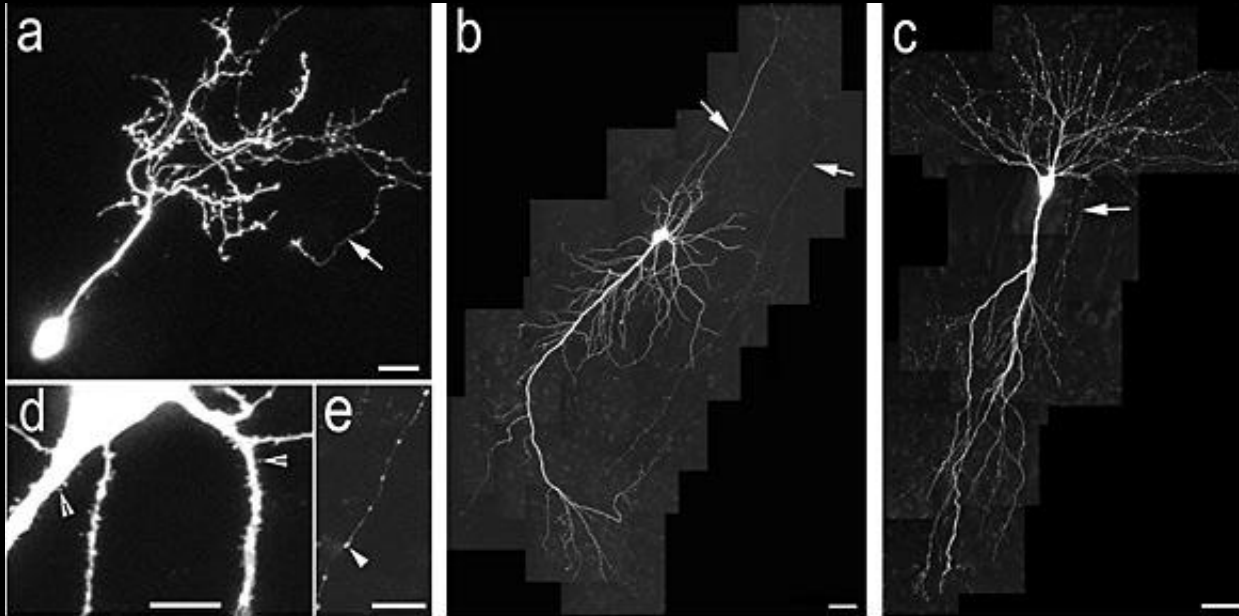
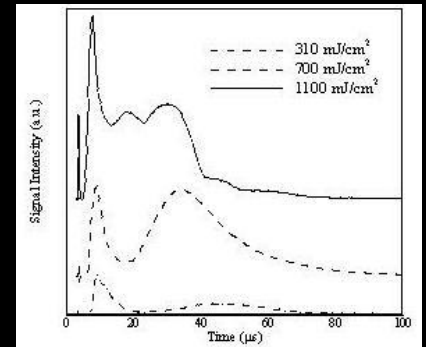
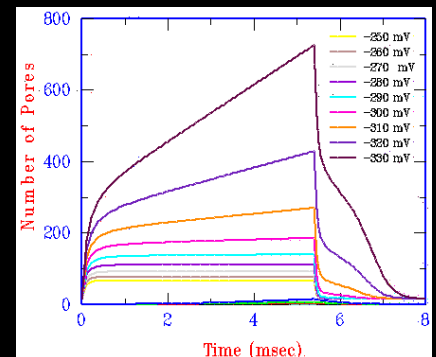


Figure 1. a) Single-cell electroporation of pGFP *in vivo* in the Xenopus tadpole brain. SCE of CA1 (b) and CA3 (c) pyramidal cells in organotypic rat hippocampal slices. d) Enlargement of the CA1 pyramidal cell showing spines, and axonal varicosities (e).

Cold Spring Harbor Laboratory, Long Island, NY

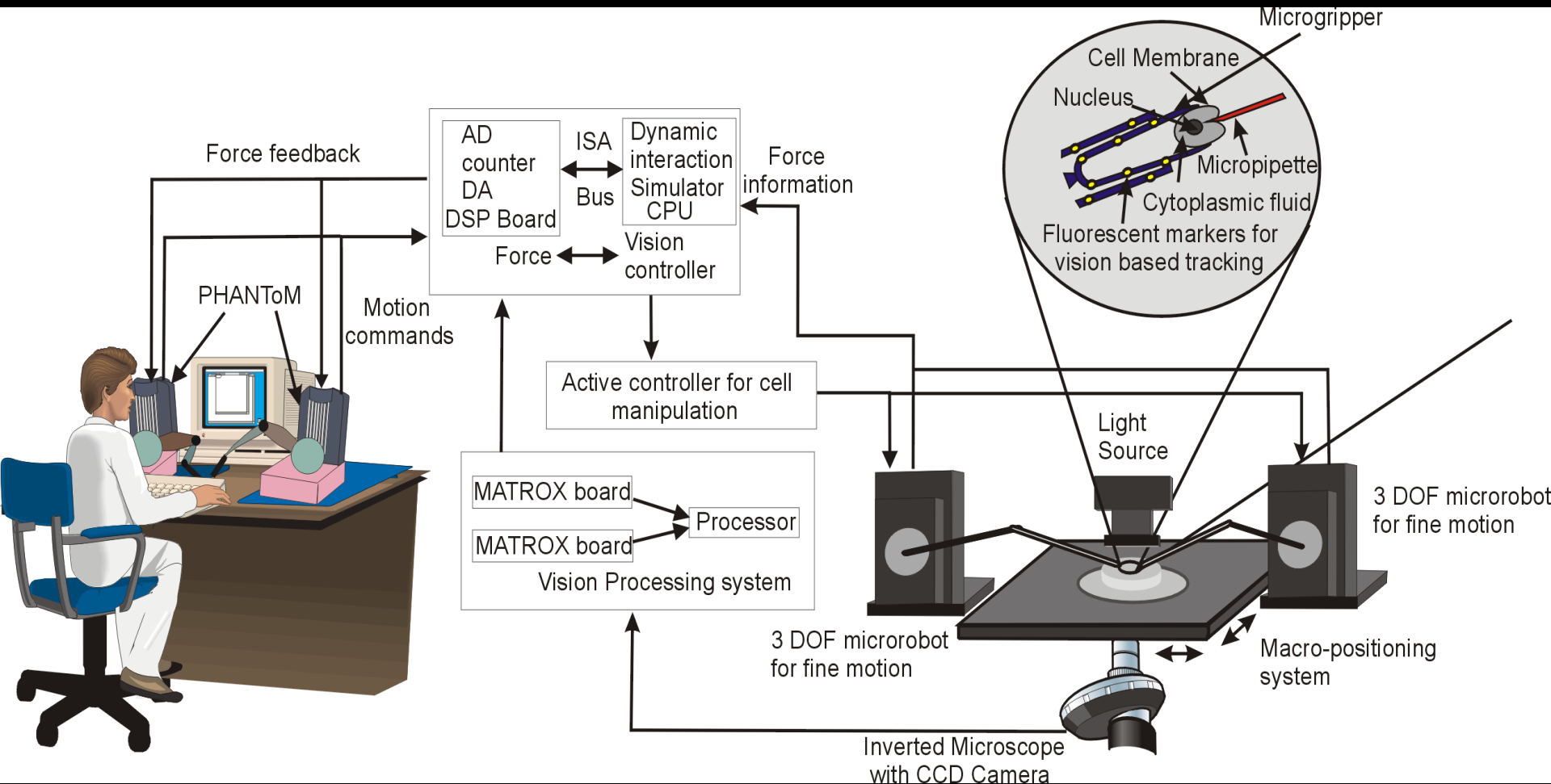


Time of Flight Spectroscopy

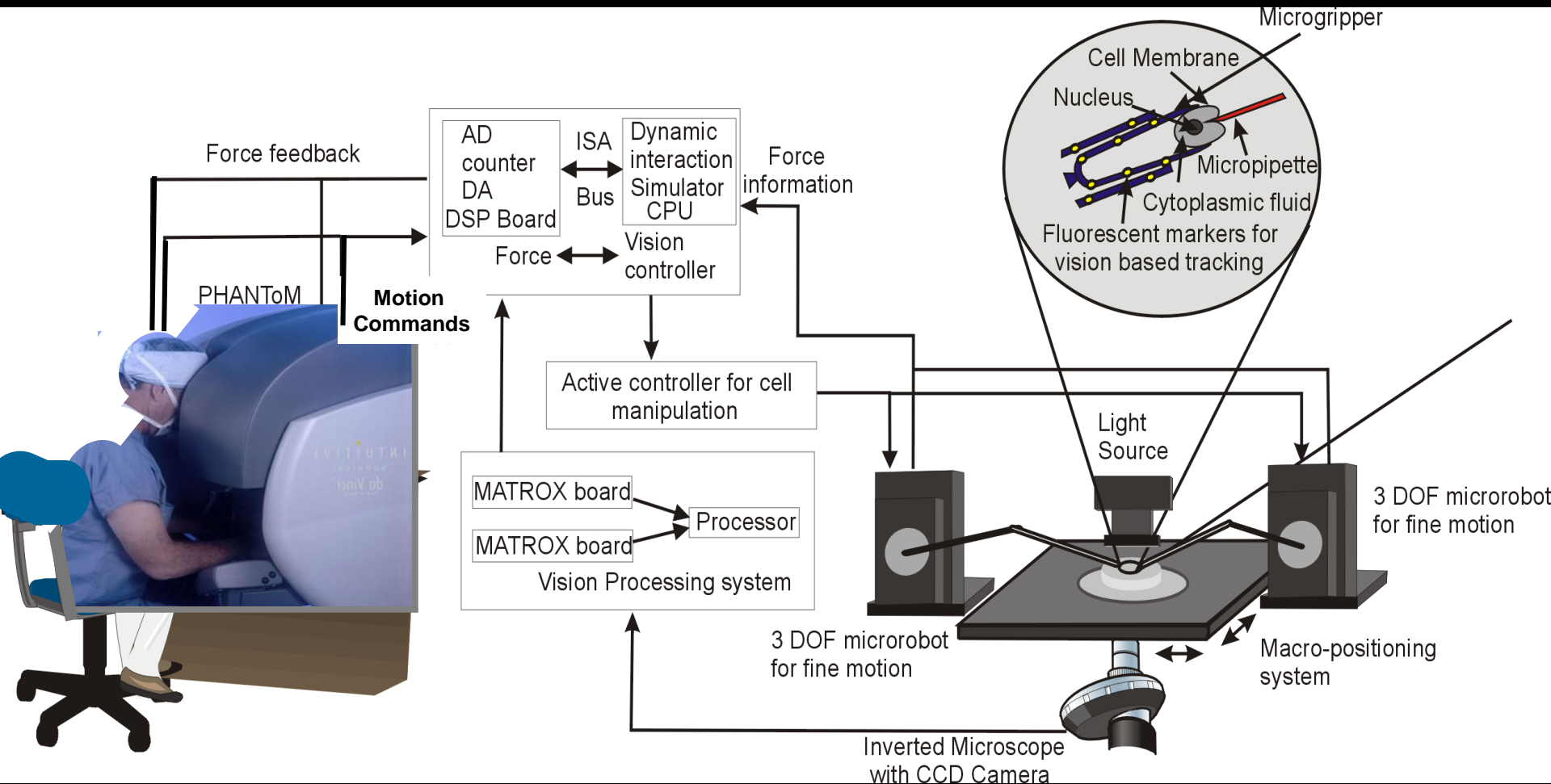


Cellular opto-poration

# Surgical Console for Cellular Surgery



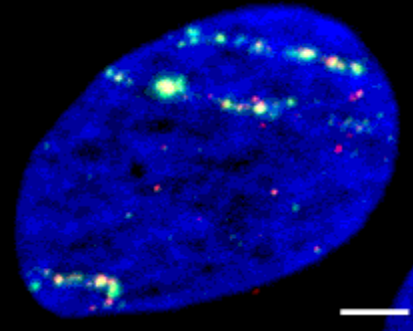
# Surgical Console for Cellular Surgery



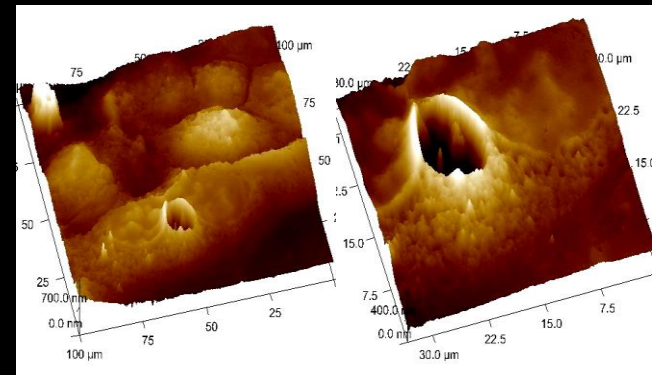
# New Surgical Tools



**Femtosecond Laser**  
Specific DNA targeting



**Atomic Force Microscopy**  
Sonoporation of an ion channel



# Radiology or Surgery?



**Accuray**  
(Cyberknife)

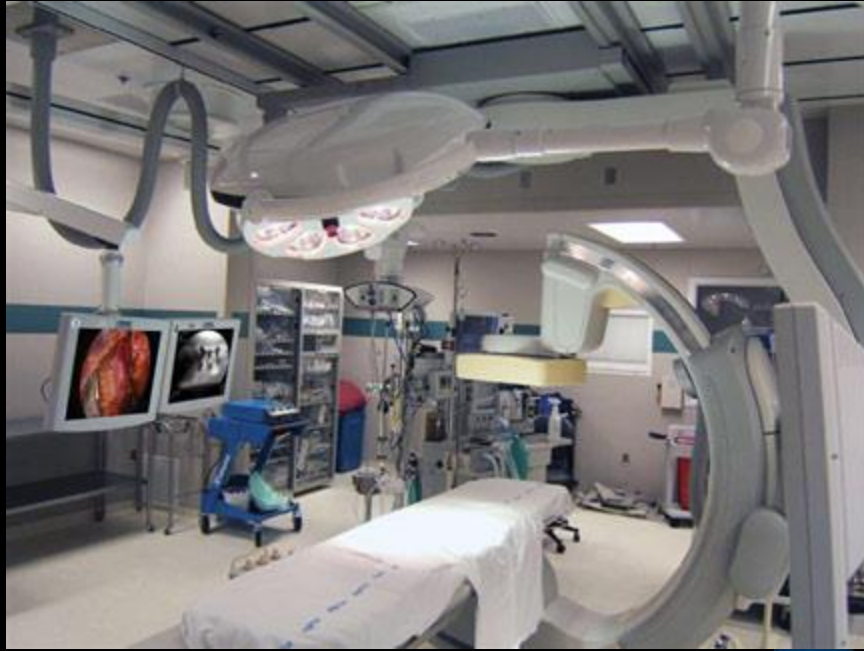
Non-invasive tumor ablation for solid organs (0.3mm accuracy)

Surgeon should be part of planning and implementation team

Surgeons may want to ‘adopt’ implementation

# Hybrid Operating Room

## Image-guided Intervention



# Humanoid Robot for Rescue Operations

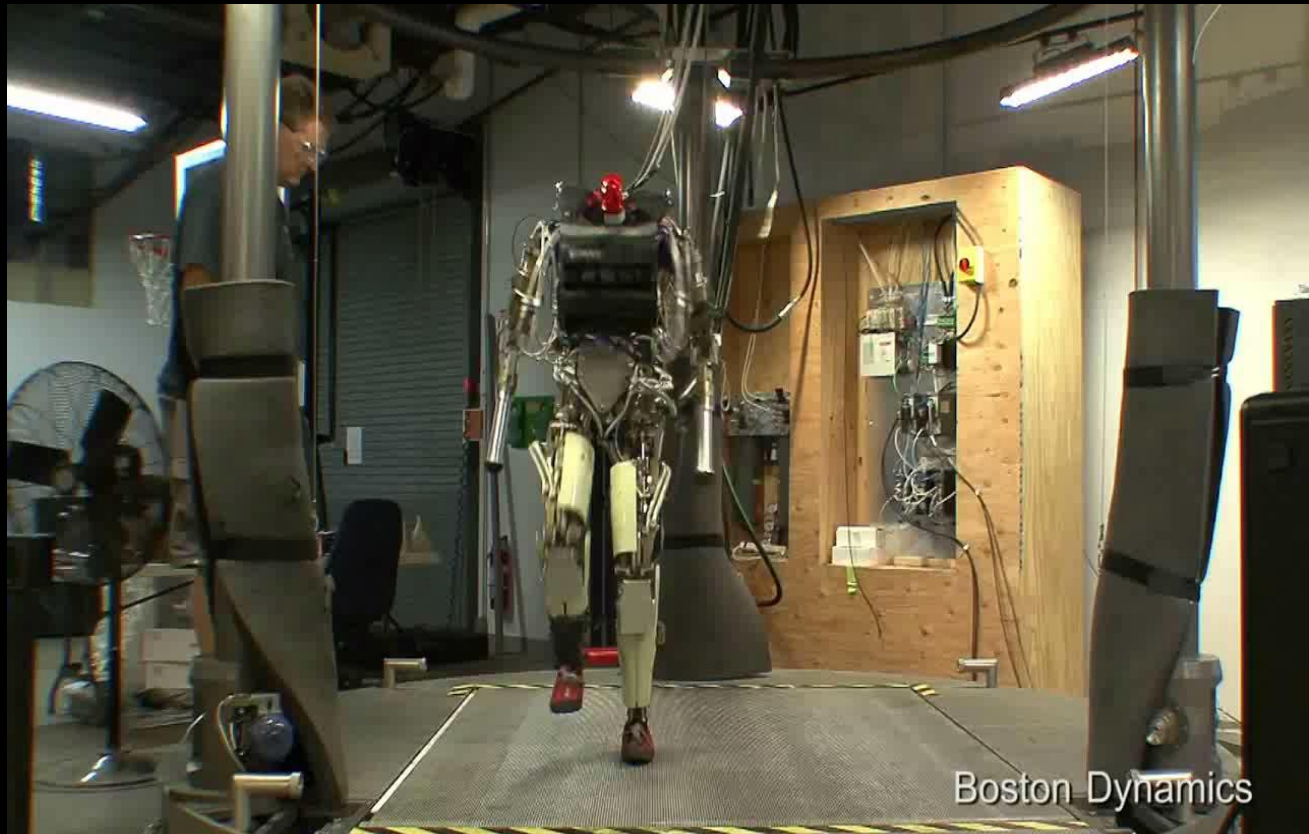
## DARPA Challenge - Rescue-Bot



In the Rescue Bot - DARPA Robotics Challenge, robots will compete in a variety of tasks, including the use of tools to cut through a wall.

This is a concept of THOR, a humanoid robot to be built by a Virginia Tech-led team.

# Humanoid Robot - navigation



Courtesy Marc Raibert, Boston Dynamics, Boston MA 2012

# REAL

The Information Age is NOT the Future

The Information Age is the Present ...

There is something else out there . . . .

# FUTURE

# **C**urrent **T**rend in **I**ntervention

**O**pen surgery



**E**ndoluminal



**M**inimal invasive



**M**ulti-invasive

All are currently in clinical practice

# **Future Direction of Intervention**

**Open surgery**



**Endoluminal**



**Minimal invasive**



**Multi-invasive**



**Non-invasive**

**Traditional surgery**



**Flexible endoscopy**



**Laparoscopic**



**Robotic**



**Directed energy**

Each 'niche' will continue to change in proportion

# Rethinking Intervention

It is the flow of information that controls  
energy which will guide the  
Future of Interventions

. . . EXAMPLES

# The Fundamental Change

(From Industrial Age to the Information Age)

From tissue and instruments

(Tangible and physical structures and objects)

to

Information and energy\*

(Intangible and non-visible functional effects)

- \* “The Information Age is about changing  
from objects and atoms to bits & bytes” . . . Nicholas Negroponte “Being Digital” - 1995  
. . . to photons and electrons ! (2013)

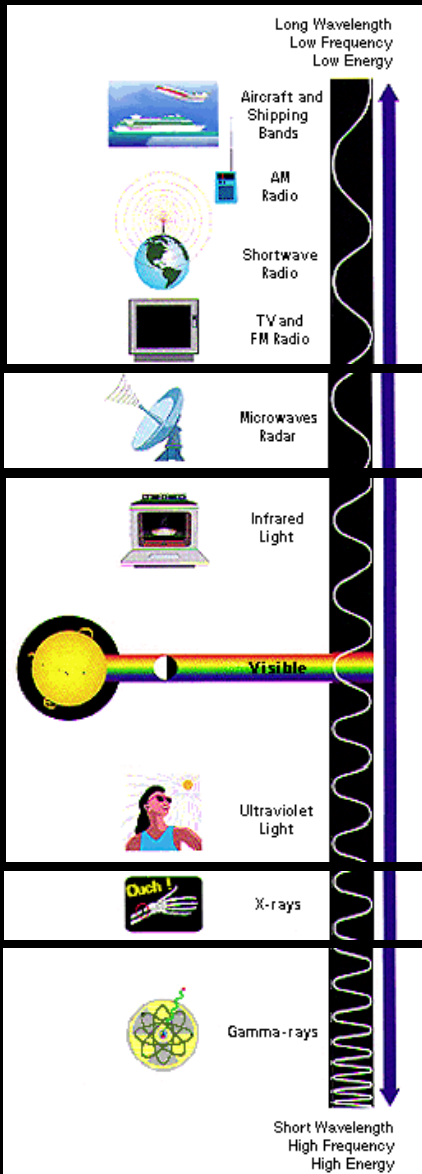
**It's about Exploiting**

**Energy Spectrum**

**and**

**Information Space**

# Electromagnetic Spectrum = ENERGY



**Radio:** Yes, this is the same kind of energy that radio stations emit into the air for your boom box to capture and turn into your favorite Mozart, Madonna, or Justin Timberlake tunes. But radio waves are also emitted by other things ... such as stars and gases in space. You may not be able to dance to what these objects emit, but you can use it to learn what they are made of.

**Microwaves:** They will cook your popcorn in just a few minutes! Used by astronomers to learn about the structure of nearby galaxies, and our own Milky Way!

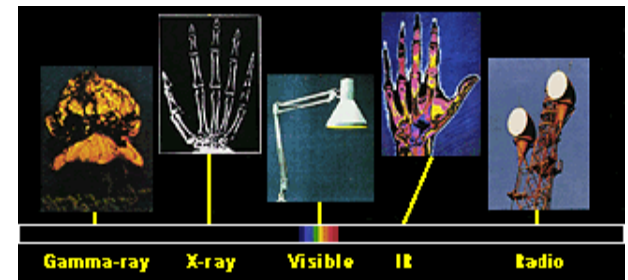
**Infrared** Our skin emits infrared light, which is why we can be seen in the dark by someone using night vision goggles. In space, IR light maps the dust between stars.

**Visible:** Yes, this is the part that our eyes see. Visible radiation is emitted by everything from fireflies to light bulbs to stars ... also by fast-moving particles hitting other particles.

**Ultraviolet:** We know that the Sun is a source of ultraviolet (or UV) radiation, because it is the UV rays that cause our skin to burn! Stars and other "hot" objects in space emit UV radiation.

**X-rays** Your doctor uses them to look at your bones and your dentist to look at your teeth. Hot gases in the Universe also emit X-rays .

**Gamma-rays:** Radioactive materials (some natural and others made by man in things like nuclear power plants) can emit gamma-rays. Big particle accelerators that scientists use to help them understand what matter is made of can sometimes generate gamma-rays. But the biggest gamma-ray generator of all is the Universe! It makes gamma radiation in all kinds of ways.

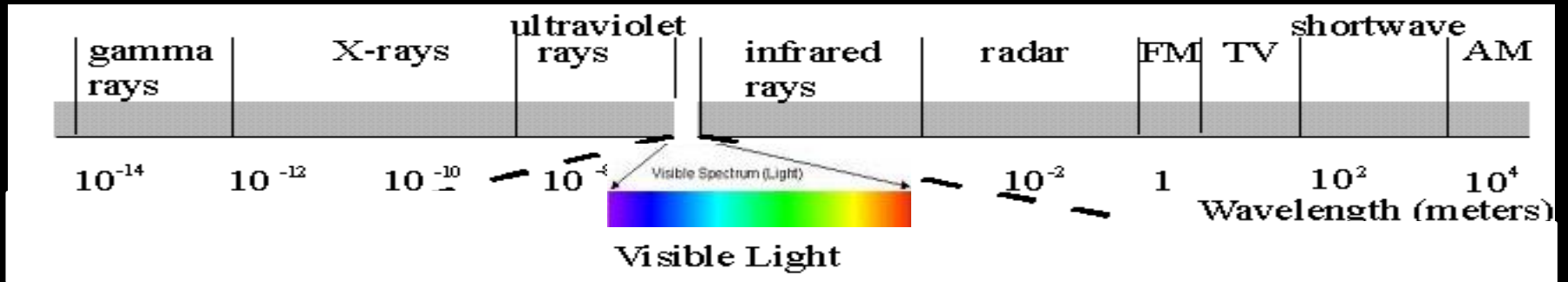


Radio waves, visible light, X-rays, and all the other parts of the electromagnetic spectrum are fundamentally the same thing, electromagnetic radiation.

Here are the different types of radiation in the EM spectrum, in order from the lowest to highest energy:

Retrieved from NASA website 12 September, 2012 <http://imagine.gsfc.nasa.gov/docs/science/known1/empectrum.html>

# Electromagnetic Spectrum = ENERGY



## Medical use of various forms of energy

- Gamma rays
- Xrays
- Ultraviolet
- Visible
- Infrared
- Ultrasound

**H**ealthcare is only using a small % of the energy spectrum

# Directed-energy Weapons

120804-N-ZZ999-001

The Laser Weapon System (LaWS) is a technology demonstrator built by the Naval Sea Systems Command from commercial fiber solid state lasers, utilizing combination methods developed at the Naval Research Laboratory. LaWS can be directed onto targets from the radar track obtained from a MK 15 Phalanx Close-In Weapon system or other targeting source. The Office of Naval Research's Solid State Laser (SSL) portfolio includes LaWS development and upgrades providing a quick reaction capability for the fleet with an affordable SSL weapon prototype. This capability provides Navy ships a method for Sailors to easily defeat small boat threats and aerial targets without using bullets. This video footage shows an exercise conducted by a technical team from the Naval Surface Weapons Center Dahlgren Division and managed & funded by ONR, Naval Sea Systems Command, OSD's High Energy Laser Joint Technology Office and supported by U.S. Fleet Forces Command (U.S. Navy video/Released)



# **I**nformation and **E**nergy

## **C**ornerstone of **S**ystems **I**ntegration

Single instrument which

- performs both diagnosis & therapy
- in real time
- at point-of-care
- hand-held, portable, low power
- could be autonomous (closed-loop feedback)
- home-based consumer product

Power to the people?

**For about 2500 years**

ca 490BC (Protagoras- Greek philosopher)

**“Man is the measure of all things”**

80-15BC (Vitruvius - Greek architect)

in architecture, man is the reference measurement

# **It's about Interacting on a different scale**

**From meters and cm . . . .**

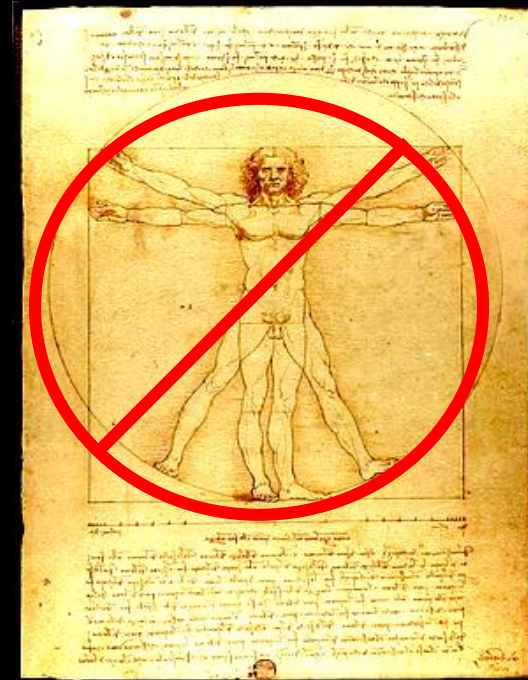
**. . . to microns and nanometers**

**From seconds and milliseconds**

**. . . to micro seconds and femtoseconds ( $10^{-15}$ )**

**From watts and kilowatts**

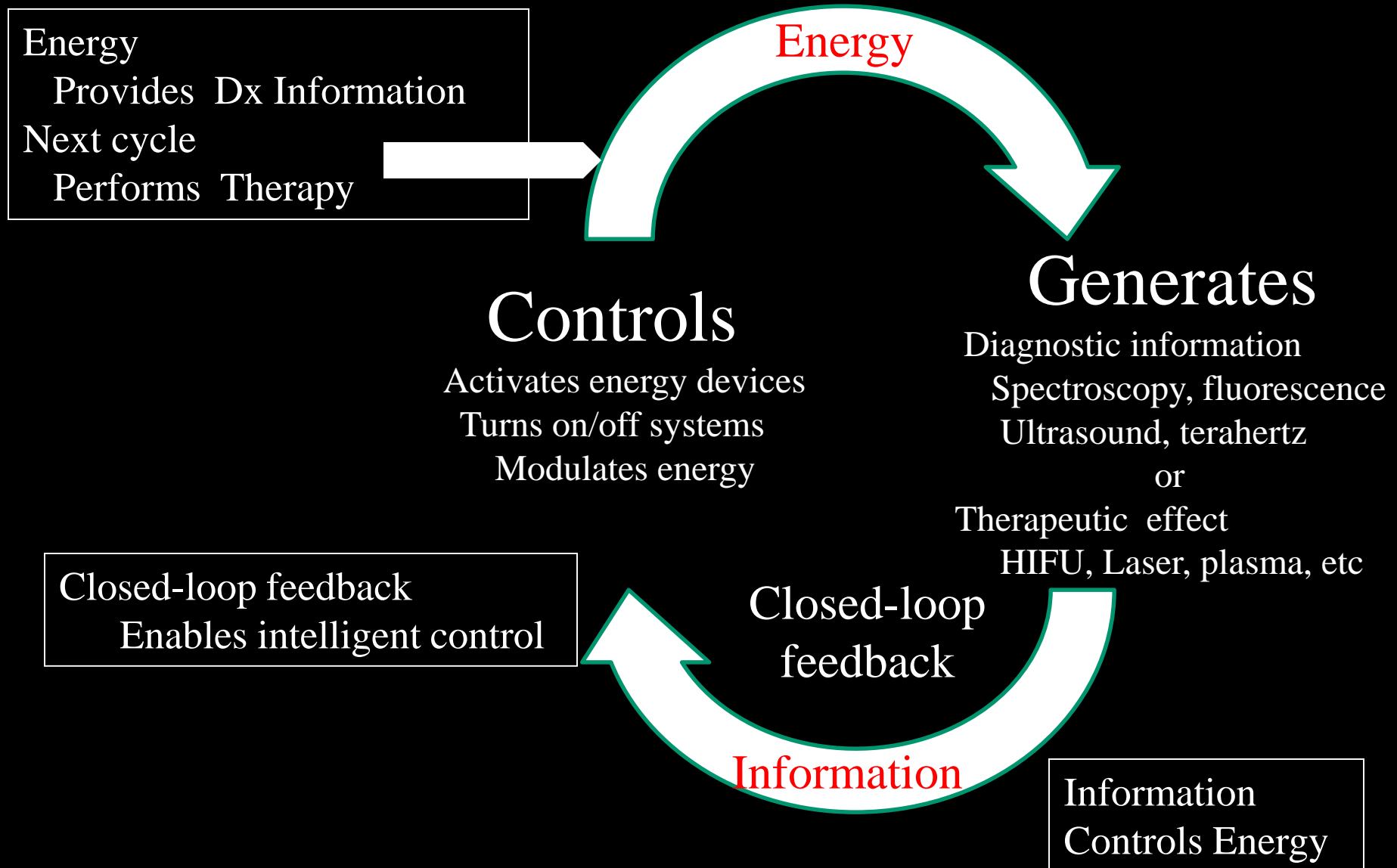
**. . . to milliwatts and microwatts**



Leonardo  
DaVinci  
Vitruvian Man  
ca 1490

**We now can control molecules, electrons & photons**

# It's about Intelligent Systems



**If the closed-loop feedback is**  
**50 msec**

**Theoretically**

**A physician can perform**

**in one second**

**20 complete procedures**

**in one minute**

**1,200 complete procedures**

**in ten minutes**

**12,000 complete procedures**

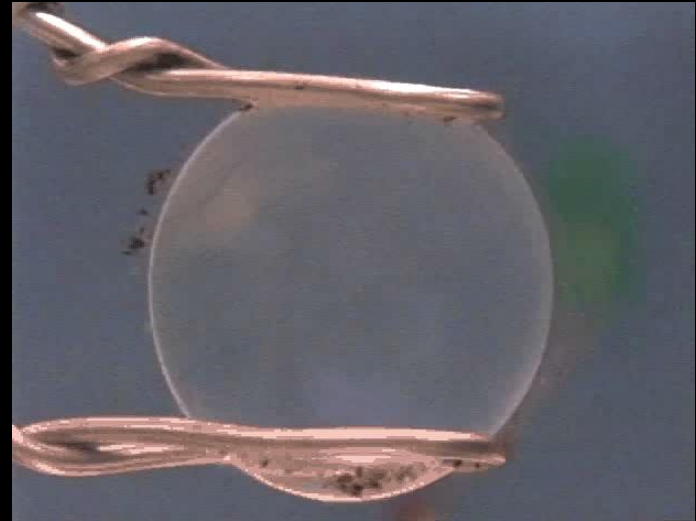
therefore, operates at the cellular level

# Intelligent Instruments for Point-of-care Non-invasive Therapy

Mechanics to energy

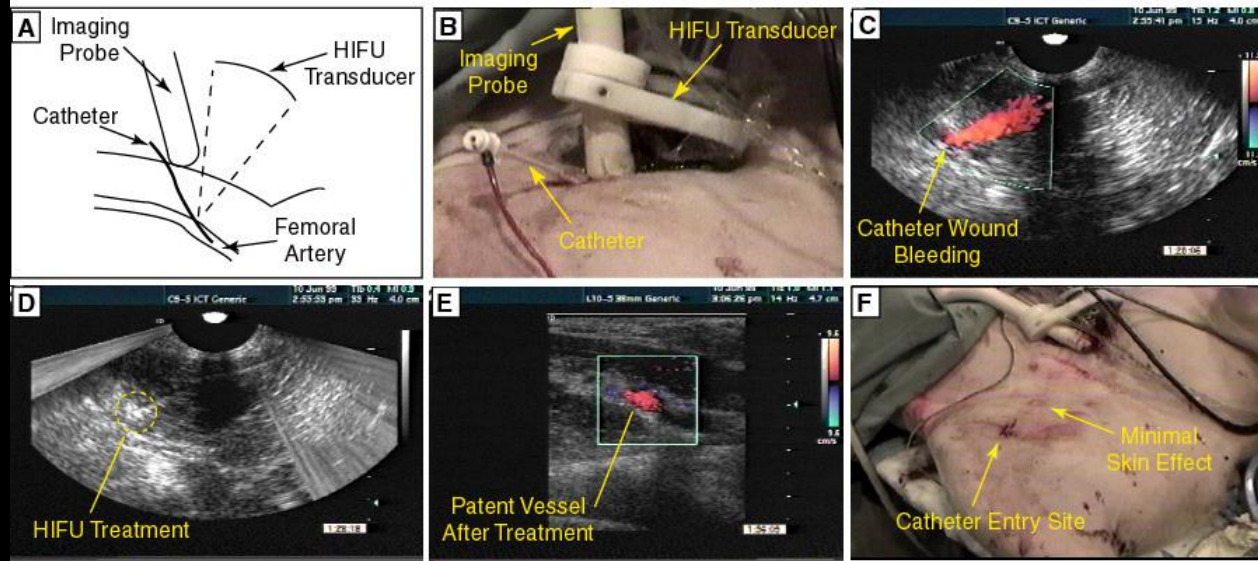


Concentric HIFU around  
central Doppler solves  
registration problem



## HIFU

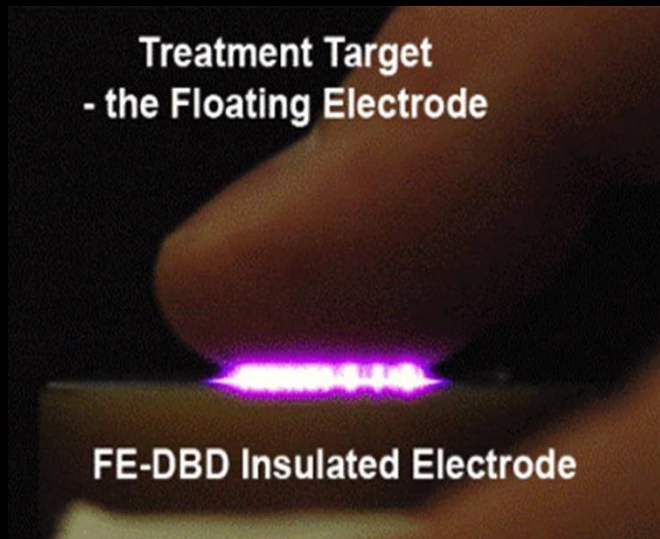
High Intensity Focused Ultrasound  
for  
Non-invasive Acoustic hemostasis



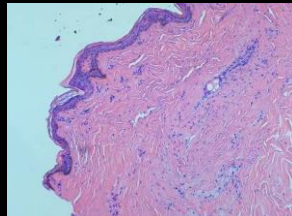
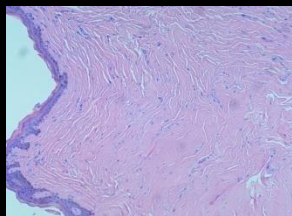
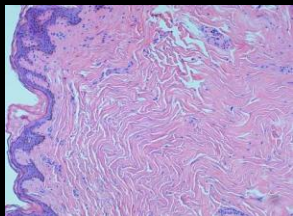
Courtesy Larry Crum,  
Univ Washington  
Applied Physics Lab  
2003

# Plasma Medicine

## Sterilization without supplies



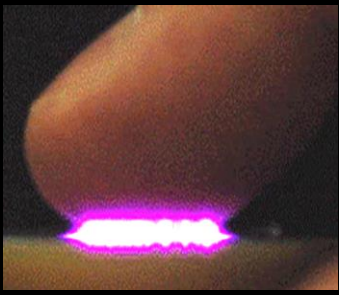
Painless



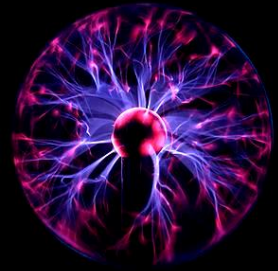
Insure safety of other cells and tissues



100% effective  
30 sec, Continuous DBD, 8kHz  
Power: 0.8 W/cm<sup>2</sup>



# Plasma Medicine

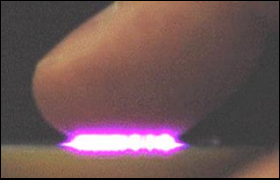


## The Science of Plasma Physics

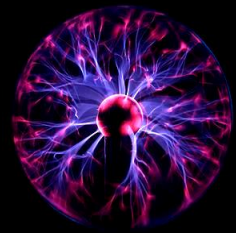
Energy is released into a “cloud” by an “electrical discharge”

### Cloud characteristics

1. charged particles  
free electrons
2. free ions  
reactive nitrogen species (RNS) NO-  
reactive oxygen species (ROS)
3. ultraviolet (UV) and near infrared (NIR)
4. visible light  
esp low level light (LLL)
5. high temperature
6. electromagnetic radiation (EM)
7. pressure pulse wave



# Plasma Medicine



## The Science

### Biological effects of plasma cloud

- |   |  |
|---|--|
| 1. Selectively turn on-off specific molecules<br>Prothrombin, cytokines, angiogenesis, VEGF | 1. charged particles<br>free ions<br>UV, NIR and visible light (bio-photonics)                                     |
| 2. Induce specific epigenetic phenomenon<br>wound healing, activate coagulation             | 2. charged particles and free ions<br>UV, NIR and visible light (bio-photonics)<br>electromagnetic radiation (EM). |
| 3. Sterilization and debridement  | 3. ultra violet (UV)<br>High temperature, ROS/RNS  |
| 4. Surface etching and electroporation  | 4. UV light, high temperature  |
| 5. Cell death (cancer)  | 5. high temperature<br>Charged particles and free ions   |
| 6. Control cell motility, adhesion<br>integrin, cadherin etc                                | 6. electromagnetic radiation (EM)<br>UV, NIR, visible (Low Level Light – LLL)                                      |

# **Plasma Medicine**

## **Clinically Relevant Applications**

Sterilization & decontamination

Cutting, coagulation & ablation

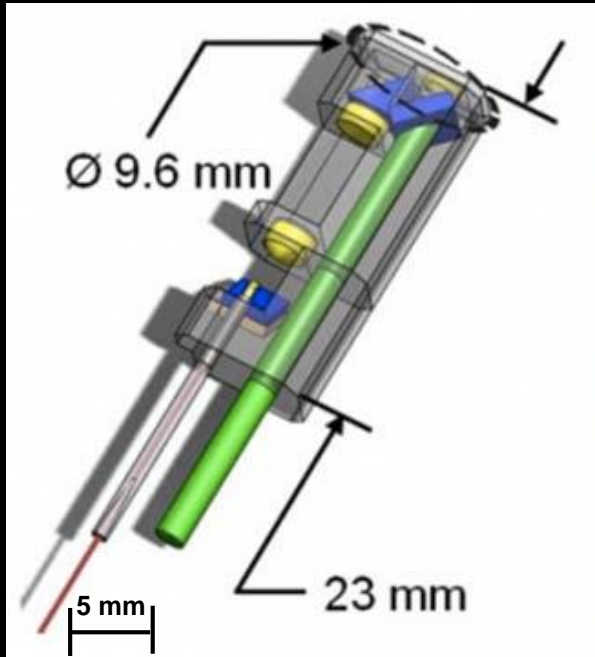
Wound healing & regeneration

Molecular activation & inhibition control

Cancer & disease control/cure

Implant surface specificity to enhance/inhibit

# Intelligent Laser Scalpel



## Mechanism of Action

Cutting/coagulation laser

Dissects tissues (ER:Yag laser)

Diagnostic laser

Detects blood vessels (660/910 nm)

Closed loop feedback

Turns off laser when blood vessel detected

↑ Cutting/coagulating laser for dissection

↑ Hyperspectral analysis laser for diagnosis



# Non-invasive Surgery



## *Light Penetrates Skull*

### Cancer-fighting laser born at Tennessee University space institute

Ashley N. Rice,

October, 2012

TULLAHOMA, Tenn. – A new technique harnesses the power of femtosecond lasers to seek, acutely map and noninvasively destroy cancerous tumors, and it could especially benefit brain cancer patients.

Developed by scientists at the Center for Laser Applications at the University of Tennessee Space Institute, the laser focuses on a specific region to find and destroy tumors.

“Using ultrashort light pulses gives us the ability to focus in a well-confined region and the ability for intense radiation,” said Christian Parigger, an associate professor of physics. “This allows us to come in and leave a specific area quickly so we can diagnose and attack tumorous cells fast.”

The new technology can be especially useful for treating brain cancer patients because it can noninvasively permeate thin layers of bone, such as the skull, and help define a targeted treatment strategy for persistent cancer.

It overcomes the restrictions posed by radiation treatments that damage portions of healthy brain tissue, and also could overcome the limitations of photodynamic therapy that have limited its acceptance and replace surgical options that are unable to remove all carcinogenic tissue.

“If you have a cancerous area such as in the brain, the notion is if you see something and take care of it, it won’t spread,” Parigger said. “This treatment overcomes difficulties in treating brain cancer and tumors. And it has the promise of application to other areas as well.”

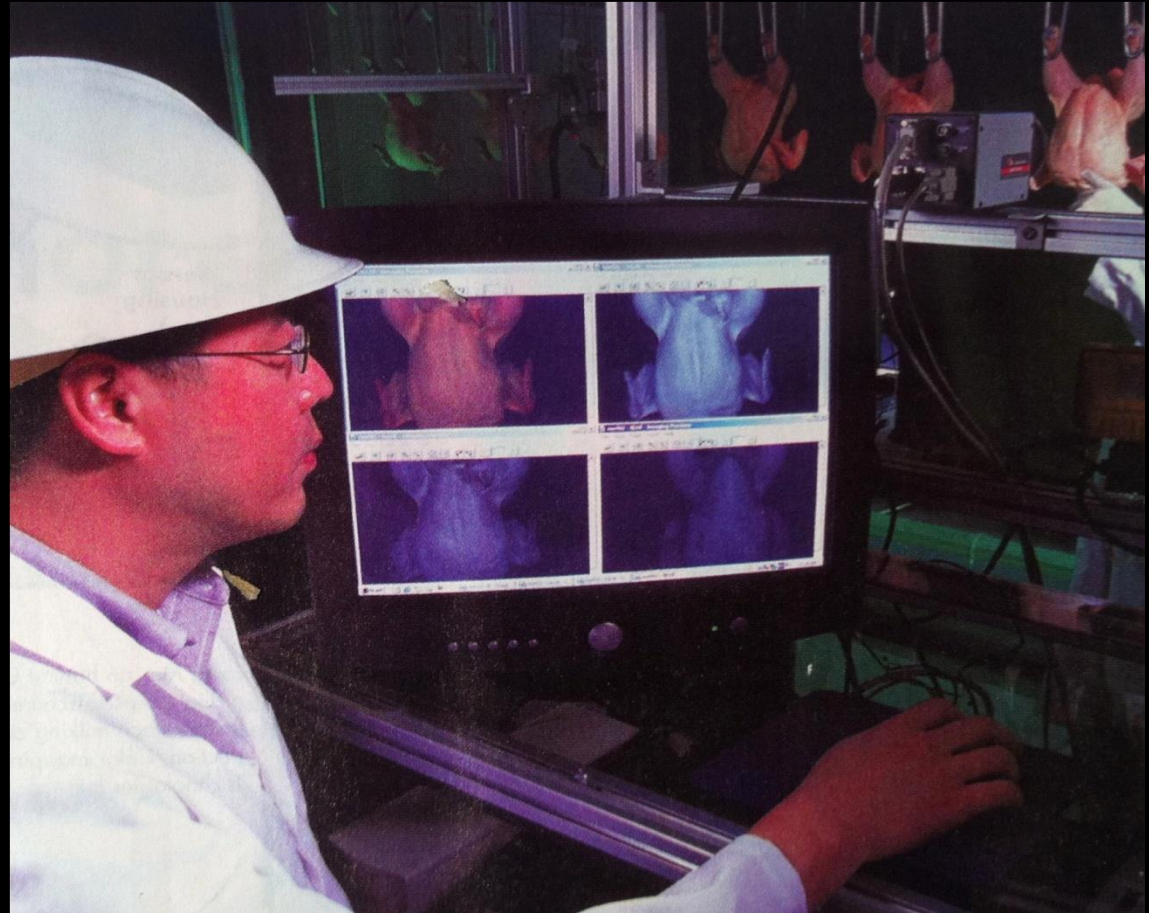
The team is working with the University of Tennessee Research Foundation to bring the technology to market

# Hyperspectral Analysis and Automatic Food Inspection

- Laser scans chicken
- Hyperspectral analysis detects bacteria, etc
- Scans 2.5 whole chickens/sec

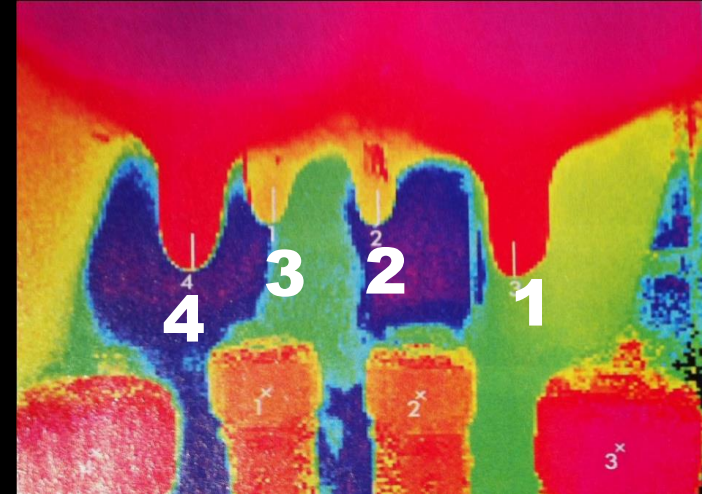


PETA Supervisor

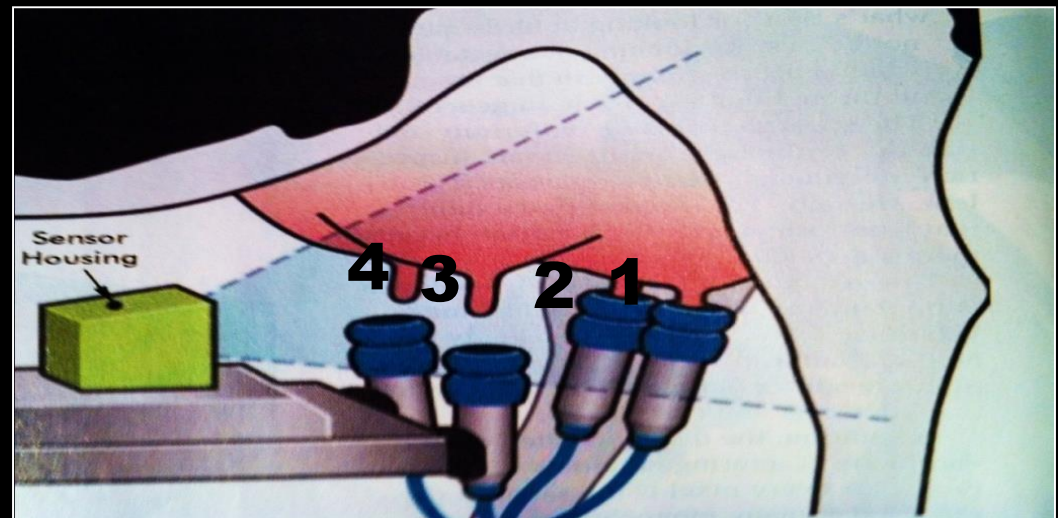


**A**uto-analysis for infectious bioagents

# Hyperspectral Analysis and Motion Control Automatic Milking Machine

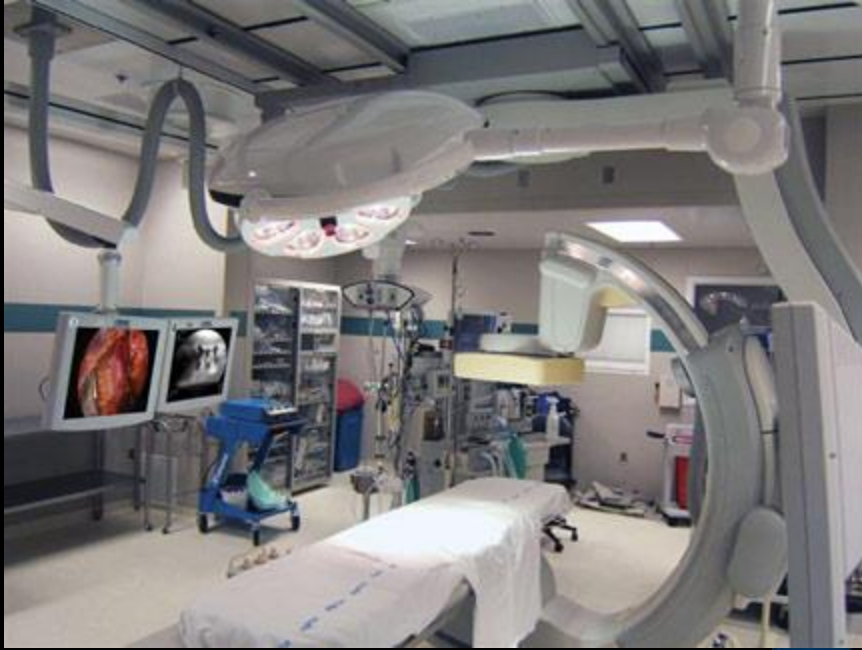


- Hyper spectral identifies udder and teats
- Near-infrared for geometry
- ToF for distance, position
- Closed loop control for cup guidance
- Robotic arms for placement



# Hybrid Operating Room

## Image-guided Surgery



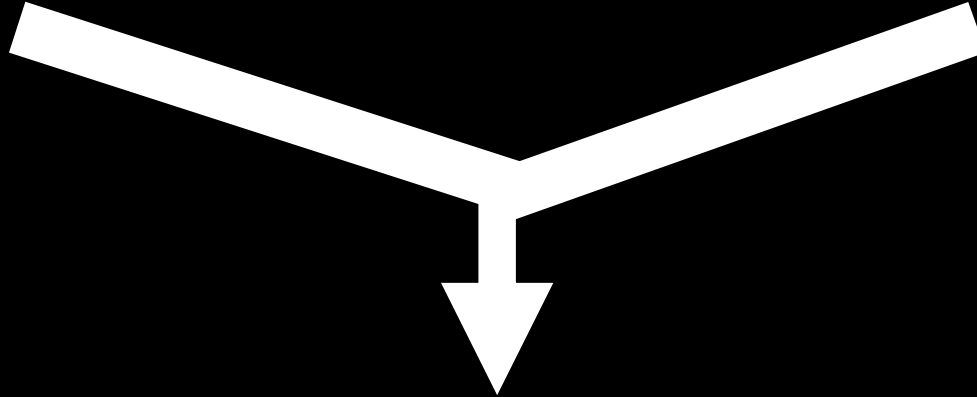


Surgical Cockpit



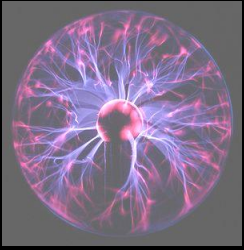
**I**mage Guidance

**E**nergy



**N**on-invasive

**D**irected-**E**nergy **S**urgery



**I s T h e F u t u r e**

**D i r e c t e d - E n e r g y I n t e r v e n t i o n ?**



**Where is the Future?**



A close-up photograph of an ostrich's head, focusing on its large, grey, textured beak and its large, orange-brown eyes with dark pupils. The ostrich has dark, spiky feathers around its face and neck. A white speech bubble with a black outline is positioned in the upper right corner, containing the text "What is radically new?". The background is a blurred natural setting with green grass and a body of water.

**What is radically new?**

# Disruptive Visions

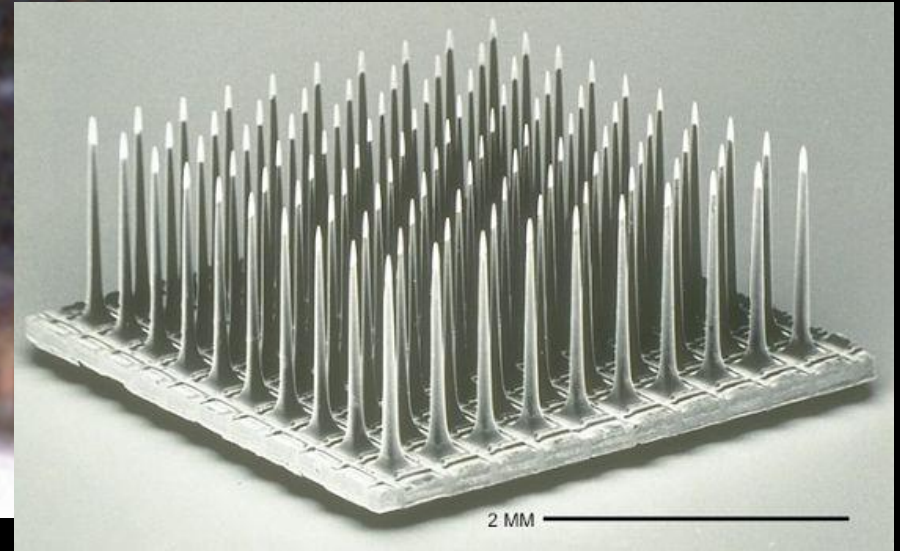
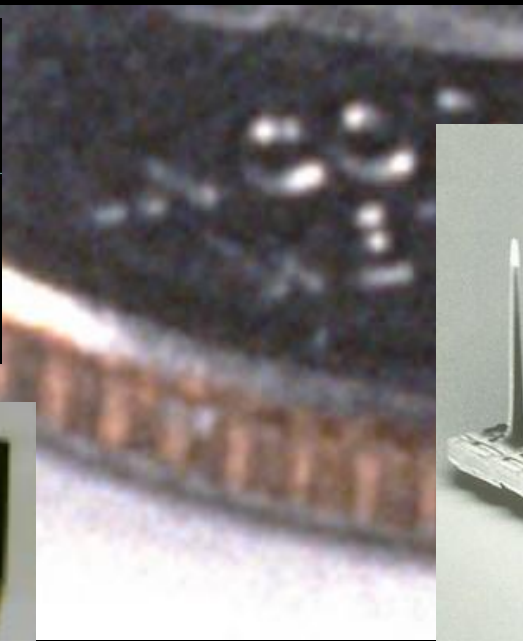
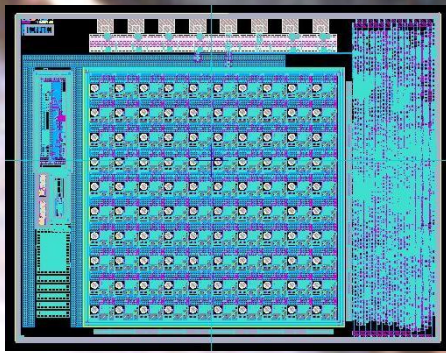
*“The Future is not what it used to be !”*

- Yogi Berra



**F**uture

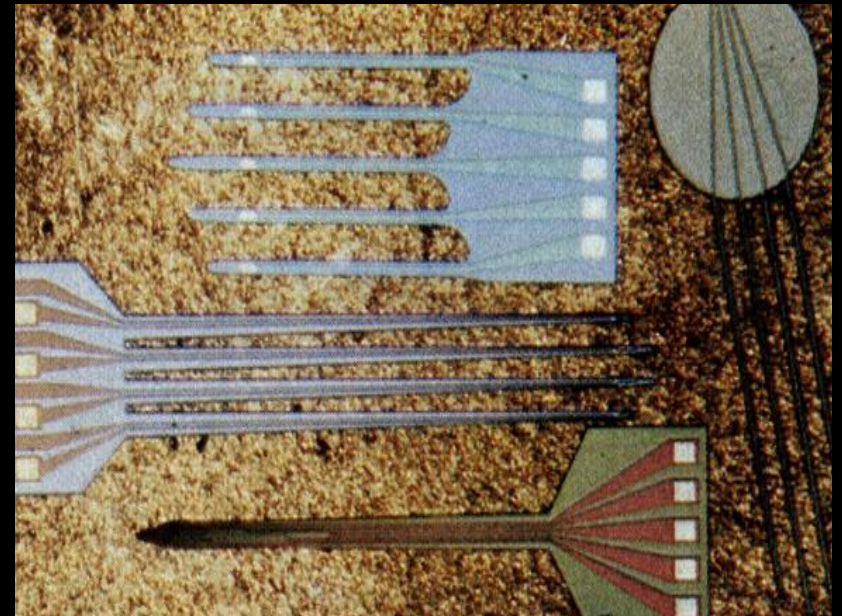
**T**echnologies



“BrainGate” John Donohue, Brown University, 2001



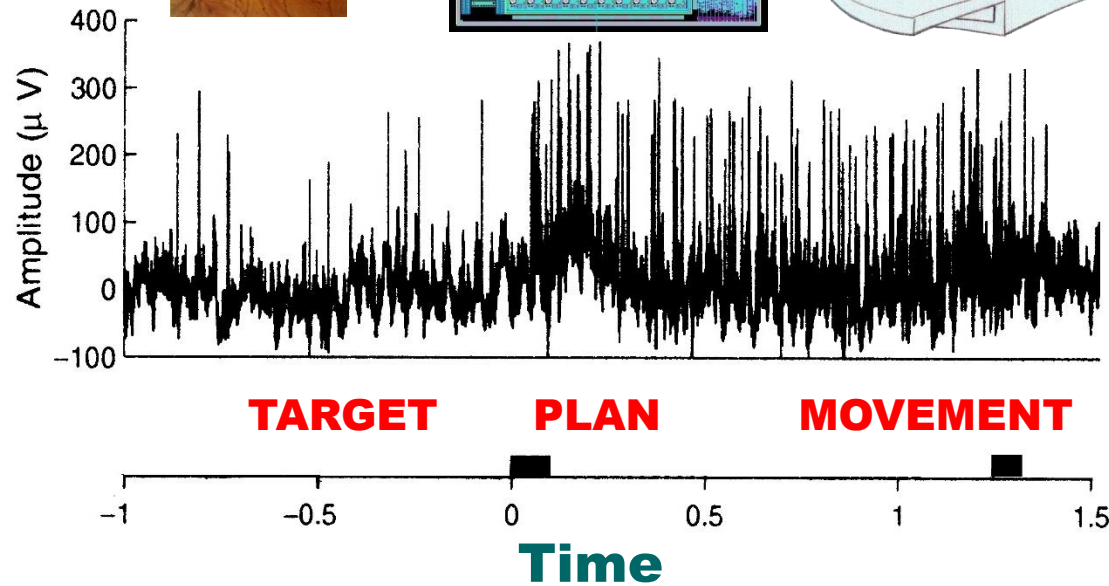
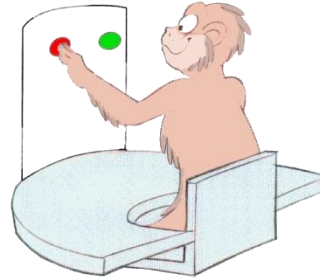
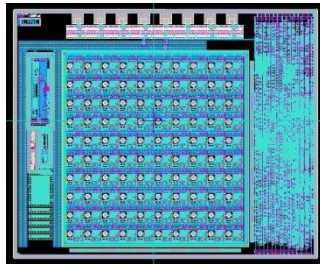
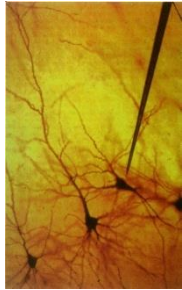
Richard Andersen, CalTech, 2003



Greg Kovacs. Stanford University, 1990

# Brain Machine Interface – Controlling motion with thoughts

Recorded activity for intended movement to a briefly flashed target.



Courtesy Richard Andersen, Cal Tech, Pasadena, CA



Direct brain implant control of robot arm

# Brain Machine Interface – Controlling motion with thoughts



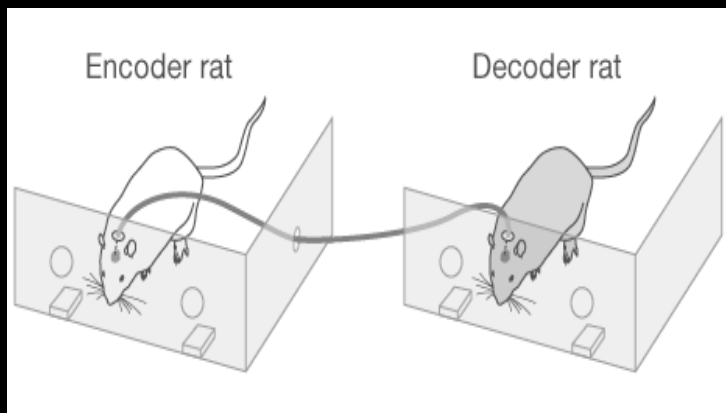
# Brain Machine Interface – Controlling motion with thoughts



Courtesy University of Hawaii 2008



Emotiv Technologies, 2009



# A Brain-to-Brain Interface for Real-Time Sharing of Sensorimotor Information

Miguel Pais-Vieira<sup>1</sup>, Mikhail Lebedev<sup>1,4</sup>, Carolina Kunicki<sup>5</sup>, Jing Wang<sup>1\*</sup> & Miguel A. L. Nicolelis<sup>1,2,3,4,5</sup>

<sup>1</sup>Department of Neurobiology, Duke University, Durham, NC 27710, USA, <sup>2</sup>Department of Biomedical Engineering, Duke University, Durham, NC 27710, USA, <sup>3</sup>Department of Psychology and Neuroscience, Duke University, Durham, NC 27710, USA, <sup>4</sup>Duke Center for Neuroengineering, Duke University, Durham, NC 27710, USA, <sup>5</sup>Edmond and Lily Safra International Institute for Neuroscience of Natal (ELSIIIN), RN 59066-060, Natal, Brazil.

A brain-to-brain interface (BTBI) enabled a real-time transfer of behaviorally meaningful sensorimotor information between the brains of two rats. In this BTBI, an “encoder” rat performed sensorimotor tasks that required it to select from two choices of tactile or visual stimuli. While the encoder rat performed the task, samples of its cortical activity were transmitted to matching cortical areas of a “decoder” rat using intracortical microstimulation (ICMS). The decoder rat learned to make similar behavioral selections, guided solely by the information provided by the encoder rat’s brain. These results demonstrated that a complex system was formed by coupling the animals’ brains, suggesting that BTBIs can enable dyads or networks of animal’s brains to exchange, process, and store information and, hence, serve as the basis for studies of novel types of social interaction and for biological computing devices.

In his seminal study on information transfer between biological organisms, Ralph Hartley wrote that “*in any given communication the sender mentally selects a particular symbol and by some bodily motion, as his vocal mechanism, causes the receiver to be directed to that particular symbol*”<sup>1</sup>. Brain-machine interfaces (BMIs) have emerged as a new paradigm that allows brain-derived information to control artificial actuators<sup>2</sup> and communicate the subject’s motor intention to the outside world without the interference of the subject’s body. For the past decade and a half, numerous studies have shown how brain-derived motor signals can be utilized to control the movements of a variety of mechanical, electronic and even virtual external devices<sup>3–6</sup>. Recently, intracortical microstimulation (ICMS) has been added to the classical BMI paradigm to allow artificial sensory feedback signals<sup>7,8</sup>, generated by these brain-controlled actuators, to be delivered back to the subject’s brain simultaneously with the extraction of cortical motor commands<sup>9,10</sup>.

In the present study, we took the BMI approach to a new direction altogether and tested whether it could be employed to establish a new artificial communication channel between animals; one capable of transmitting behaviorally relevant sensorimotor information in real-time between two brains that, for all purposes, would from now on act together towards the fulfillment of a particular behavioral task. Previously, we have reported that specific motor<sup>11,12</sup> and sensory parameters<sup>13,14</sup> can be extracted from populations of cortical neurons using linear or nonlinear decoders in real-time. Here, we tested the hypothesis that a similar decoding performed by a “recipient brain” was sufficient to guide behavioral responses in sensorimotor tasks, therefore constituting a Brain-to-Brain Interface (BTBI)<sup>15</sup> (Figure 1). To test this hypothesis, we conducted three experiments in which different patterns of cortical sensorimotor signals, coding a particular behavioral response, were recorded in one rat (heretofore named the “encoder” rat) and then transmitted directly to the brain of another animal (i.e. the “decoder” rat), via intra-cortical microstimulation (ICMS). All BTBI experiments described below were conducted in awake, behaving rats chronically implanted with cortical microelectrode arrays capable of both neuronal ensemble recordings and intracortical microstimulation<sup>16</sup>. We demonstrated that pairs of rats could cooperate through a BTBI to achieve a common behavioral goal.

## Results

In our training paradigm, animals learned basic elements of the tasks prior to participating in any BTBI experiments. First, prospective encoder rats were trained to respond to either tactile or visual stimuli until they reached 95% correct trials accuracy. Meanwhile, decoder rats were trained to become proficient while receiving ICMS as a stimulus. A train of ICMS pulses instructed the animal to select one of the levers/nose pokes, whereas a single ICMS pulse instructed a response to the other option. Decoder rats reached a  $78.77\% \pm 2.1$  correct trials

# Replacing Human Body Parts

## Intelligent Prostheses



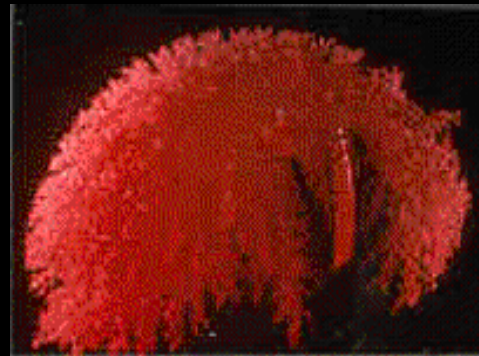
a) Rheo Bionic knee  
Ossur,  
Reykjavik, Iceland

b) C-leg  
Otto Bock,  
Minneapolis, MN

## Tissue Engineering



Artificial Ear



Liver Scaffolding



Artificial Blood Vessel

# Organs which have been grown synthetically

*Dozens of biotech companies and university labs are developing ways to replace or regenerate failed body parts. Here are a few of the projects:*



## BONE

Bone-growth factors or stem cells are inserted into a porous material cut to a specific shape, creating new jaws or limbs. A product that creates shinbones is in clinical trials.

**COMPANIES:** Creative Biomolecules, Orquest, Sulzer Orthopedics Biologics, Genetics Institute, Osiris Therapeutics, Regeneron.



## SKIN

Organogenesis' Apligraf, a human-skin equivalent, is the first engineered body part to win FDA approval, initially for leg

ulcers. Other skins are in the works for foot ulcers and burns.

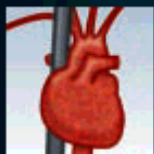
**COMPANIES:** Organogenesis, Ad-vanced Tissue Sciences, Integra LifeSciences, LifeCell, Ortec International.



## PANCREAS

Insulin-manufacturing cells are harvested from pigs, encapsulated in membranes, and injected into the abdomen. The method has been tested in animals and could be in human trials in two years.

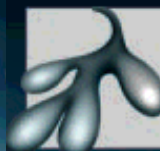
**COMPANIES:** BioHybrid Technologies, Neocrin, Circe Biomedical



## HEART VALVES, ARTERIES, AND VEINS

A 10-year initiative to build a heart has just started. Genetically engineered proteins have been successfully used to regrow blood vessels.

**COMPANIES:** Organogenesis, Advanced Tissue Sciences, Genetech, LifeCell, Reprogenesis.



## SALIVA GLANDS

Proteins called aquaporins that allow cells to secrete water are used to recreate saliva glands damaged by disease successful in mice.

**COMPANIES:** None yet.



## URINARY TRACT

Cartilage cells are taken from the patient, packed into a tiny matrix, and injected into the weakened ureter, where they bulk up the tissue walls to prevent urinary backup and incontinence. The method is in late-phase clinical trials.

**COMPANIES:** Reprogenesis, Integra LifeSciences.

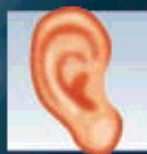


## BLADDER

Doctors at Children's Hospital in Boston have grown bladders from skin cells and implanted them in sheep.

They are about to try the same process on a patient

**COMPANIES:** Reprogenesis.



## CARTILAGE

A product is already on the market that regrows knee cartilage. A chest has been grown for a boy and a human

ear on a mouse.

**COMPANIES:** Genzyme Tissue, Biomatrix, Integra LifeSciences, Advanced Tissue Sciences, ReGen Biologics, Osiris Therapeutics



## TEETH

Enamel matrix proteins are used to fill cavities. It works in dogs; human trials are a few years away.



## BREAST

In preclinical studies, several companies have been able to create a cosmetic nipple by inserting a ball of cartilage. Researchers are now trying to grow a whole cosmetic breast.

**COMPANIES:** Reprogenesis, Integra LifeSciences.



## LIVER

A spongy membrane is built up and then seeded with liver cells. Organs the size of a dime

have been grown, but a full-size liver could take 10 years due to its complexity.

**COMPANIES:** Advanced Tissue Sciences, Human Organ Sciences, Organogenesis.



## SPINAL CORD NERVES

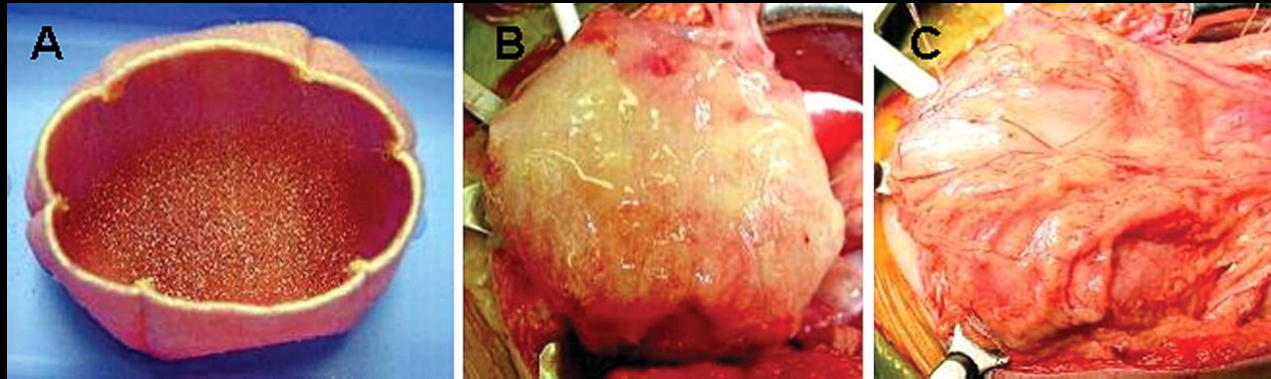
Scientists are investigating nerve-growth factors, injecting them at the site of damage to encourage regeneration or seeding them along biodegradable filaments and implanting them. Rats have been made to walk again.

**COMPANIES:** Acorda, Regeneron, CytoTherapeutics, Guilford Pharmaceuticals.

# Tissue-engineered Urinary Bladder



Anthony Atala, MD

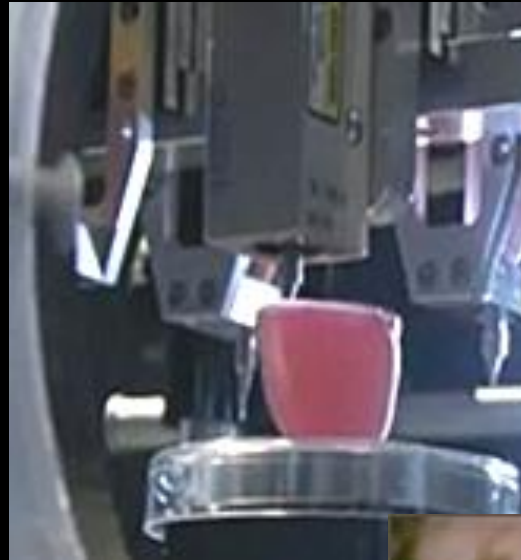
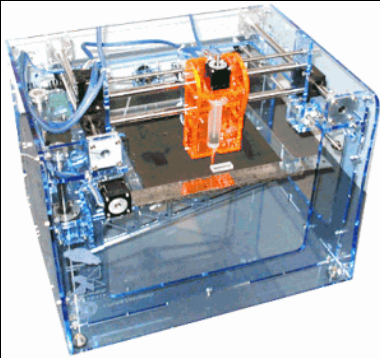


Pediatric patients	n = 12	10 year follow up
End of year 1	all 12 survived, no rejection (no meds)	
	11/12 spontaneous return bladder control	
End of year 2	All had complete bladder control	
End of year 10	All remained normal & healthy - no rejections	

Atala A, Bauer SB, Soker S, Yoo JJ, Retik AB. Tissue-engineered autologous bladders for patients needing cystoplasty. Lancet. 2006 Apr 15;367(9518):1241-6.

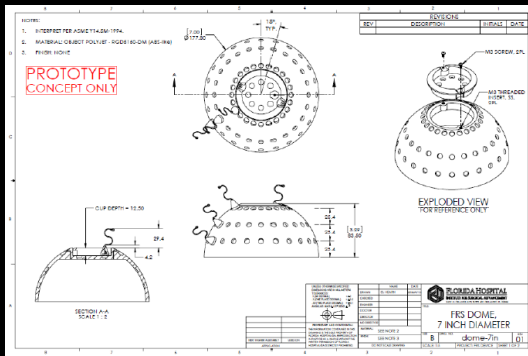
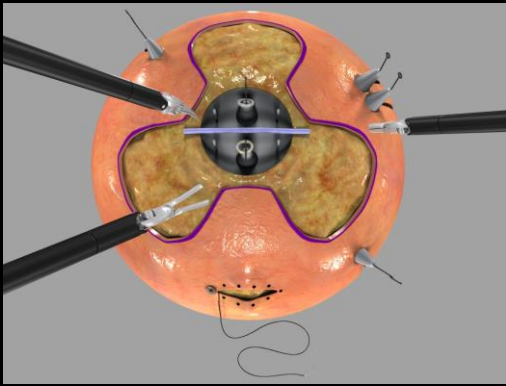
Atala A. Br Med Bull 2011;97:81-104

# 3-D Printing (Stereolithography) The Future of Surgery



# 3-D Printing (Stereo-lithography)

## Parts for the FRS psychomotor skills



CAD/CAM model



Makerbot Replicator



Physical Dome



Parts for Dome

# Genetically Re-engineering Food & Drugs



JAGRAN  
**Post**  
world's largest read daily now in english

Posted on: 27 Jun 2011, 08:43 PM

## Test tube-burger coming soon

**London:** Coming soon, the world's first test-tube hamburger, say scientists. A team at Maastricht University in the Netherlands claims that the first such laboratory-made burger could be a year away. It will have meat grown from stem cells, paving the way for eating meat without animals being slaughtered.

The Scientists are currently developing the burger which will be grown from 10,000 stem cells extracted from cattle, which are then multiply more than a billion times to produce muscle tissue similar to beef. The product is called "in vitro" meat.

Prof Mark Post, who is leading the team, was quoted as saying, "I don't see any way you could rely on old-fashioned livestock in the coming decades. In vitro meat will be the only choice left."

A colleague of Prof Post said, "When we are eating a hamburger we don't think, 'I'm eating a dead cow'. And when people are already far from what they eat, it's not too hard to see them

Prof. Mark Post, Maastricht University Netherlands, 2011



## Tobacco Plants Make HIV Antibody

For the first time, a plant-produced antibody gets the green light for clinical trials in the United Kingdom.

By Cristina Luiggi | July 21, 2011

Last month, a monoclonal antibody produced in the leaves of tobacco plants entered phase I clinical trials in the United Kingdom. The antibody, known as P2G12, recognizes an HIV surface protein and is expected to help stop the transmission of the virus, although it has never been tested in humans.

This is the first plant-produced antibody to be cleared for clinical trials by the Medicines and Healthcare Products Agency. Producing the antibody using tobacco plants grown in a greenhouse in Germany is 10 to 100 times cheaper than using conventional methods employing bacteria or mammalian cells, *Smart Planet* reports.

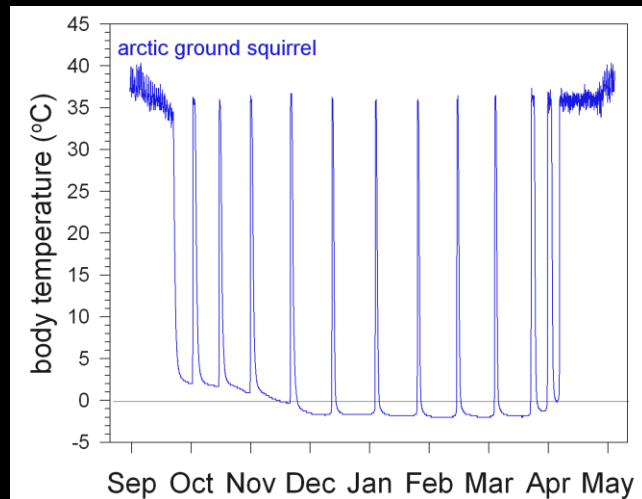
"Monoclonal antibodies can be made in plants to the same quality as those made using existing conventional production systems," Professor Julian Ma from St George's University, London and joint coordinator of the project, told

"That is something many people did not believe could be achieved."

Floss DM, Sack M, Stadlmann J, Rademacher T, Scheller J, Stöger E, Fischer R, Conrad U.. Biochemical and functional characterization of anti-HIV antibody-ELP fusion proteins from transgenic plants.. **Plant Biotechnol J.** 2008 May;6(4):379-91.

# Suspended Animation (Auto-anesthesia – FRAMR)

Institute of Arctic Biology's  
Toolik Field Station,  
Alaska's North Slope



	active	hibernating
heart rate (beats/min)	300	3
resp. rate (breaths/min)	150	<1
body temp.	37°C	-2°C
gene function	ongoing	transcription and translation suppressed
metabolic rate (mlO <sub>2</sub> /g/h)	0.5	0.01 (2%)



Confidential

# Hypothesis **The Scientific Method**

... make evidence-based decisions

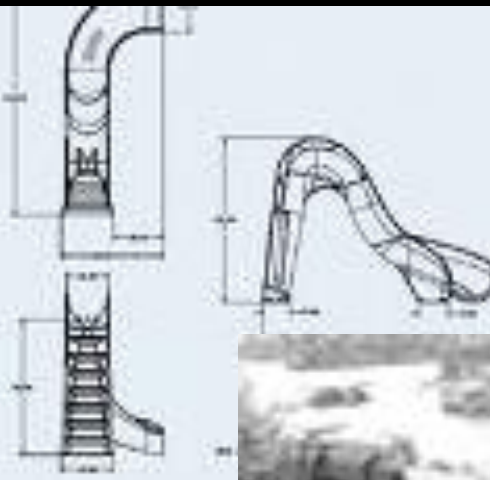
Design

Experiment

Results

Report

In Science and Discovery,  
there is always Risk . . .



# Be careful of unintended consequences

Experience is the name everyone  
gives to their mistakes - Oscar Wilde

The only thing more dangerous  
than trying too hard and failing ...  
... is not trying hard enough  
and succeeding ! Michelangelo 1503



# **The Moral Dilemma**

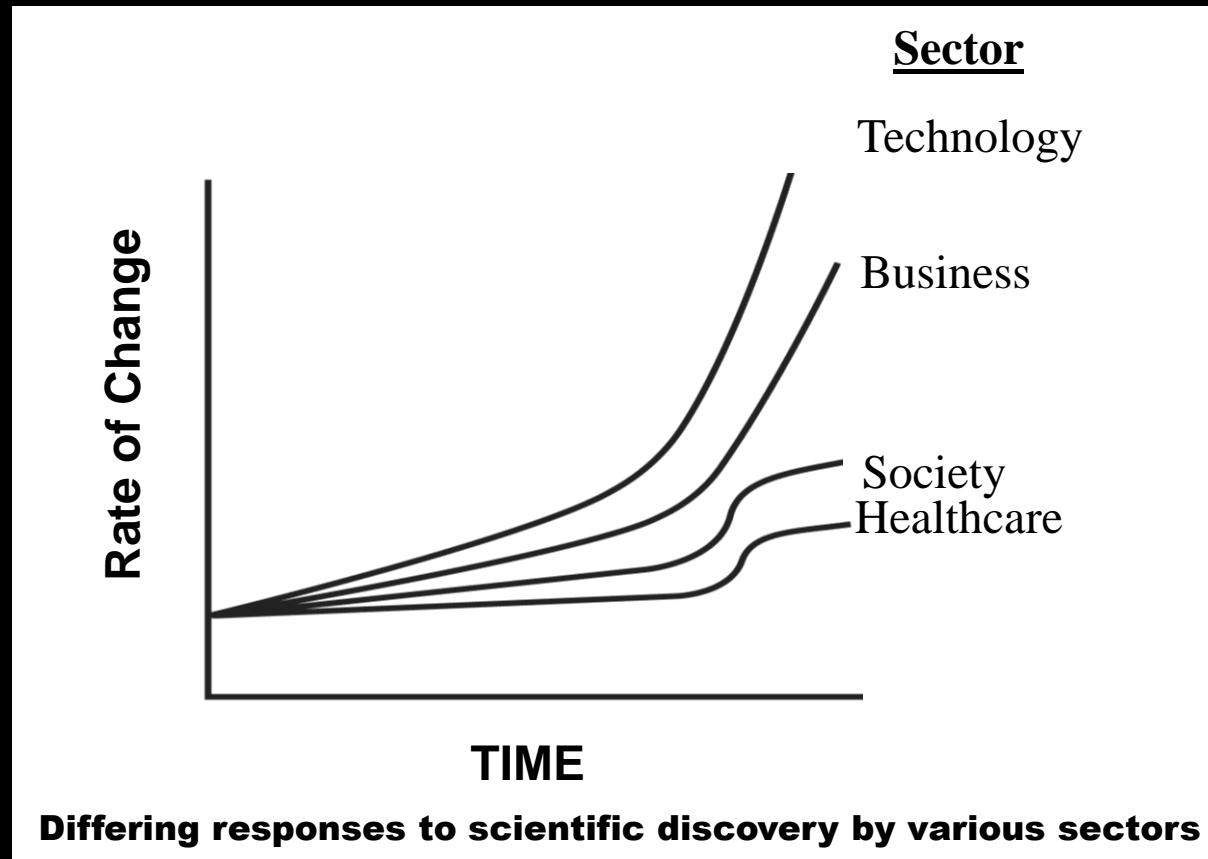
Technology is Neutral - it is neither good or evil

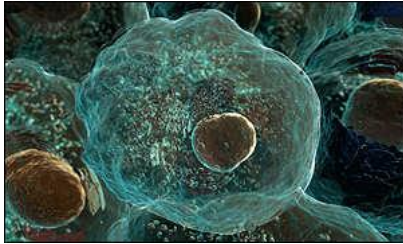
It is up to us to breathe the moral and ethical life  
into these technologies

And then apply them with empathy and compassion  
for each and every patient

# Technologies Will Change the Future

- The rate of new discovery is accelerating exponentially
- The changes raise profound fundamental issues
- Moral and ethical solutions will take decades to resolve





## Chinese Cloning Control Required

Tuesday 16 April, 2002, 10:41 GMT 11:41 UK

Strict ethical guidelines are needed in China to calm public fears about new cell technologies such as cloning, the country's leading scientist said.

Professor Ching-Li Hu, the former deputy director of the World Health Organization, was speaking at the Seventh Human Genome Meeting in Shanghai. His call follows recent reports that Chinese scientists are making fast progress in these research fields.

**One group in the Central South University in Changsa is said to be producing human embryo clones**, while another team from the Sun Yat-sen University of Medical Sciences in Guangzhou is reported to have fused human and rabbit cells to make tissues for research.



## Human embryos cloned

February 12, 2004

### South Korean team demonstrates cloning efficiency for humans similar to pigs, cattle | Thersa Tamkins

After outlandish claims, a few media circuses, and some near misses by legitimate researchers, **a team of South Korean researchers reports the production of cloned human embryos**. The findings, were released Wednesday (*Science*, DOI:10.1126/science.1094515, February 12, 2004). Wook Suk Hwang and Shin Yong Moon of Seoul National University used somatic cell nuclear transfer to produce 30 human blastocysts and a single embryonic stem cell line; SCNT-hES-1. Using 242 oocytes and cumulus cells from 16 unpaid donors, the group achieved a cloning efficiency of 19 to 29%, on par with that seen in cattle (25%) and pigs (26%).

# Genetically “designed” child



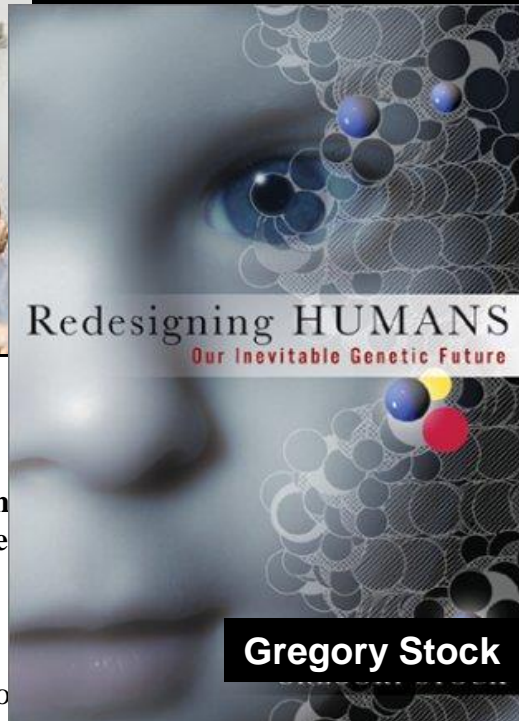
## Preimplantation Genetic Screening General Science: May 13, 2006

A British woman has become the first in the country to conceive a “**designer baby**” specifically to avoid an inherited cancer,

The woman, who was not identified, used controversial genetic screening [technology](#) so she does not pass on to her child the condition retinoblastoma, an hereditary form of eye cancer from which she suffers.

Doctors tested embryos created by the woman and her partner using in-vitro fertilisation (IVF) for the cancer gene. Only unaffected embryos were implanted in her womb, the newspaper said.

It suggested the woman's pregnancy would increase controversy over the procedure -- preimplantation genetic diagnosis (PGD) -- because critics say it involves destroying otherwise healthy embryos whose conditions are treatable.



Gregory Stock



## Emergence of Novel Color Vision in Mice Engineered to Express Human Cone Photo-pigment

Changes in the genes encoding sensory receptor proteins are an essential step in the evolution of new sensory capacities “**new sensory capacities**”. In primates, trichromatic color vision evolved after changes in x chromosome linked photopigment genes. Heterozygous mouse females **whose retinas contained both mouse pigment and human L pigments** showed enhanced long-wavelength sensitivity and chromatic discrimination. An inherent plasticity in the mammalian visual system thus permits emergence



## Five “designer babies” created for stem cell harvest

Five healthy babies have been born to provide stem cells for siblings with serious non-hereditary conditions. This is the first time “**savior siblings**” have been created to treat children whose condition is not genetic, says the medical team. The five babies were born after a technique called preimplantation genetic diagnosis (PGD) was used to test embryos for a tissue type match to the ailing siblings, reports the team, led by Anver Kuliev at the Reproductive Genetics Institute in Chicago, US. The aim in these cases was to provide stem cells for transplantation to children who are suffering from leukaemia “**Unlawful and unethical**” However, the use of this technology to

Science Vol 315: 1723-25, Mar 2007

# Extending Longevity



A strain of mice that have lived . . .  
. . . more than three normal lifespans

Should humans live 200 years?



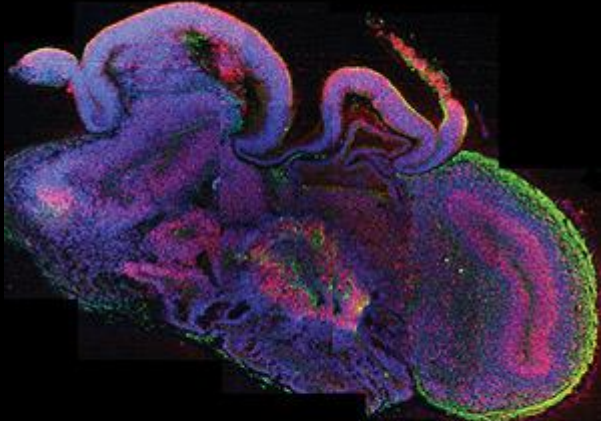
April 14, 2004

## Life extension

Life extension consists of attempts to extend human life beyond the natural lifespan. So far none has been proven successful in humans. Several aging mechanisms are known, and anti-aging therapies aim to correct one or more of these:

Dr. Leonard Hayflick discovered that mammalian cells divide only a fixed number of times. This "Hayflick limit" was later proven to be caused by telomeres on the ends of chromosomes that shorten with each cell-division. When the telomeres are gone, the DNA can no longer be copied, and cell division ceases. In 2001, experimenters at Geron Corp. lengthened the telomeres of senescent mammalian cells by introducing telomerase to them. They then became youthful cells. Sex and some stem cells regenerate the telomeres by two mechanisms: Telomerase, and ALT (alternative lengthening of telomeres). At least one form of progeria (atypical accelerated aging) is caused by premature telomeric shortening. In 2001, research showed that naturally occurring stem cells must sometimes extend their telomeres, because some stem cells in middle-aged humans had anomalously long telomeres.

# Growing Human Brains: The First Steps



## Cerebral organoids model human brain development and microcephaly

Lancaster MA, Renner M, Vartin CA, Wenzel D Bicknell L  
Hurles M, Homfray T, Penninger JM, Jackson A ,Knoblich J

University of Vienna, Austria  
August 29, 2013



### Abstract

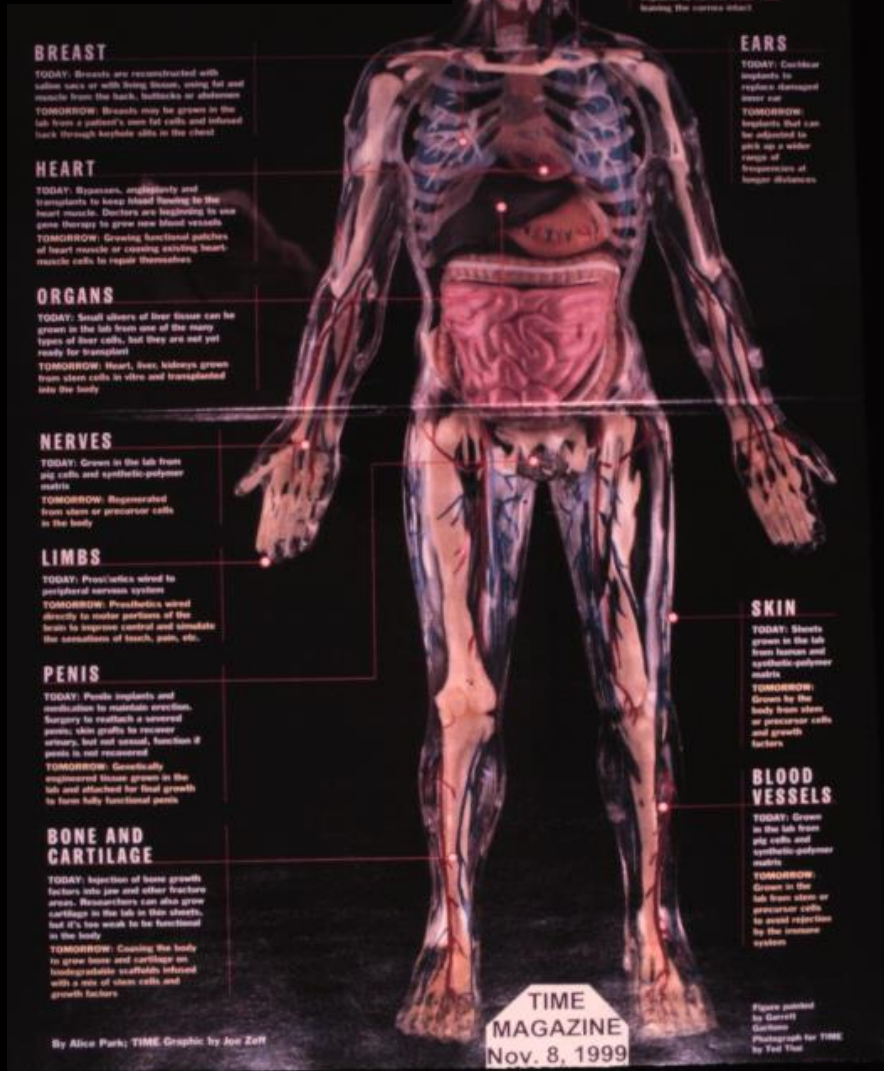
The complexity of the human brain has made it difficult to study many brain disorders in model organisms, highlighting the need for an *in vitro* model of human brain development. Here we have developed a human pluripotent stem cell-derived three-dimensional organoid culture system, termed cerebral organoids, that develop various discrete, although interdependent, brain regions. These include a cerebral cortex containing progenitor populations that organize and produce mature cortical neuron subtypes.

Furthermore, cerebral organoids are shown to recapitulate features of human cortical development, namely characteristic progenitor zone organization with abundant outer radial glial stem cells.

Finally, we use RNA interference and patient-specific induced pluripotent stem cells to model microcephaly, a disorder that has been difficult to recapitulate in mice.

We demonstrate premature neuronal differentiation in patient organoids, a defect that could help to explain the disease phenotype. Together, these data show that three-dimensional organoids can recapitulate development and disease even in this most complex human tissue.

# CAN I REPLACE MY BODY ?



Artificial organs

Smart Prostheses

Genetic engineering

Regeneration

If I replace 95%  
of my body . . .

. . . Am I still “human”?

Should there be replacement  
“parts” for astronauts?

# Moral and Ethical Issues

Raised by Technological Success  
will take DECADES of debate

## Summary of Examples

Should we do research in areas we may not be able to control?  
(eg, genetics, cloning, nanobots, intelligent machines?)

Will prolonging life result in more disease in the overall population

Can we change medicine from treatment to prevention of disease

In defeating diseases, will technology change a human into a combination of man and machine - what does it mean to be “human”

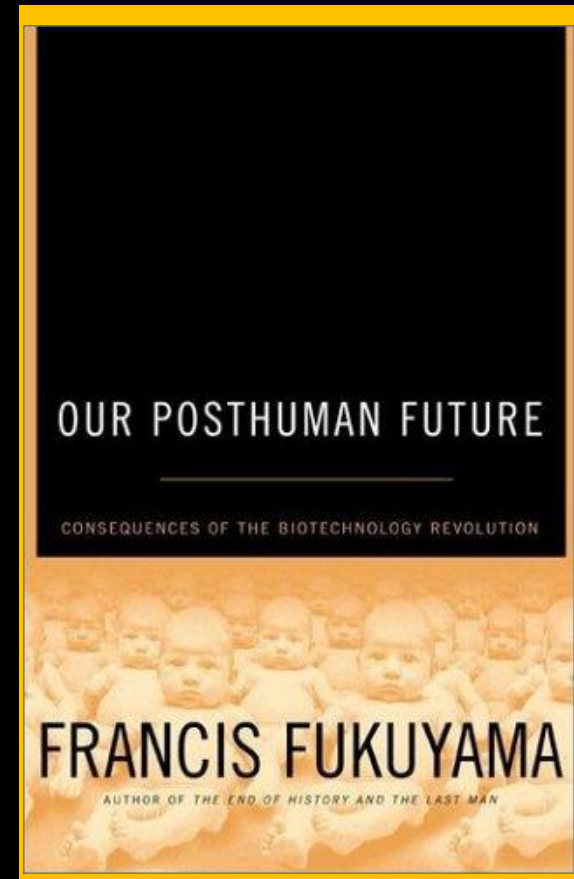
How will we decide who gets the technology, especially in 3rd World

# The Ultimate Ethical Question?

For the first time in history,  
there walks upon this planet,  
a species so powerful,  
that it can control its own evolution,  
at its own time of choosing ...

... *homo sapiens*.

Who will be the next “created” species?





## **Planet Earth**

Represented as a 4-D structure



**Do Robots Dream ?**

<http://depts.washington.edu/biointel>

