

# SCIENCE-FICTION VS SCIENCE-FACT

- Nanobiotechnology Applications for Delivery -

# Background – Nano-Biotechnology / Bio-Nanotechnology

(See: previous presentation by Professor Zhang)

## Nanotechnology:

nano(s): 'dwarf' (Greek), denoting a factor of  $10^{-9}$  (used in units of measurement)  
read (in this context): technology involving ('inorganic'/non-biological) matter, utilising phenomena at a length-scale of  $10^{-9}\text{m}$

Enabling technology @ the active Interface ( $10^{-9}\text{m}$ )  
between 'inorganic' engineering and biology

## nano-Biotechnology / bio-Nanotechnology:

read (in this context): technology using non-biological (and biological/living matter) inside biological/living systems, utilising phenomena at a length-scale of  $10^{-9}\text{m}$

## Biotechnology:

bio(s): 'course of human life' relating to life, of living beings  
read (in this context): technology using 'organic'/'living/biological matter'

# Overview – Nanobiotech in Weaponry, Security & Defence

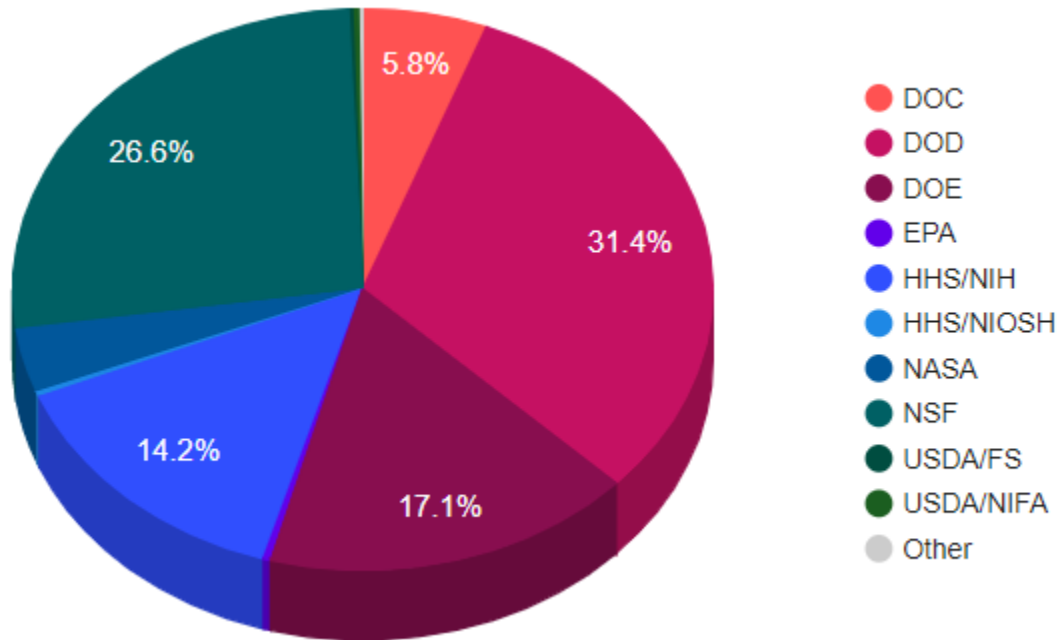
| Attack                                                                                                                                                                                                                                                                                                                           | Defence                                                                                                                                                 | Biological (human) Enhancement                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                         | external / non-invasive                                                                                                                                                                          | internal / invasive                                                                                                                                                                                                                                                                                        |
| <ul style="list-style-type: none"> <li>• nano-robots / bio-robots</li> <li>• delivery of nerve-agents:                             <ul style="list-style-type: none"> <li>- choking agents</li> <li>- vesicants (blister agents)</li> <li>- incapacitants</li> <li>- nerve agents</li> <li>- blood agents</li> </ul> </li> </ul> | <ul style="list-style-type: none"> <li>• chemical sensing</li> <li>• biological sensing</li> <li>• nuclear detection</li> <li>• nanomedicine</li> </ul> | <ul style="list-style-type: none"> <li>• exo-skeletons</li> <li>• self-repairing materials</li> <li>• invisibility shields/cloaks</li> <li>• smart textiles (i.e. sensing/diagnostic)</li> </ul> | <ul style="list-style-type: none"> <li>• neuro-stimulants                             <ul style="list-style-type: none"> <li>- pharma targeted drug delivery</li> <li>- implants</li> </ul> </li> <li>• nutraceuticals nutrient technology</li> <li>• nanomedicine</li> <li>• artificial organs</li> </ul> |
|                                                                                                                                                                                                                                                                                                                                  | <ul style="list-style-type: none"> <li>- robotics / automation</li> <li>- virtual reality systems</li> </ul>                                            |                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                            |
|                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                         |                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                            |



# Science-Fact – R&D Spending

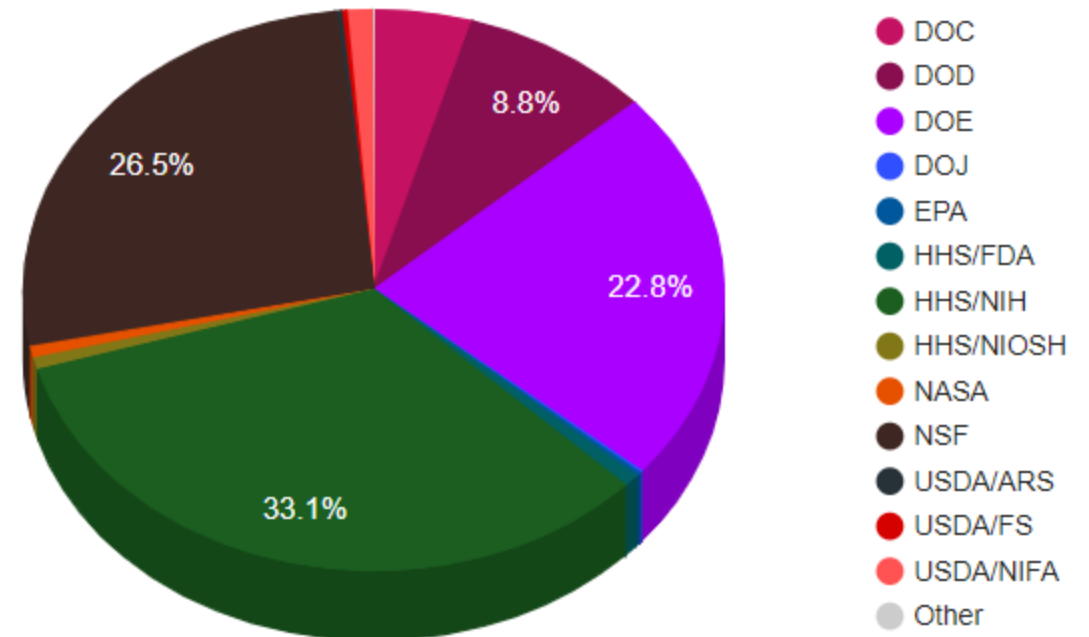
US National Nanotechnology Initiative (NNI) R&D Spending (by Agency):

**2006**, as percentage of the total of USD 1351.2 Mio.)



DOD (Department of Defense): USD 423.9

**2020**, as percentage of the total of USD 1468.7 Mio.)



DOD (Department of Defense): USD 129.7

[source: US NNI ([www.nano.gov](http://www.nano.gov))]

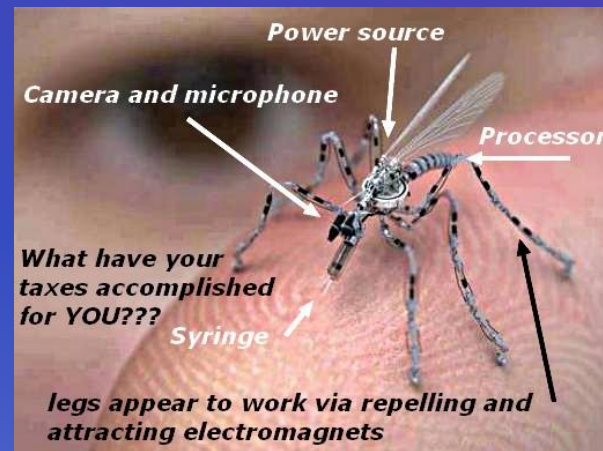
# Science-Fact – Nanobiotechnology close to Field Application: **ATTACK**

Nano-drones (e.g. tiny, flying robots that fly in large swarms):

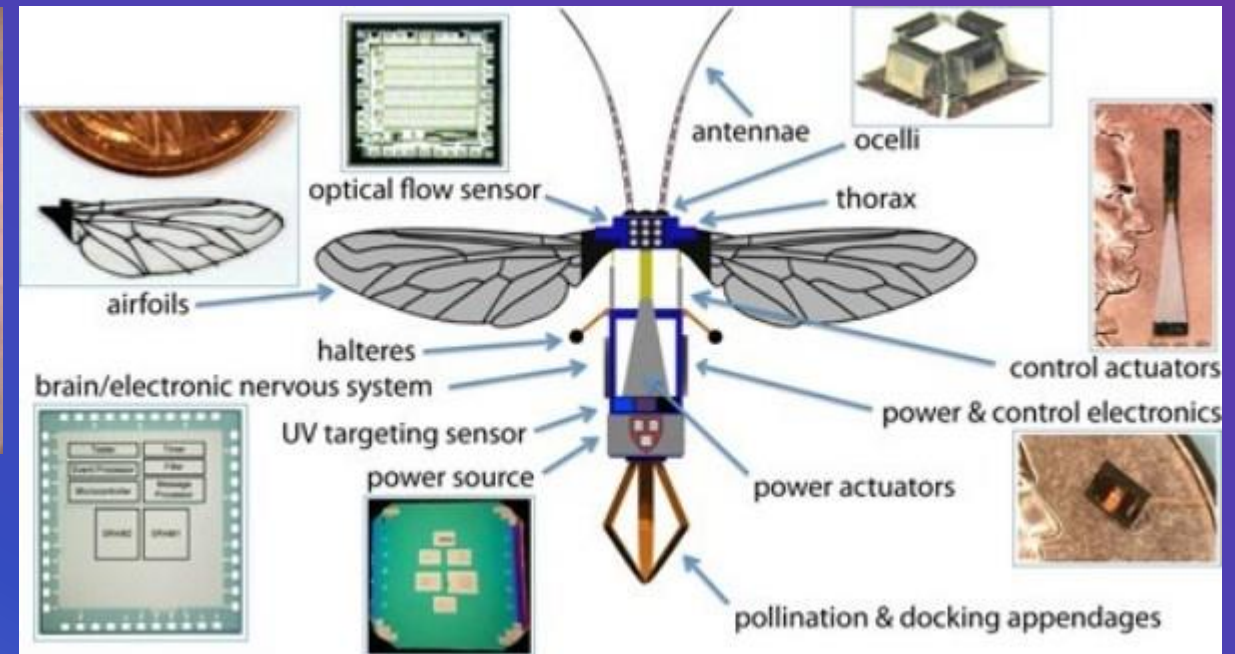
- to produce and deliver protein-based biological warfare agents
- to act as micro-explosives, micro-weapons or inhalable micro-particles (for (delayed) toxin release)

Current R&D Interests:

- US Air Force Office of Scientific Research: micro aerial vehicle (MAV)
- France: bio-inspired micro drones
- Netherlands: BioMAV (Biologically Inspired AI for Micro Aerial Vehicles)
- Israeli Aerospace Industries (IAI) has produced a butterfly-shaped drone (20 grams.



Suggested example of 'spy drones' (source: <https://www.roboticstomorrow.com/>)

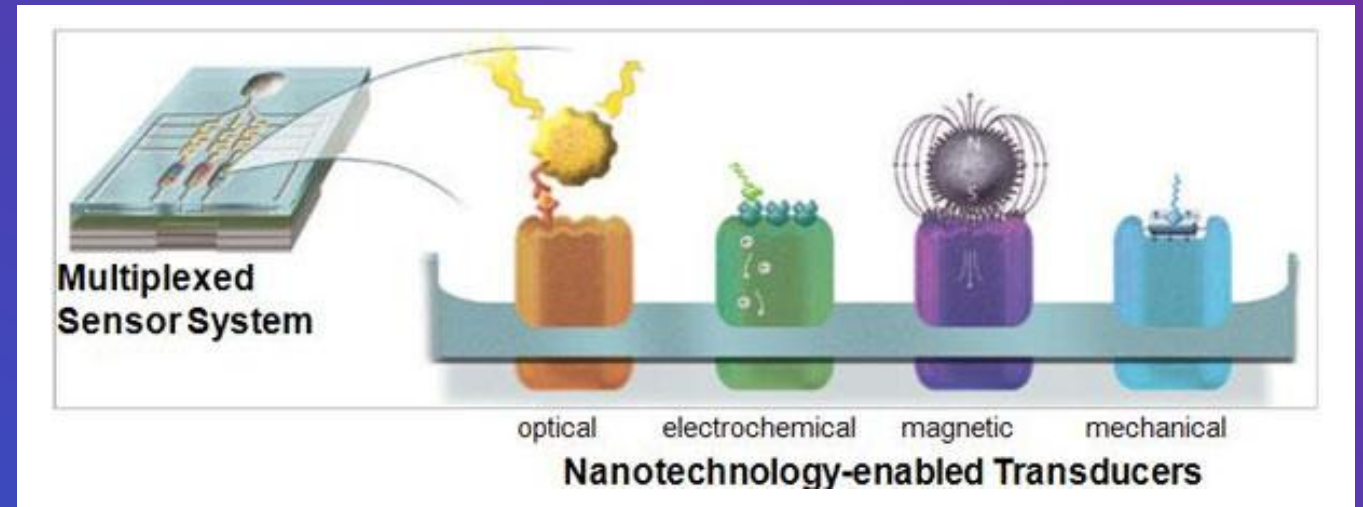
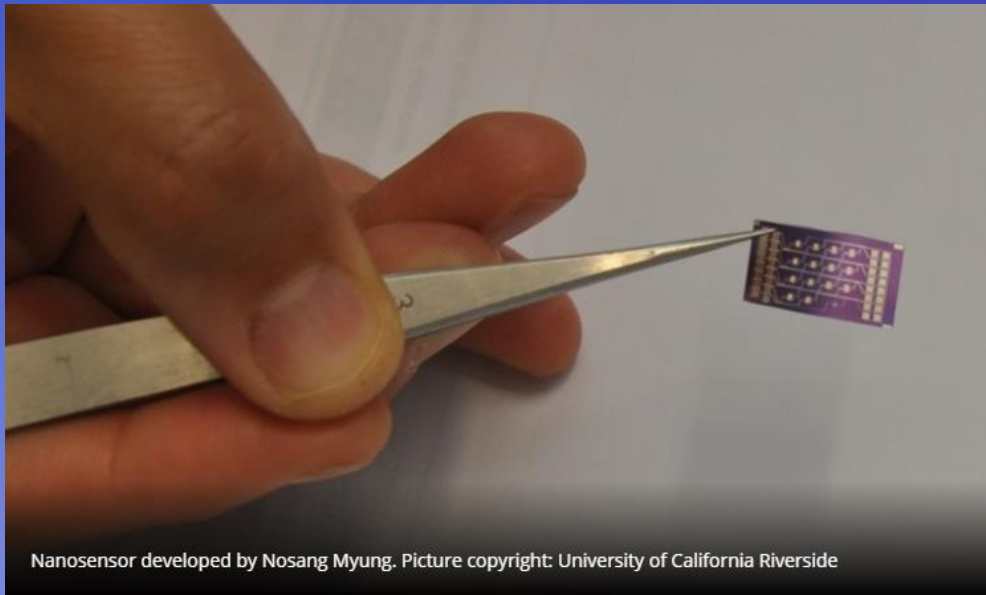


[source: <https://www.cnn.com/2017/03/17/mini-nukes-and-inspect-bot-weapons-being-primed-for-future-warfare.html>.]

# Science-Fact – Nanobiotechnology close to Field Application: DEFENSE

Nanotechnology-based sensors for chemical and biological (and nuclear) weapons:

- advantage: multiplexing enables the combination of different sensing capabilities



[source: <https://www.nanowerk.com/news2/newsid=25891.php>.]

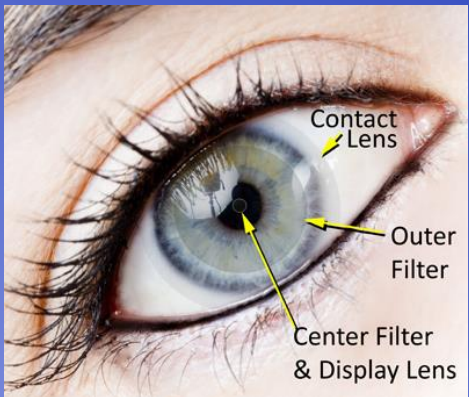
[source: <https://www.foodnavigator-usa.com/Article/2013/06/18/Nanosensor-being-developed-for-food-safety>.]



# Science-Fact – Nanobiotechnology close to Field Application: NON-INVASIVE HUMAN ENHANCEMENT

Smart contact lens (with flexible micro battery) providing augmented vision assistance and relaying visual information wirelessly:

Since 2012, DARPA (US Defense Advanced Research Projects Agency) had been developing a contact lenses designed to **enhance normal vision by projecting digital images onto a standard pair** of eyeglasses like a miniaturized heads-up display, “allow[ing] a wearer to view virtual and augmented reality images without the need for bulky apparatus”:



[image source:  
[https://web.archive.org/web/20120205025653/  
http://www.darpa.mil/NewsEvents/Releases/2012/01/31.aspx](https://web.archive.org/web/20120205025653/http://www.darpa.mil/NewsEvents/Releases/2012/01/31.aspx) ]



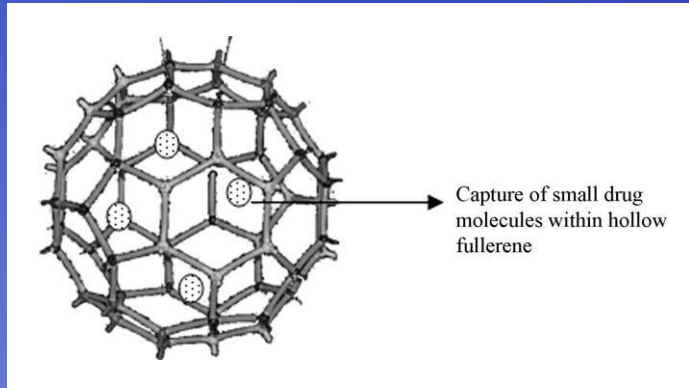
[image source: [www.electronicweek.com](http://www.electronicweek.com)]

[source: <https://nationalinterest.org/blog/buzz/darpa-eyeing-high-tech-contact-lens-straight-out-mission-impossible-54617/>]

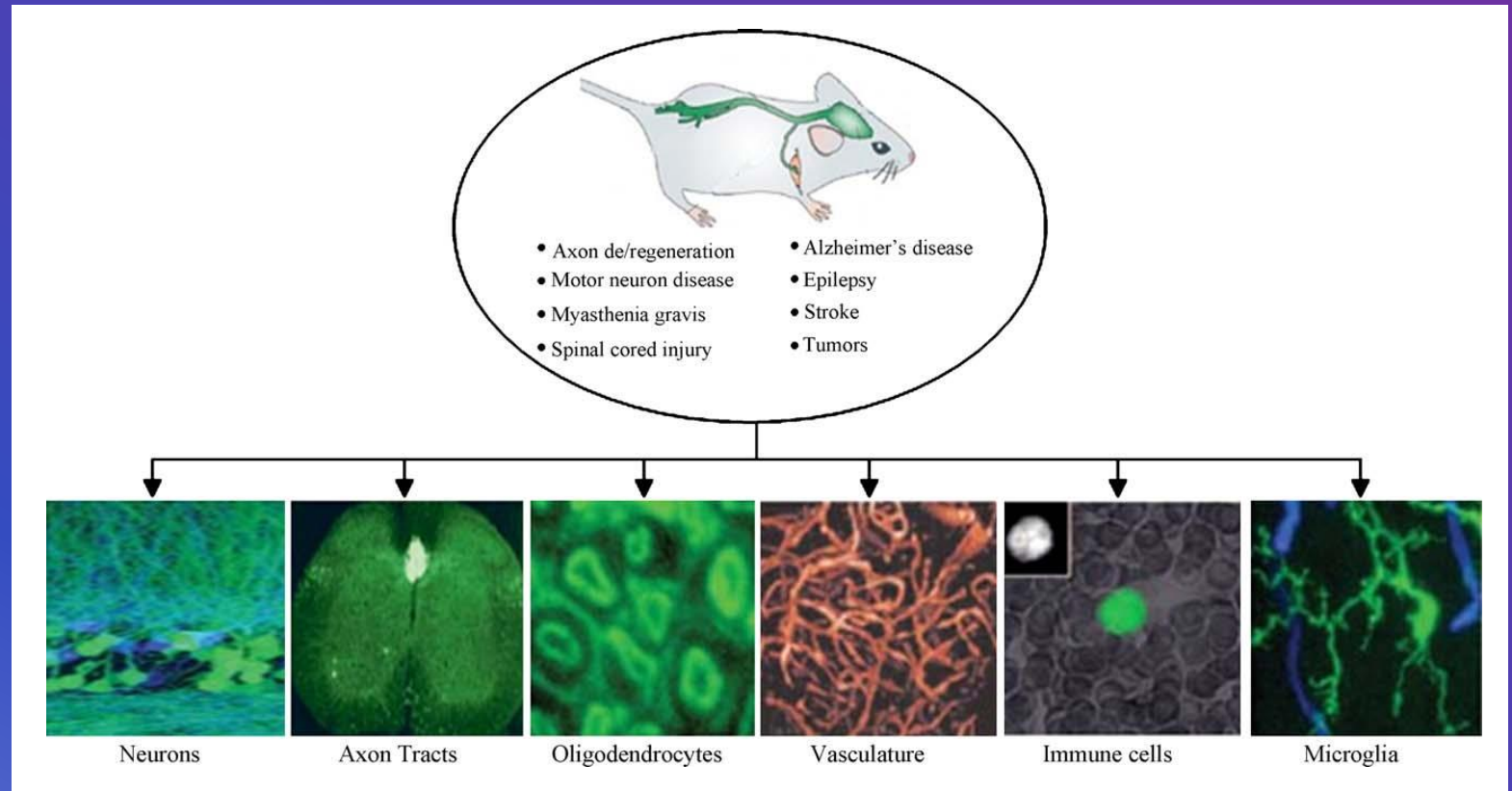
# Science-Fact – Nanobiotechnology close to Field Application: INVASIVE HUMAN ENHANCEMENT

Design and integration of specific nano-enabled applications to the central nervous system:

*In vivo* imaging of encapsulated [...] nanoparticles delivered to the mice brain by direct intra-hippocampal injection



A typical carbon-60 fullerene-based structure for entrapping neuroprotective compounds.



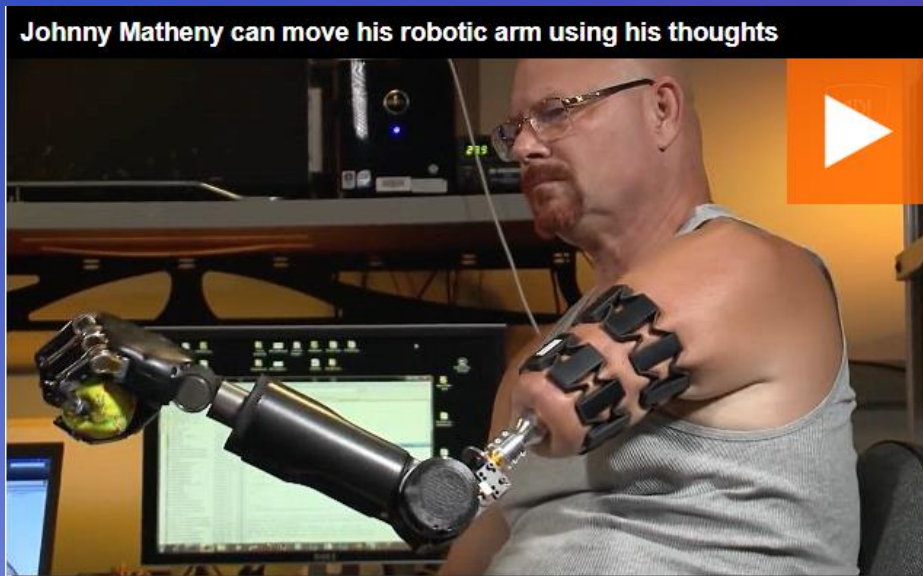
[source: Girshi Modi et al., Nanotechnological applications for the treatment of neurodegenerative disorders, Progress in Neurobiology, 88 (2009) 272-285, <https://doi.org/10.1016/j.pneurobio.2009.05.002>.]



# Science-Fact – Nanobiotechnology close to Field Application:

## INVASIVE – TO – NON-INVASIVE HUMAN ENHANCEMENT

1. Osseointegration (i.e. implantation into the marrow space of bone in the residual limb) to move artificial limbs
2. Brain-implants enable thought-computer



Johnny Matheny can move his robotic arm using his thoughts  
[source: <https://www.dailymail.co.uk/sciencetech/article-3397823/Man-moves-robotic-arms-MIND-brain-controlled-prosthetic-attaches-implant-patient-s-bone.html>]



A quadriplegic woman with sensors implanted onto her brain controlled one of the robotic limbs to grab a cup, shake hands and eat a chocolate bar. She even flew an F-35 Joint Strike Fighter simulator using just her thoughts.

[source: <https://www.military.com/daily-news/2015/03/19/after-terminator-arm-darpa-wants-implantable-hard-drive.html>]

# Science-Fact – EXAMPLE: Civil Applications

## INVASIVE – TO – NON-INVASIVE HUMAN ENHANCEMENT

Existing 'human enhancement' / 'disability correction' through proxy:

Mr Harbisson, of Camden, London, was born with achromatopsia, a rare condition which means he can only see in black and white.

But he has now convinced surgeons to implant the chip inside his skull so that he can perceive more intricate colours.

A wifi connector inside the chip allows him to hear images sent from a mobile phone - without even looking at them.

The cyborg antenna - or 'eyeborg' - is composed of a camera on one end and an audio input on the other end.

The audio input - which is now implanted inside the back of his skull - allows him to receive the visual spectrum captured by his camera via bone vibrations.

[source: <https://www.dailymail.co.uk/sciencetech/article-2582019/Colour-blind-artist-worlds-eyeborg-having-antenna-implanted-inside-skull-hear-colours.html>]



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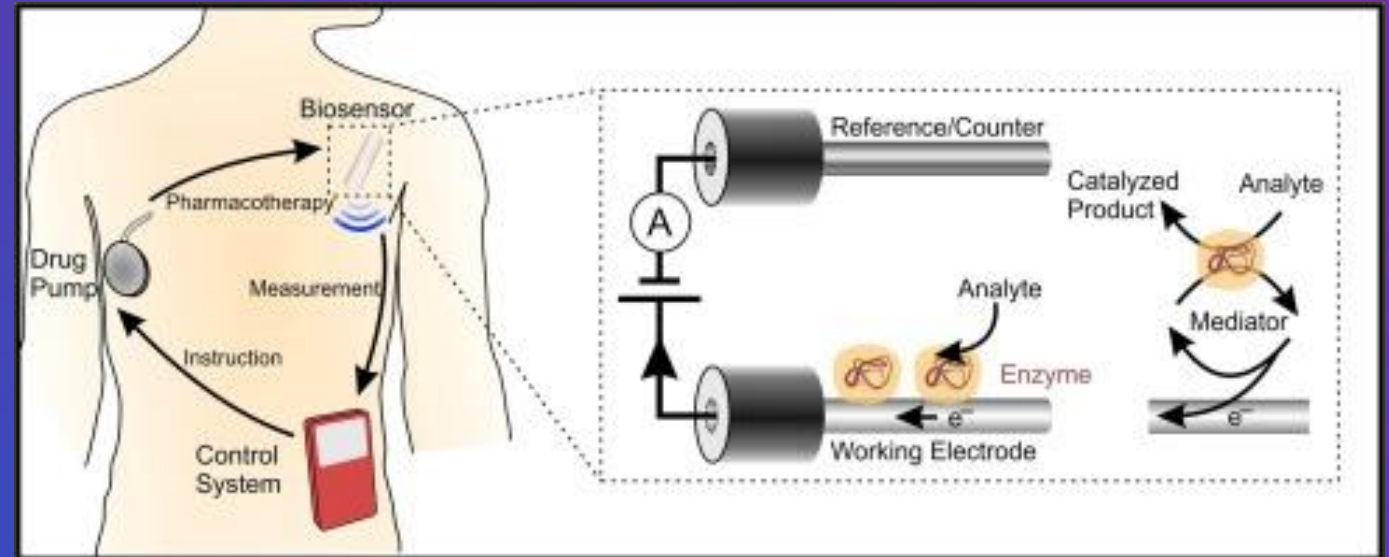


# Science-Fact – EXAMPLE: Civil Applications

## INVASIVE – TO – NON-INVASIVE HUMAN ENHANCEMENT

Closed-loop implantable Bio-Sensors:

- (i) an implanted biosensor which monitors physiological condition, circulating drug concentration, or biomarker level;
- (ii) a control system which receives input from the sensor and provides medication dosing instructions; and
- (iii) a drug delivery device which provides pharmacotherapy with the goal of creating a measurable change in patient-condition as monitored by the sensor (closing the loop).



Implantable biosensors for closed-loop glucose control and other drug delivery applications

[source: <https://www.sciencedirect.com/science/article/pii/S0378517318301030?via%3Dihub>]



# Wrap-Up & Conclusions

As an enabling technology, nanotechnology (as such) does not introduce new weapons, but allows a wide range of enhancements to existing weaponry-, security-and defense-technologies:

- **ATTACK:** Super-powerful bombs (cf. demonstrated by Russia (2007))
- **DEFENSE:** Powerful multiplex sensors for chemical, biological and nuclear weapons; advanced surveillance technologies
- **EXTERNAL HUMAN ENHANCEMENT:** connectivity between biological, living systems (e.g. brain, muscle) and 'inorganic' external technologies
- **INTERNAL HUMAN ENHANCEMENT:** delivery of neuro-stimulating drugs through the blood-brain barrier

New features and main innovations:

- High accuracy (i.e. engineering on a molecular level)
- Automation of sensing, information analysis (AI), and actuation (i.e. in medical applications: diagnosis + treatment)
- Non-detectability

# THANK YOU!

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