



**KAPITAŁ LUDZKI**  
NARODOWA STRATEGIA SPÓJNOŚCI

**UNIA EUROPEJSKA**  
EUROPEJSKI  
FUNDUSZ SPOŁECZNY



## **„MEDICAL ELECTRONICS”**

**Prezentacja multimedialna współfinansowana przez  
Unię Europejską w ramach  
Europejskiego Funduszu Społecznego w projekcie pt.  
*„Innowacyjna dydaktyka bez ograniczeń - zintegrowany  
rozwój Politechniki Łódzkiej - zarządzanie Uczelnią,  
nowoczesna oferta edukacyjna i wzmacniania zdolności  
do zatrudniania osób niepełnosprawnych”***



Politechnika Łódzka

Politechnika Łódzka, ul. Żeromskiego 116, 90-924 Łódź, tel. (042) 631 28 83  
[www.kapitalludzki.p.lodz.pl](http://www.kapitalludzki.p.lodz.pl)



## Contact information – course instructors

Biomedical Engineering

# Medical Electronics



prof. Paweł Strumiłło



**dr Aleksandra Królak**  
course principal instructor



prof. Andrzej Materka





## Course form and assesment

- Lectures: 30h
- Laboratories and projects: 30h



- 
- Exam score: 50% of the mark
  - Laboratory reports: 25% of the mark
  - Project report: 25% of the mark



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# Literature

- Lecture and laboratory notes (\*.pdf) available at:  
<http://www.eletel.p.lodz.pl/byczuk/>
- J.D. Bronzino, „The handbook of biomedical engineering”, CRC Press, 1995 (new editions were published)
- R.S. Khandpur, „Biomedical Instrumentation: technology and applications”, McGraw-Hill, 2005.
- **Wikipedia** – becomes a reliable source of scientific information (though use with caution!)
- Google books: <http://books.google.pl/>
- Scientific Journals: e.g. (available on-line from university sites):
  - IEEE Transactions on Biomedical Engineering
  - IEEE Engineering in Medicine and Biology <http://ieeexplore.ieee.org>
  - IEEE Neural Systems and Rehabilitation Engineering
  - IEEE Transactions on Biomedical Circuits and Systems
- Also other publishers: Elsevier, Springer Verlag,..

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# Medical engineering in Egypt

- ❑ **Egyptians** had skills in internal medicine, e.g. they knew how to heal cataract and repair bone fractures
- ❑ obeyed rules of hygiene
- ❑ ... used elements of astrology and magic
- ❑ ... the doctor was punished in case of unsuccessful therapy



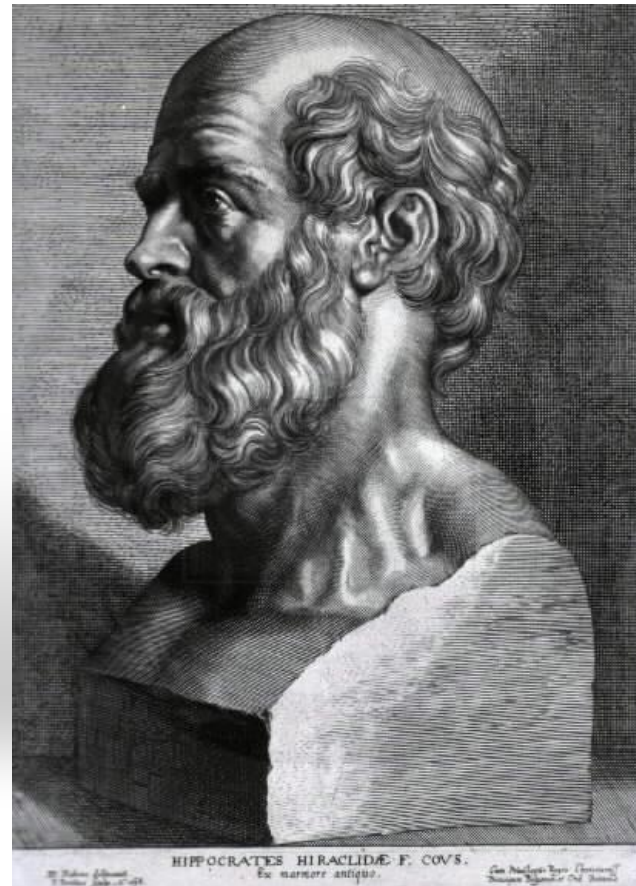
***Surgery tools pictured on the wall of the temple Kom Ombo, Egypt***

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## Greece

- ❑ the Greeks shifted medicine from magic to rational procedures
- ❑ **Hippokrates** of Kos (c. 460 BC – c. 370 BC)  
the father of western medicine
- ❑ introduced principles of treatment:  
observation, diagnosis, treatment and prognosis
- ❑ → **evidence based medicine**
- ❑ „The Hippocratic Oath”
- ❑ the key ethical principle of Hippocrates is:  
***Primum non nocere*** – “***First, do no harm.***”



***Engraving by Peter Paul Rubens, 1638***

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***The Stone Operation  
- Hieronymus Bosch  
(13th - 14th century)***

***„Primum non nocere”***

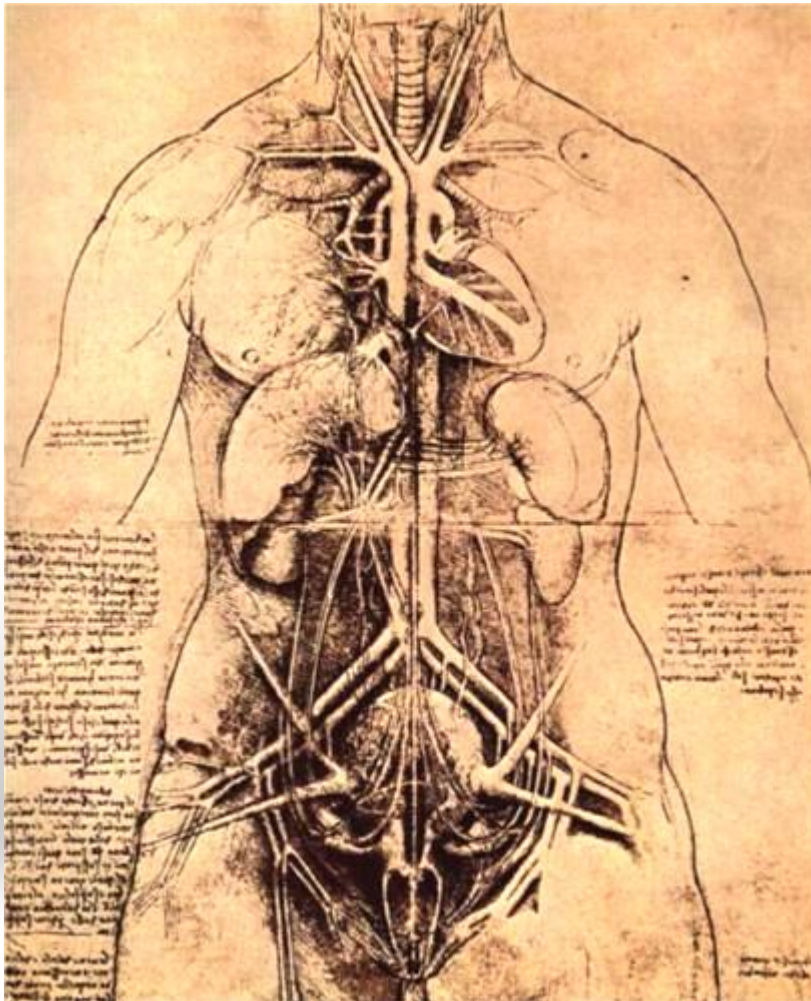


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# Human anatomy by Leonardo da Vinci



Leonardo da Vinci had a permission to dissect human corpses;

He is the Author of the first comprehensive anatomy atlas

***Internal organs  
of a woman's body - 1509***

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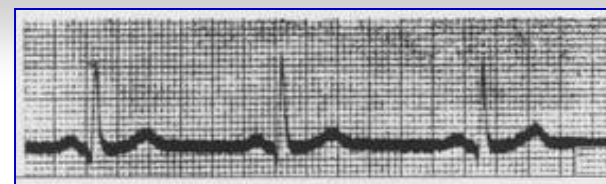
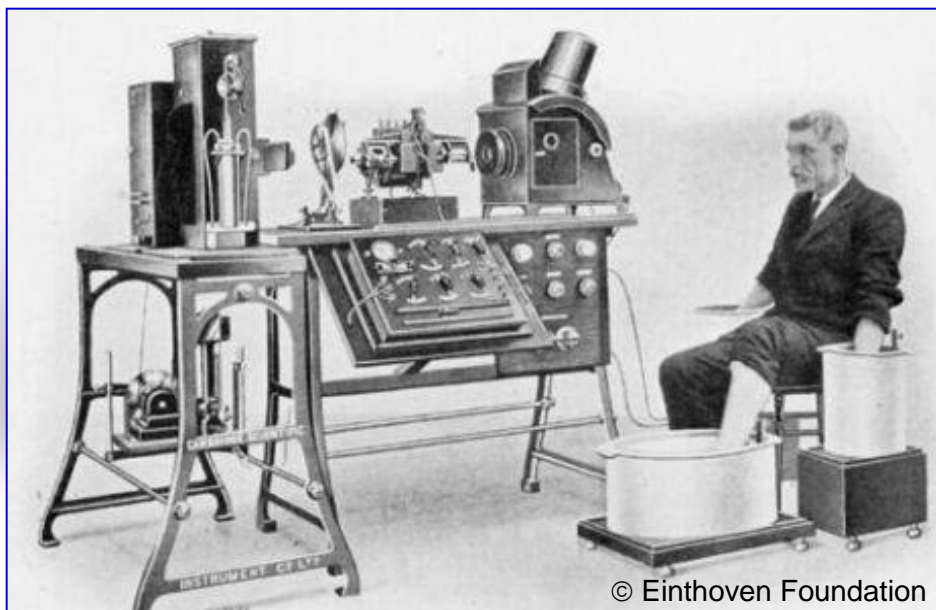
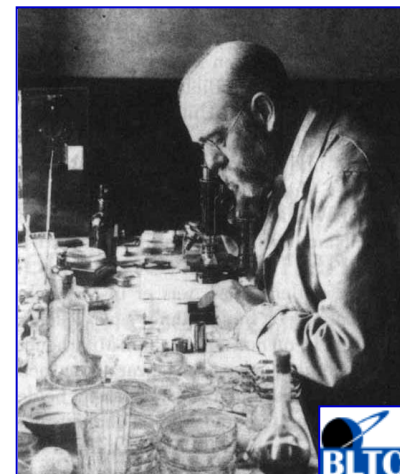


# Medical technologies - diagnosis (era before computers)

9

Diagnosis

- **first microscope**  
- microbiology: Robert Koch – Nobel Prize in **1905**
- **X rays:** Wilhelm Roentgen in **1896 (Nobel Prize 1901)**
- **first ECG recordings:** Willem Einthoven – Nobel Prize in **1924** for „explaining the mechanism of the electrocardiogram”



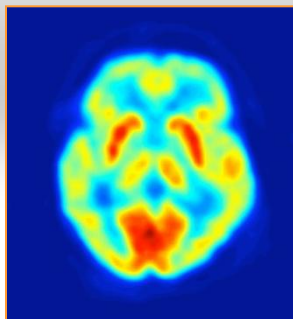
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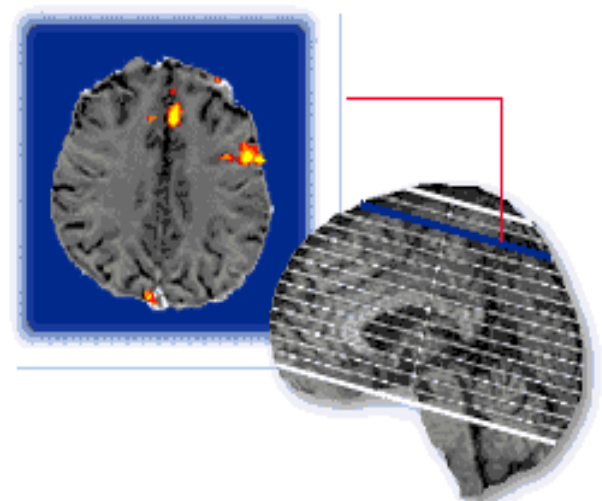
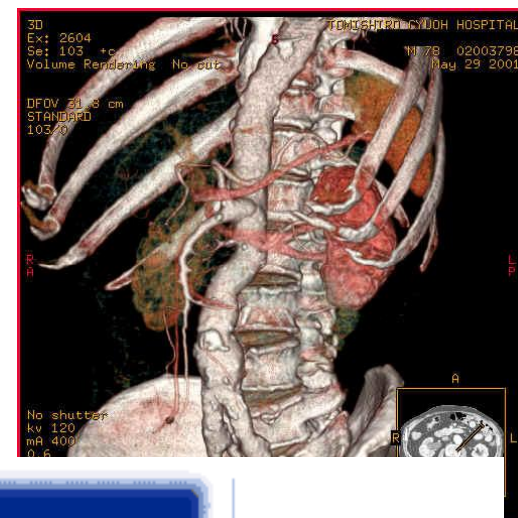


Diagnosis

- **Computed X-ray Tomography (CT)**  
(Cormack, Hounsfield – Nobel Prize in 1979)
- **Magnetic Resonance Imaging (MRI)**  
(Lautenbourg, Masfield – Nobel Prize in 2003)
- **functional MRI (fMRI)**
- **Positron Emission Tomography (PET)**
- **Wireless endoscopy**
- **Ultrasonography**



© 2003 Kent Medical Imaging



© 2005 Columbia University functional MRI

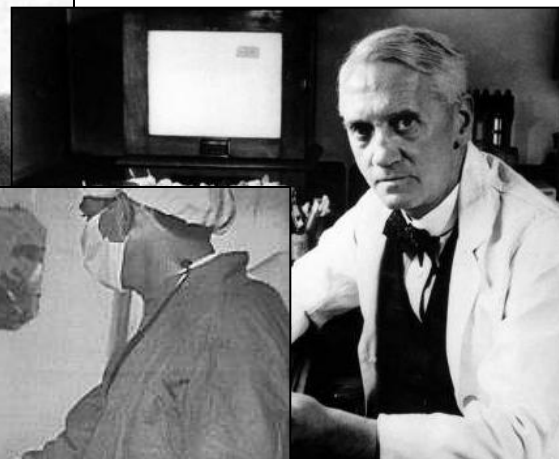
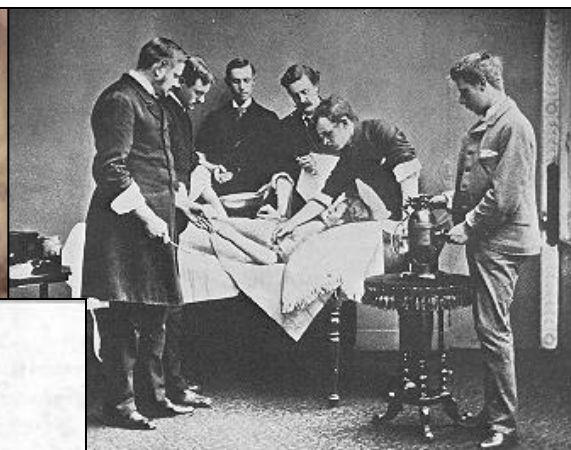
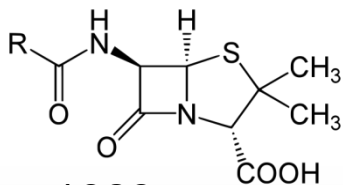
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Treatment

- **Narcosis**  
(chloroform, J.Y.Simpson -1847)
- **Antiseptics in surgery**  
(carbolic acid, Joseph Lister -1865)
- **Vaccines**  
(L. Pasteur - 1885)
- **Farmacology**  
(penicilin, A. Fleming, 1928  
Nobel Prize **1948**)
- **Transplatations**  
(Ch. Barnard – 1967)

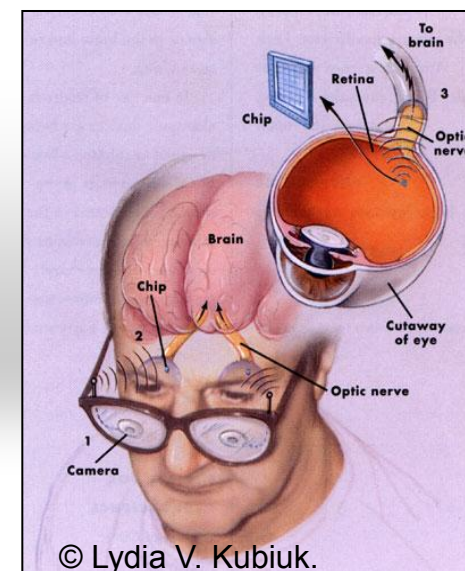
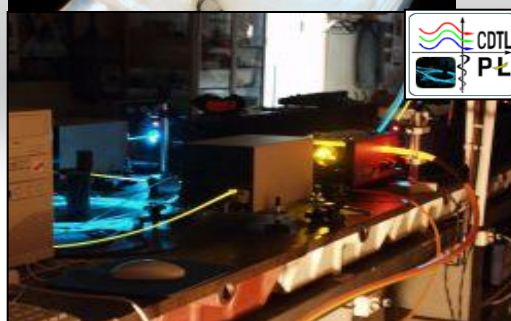
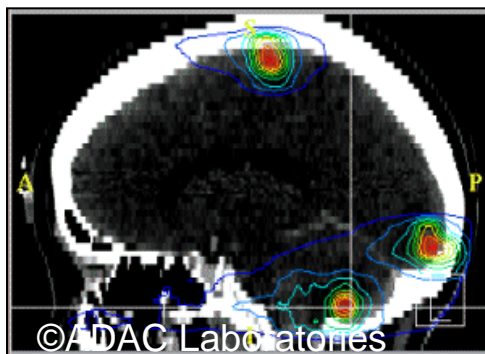


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Treatment

- **Surgical robots**  
(cardiology)
- **Therapy planning**
- **Laser therapy**
- **Prosthesis** (hearing, sight, artificial heart, intelligent defibrillators)
- **Nanotechnology**



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# New IEEE Journal

*„... the journal provides up-to-date and authoritative reviews of the most important bioengineering research.”*

J.C. Principe  
*Editor-in-Chief*

Two paper types:

Methodological Reviews  
&  
Clinical Application Reviews

# IEEE REVIEWS IN BIOMEDICAL ENGINEERING

A PUBLICATION OF THE IEEE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY

**EMB**

TECHNICALLY COSPONSORED BY THE IEEE CONSUMER ELECTRONICS SOCIETY

**CES**

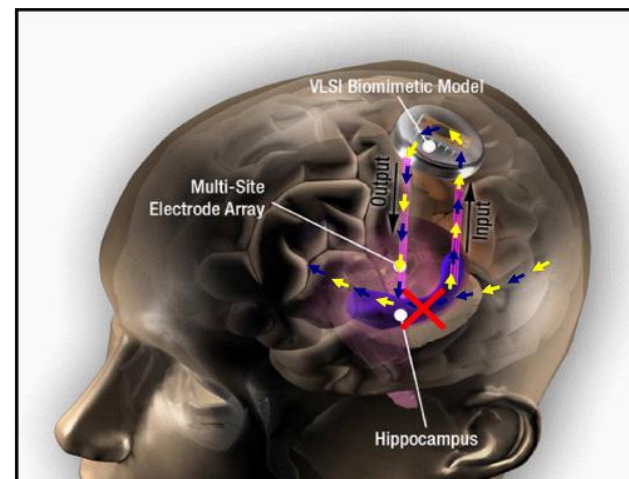
IEEE CONSUMER  
ELECTRONICS SOCIETY

2008

VOLUME 1

IRBECCO

(ISSN 1937-3333)



Conceptualization for a hippocampal prosthesis, as described in the paper “The Impact of Neurotechnology on Rehabilitation” by T. W. Berger, G. Gerhardt, M. A. Liker, and W. Soussou, on page 177.

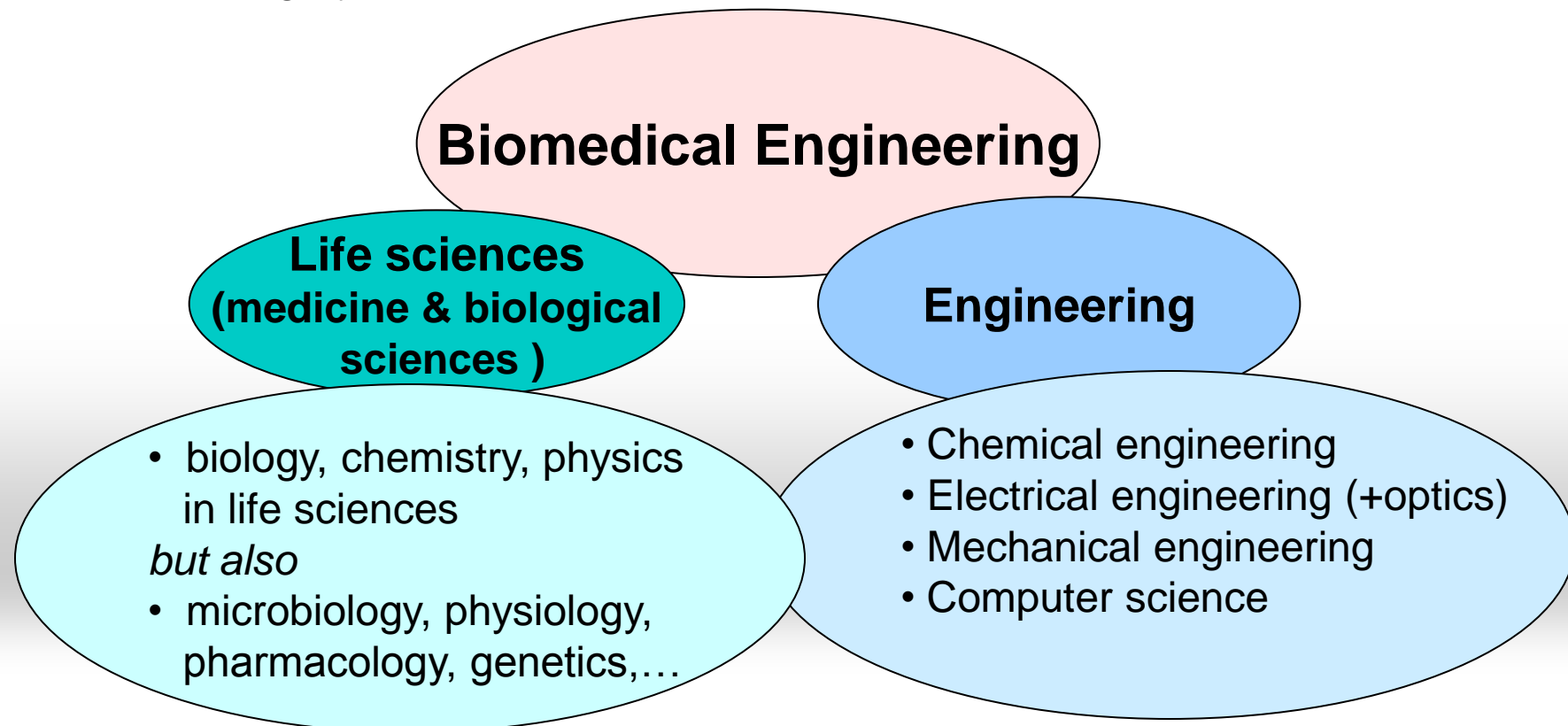
 **IEEE**



# What is Biomedical Engineering?

## Biomedical Engineering –

application of engineering principles and techniques in medical diagnosis and treatment (surgery).



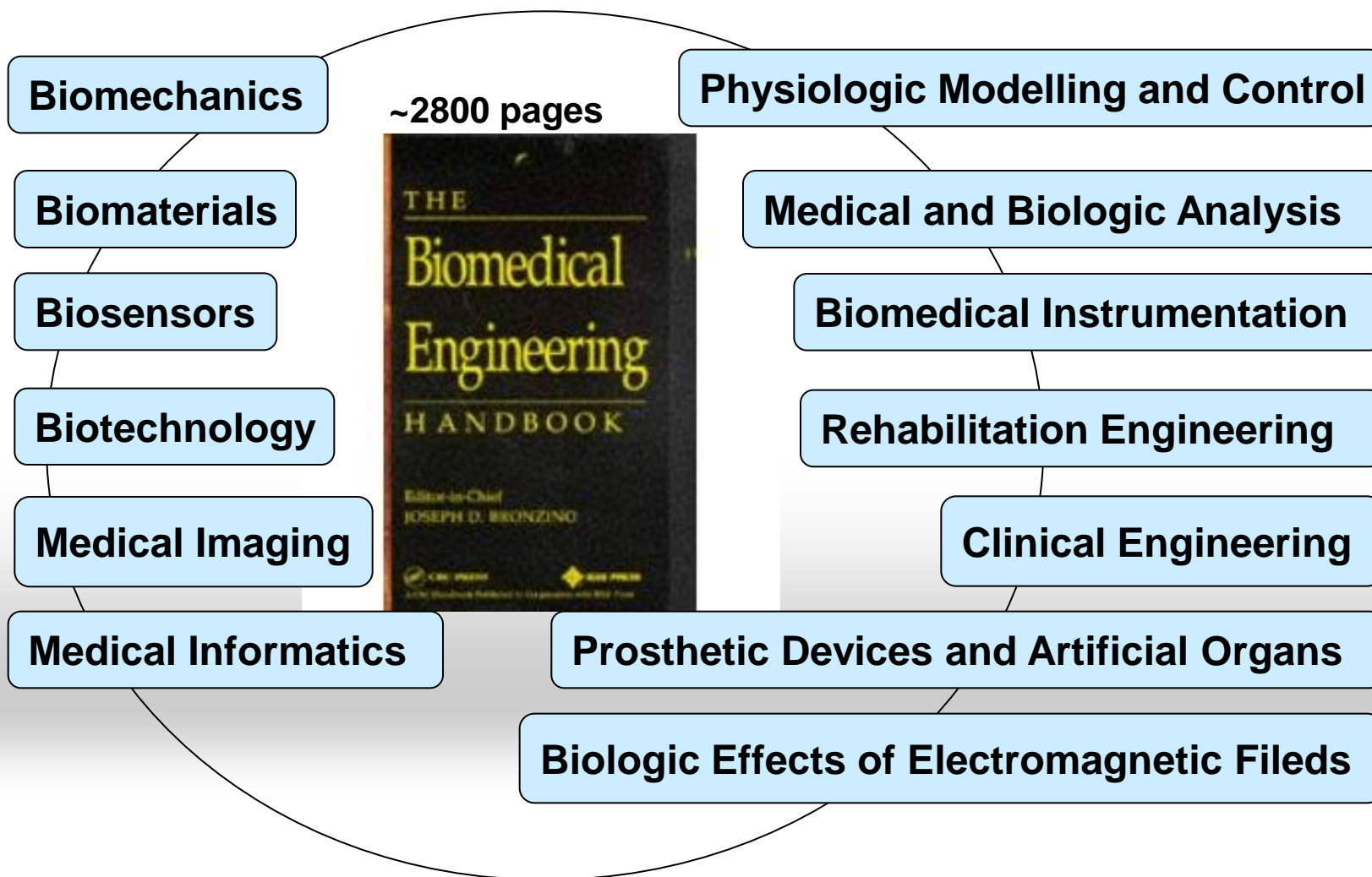
**Interdisciplinary field!**

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# Subdisciplines of Biomedical Engineering - I



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## Subdisciplines of Biomedical Engineering - II

- Biomechanics** - study of static and fluid mechanics in physiologic systems
- Biomaterials** - design and development of bioimplantable materials
- Biosensors** – detection of biological events and conversion to electrical signals
- Biotechnology** - to create or modify biologic material including tissue engineering
- Medical Imaging** – imaging and analysis of anatomic detail and physiologic function
- Medical Informatics** - store and interpret medical data, decision making (expert systems)
- Physiologic Modelling and Control** - use of computer simulations to develop an understanding of physiologic relationships
- Medical and Biologic Analysis** - to detect, classify and analyze bioelectric signals
- Biomedical Instrumentation** - monitoring and measurement of physiologic events
- Rehabilitation Engineering** - design and development of therapeutic and rehabilitation devices and procedures
- Clinical Engineering** - design and development of clinically related facilities, devices, systems and procedures
- Prosthetic Devices and Artificial Organs** - design and development of devices for replacement or augmentation of bodily function
- Biologic Effects of Electromagnetic Fields** - study of the effects of electromagnetic fields on biologic tissue

Examples?

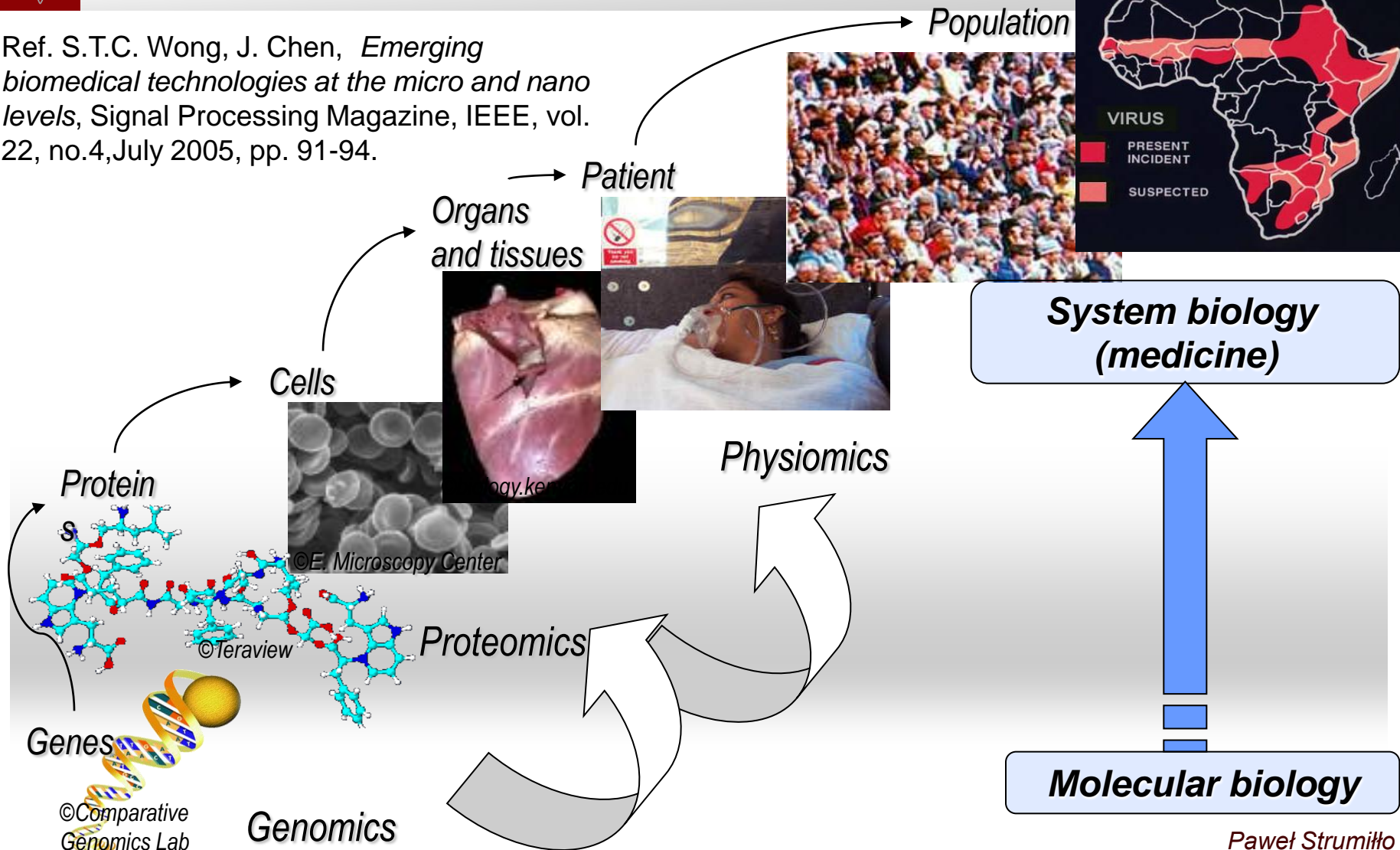
**You can find applications of medical electronic systems in any of the biomedical engineering subdisciplines**

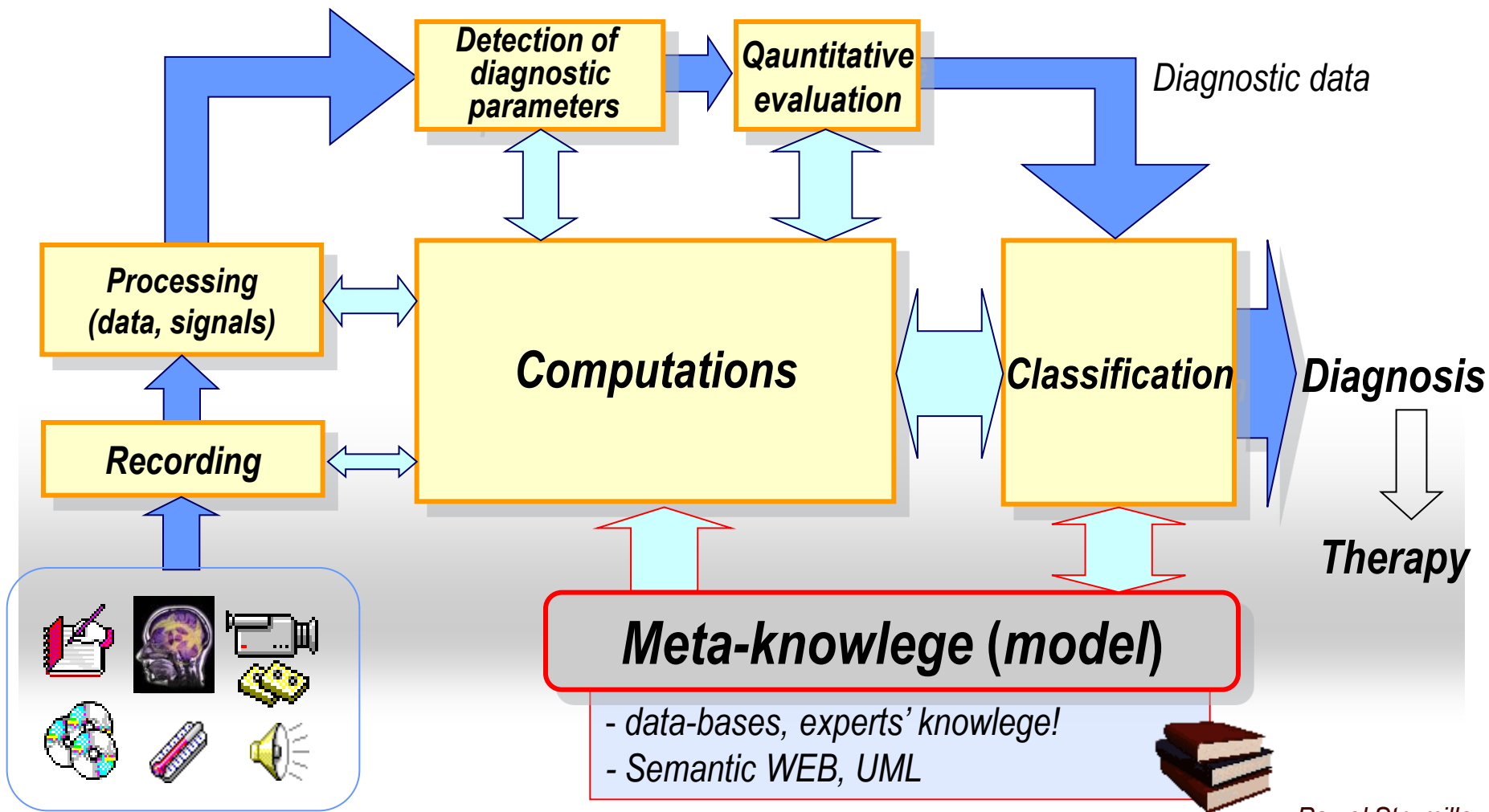




# Biomedical Engineering – at different scales

Ref. S.T.C. Wong, J. Chen, *Emerging biomedical technologies at the micro and nano levels*, Signal Processing Magazine, IEEE, vol. 22, no.4, July 2005, pp. 91-94.

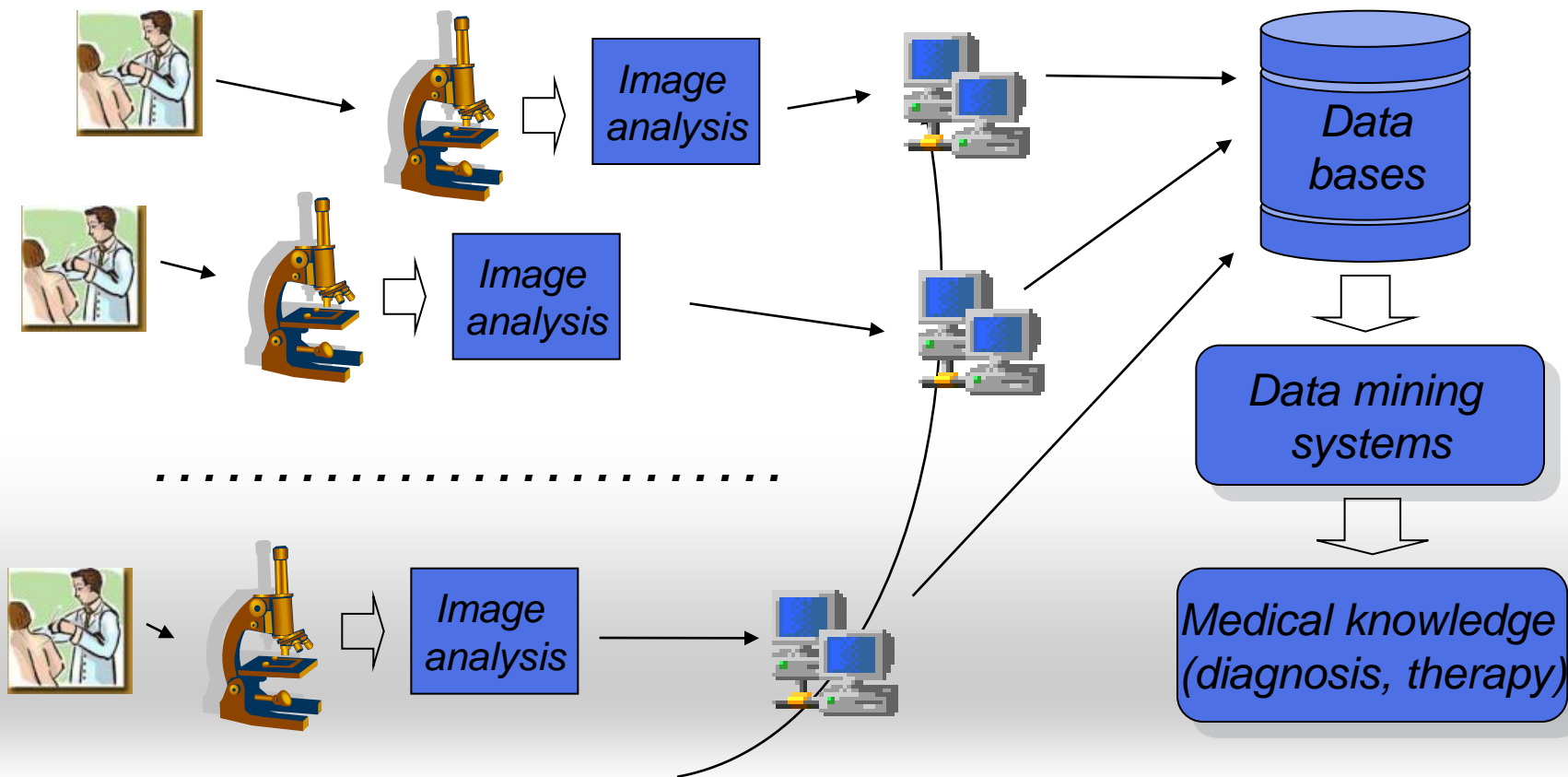




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# Global health networks - problems



Technology



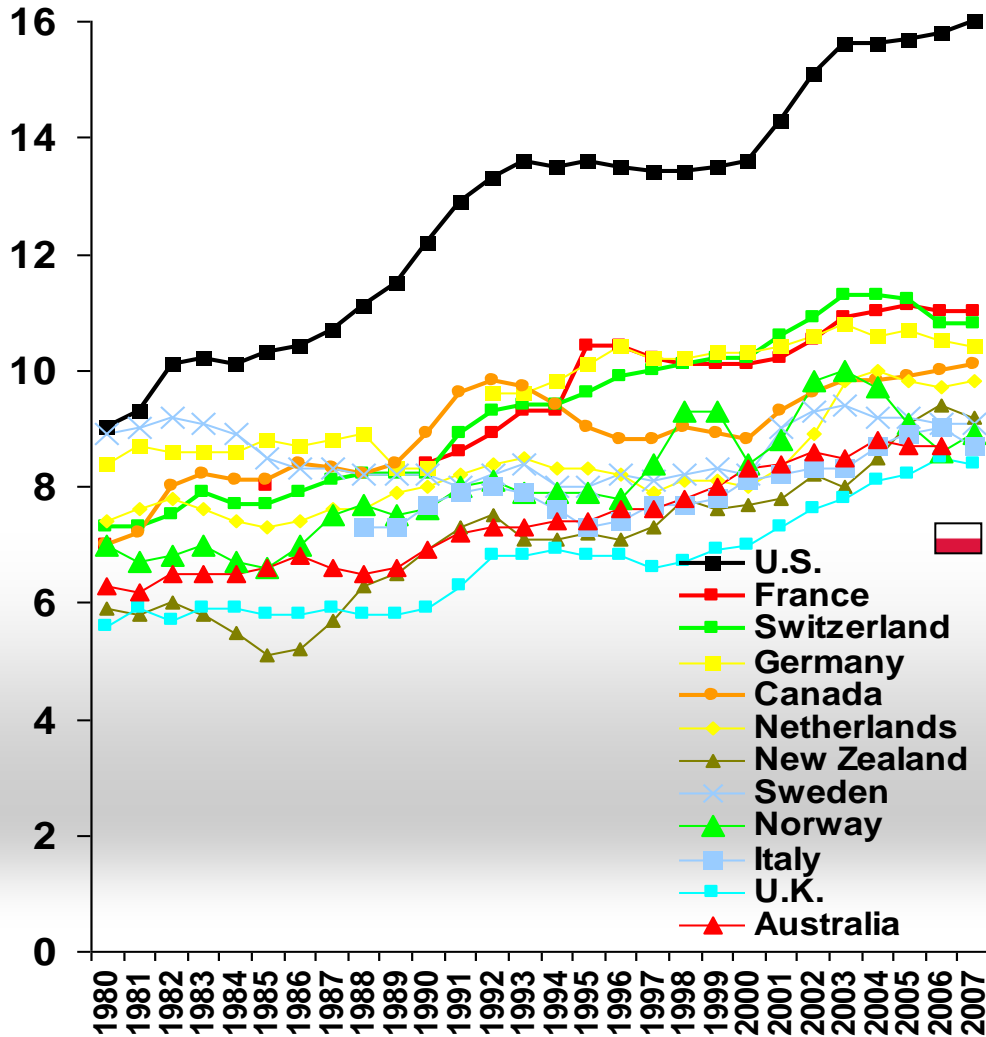
Standards: data, databases, good practices

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# International Comparison of Spending on Health, 1980–2007



Total expenditures on health as percent of GDP

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# New IEEE Journal

## First issue spotlights:

- BioInstrumentation
- Biomedical Imaging
- Biomedical Signal Processing
- Cardiovascular Engineering
- Health Information Systems
- Neuroengineering
- Tissue and Molecular Engineering

Present a one slide, 5 min presentation on:

„Medical breakthroughs of the 21st century – my view”

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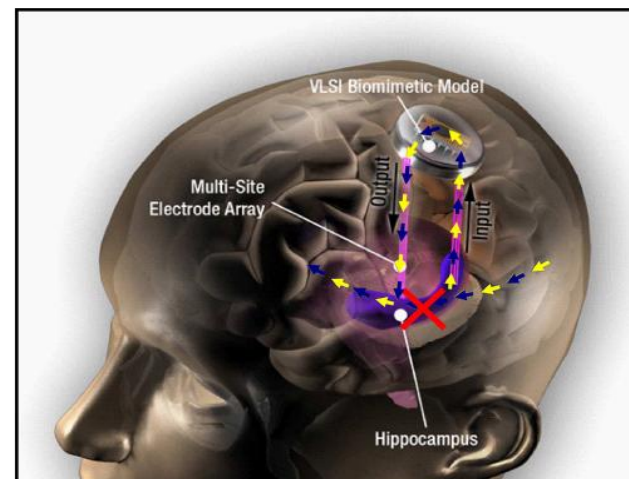
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 **IEEE**



# Medical Electronics – lecture outline

## Introduction:

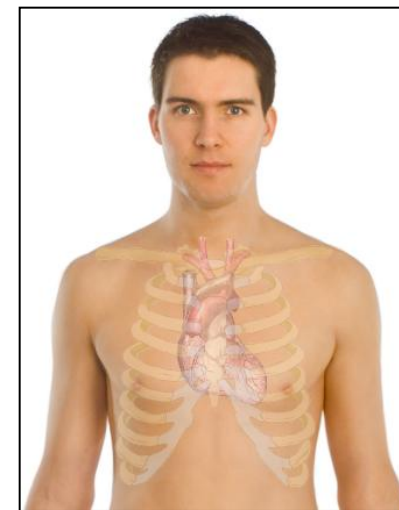
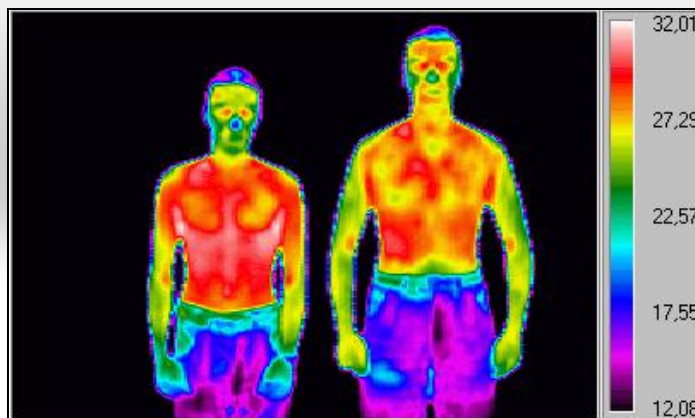
- biomedical engineering – history, definition
- human anatomy and physiology (brief review)
- patient safety

## Biomedical instrumentation:

- ECG, EEG, EMG, EOG, and others
- transducers,
- measuring, recording, monitoring and therapy

## Imaging systems:

- RTG
- MRI and fMRI,
- USG,
- Thermal imaging



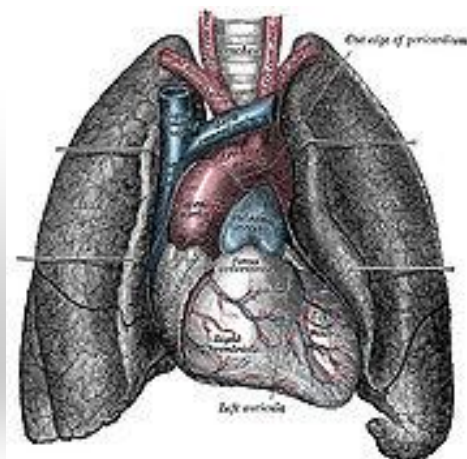
Insulin pump

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# Anatomy and physiology of the human – brief review\*

The science of structure of the living body and its functions is known as:

## Anatomy and Physiology

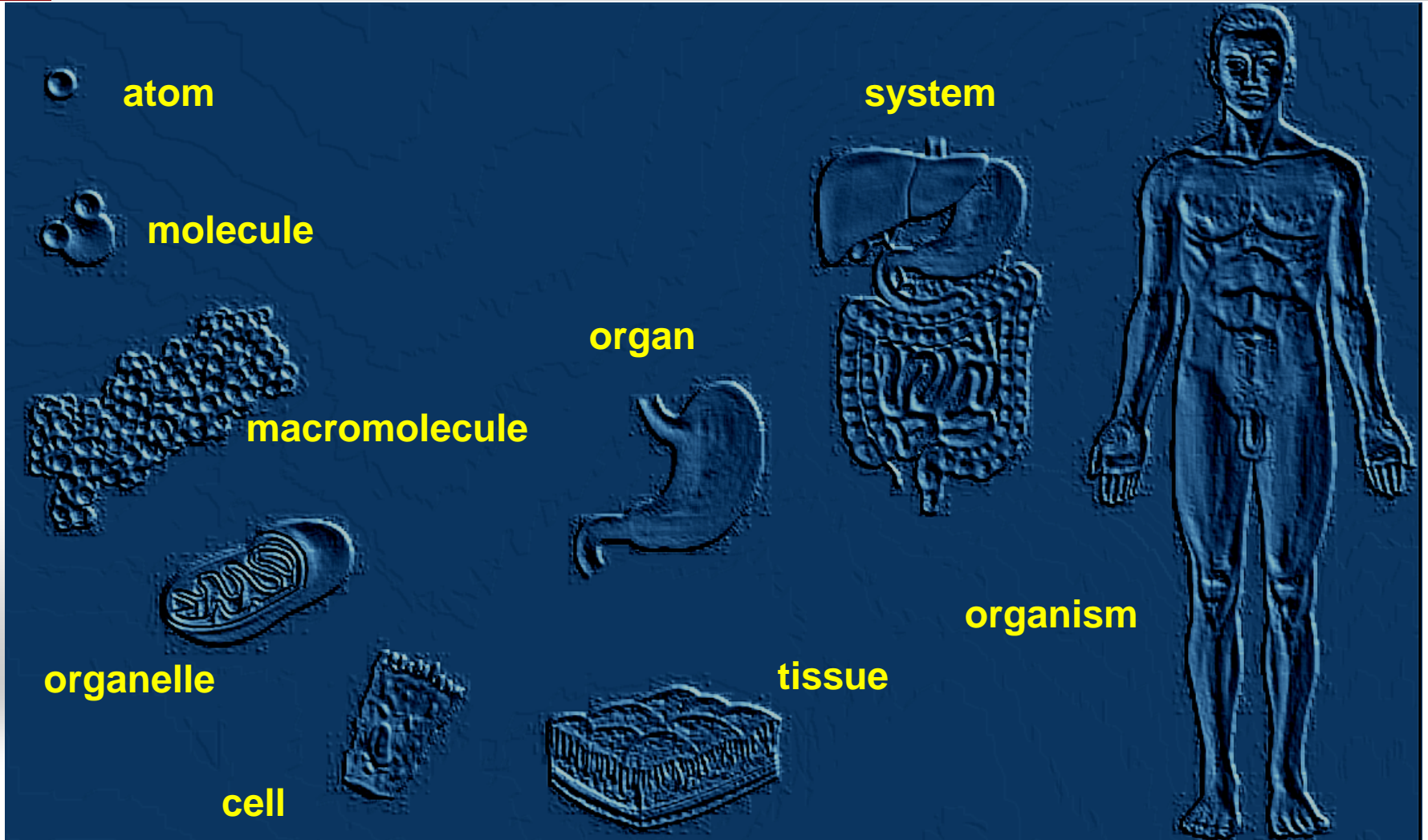


[www.youtube.com/watch?feature=endscreen&v=GnpLm9fzYxU&NR=1](http://www.youtube.com/watch?feature=endscreen&v=GnpLm9fzYxU&NR=1)

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# Anatomy – levels of organization



From dr Cyprain Wolski's lecture: Anatomy and physiology

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# Organ systems

The **organs** of the body work together in **systems** which are usually divided into five functional categories\*:

- ❑ **protection**
- ❑ **support and movement**
- ❑ **integration and coordination**
- ❑ **maintenance of the body**
- ❑ **reproduction and development**



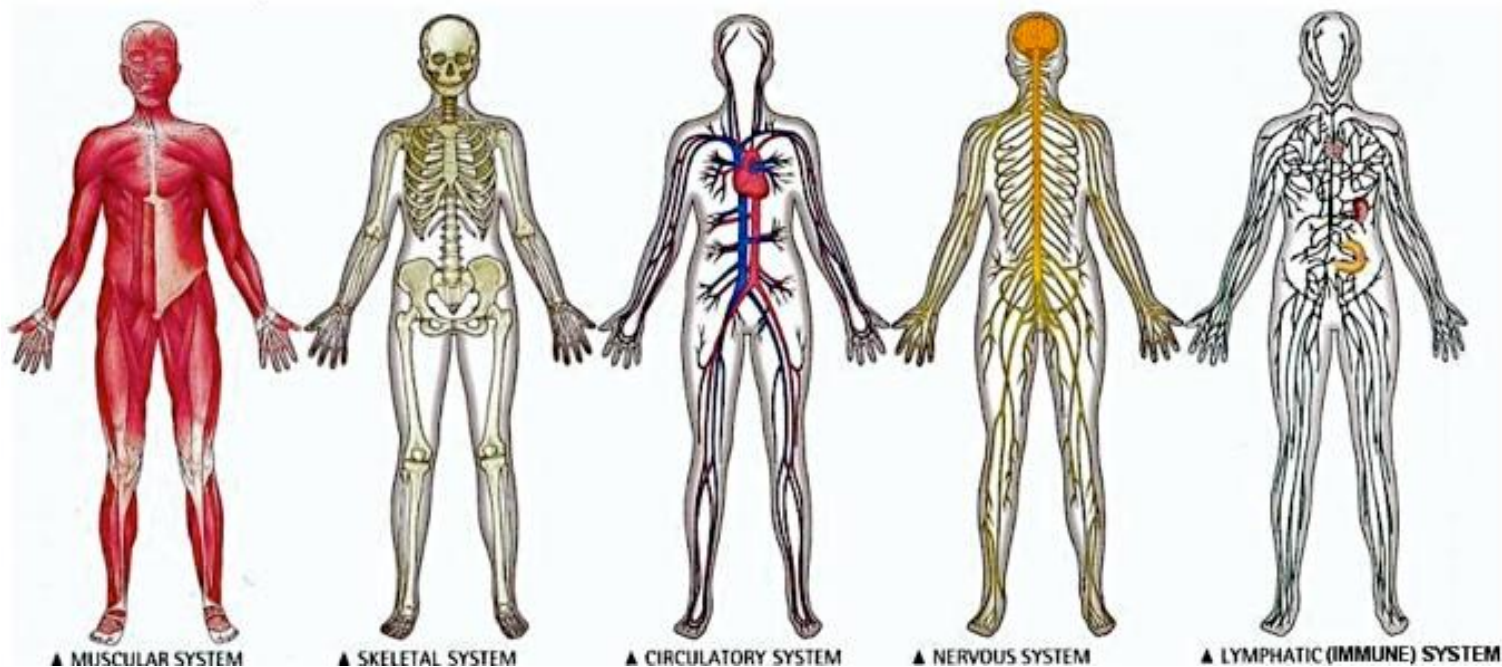
\*) From dr Cyprain Wolski's lecture: Anatomy and physiology

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# Complexity of human body

<http://www.as.edu.au>



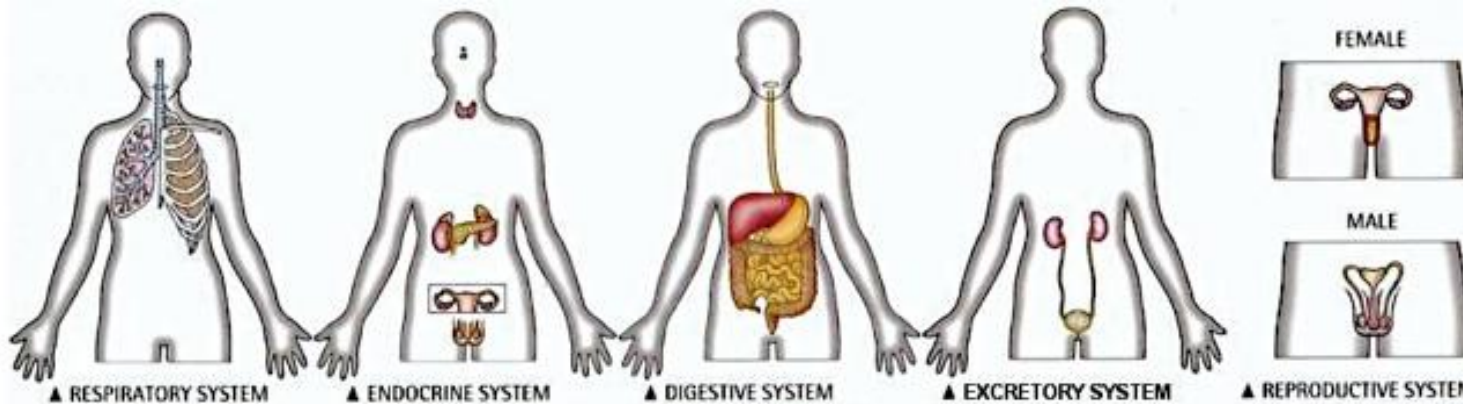
▲ MUSCULAR SYSTEM

▲ SKELETAL SYSTEM

▲ CIRCULATORY SYSTEM

▲ NERVOUS SYSTEM

▲ LYMPHATIC (IMMUNE) SYSTEM



▲ RESPIRATORY SYSTEM

▲ ENDOCRINE SYSTEM

▲ DIGESTIVE SYSTEM

▲ EXCRETORY SYSTEM

▲ REPRODUCTIVE SYSTEM

FEMALE



MALE



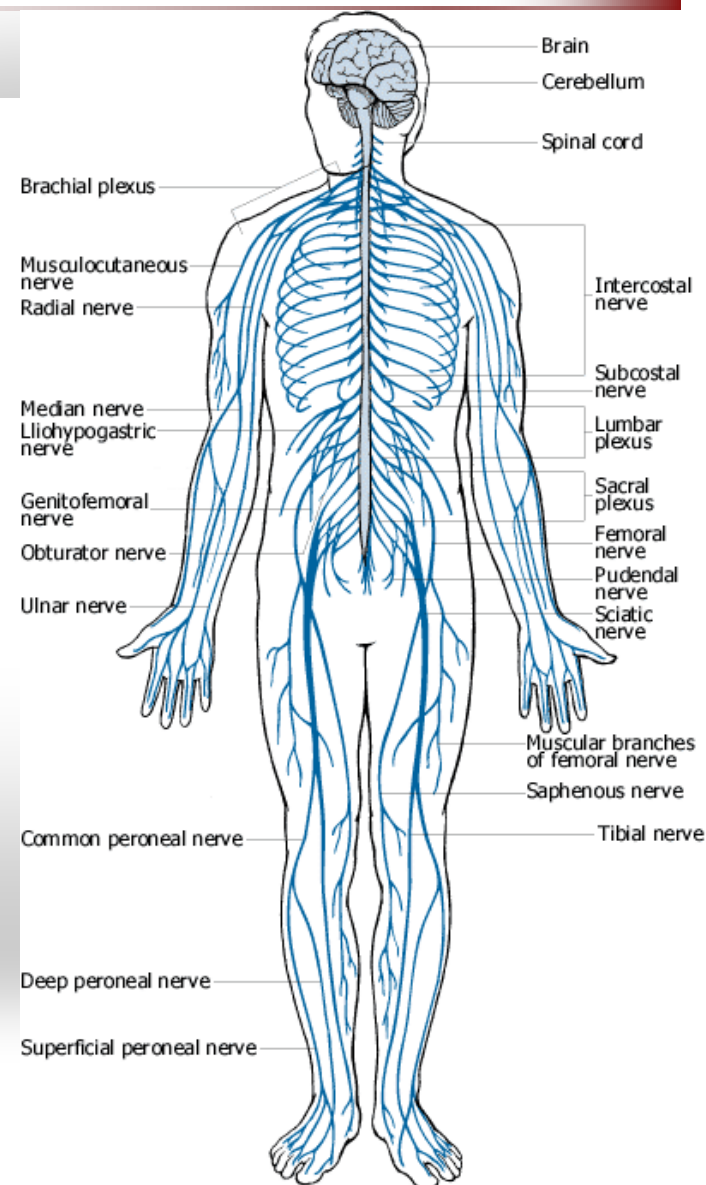


## Nervous system (Wikipedia)

The [nervous system](#) consists of the [central nervous system](#) (which is the [brain](#) and [spinal cord](#)) and [peripheral nervous system](#). The brain is the organ of thought, emotion, and sensory processing, and serves many aspects of communication and control of various other systems and functions. The [special senses](#) consist of [vision](#), [hearing](#), [taste](#), and [smell](#). The [eyes](#), [ears](#), [tongue](#), and [nose](#) gather information about the body's environment.

Clinical study: [neuroscience](#), [neurology](#) (disease), [psychiatry](#) (behavioral), [ophthalmology](#) (vision), [otolaryngology](#) (hearing, taste, smell)

### Integration and coordination



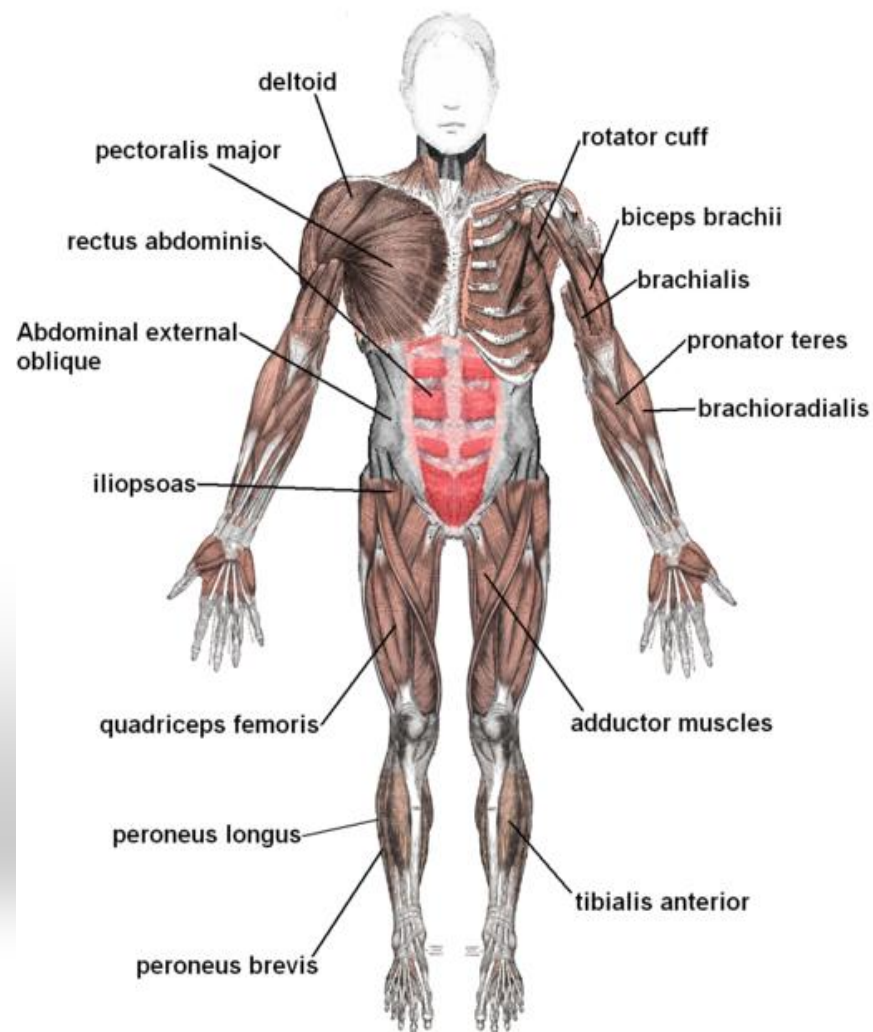


# Musco-skeletal system (Wikipedia)

The [musculoskeletal system](#) consists of the [human skeleton](#) (which includes [bones](#), [ligaments](#), [tendons](#), and [cartilage](#)) and attached [muscles](#). It gives the body basic structure and the ability for movement. In addition to their structural role, the larger bones in the body contain [bone marrow](#), the site of production of blood cells. Also, all bones are major storage sites for [calcium](#) and [phosphate](#).

Clinical study: [osteology](#) (skeleton),  
[orthopedics](#) (bone disorders)

**Support and movement**



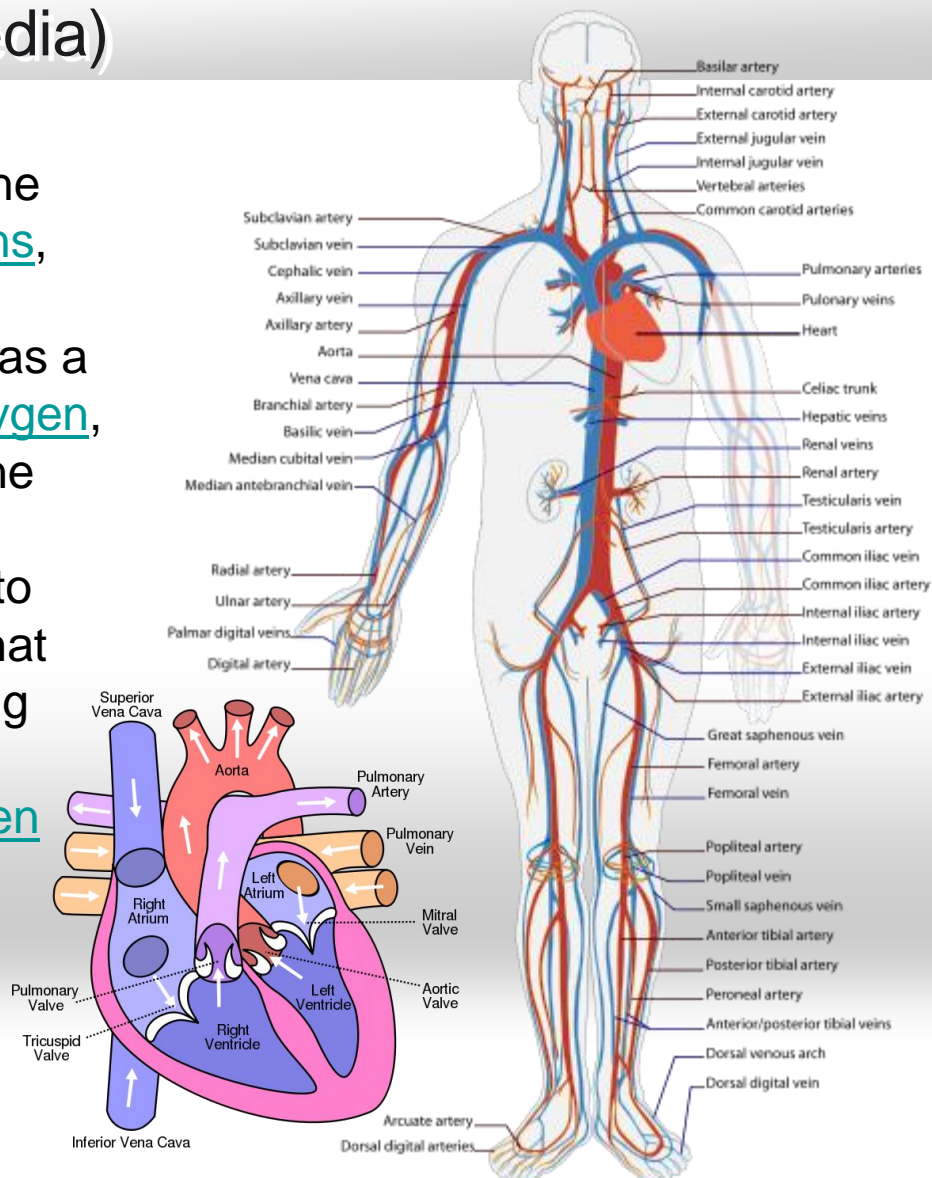


# Circulatory system (Wikipedia)

The **circulatory system** consists of the **heart** and blood vessels (**arteries**, **veins**, **capillaries**). The heart propels the circulation of the **blood**, which serves as a "transportation system" to transfer **oxygen**, fuel, nutrients, waste products, immune cells, and signalling molecules (i.e., **hormones**) from one part of the body to another. The **blood** consists of fluid that carries **cells** in the circulation, including some that move from tissue to blood vessels and back, as well as the **spleen** and **bone marrow**.

Clinical study: **cardiology** (heart),  
**hematology** (blood)

**Maintenance of the body**



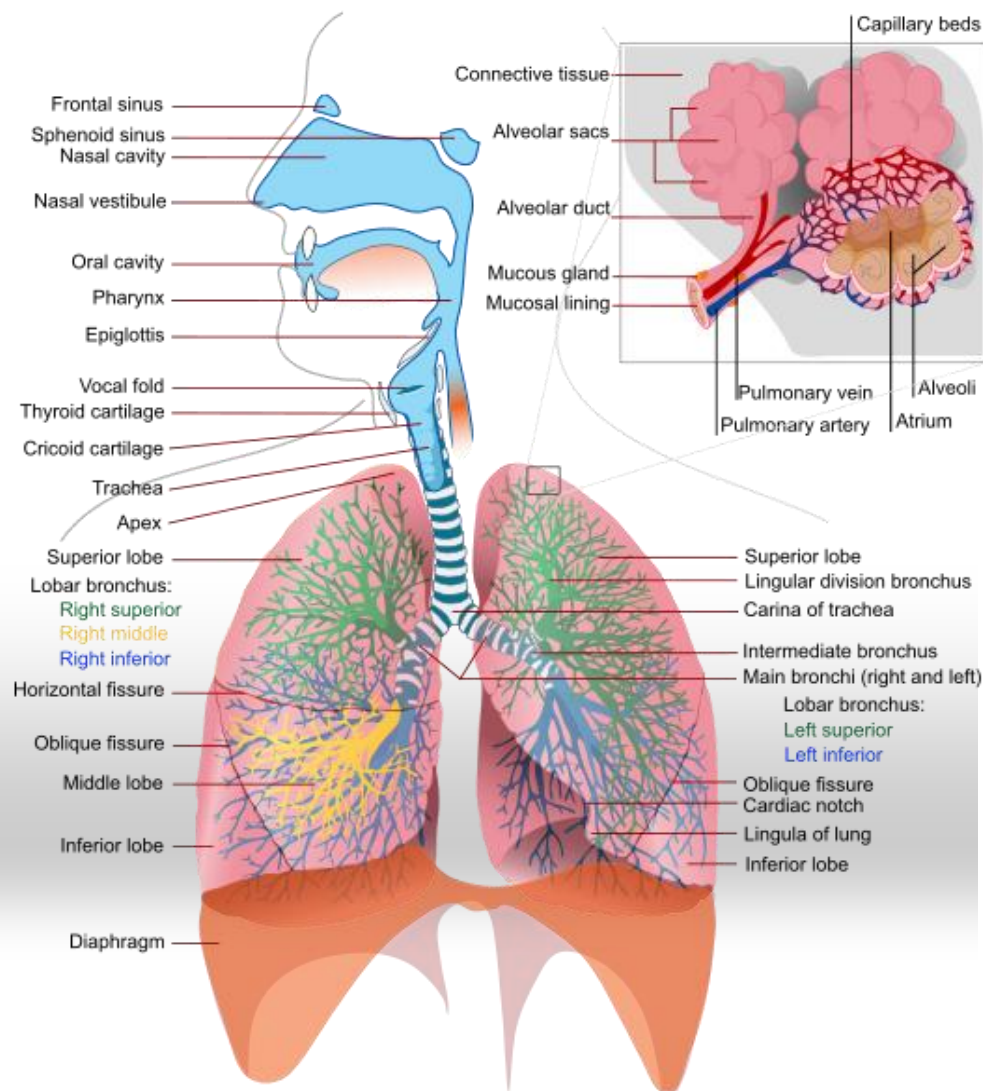


# Respiratory system (Wikipedia)

The [respiratory system](#) consists of the [nose](#), [nasopharynx](#), [trachea](#), and [lungs](#). It brings oxygen from the air and excretes [carbon dioxide](#) and [water](#) back into the air.

Clinical study: [pulmonology](#).

**Maintenance of the body**



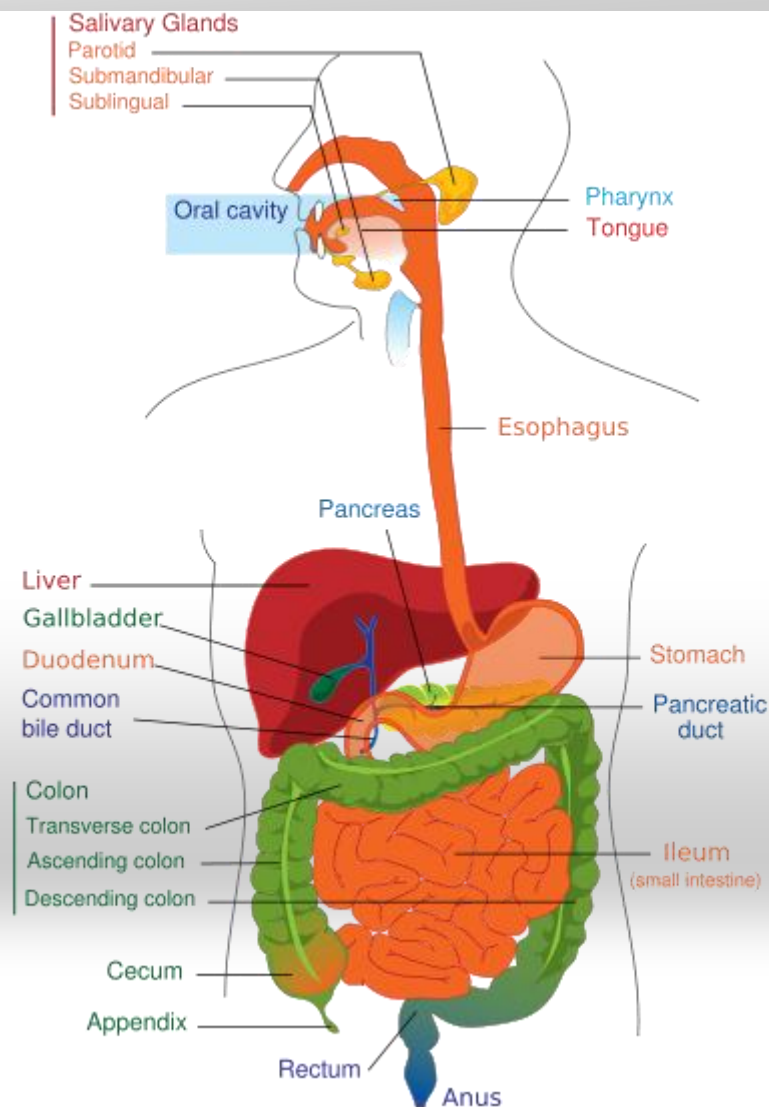


# Digestive system (Wikipedia)

The [gastrointestinal system](#) consists of the [mouth](#), [esophagus](#), [stomach](#), [gut](#) ([small](#) and [large](#) [intestines](#)), and [rectum](#), as well as the [liver](#), [pancreas](#), [gallbladder](#), and [salivary glands](#). It converts food into small, nutritional, non-toxic [molecules](#) for distribution by the circulation to all tissues of the body, and excretes the unused residue.

Clinical study: [gastroenterology](#) .

**Maintenance of the body**



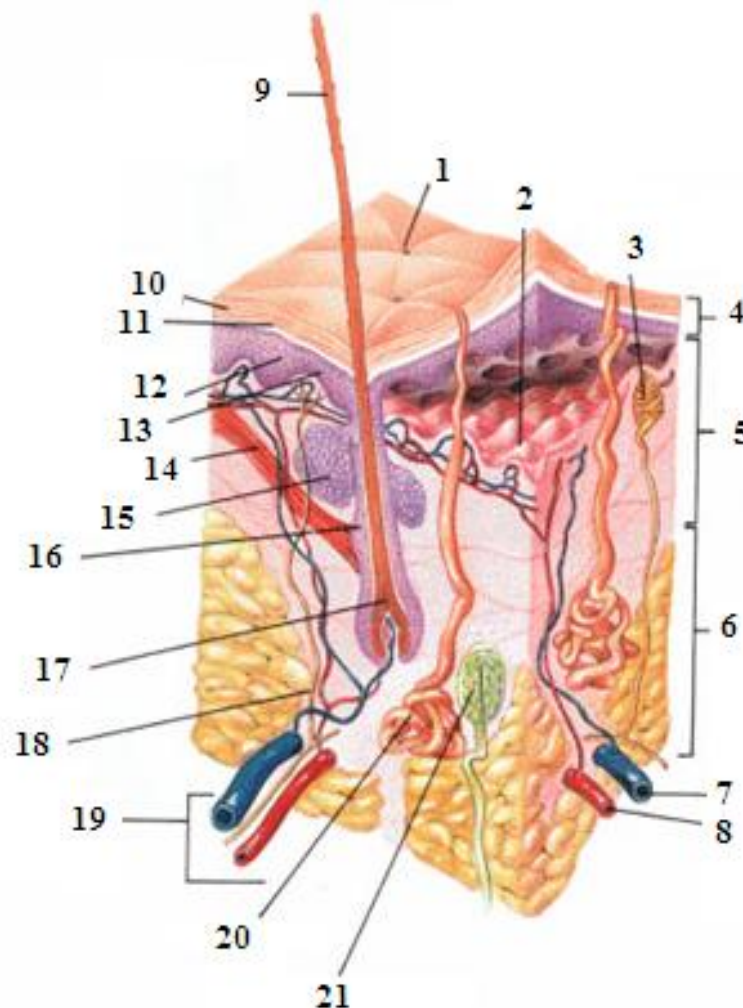


# Integumentary system (Wikipedia)

The [integumentary system](#) consists of the covering of the body (the [skin](#)), including [hair](#) and [nails](#) as well as other functionally important structures such as the [sweat glands](#) and [sebaceous glands](#). The skin provides containment, structure, and protection for other organs, but it also serves as a major sensory interface with the outside world.

Clinical study: [dermatology](#)

**Protection**



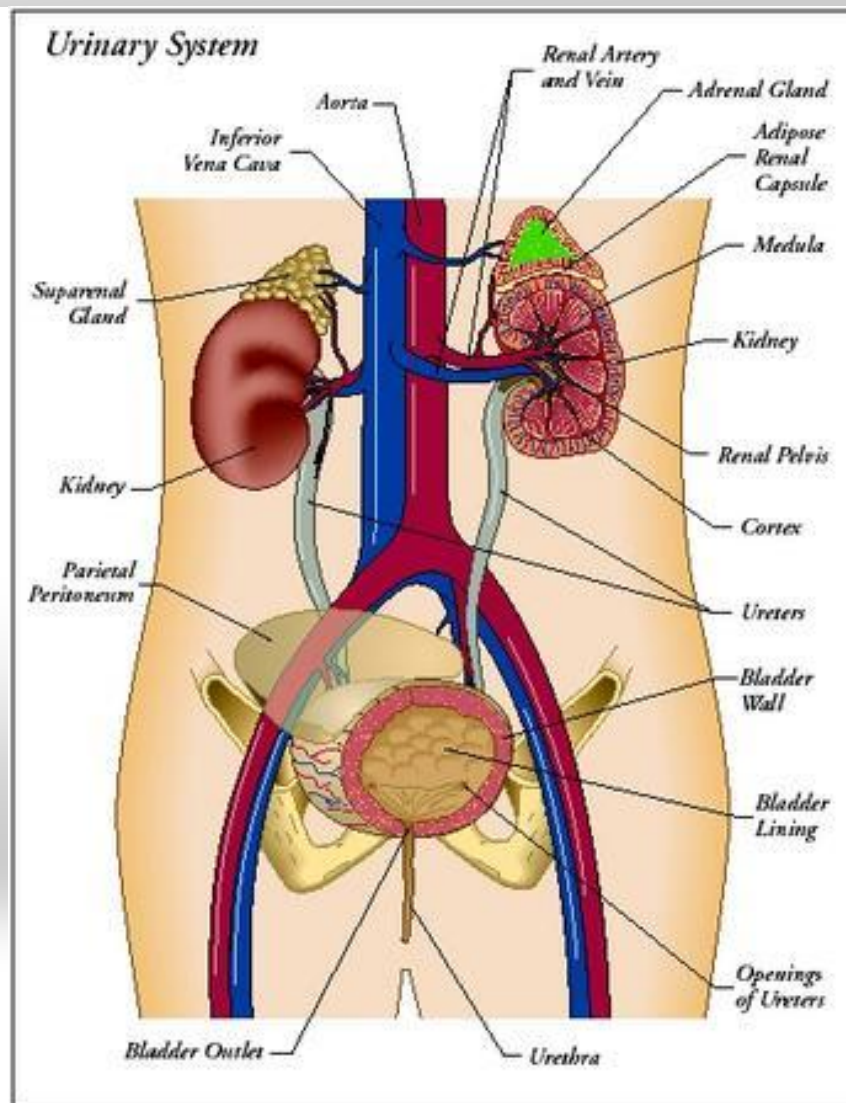


# Urinary system (Wikipedia)

The urinary system consists of the kidneys, ureters, bladder, and urethra. It removes water from the blood to produce urine, which carries a variety of waste molecules and excess ions and water out of the body.

Clinical study: nephrology (function),  
urology (structural disease)

**Maintenance of the body**



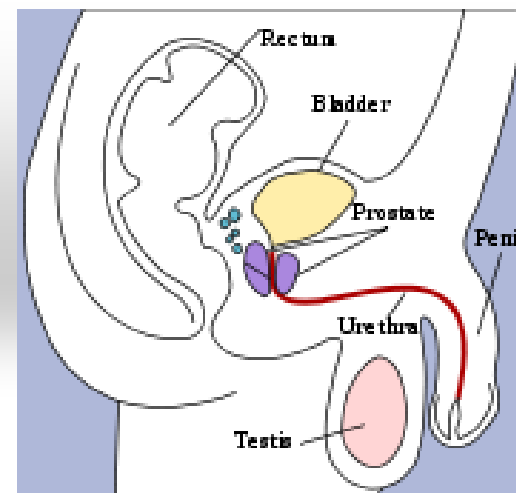
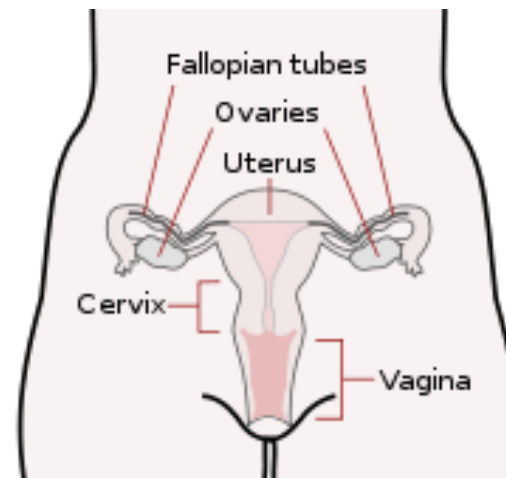


## Reproductive system (Wikipedia)

The [reproductive system](#) consists of the [gonads](#) and the internal and external [sex organs](#). The reproductive system produces [gametes](#) in each [sex](#), a mechanism for their combination, and a nurturing environment for the first 9 months of development of the offspring.

Clinical study: [gynecology](#) (women), [andrology](#) (men), [sexology](#) (behavioral aspects) [embryology](#) (developmental aspects)

### Reproduction and development



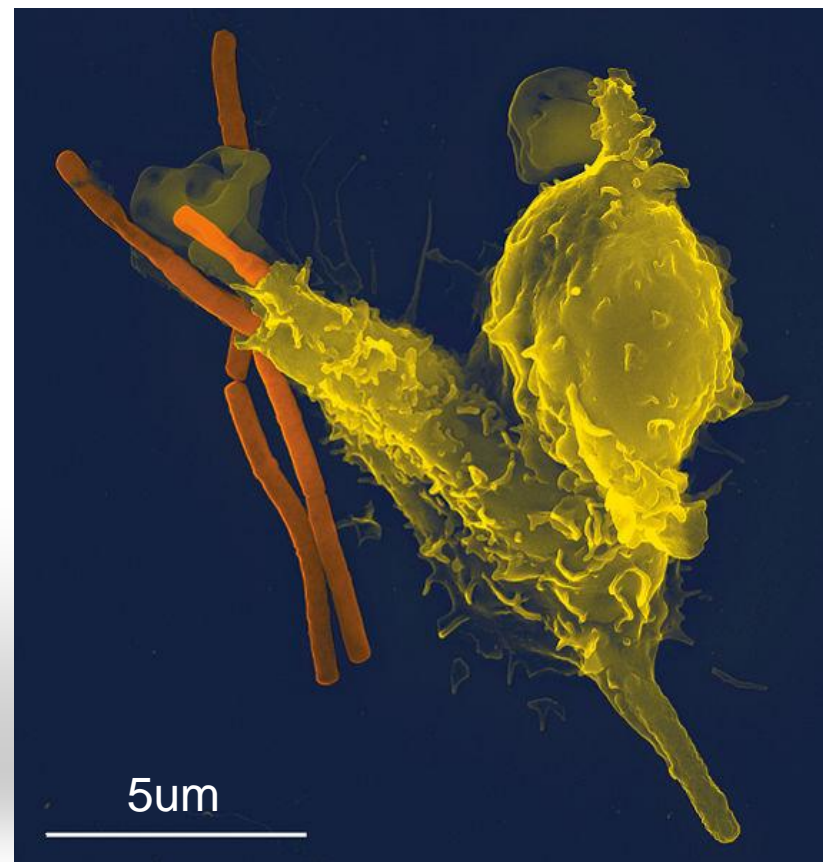


## Immune system (Wikipedia)

The [immune system](#) consists of the [white blood cells](#), the [thymus](#), [lymph nodes](#) and [lymph](#) channels, which are also part of the [lymphatic system](#). The immune system provides a mechanism for the body to distinguish its own cells and tissues from alien cells and substances and to neutralize or destroy the latter by using specialized proteins such as [antibodies](#), [cytokines](#), and [toll-like receptors](#), among many others.

Clinical study: [immunology](#)

**Maintenance of the body  
Protection**



A scanning electron microscope image of a single neutrophil (yellow), engulfing anthrax bacteria (orange).



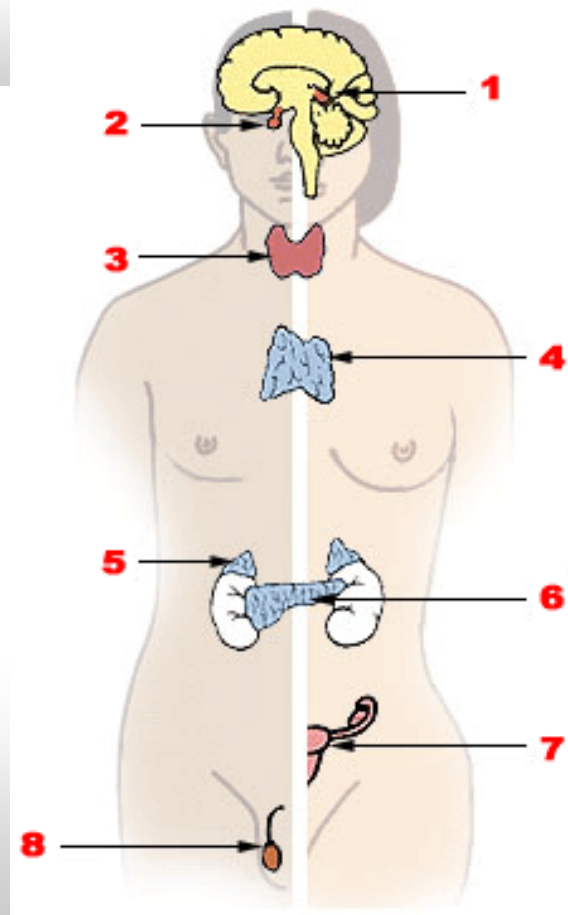


## Endocrine system (Wikipedia)

The [endocrine system](#) consists of the principal endocrine glands: the [pituitary](#), [thyroid](#), [adrenals](#), [pancreas](#), [parathyroids](#), and [gonads](#), but nearly all organs and tissues produce specific endocrine [hormones](#) as well. The endocrine system controls body processes that happen slowly, e.g. cell growth. Hormone levels are influenced by stress, infection, and variations in the balance of fluid and minerals in blood.

Clinical study: [endocrinology](#)

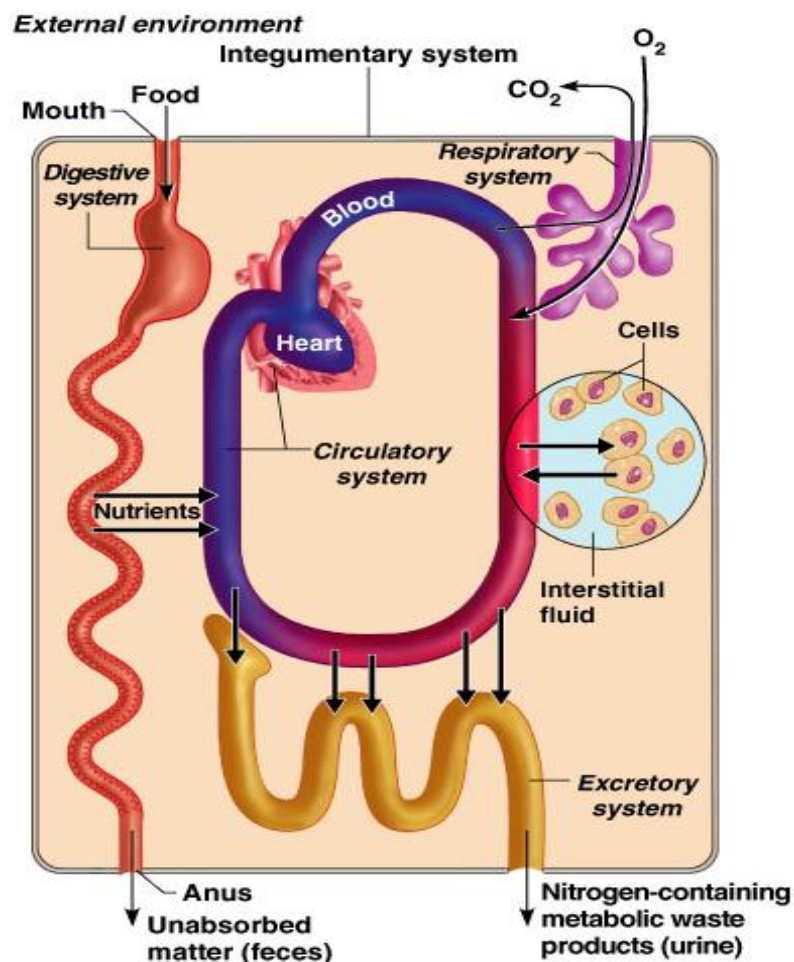
### Integration and coordination



Major endocrine glands. ([Male](#) on the left, [female](#) on the right.) 1. [Pineal gland](#)  
2. [Pituitary gland](#) 3. [Thyroid gland](#)  
4. [Thymus](#) 5. [Adrenal gland](#) 6. [Pancreas](#)  
7. [Ovary](#) 8. [Testes](#)



# Organ systems Interrelationship\*



- ❑ The integumentary system protects the body from the external environment
- ❑ Digestive and respiratory systems, in contact with the external environment, take in nutrients and oxygen
- ❑ Nutrients and oxygen are distributed by the blood
- ❑ Metabolic wastes are eliminated by the urinary and respiratory systems

\*) From dr Cyprain Wolski's lecture: Anatomy and physiology

*Paweł Strumiłło*



<http://msjensen.cehd.umn.edu/Webanatomy>

## Organ Systems 1

## QUIZ

1.	This system transforms food particles into a size that can be absorbed.	<input type="text"/>	<b>Make a selection</b> Circulatory system Digestive system Endocrine system Integumentary system Lymphatic system Muscular system Reproductive system Respiratory system Skeletal system Urinary system
2.	This is the most superficial organ system. (Clue: Superficial Vs. Deep)	<input type="text"/>	
3.	The organ system that secretes hormones, i.e., chemical messengers.	<input type="text"/>	
4.	This system helps the body fight disease.	<input type="text"/>	
5.	This system removes waste products from the blood and it assists in maintaining water and electrolyte balance.	<input type="text"/>	
6.	The parts of this system provides frameworks and protective shields for softer tissues, serve as attachments for muscles, and is also involved in the production of blood.	<input type="text"/>	
7.	This system provides the forces that produces body movements.	<input type="text"/>	
8.	This system provides for the intake and output of air and for the exchange of gases between blood and air.	<input type="text"/>	
9.	The system that transports items such as oxygen, carbon dioxide, hormones, glucose, etc. through the body.	<input type="text"/>	
10.	The system that enables the production of offspring. (CLUE: Where do babies come from?)	<input type="text"/>	

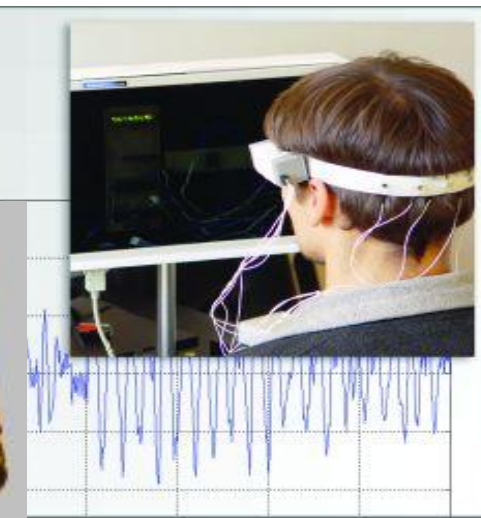
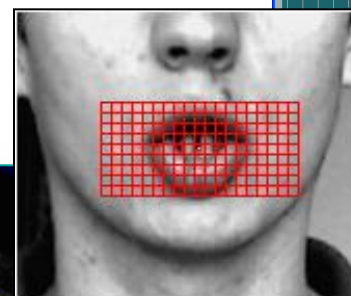
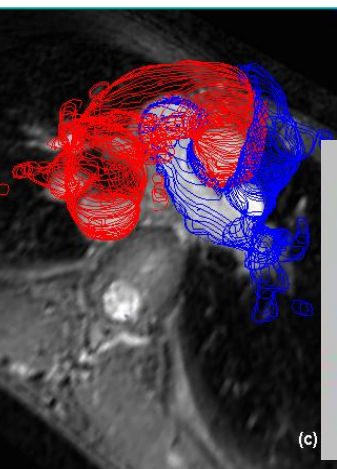
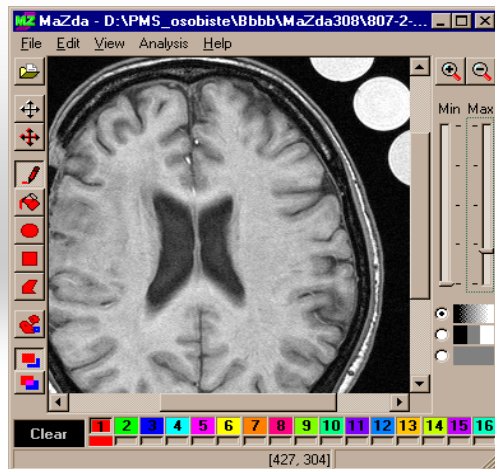
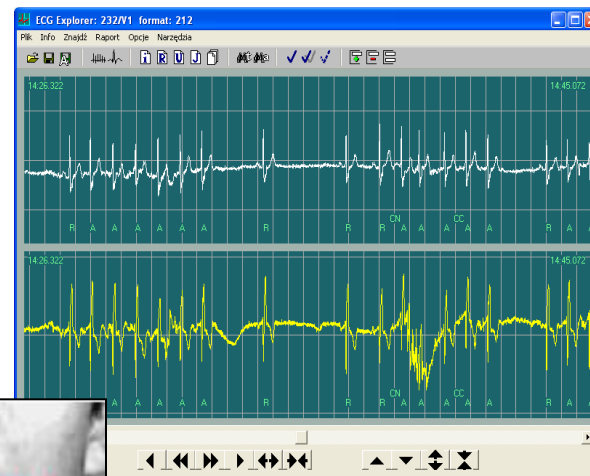
Score Test

Clear Form

*Paweł Strumiłło*

# Medical Electronics Division - research

- ❑ *processing and analysis of **biomedical signals** (ECG, EEG) and **images** (CT, MRI)*
- ❑ *hardware implementations (FPGA, ASIC)*
- ❑ *computational intelligence in medicine (biometry, diagnosis support,*  
**human-machine interfaces,**  
**systems aiding the disabled)**



Paweł Strumiłło

# Human-Computer Interfaces for aiding the disabled

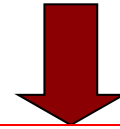
## **Physical disabilities:**

- ❑ *Brain-Computer Interface*
- ❑ *Eyeblink controlled computer*

*2 completed research grants  
and  
3 grants in progress  
2 projects being deployed*

## **Hearing impairment:**

- ❑ *Sign language recognition*
- ❑ *„Lip-reading” system*



*Interdisciplinary research*

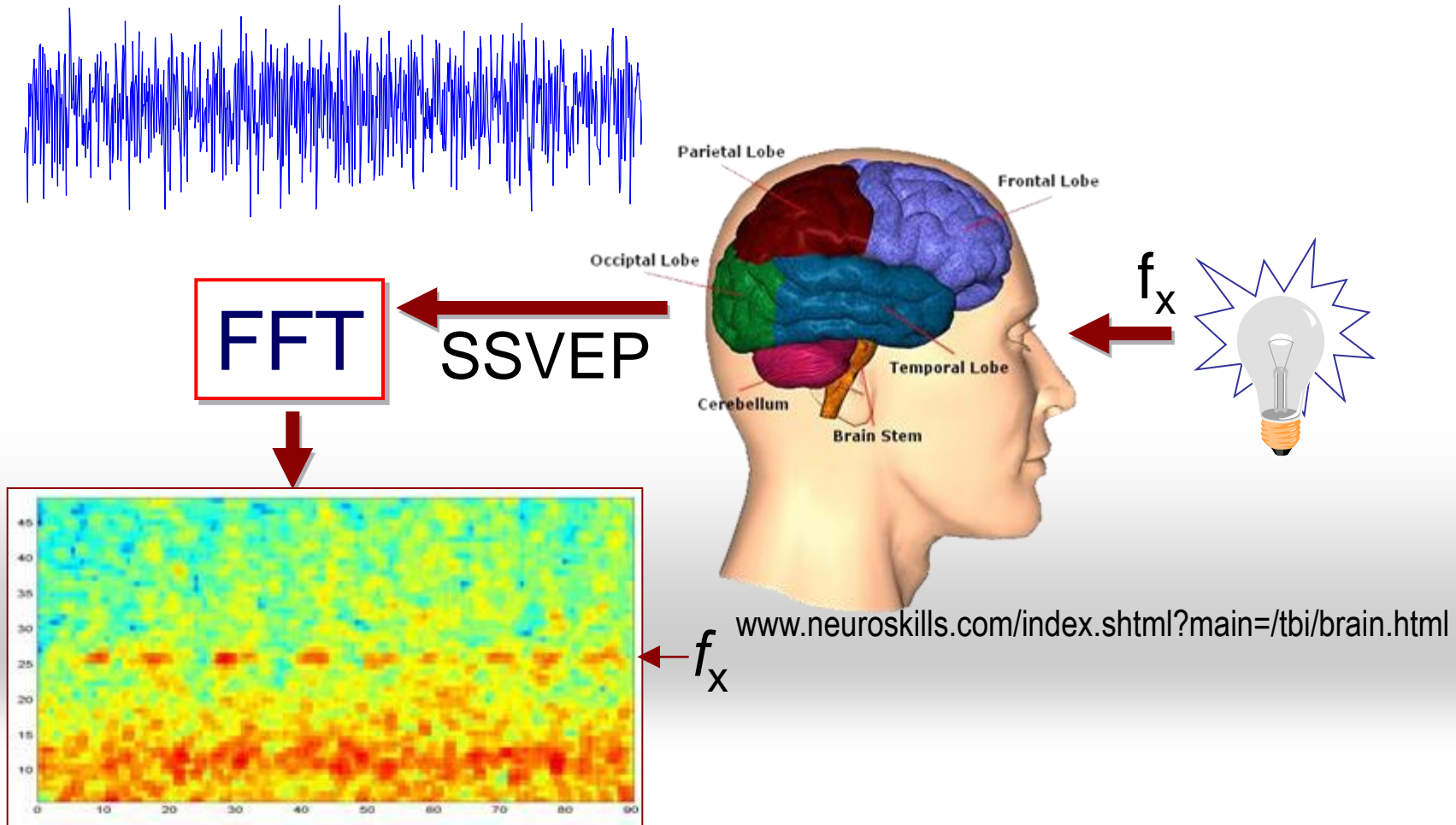
## **Visual impairment:**

- ❑ *Auditory display system (stereovision -> 3D audio)*
- ❑ *Remote navigation (video transmission, GPS, digital maps)*
- ❑ *Applications for mobile devices (sound-enabled menu)*

*Paweł Strumiłło*



# Brain Computer Interface



Paweł Strumiłło

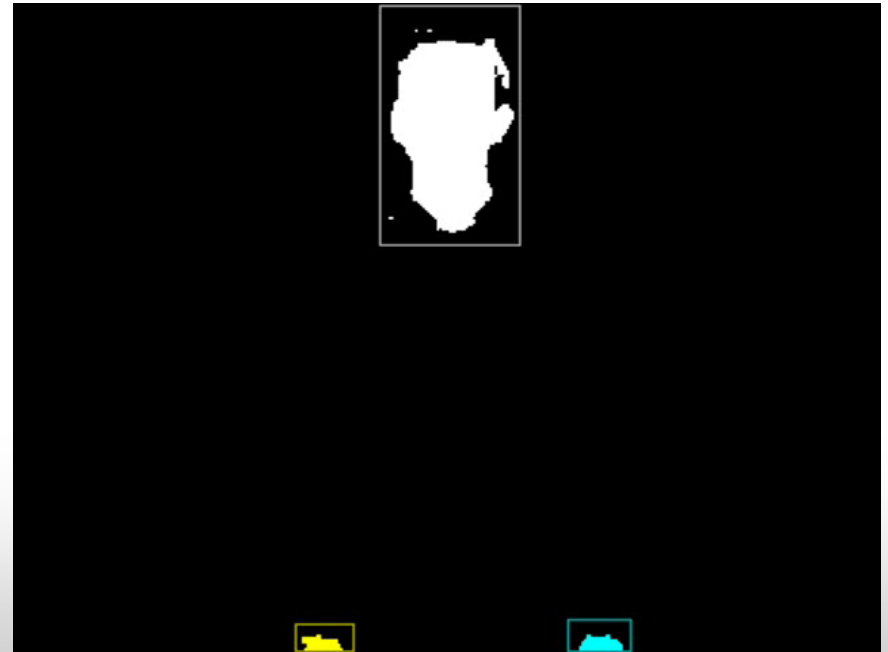


# Eyeblink controlled interface

The screenshot illustrates an eyeblink controlled interface. It shows a desktop environment with a blue background and several icons. A window titled "Unregistered HyperCam 2" displays a grayscale image of a person's face with two red circles around the eyes, indicating eye tracking. Another window titled "Blink Browser" displays the tp.pl website. The website features a search bar, a login section, and several promotional banners. At the bottom of the desktop, there is a control panel with buttons for "TP SA", "Onet.pl", "NEOSTRADA.PL", and "Przeglądarka". The mouse cursor is pointing at the "Przeglądarka" button.

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# Sign language recognition

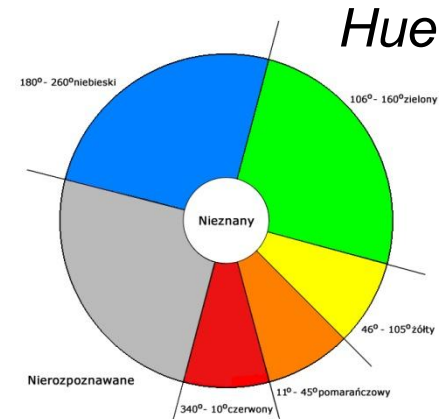
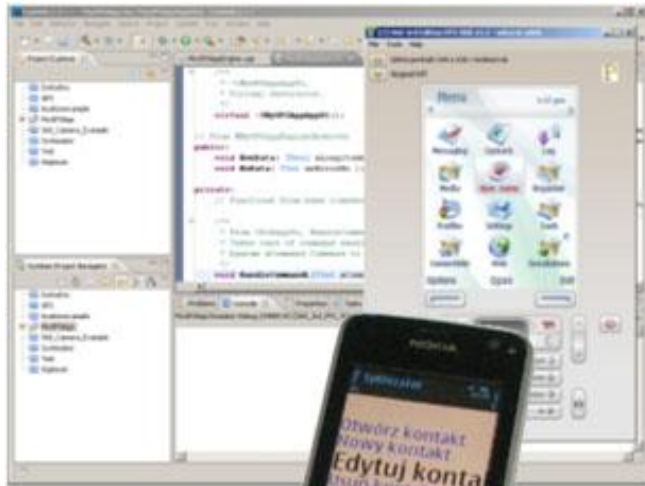


- *skin detection (Bayes classifier)*
- *the Kalman filter for tracking*

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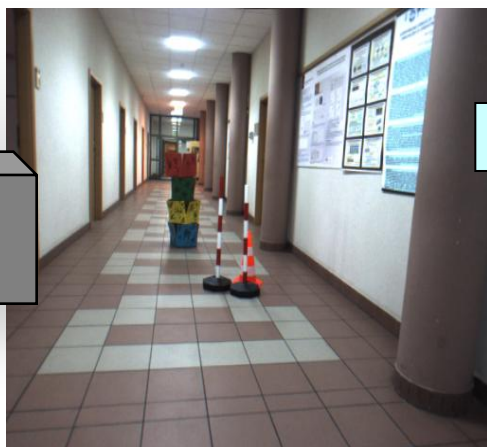
# Smartphone for the visually impaired



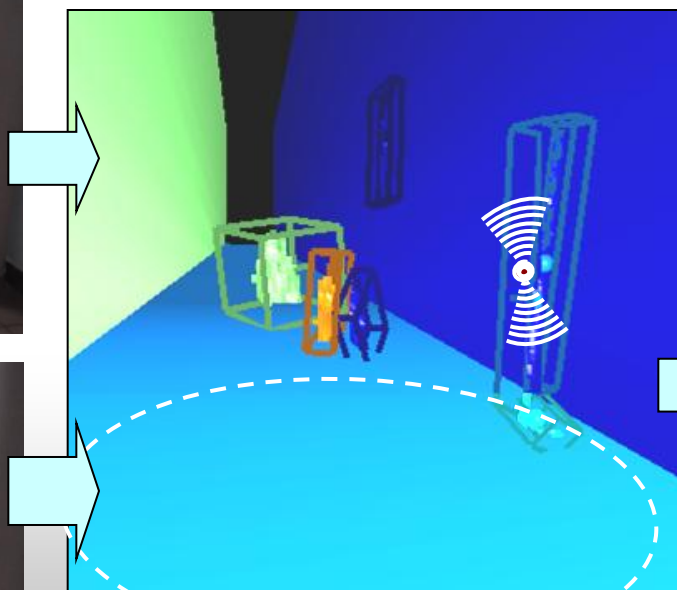
- *Eclipse- and CodeWarrior-based development environments (Carbide C++)*
- *SDK, phone emulator*



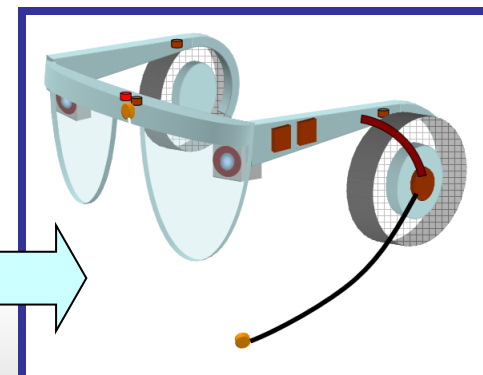
# Auditory scene display



*Stereovision*



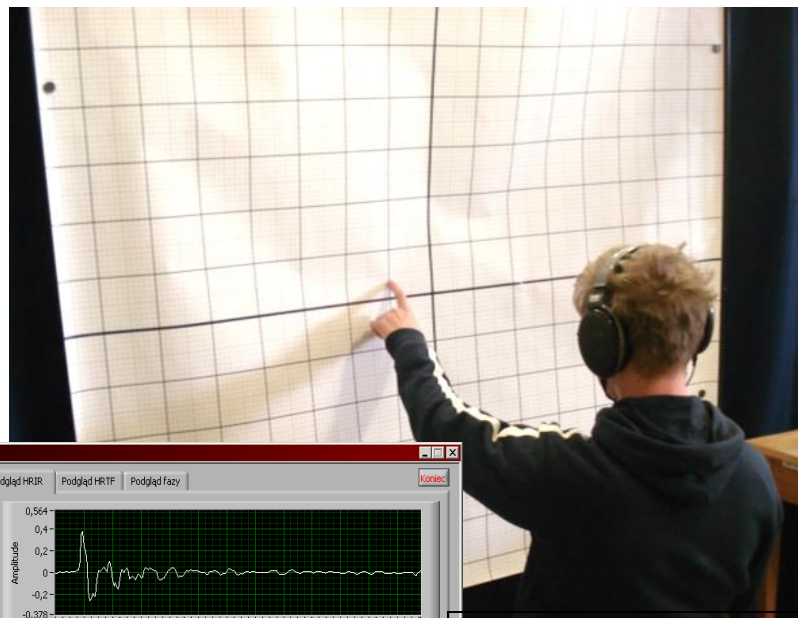
*Segmented 3D scene*



*3D audio*

**P. Skulimowski** – „*Detection and tracking objects in video sequences for 3D scene auditory display*”, PhD, Lodz, 2009

# Spatial sound space - HRTF



**HRIR Converter**

Fs: 44100    Opis: Pomiar z charakterystykami odniesienia  
 Liczba próbek: 1024    Michał Bujacz  
 dzień=14

Liczba kątów - azymut: 72    Liczba kątów - wzniesienie: 16

Kąty - azymut:  
 180, 175, 170, 165, 160, 155, 150, 145, 140, 135, 130, 125, 120, 115, 110, 105, 100, 95, 90, 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, 15, 10, 5, 0, 355, 350, 345, 340, 335, 330, 325, 320.

Kąty - wzniesienie:  
 90, 81, 72, 63, 54, 45, 36, 27, 18, 9, 0, -9, -18, -27, -36, -45

Postęp wczytywania danych z pliku tekstowego

Otwórz

Srednica głowy [cm]: 14    Krok wzniesienia: 9  
 Zamienione kanały:    Krok azymutu: 5

Zapisz do SLAB

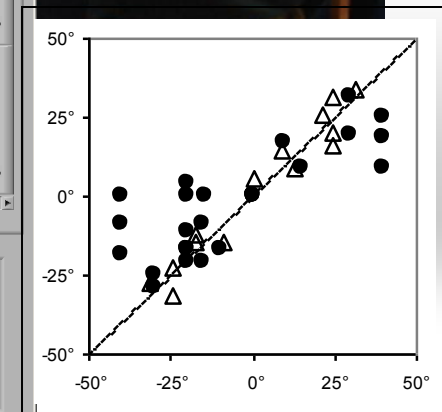
error out  
 status: source:    
 code: 30

Podgląd HRIR    Podgląd HRTF    Podgląd fazy

Amplitude vs Nr próbki (0-256)

Azymut: 0    Liczba wyświetlanych / zapisywanych próbek: 256    Filtr: rząd filtru: 2, f.dolna: 200, f.gorna: 10000

Wzniesienie: 0    Pokaż:  Suwak     Usuń martwy czas     Filtruj



Paweł Strumiłło

# Remote navigation for the visually impaired



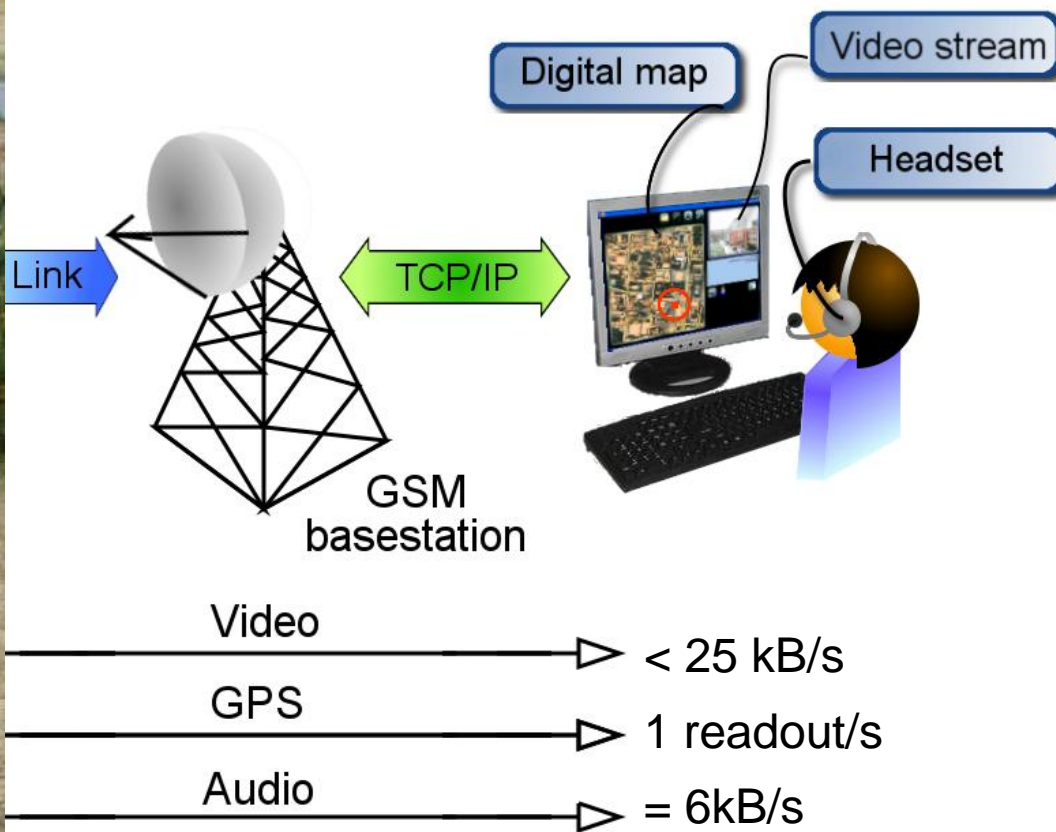
earphone

microphone

GPS

fish-eye lens camera

laptop

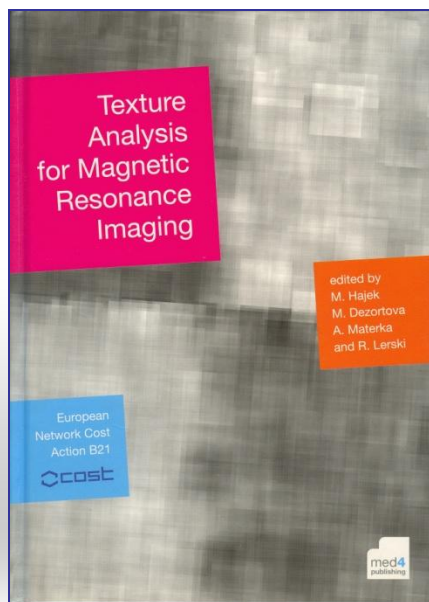


Paweł Strumiłło

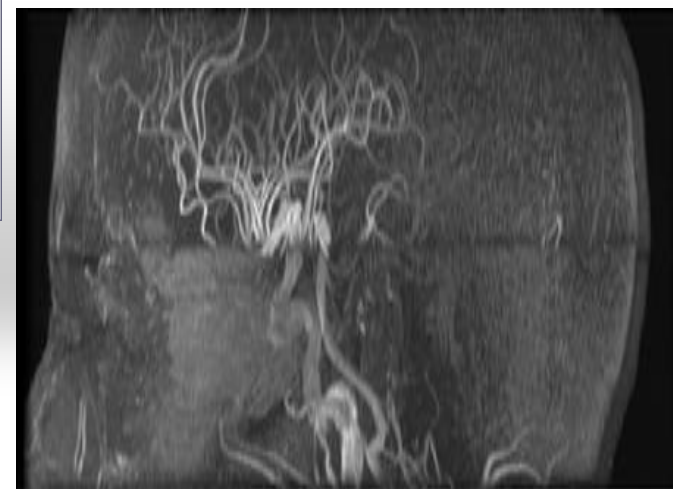
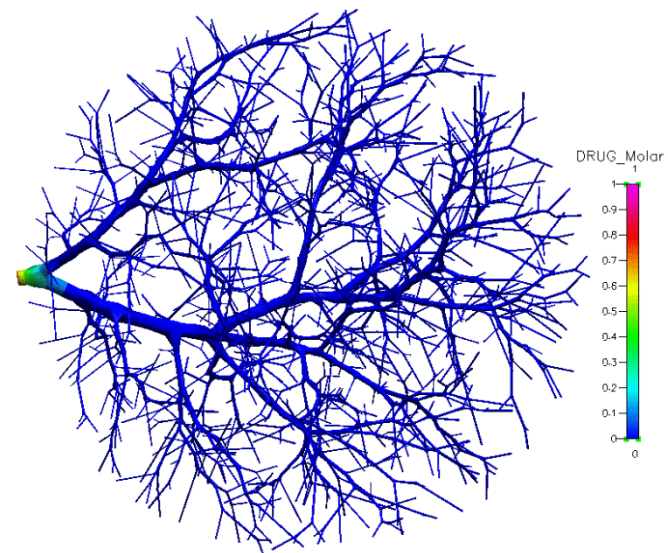




# Magnetic resonance image analysis



[www.eletel.p.lodz.pl/mazda/](http://www.eletel.p.lodz.pl/mazda/)

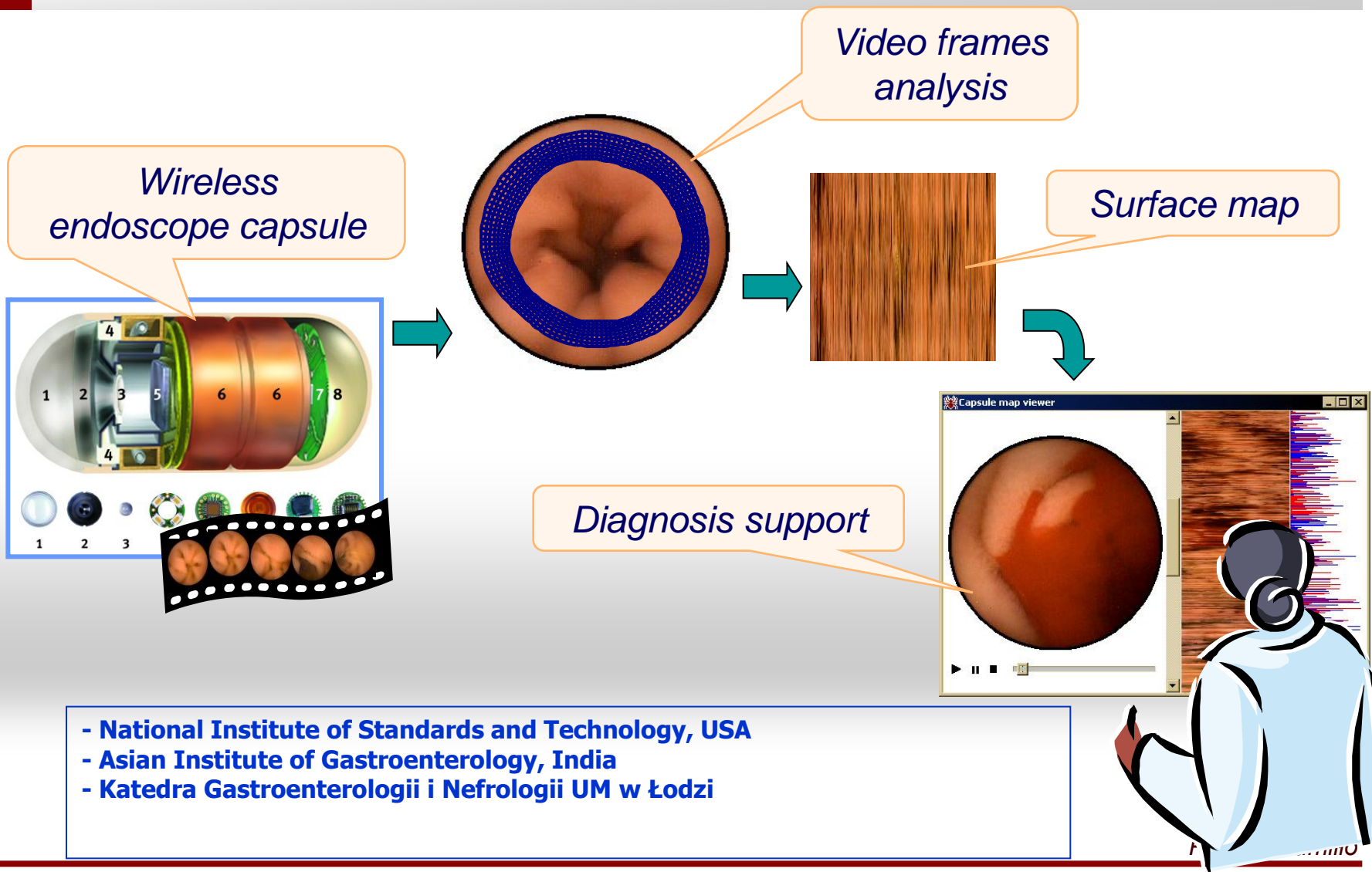


**2002-04:** COST B11 (18 partners)

**2004-07:** COST B21 (18 partners)

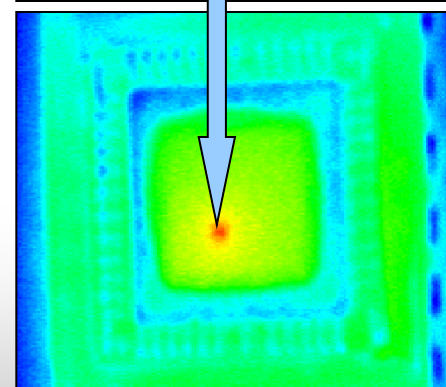
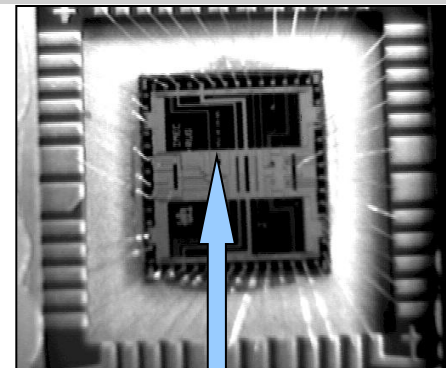
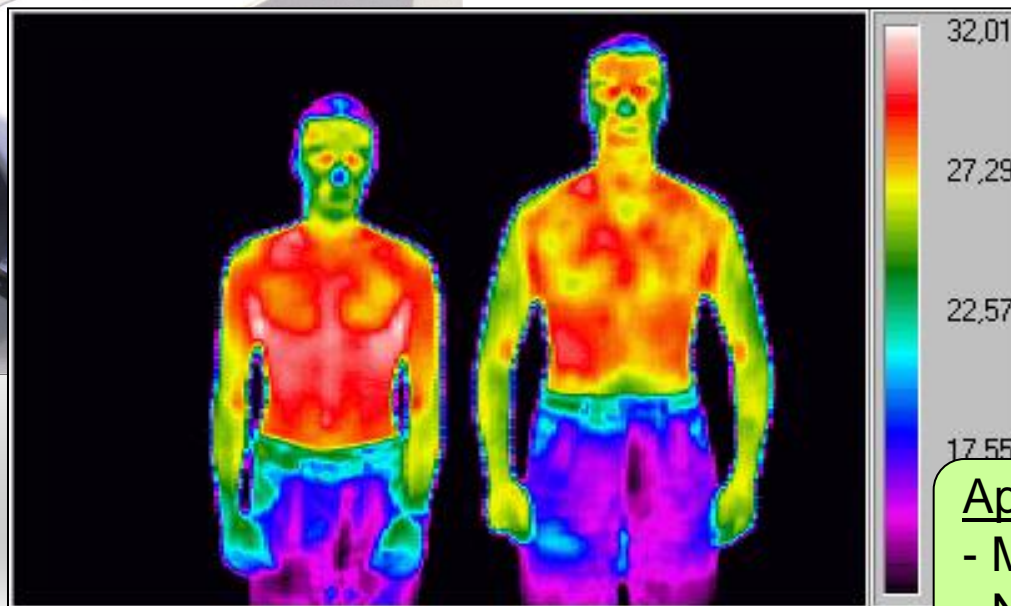
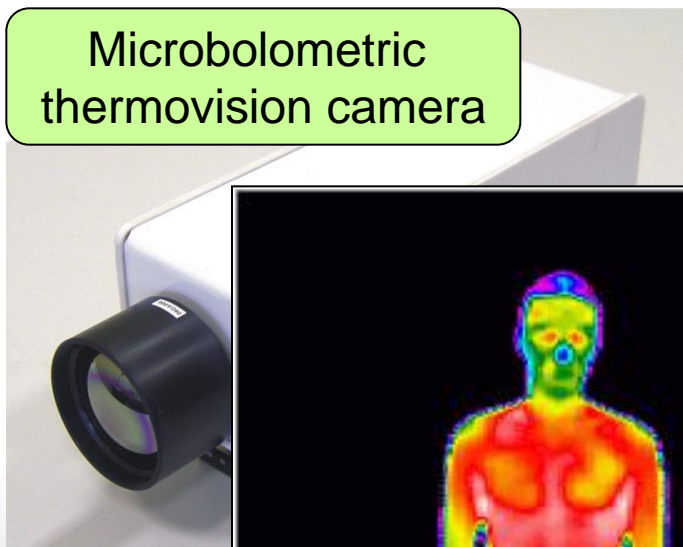
**2007-10:** DFG (2 partners)

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# Computed thermography systems

Microbolometric  
thermovision camera



## Applications

- Medical diagnosis
- Noninvasive testing
- Evaluation of heat loss in buildings, etc.

## Computed thomography group

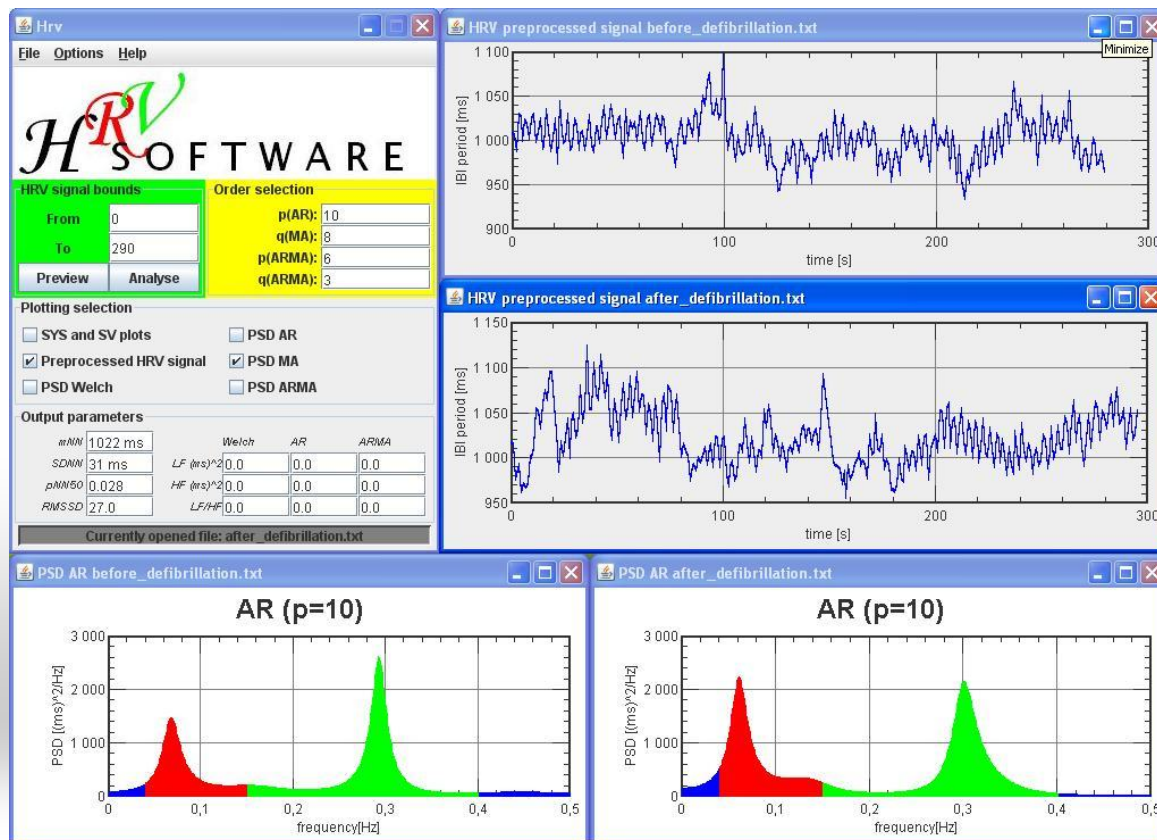
*Paweł Strumiłło*



# MSc thesis - example

Krzysztof Kudryński –  
„Heart rate analysis”  
(supervisor: P. Strumiłło)

Awarded first price in 2007 in  
the contest of best MSc's  
funded by the Association  
of Polish Electrical Engineers



Algorithm prototypes: **Matlab** → application: **Java**

Paweł Strumiłło

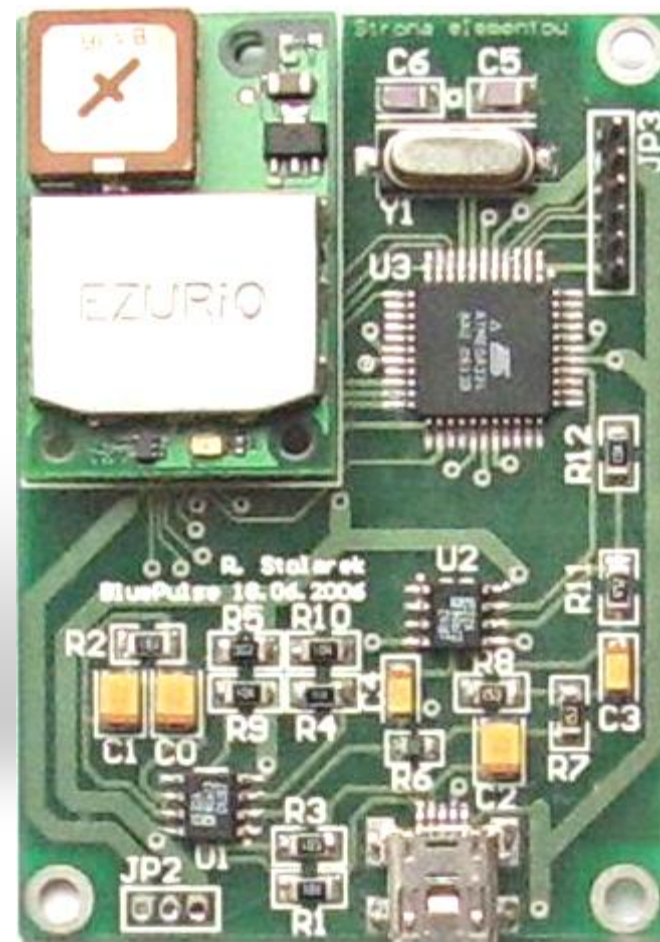
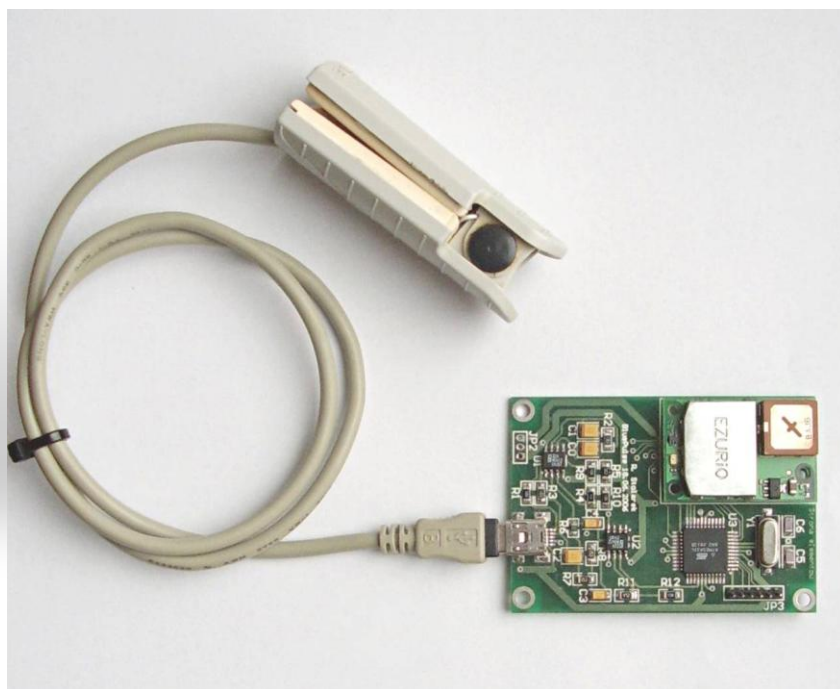


# MSc thesis - example

Remigiusz Stolarek –

**„A system for wireless transmission of human pulse”**

(supervisor: Piotr Romaniuk)



*Power Strumień*



## Introducing the Qualcomm Tricorder XPRIZE. A \$10 million competition to bring healthcare to the palm of your hand.

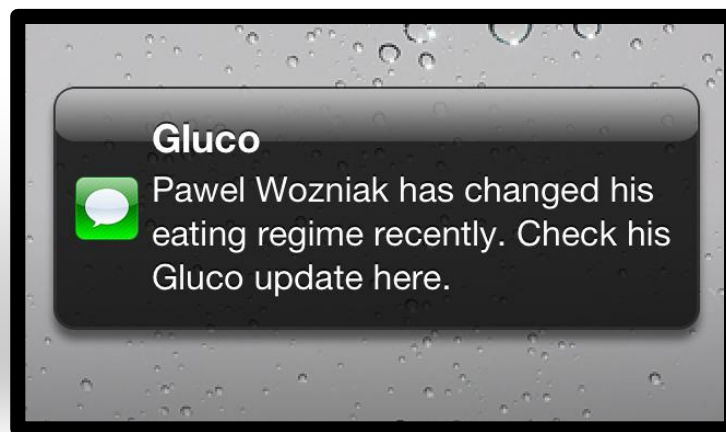
Imagine a portable, wireless device in the palm of your hand that monitors and diagnoses your health conditions....

*Paweł Strumiłło*





- ❑ Diabetic calculator
- ❑ Finalist of the International Telecommunication Union (ITU) World Young Innovator Competition 2011



*Paweł Strumiłło*



# Examples of future biomedical engineering



GestoNurse: A Multimodal Robotic Scrub Nurse

[www.youtube.com/watch?v=s8eTLT1QexM#t=90](http://www.youtube.com/watch?v=s8eTLT1QexM#t=90)



Nurse Robot Exoskeleton on Beyond Tomorrow

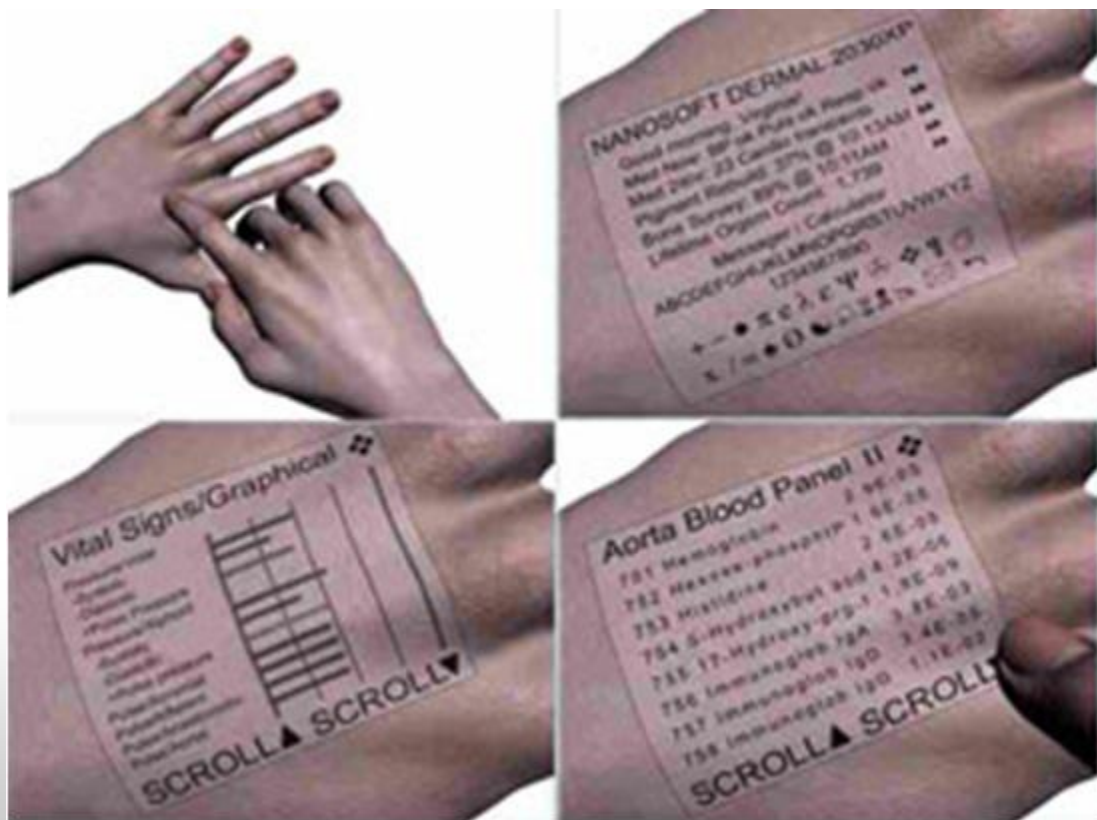
[www.youtube.com/watch?v=Yz618qJIIBA](http://www.youtube.com/watch?v=Yz618qJIIBA)

*Paweł Strumiłło*



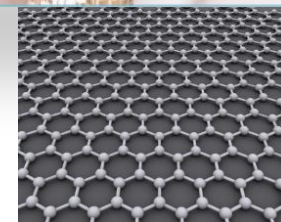


# Dermal computer and display → bionic skin

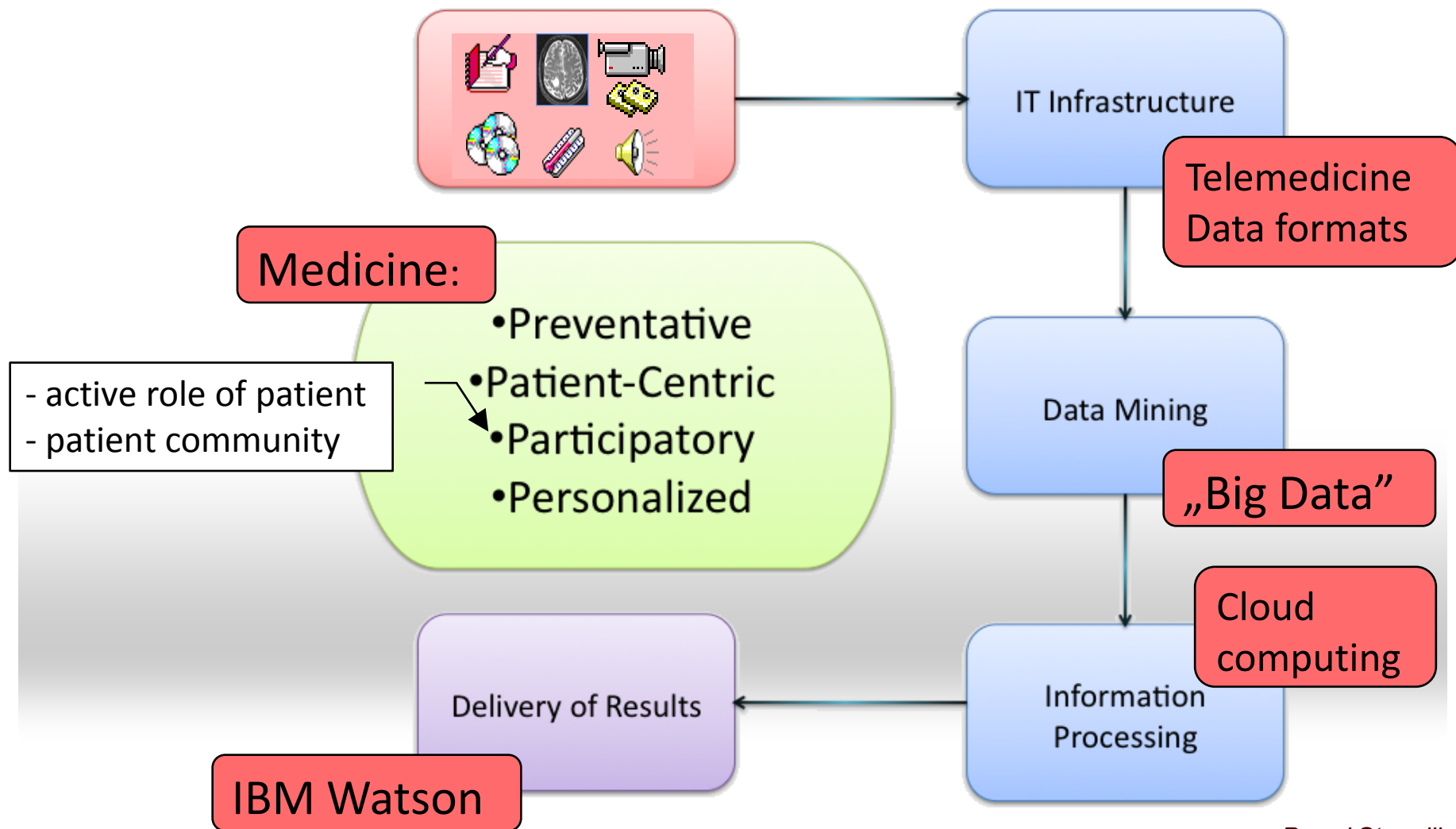


Artist's vision: Gina Miller, 2007

**New material: Graphene!**



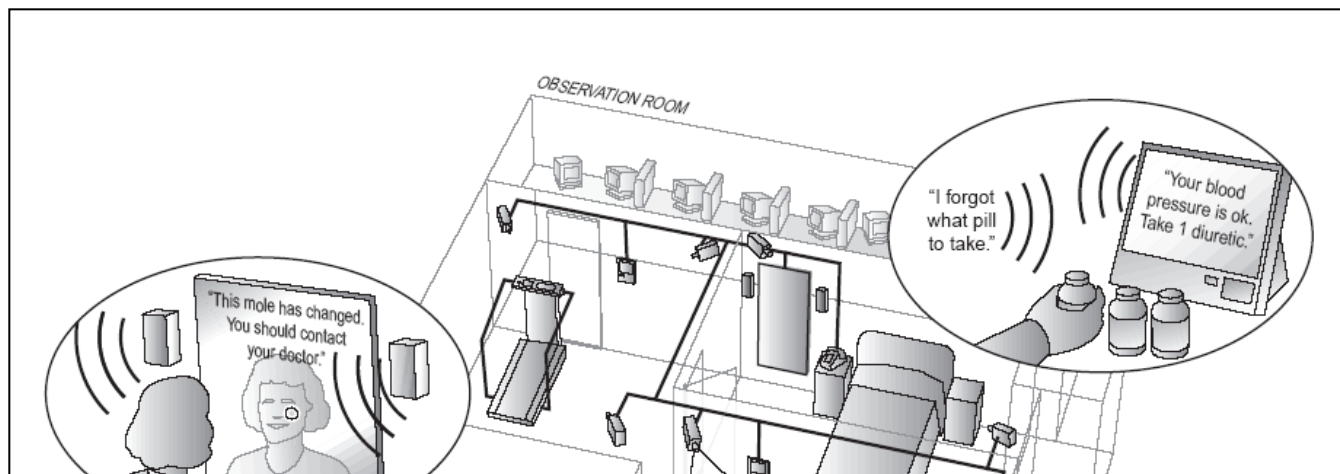
Paweł Strumiłło



Paweł Strumiłło

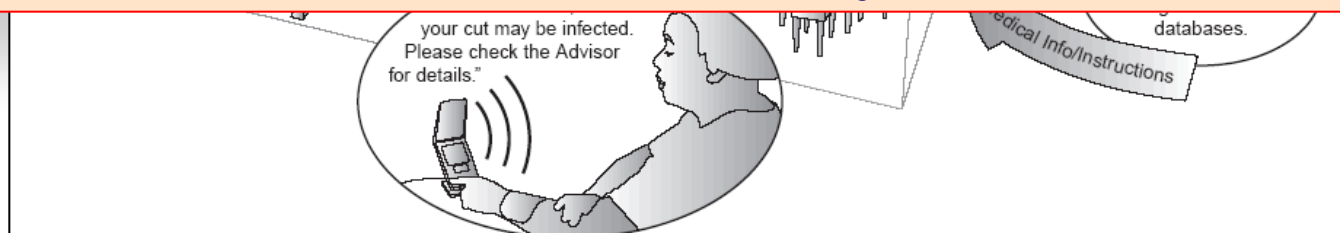


# Intelligent monitoring



**„....We are still living in the “mainframe” era of healthcare ... what we need is ...the healthcare equivalent to the low cost PC”**

**Andy Grow, Intel Corp.**



*Paweł Strumiłło*



# Be aware of ... unpredictable technological advancements

*...640K should be enough for anybody..*

**Bill Gates** (1981)  
Microsoft founder

*Now more information can be sent over a single cable in a second than filled the Internet in a month in 1997*

**George Gilder**,  
Telecosm, The Free Press, New York

*You can expect to have on your wrist tomorrow what you have on your desk today, what filled a room yesterday.*

**Nicolas Negroponte**,  
Being Digital, Vintage Books, New York (1996)

*Paweł Strumiłło*



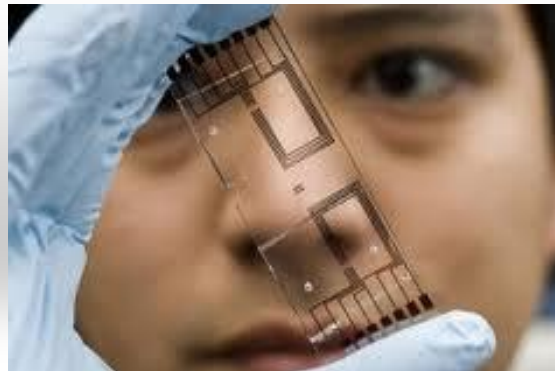


## Prospects are good for biomedical engineers ...

Biomedical Engineering (BME) is the fastest growing engineering discipline with a projected employment growth of 72% by 2018.

*"In industry, biomedical engineers work in corporate research, production, quality control and management,"* says Katharina Jäger from the human-resources department of Baxter, a global medical-technology company based in Vienna. *"University graduates usually acquire leading positions after one or two years...."*

Naturejobs



*Paweł Strumiłło*



**KAPITAŁ LUDZKI**  
NARODOWA STRATEGIA SPÓJNOŚCI

**UNIA EUROPEJSKA**  
EUROPEJSKI  
FUNDUSZ SPOŁECZNY



## „Medical Electronics”

**Prezentacja multimedialna współfinansowana przez  
Unię Europejską w ramach  
Europejskiego Funduszu Społecznego w projekcie pt.  
*„Innowacyjna dydaktyka bez ograniczeń - zintegrowany  
rozwój Politechniki Łódzkiej - zarządzanie Uczelnią,  
nowoczesna oferta edukacyjna i wzmacniania zdolności  
do zatrudniania osób niepełnosprawnych”***



Politechnika Łódzka

Politechnika Łódzka, ul. Żeromskiego 116, 90-924 Łódź, tel. (042) 631 28 83  
[www.kapitalludzki.p.lodz.pl](http://www.kapitalludzki.p.lodz.pl)