



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

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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
- 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



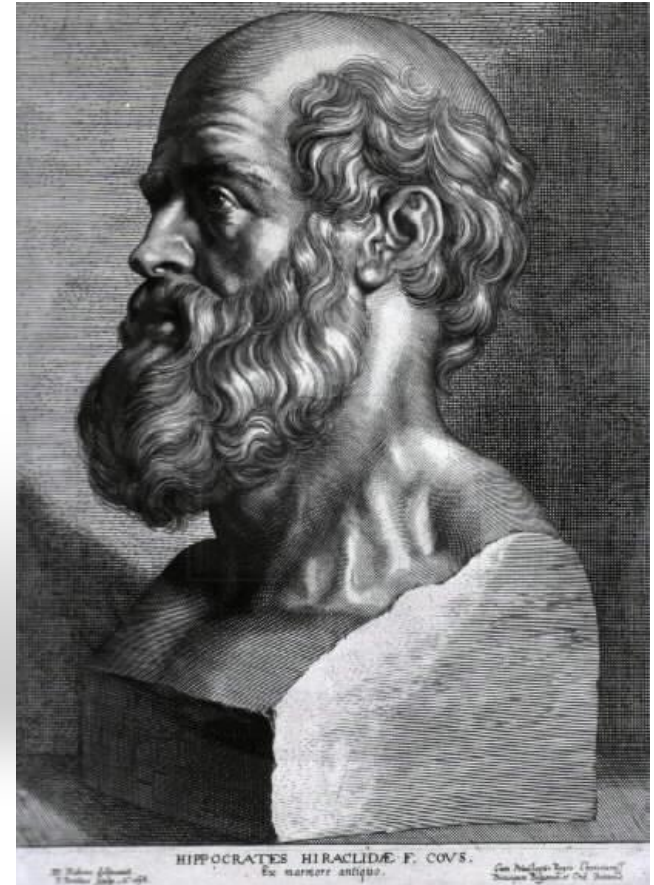
Surgery tools pictured on the wall of the temple Kom Ombo, Egypt

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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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Medival ages



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

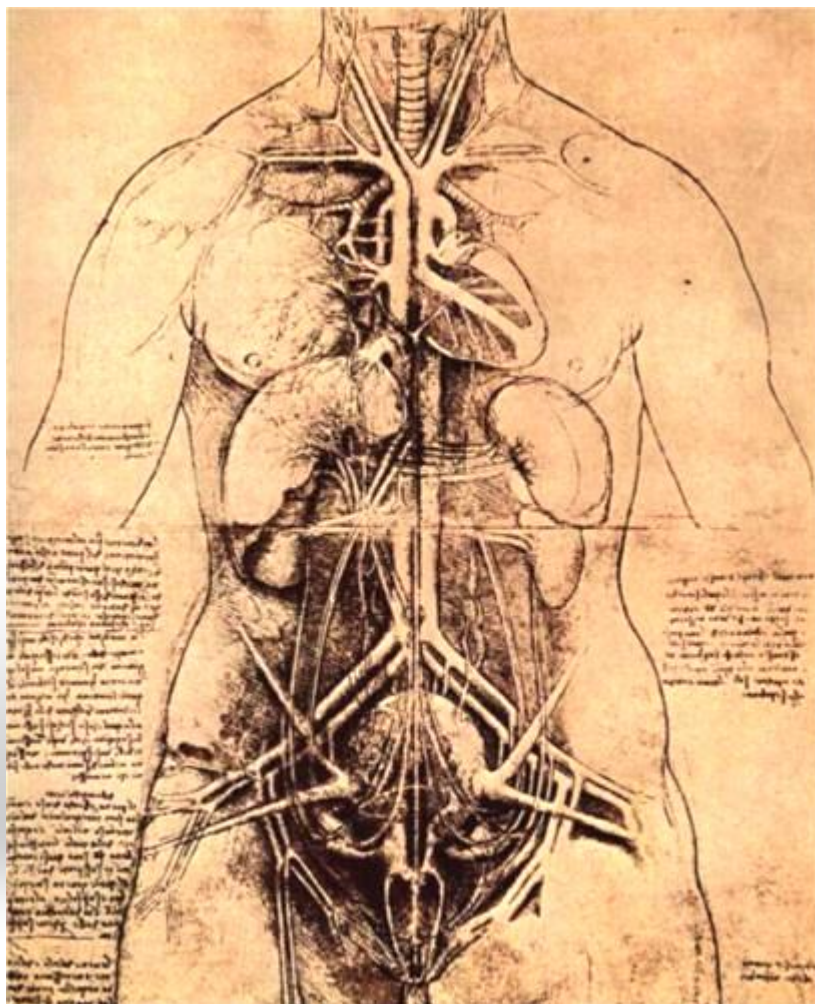
„Primum non nocere”



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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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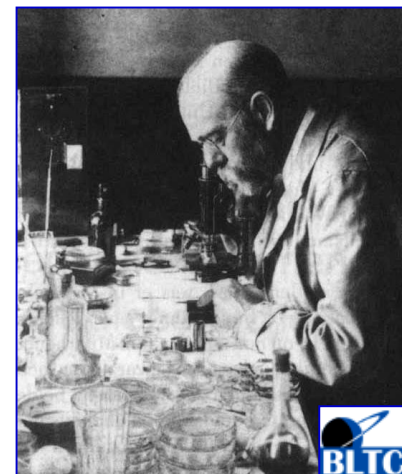




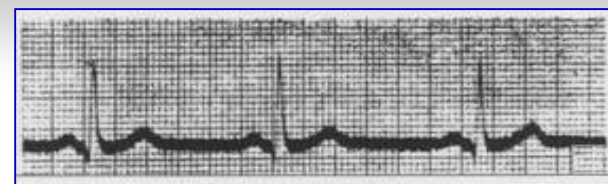
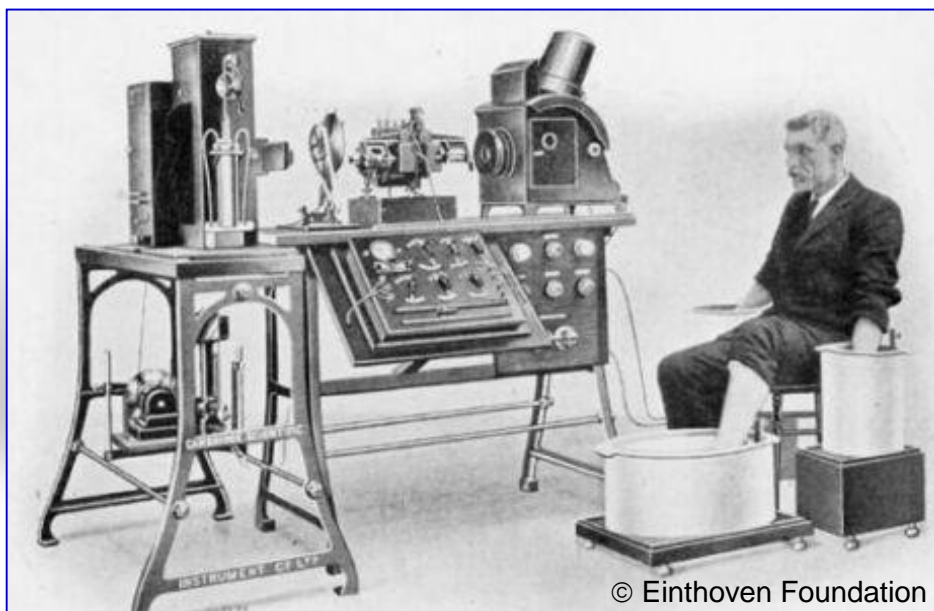
Medical technologies - diagnosis (era before computers)

9

- **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”



Diagnosis



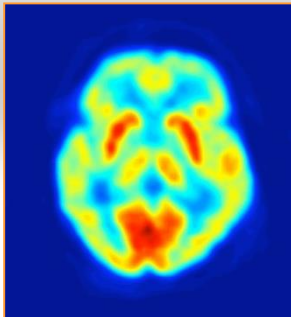
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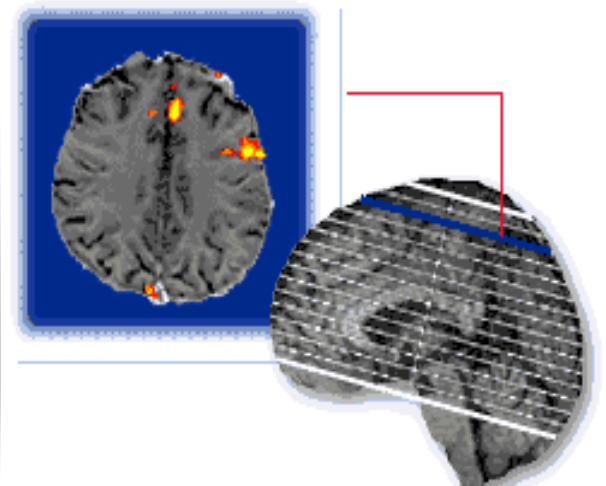
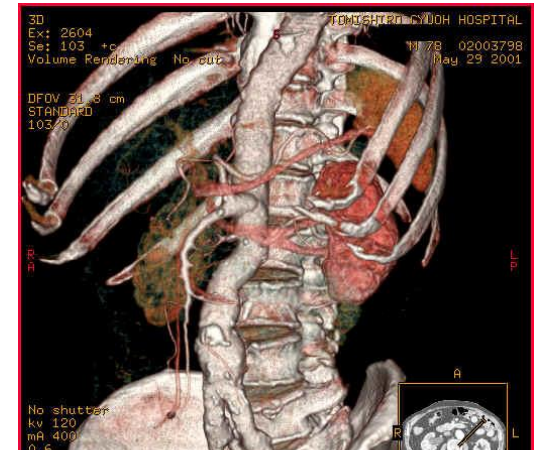


- **Computed X-ray Tomography (CT)**
(Cormack, Hounsfield – Nobel Prize in 1979)
- **Magnetic Resonance Imaging (MRI)**
(Lautenbourg, Masfield – Nobel Prize in 2003)
- **functional MRI (fMRI)**
- **Positron Emission Tomography (PET)**
- **Wireless endoscopy**
- **Ultrasonography**

Diagnosis



© 2003 Kent Medical Imaging



© 2005 Columbia University functional MRI

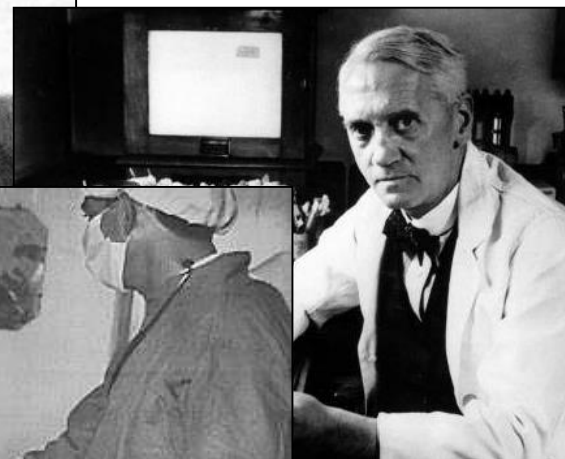
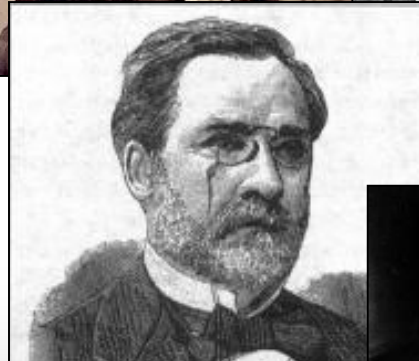
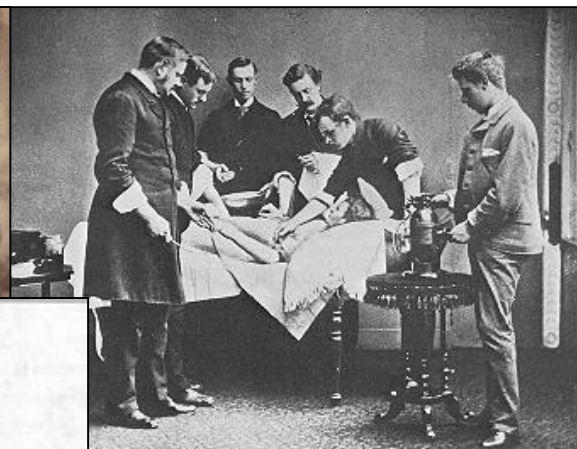
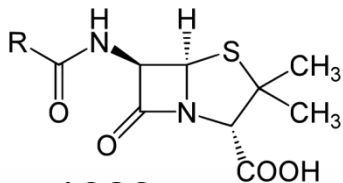
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Medical technologies – treatment, therapy (era before computers)

11

- **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)

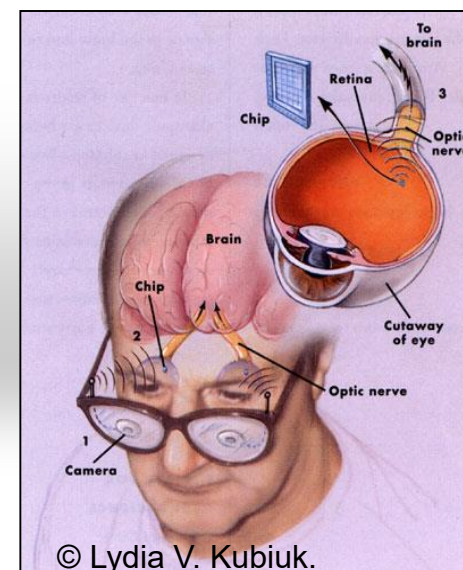
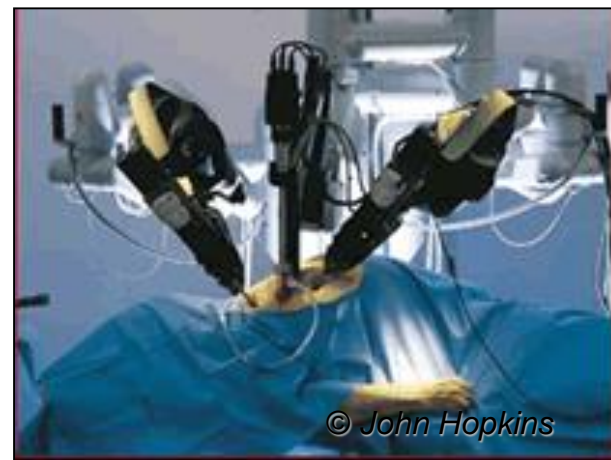
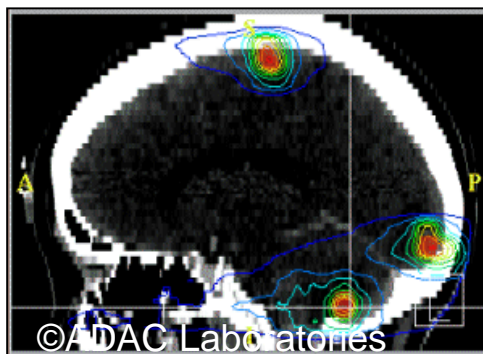


Treatment

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



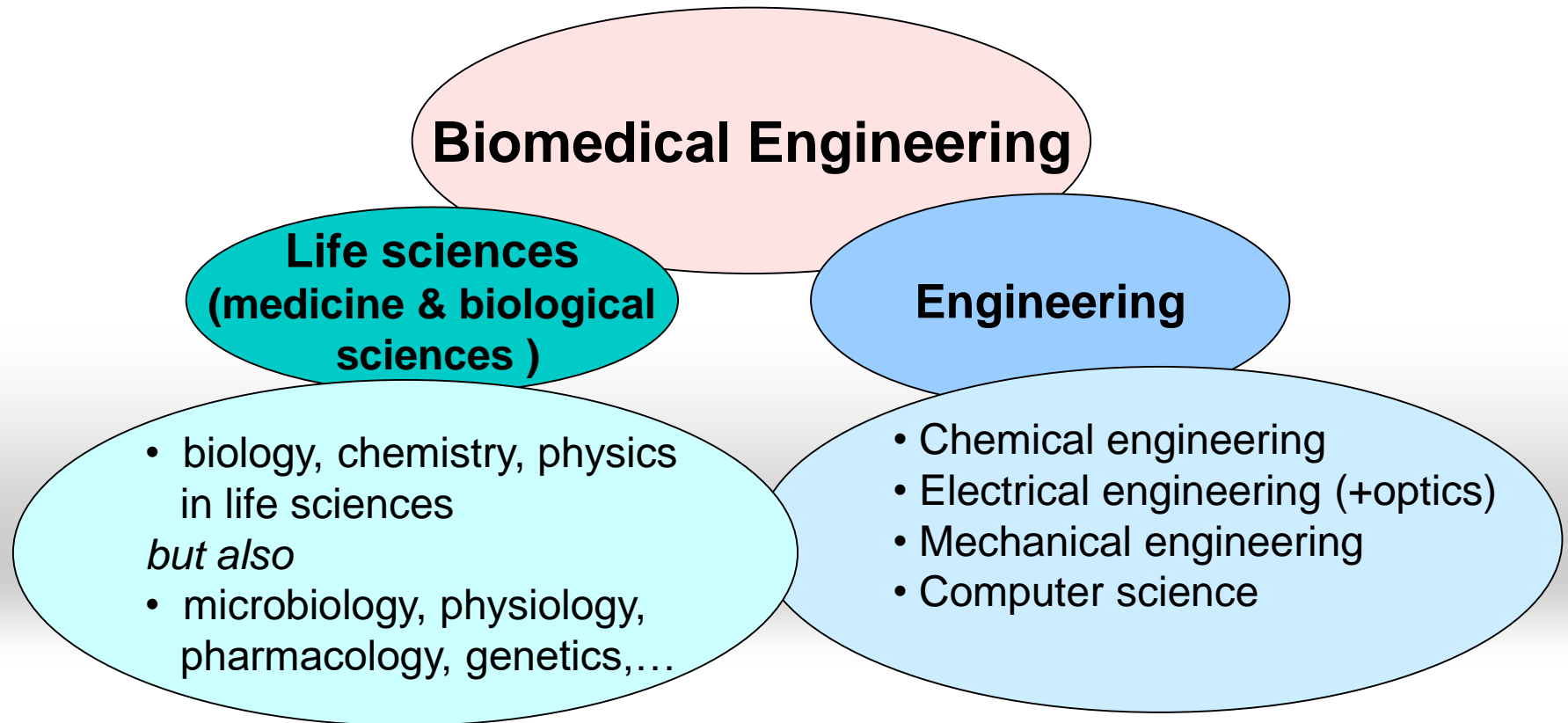
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What is Biomedical Engineering?

Biomedical Engineering –

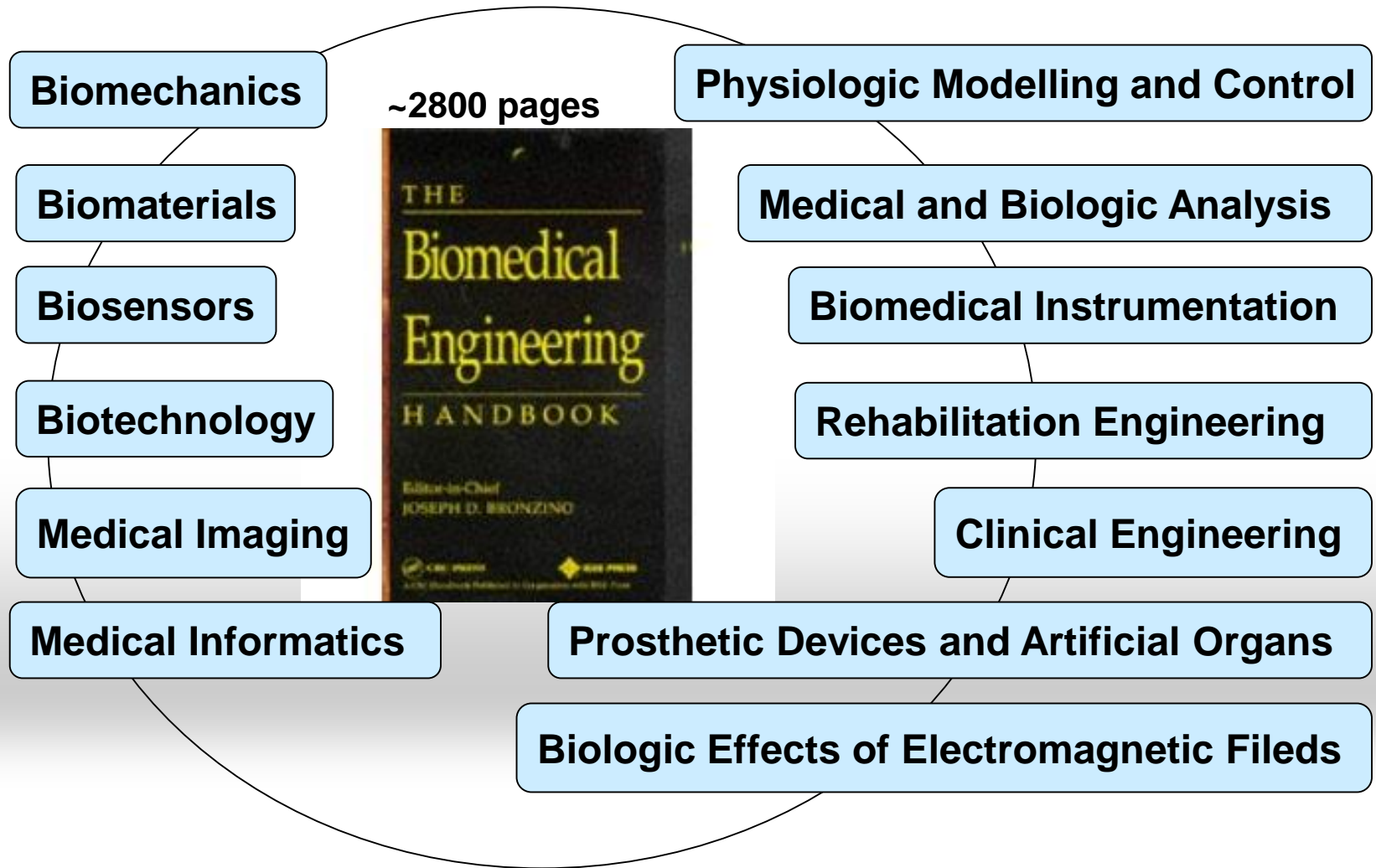
application of engineering principles and techniques in medical diagnosis and treatment (surgery).



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

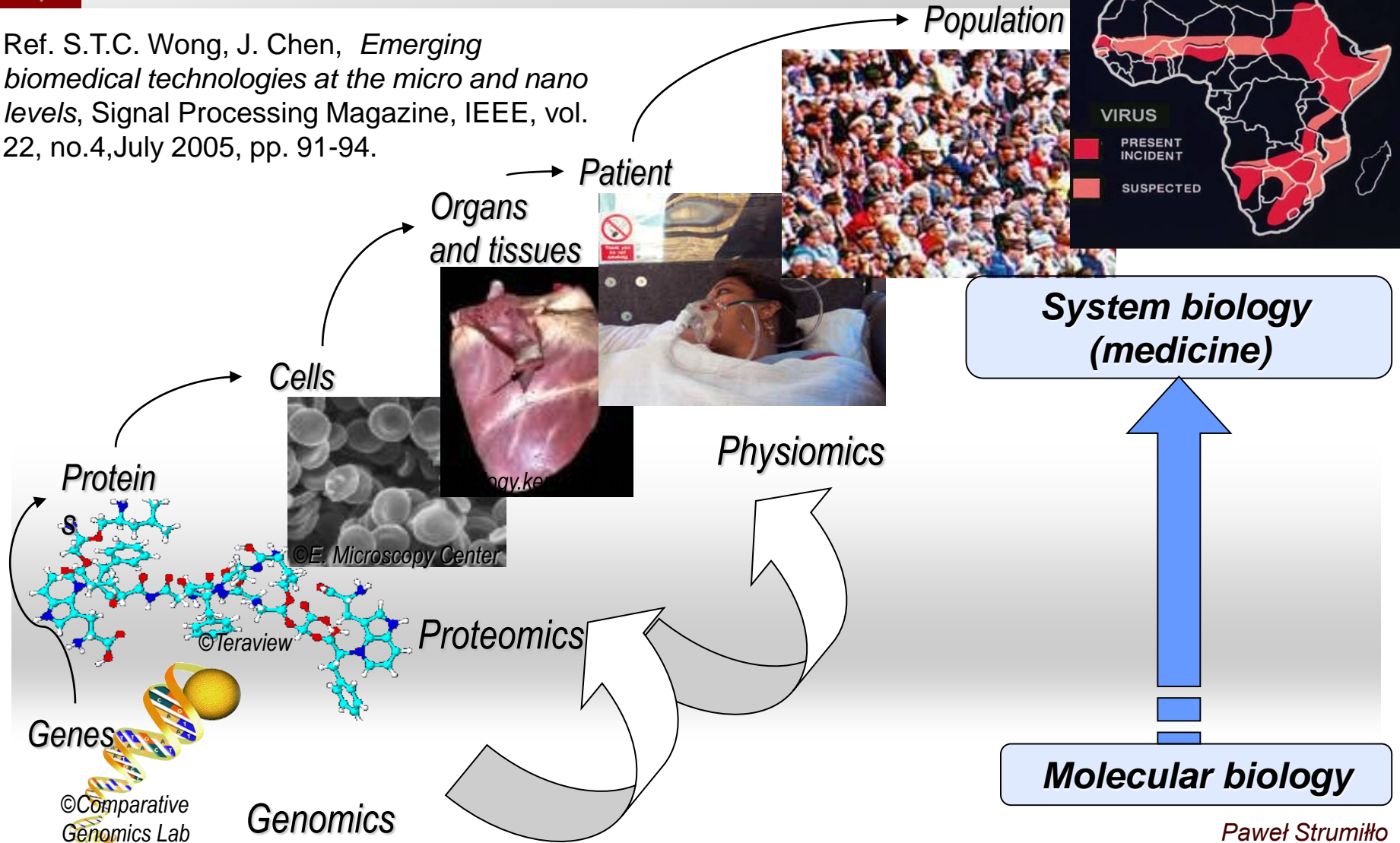
Biologic Effects of Electromagnetic Fields - study of the effects of electromagnetic
fields on biologic tissue

Examples?

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

Biomedical Engineering – at different scales

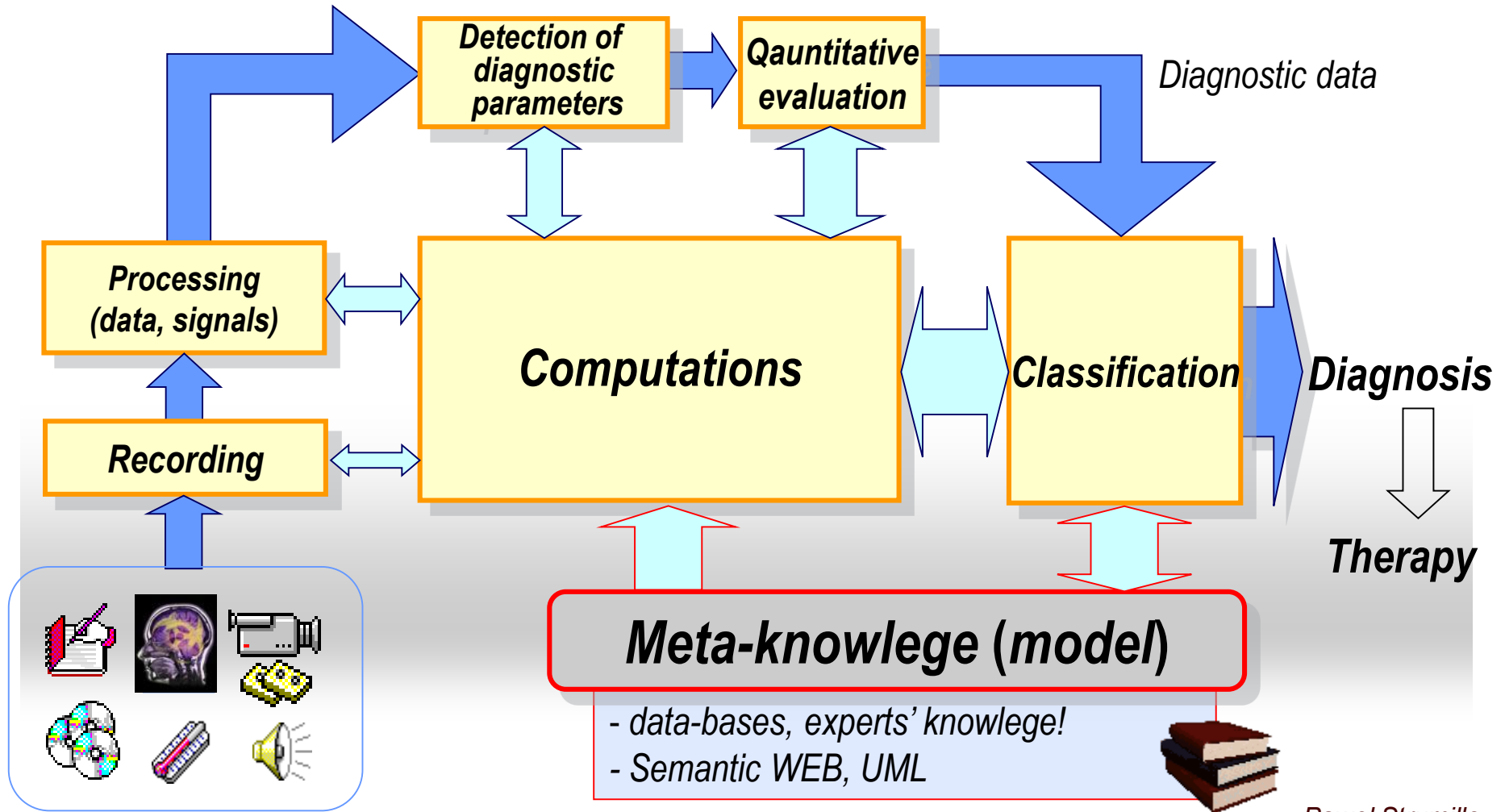
Ref. S.T.C. Wong, J. Chen, *Emerging biomedical technologies at the micro and nano levels*, Signal Processing Magazine, IEEE, vol. 22, no.4, July 2005, pp. 91-94.



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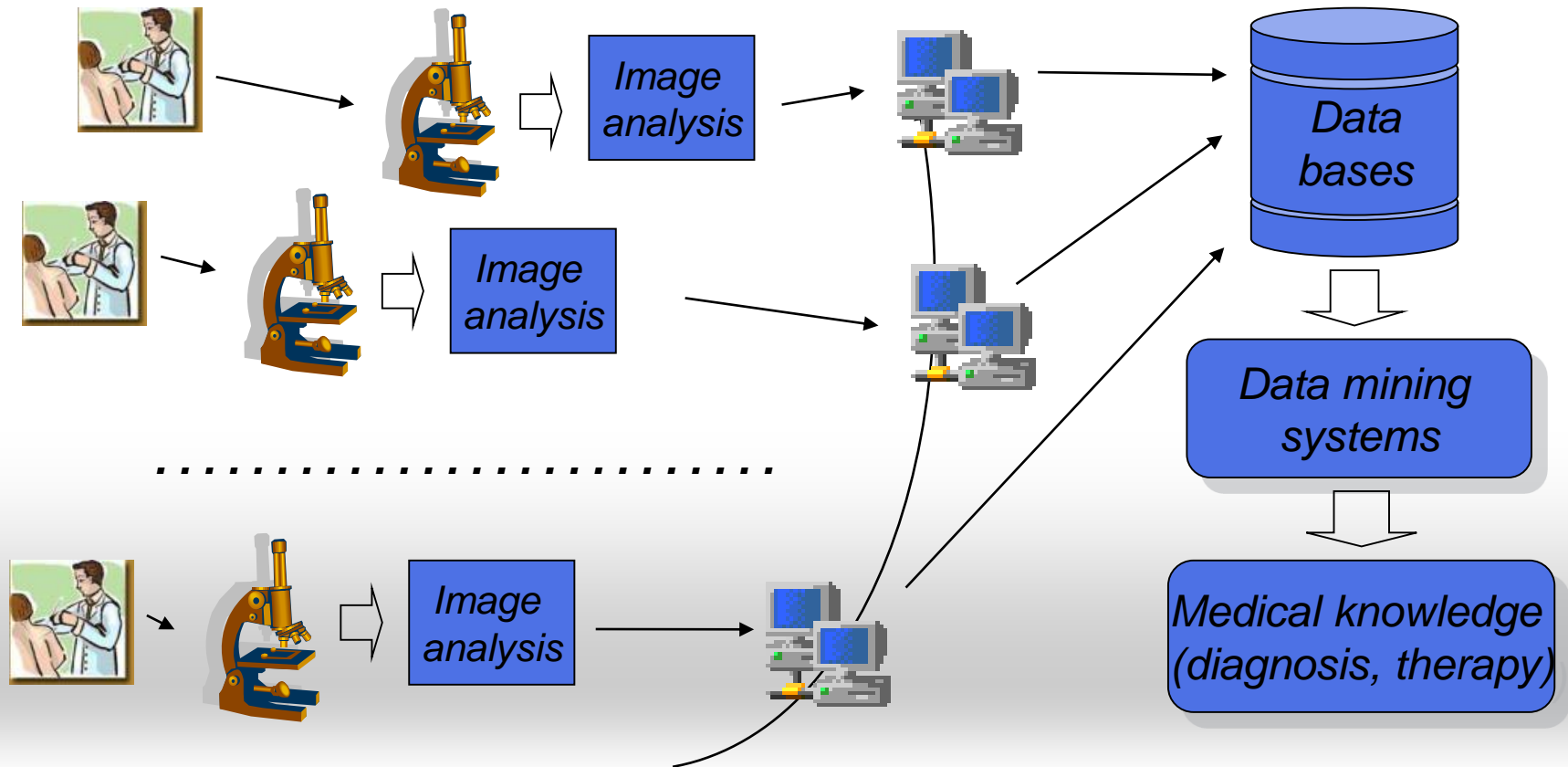
The concept of modern diagnostic system



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Global health networks - problems



Technology

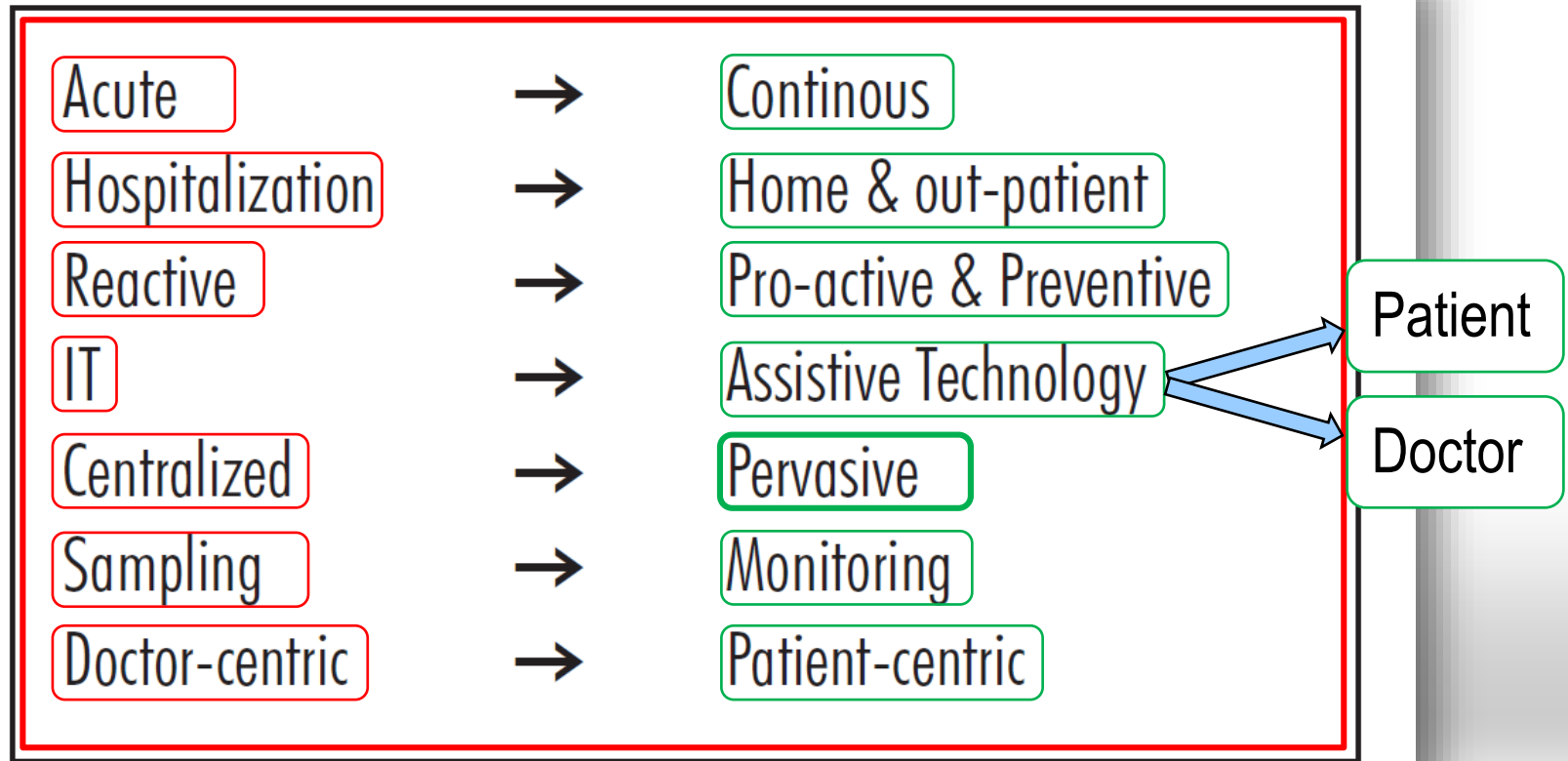


Standards: data, databases,
good practices

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Centralized → continuous and ubiquitous healthcare

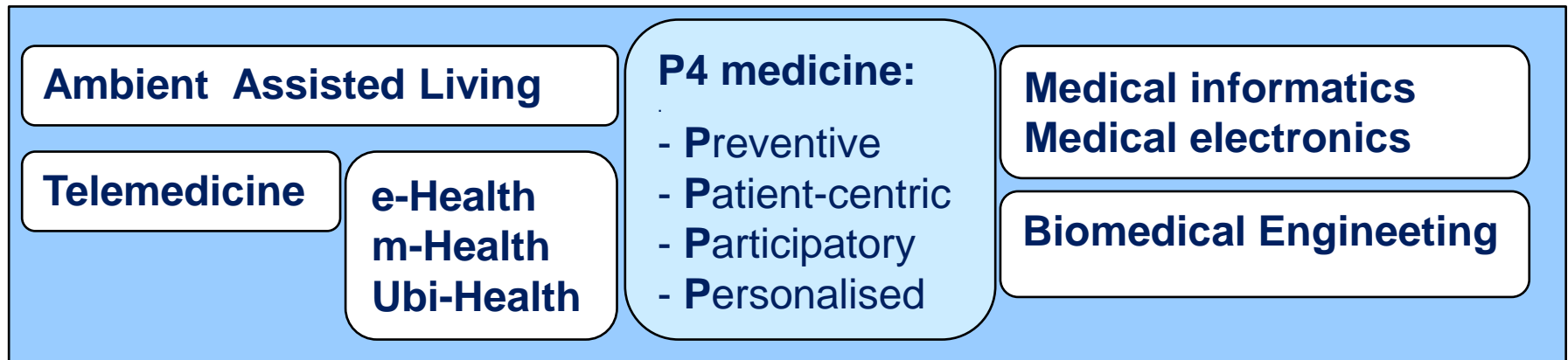


Source: Bardram JE, *Pervasive healthcare as a scientific discipline*, Methods Inf. Med., 2008;47(3):178-185.

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Pervasive Healthcare



Is making **healthcare** available:



Any Time



Any Where

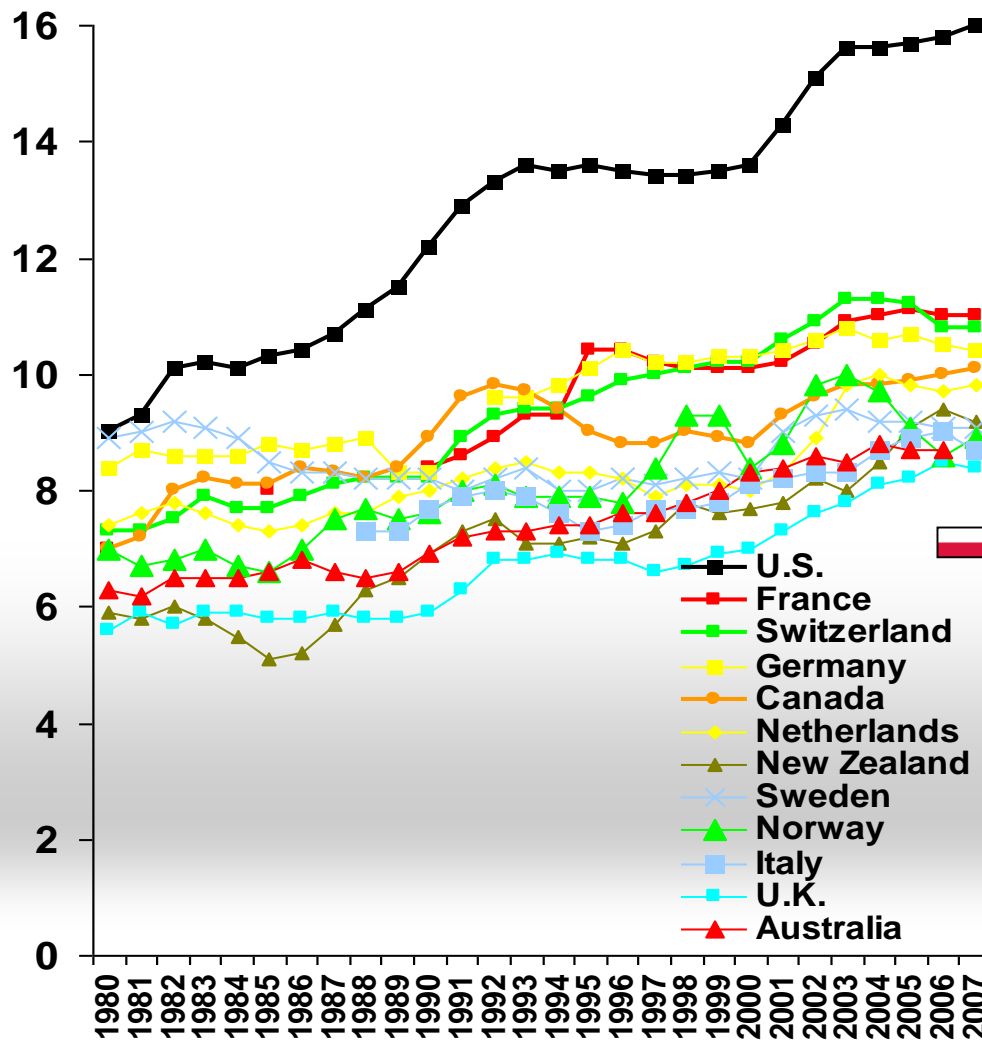


To any One

... and seamlessly



International Comparison of Spending on Health, 1980–2007



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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”

IEEE REVIEWS IN BIOMEDICAL ENGINEERING

A PUBLICATION OF THE IEEE ENGINEERING IN MEDICINE AND BIOLOGY SOCIETY



TECHNICALLY COSPONSORED BY THE IEEE CONSUMER ELECTRONICS SOCIETY



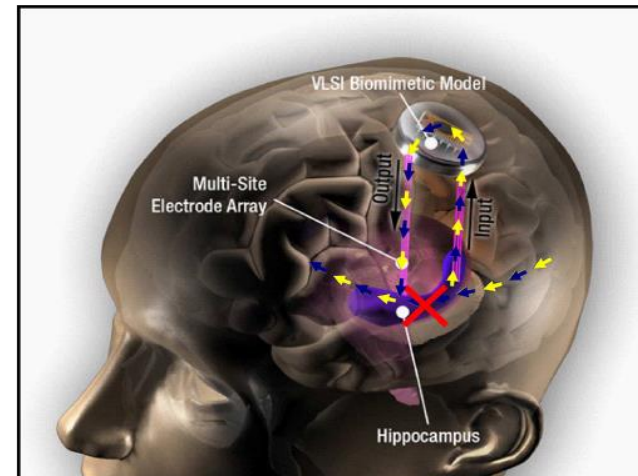
IEEE CONSUMER ELECTRONICS SOCIETY

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.



Medical Electronics – lecture outline

Introduction:

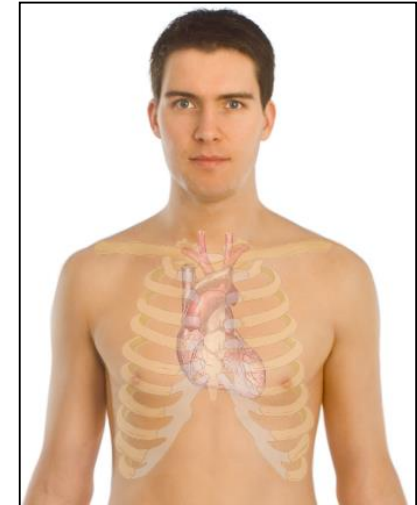
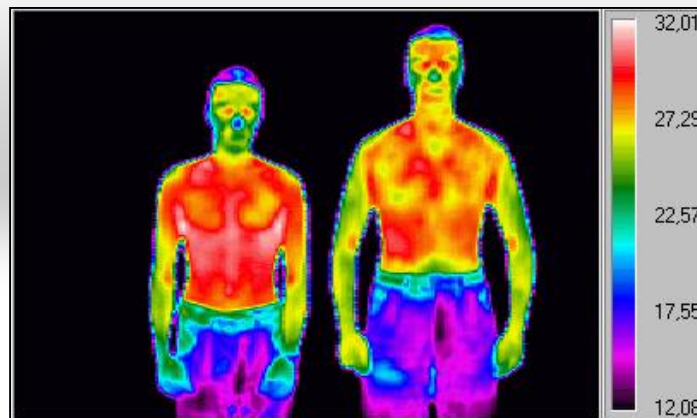
- biomedical engineering – history, definition
- human anatomy and physiology (brief review)
- patient safety

Biomedical instrumentation:

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

Imaging systems:

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



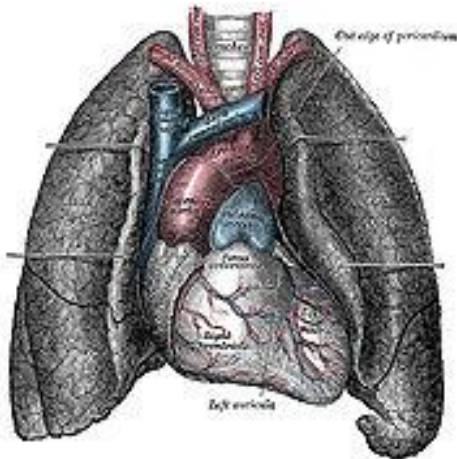
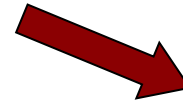
Insulin pump

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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:

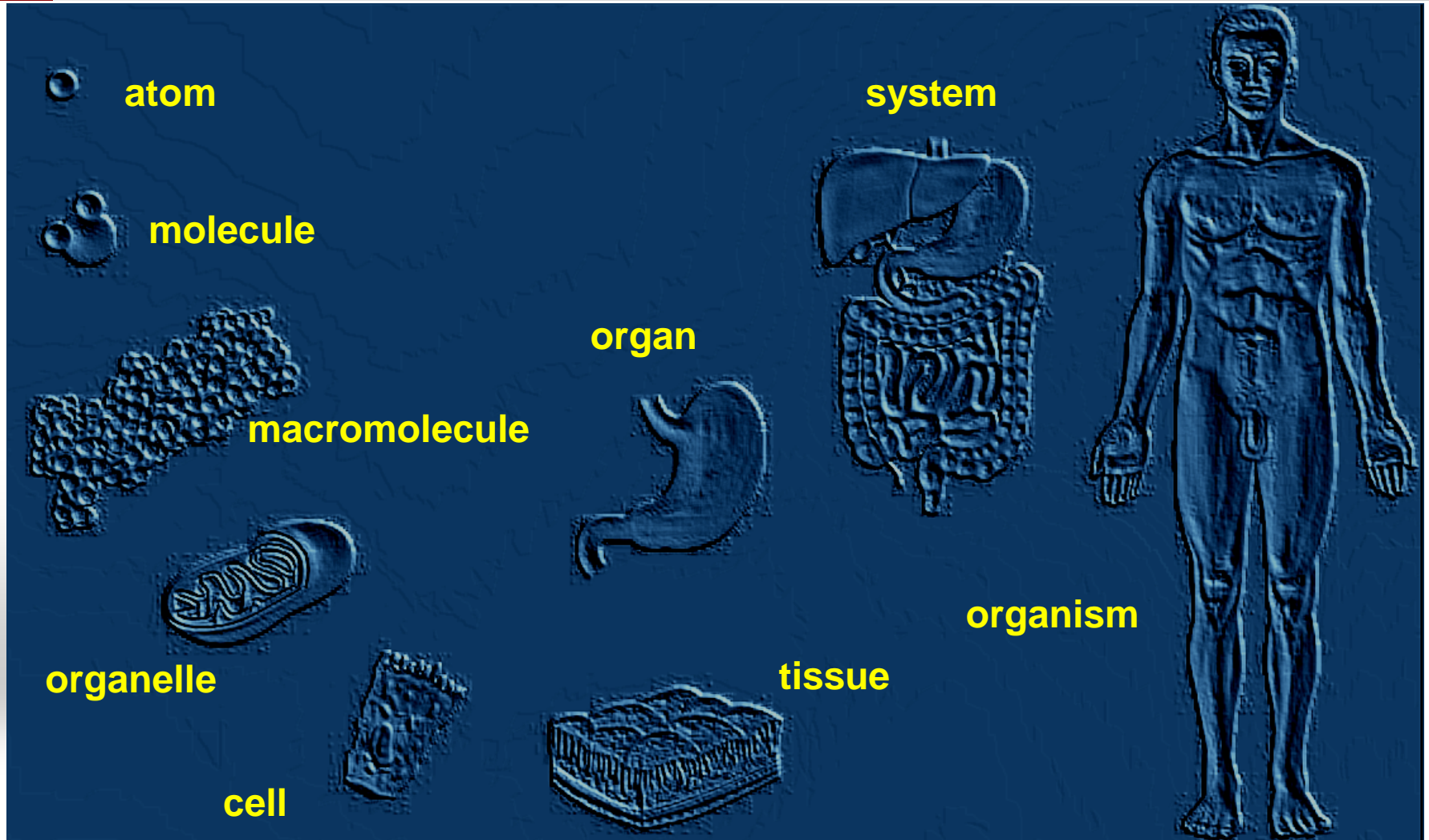
Anatomy and Physiology



www.youtube.com/watch?feature=endscreen&v=GnpLm9fzYxU&NR=1

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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**



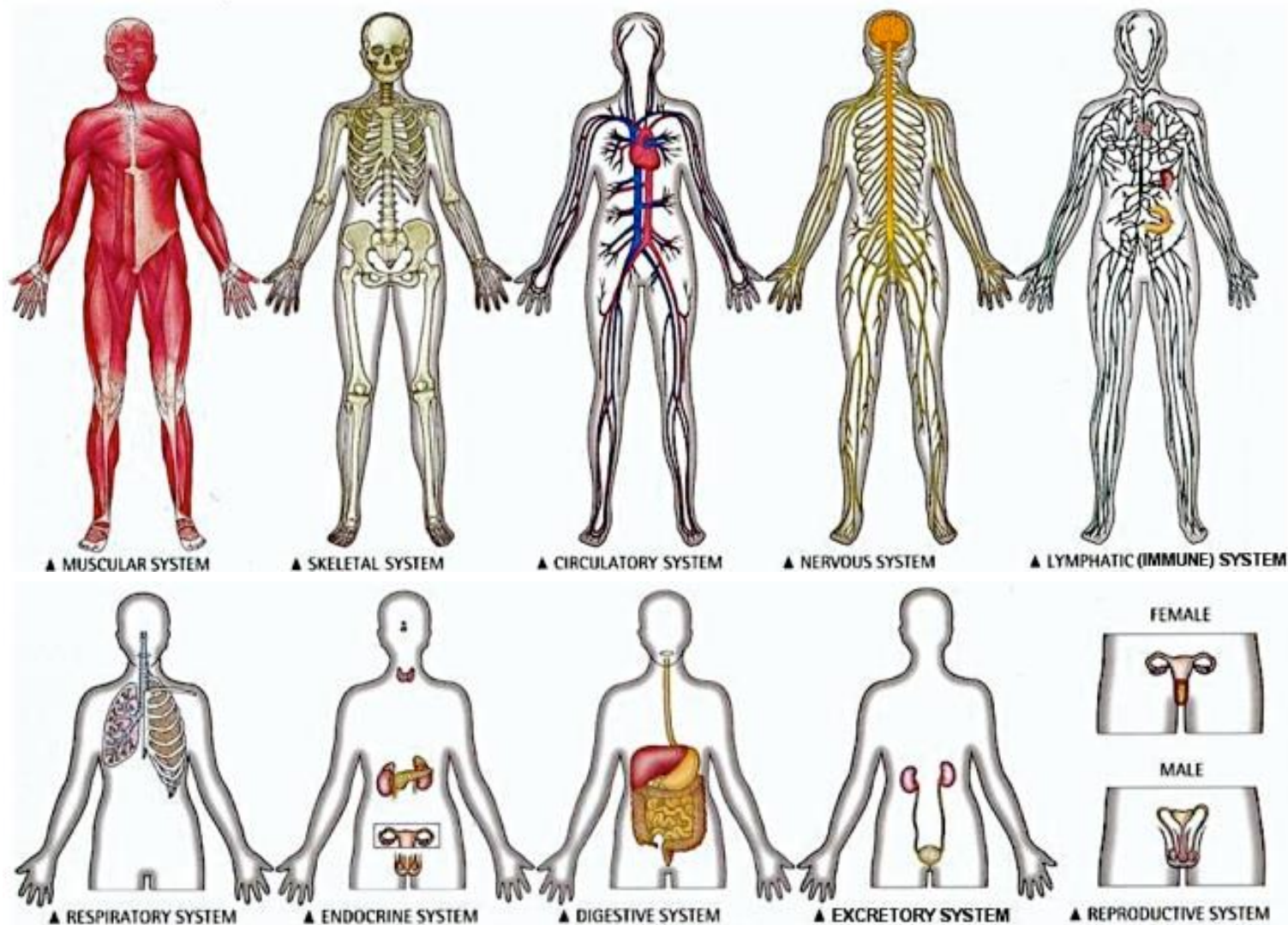
*) From dr Cyprain Wolski's lecture: Anatomy and physiology

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Complexity of human body

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



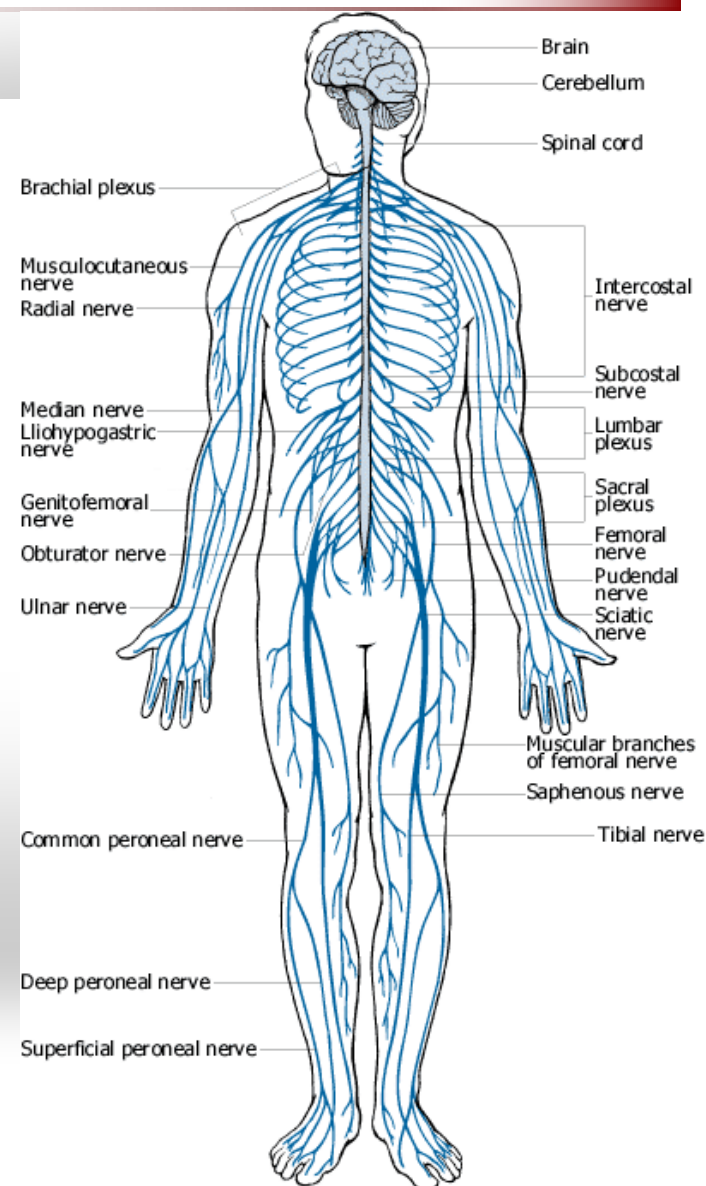


Nervous system (Wikipedia)

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

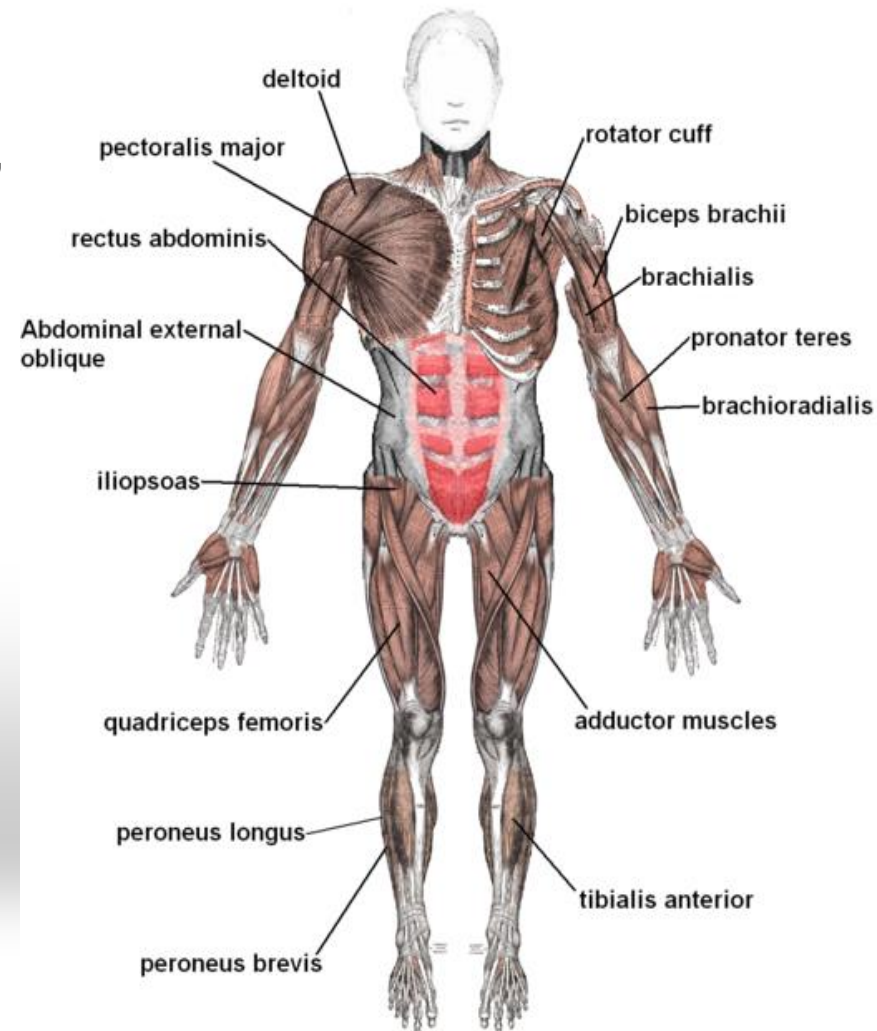


Musco-skeletal system (Wikipedia)

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



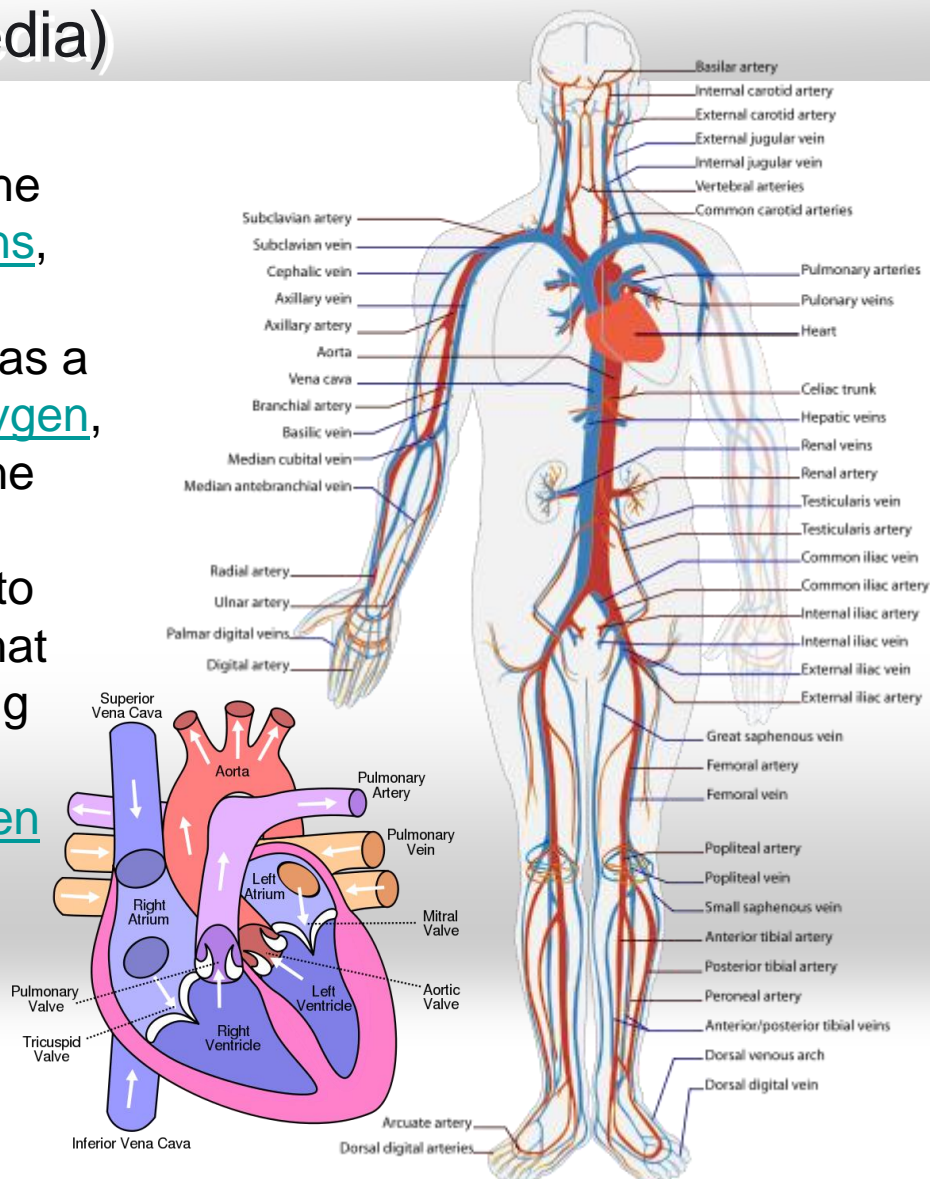


Circulatory system (Wikipedia)

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



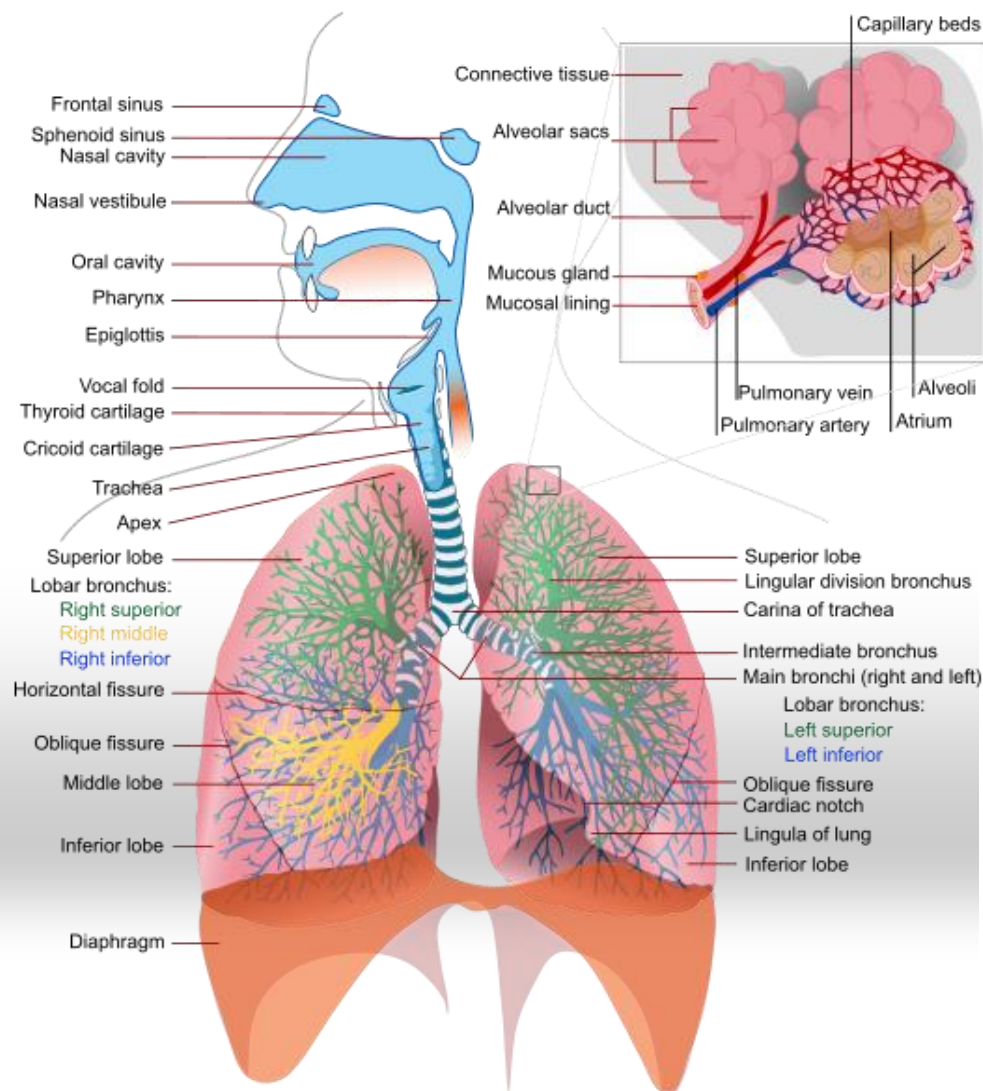


Respiratory system (Wikipedia)

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

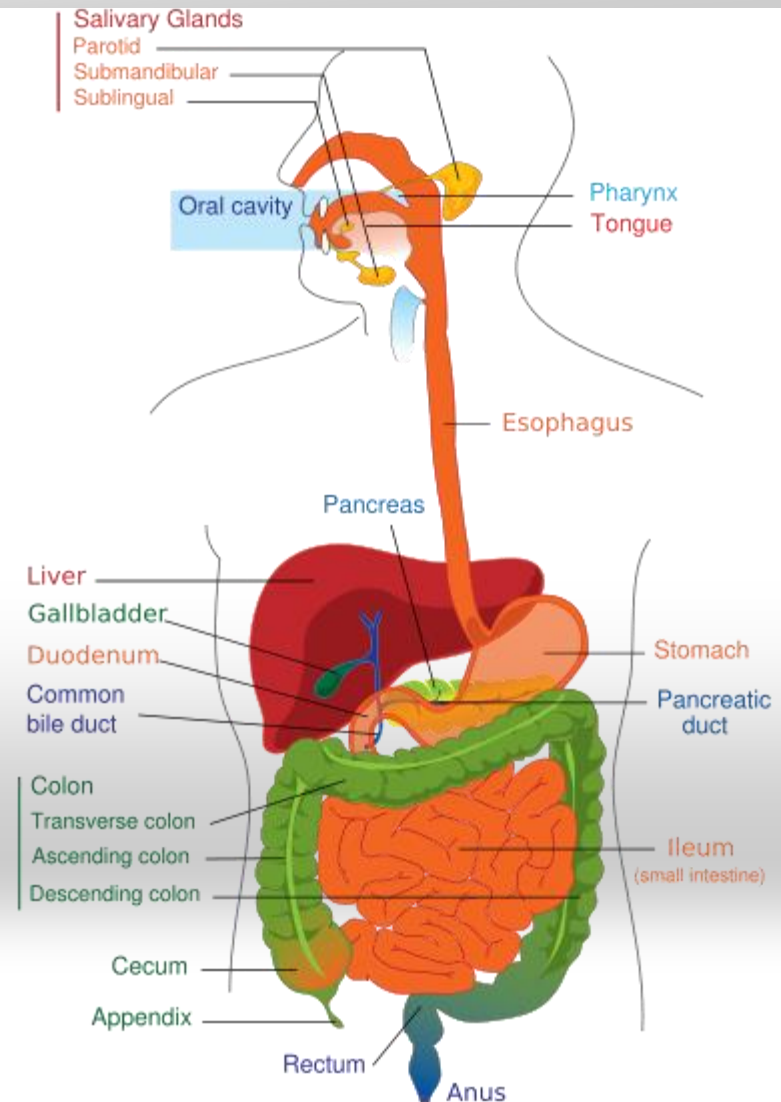


Digestive system (Wikipedia)

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

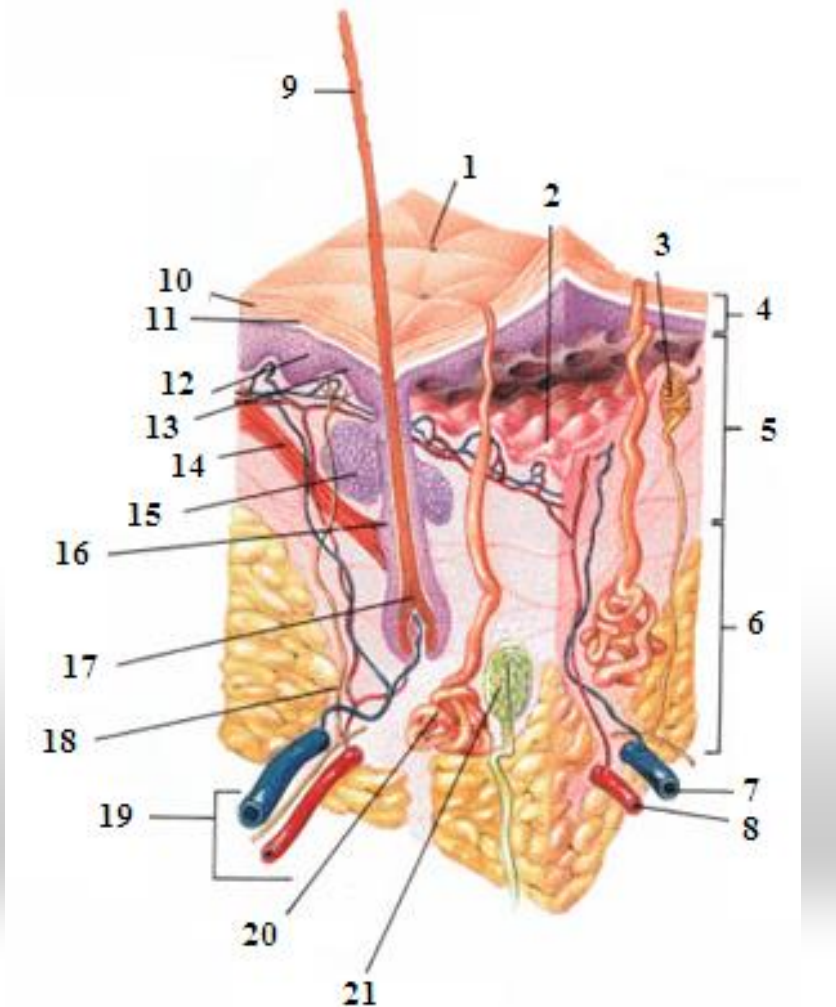


Integumentary system (Wikipedia)

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

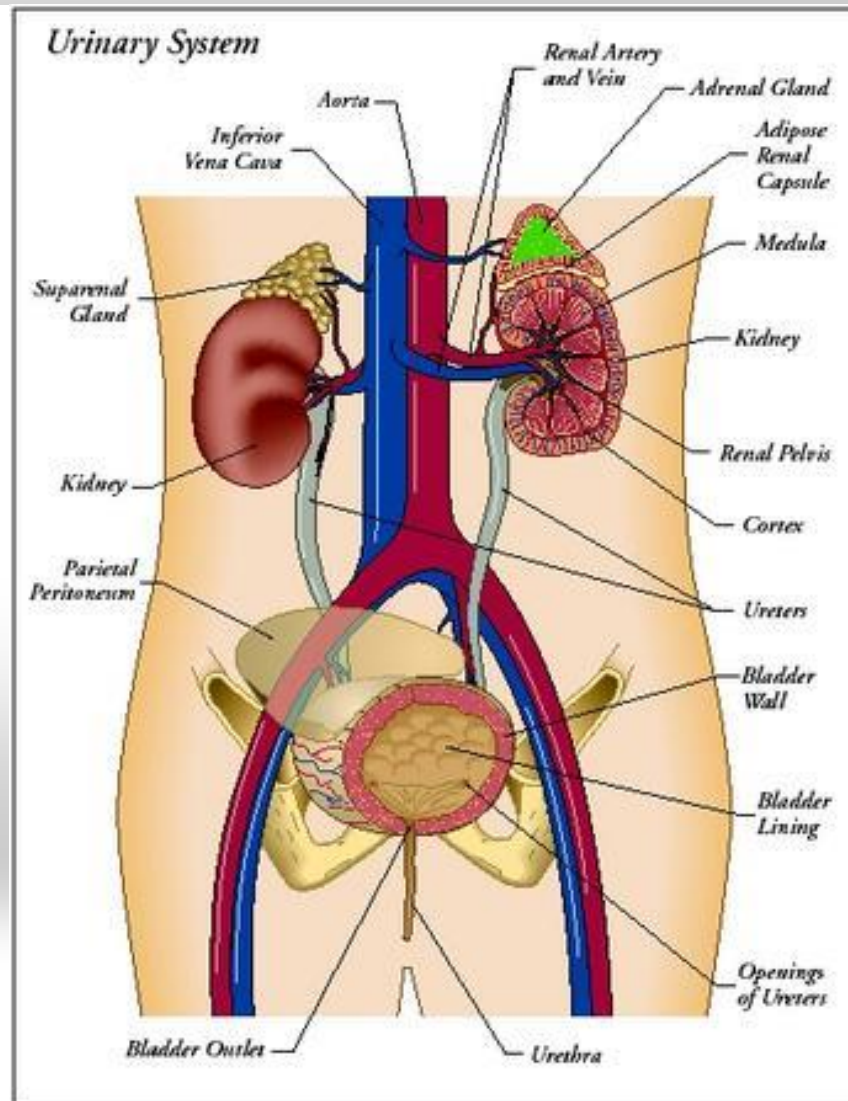


Urinary system (Wikipedia)

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

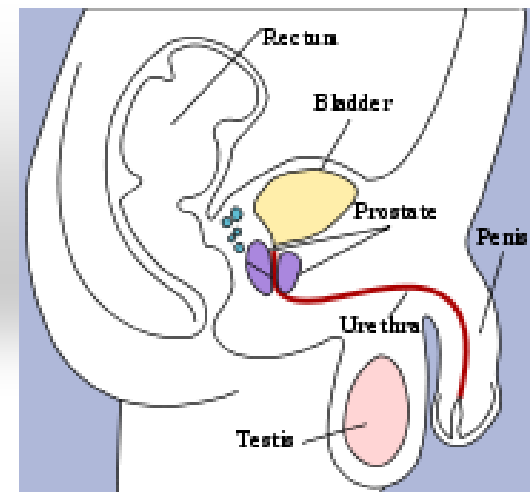
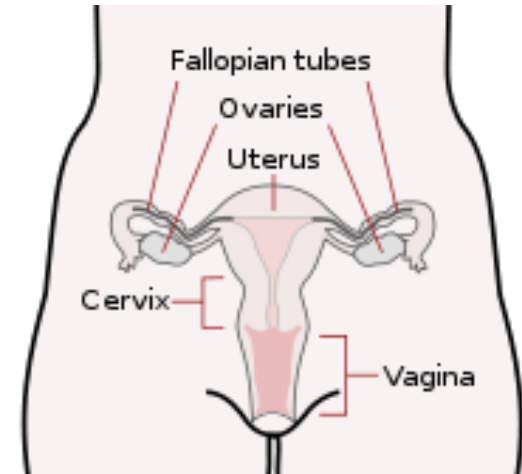


Reproductive system (Wikipedia)

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

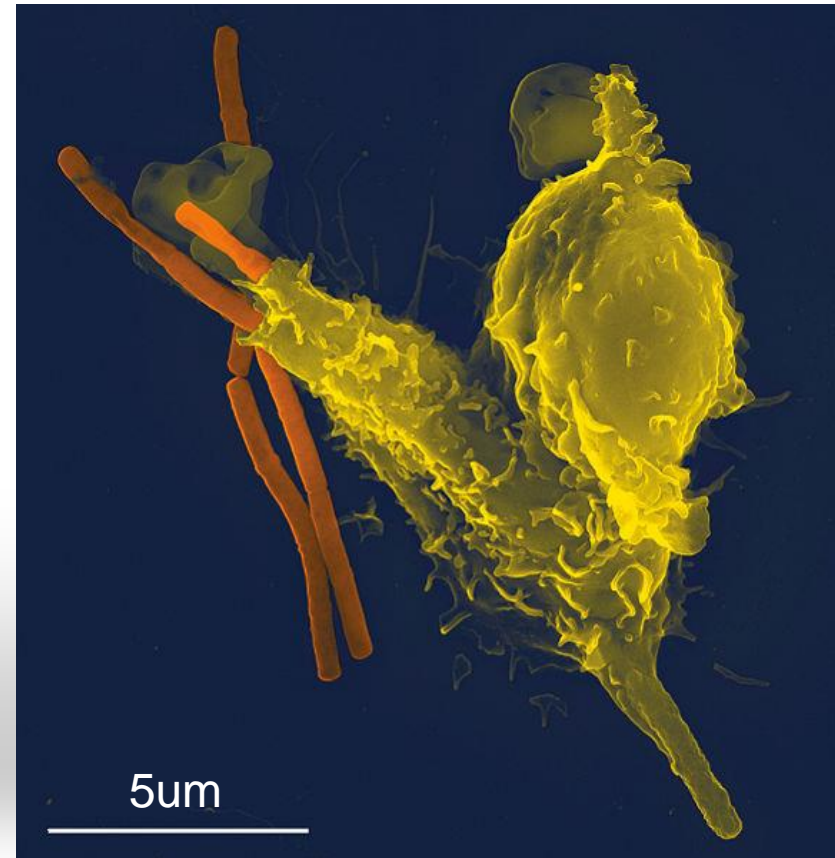


Immune system (Wikipedia)

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).

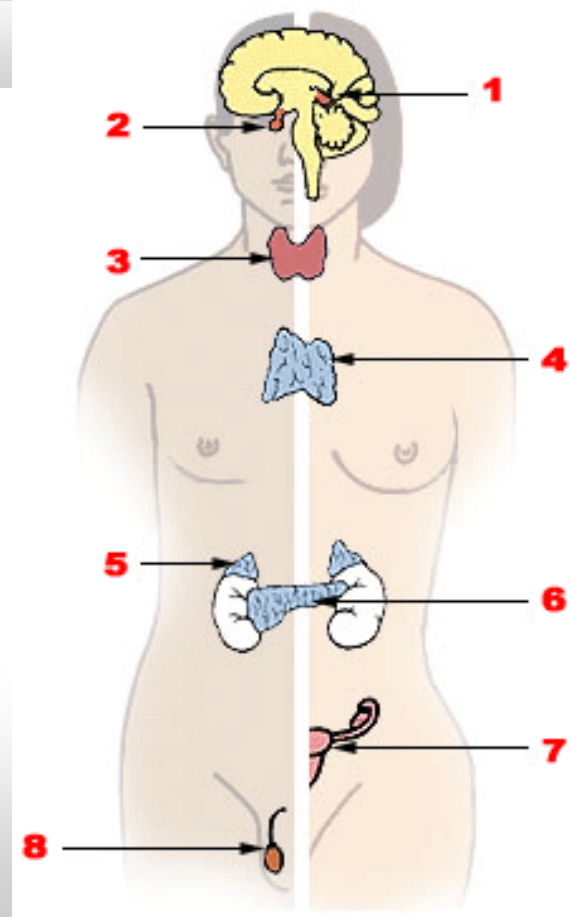


Endocrine system (Wikipedia)

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](#)

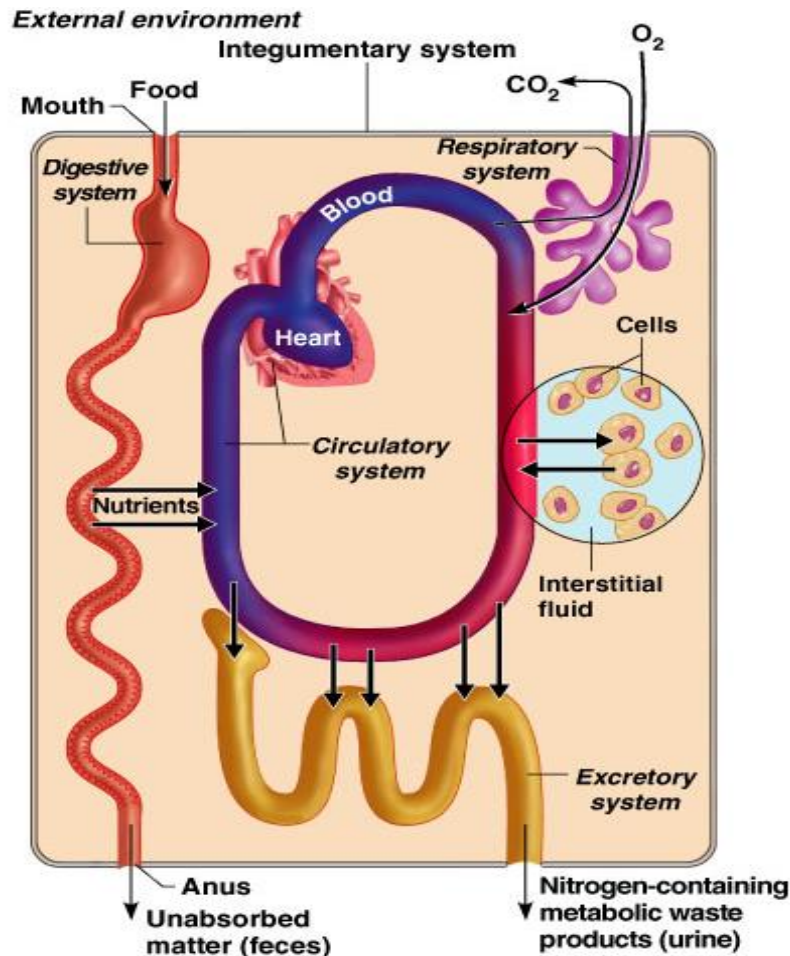
Integration and coordination



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

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<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"/>	Make a selection 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"/>	

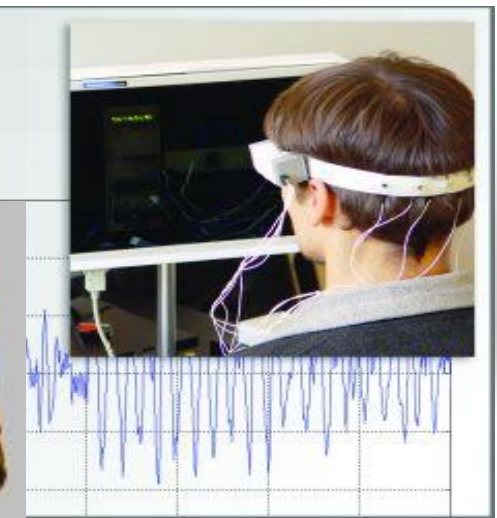
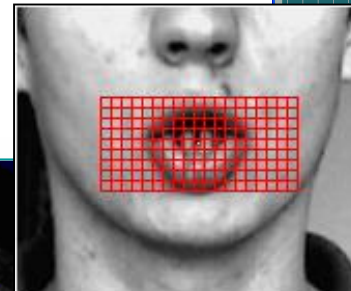
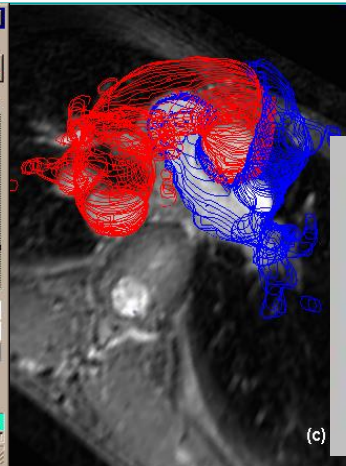
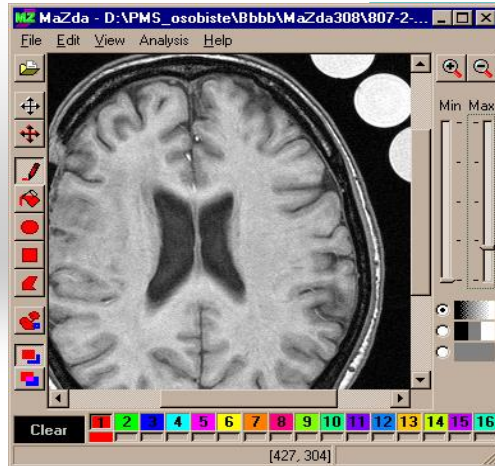
Score Test

Clear Form

Paweł Strumiłło

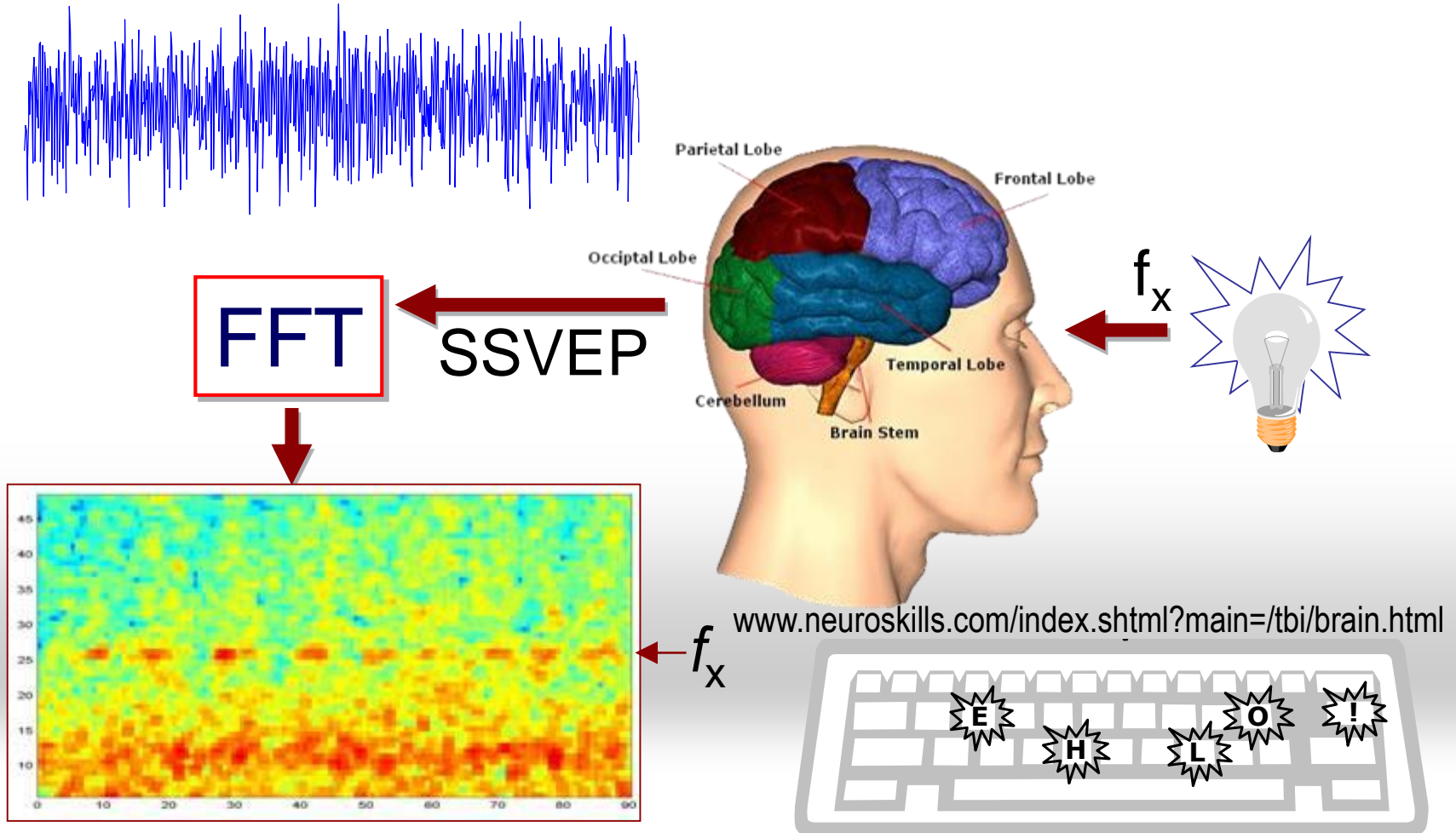
Medical Electronics Division - research

- ❑ 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)



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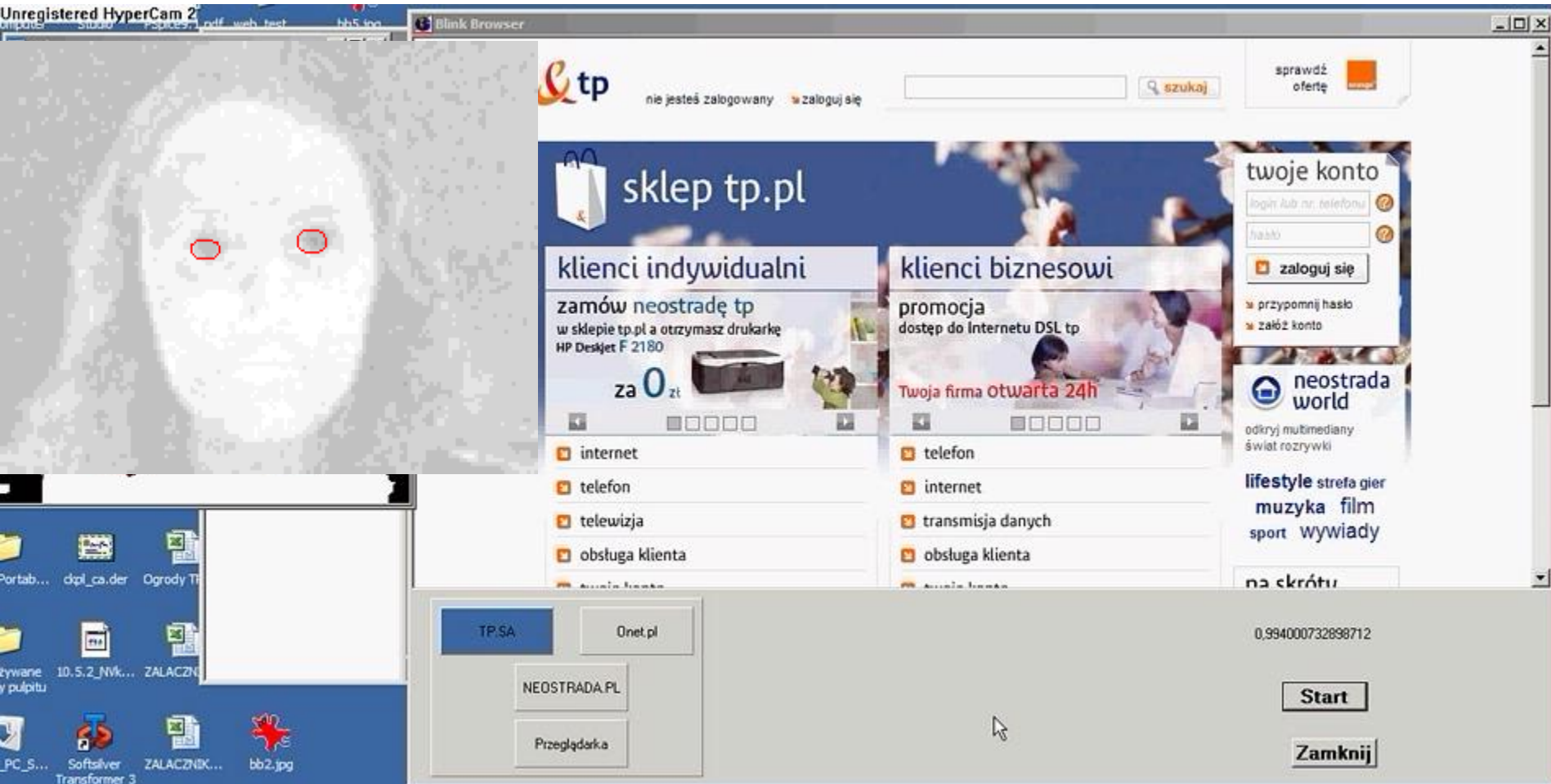
Brain Computer Interface



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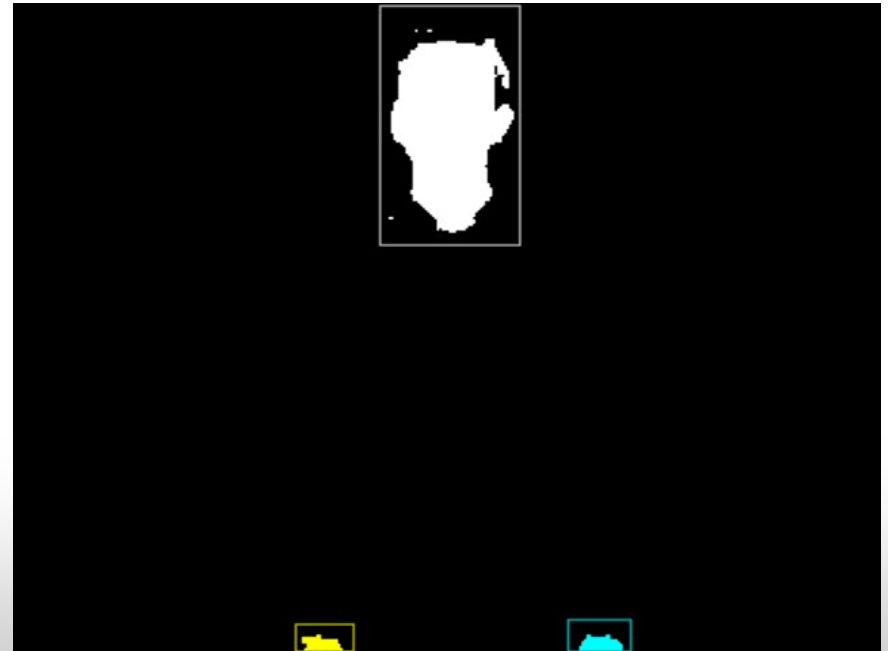


Eyeblink controlled interface



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Sign language recognition

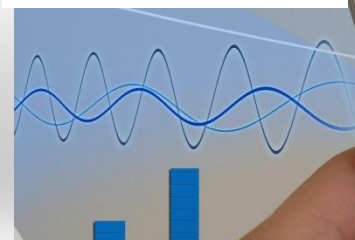
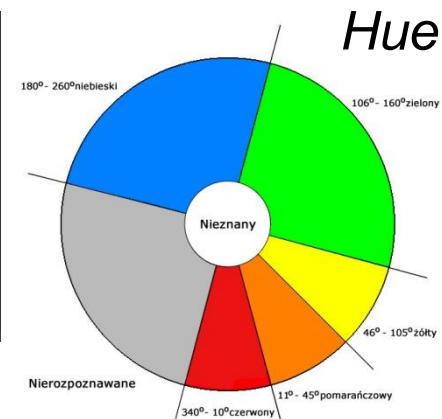
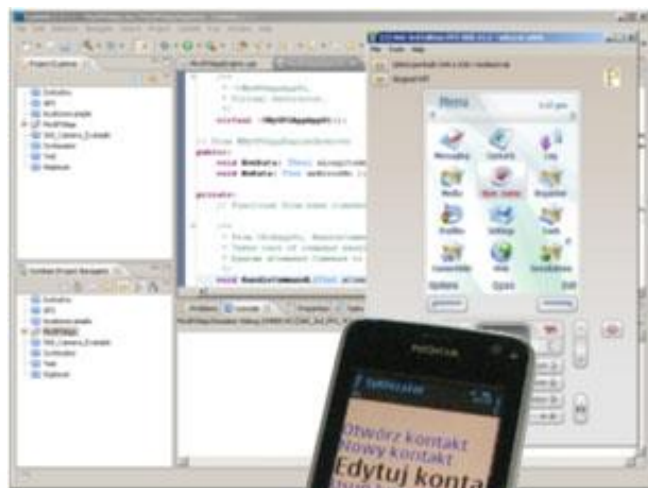


- *skin detection (Bayes classifier)*
- *the Kalman filter for tracking*

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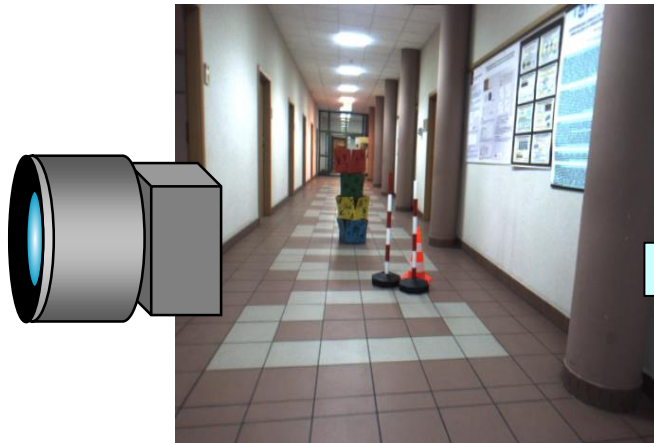
Smartphone for the visually impaired



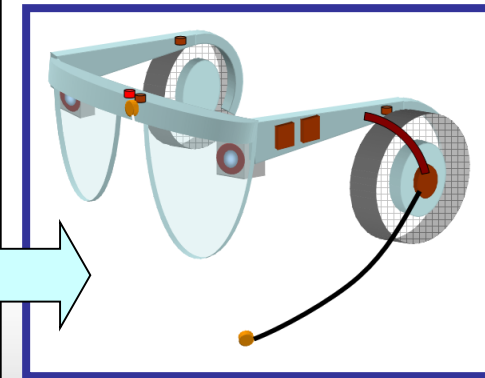
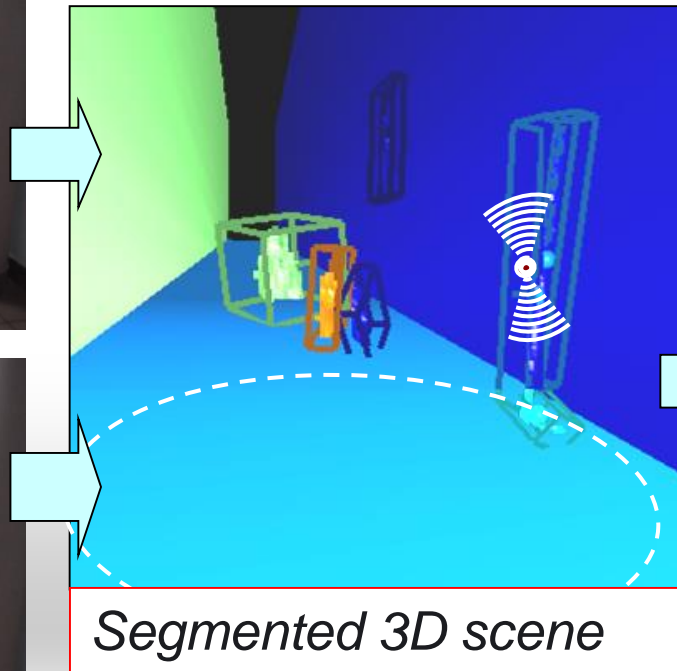
- *Eclipse- and CodeWarrior-based development environments (Carbide C++)*
- *SDK, phone emulator*



Auditory scene display



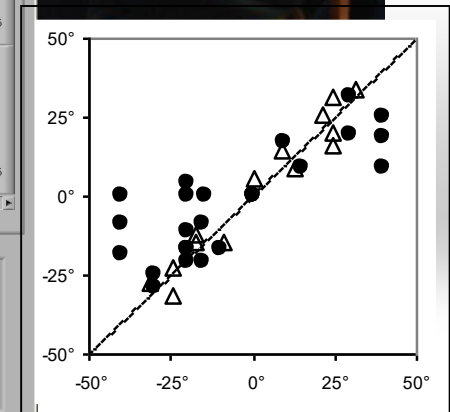
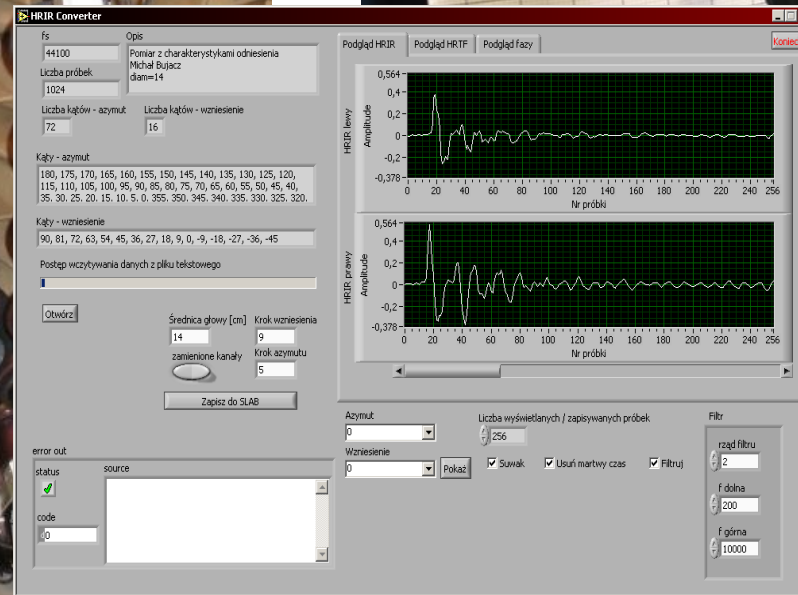
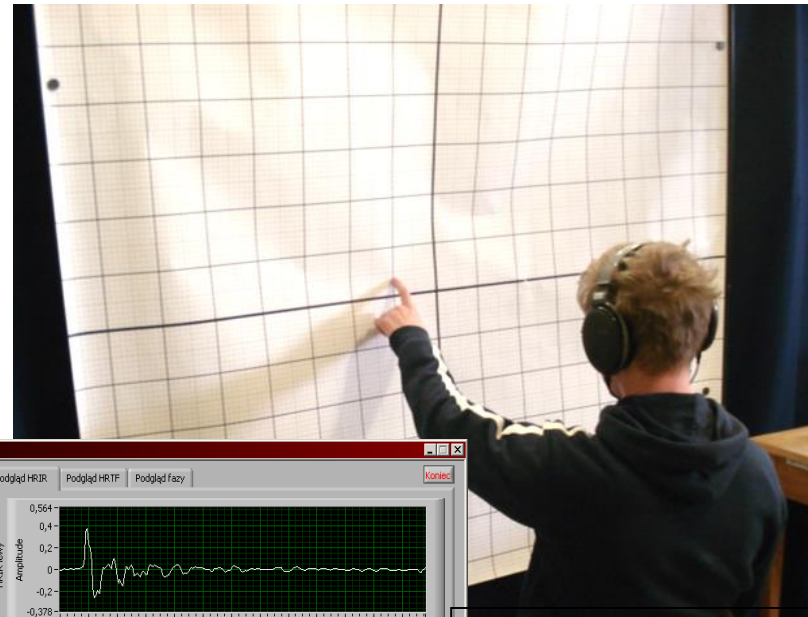
Stereovision



3D audio

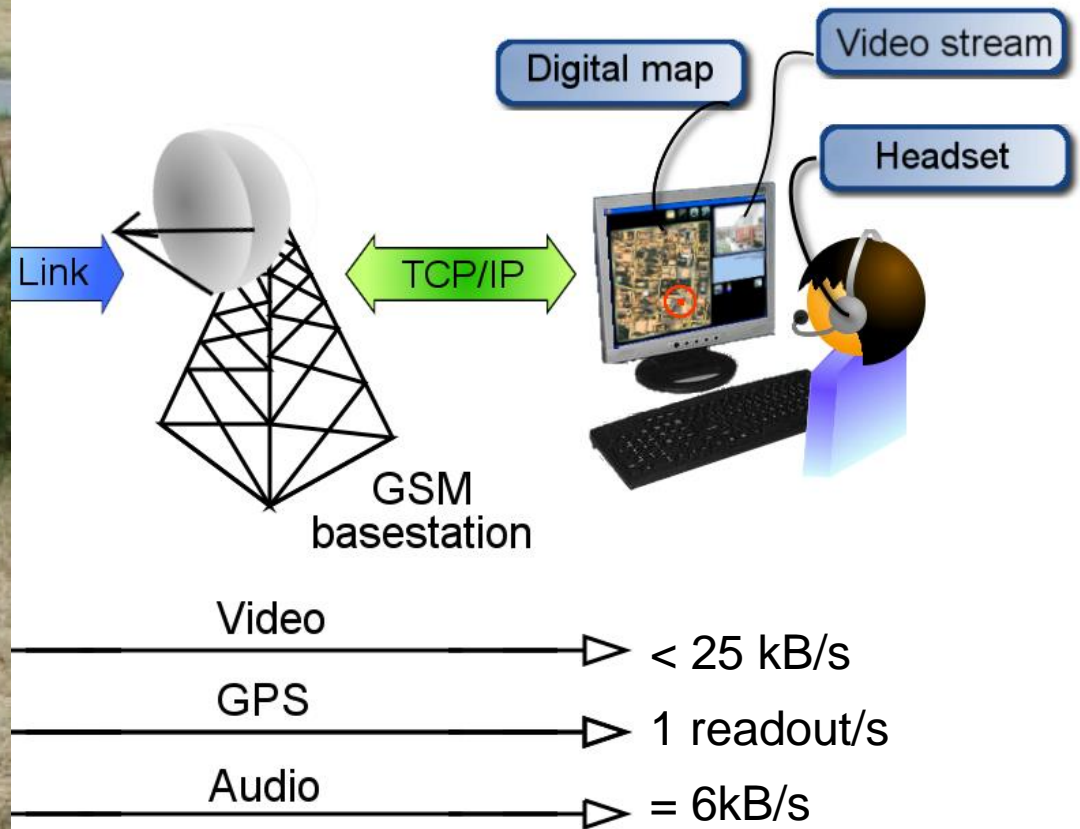
P. Skulimowski – „Detection and tracking objects in video sequences for 3D scene auditory display”, PhD, Lodz, 2009

Spatial sound space - HRTF

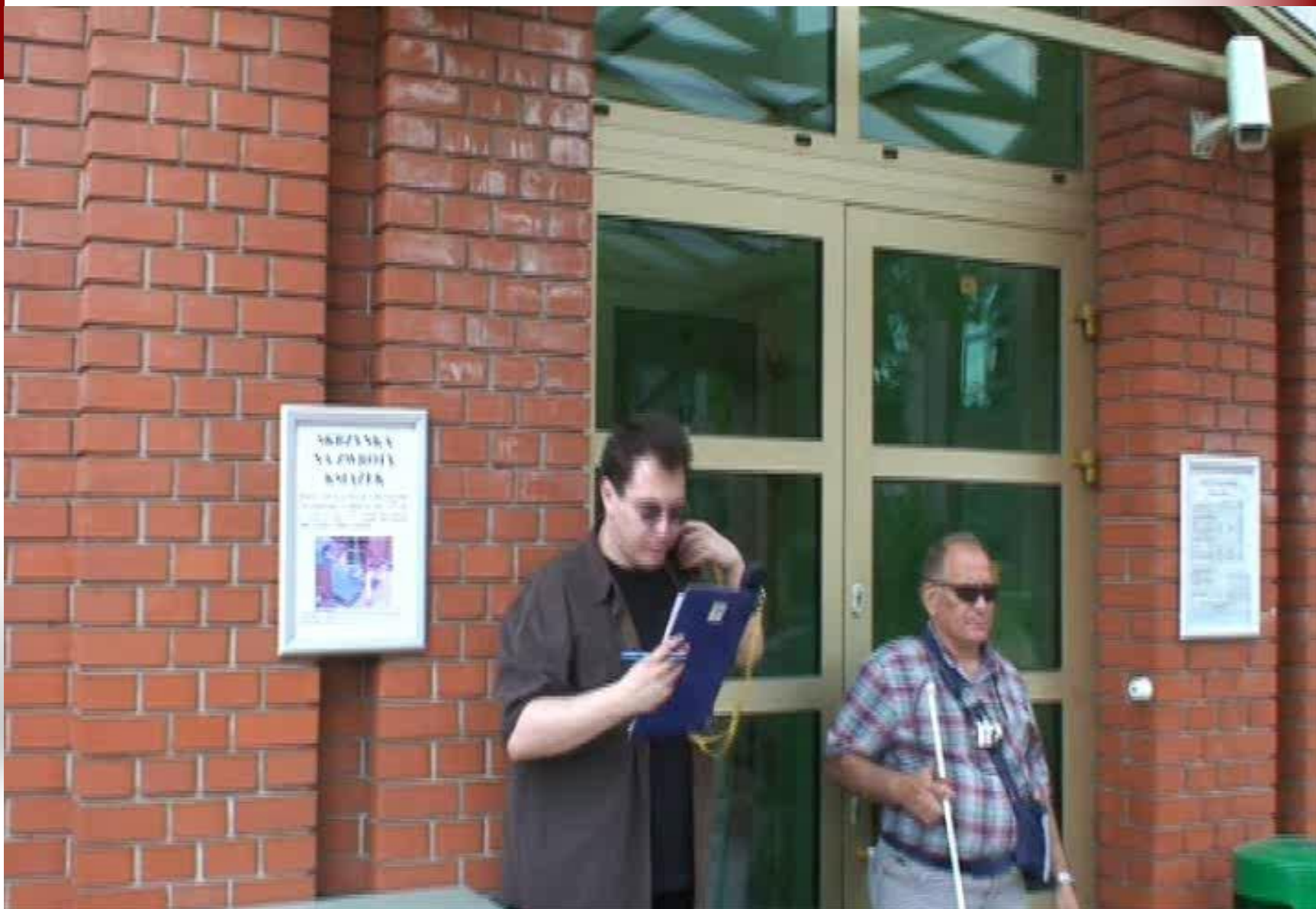


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Remote navigation for the visually impaired



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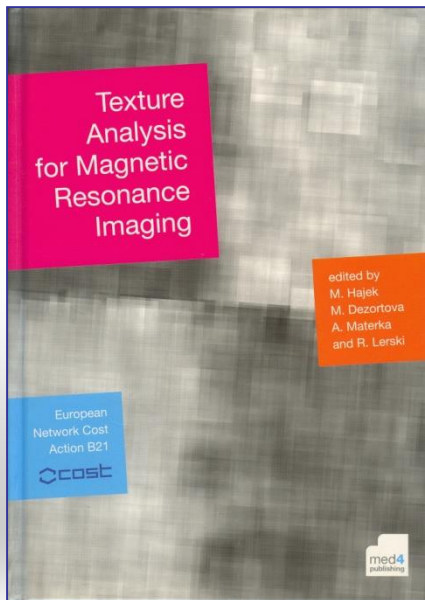


Navigation aid for the visually impaired

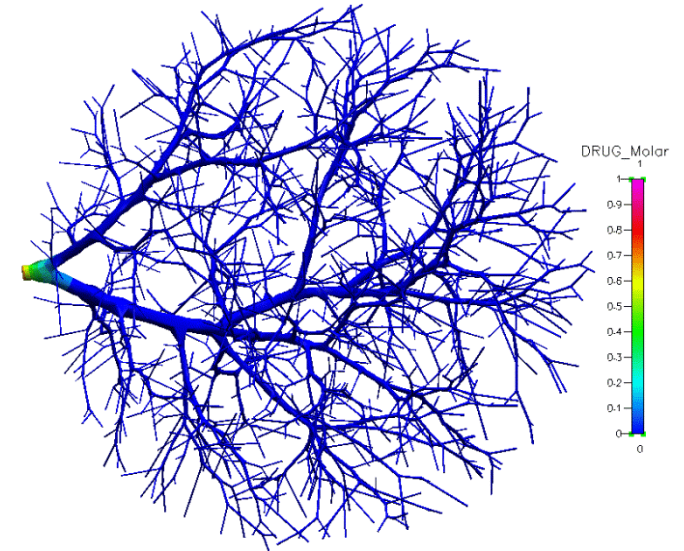


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Magnetic resonance image analysis



www.eletel.p.lodz.pl/mazda/



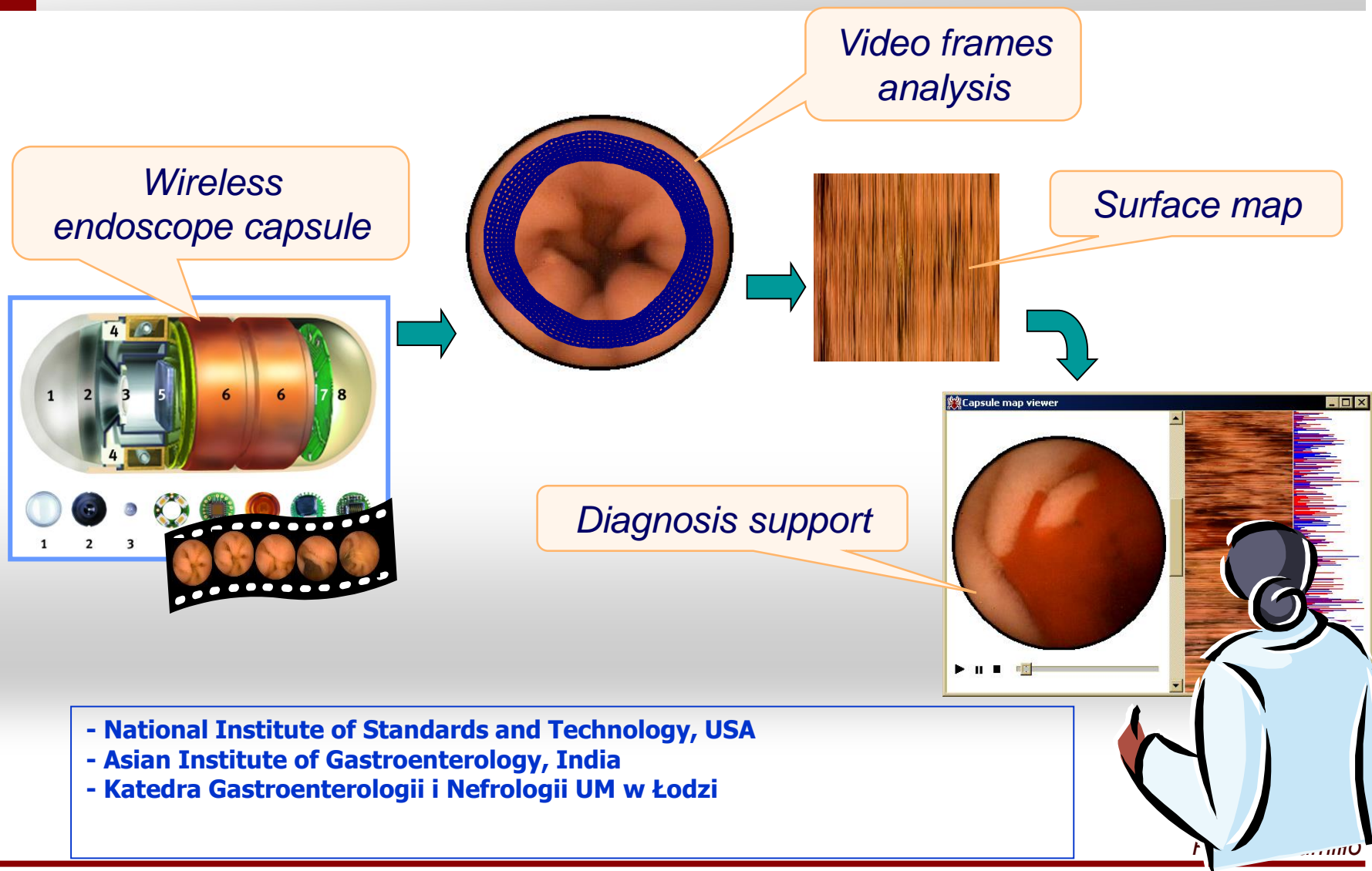
2002-04: COST B11 (18 partners)

2004-07: COST B21 (18 partners)

2007-10: DFG (2 partners)

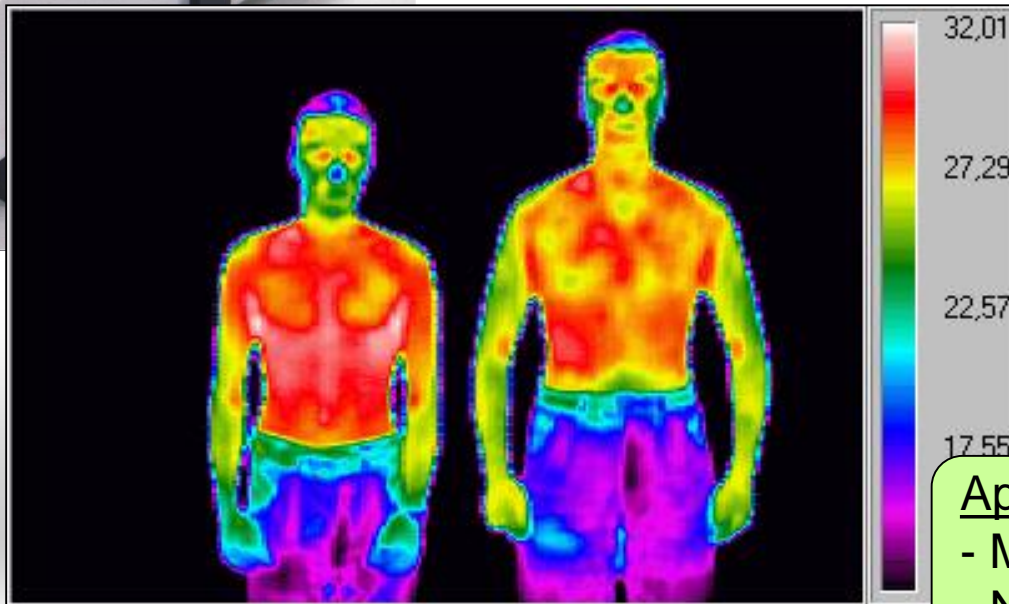
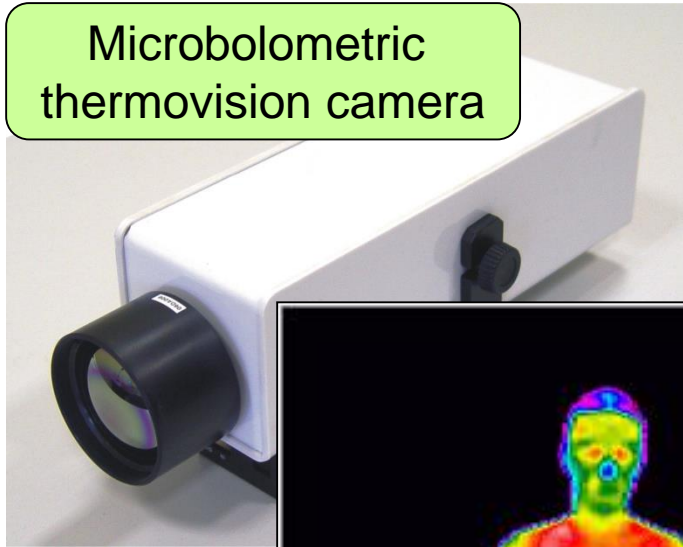
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Wireless endoscope capsule



Computed thermography systems

Microbolometric
thermovision camera



Applications

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

Computed thomography group

Paweł Strumiłło



Received: 2011.01.16
Accepted: 2011.04.01
Published: 2011.09.01

Authors' Contribution:

- A** Study Design
- B** Data Collection
- C** Statistical Analysis
- D** Data Interpretation
- E** Manuscript Preparation
- F** Literature Search
- G** Funds Collection

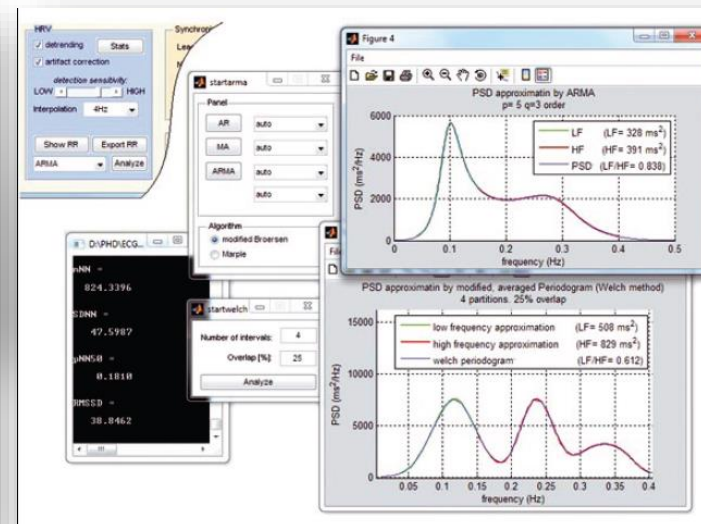
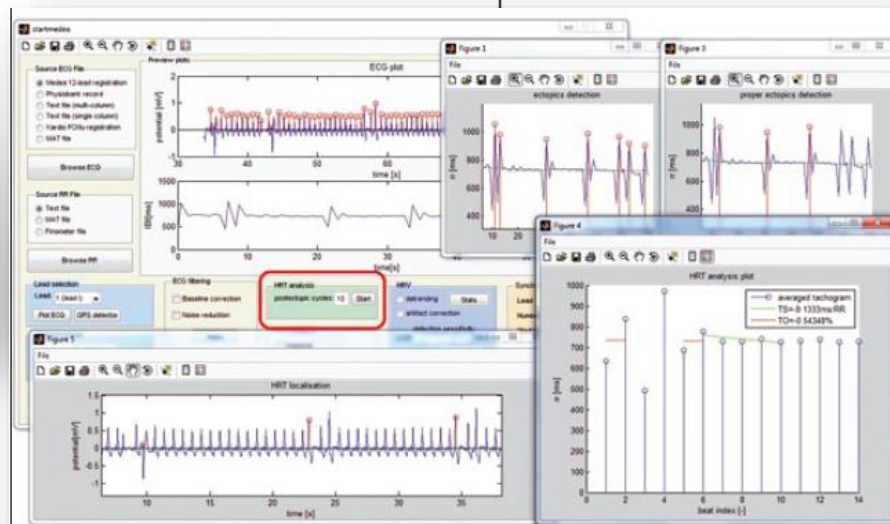
Computer Software tool for heart rate variability (HRV), T-wave alternans (TWA) and heart rate turbulence (HRT) analysis from ECGs

Krzysztof Kudryński^{1A,B,C,E,F}, Paweł Strumiłło^{1A,E,G}, Jan Ruta^{2D}

¹ Institute of Electronics, Technical University of Lodz, Lodz, Poland

² Department of Electrocardiology, Medical University of Lodz, Lodz, Poland

Source of support: Krzysztof Kudryński is a scholarship holder of project entitled "Innovative education..." supported by the European Social Fund. This work has been in part supported by the Ministry of Education and Science of Poland research grants no. N N518 506339 in years 2010-2011



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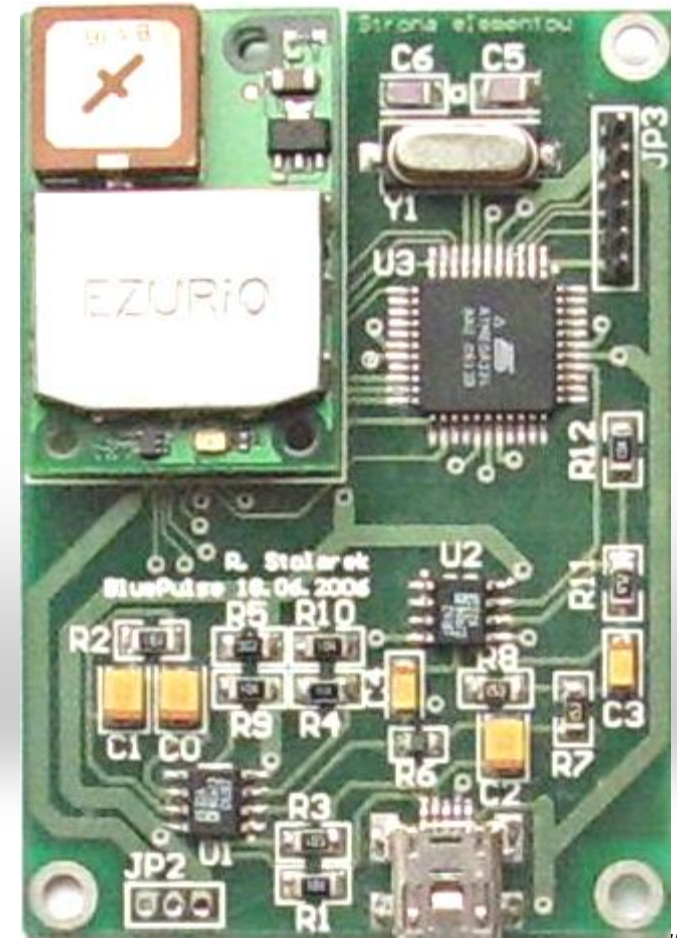
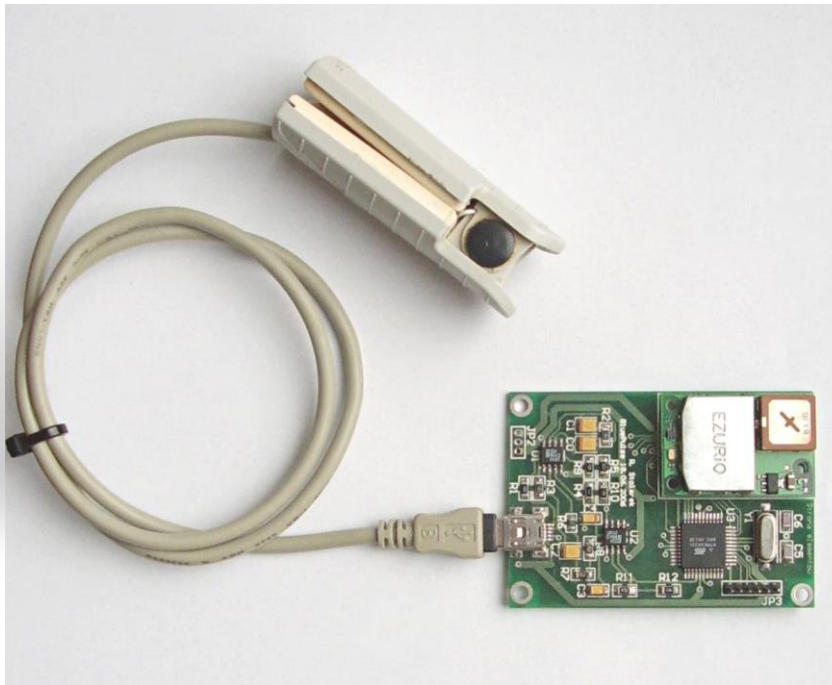


MSc thesis - example

Remigiusz Stolarek –

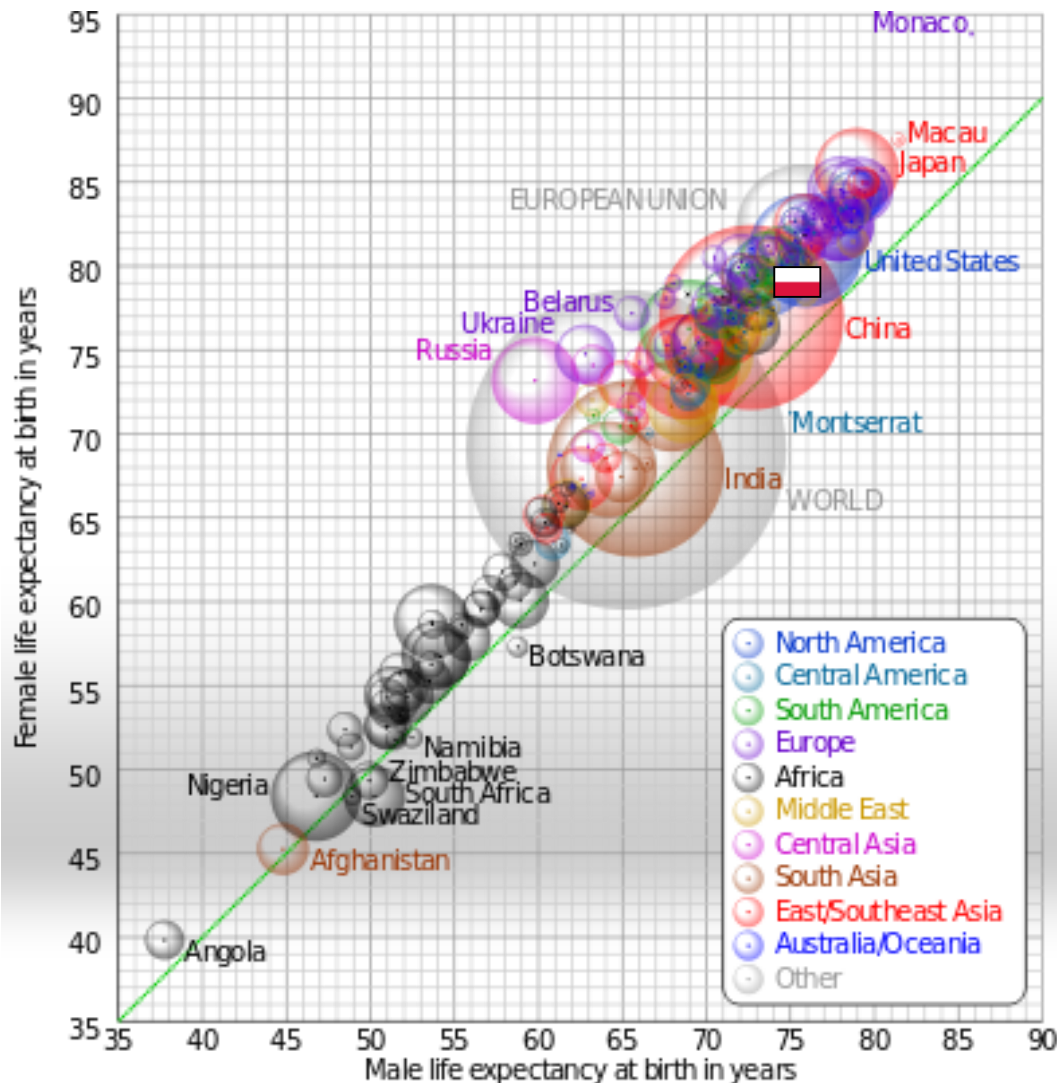
„A system for wireless transmission of human pulse”

(supervisor: Piotr Romaniuk)



Power Strumień

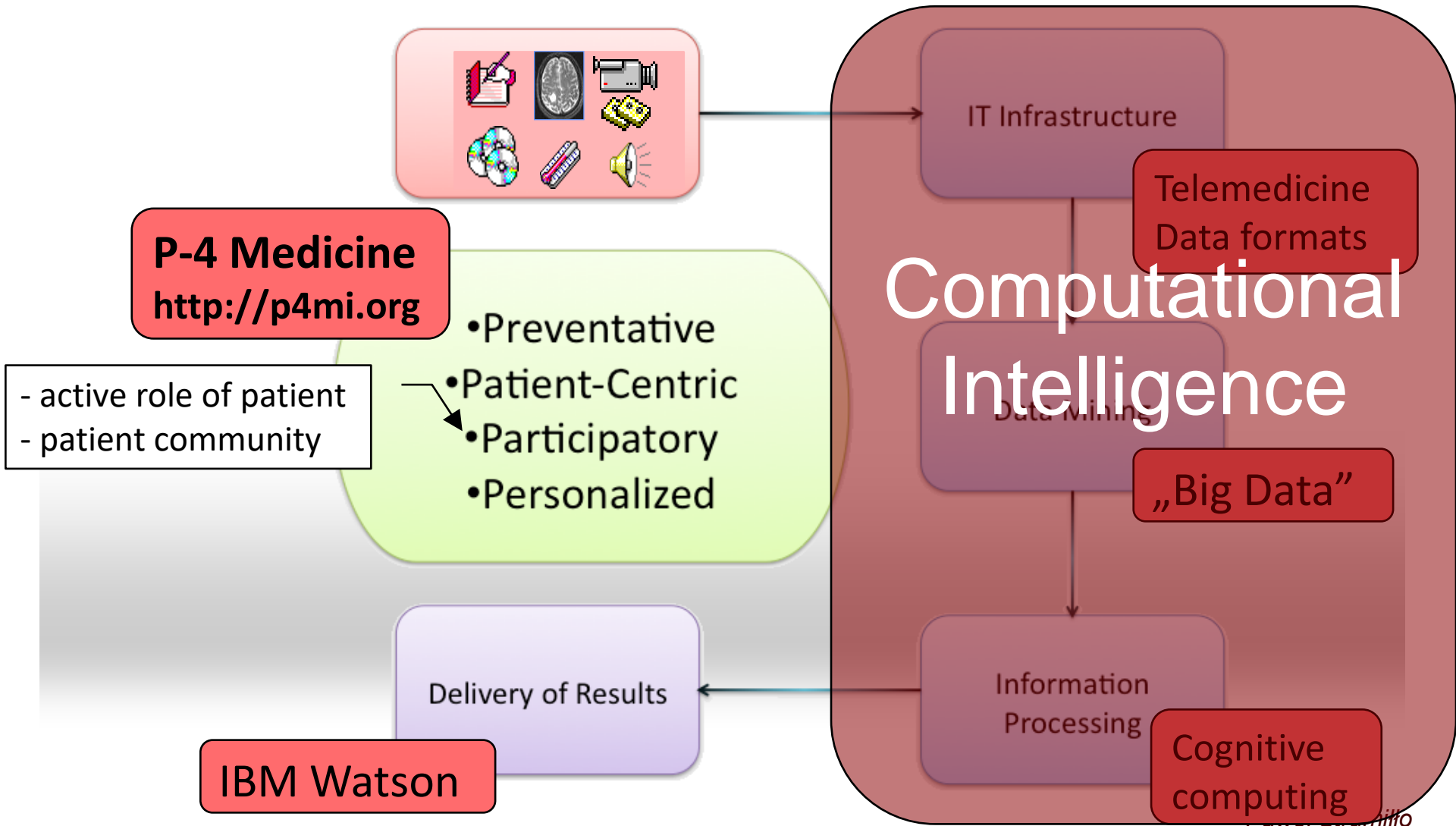
Challenges lifestyle diseases



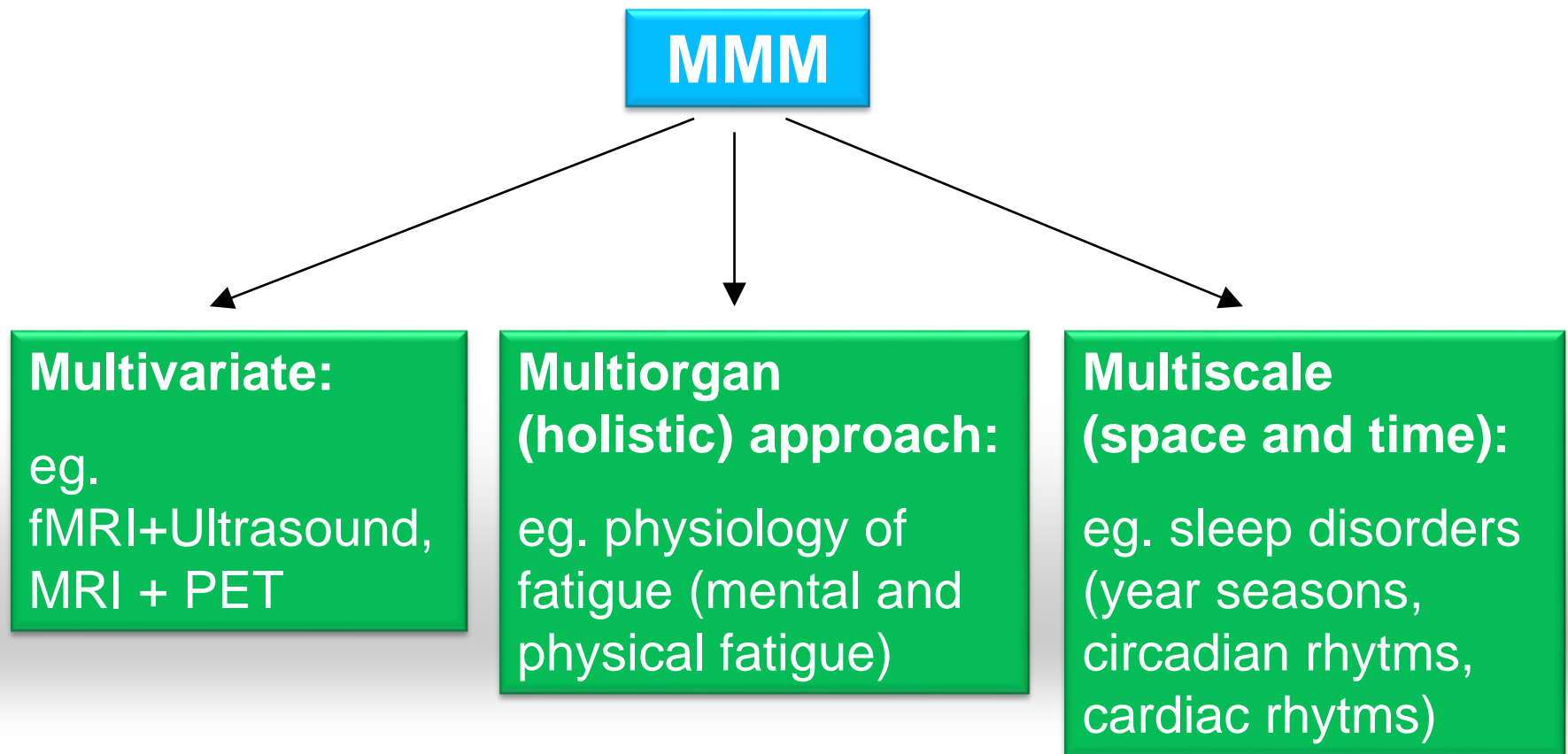
Life expectancy rates start to drop due to lifestyle diseases!



Paweł Strumiłło



MMM (Multivariate Multiorgan Multiscale)





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....

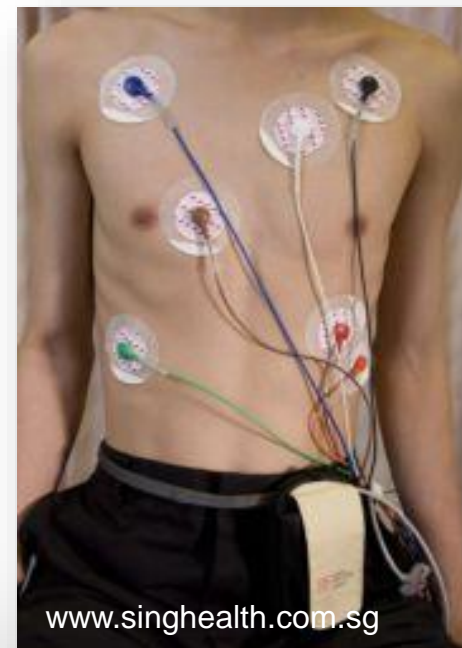
Paweł Strumiłło





Vital signs

Vital sign	Sensor
ECG, heart rate	Body surface electrodes
Blood pressure	Pressure cuff (Korotkov pulses)
Body temperature	Temperature sensor
Respiratory rate	Piezoelectric sensor
O ₂ Saturation	Optical sensor (pulsoximeter)



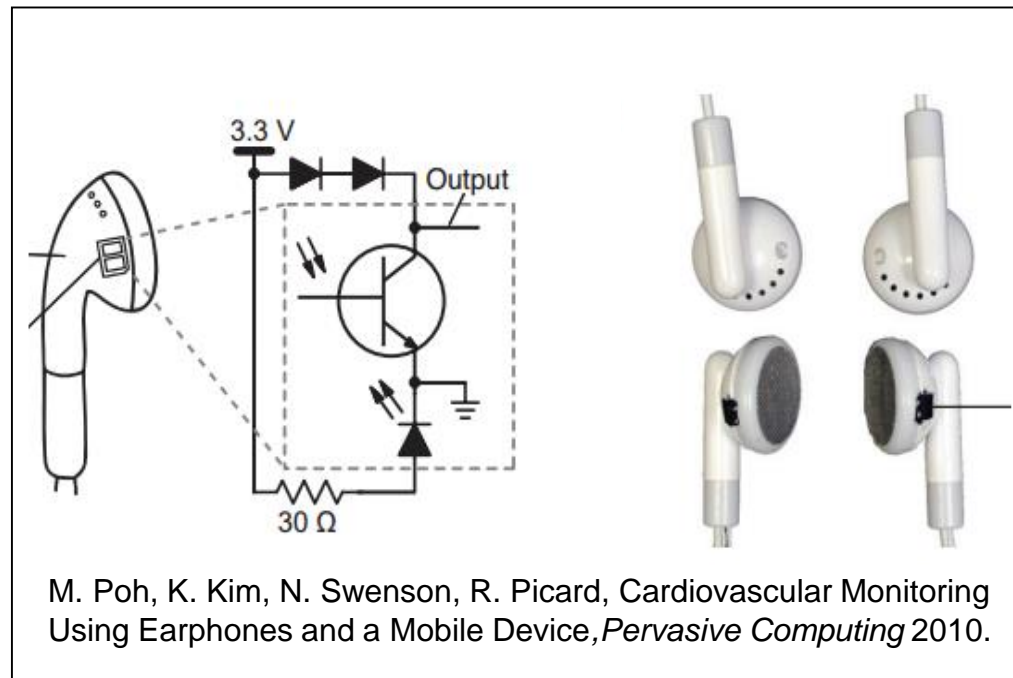
Photoplethysmography

Photoplethysmography – indirect measurement of blood volume flowing in finger veins.

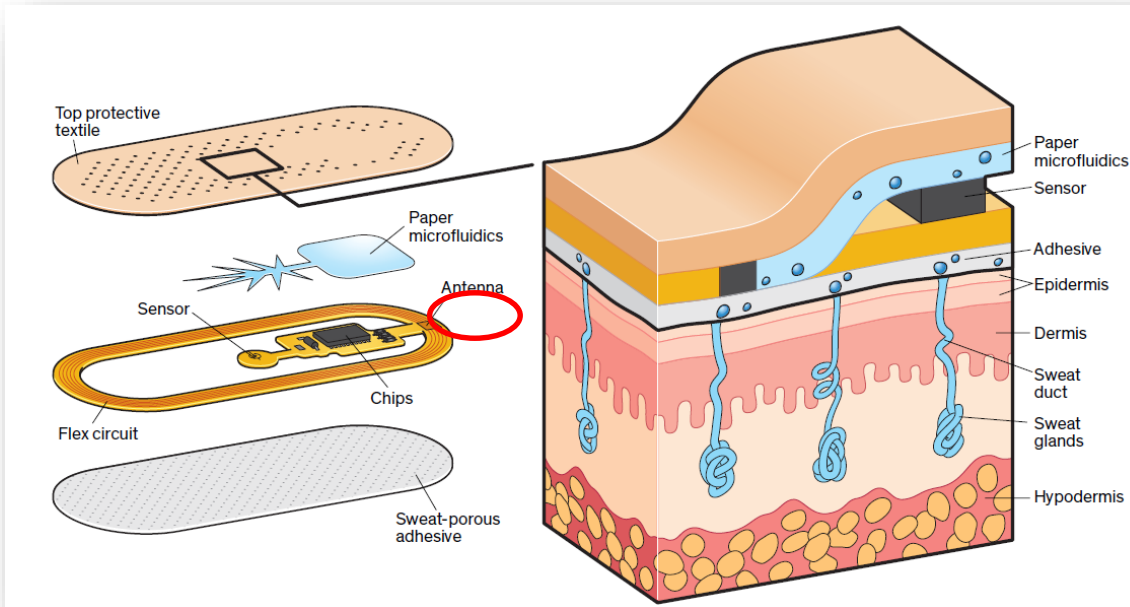
→ measurement: O_2 , heart rate, respiratory rate, blood pressure

$$BP = \frac{1}{b} \ln \left(\frac{L^2 \rho b}{PTT^2} - 1 \right)$$

L – distance travelled by pulse
 PTT – pulse transit time
 b – patient dependent parameter
 ρ – blood mass density kg/m^3



Analysis of chemical compounds in sweat

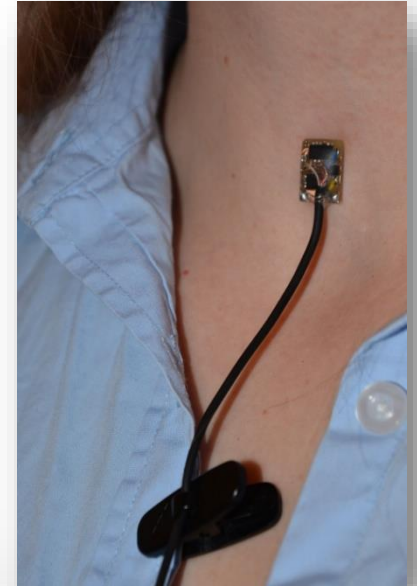
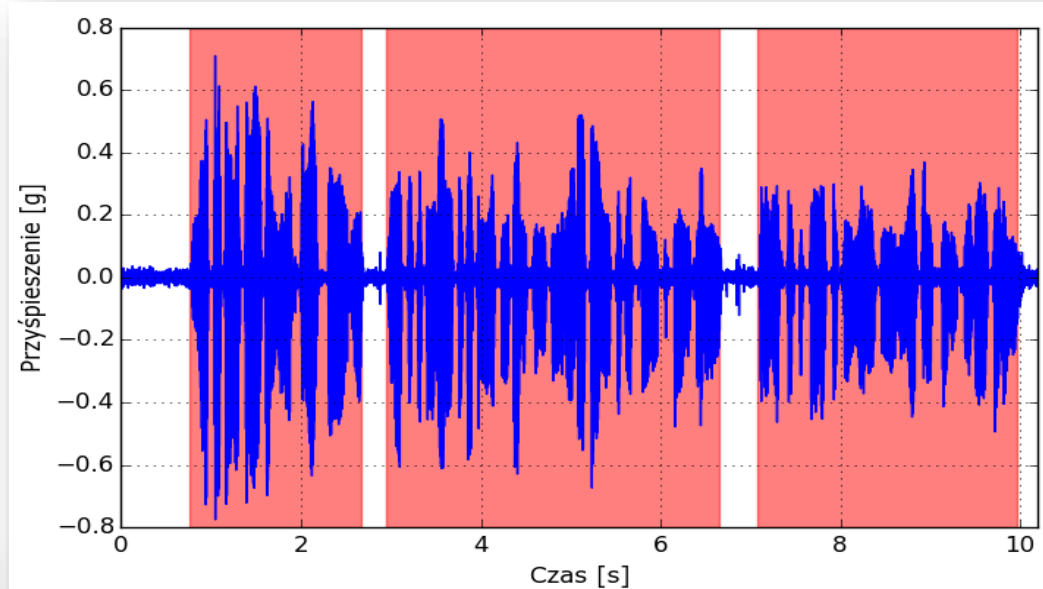


Measurement:

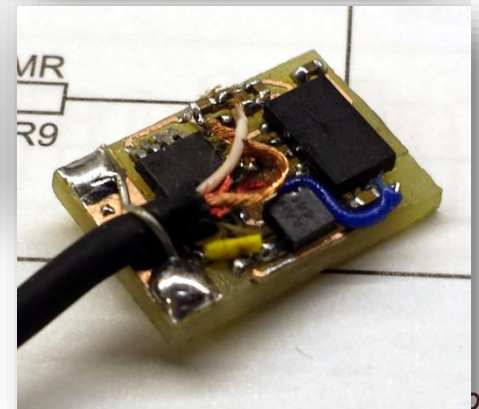
- concentration of medicine,
- concentration and balance of electrolytes,
- dehydrating

- *J. Heikenfeld, Your sweat may bring medical diagnostics to Fitbits and Fuelbands , IEEE Spectrum, Nov. 2014*

Voice load (Institute of Occupational Medicine in Lodz)



Parametr	Before work	After work
Fundamenta frequency [Hz]	113,1	124,5
Average power [dB(SAL)]	33,5	31,2



Examples of future biomedical engineering



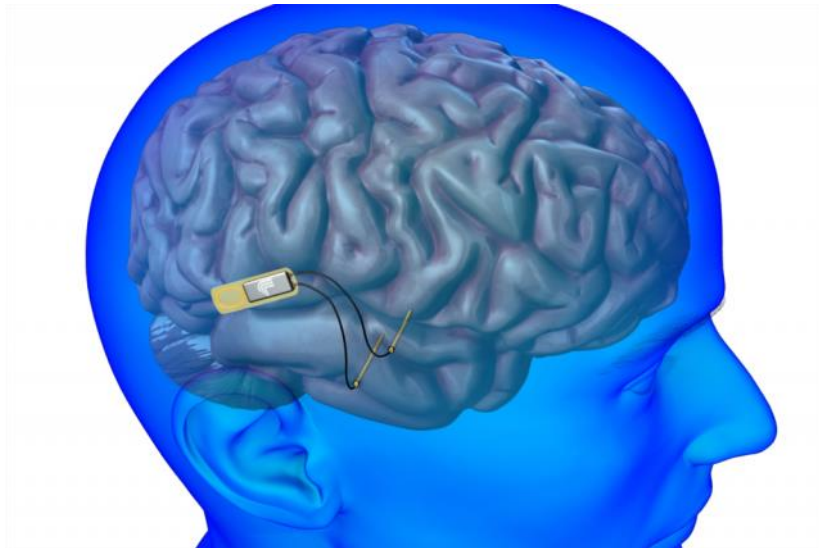
www.youtube.com/watch?v=s8eTLT1QexM#t=90

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Deep brain stimulation

Brain implant capable of restoring lost memories (a 4 year DARPA project)



<http://www.digitaltrends.com/cool-tech/us-military-developing-brain-implant-to-restore-memory/>

Parkinson Disease implant

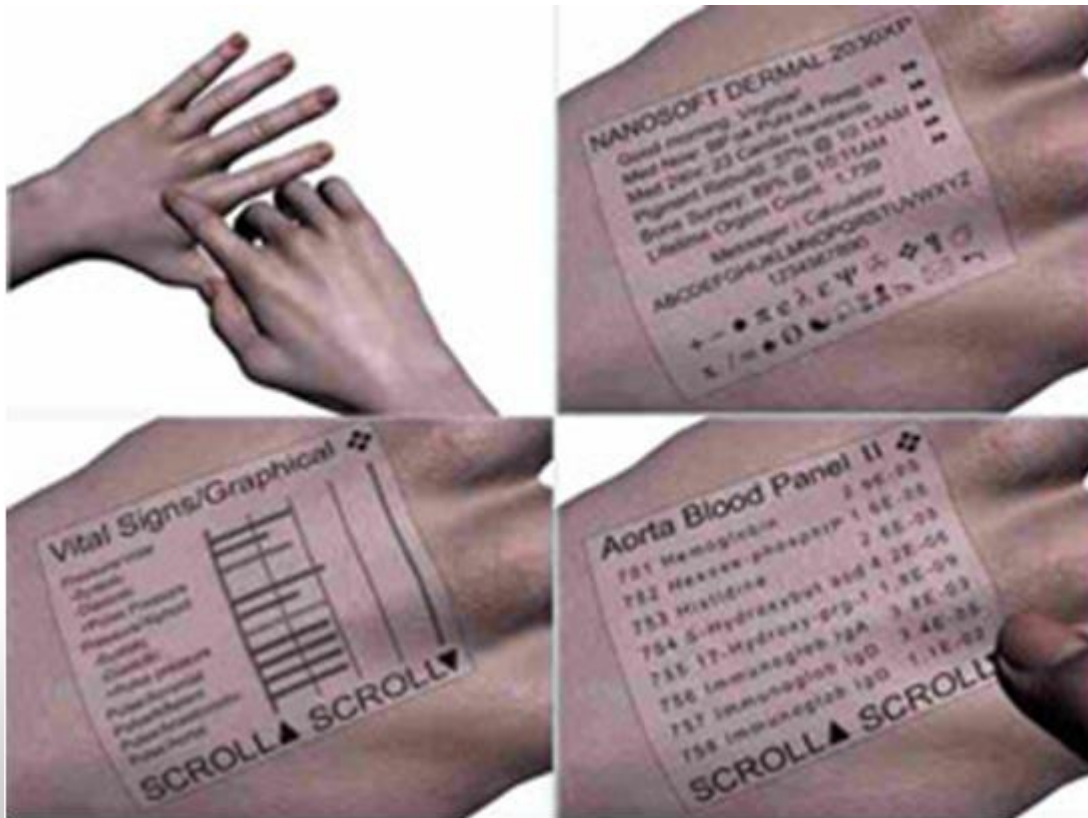


<http://www.bbc.com/news/health-35734888>

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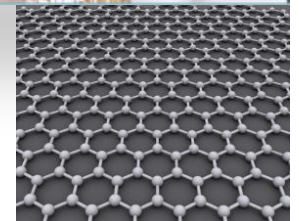


Dermal computer and display → bionic skin



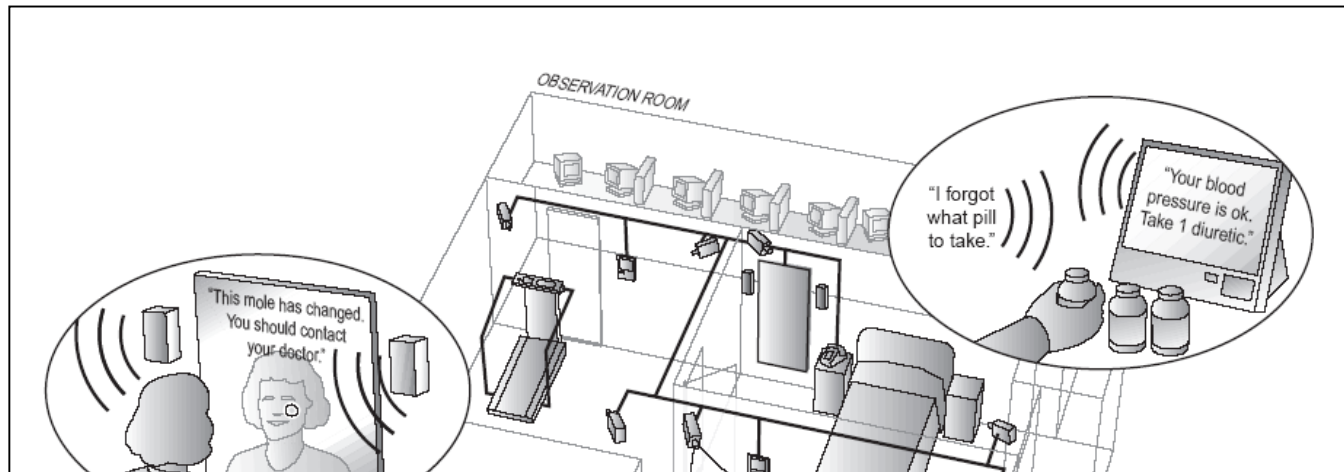
Artist's vision: Gina Miller, 2007

New material: Graphene!



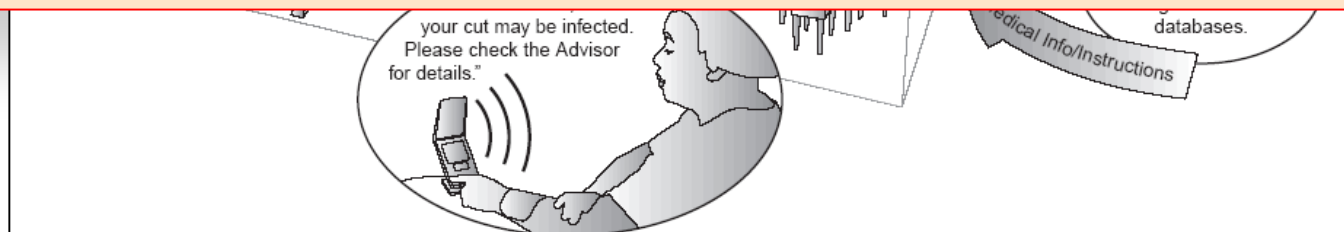
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Intelligent monitoring



„....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)

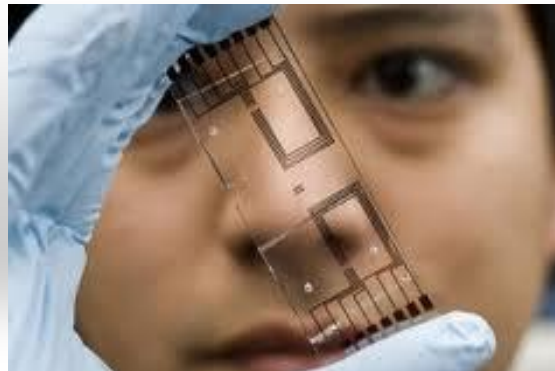
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Prospects are good for biomedical engineers ...

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



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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”***



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www.kapitalludzki.p.lodz.pl