

Acquisition and Analysis of Biosignals

DTEK0042

Introduction to Biosignals

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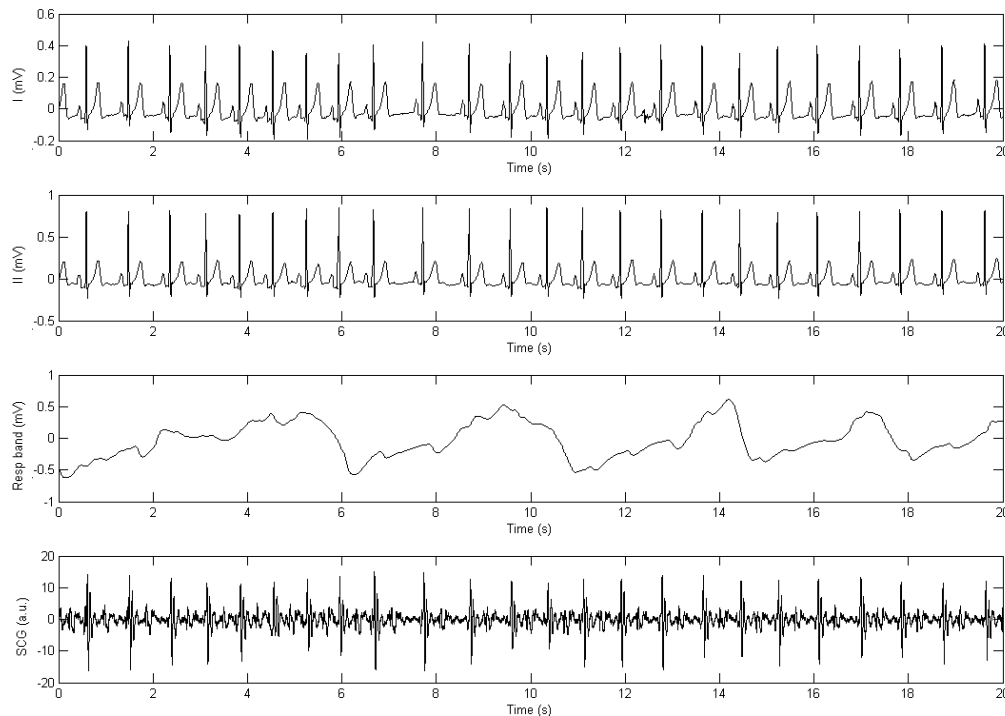


Turun yliopisto
University of Turku

Biosignals

- ☐ What is a biosignal?
- ☐ Why is it important?
- ☐ How is it used?
- ☐ For which applications?
- ☐ How is it collected?
- ☐ How is it categorized?

Samples of ECG, breathing and SCG signals



<https://www.physionet.org/content/cebsdb/1.0.0/>

Biosignals

☐ What is a biosignal?

☐ Why is it important?

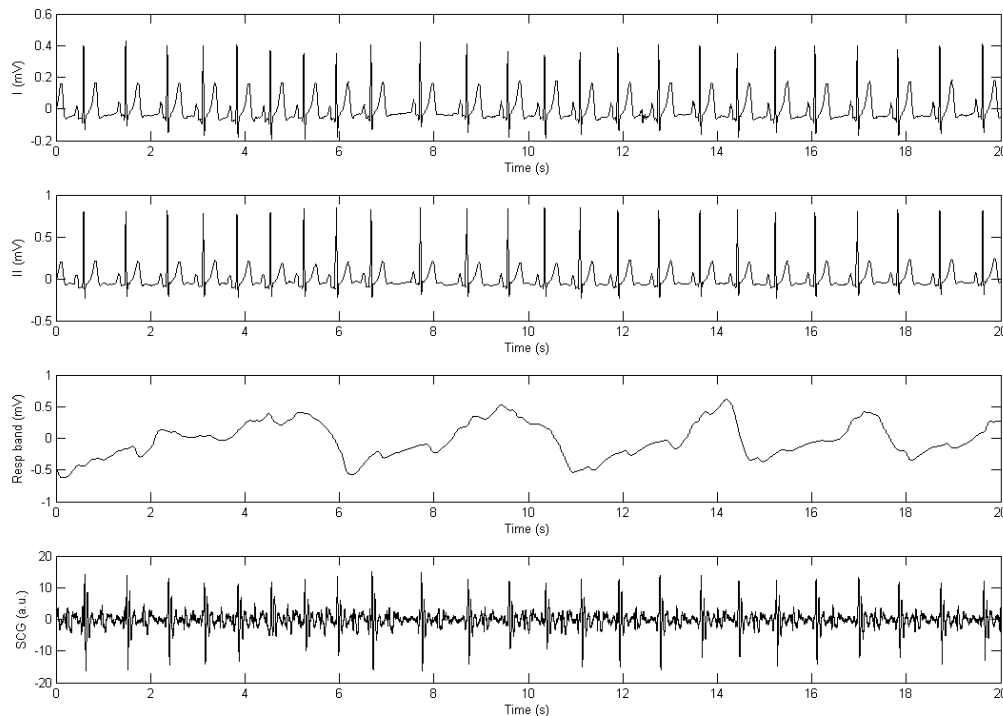
☐ How is it used?

☐ For which applications?

☐ How is it collected?

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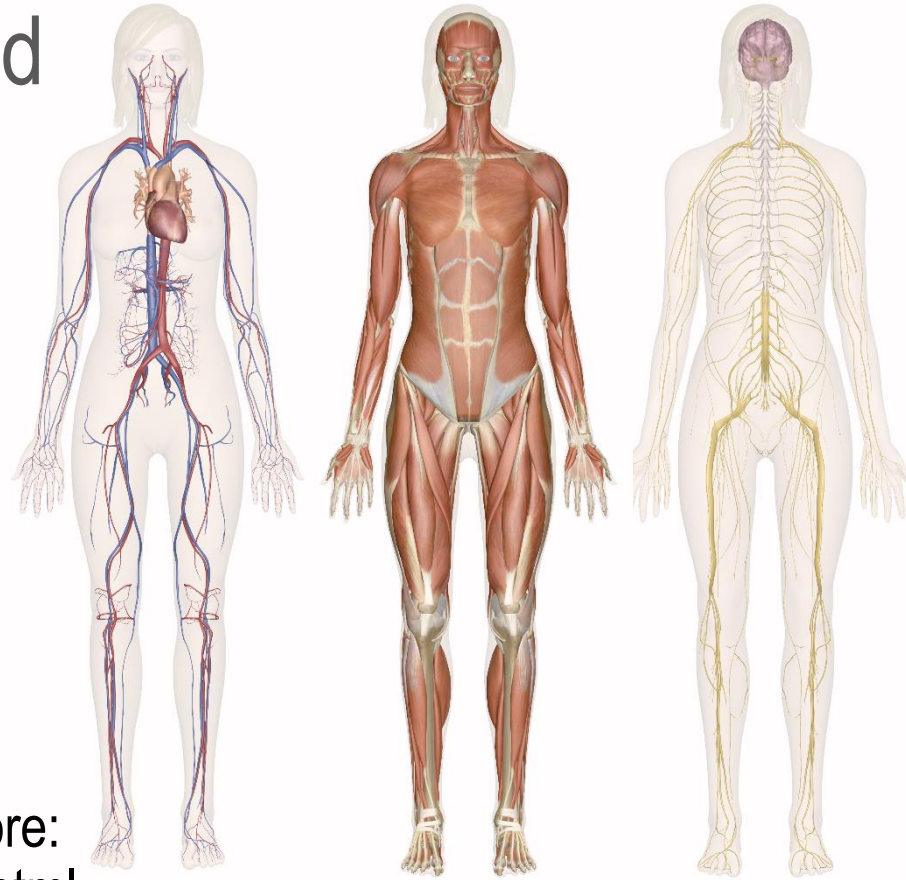
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Physiological systems and processes

- ❑ Living organisms include many component systems
 - Cardiovascular
 - Muscular
 - Nervous
- ❑ Physiological processes are complex phenomena, including nervous or hormonal stimulation and control
- ❑ An educational source for learning more:
<https://www.innerbody.com/htm/body.html>



<https://www.innerbody.com/image/cardov.html>

<https://www.innerbody.com/image/musfov.html>

<https://www.innerbody.com/image/nervov.html>

Physiological process and biosignals

- ❑ Most **physiological processes** are accompanied by or manifest themselves as **signals** that reflect their nature and activities.
- ❑ Diseases or defects in a physiological system change the process and the biosignals.
- ❑ In such situations, the biosignals are different from the normal condition.

First example: body temperature

Most infections cause a rise in the body temperature (BT)

A single measurement of BT $\Rightarrow \mathbf{x}$

- A scalar which shows the BT at a certain instant of time

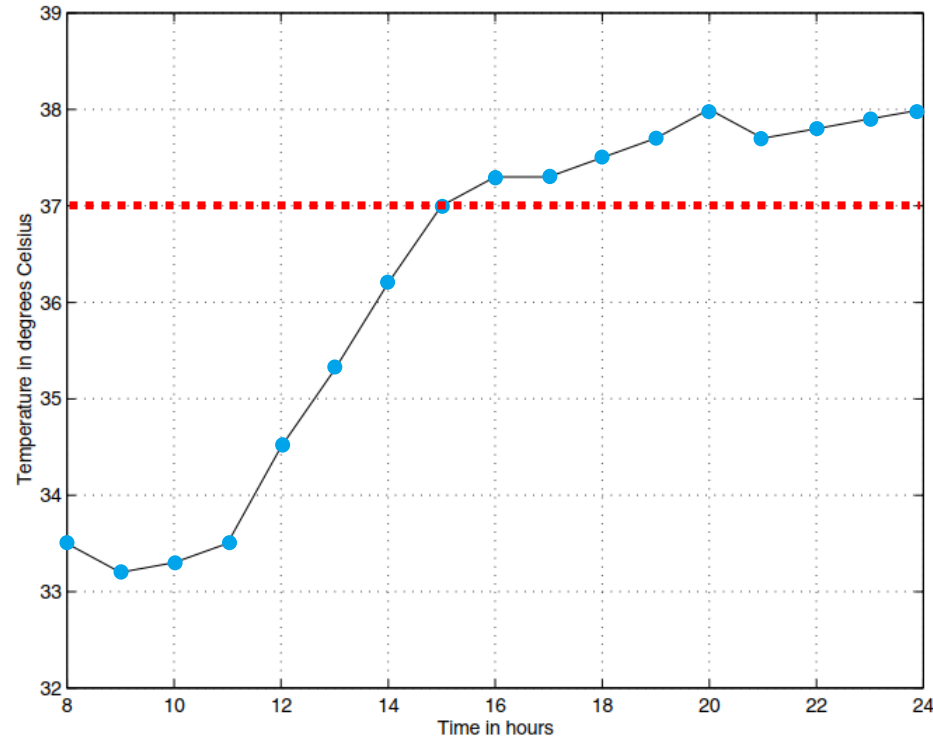
Continuous measurement of BT $\Rightarrow \mathbf{x(t)}$

- A signal which shows the BT as a function of time

But, our measurement is discrete $\Rightarrow \mathbf{x(n)}$

$$\mathbf{x(n)} = [\mathbf{x_1} \ \mathbf{x_2} \ \mathbf{x_3} \ ... \ \mathbf{x_N}]$$

E.g., to detect a disease: if the value of BT is higher than a **threshold** (e.g., 37°C)



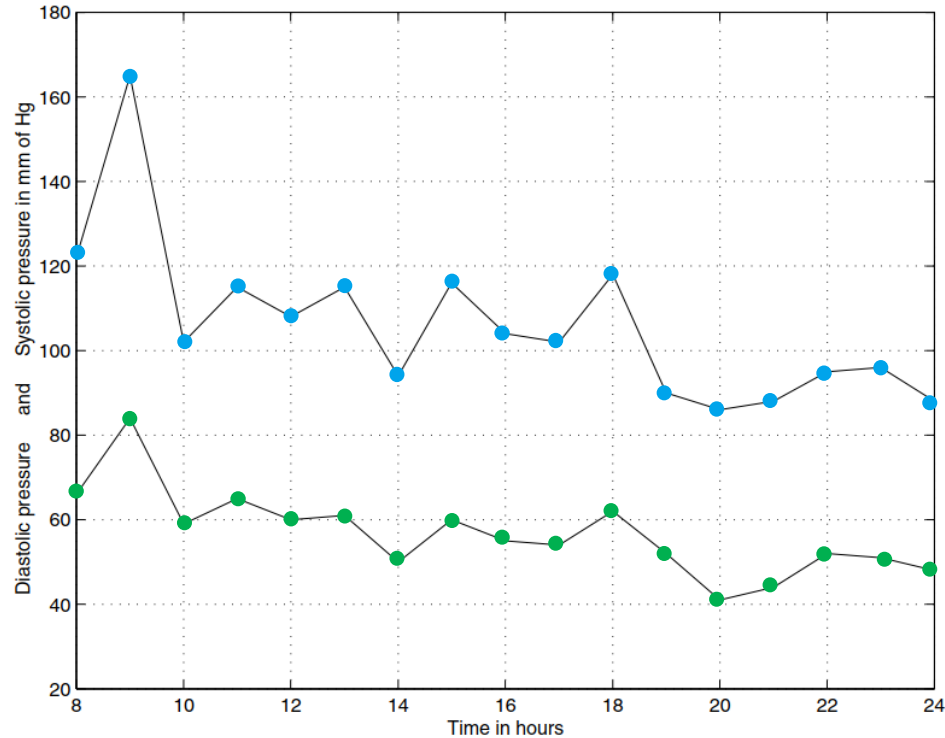
Second example: blood pressure

Blood pressure (BP) shows the pressure on the walls of the vessels

- ❑ Systolic BP: the pressure when the heart beats
- ❑ Diastolic BP: the pressure when the heart muscle relaxes

Measurements of the BP => $\mathbf{x}(n)$

$$\mathbf{x}(n) = \begin{bmatrix} x_{1,1} & x_{1,2} & x_{1,3} & x_{1,N} \\ x_{2,1} & x_{2,2} & x_{2,3} & \dots & x_{2,N} \end{bmatrix}$$



Rangayyan, R. M. Biomedical signal analysis. 2nd Edition, Vol. 33. John Wiley & Sons, 2015.

Third example: vital signs (1)

Vital signs are the measurements of the body functions.

Vital signs include:

- Heart rate
- Blood pressure
- Respiration rate (Breathing rate)
- Body temperature

They indicate the health condition of a patient => good or critical

Third example: vital signs (2)

- ❑ Monitoring of vital signs allows early-detection of health deterioration or death.
- ❑ Early Warning Score (EWS) is a scoring method used in hospitals for assessment of patients' conditions.
- ❑ Higher scores are statistically linked to increased likelihood of health deterioration.

| Physiological parameters | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
|-----------------------------------|--------|---------|---------|-----------|---------|-----------|-------|
| Respiration rate (breaths/minute) | | 0-8 | | 9-14 | 15-20 | 21-29 | 30+ |
| Oxygen saturation (%) | 0%-84% | 85%-89% | 90%-94% | 95%-100% | | | |
| Temperature (oC) | | 0-35 | | 35.1-38.0 | | 38.1-39.5 | 39.6+ |
| Systolic BP (mmHg) | 0-69 | 70-80 | 81-100 | 101-149 | 150-169 | 170-179 | 180+ |
| Heart rate (beats/minute) | 0-39 | 40-50 | 51-59 | 60-100 | 101-110 | 111-129 | 130+ |
| Level of consciousness | | | | A | V | P | U |

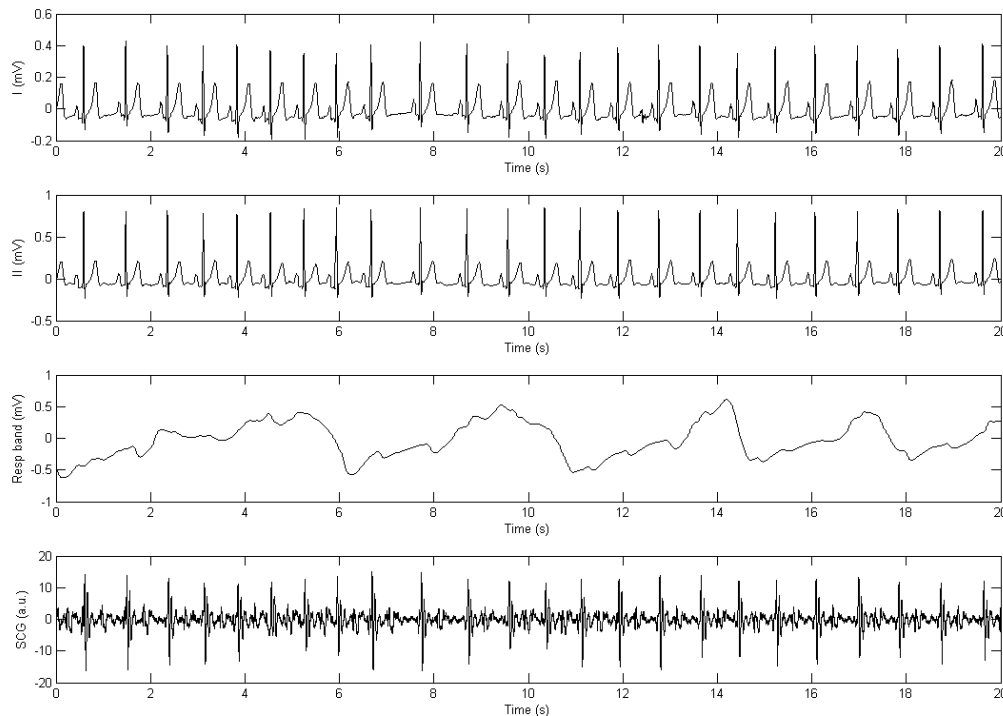
* A=Alert, V=response to voice, P=response to pain, U=unresponsive

Alam, N., et al. "The impact of the use of the Early Warning Score (EWS) on patient outcomes: a systematic review." Resuscitation 85.5 (2014): 587-594.

Biosignals

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- ☐ Why is it important?
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- ☒ **For which applications?**
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In-hospital applications

Biosignals are acquired in hospitals to monitor the health conditions of patients.

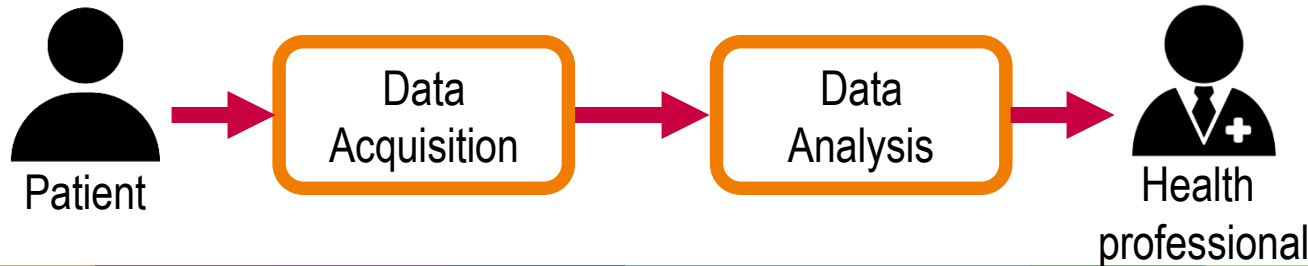
Hospital equipment

- E.g., ECG Machines
- Stationary and Wired

In summary:



<https://healthnewshub.org/eastern-ct/healthy-living/causes-irregular-heartbeat/>



Out-of-hospital monitoring

- ❑ Health monitoring is not limited to hospital settings anymore
- ❑ People can benefit from healthcare services at-home.
 - Reduce hospital stays
 - Reduce healthcare costs
- ❑ Advancements in recent technologies enables **remote, continuous,** and **long-term** monitoring of individuals.

More “Things” are being connected

- ❑ Home/daily-life devices
- ❑ Business and Public infrastructure
- ❑ Health-care

...

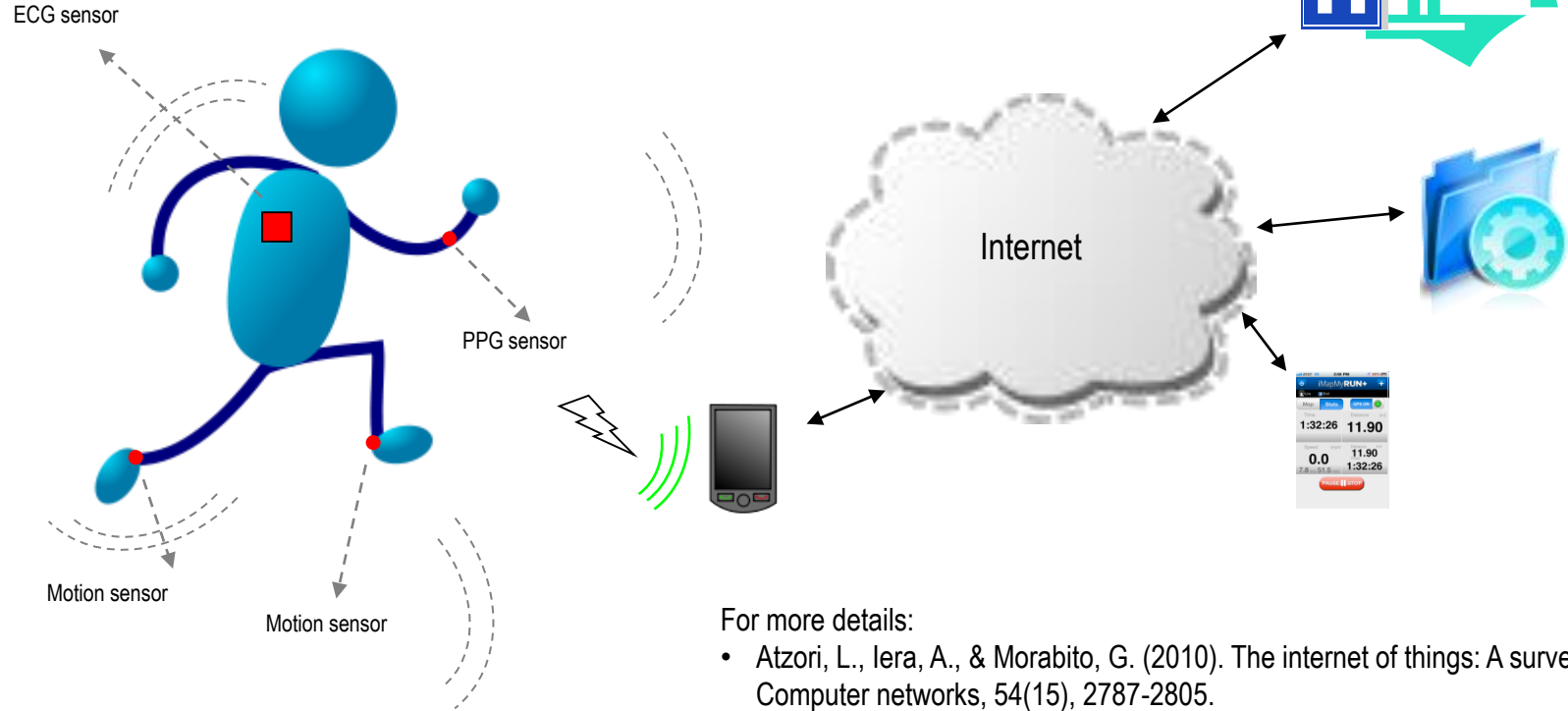


Sensor devices are becoming widely available

- ❑ Small
- ❑ Light
- ❑ Energy efficient
- ❑ Wireless
- ❑ Programmable



Internet of Things (IoT)



For more details:

- Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. *Computer networks*, 54(15), 2787-2805.
- Touati, F., & Tabish, R. (2013). U-healthcare system: State-of-the-art review and challenges. *Journal of medical systems*, 37(3), 9949.

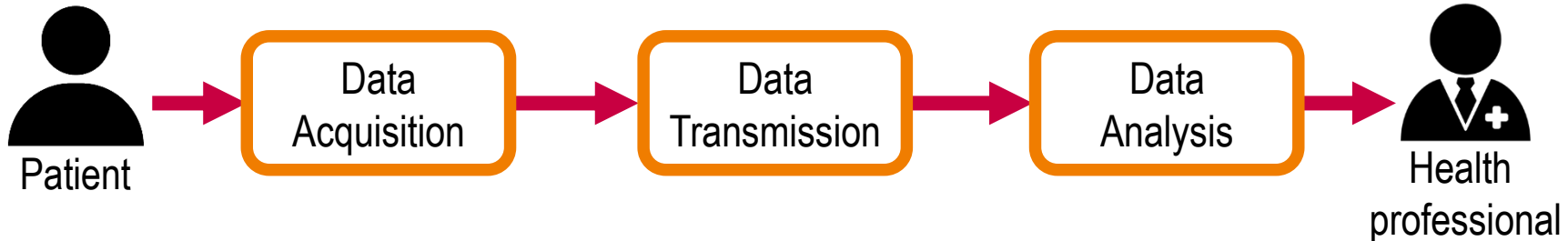
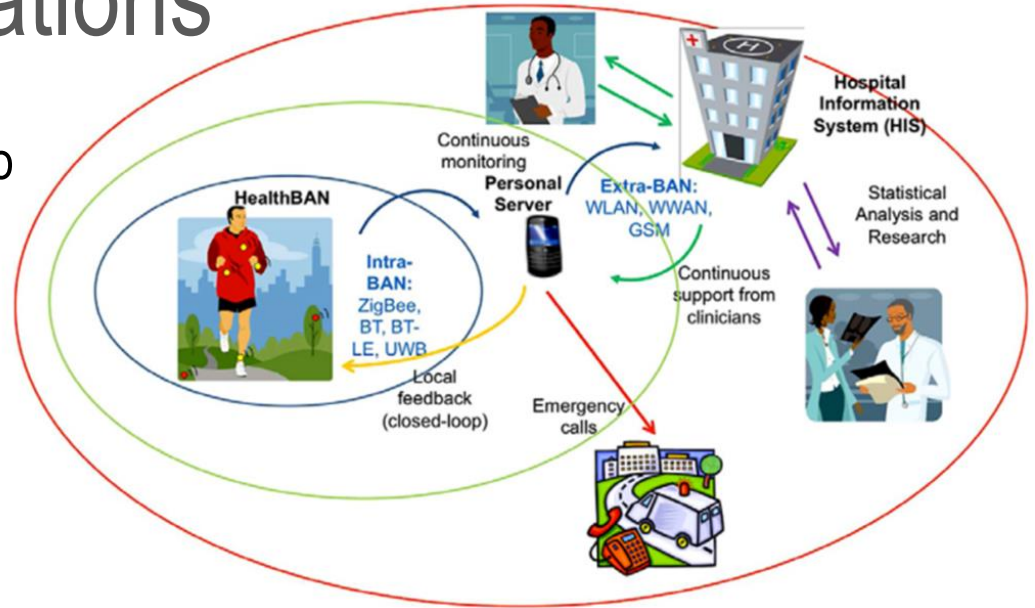
Telehealth applications

Biosignals are acquired remotely to monitor user's health, well-being, and lifestyle.

Wearable electronics

- ☐ Anywhere
- ☐ Anytime

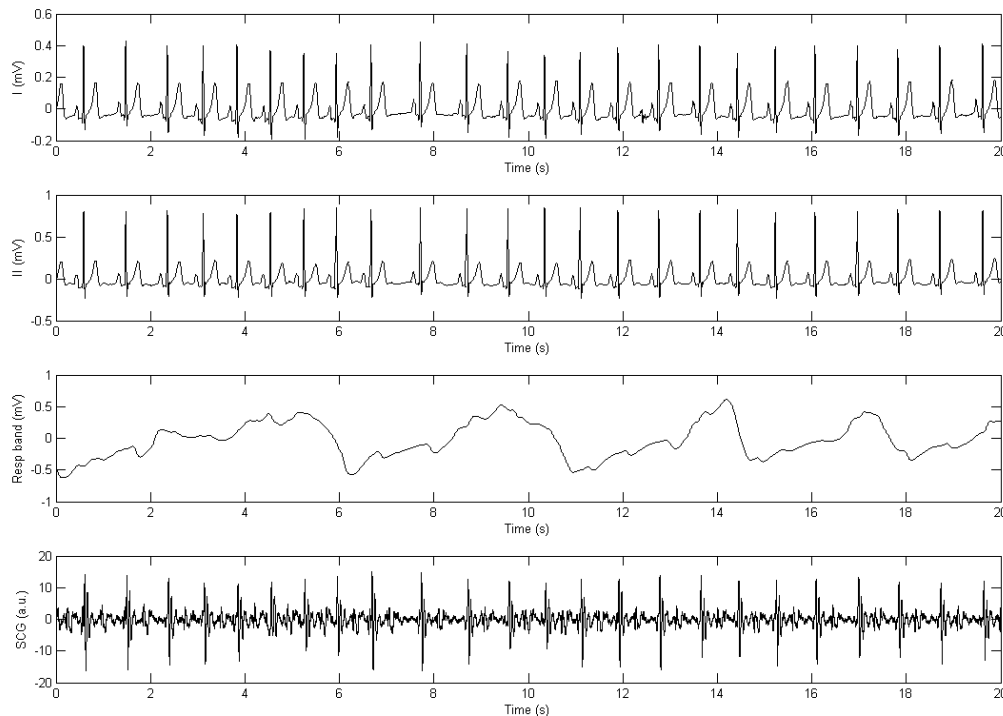
In summary:



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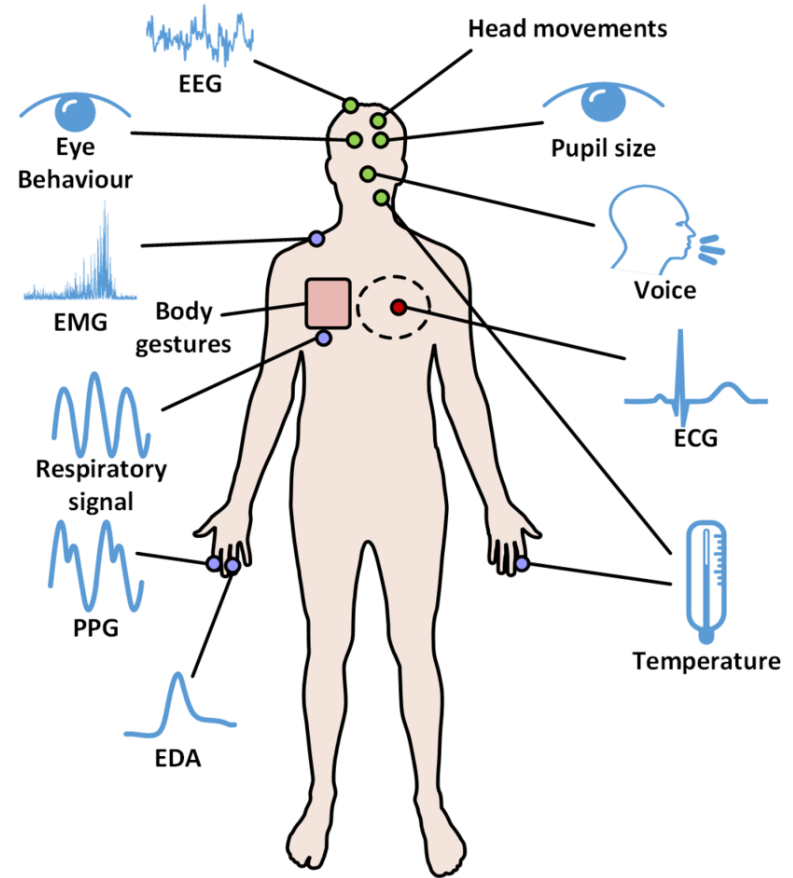
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Types of biosignals

- ❑ There are many types of biosignals with different origins.
- ❑ They are collected from different body regions.
- ❑ They are collected using different sensors
 - Electrodes / Electric potential sensors
 - Pressure sensors
 - Optical sensors
 - ...
- ❑ In general, the biosignals can be classified according to their:
 - Existence
 - Dynamic
 - Origin



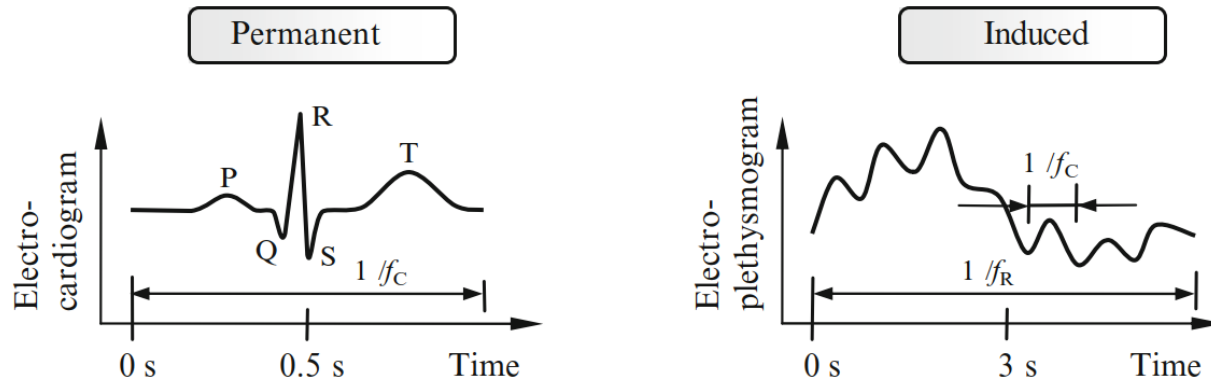
Existence of biosignal

1. Permanent biosignals

- Exist without any artificial impact, trigger, or excitation from outside the body are available at any time

2. Induced biosignals

- Artificially triggered, excited, or induced
- When the artificial impact is over, the induced biosignal decays



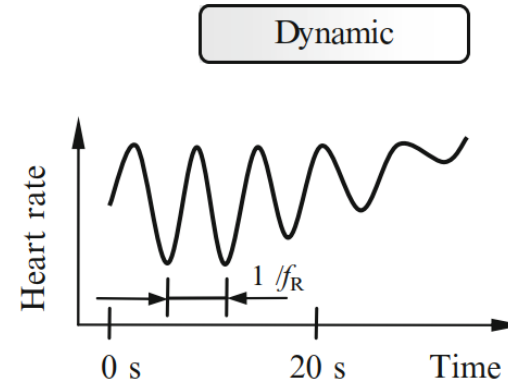
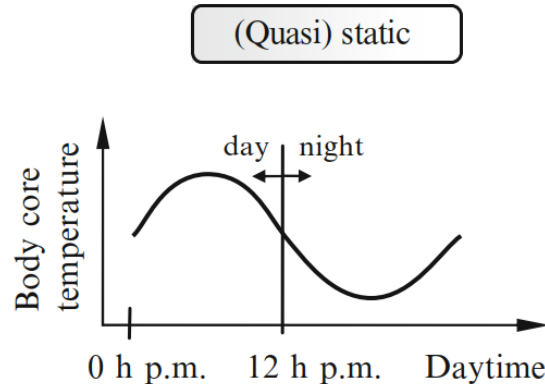
Dynamic of biosignal

1. Static biosignals

- carries information in its steady-state level

2. Dynamic biosignals

- has extensive changes in the time domain, with dynamic processes including physiological information of interest



Origin of biosignal (1)

1. Electric biosignals

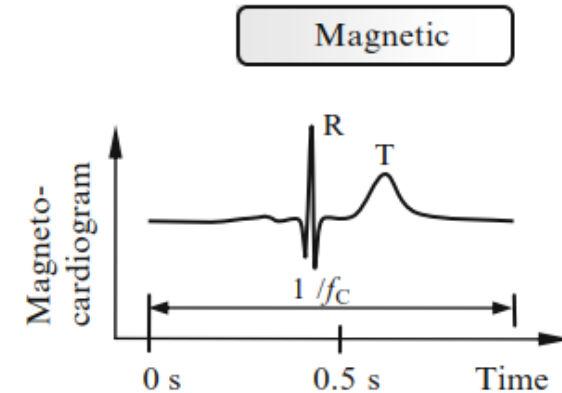
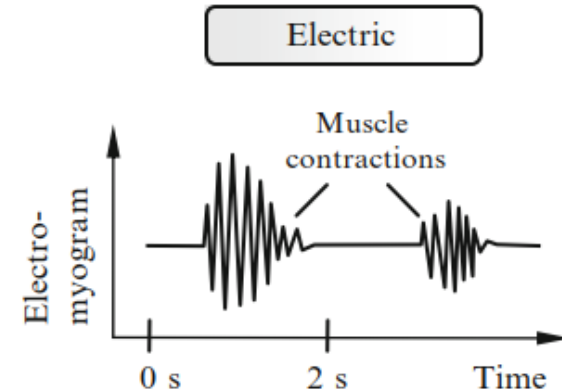
☐ Reflect electrical activity

- Electrocardiogram (ECG)
- Electromyogram (EMG)
- Electroencephalogram (EEG)

2. Magnetic biosignals

☐ Reflect magnetic field induced by non-stationary currents

- Magnetocardiogram (MCG)



Origin of biosignal (2)

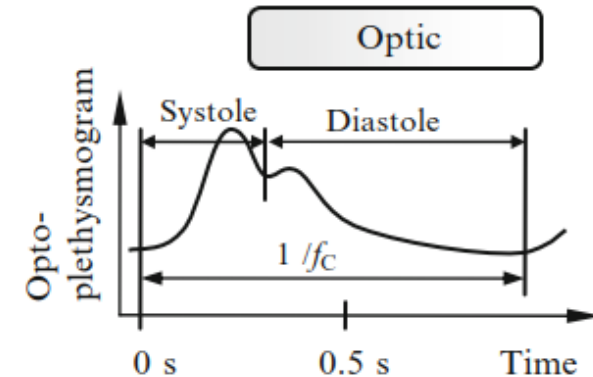
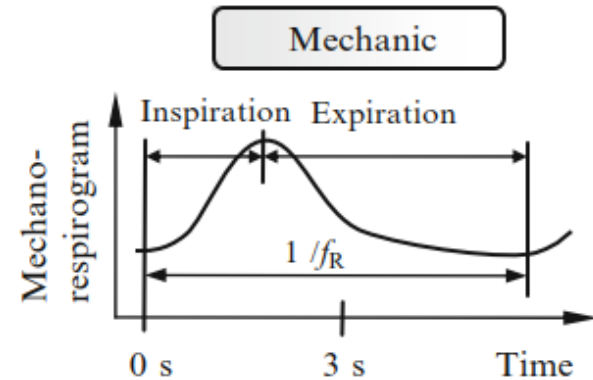
3. Mechanic biosignals

- ☐ Reflect body deformations or local body vibrations

- Seismocardiogram (SCG)
- Mechanorespirogram (MRG)

4. Optic biosignals

- ☐ Light absorption and scattering
 - Photoplethysmogram (PPG)



Origin of biosignal (3)

5. Acoustic biosignals

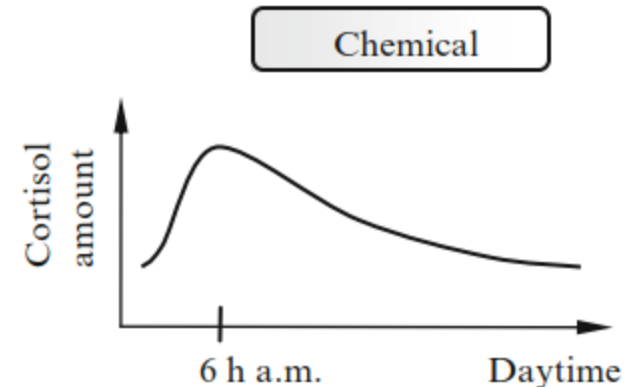
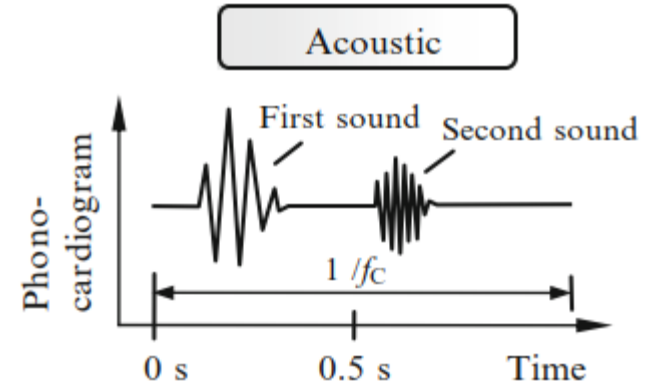
☐ Diverse body sounds

- Phonocardiogram (PCG)
- The speech signal

6. Chemical biosignals

☐ Reflect chemical composition and its temporal changes

- Cortisol (stress hormone)



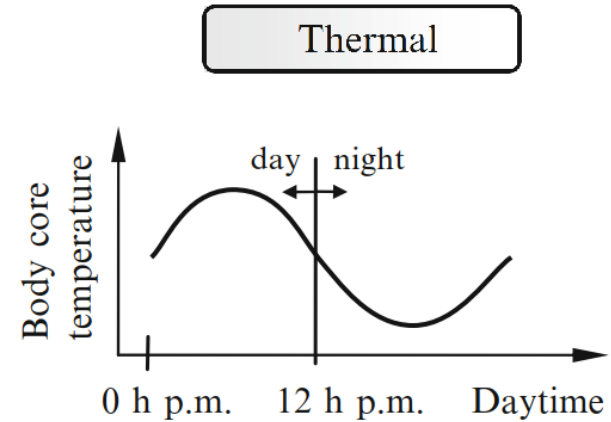
Origin of biosignal (4)

7. Thermal biosignals

- ☐ Heat loss and heat absorption
 - Body core temperature

8. Others

- ☐ Pressure
 - Blood pressure
- ☐ Skin resistance / conductance
 - Electrodermal activity (EDA)
- ☐ ...



Kaniusas, E. (2012). Fundamentals of biosignals. In Biomedical signals and sensors I (pp. 1-26). Springer, Berlin, Heidelberg.

Summary

In this session, we learned:

- ☐ Basic definitions of biosignals
- ☐ The role of biosignals in health applications
- ☐ Different types of biosignals

In the next session, we will learn:

- ☐ The origin of biosignals
- ☐ The acquisition of biosignals (nervous and muscular systems)

Thank You
Questions?



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