BIOELECTRICAL SIGNAL PROCESSING

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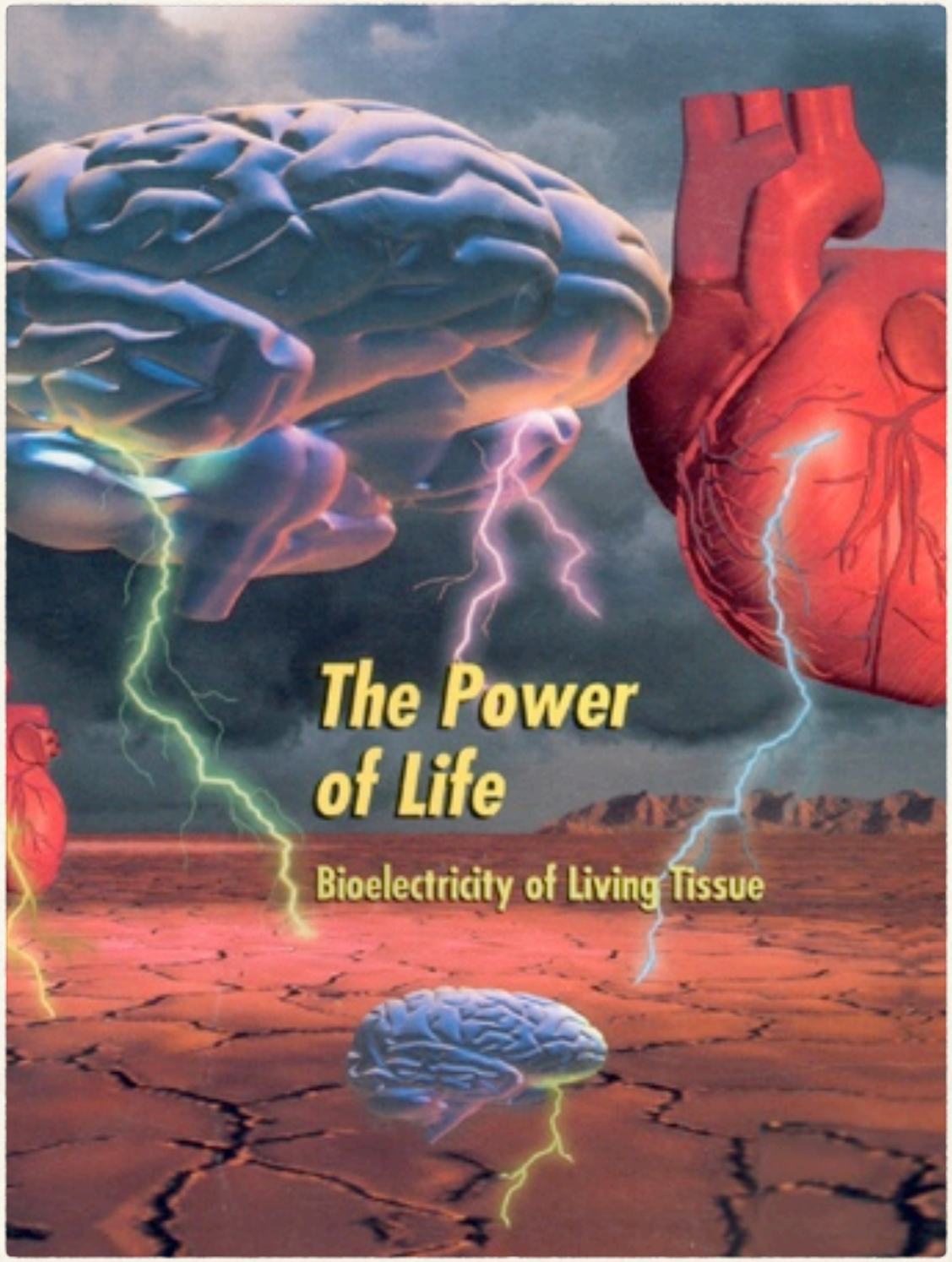
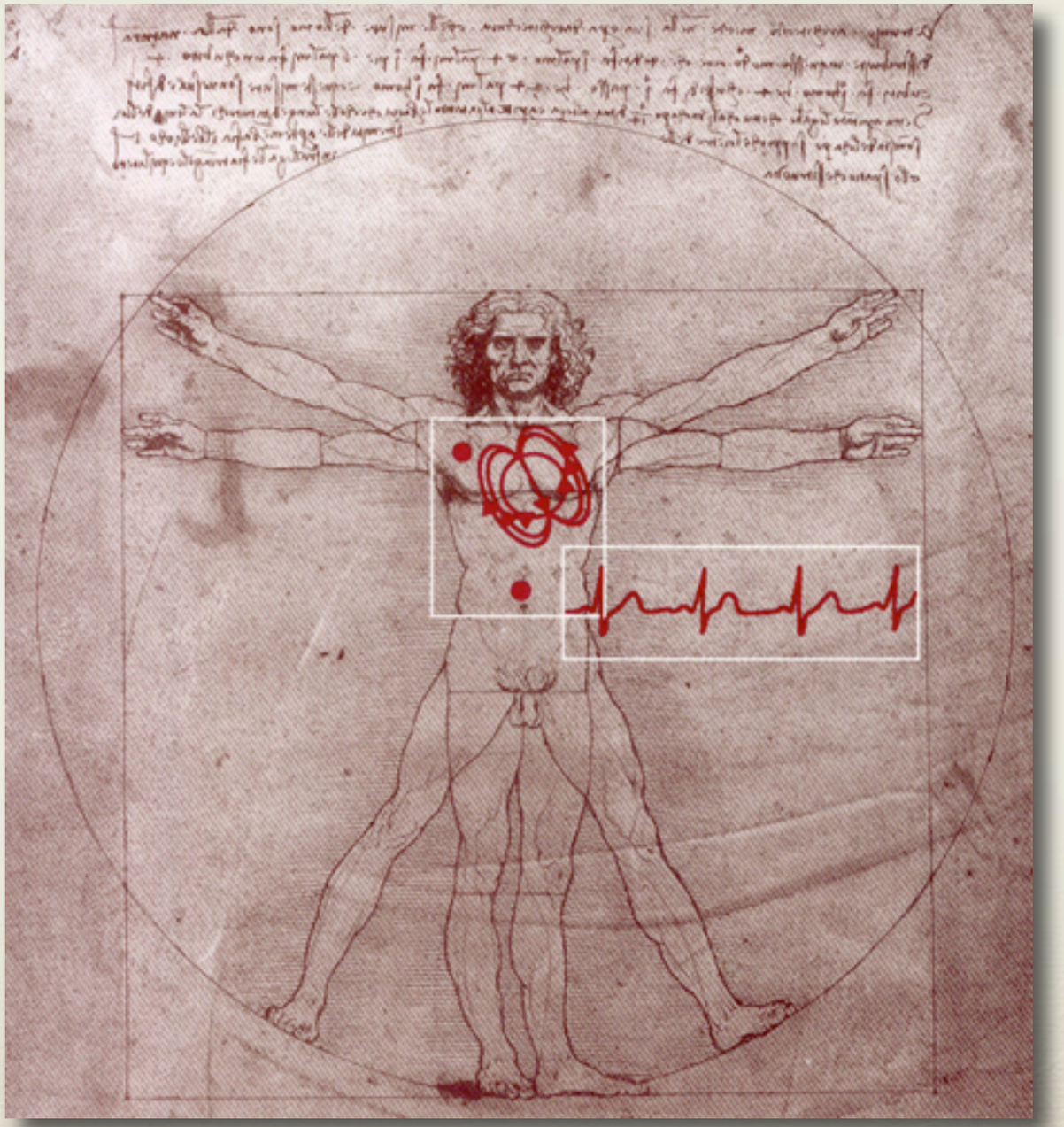
EVICAB, 2010

- Electrical signals of the body reflect properties of underlying biological systems.
- Decoding of such signals has been found very helpful in explaining and identifying various pathological conditions.



The Human Body – A Crash Course in Anatomy...

The Biomedical Signal: Reflections of A Secret



Origin of Bioelectrical Signals

* Related to ionic processes which arise as a result of electrochemical activity of a special group of cells having the property of excitability.
* The mechanisms which govern the activity of such cells are similar, regardless of whether the cells are part of the brain, the heart, or the muscles.

Learn more in the excellent textbook by Malmivuo&Plonsey ”Bioelectromagnetism”

Why This Textbook?

* First comprehensive overview of different techniques for the processing of bioelectrical signals.
* Problem-driven presentation where the application motivates the technique (not the reverse as is the case in many textbooks).
* The content covers many important signal processing techniques, though not all!
* Large collection of mathematical problems at the end of each chapter (solutions manual is available).

Where Is Bioelectricity Measured?

- Inside the cell – cellular.
- Inside the body – invasive.
- On the body surface – noninvasive.

This course only deals with bioelectrical signals measured on the body surface.

BTW: Is there any difference between signals measured on the body surface and inside the body?

The Brain, Heart, and Muscles and their Electrical Activity

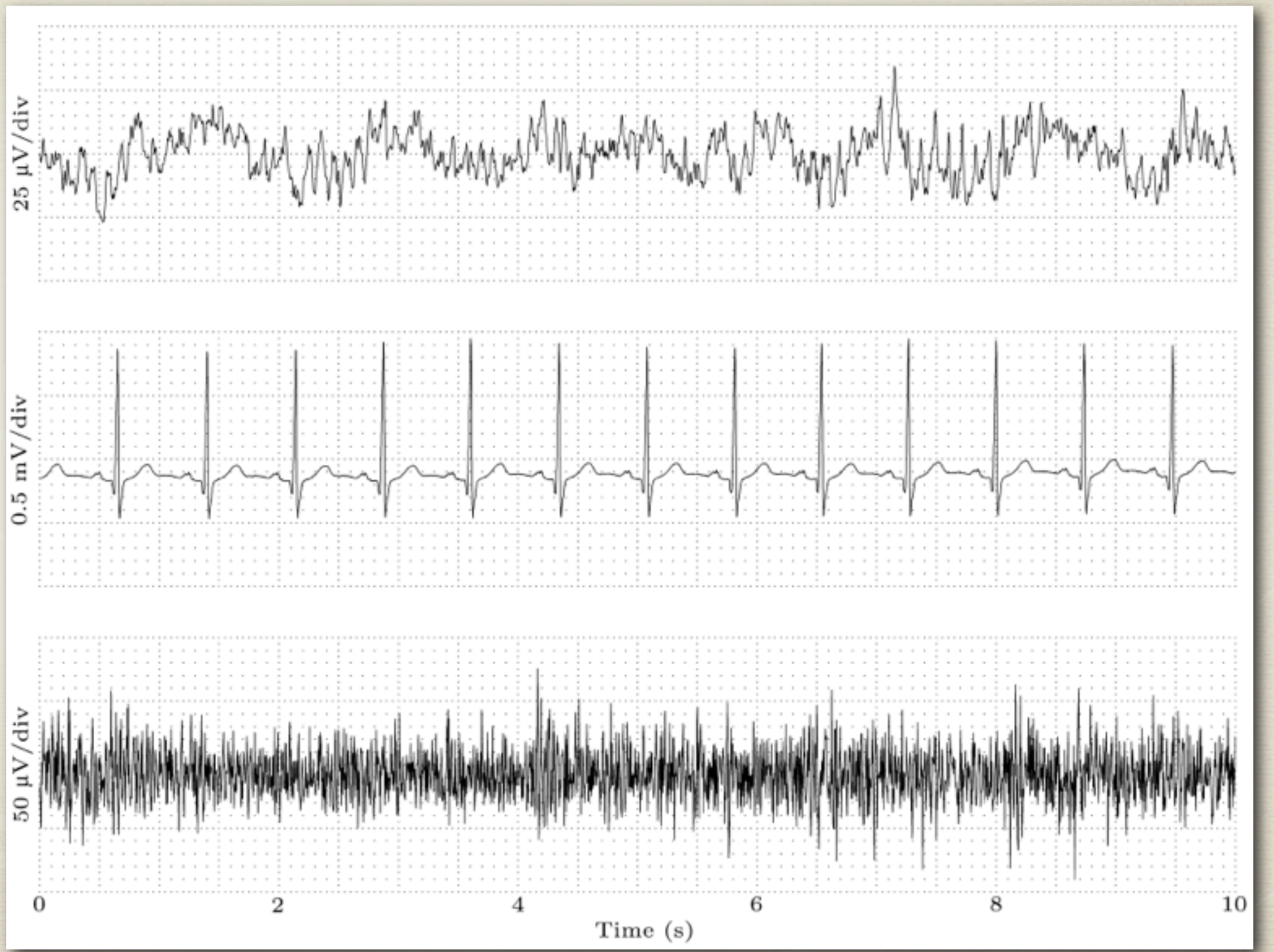
* Electroencephalogram – EEG
* Evoked potentials – EP
* Electrocardiogram – ECG
* Electromyogram – EMG
* The eyes and the stomach also produce electrical activity (not dealt with in the textbook).

Electrical Signals–Spontaneous

EEG

ECG

EMG

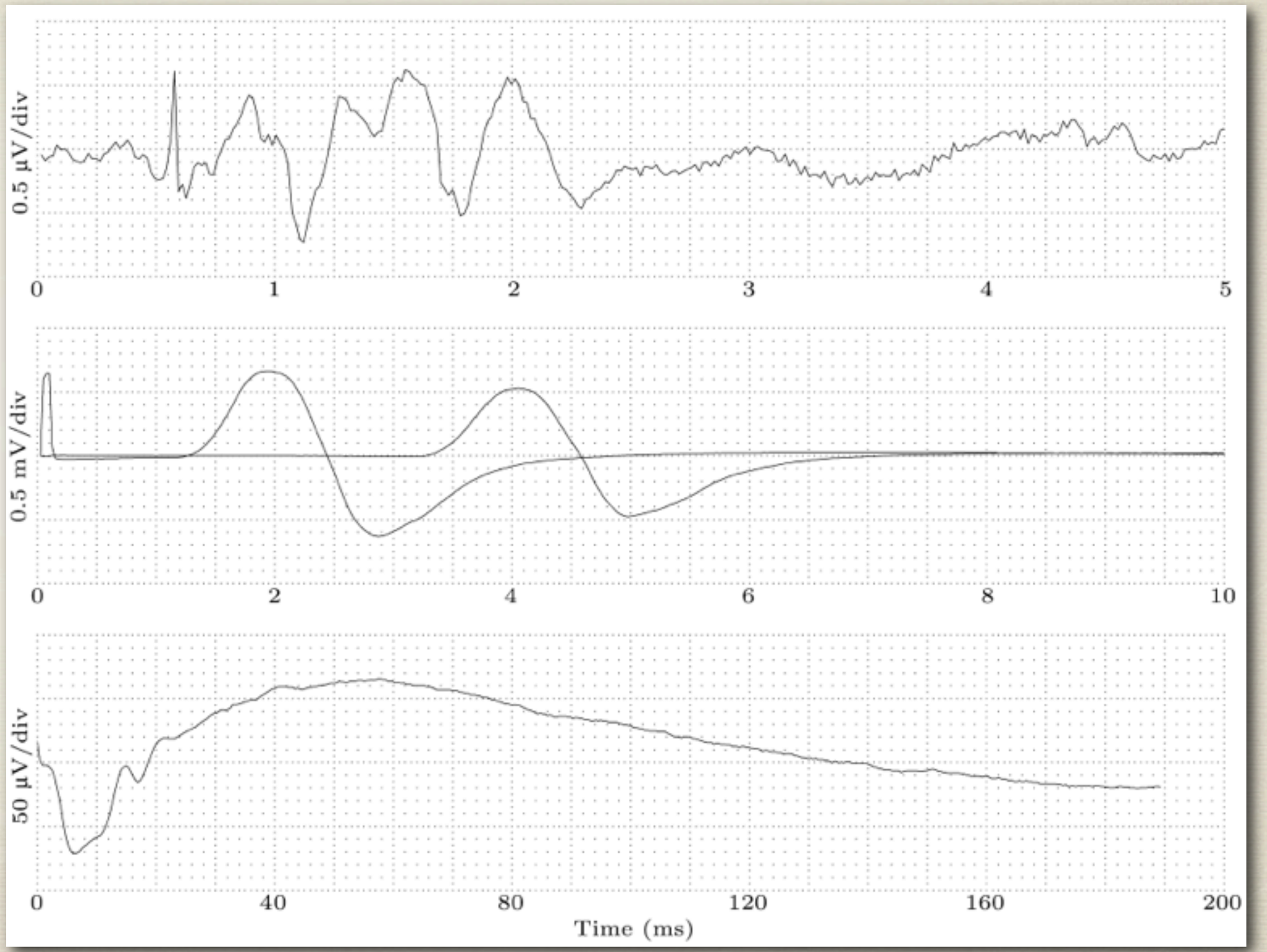


Electrical Signals–Stimulation

EP

ENG

ERG



Multimodal Signal Recording

ECG

Blood pressure

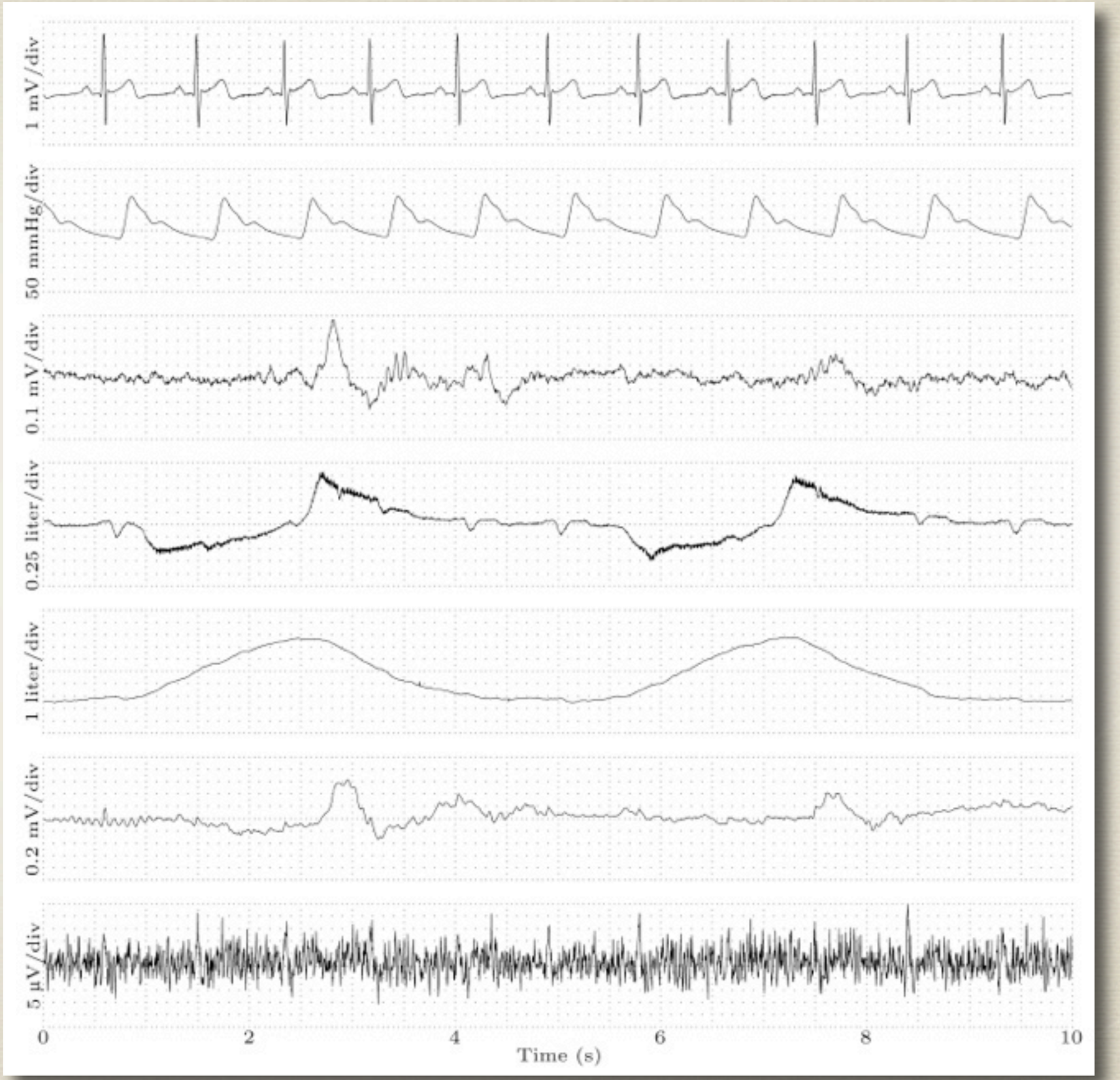
EEG

Nasal respiration

Abdominal respiration

Eye movements

EMG



electrical / pressure signal

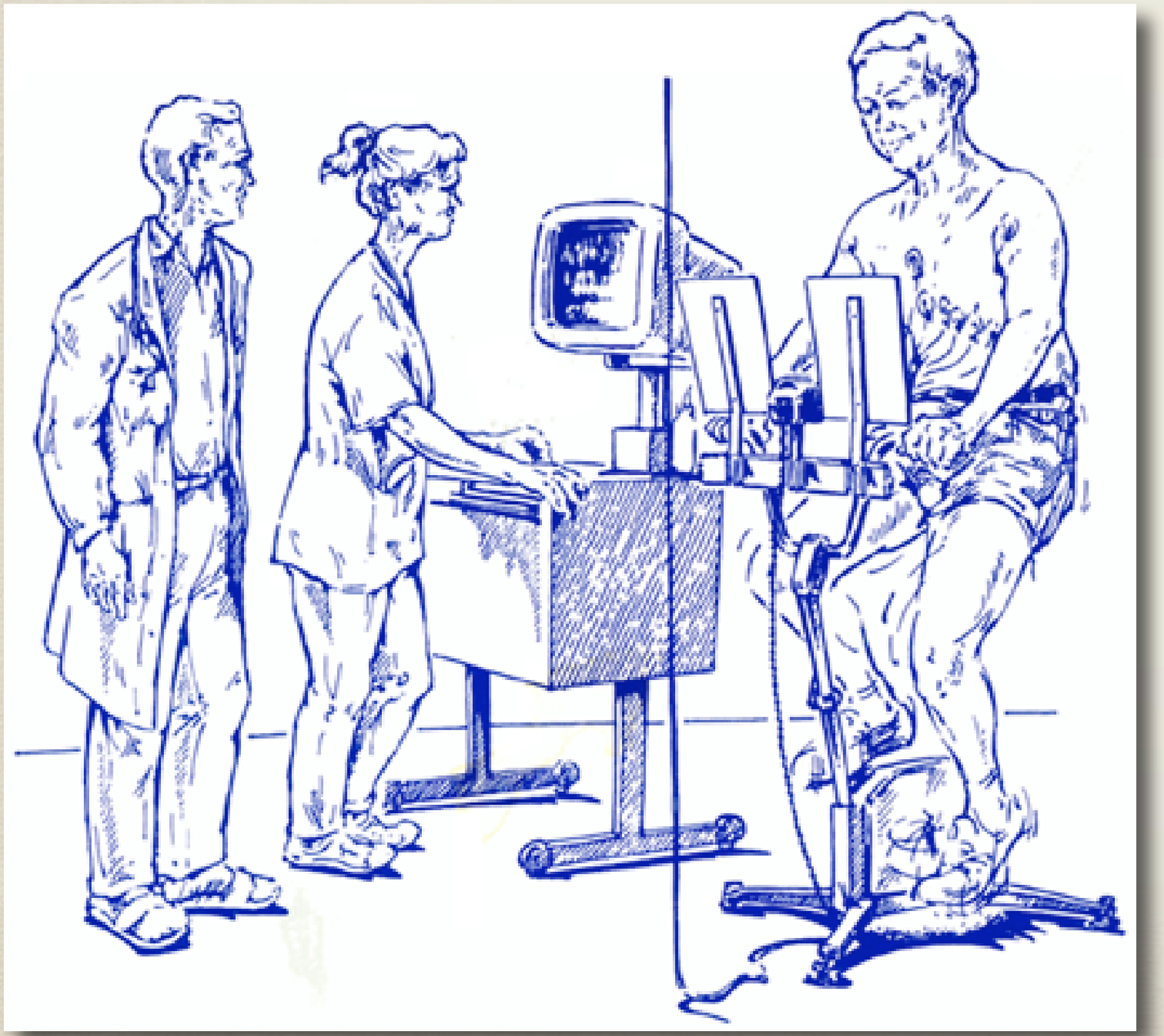
Purposes of Biomedical Signal Processing

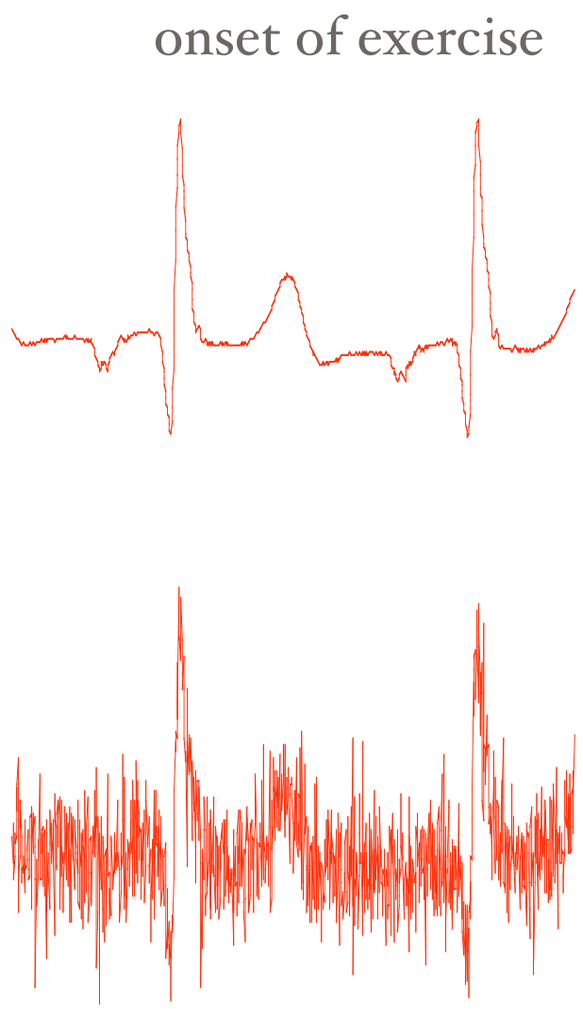
* To improve signal quality.
* To improve measurement accuracy.
* To reduce the amount of data.
* To visualize complex events.
* To make therapeutic devices, such as pacemakers and hearing aids, more intelligent.

Signal Processing Constraints

- ”Battery-powered” signal processing as required in, for example, a pacemaker or a hearing device must be based on extremely power efficient algorithms.
- Signal processing in monitoring devices must not introduce a delay which is longer than a few seconds from observation to decision.
- ”Batch” signal processing, being performed offline, is allowed to be time-consuming as long as the outcome is judged as valuable.

Noisy Signal Situation – Stress Testing





Signals Must Be Available

* One or many databases with representative signals are required for algorithmic development and related performance evaluation.

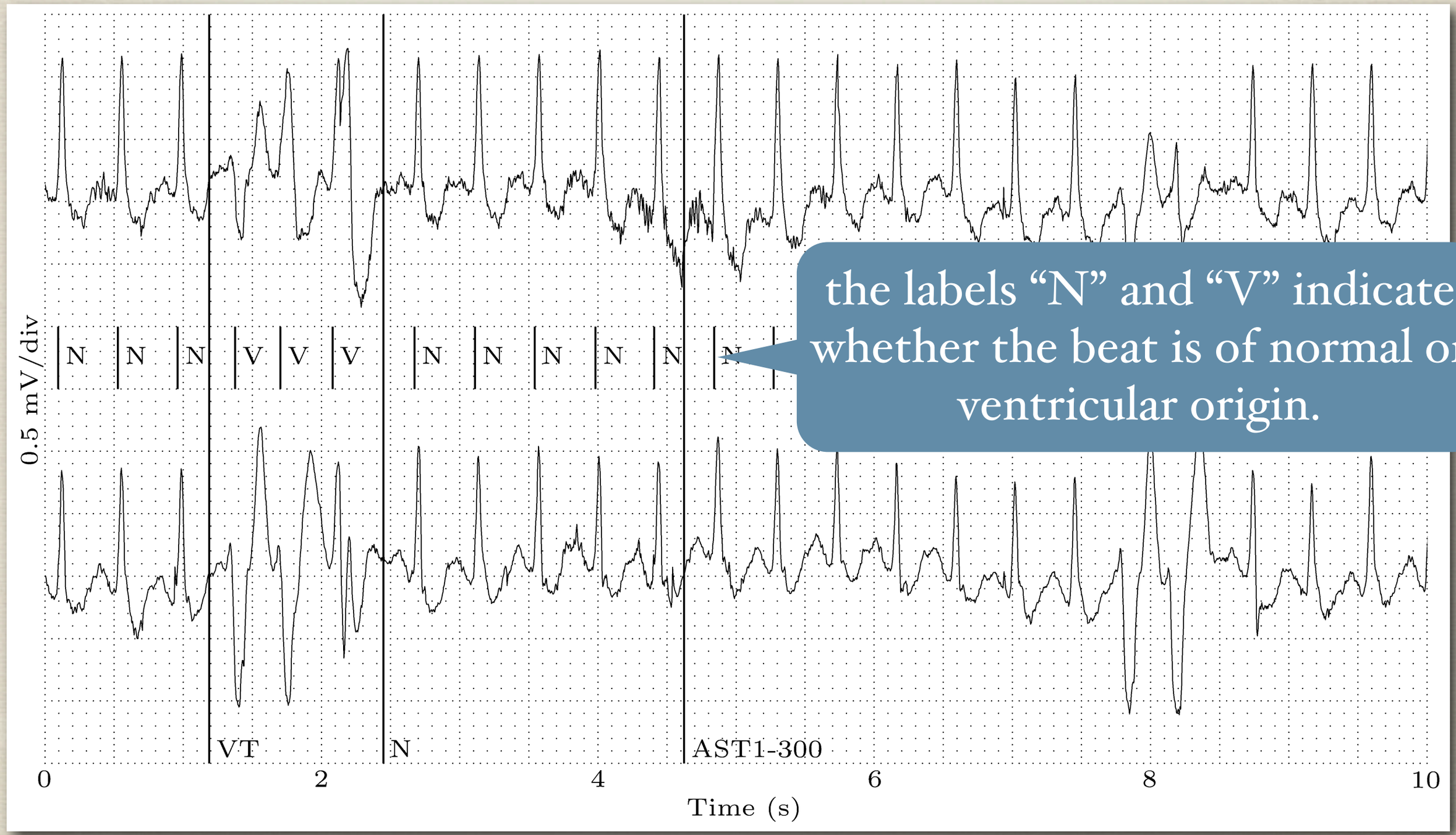
* Collecting a database is hard work, but crucial and rewarding for better understanding of the signals.

* Simulated signals can also be very helpful, however, they are not sufficient for making an overall judgement of performance.

Biomedical Signal Databases

* Some databases are public, most are not.
* The most comprehensive public database resource is www.physionet.org, where many different types of signals can be downloaded for free, also multimodal. Emphasis on cardiac signals.
* European database initiatives exist though no common web site is available.
* Signals used for the Computing in Cardiology (CinC) Challenges are available at Physionet.

Annotated Signal for Evaluation



the labels “N” and “V” indicate whether the beat is of normal or ventricular origin.

Performance Measures

N_{TP} = the number of diseased subjects with a positive result (True Positive)

N_{TN} = the number of healthy subjects with a negative result (True Negative)

N_{FN} = the number of diseased subjects with a negative result (False Negative)

N_{FP} = the number of healthy subjects with a positive result (False Positive)

The Biomedical Signal Processing Challenge

Unlike many other signal processing applications:

* The signals originate from a source within the body whose "exact message" is not known in advance, i.e., no control over the transmitted message.

* Thus, the "truth" is rarely available in biomedical signal processing.

Why Simulated Signals?

* The possibility to investigate conditions which are difficult to deal with experimentally.
* The p tly contr
* Mode en assoc y lend them
* Simpler models only accounting for a partial phenomenon of the signal can still be very useful for algorithm development and are often considered.

And Why Not Only Simulated Signal?