# Foundations of Psychophysiology

## Part 6.2: Cardiovascular measures

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NEUROADAPTIVE
HUMAN-COMPUTER
INTERACTION

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# Cardiovascular measures

Blood pressure

Peripheral blood volume

The electrocardiogram

Psychophysiology

# Blood pressure

# Blood pressure

Pressure refers to a force acting upon a surface.

In the cardiovascular circulations, blood presses against the vessel walls.

In medicine, the unit millimetres of Mercury (mmHg) is generally used instead of the SI unit Pascal ($N/m^2$).

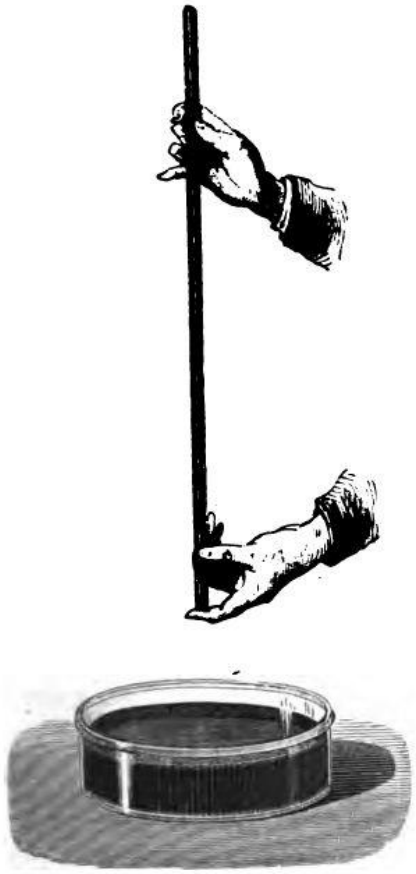
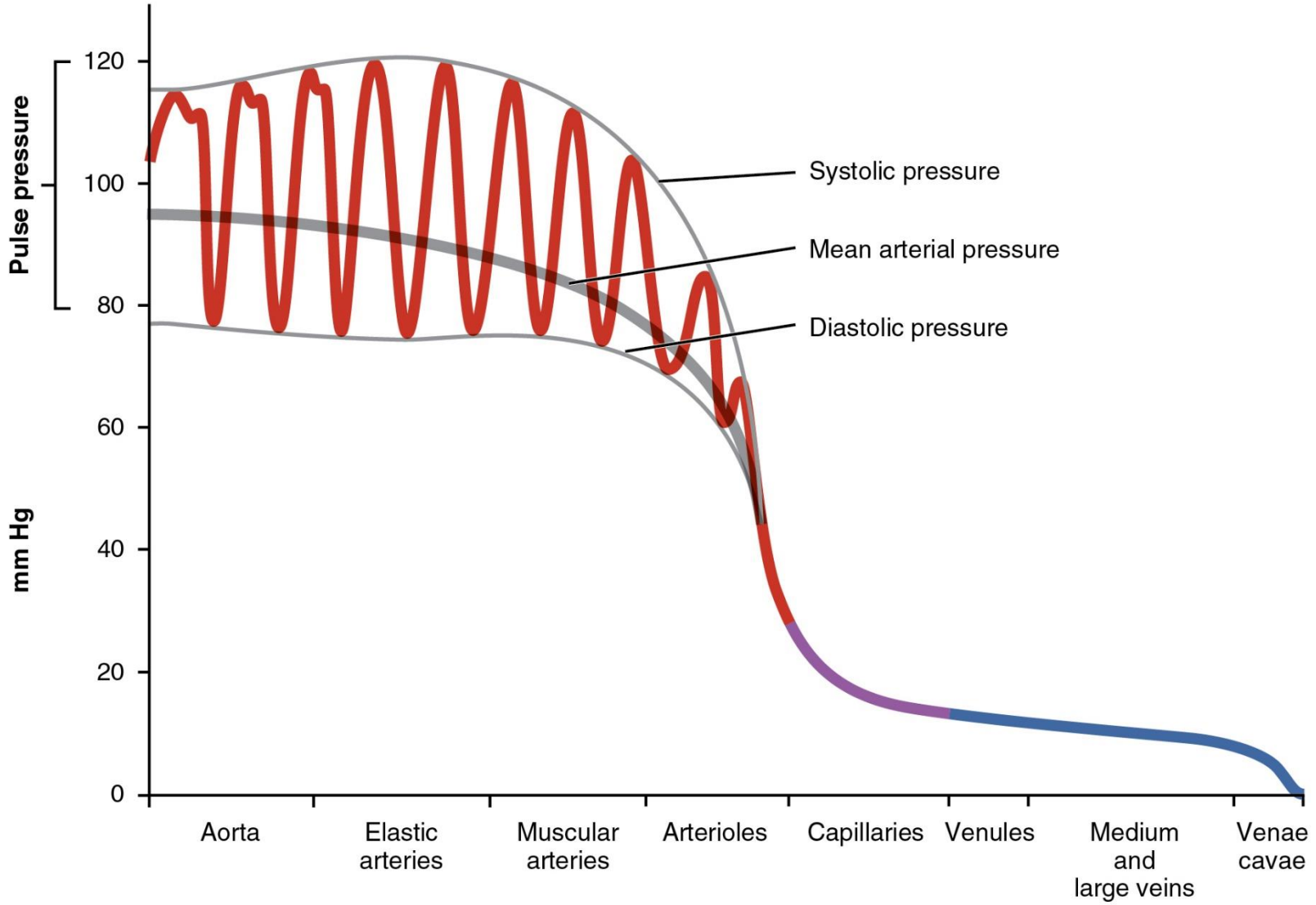


Fig. 8. — Le tube plein de mercure.

Fig. 9. — Le tube dans la cuvette.

Figure: Flammarion, C. (1872). *L'Atmosphère: Descriptions des Grands Phénomènes de la Nature* (pp. 35). Paris: Librairie Hachette et Cie.

# Blood pressure in the systemic circulation



# Blood pressure and the baroreflex

Pressure depends on the **cardiac output** (heart rate × stroke volume), and on vascular **resistance** (vessel elasticity and diameter).

The **baroreflex** and other feedback loops regulate these parameters.

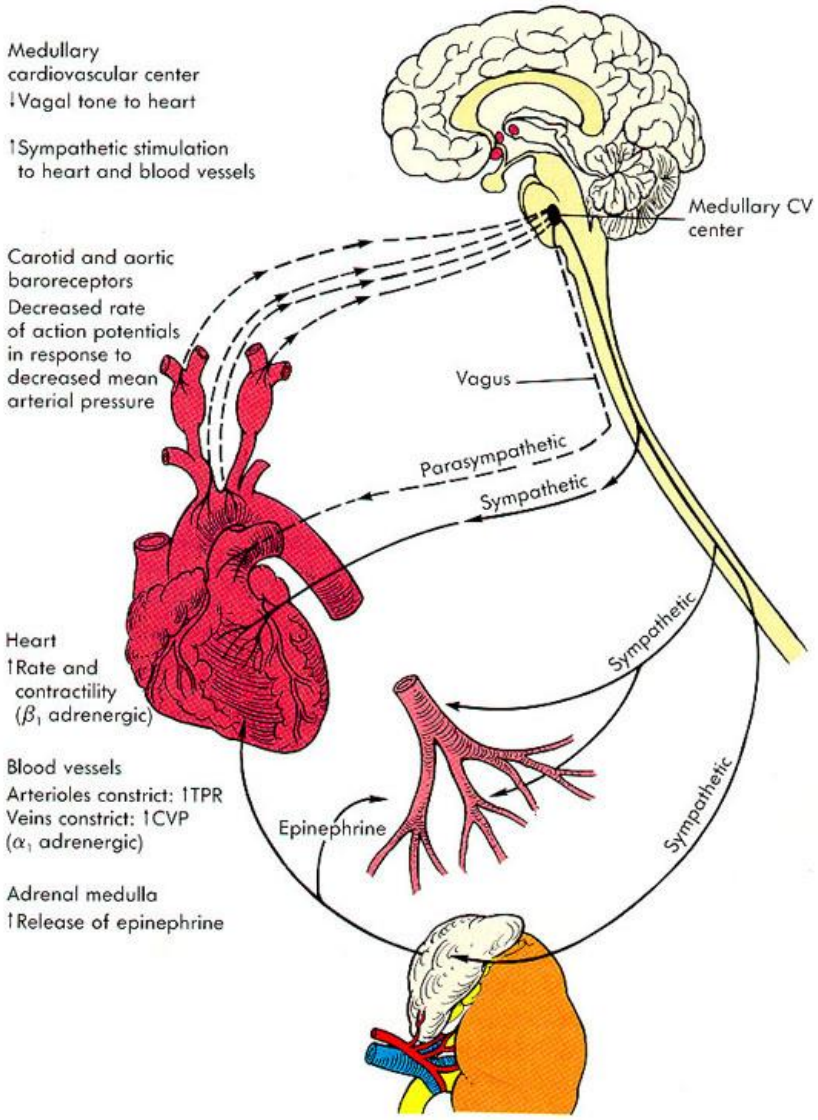
In the baroreflex, when arterial baroreceptors sense an increase in blood pressure, this leads to a decrease in cardiac output, and vice versa.

# Cardiovascular innervation

The **vasomotor centre** in the medulla oblongata regulates blood pressure.

The heart has both para- and sympathetic efferents; most blood vessels only have sympathetic innervation (effecting mostly **vasoconstriction**).

Higher structures (cerebral cortex, limbic system) can influence the vasomotor centre, which explains cardiovascular responses to e.g. emotional stress.

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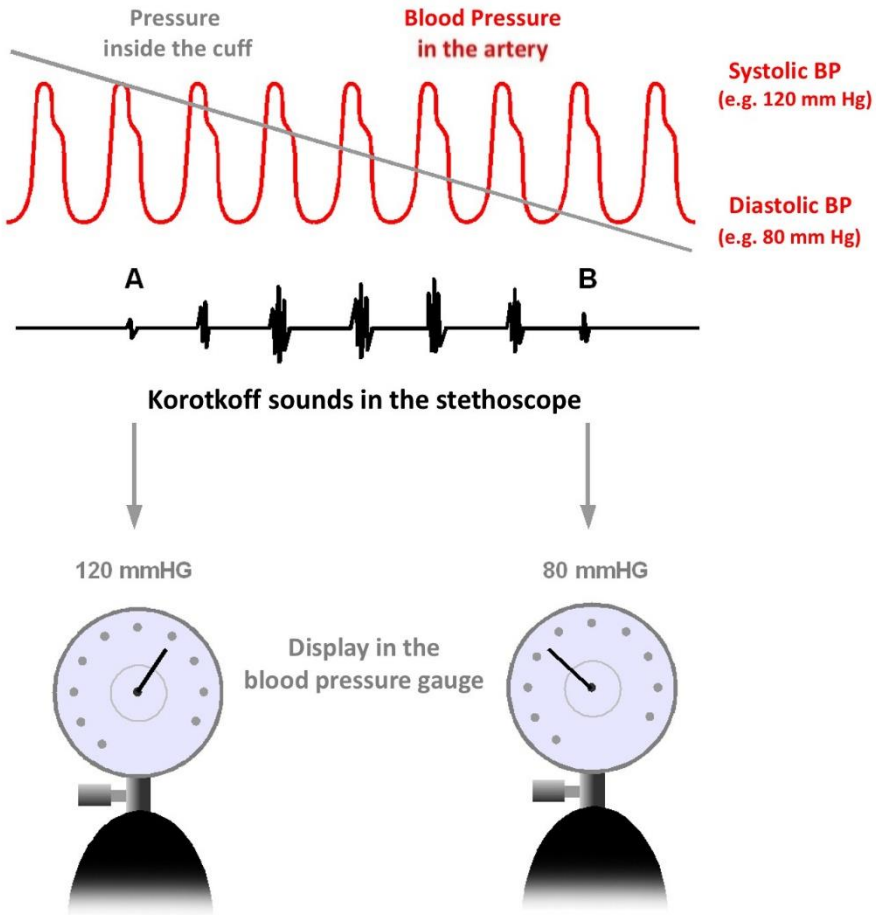
# Psychophysiology: Cardiovascular: Pressure: Measurement

## Sphygmomanometry

## Sphygmomanometry: Disadvantages

Not fully accurate: may be off by some 5-10 mmHg

Temporarily deforms the arteries: a 10-minute recovery period should be allowed before additional measurements on the same arm

Not continuously measurable

Not unobtrusively measurable

# Continuous measurement

Continuous measurement of true blood pressure is only possible invasively.

An arterial line must be inserted into the artery.

Other techniques have been developed, but rely on correlations of blood pressure with other measures.

These correlations are complex. No standard has yet emerged.

# Blood pressure

Blood pressure varies between systolic maxima and diastolic minima, which can be measured in the arteries.

Sphygmomanometry is commonly used to obtain single measures of blood pressure.

Continuous measurement for psychophysiology is not practically viable.

# Peripheral blood volume

# Peripheral blood volume

Vasomotor activity of peripheral blood vessels allows more or less blood to enter specific regions.

This is sometimes readily observed, e.g. in blushing.

Accurate measures can also detect minimal changes, some of which have psychological relevance.

Figure: Wappers, G. (1827). *Anthonie van Dijck verliefd op zijn model*. Rijksmuseum SK-A-1159

# Peripheral blood volume

Peripheral blood volume is usually measured at the finger, where many blood vessels are close to the skin surface.

Furthermore, measurements at the finger are not complicated by the presence of skeletal muscles.

Vasomotor activity in the skin is exclusively under sympathetic control. Peripheral blood volume measures thus indirectly describe sympathetic ANS activity.

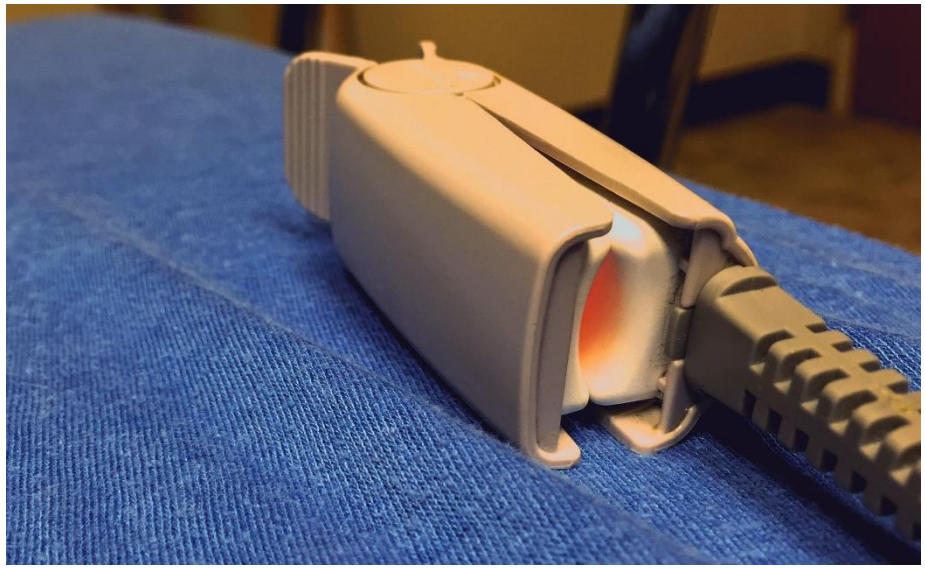
Peripheral blood volume also varies with heart rate: systole increases, and diastole decreases the blood volume in the arteries. As a result, it is often primarily used as a heart rate monitor.

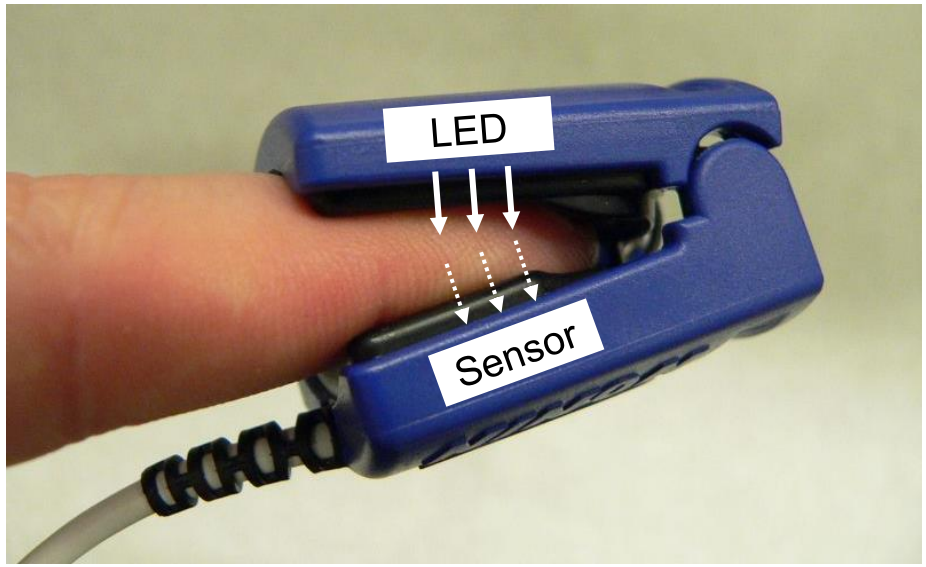
# Photoplethysmography (PPG)

A **plethysmograph** measures and records changes in the volume of a (part of a) body.

A **photoplethysmograph** uses infrared light to measure changes in blood volume indirectly.

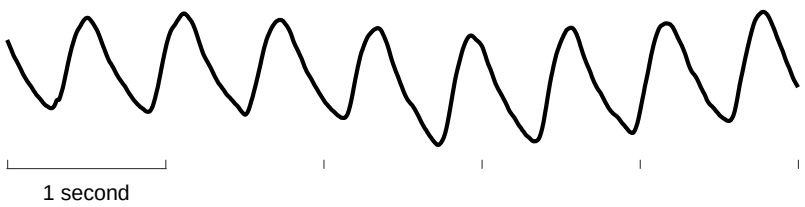
It detects changes in light absorption and refraction, which depend on blood perfusion.

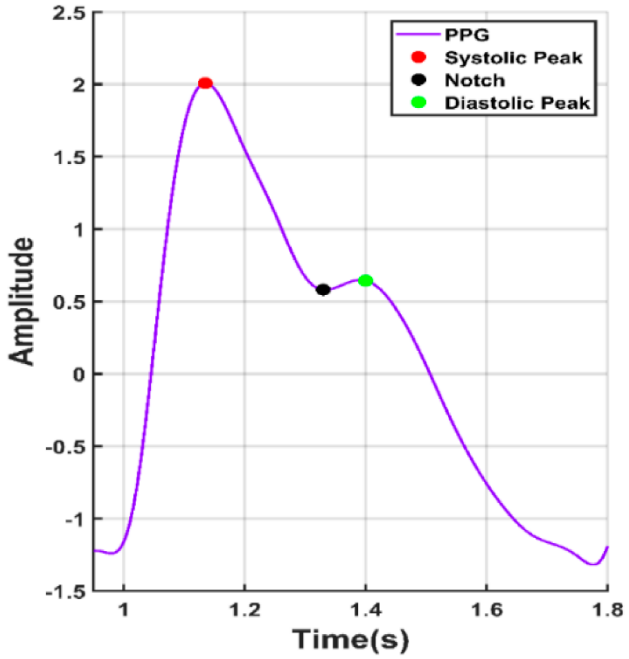


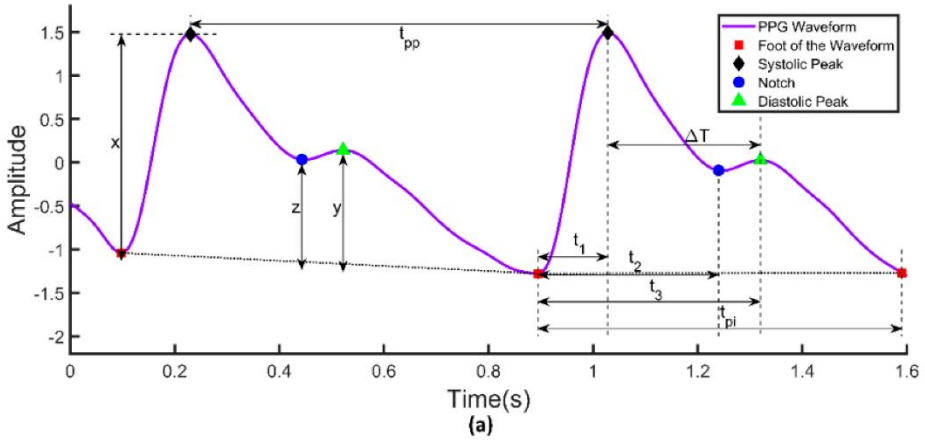


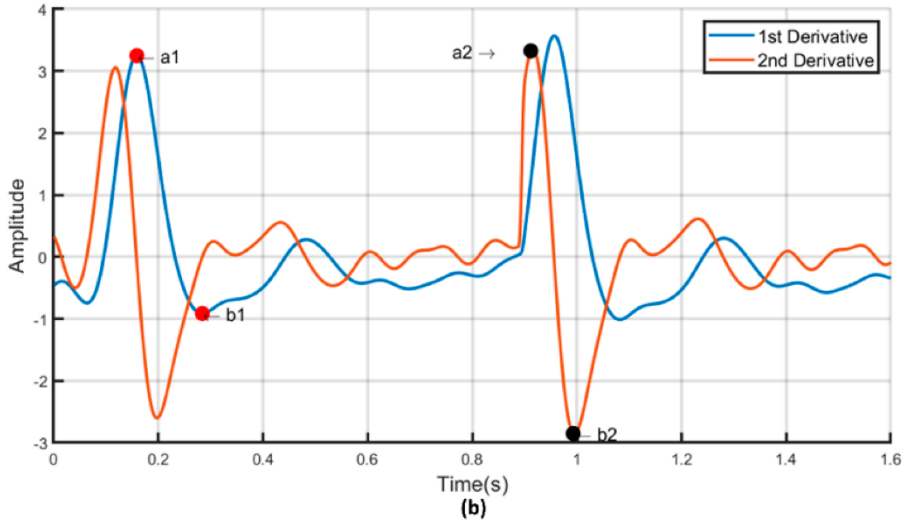
# Psychophysiology: Cardiovascular: Volume

## Photoplethysmogram



## Photoplethysmography: Disadvantages

Local measurements are susceptible to local noise, primarily related to temperature and movement.

Local measurements may not correspond to whole-body physiology.

# Psychophysiology: Cardiovascular: Volume

## “Webcam photoplethysmography”


Wu, H. Y., Rubinstein, M., Shih, E., Guttag, J., Durand, F., & Freeman, W. (2012). Eulerian video magnification for revealing subtle changes in the world. *ACM Transactions on Graphics (TOG)*, *31*(4), 1-8.

# Peripheral blood volume

Photoplethysmography is an indirect, but simple method to measure peripheral blood volume.

Aside from blood volume, the resulting PPG allows measures that correlate with heart rate and other physiological indications to be extracted.

Psychophysiology

# The electrocardiogram

# Electrocardiography

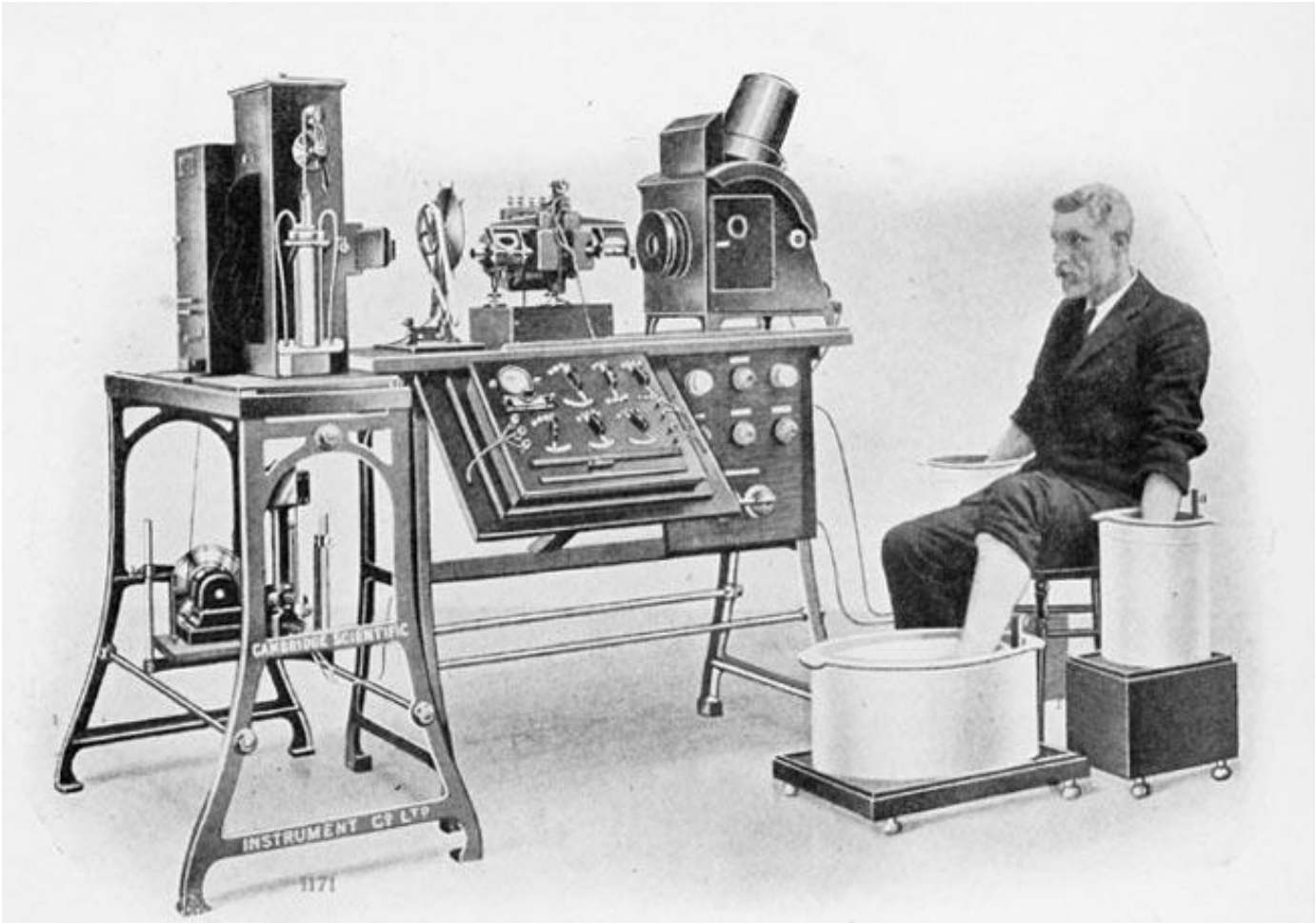
An electrocardiogram (ECG) measures and records the biopotentials generated by cardiac electrical activity.

This activity represents the summed action potentials of the myocardium throughout the cardiac cycle.

The high amplitude of the ECG biosignal makes it detectable even with generic hardware. The activity is in the range of 1-100 Hz.

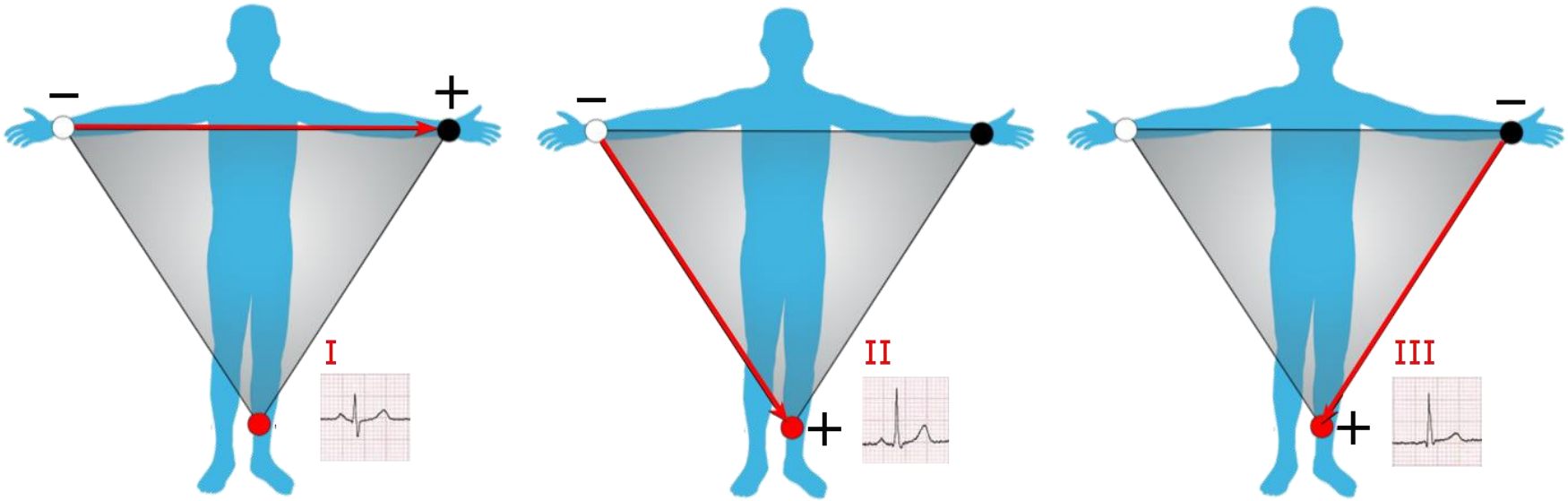
There are a number of different ways to place the electrodes.

# Electrode (lead) placement



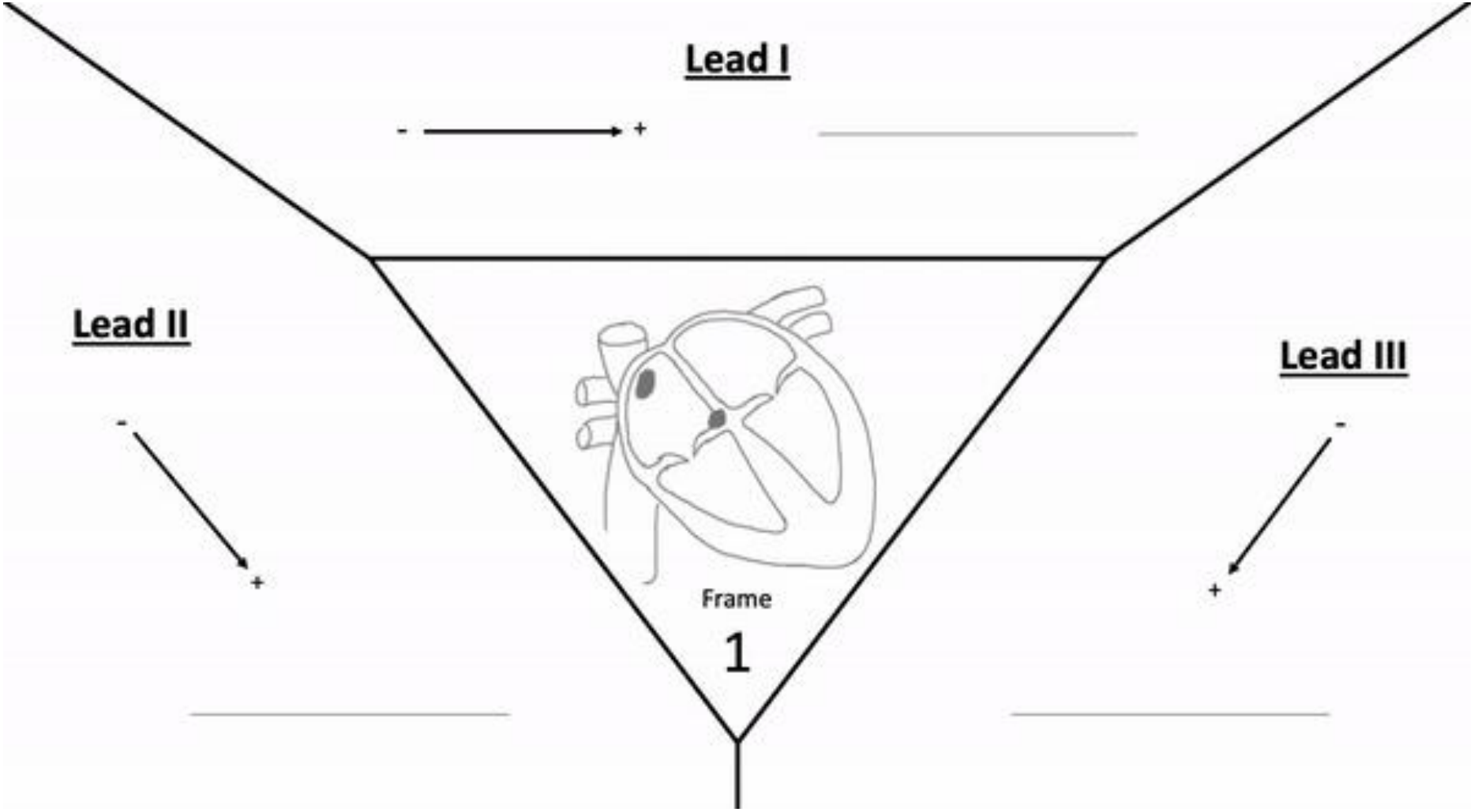

PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSED IN JARS OF SALT SOLUTION

# Einthoven's triangle



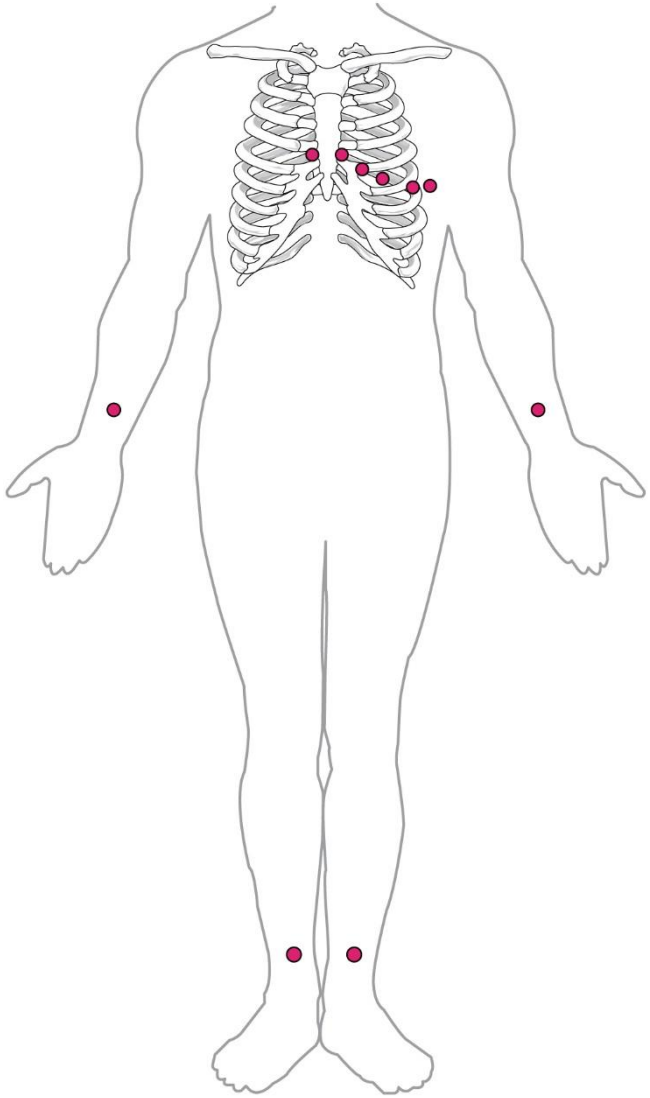
# Psychophysiology: Cardiovascular: ECG: Placement

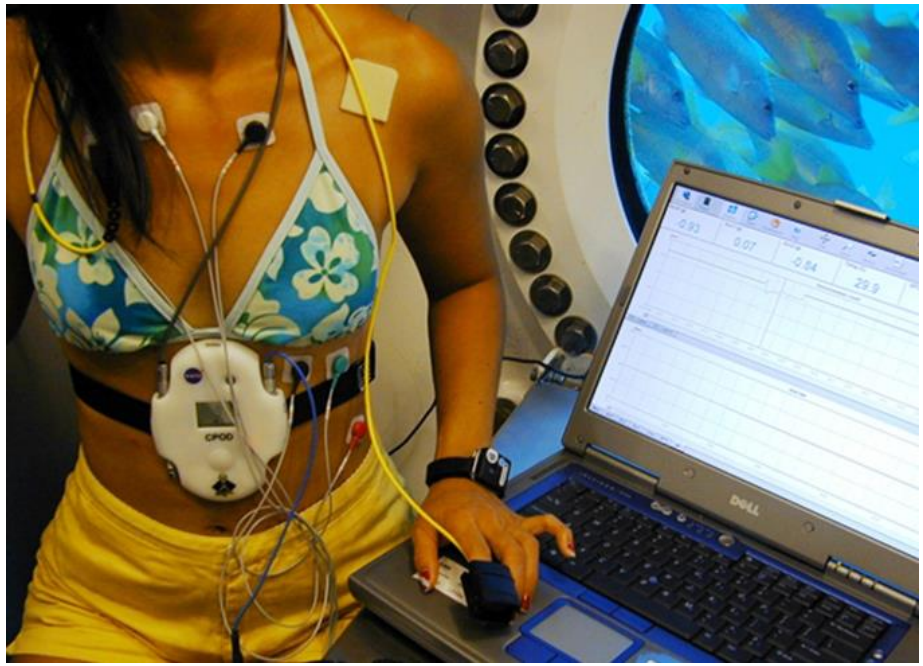
## Einthoven I, II, and III



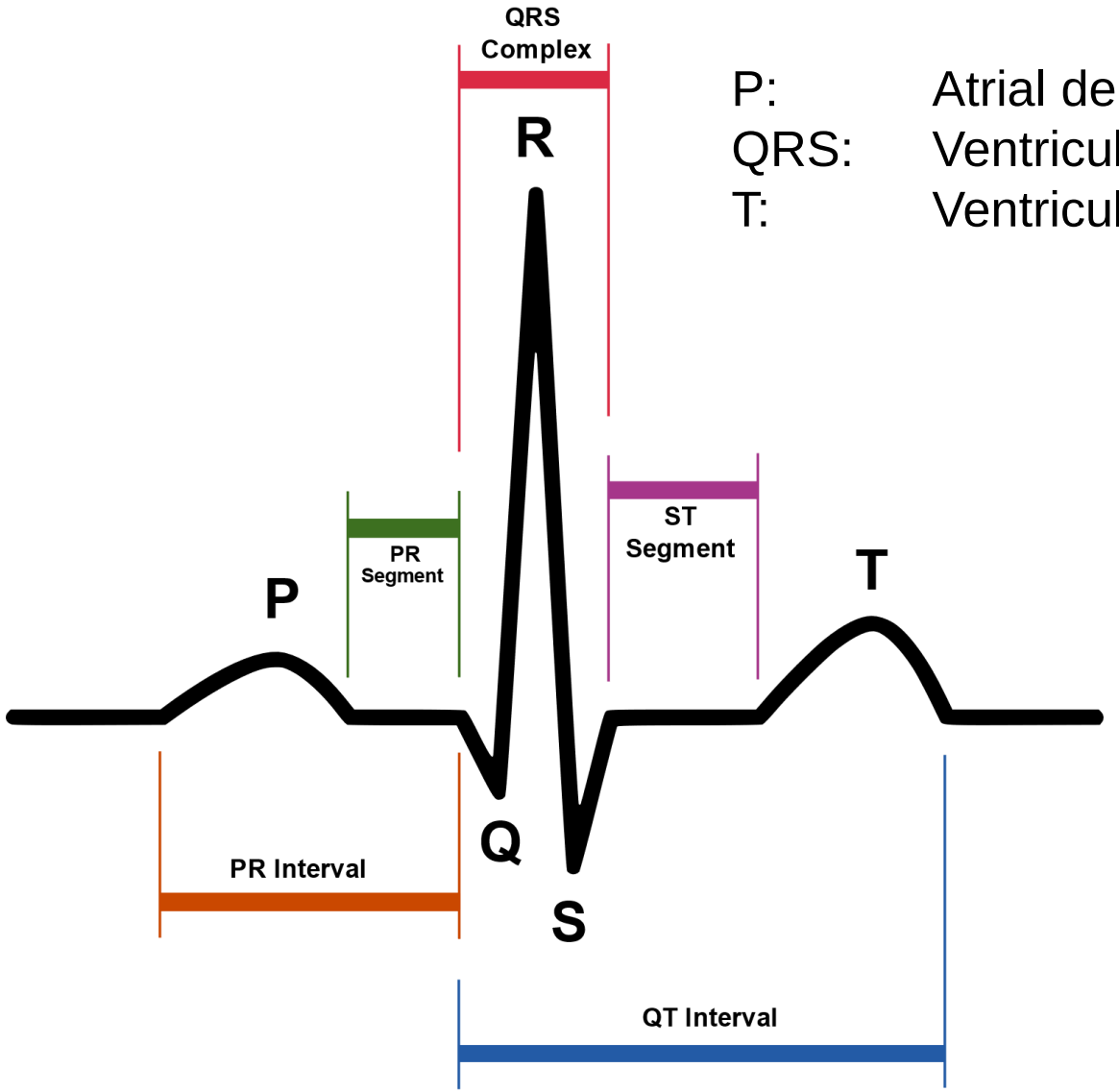
# Psychophysiology: Cardiovascular: ECG: Placement

## Modern developments



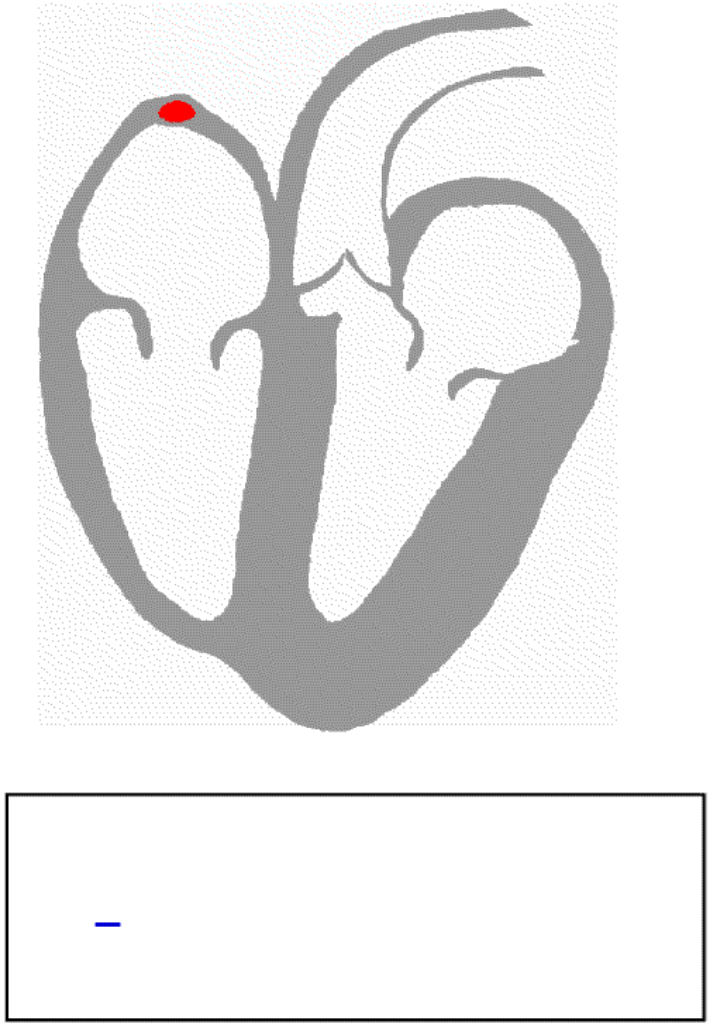


# Peaks and intervals

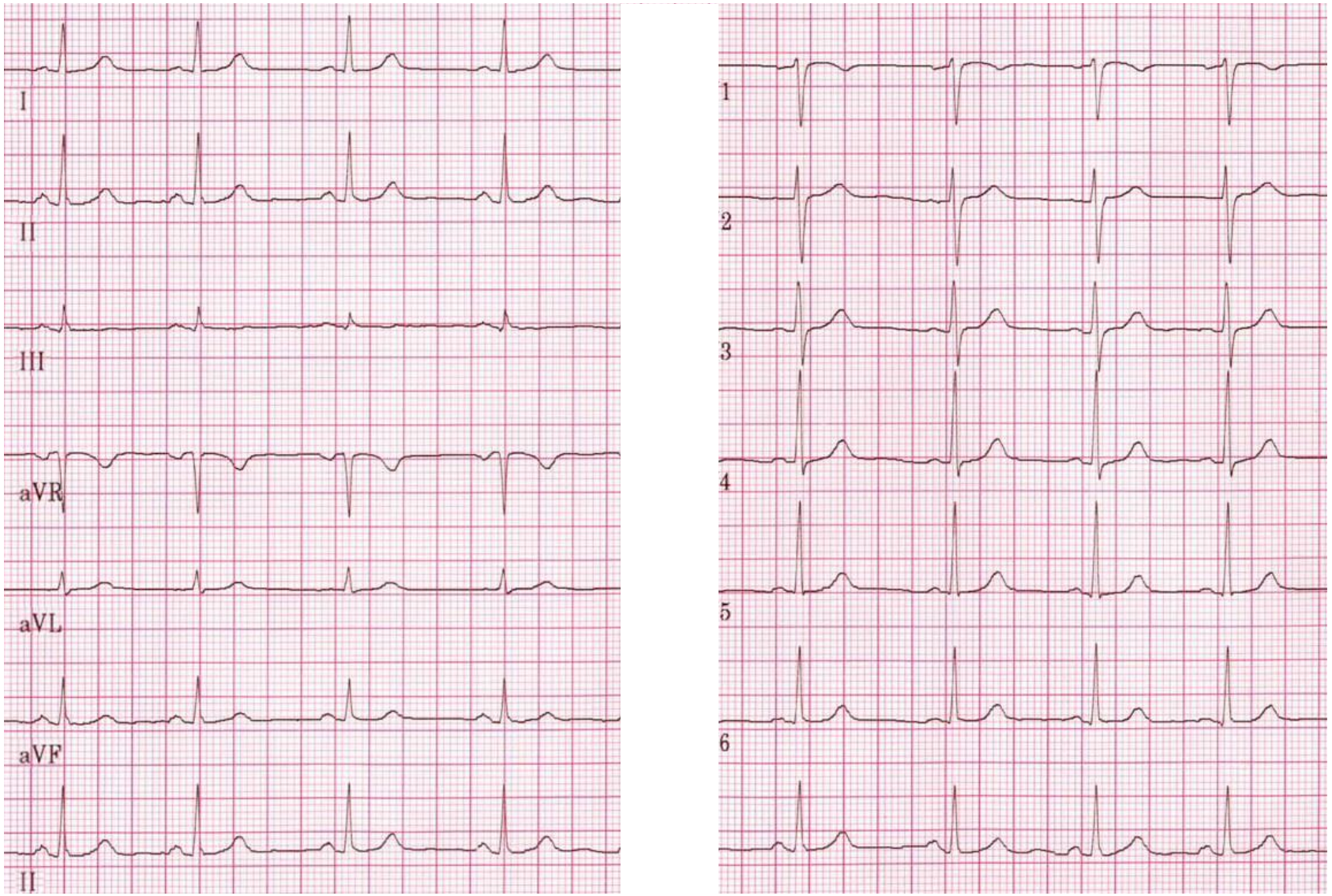



P: Atrial depolarization
QRS: Ventricular depolarization
T: Ventricular repolarisation

# Neural conduction and the ECG



# Electrocardiogram



# Ventricular fibrillation

## Heart rate

Heart rate (HR) is the number of contractions (beats) of a heart per minute (bpm).

Easily operationalised from an ECG as the number of R peaks per minute.

HR responds to almost all physical and psychological changes: e.g., pain and fear increase, whereas relaxation and attention decrease HR; but even circadian and menstrual cycles can influence HR.

This bidirectionality is an advantage for psychophysiology.

Slow changes can be recorded by taking e.g. HR measurements per minute.

## Heart rate variability

Changes in HR can also be operationalised as another metric in itself: **heart rate variability** (HRV).

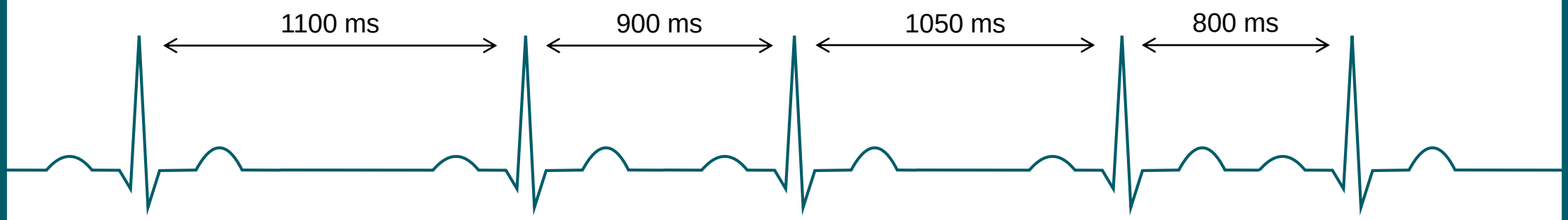
The inter-beat interval (IBI) is the distance between two successive R peaks.

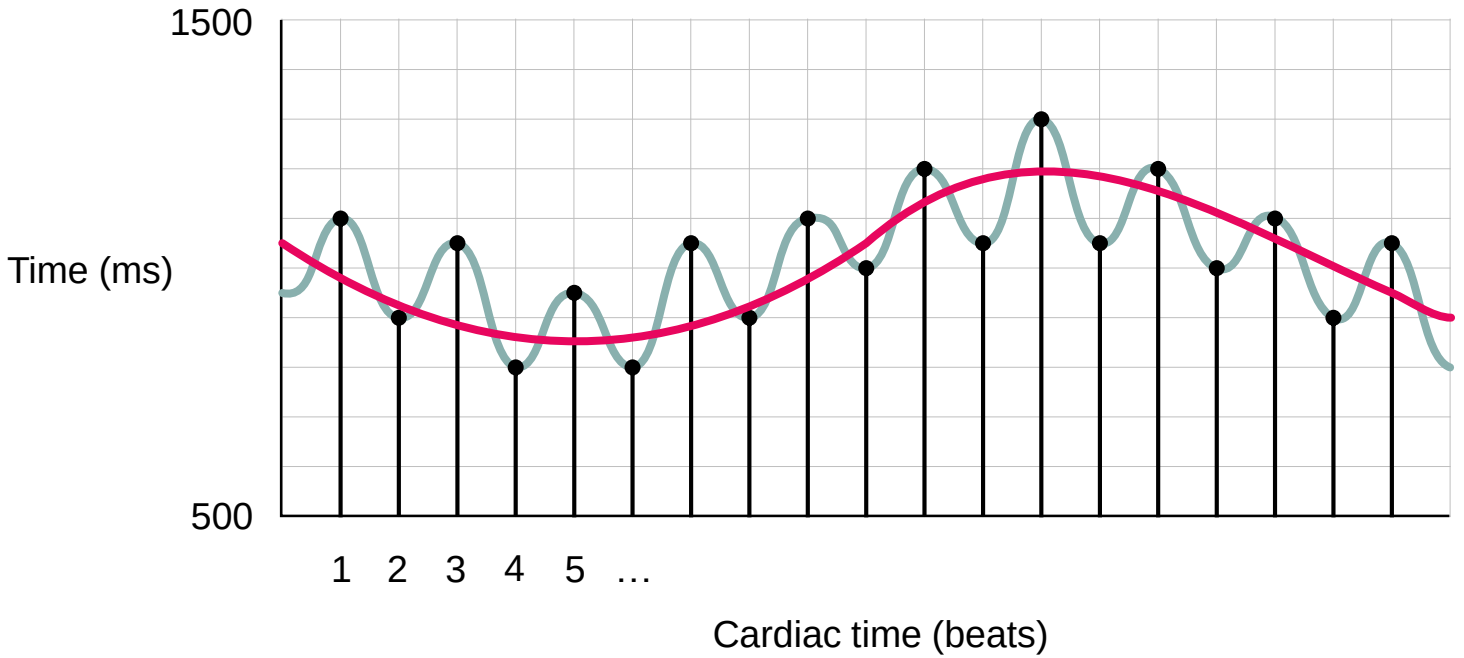
Many metrics can be constructed from this, e.g. arithmetic means, standard deviations, $RMSSD = \sum_{i=1}^{N-1} \frac{(IBI_{i+1} - IBI_i)^2}{N-1}$, proportion of successive intervals above a threshold, …

RMSSD (root mean square of successive differences) is often preferred for statistical reasons.

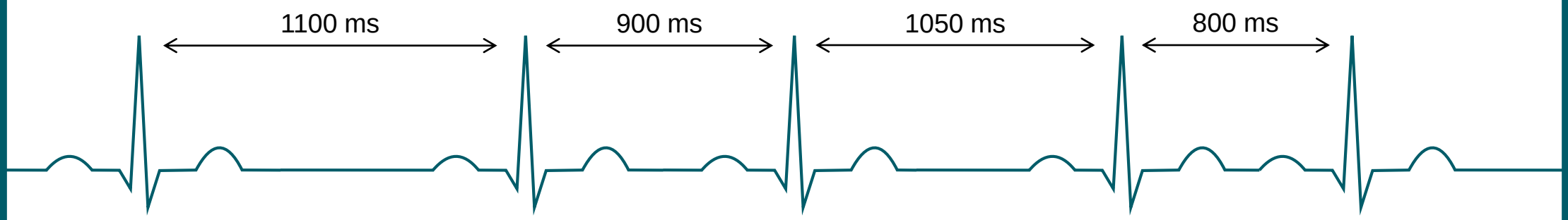
HRV also allows spectral analyses.

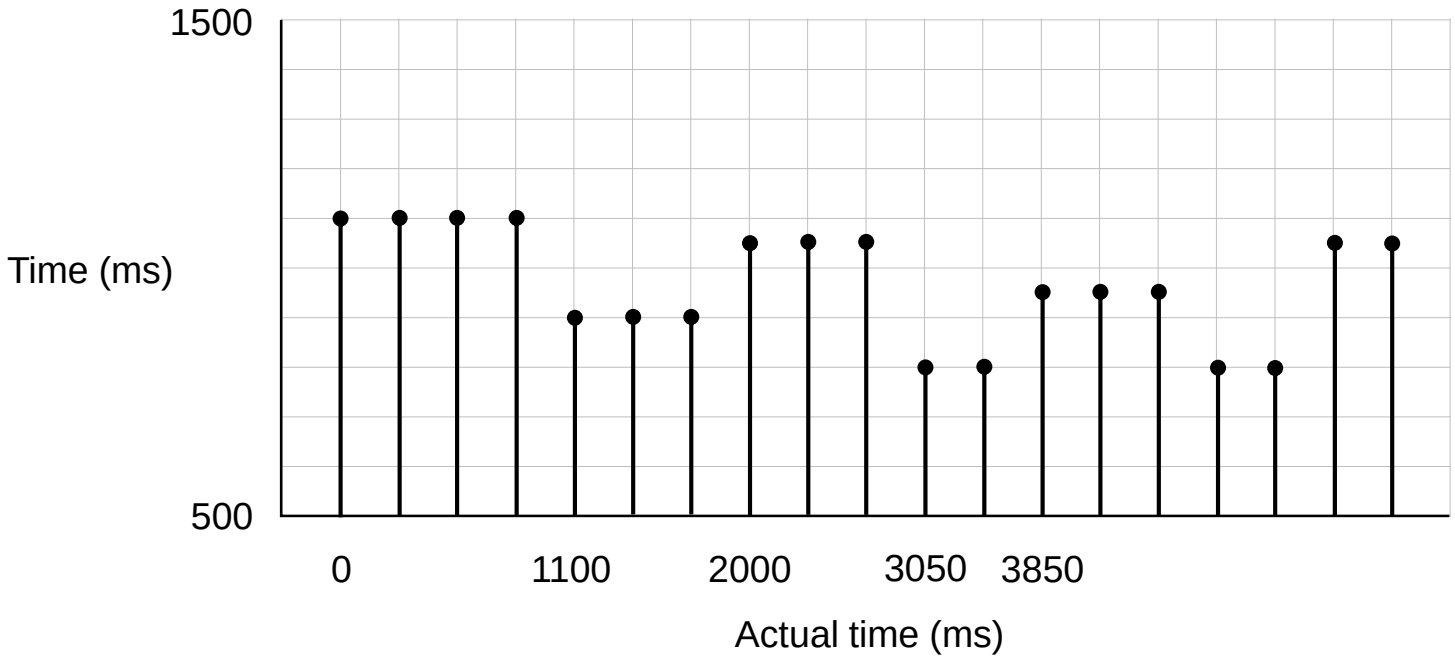
# Spectral analysis: Cardiac time



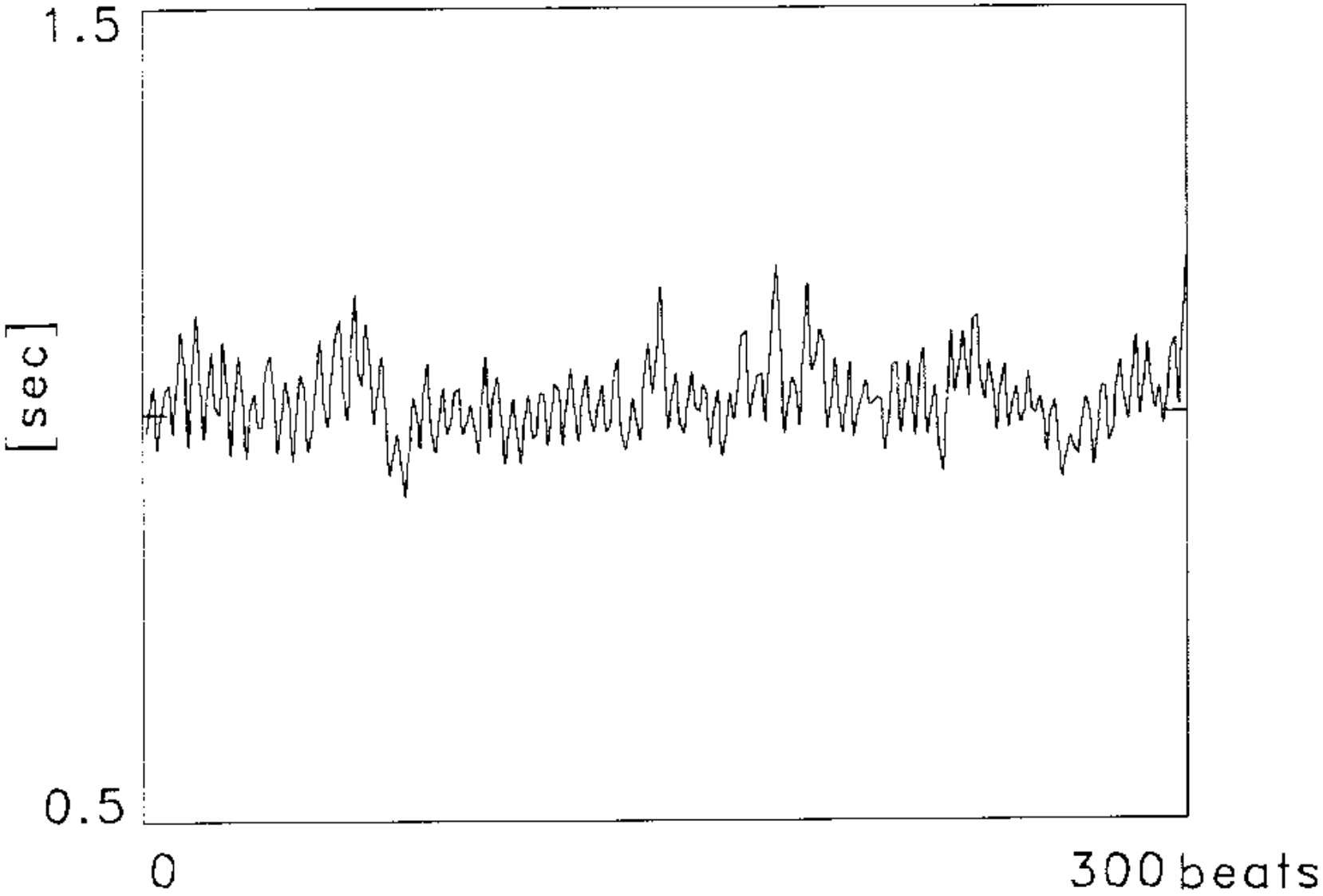



# Spectral analysis: Actual time



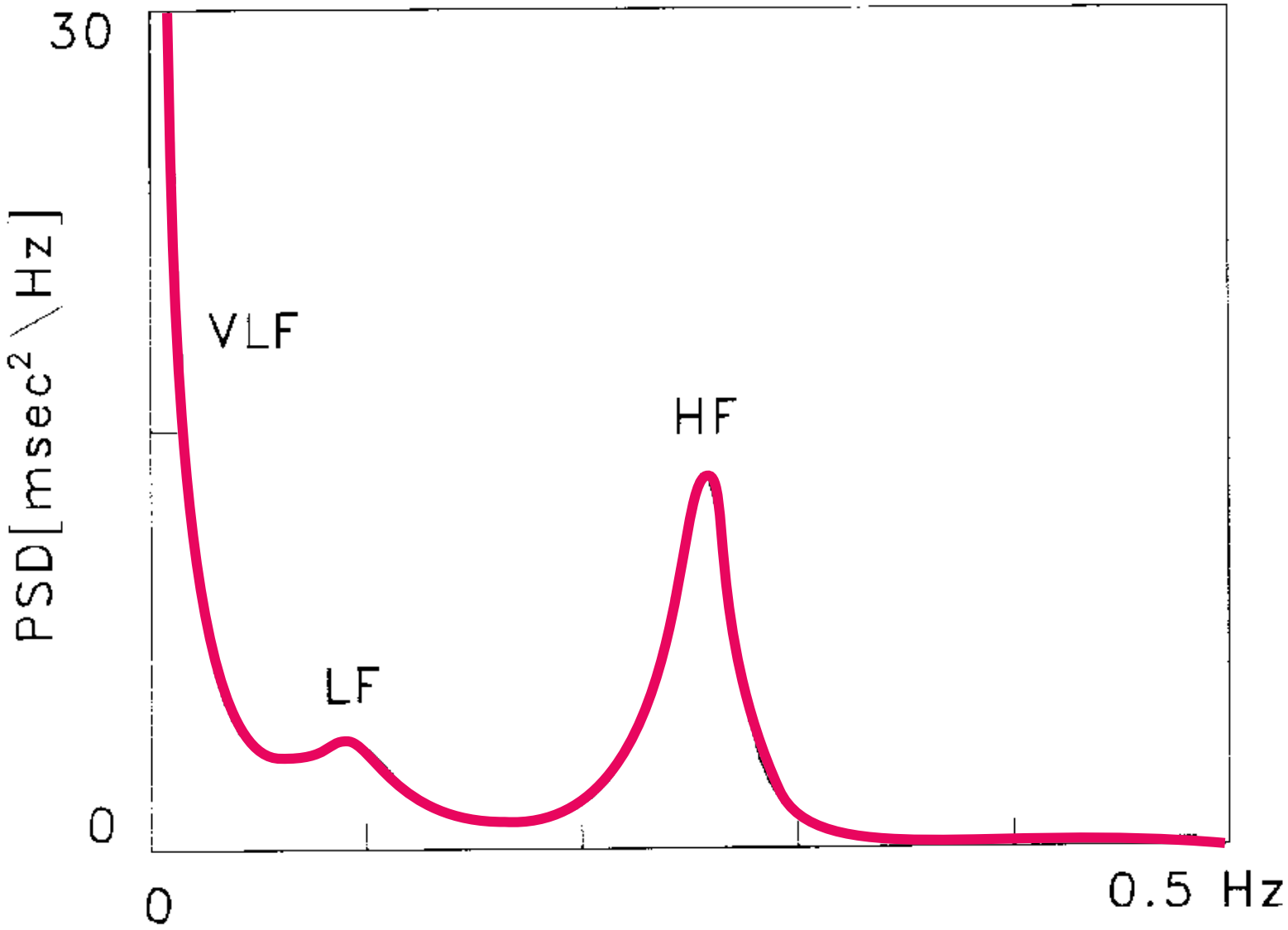



# Spectral analysis: Processed signal




Lombardi, F. (1997). Spectral Analysis of Heart Rate Variability. *Cardiac Electrophysiology Review, 3*, 335-337.

## Spectral analysis




Lombardi, F. (1997). Spectral Analysis of Heart Rate Variability. *Cardiac Electrophysiology Review, 3*, 335-337.

# Interpretation

Very Low Frequency (0 - 0,04 Hz):

- Circadian rhythm, metabolism, thermoregulation

Low Frequency (0,04 - 0,15 Hz):

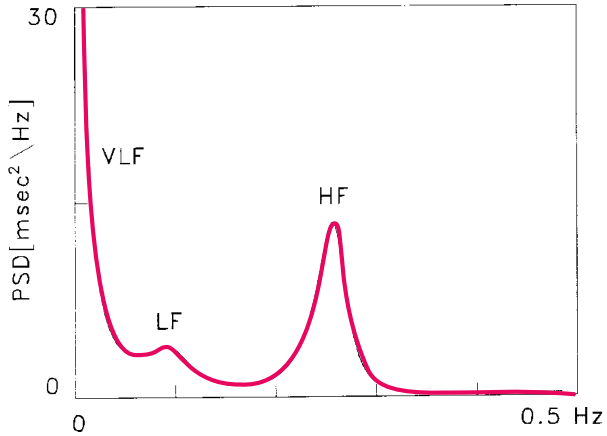
- Blood pressure regulation
- Para- and (mostly) sympathetic modulation

High Frequency (0,15 - 0,40 Hz)

- Respiratory sinus arrhythmia
- Parasympathetic modulation

LF / HF Ratio

- Balance of para-/sympathetic activity



# The electrocardiogram

The electrocardiogram traces biopotentials generated by simultaneous muscle fiber activity in the myocardium.

The various peaks and intervals have clinical significance.

In psychophysiology, more focus is placed on heart rate and heart rate variability.

HRV can be spectrally analysed to obtain information about ANS balance.

# Psychophysiology
# Part 6.2: Cardiovascular measures

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