# Foundations of Psychophysiology

## Part 5: Electromyography

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NEUROADAPTIVE
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# Electromyography (EMG)

History

Physiological origins

Measuring EMG

Analysis of EMG

# Psychophysiology: Electromyography

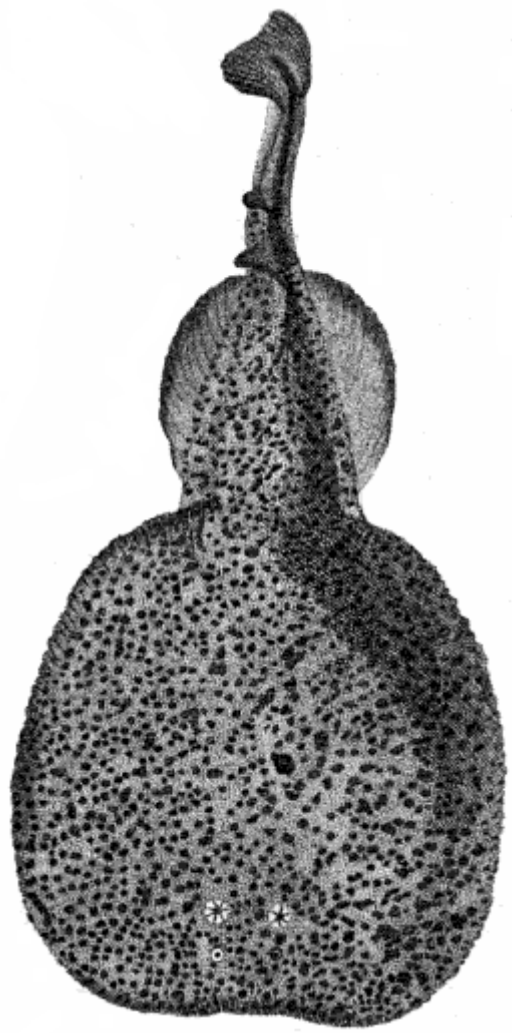
## History

# History

The electric organ in fish was discovered to consist of specialized muscle cells by Francesco Redi and Stefano Lorenzini in the 17th century.

Also because no sparks were visible during movement, shock and muscle activity was assumed to be mechanical in nature.

In 1773, sparks from an eel's shock were finally demonstrated by John Walsh.



Cacioppo, J. T. & Tassinary, Louis G. (1990). Principles of psychophysiology: Physical, social, and inferential elements. Cambridge, UK: Cambridge University Press.
Figure: Risso, A. (1810). *Ichthyologie de Nice*. Paris, FR: F. Schoell.

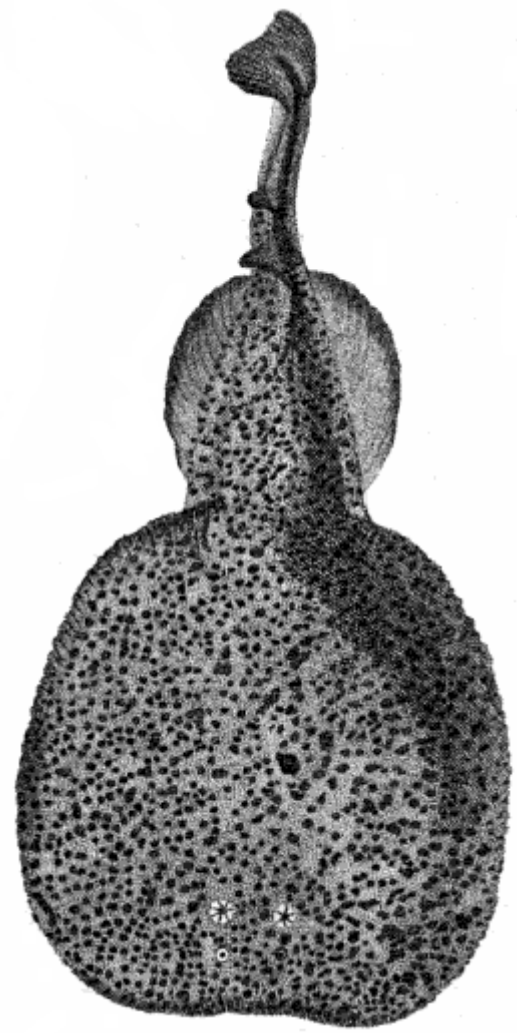
# Psychophysiology: Electromyography

## History

It is with particular ſatisfaction I make to you my firſt communication, that the effect of the Torpedo appears to be abſolutely electrical;

...

A large Torpedo, very liberal of his ſhocks, being held with both hands by his electric organs above and below, was briſkly plunged into water to the depth of a foot, and inſtantly raiſed an equal height into air; and was thus continually plunged and raiſed, as quick as poſſible, for the ſpace of a minute. In the inſtant his lower ſurface touched the water in his deſcent, he always gave a violent ſhock, and another ſtill more violent in the inſtant of quitting the water in his aſcent;



Walsh, J. (1773). *Of the Electric Property of the Torpedo. In a Letter from John Walsh, Esq; F. R. S. to Benjamin Franklin, Esq; LL.D., F. R. S., Ac. R. Par. Soc. Ext., &c*. Philosophical Transactions, 63 (1773-1774), pp. 461-480.
Illustration : Risso, A. (1810). *Ichthyologie de Nice*. Paris, FR: F. Schoell.

# History

In 1791, Luigi Galvani discovered that frog legs twitched when subjected to electrical current.

Ultimately, Emil du Bois-Reymond (1849) used a galvanometer to demonstrate increased electric activity during muscle contractions.

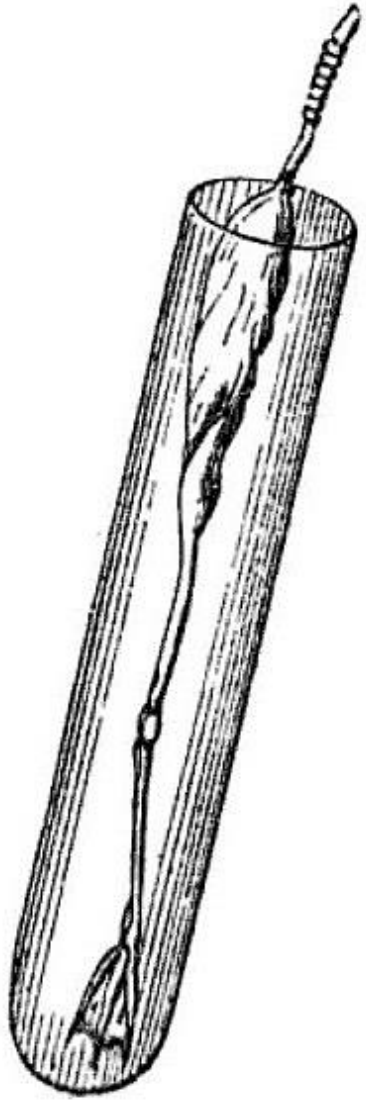


Illustration: Hogg, J. (1861). *Elements of experimental and natural philosophy* (p. 502). London, UK: Henry G. Bohn.

# Psychophysiology: Electromyography

## Physiological origins

## Muscle types

- Smooth muscle (involuntary, ANS-controlled)
- Cardiac muscle (striated; involuntary, ANS-controlled)
- Skeletal muscle (striated; voluntary, SNS-controlled)

Striated refers its striated appearance under a microscope.


Photograph of "Lotti" (1925) by Mac Walten is in the Stadtmuseum Berlin

## Voluntary control?

- Facial expressions
- Shivering when cold
- Muscle tension due to disorders and stress
- Relaxation during sleep

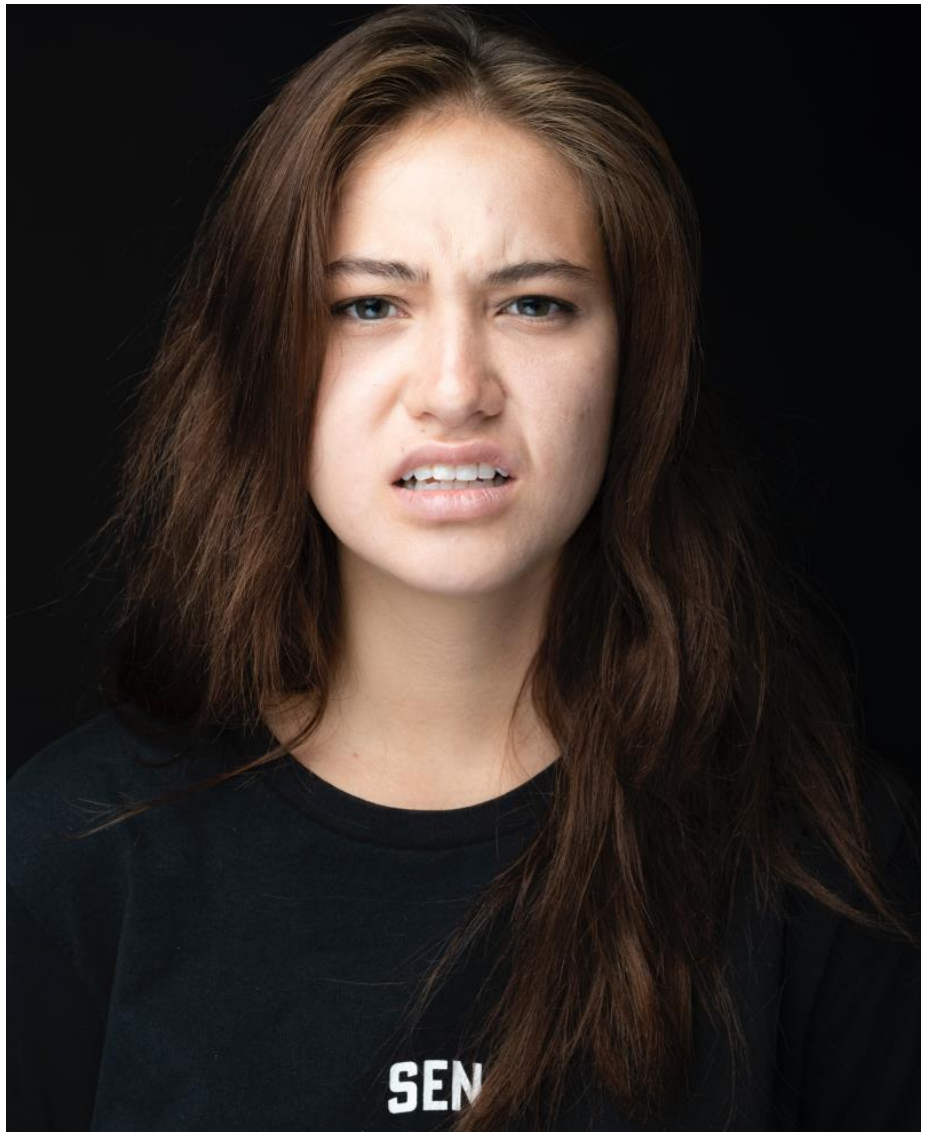
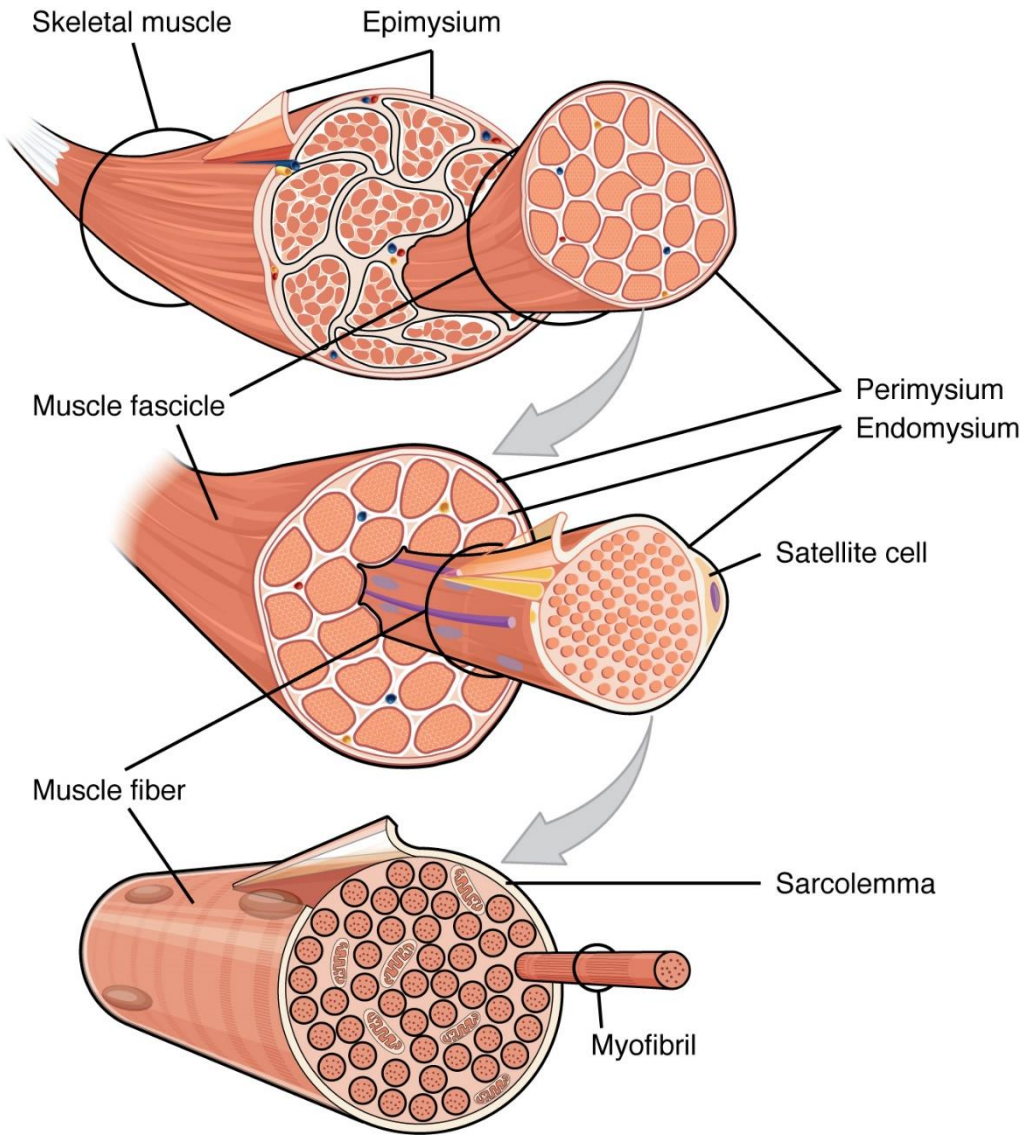
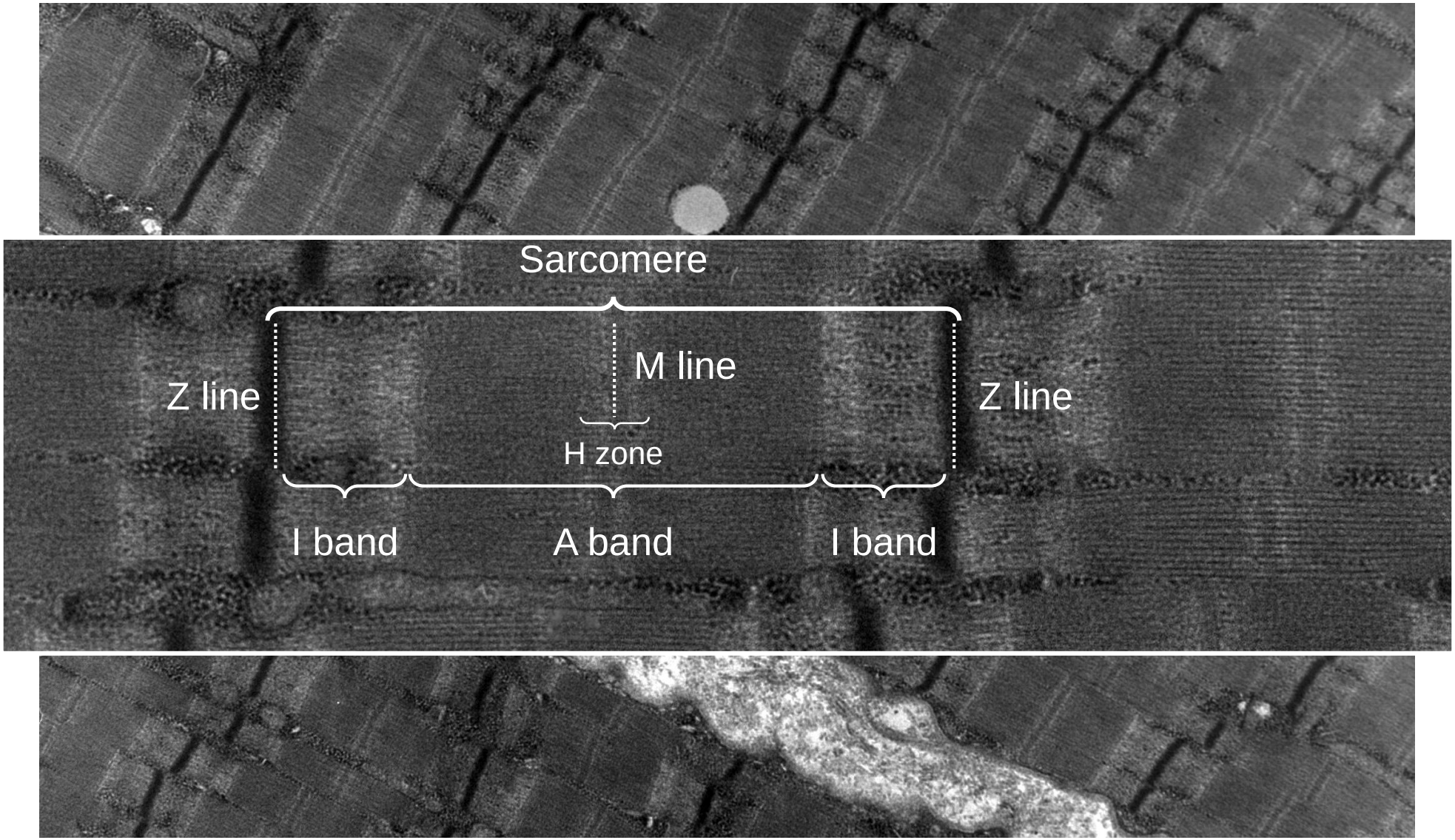



Photo: Ospan Ali on Unsplash

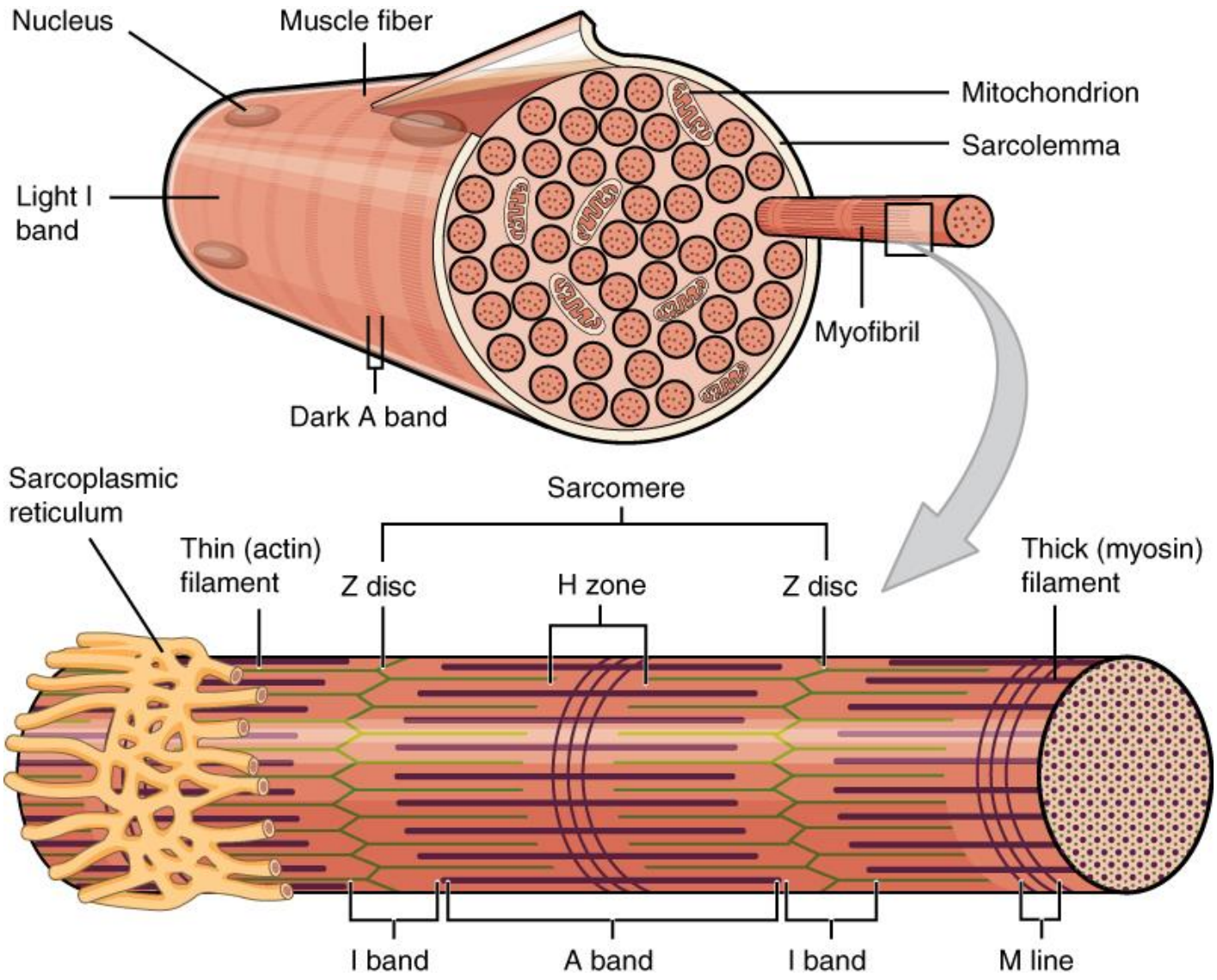
# Skeletal muscle



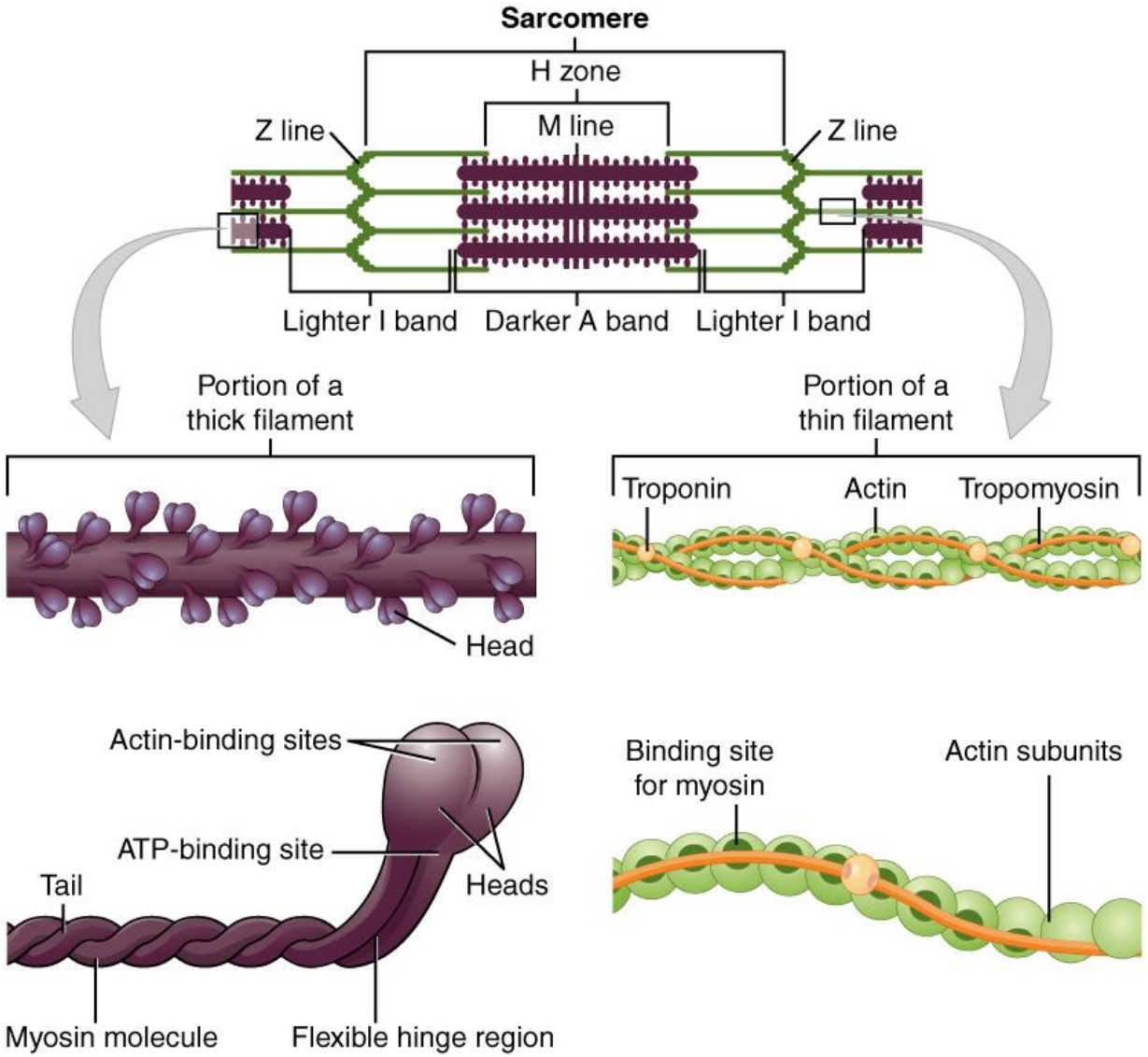
# Sarcomere



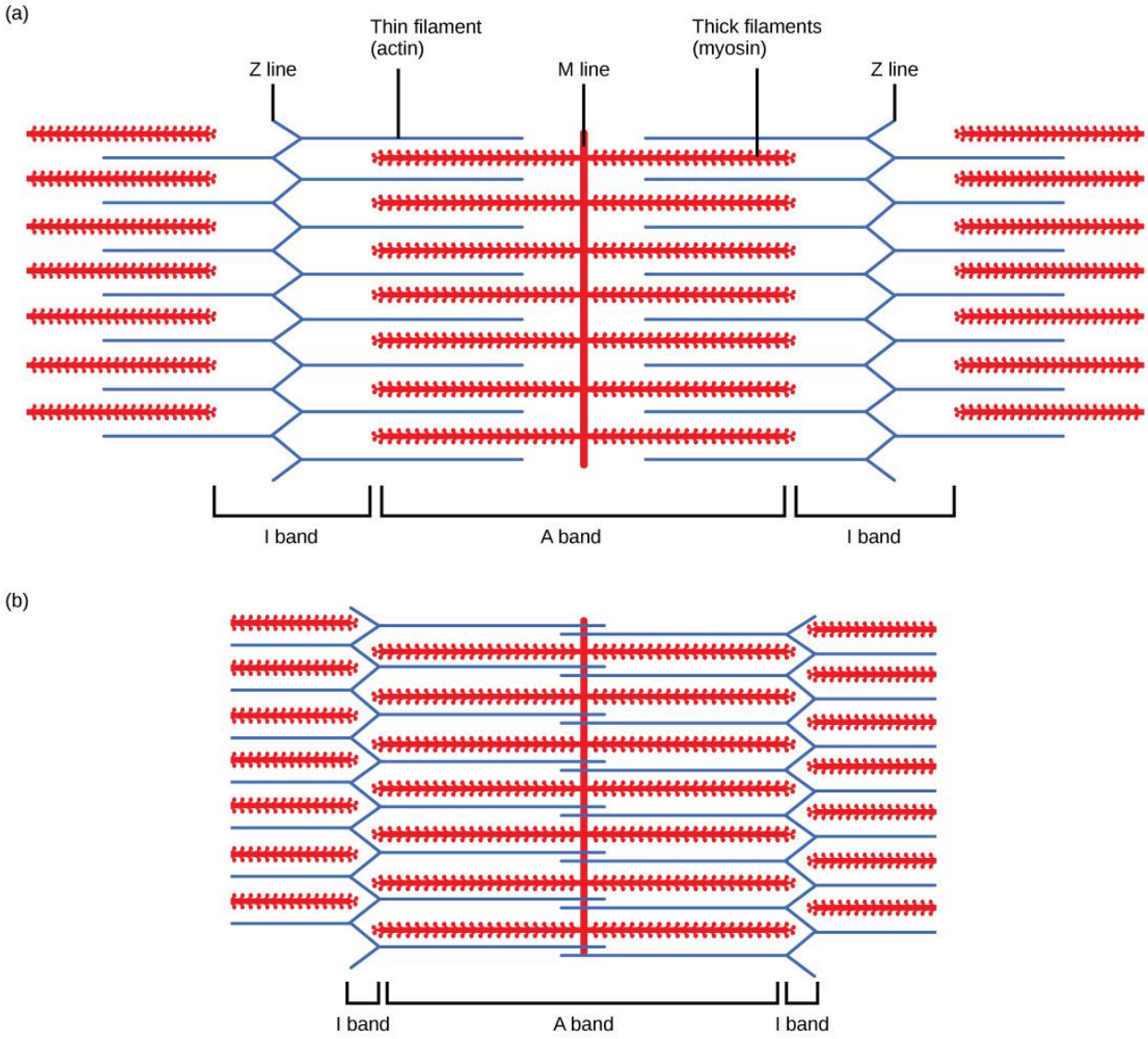
# Muscle fiber and myofibril



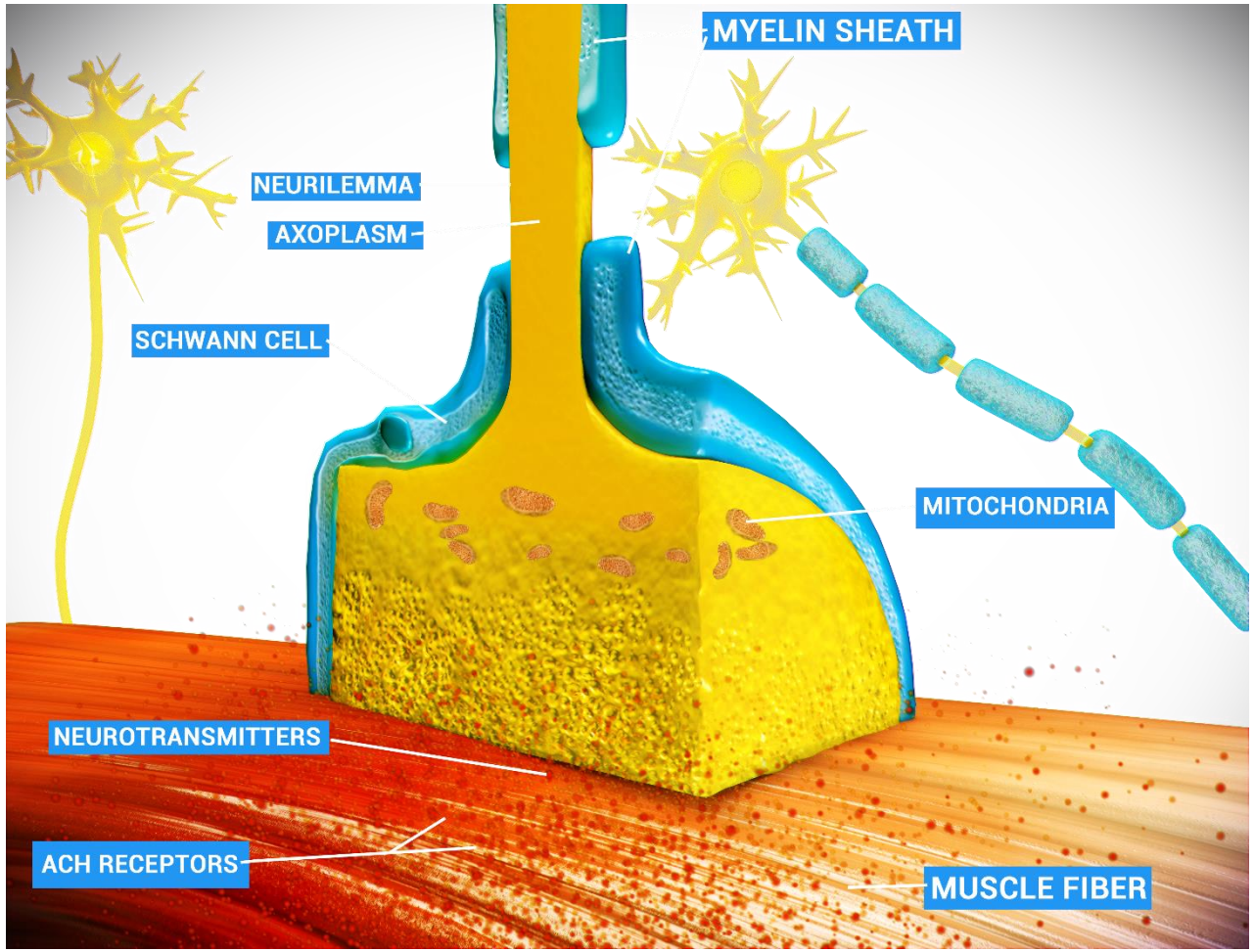
# Sarcomere



# Sarcomere contraction



# Neuromuscular junction



## Motor units

A *motor unit* consists of a single motor neuron, its axon, and all the muscle fibers innervated by it.

Activation of a motor unit follows an all-or-nothing principle.

Activation of a muscle can vary depending on the amount and size of active motor units.

The ratio ranges from 1:3 to 1:3000, allowing fine or gross motor activity.

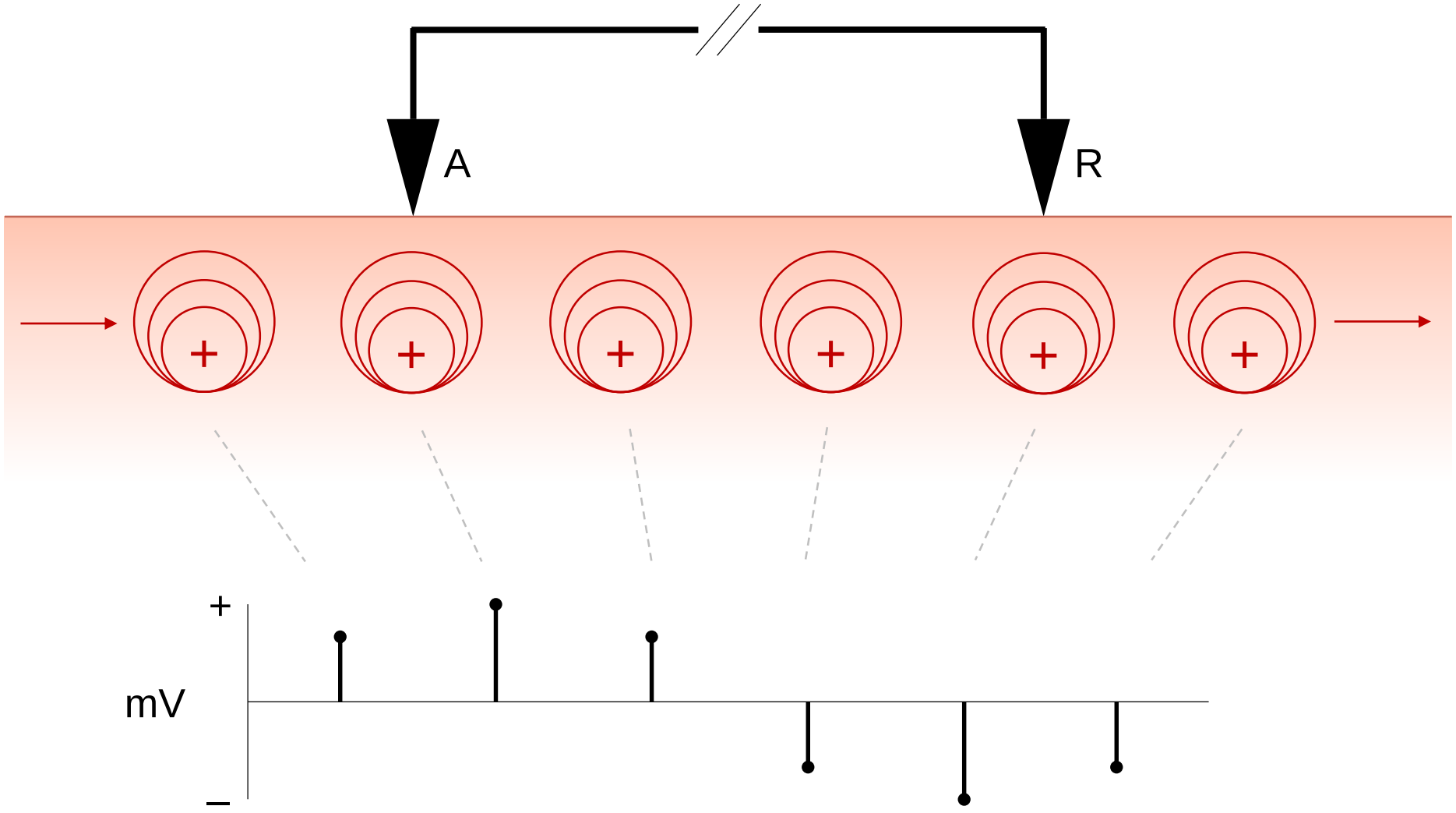
# Motor unit / muscle fiber action potentials

A motor unit action potential (MUAP) is carried by the neuron, triggering a muscle fiber action potential (MFAP) in the postsynaptic muscle fibers.

Muscle fiber action potentials have

- a slightly lower resting potential (-85 mV),
- a slightly longer duration (up to 5 ms), and
- a slower velocity (3 – 5 m/s).

# Origin of EMG



## Motor unit potentials

A motor unit potential (MUP) refers to the sum of all muscle fiber action potentials of a single motor unit. This is what EMG measures.

The measured signal is thus a function of

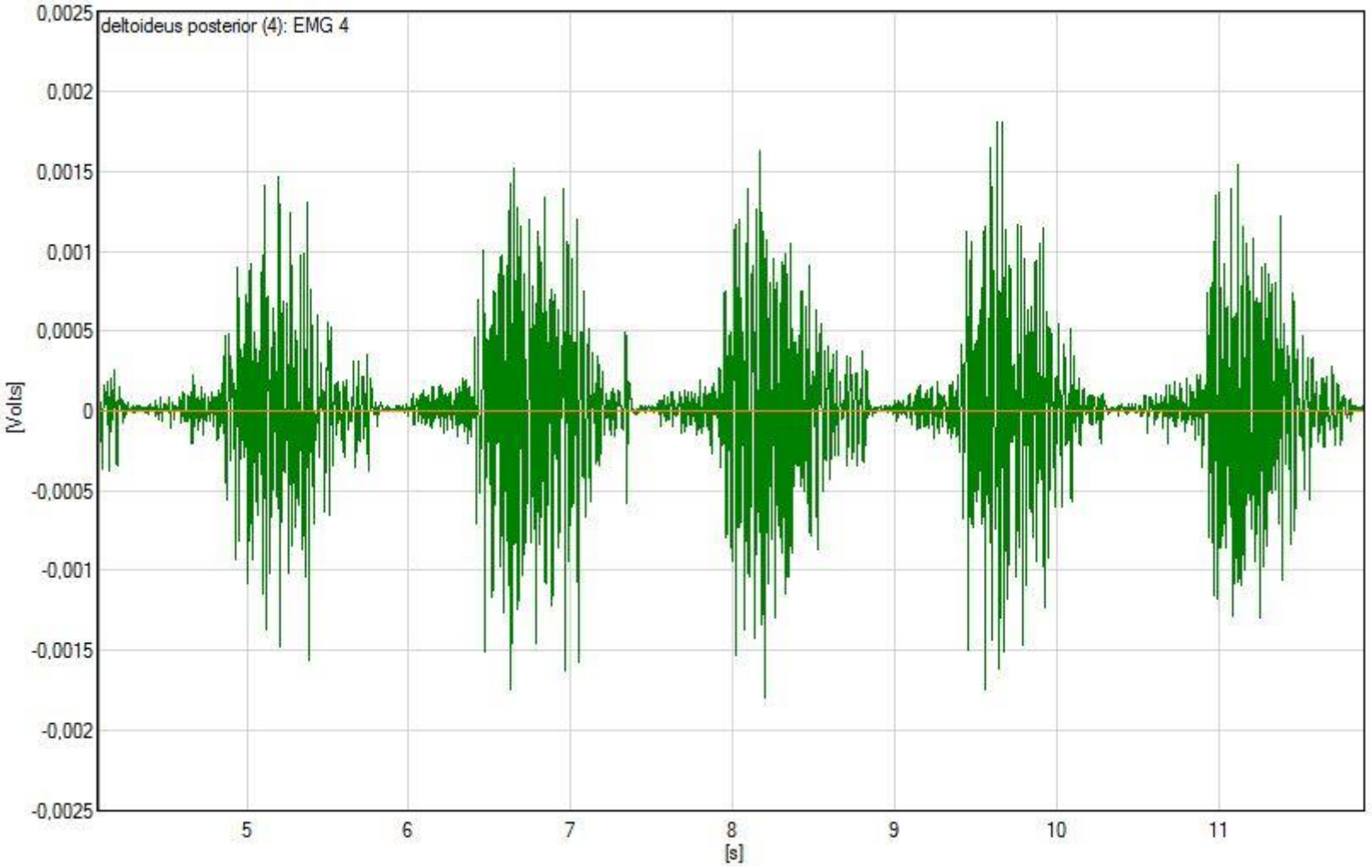
- the number of detected active motor units, and
- the rate at which they are firing.

Multiple motor units each firing at around a maximum of 50 Hz, but not all firing at the same time, can add up to much higher frequencies.

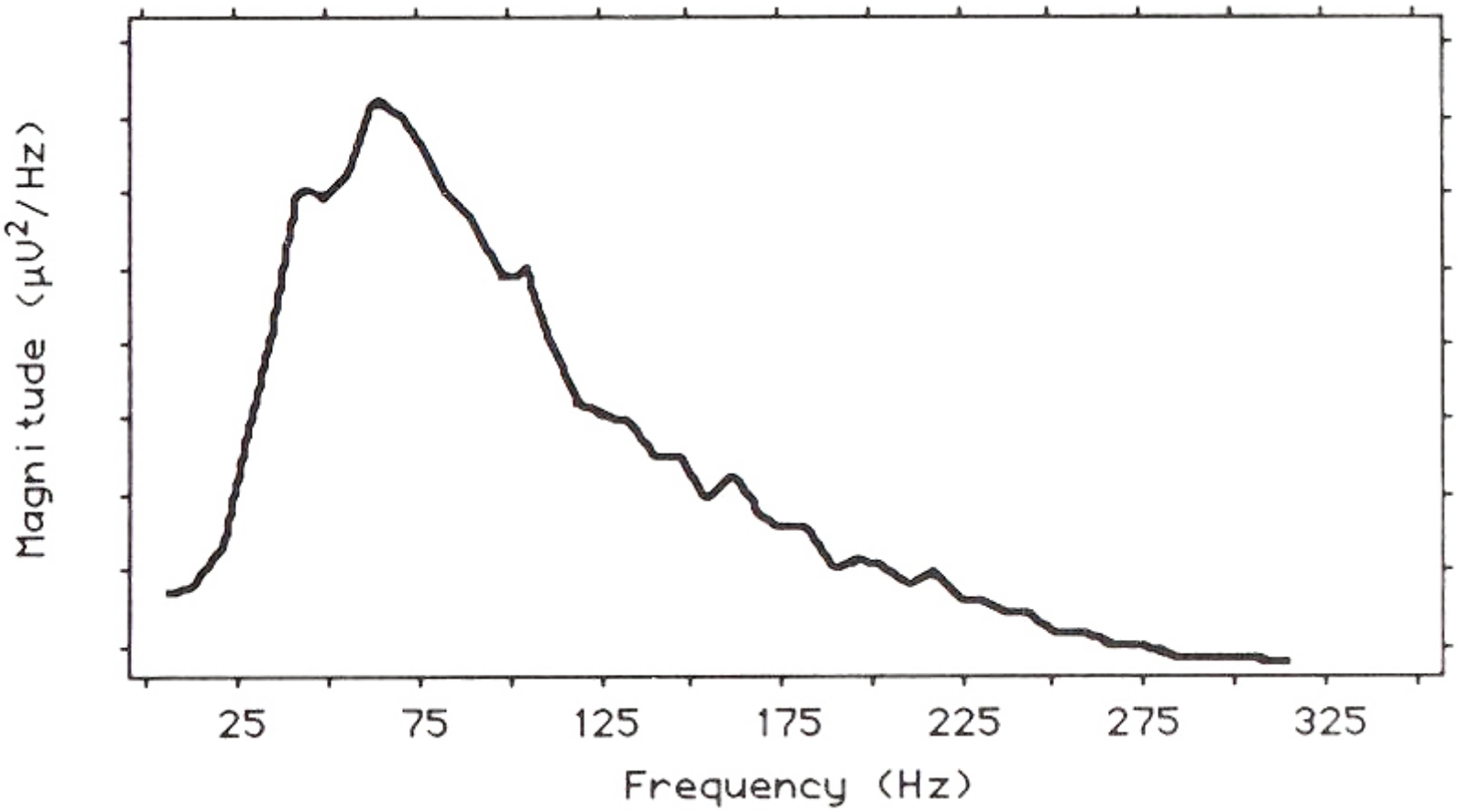
This is why muscle activity is often broadband signal.

# Measuring EMG

# The EMG signal: Raw



# The EMG signal: Spectrum




Cacioppo, J. T. & Tassinary, Louis G. (1990). Principles of psychophysiology: Physical, social, and inferential elements. Cambridge, UK: Cambridge University Press.

## Recording

The amplifier needs to be capable of recording broad spectrum signal with most power in 40 – 100 Hz.

Good ground site important to filter out overlapping mains noise.

High-pass filter can be applied to filter out eye activity when recording from the face.

Subdermal electrodes can be used for precise measurement.

Abrade the skin before applying surface electrodes. Smaller sizes can be used for face recordings.

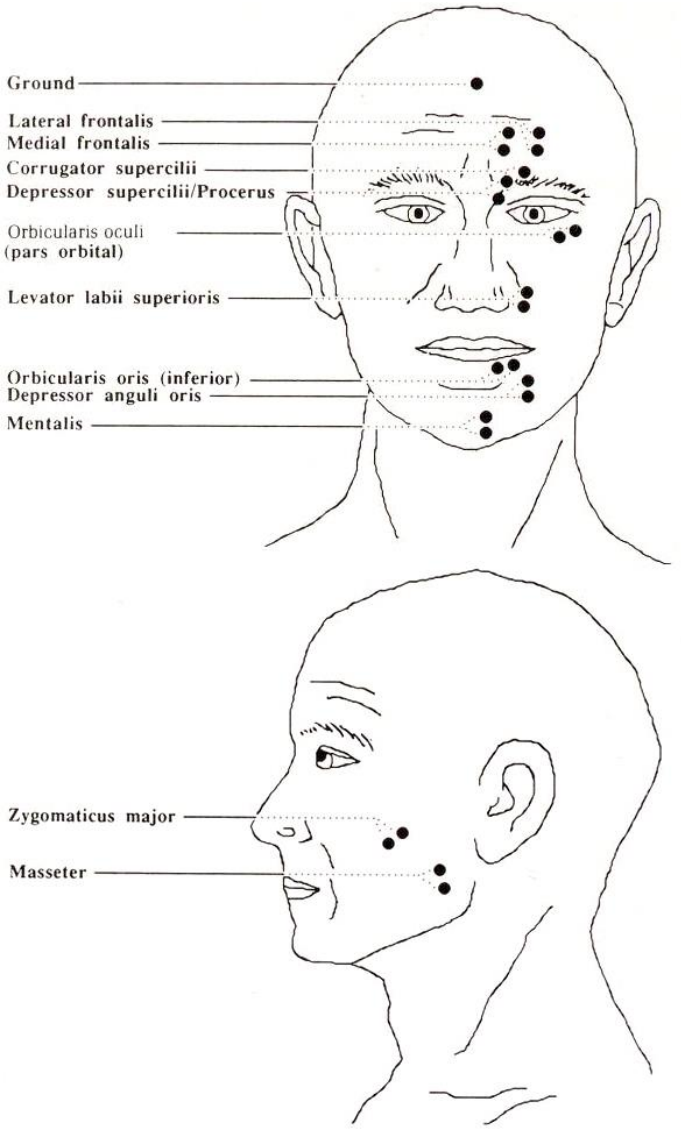
## Electrode placement

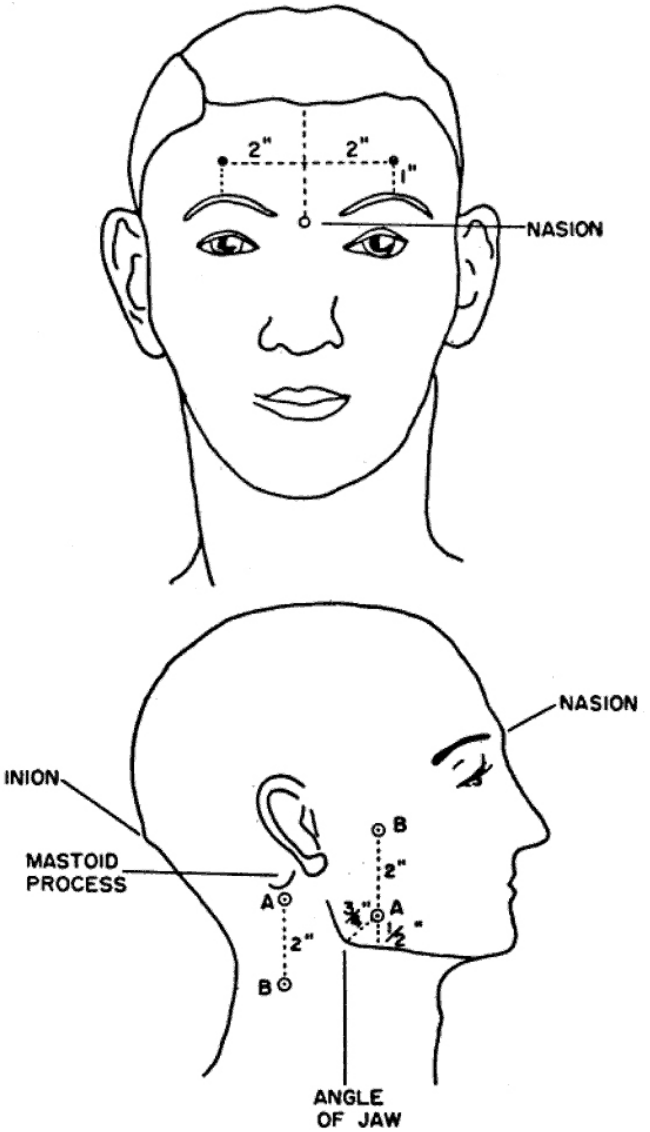
Usually a bipolar recording with one electrode placed in the middle, the other at the end of the muscle of interest

A few mm can make a big difference.

- Absolute value are therefore mostly meaningless.
- Repeated measures are difficult, even within subjects.
- Focus on within-subject, within-session differences.

# Electrode placement: Face




Left: Cacioppo, J. T. & Tassinary, Louis G. (1990). Principles of psychophysiology: Physical, social, and inferential elements. Cambridge, UK: Cambridge University Press.

Right: Davis, J. F. (1959). Manual of surface electromyography (WADC Tech. Rep. No. 59-184). Dayton, OH, USA: Wright Air Development Center

## Facial muscle relevance

Corrugator: frown

Orbicularis: bright light, averse stimuli

Levator: disgust

Mentalis: sleep

Zygomaticus: smile

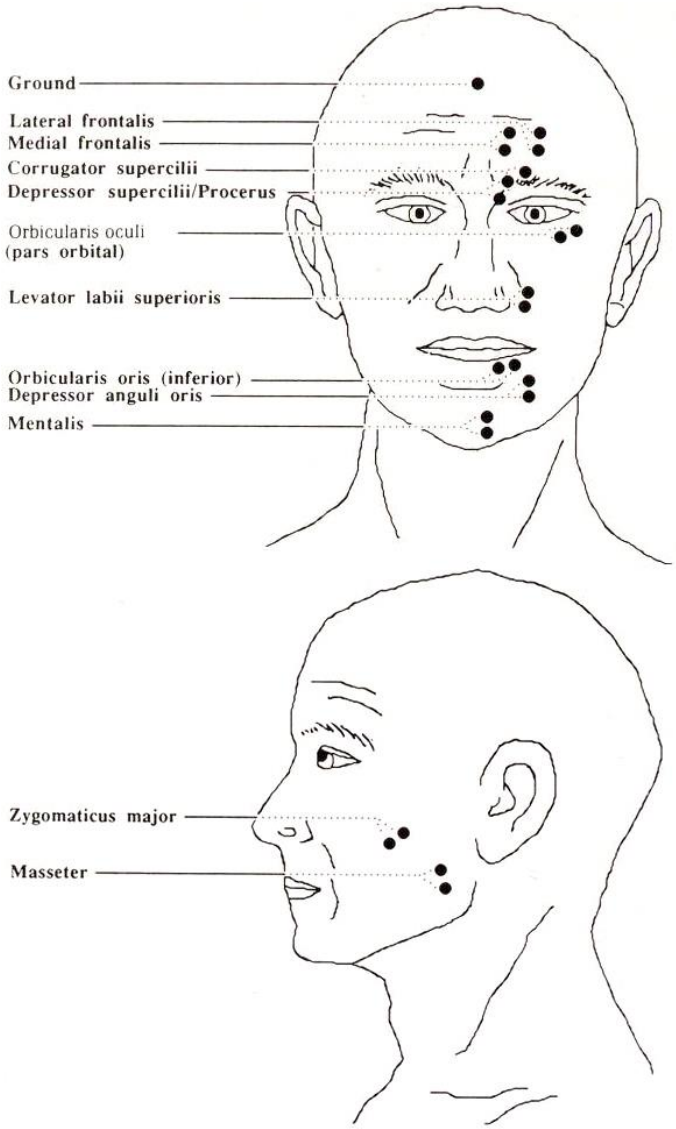
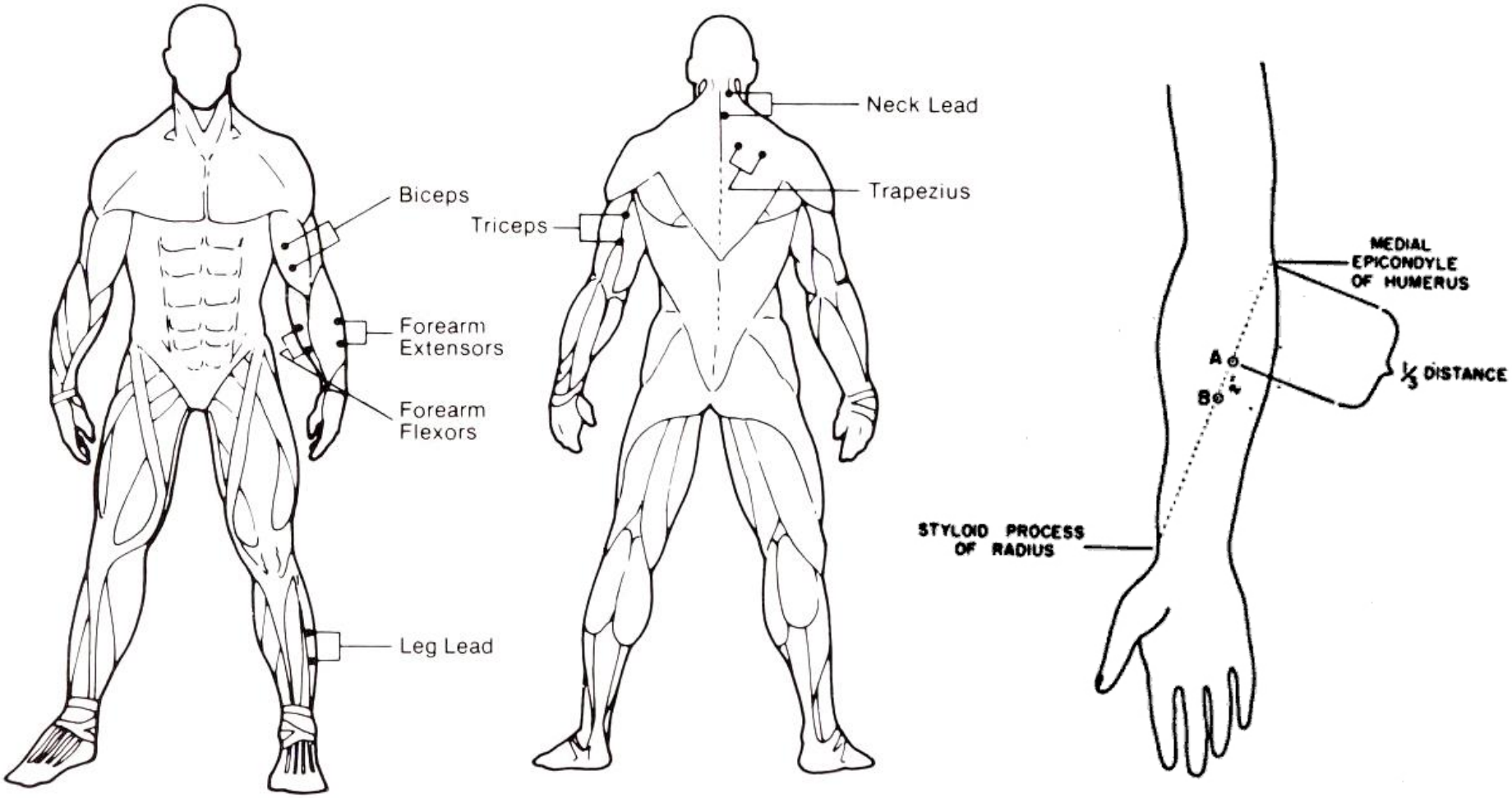



Figure: Cacioppo, J. T. & Tassinary, Louis G. (1990). Principles of psychophysiology: Physical, social, and inferential elements. Cambridge, UK: Cambridge University Press.

# Electrode placement: Body

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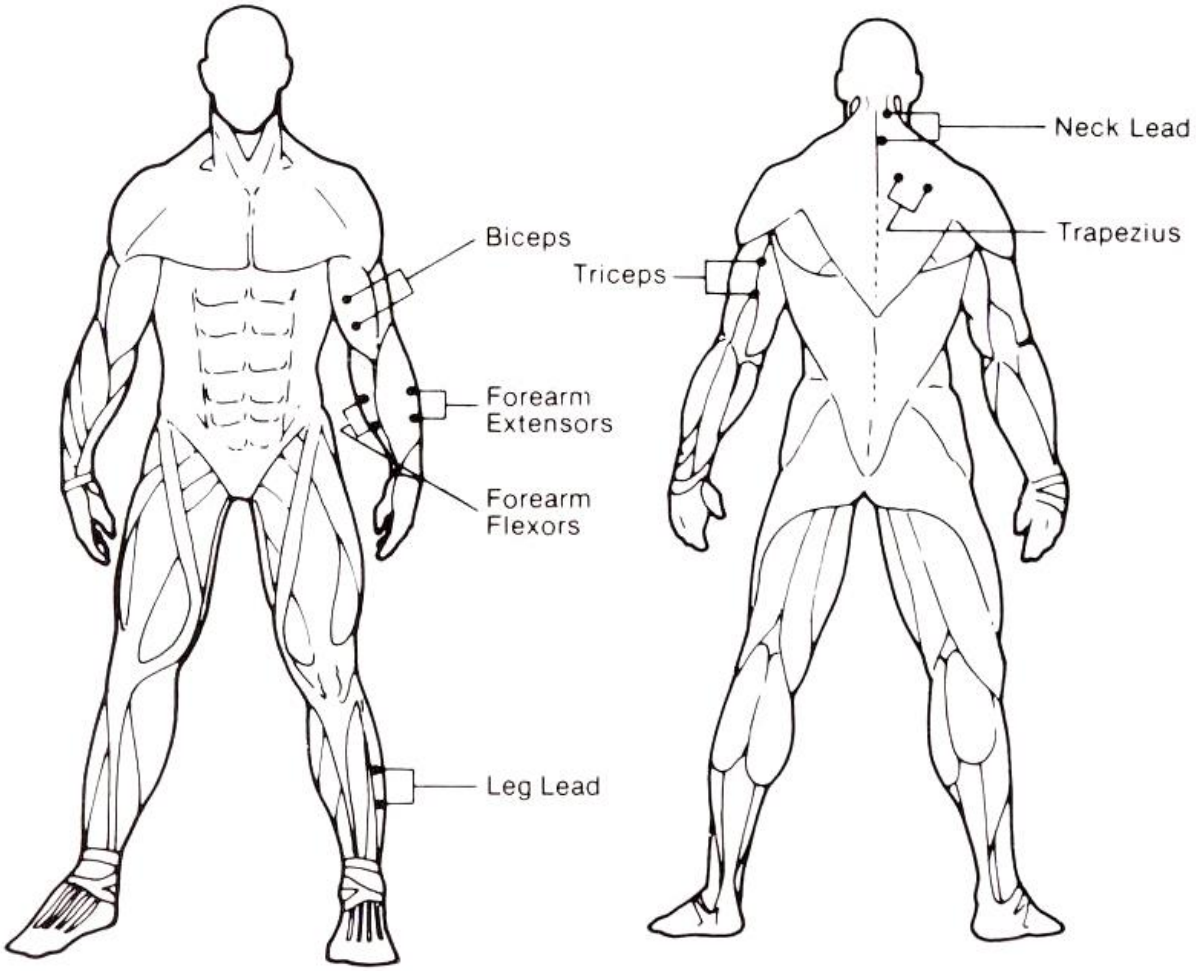
# Body muscle relevance




Splenius (neck): aversive stimuli

Trapezius: stress

Tibialis (leg): stress

Figure: Cacioppo, J. T. & Tassinary, Louis G. (1990). Principles of psychophysiology: Physical, social, and inferential elements. Cambridge, UK: Cambridge University Press.

## Artefacts

Aside from the obvious, in particular

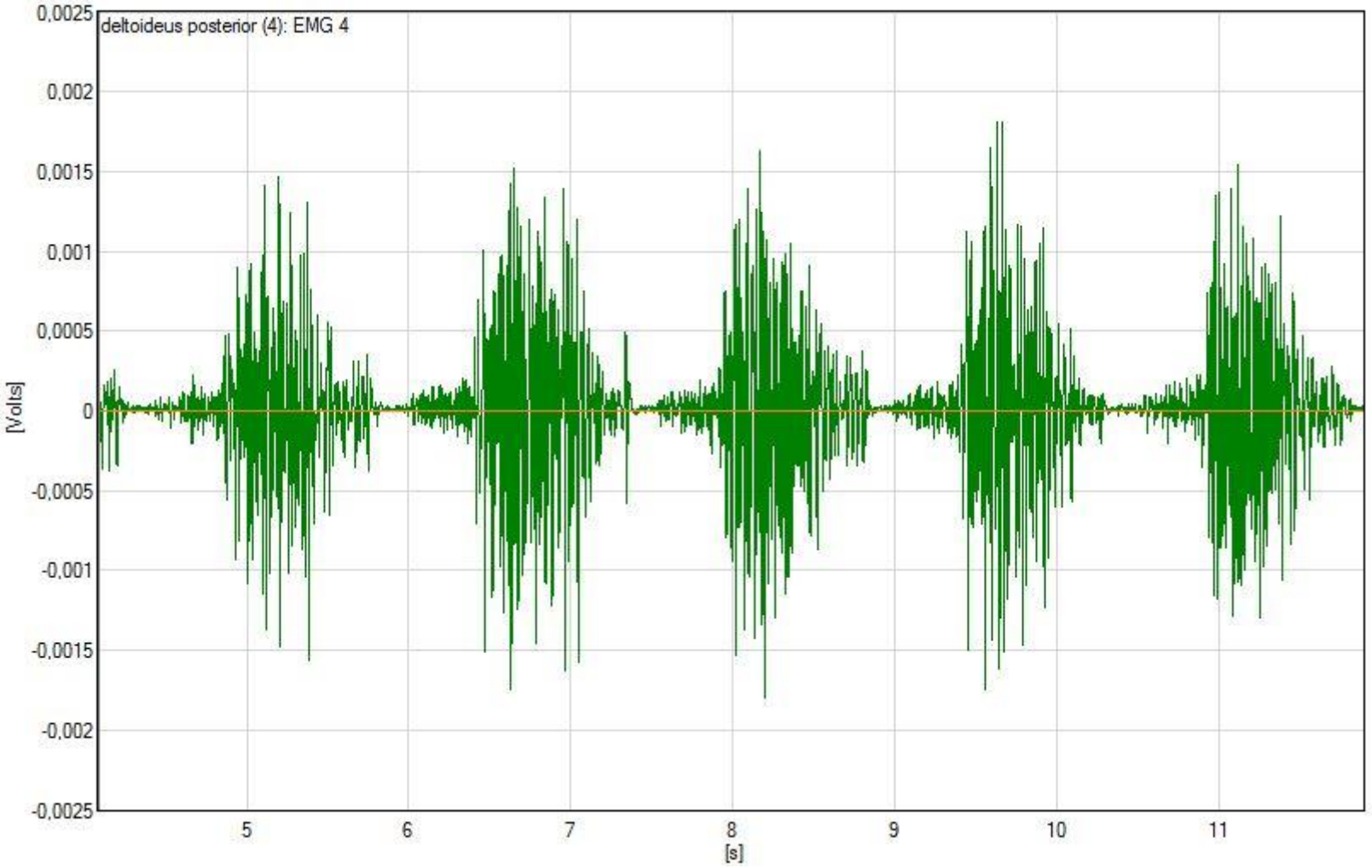
- posture,
- movement artefacts,
- electrode shifts due to muscular activity, and sometimes
- ECG, depending on electrode positions,

need to be taken into account.

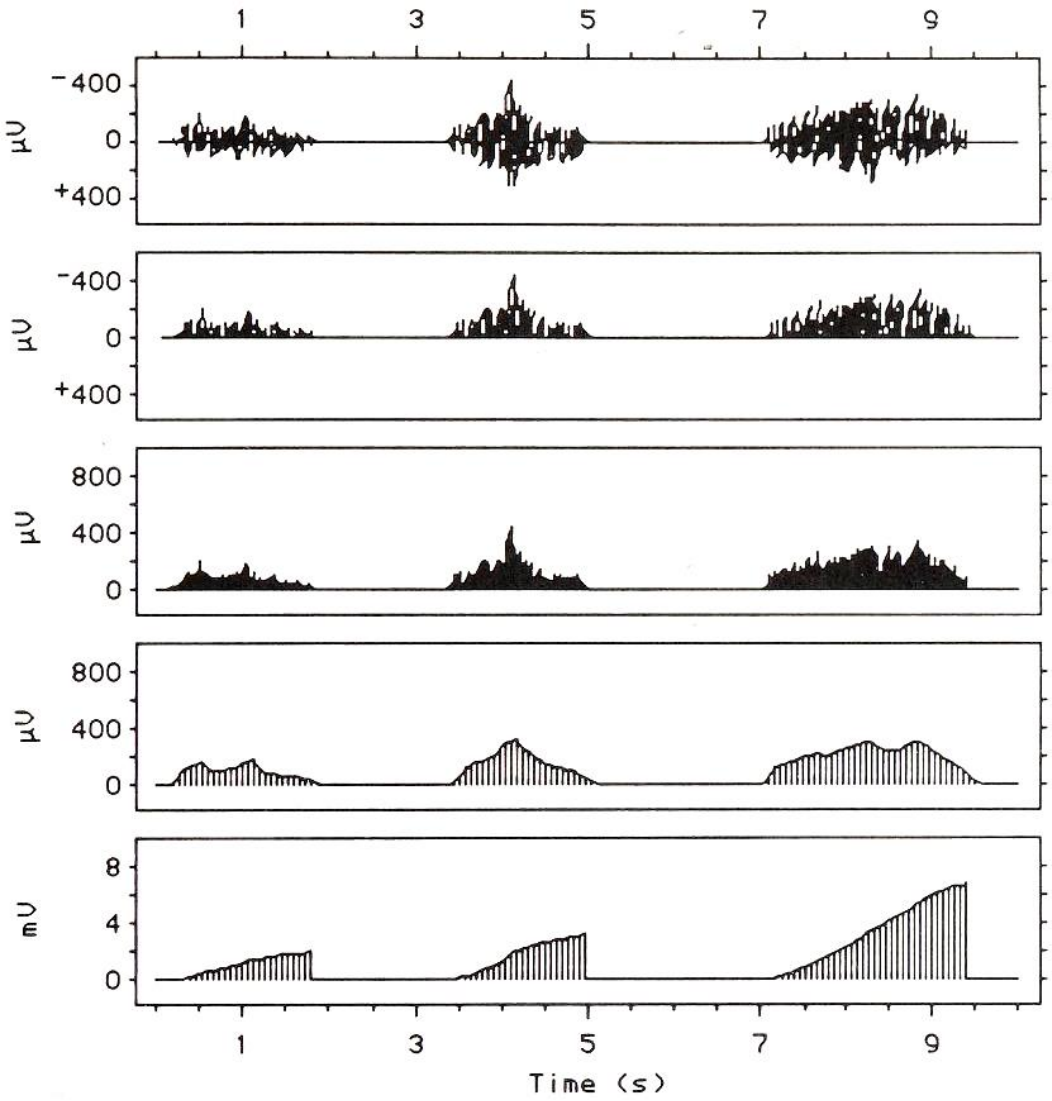
Psychophysiology: Electromyography

# Analysing EMG

# The EMG signal: Raw



# EMG processing




1. Raw signal
2. Rectification
   - Half-wave: Only retain positive samples
   - Full-wave: take absolute values
3. Smoothing
4. Integration

Figure: Cacioppo, J. T. & Tassinary, Louis G. (1990). Principles of psychophysiology: Physical, social, and inferential elements. Cambridge, UK: Cambridge University Press.

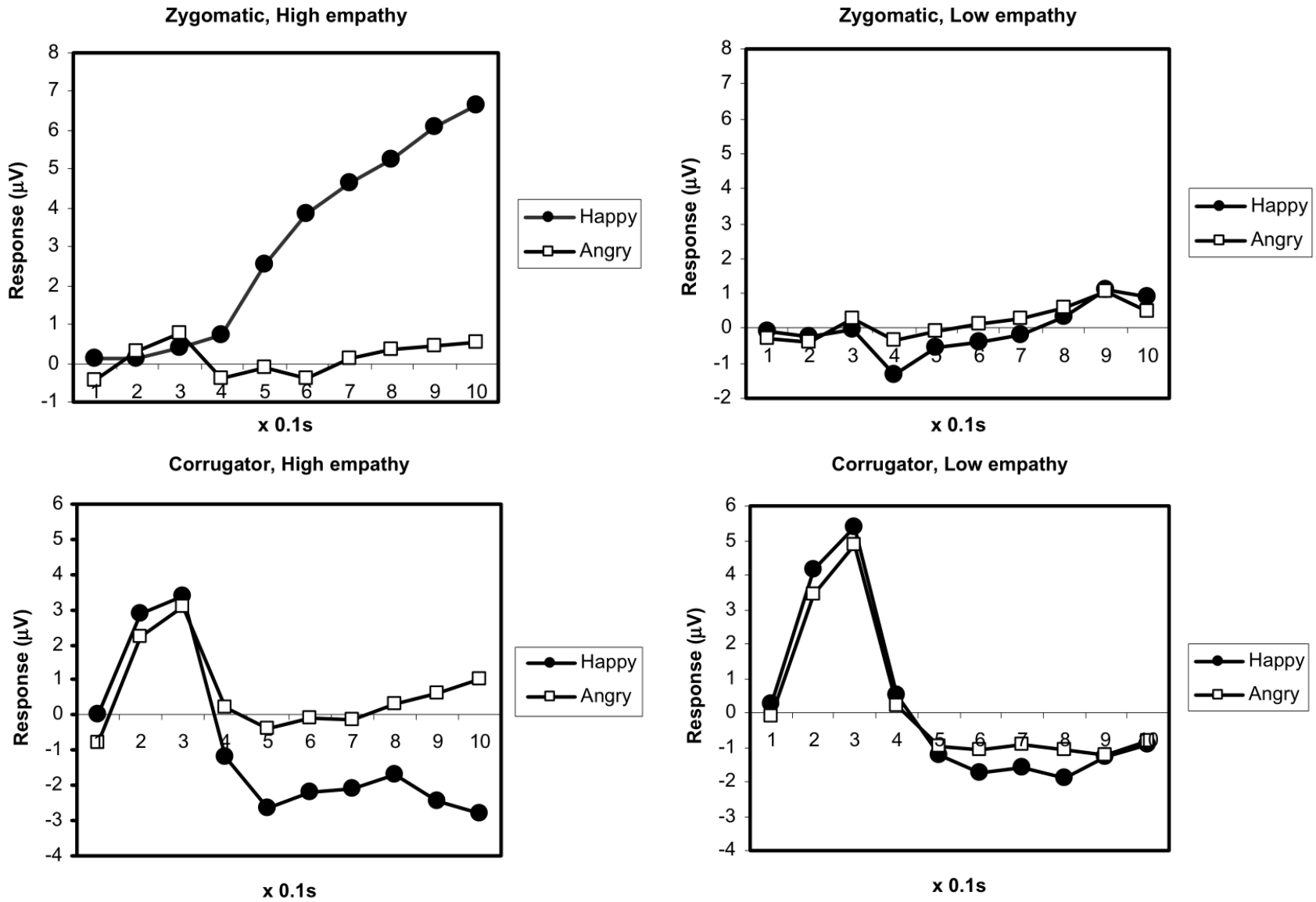
## EMG processing: Integration

Integration reflects a measure of “total EMG output over a given period of time”.

The *period of time* is thus a free parameter, dependent on the research question, and can vary from milliseconds to seconds.

# Psychophysiology: Electromyography: Analysis

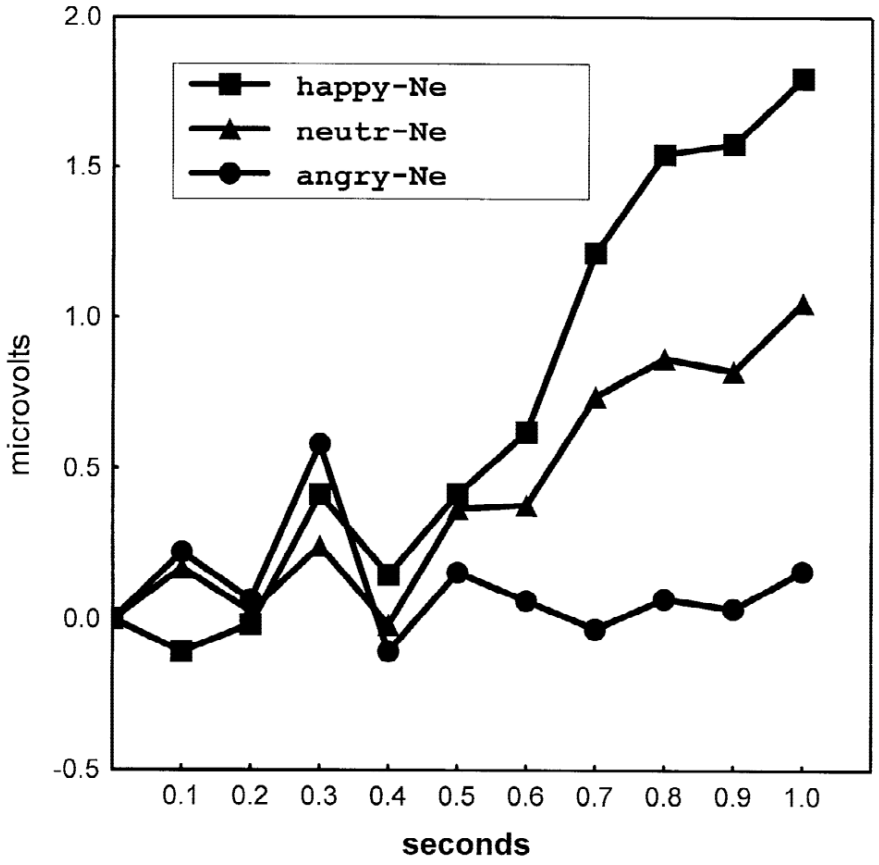
## Example

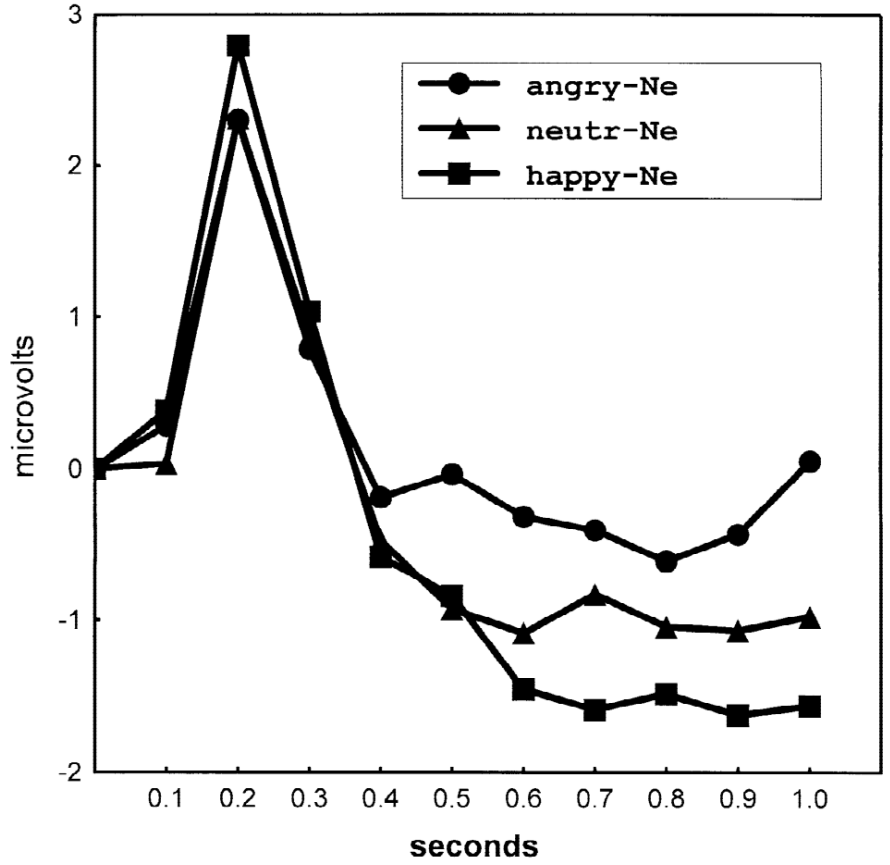



Dimberg, U., & Thunberg, M. (2012). Empathy, emotional contagion, and rapid facial reactions to angry and happy facial expressions. *PsyCh Journal, 1*(2), 118-127.

# Psychophysiology: Electromyography: Analysis

## Example

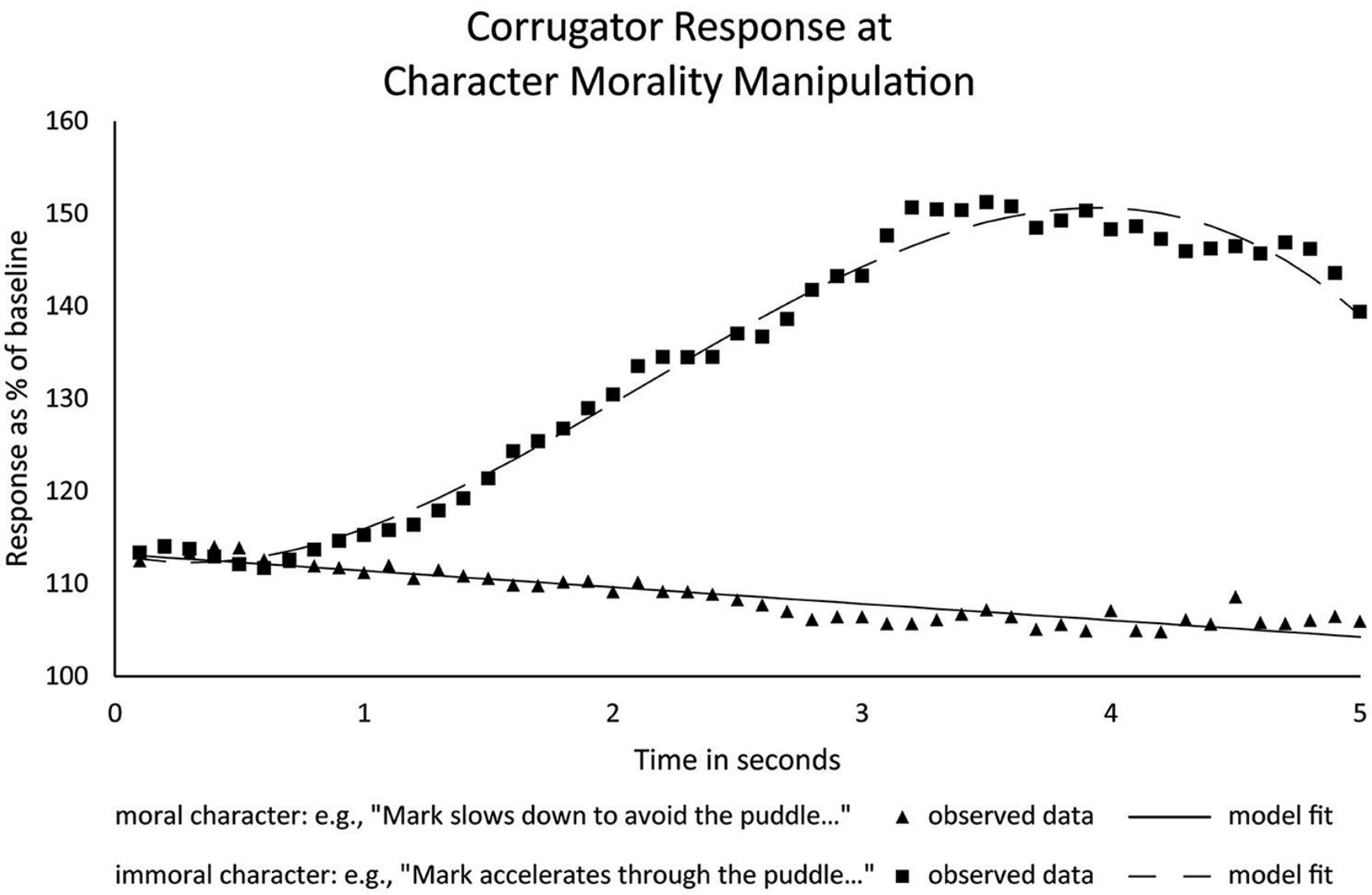



Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science, 11*(1), 86-89.

# Psychophysiology: Electromyography: Analysis

## Example




't Hart, B., Struiksma, M. E., van Boxtel, A., & van Berkum, J. J. A. (2018). Emotion in stories: Facial EMG evidence for both mental simulation and moral evaluation. Frontiers in Psychology, 9, 613.

# Electromyography

Simultaneous motor fiber action potentials recorded from surface electrodes result in a broad-spectrum signal.

Through integration over time, a general EMG output signal can be constructed.

The activity of different muscles, in particular those in the face, can be correlated to different psychological states.

# Psychophysiology
# Part 5: Electromyography

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