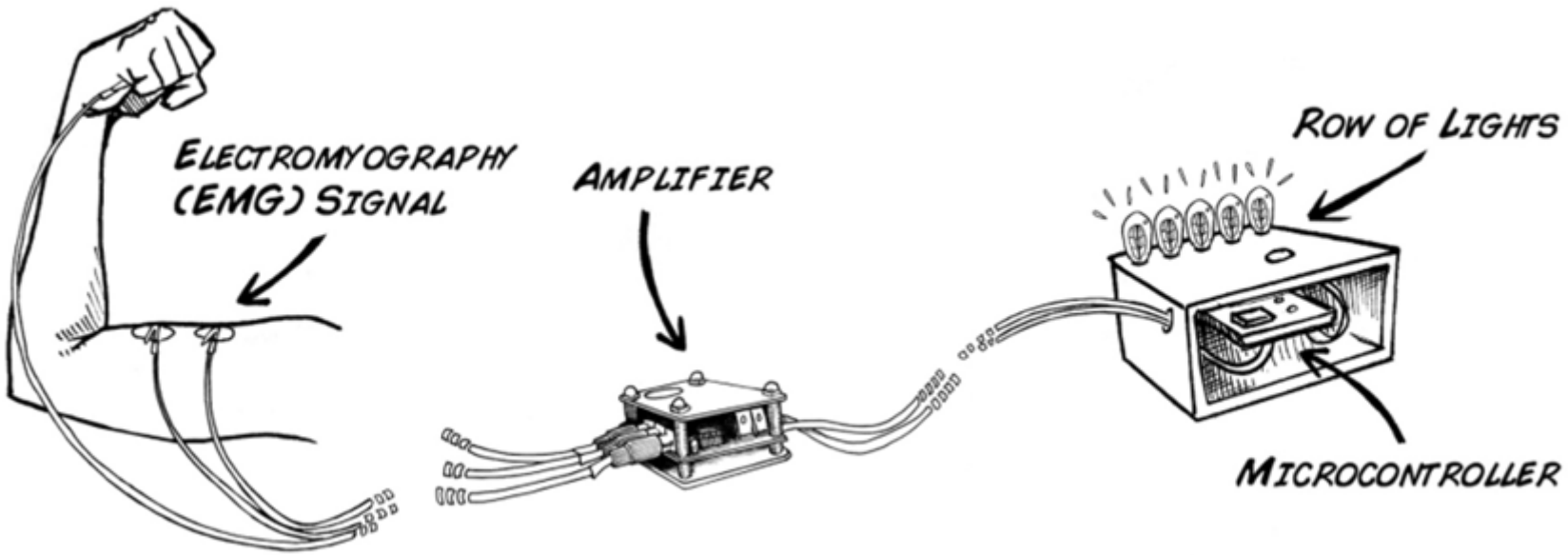
Before the lecture

- Download the app “Socrative Student” from the App Store (Apple or Android)
- Classroom name is BIOMEDTECHSTREAM
- Answer the three anonymous, multiple choice questions.
- This will help me target the lecture.

Context of Biomedical Technical Stream: Electromyography and Prosthetics

EMG is the technique for evaluating and recording electrical activity of skeletal muscle.



Aim of technical lectures

- Understand physiology behind EMGs
- Understand practical issues around obtaining an EMG
- Introduce hand gripping mechanics
- Get insight into real-world prosthetic design
- Gain biomedical industry perspective on engineering design

Outline of the technical lectures

Week	Topic
3	Nerves and Muscles
4	Function of the Hand, Practical Issues of EMGs
5	Prosthetics in reality, Materials
6	Industry Perspective, Workshop safety

UNSW SYDNEY | Australia's Global University

ENGG1000 Session 2018 Biomedical Engineering Technical Stream

Lecture 1: Nerves and muscles

Aims of this lecture

- Introduction to cell anatomy - particularly cell membranes
- Introduction to neurons
- Understanding electrical properties of cells
- Understand action potentials, and how they can be used to communicate
- Understand how an action potential can lead to muscle contraction.

So we can understand why there is a relationship between nerves and muscles

Introductory Activity

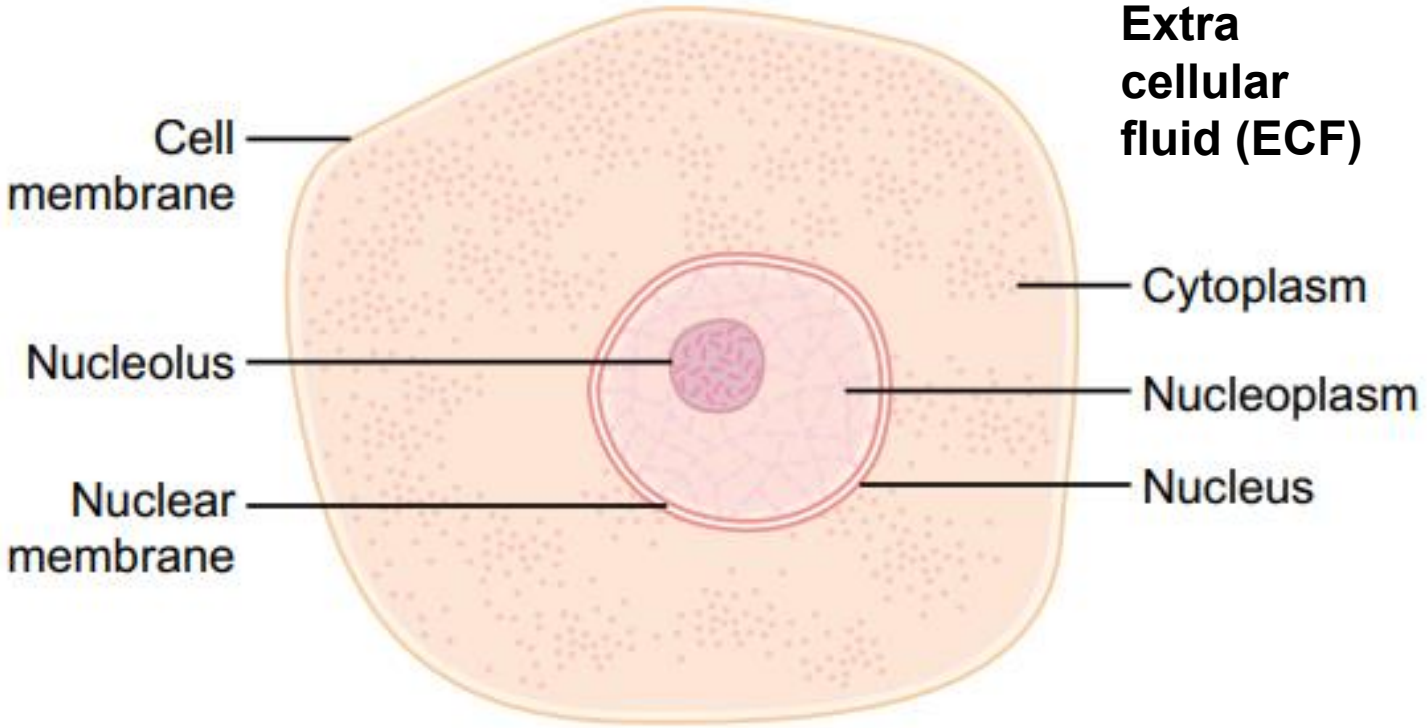
Introductory Activity

- Turn to the person next to you, and introduce yourself
- Take turns explaining what you think happened inside your body, from the moment I said “flex your bicep”, to when you could feel your muscle move under your hand.
- Once you’re happy with your explanation, open up Socrative, and enter your answer there
- It’s 100% anonymous
- I don’t care about spelling or grammar
- We’ll show the answers on screen

Hierarchy of components in the body

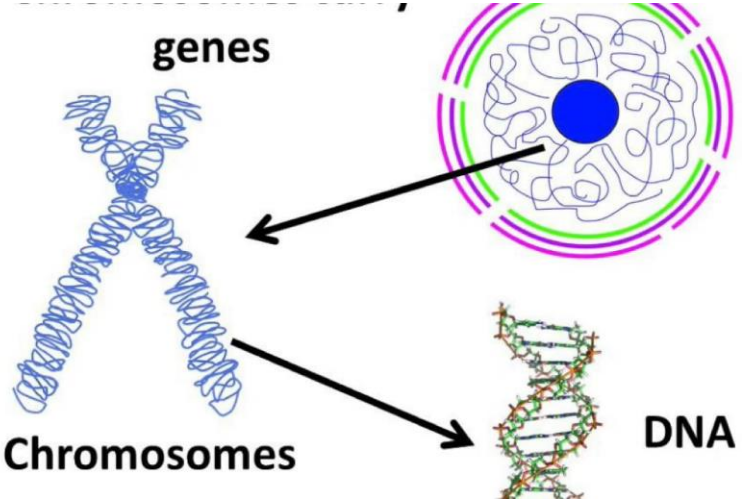
1. Chemical/Atomic - proteins, ions, molecules
2. Cells - smallest object of life (e.g. bacteria)
3. Tissues - cluster of similar cells (e.g. epithelial, muscular, connective, nervous)
4. Organs - 1 tissues together, forming a structure (e.g. heart)
5. Organ Systems - multiple organs together (digestive system)
6. The Body

A generic cell - what you need to know for this course...



Nucleus - “The Brains of the Cell”

- Nucleus: contains genetic material, as strands of DNA proteins

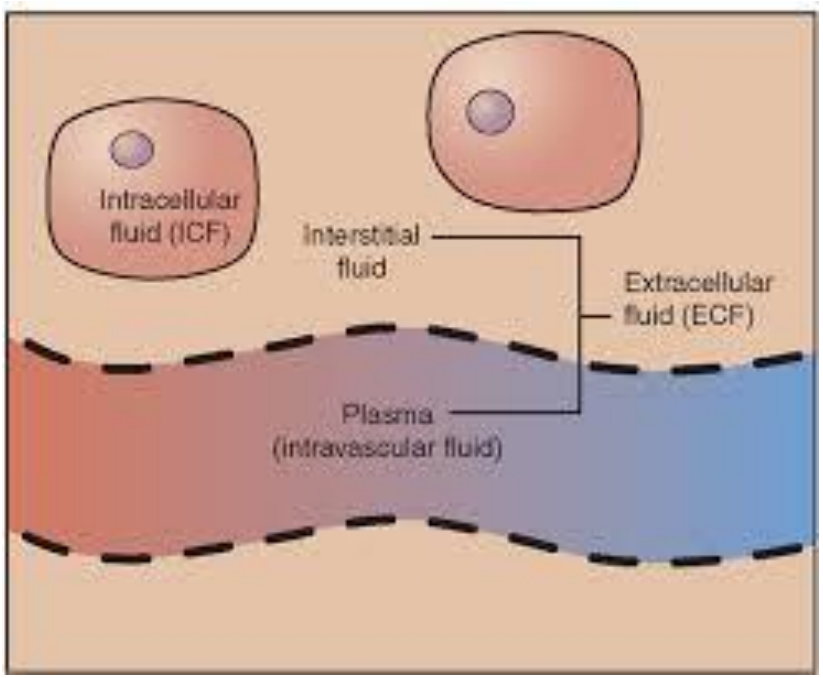


Extracellular Fluid (ECF)

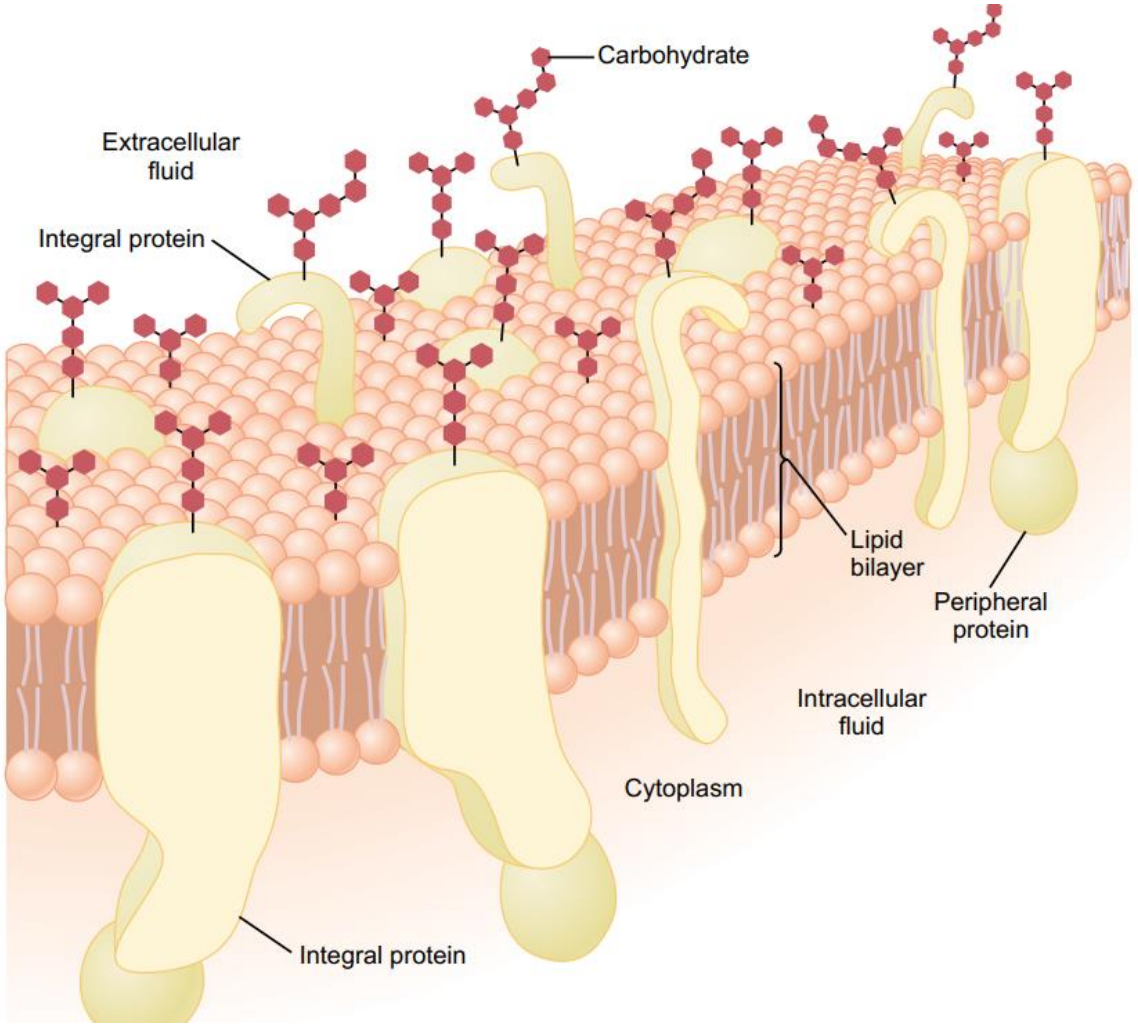
- Contains ions and nutrients required to sustain cell life.
- Mainly sodium, chloride and bicarbonate ions.
- Also contains oxygen, glucose, fatty acids, waste products.

Intracellular Fluid (ICF)

- Fluid enclosed by cell membrane.
- Contains Potassium, magnesium, phosphate ions.



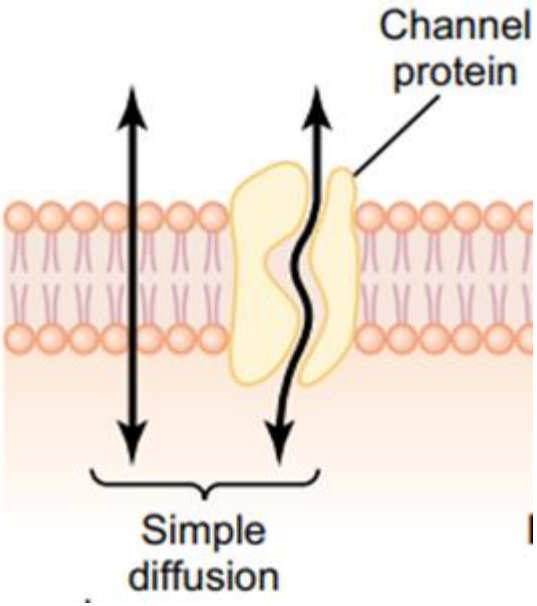
The cell membrane



- Cell membrane: 7.5-10nm thick.
- Made of proteins and lipids.
- Impedes water penetration, but fat soluble substances can pass through.

The cell membrane

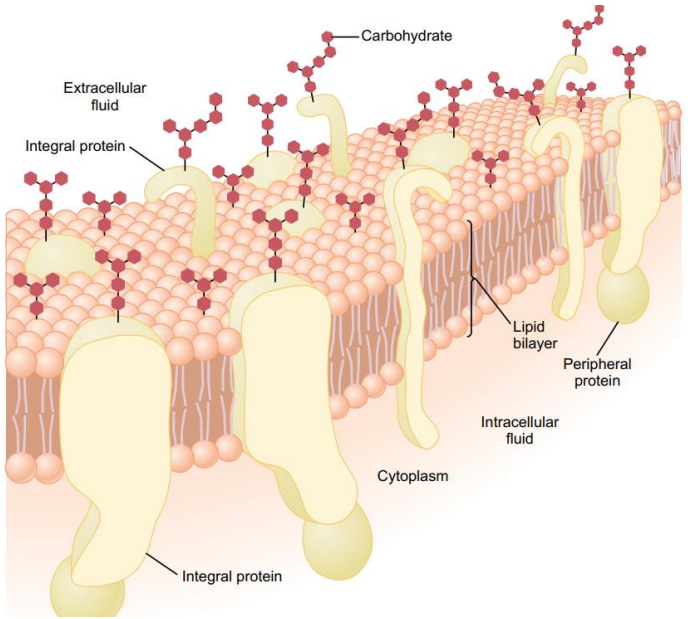
- Biphasic phospholipid
- Impermeable to water
- Permeable to lipids.
- Ionic Channels



Cells - Take home messages

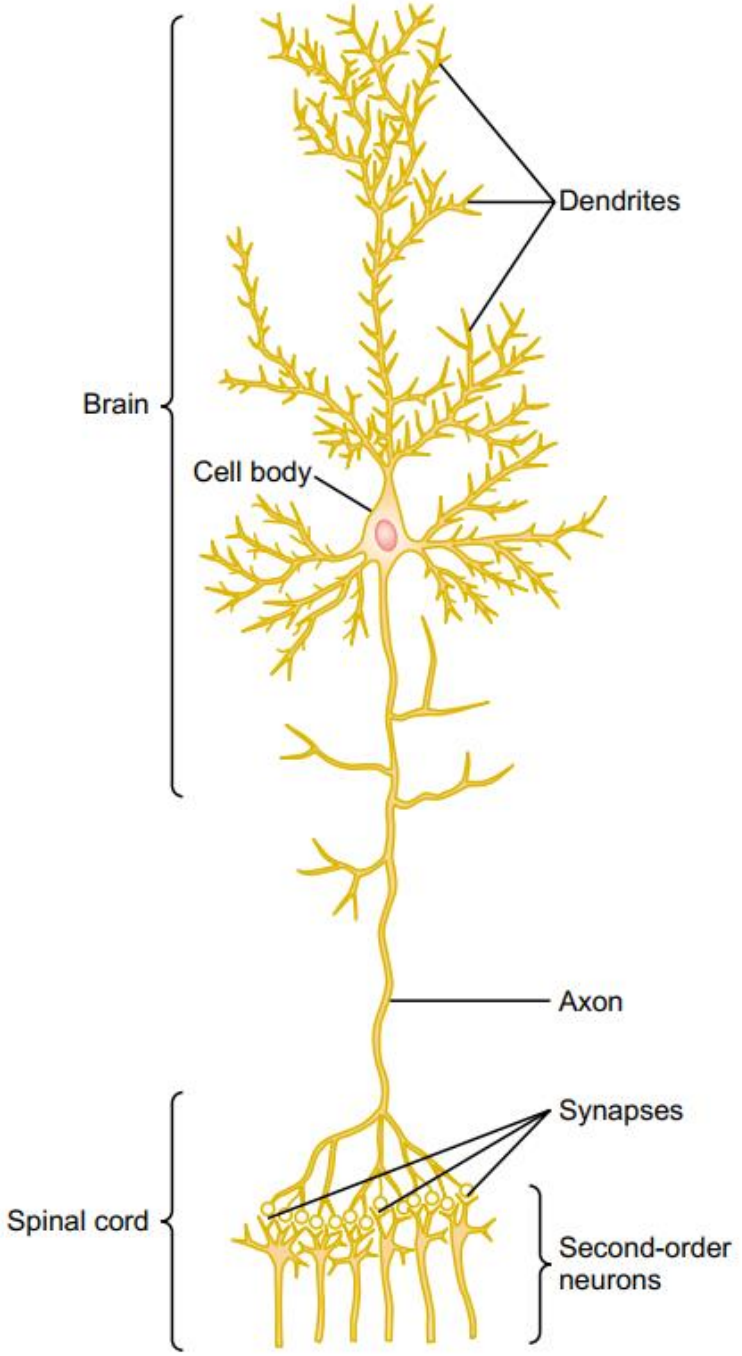
- Cells are the building blocks of life. Smallest unit of life.
- ECF and ICF: life-sustaining fluid.
- There are differences in components of these.
- ECF and ICF are separated by the cell membrane
- Membrane is impermeable to water. But fat-soluble molecules can pass through easily.
- Ionic channels in membrane allow ions to move in and out.

TEST YOUR KNOWLEDGE



The Nerve Cell - Neuron

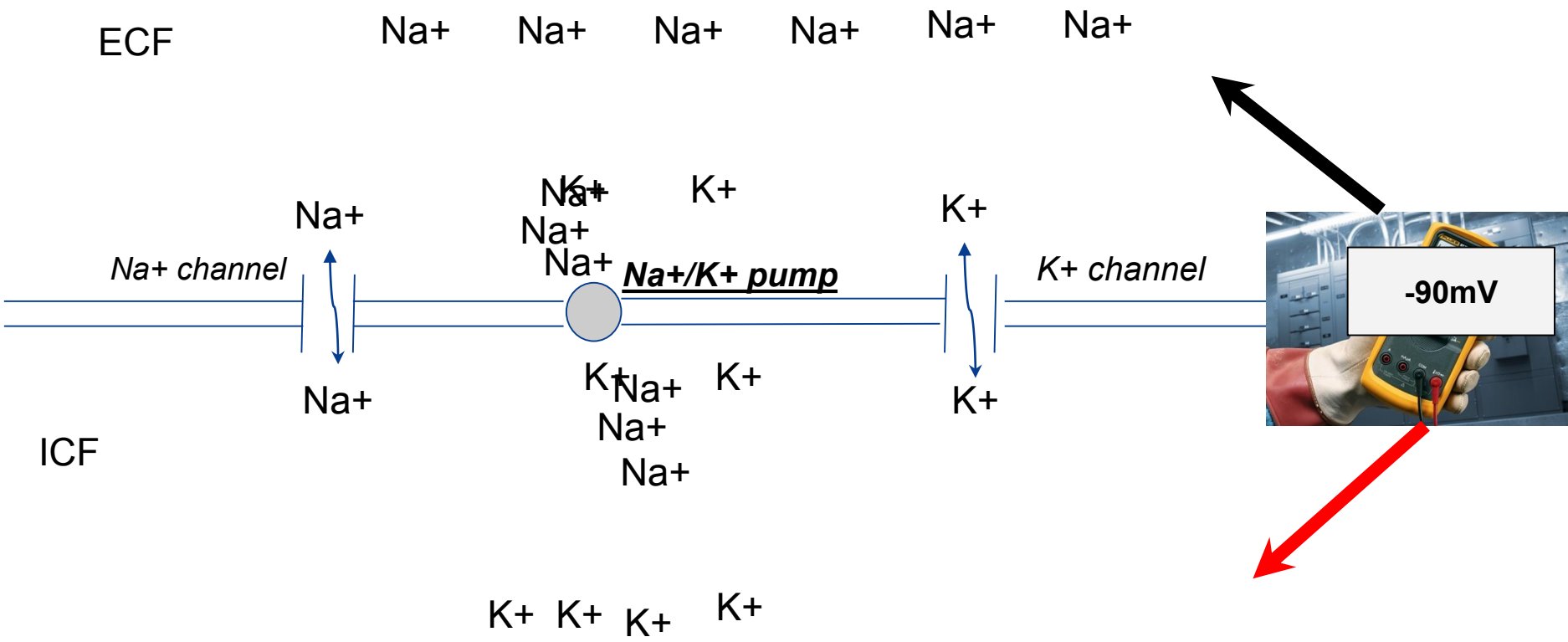
- Cell Body: Soma
- Dendrites: Receiving ports
- Axon: many times length of cell body, connects to other nerves at synapses.
- Nerves communicate by sending “buzzes” or “blips” of electricity along them, to other nerves.
- Let’s look at how this electricity is formed in the cell.



Electronics 101

- Current: Flow of electrons along a conductive medium
- Voltage: Energy due to potential difference between charge.
- Resistance: Resistance to current.
- Demonstration

Cell Membrane of Neurons



At rest, nerve cell is like a battery!

Separation of charge

Creates a potential source of energy

Voltage!

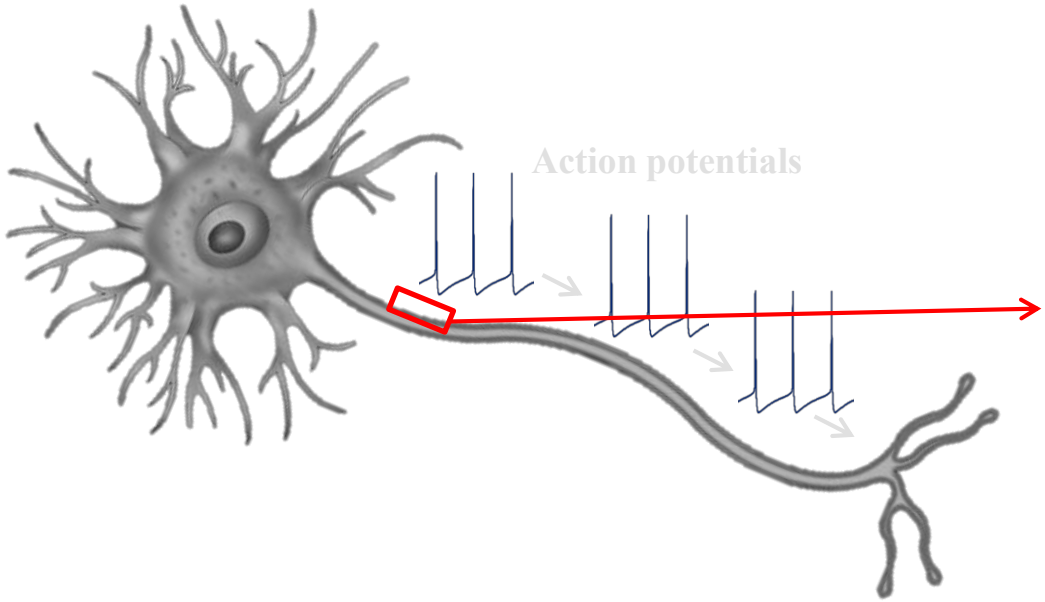
Neurons: Summary

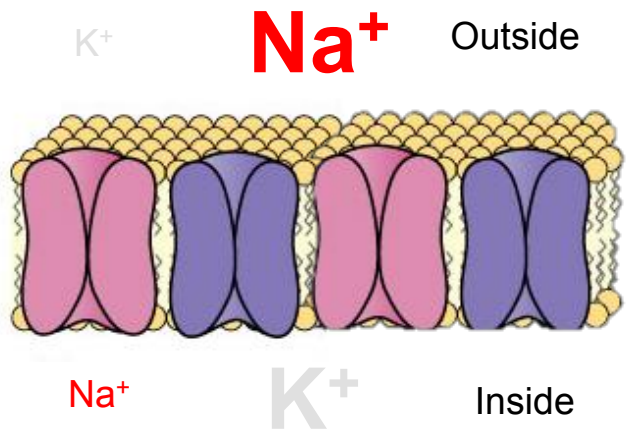
- At rest, electrical potential difference between ECF and ICF - across cell membrane
- Called resting membrane potential = -90mV.
- Cell membrane is impermeable to water soluble molecules and ions
- Channels allow movement of ions in and out.
- Sodium Potassium pump: Helps keep resting membrane potential at -90mV

TEST YOUR KNOWLEDGE

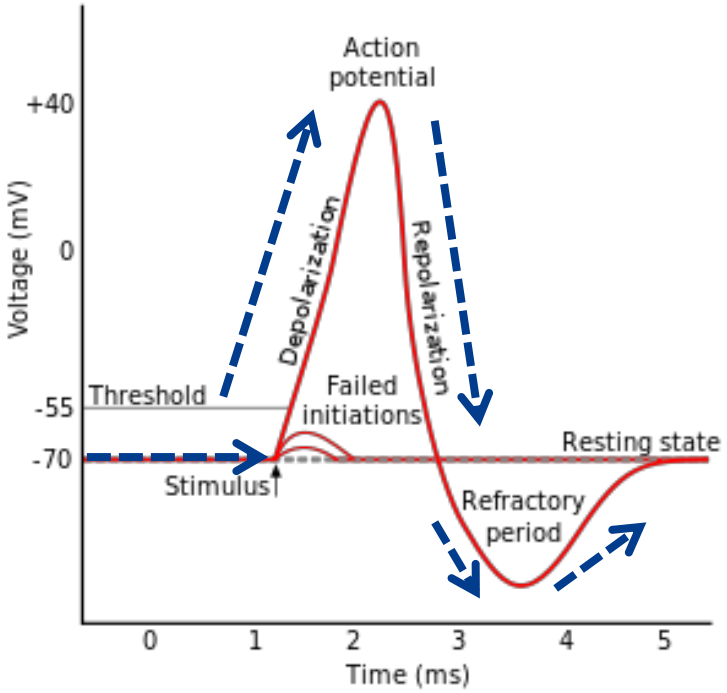
What is action potential ?

- An **action potential** (also known as a nerve impulse or spike) is a pulse-like wave of voltage that travels along excitable cell membranes.





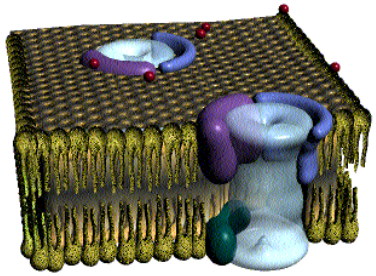
What is action potential ?

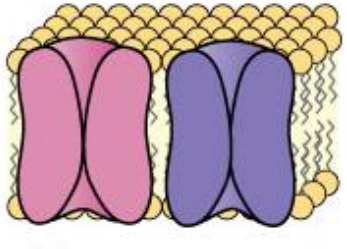


1991.

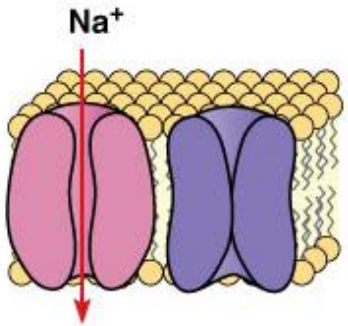
The function of single ion channels in cells

Erwin Neher and Bert Sakmann

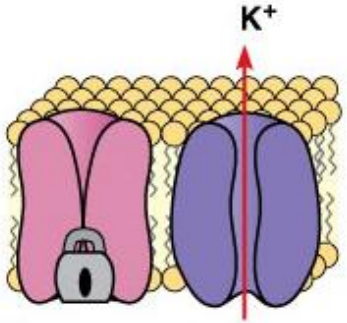




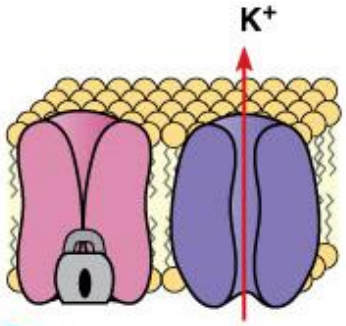
1. Resting state: all voltage-gated Na^+ and K^+ channels closed.



2. Depolarization: Na^+ channels open. An action potential begins when the neuron is depolarized to its threshold potential.

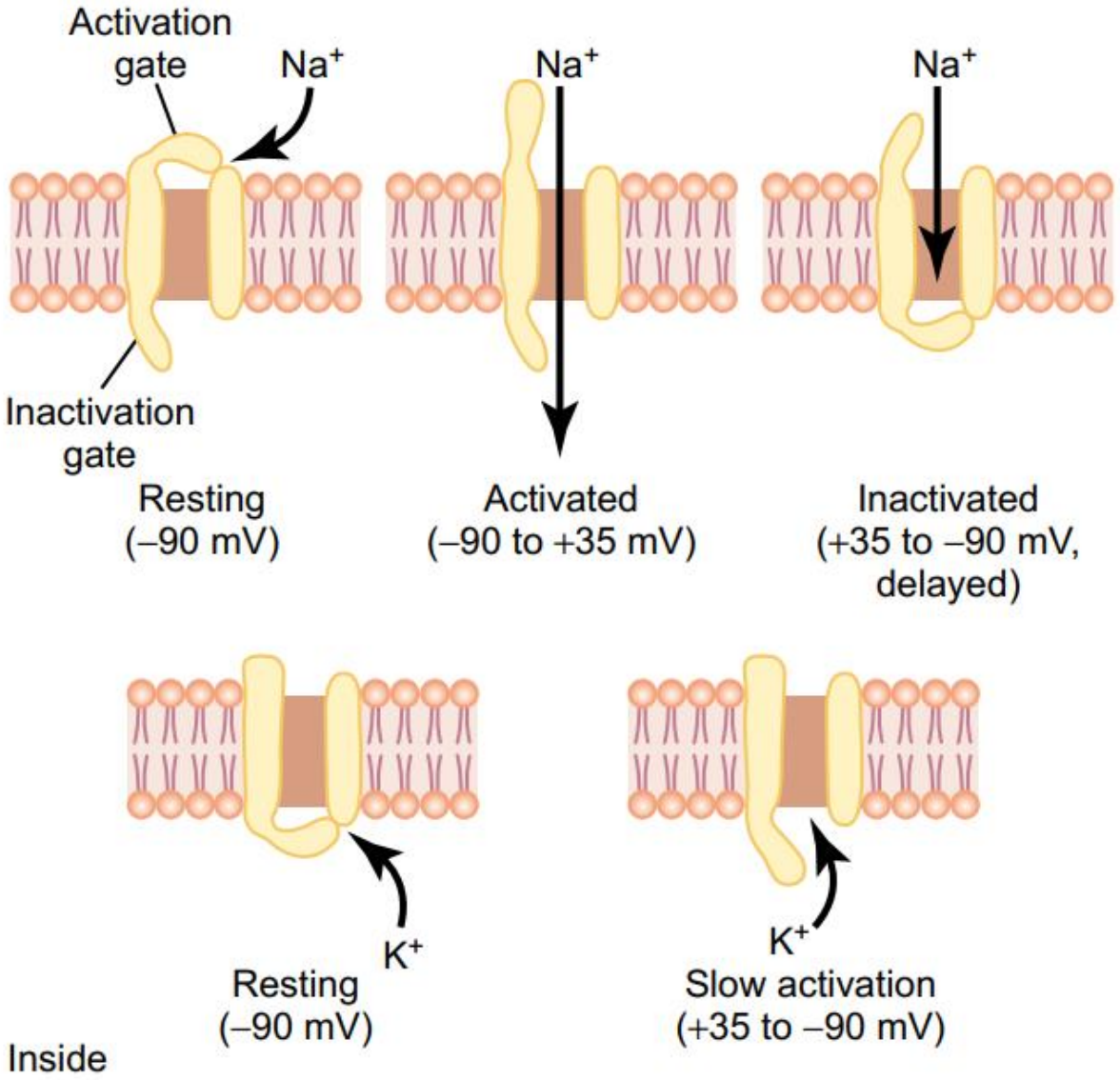


3. Repolarization: Once the cell reaches its peak positive potential, Na^+ channels inactivated and K^+ channels open. The cell repolarizes to a negative membrane potential

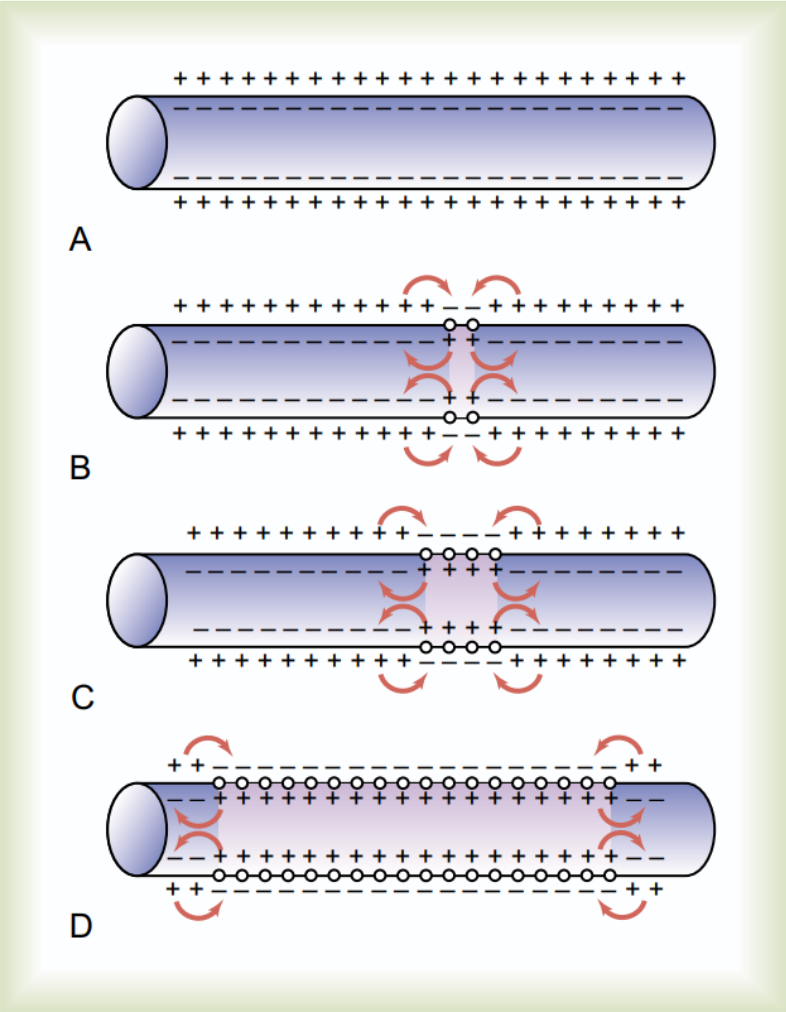


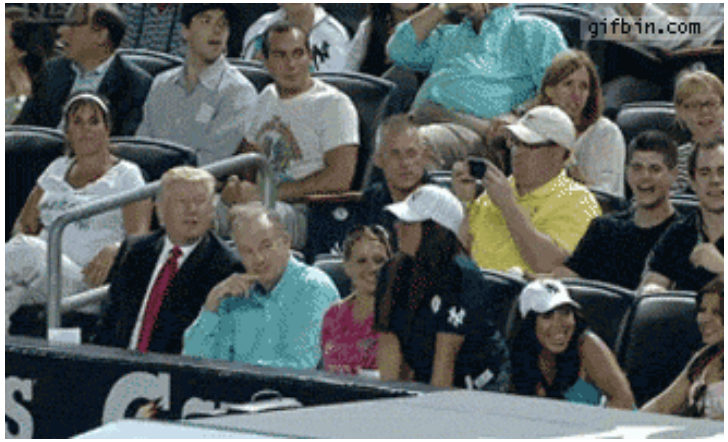
4. Hyperpolarization: K^+ channels remain open and Na^+ channels inactivated. The membrane potential becomes more negative than the resting potential

Action potentials - another schematic



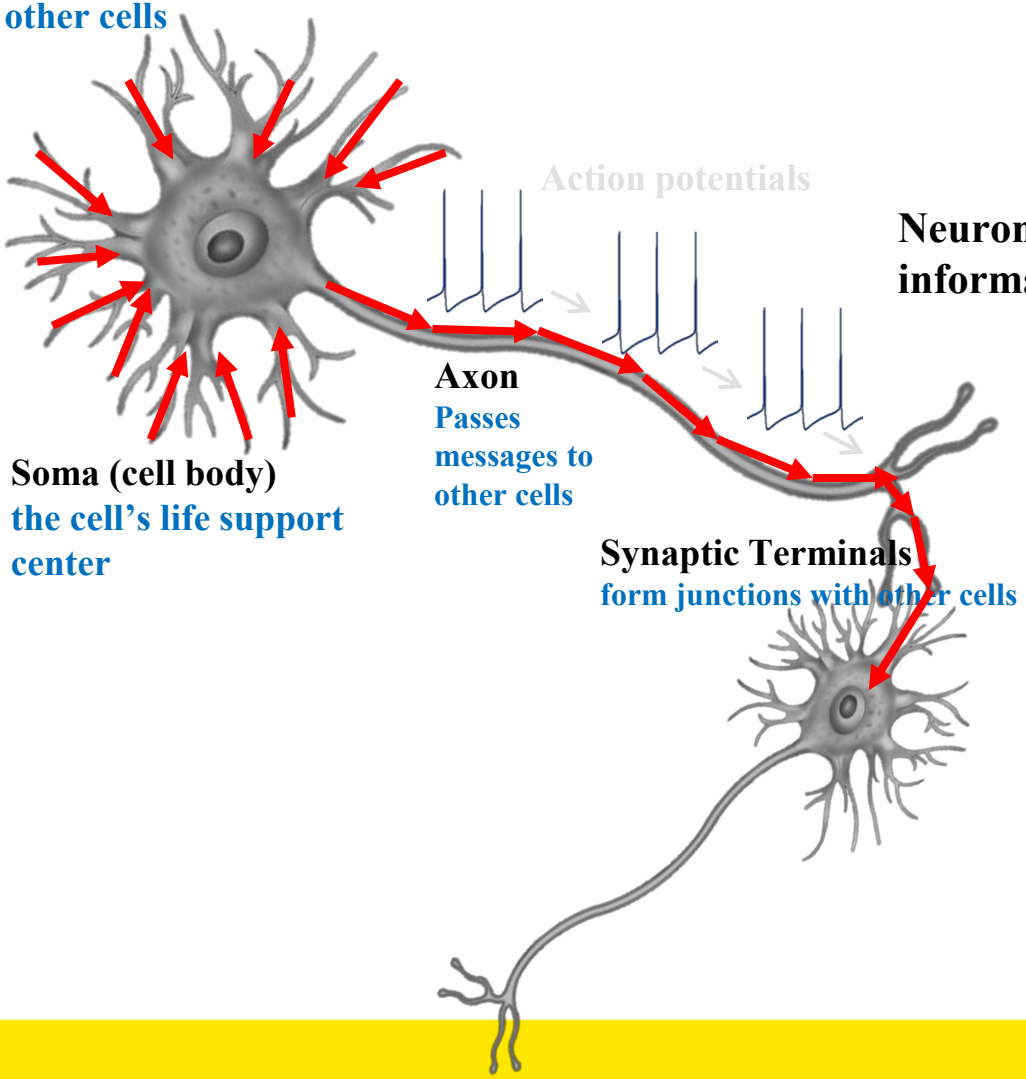
Propagation of Action Potentials

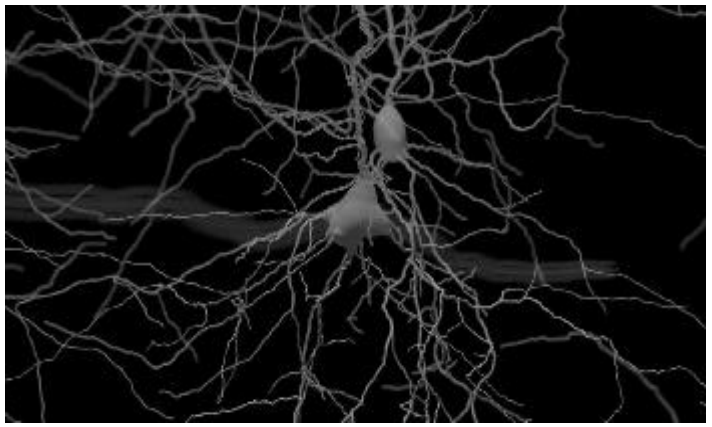




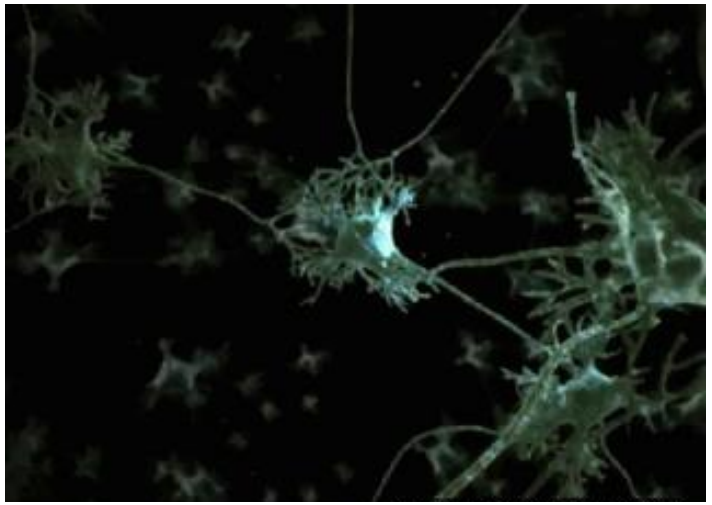
Propagation of AP

Dendrites
receive messages from other cells





Neurons are electrically excitable cells processes information through electrical and chemical signals.

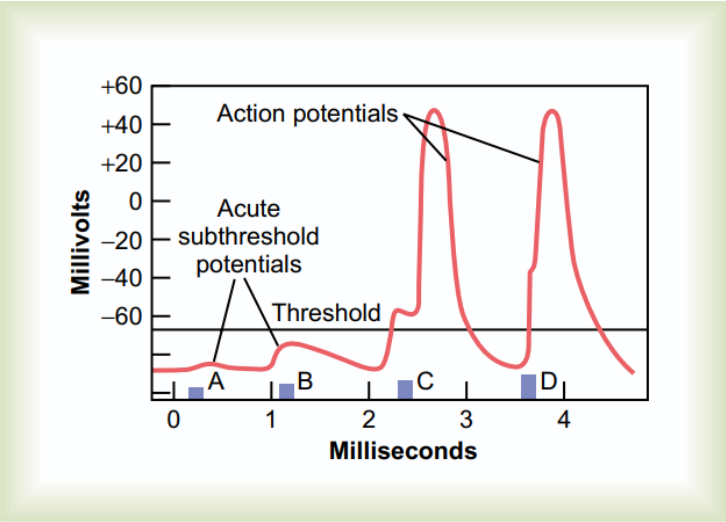


Neurons communicate with each other through their dendrites and axon.

Excitation: Initialisation on action potential

Any factor that allows Na+ to inflow into the cell. Mechanical disturbance, chemical effects, or the passage of electricity through membrane.

- Mechanical: Sensory receptors on skin
- Chemical: neurotransmitters to transmit signals between neurons
- Electrical: current between heart muscle cells and smooth muscle cell



Refractory Period

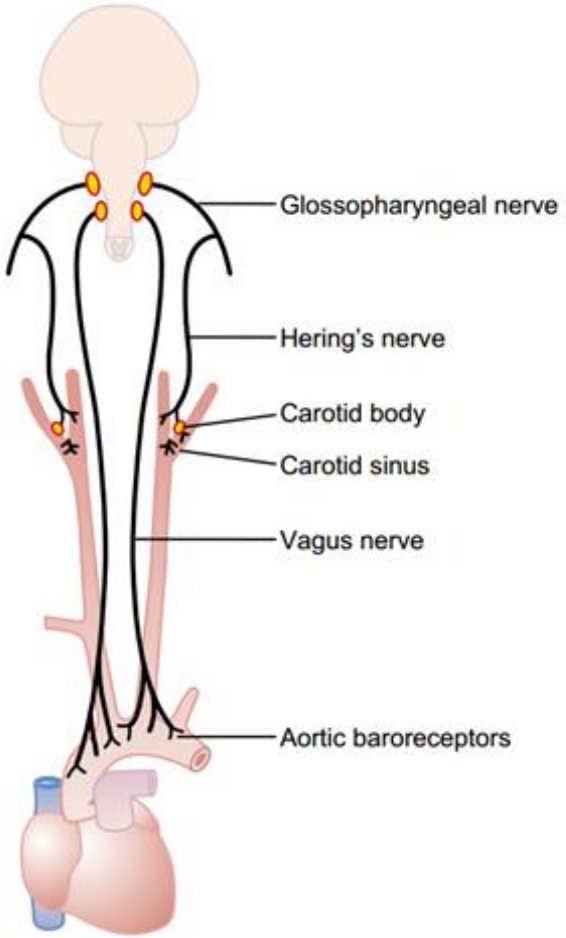
- A new action potential cannot occur in an excitable fibre as long as the membrane is still depolarized from previous action potential.
- The Na (or Ca) channels become inactivated after an action potential, and no amount of stimulus can reactivate them.
- The MP must return to the resting potential to open these inactivation gates.
- Period is about 1/2500 of a second.

WHY?

- Ensures one way traffic along a nerve.
- action potential travel away from the source of stimulation.
- If the stimulus starts at one end, it will be forced to propagate along to the axon in one direction
- cannot re-excite the area it was just present in.

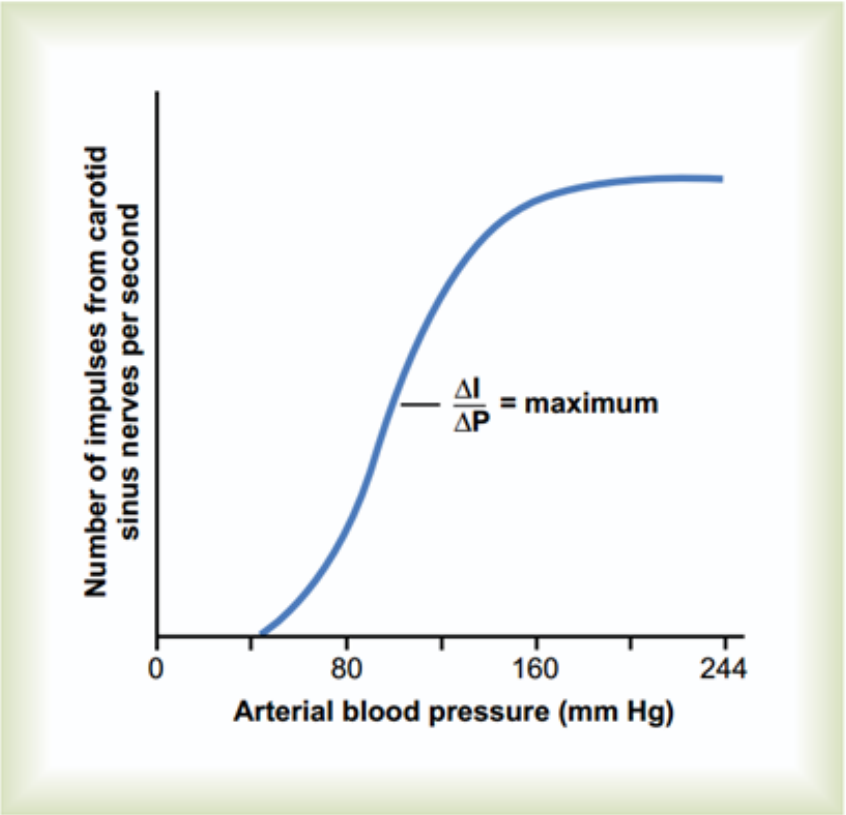
Communication using Action Potentials

- Action potential: Same voltage change, same time it takes for channels to open.
- How can we send different signals, to communicate different things?
- Frequency!



Communication using Action Potentials

- Action potential: Same voltage change, same time it takes for channels to open.
- How can we send different signals, to communicate different things?
- Frequency!

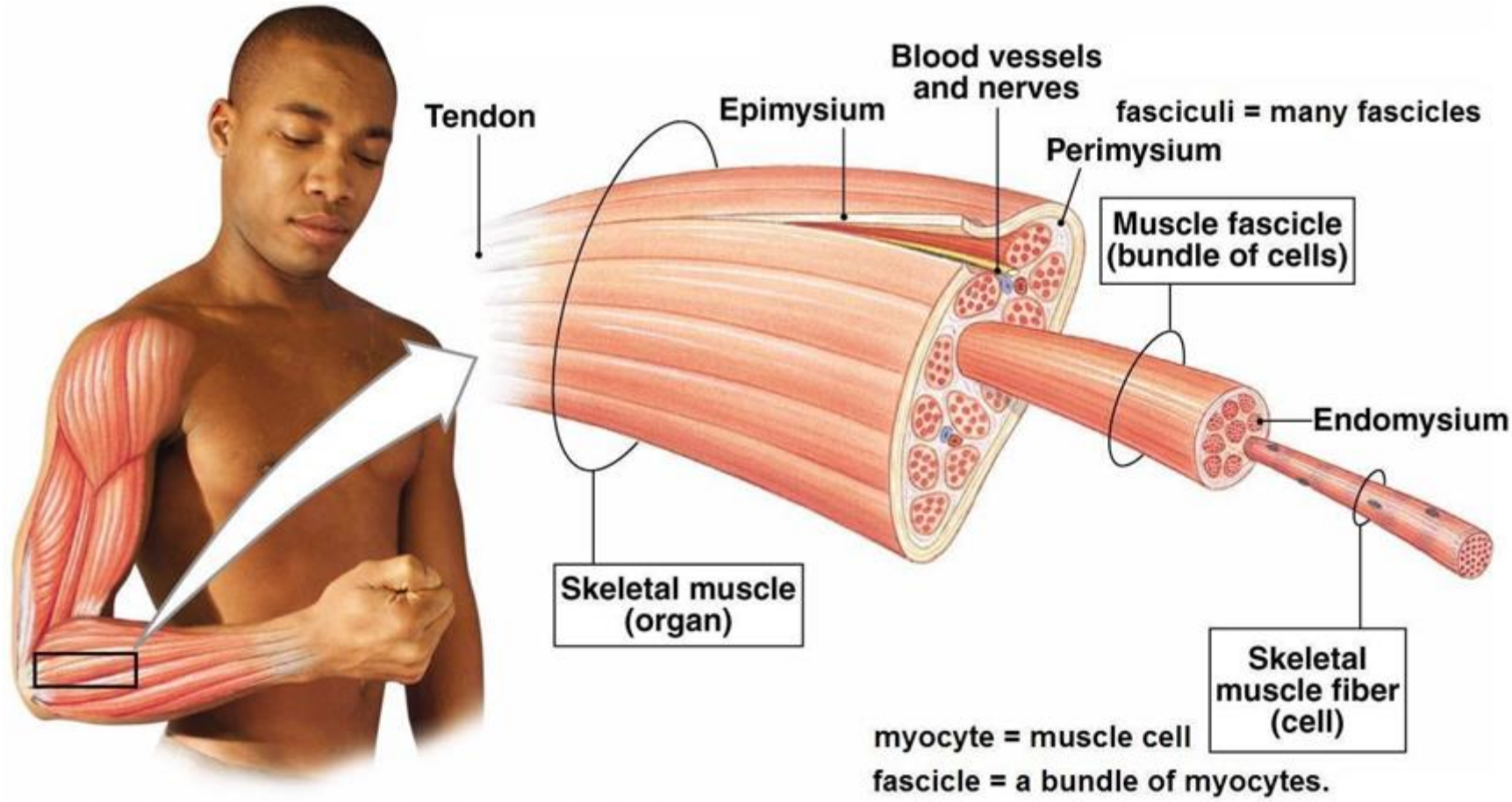


Summary of Action Potentials

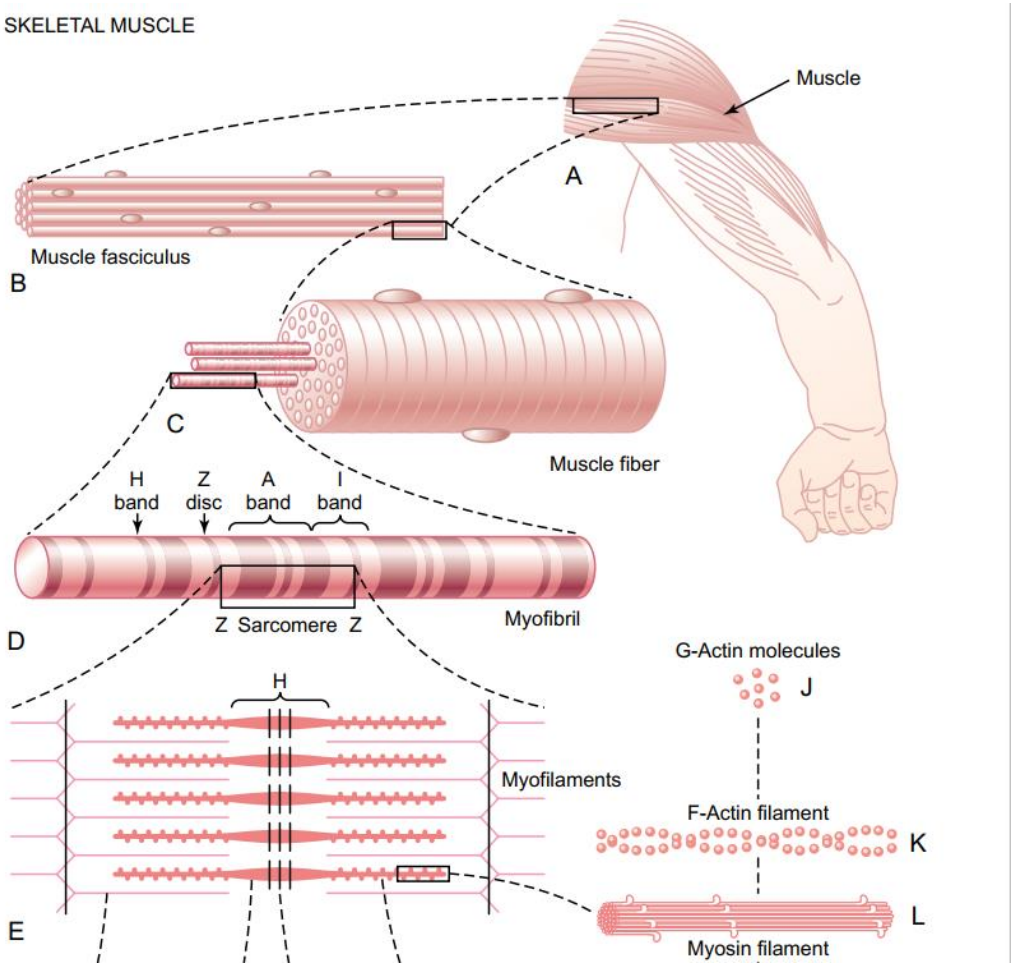
- Signals are sent along nerves as action potentials.
- Action potentials propagate quickly along nerves
- They are a feed-forward system - an action potential in one area can cause an action potential in an adjacent area
- They are all-or-nothing: if it's interrupted, then it stops.
- Action potentials are usually the same voltage and duration.
- The brain process incoming action potentials and looks at frequency of the incoming pulses

TEST YOUR KNOWLEDGE

Muscle Anatomy



Muscle Anatomy



General Mechanism of Muscle Contraction

1. **Action potential travels along motor nerve to ending on muscle fibres**
2. Neurotransmitter, acetylcholine (ACTY), secreted by nerve
3. ACTY acts on local area of muscle fibre membrane, opens multiple ACTY gated channels
4. Na+ ions rush through into the muscle fiber, initiating an action potential at this point along the membrane
5. Action potential travels along muscle fiber membrane in same way as nerves.
6. AP depolarises entire muscle membrane, **action potential electricity flows through centre of muscle. Releases Ca+ ions**
7. Ca+ ions initiate attractive forces between actin and myosin filaments, causing them to slide along one another
8. Ca+ ions pumped back into sarcoplasmic reticulum, stored here till the next contraction.

Electricity in muscles

6. AP depolarises entire muscle membrane, **action potential electricity flows through centre of muscle. Releases Ca+ ions**

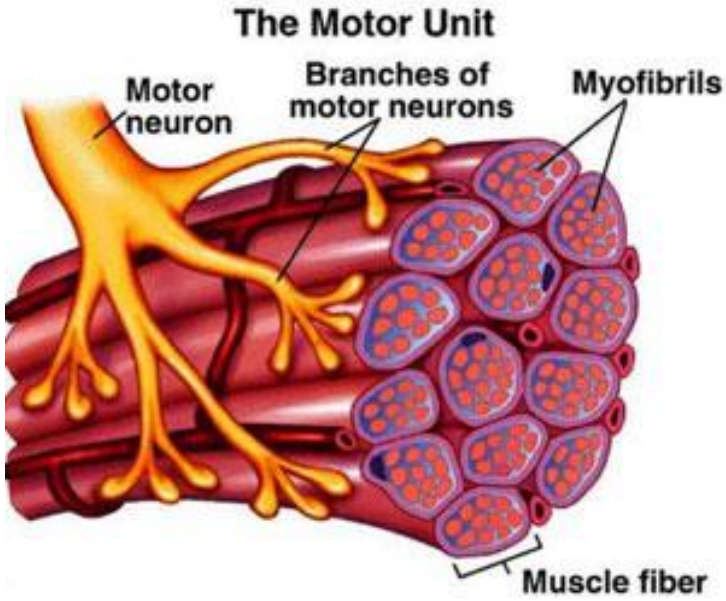
This electricity is what we are measuring during the EMG.

Motor Units

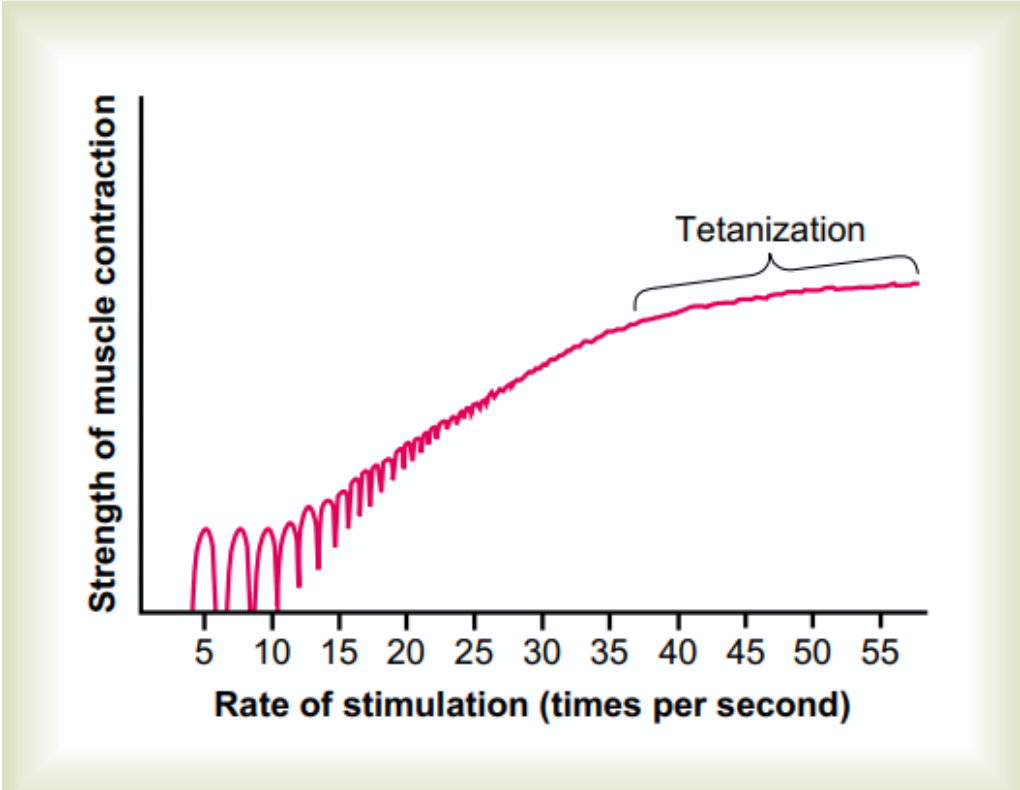
All muscle fibers innervated by a single nerve

Small fast-reacting muscles, or muscles that require fine control - have very small muscle-nerve ratio (2 or 3 muscles per motor unit in laryngeal muscles).

Large muscles may have several hundred fibers per unit.



Summation of Forces - Frequency Summation



Summary - what have we learnt today?

CELLS

NERVE CELLS

RESTING MEMBRANE POTENTIAL

ACTION POTENTIAL PROPAGATION

ACTION POTENTIALS

MUSCLE CELLS

MUSCLE CELL CONTRACTION

Next Week

- Design Lecture (Mon 2-4 CLB 7): Concept Generation
- Technical Stream Lecture (Thurs 2-4 Red Centre M032): Function of the hand, Electromyography in Reality
- Mentor Sessions: Problem Statement Presentation

References

A. C. Guyton, Textbook of Medical Physiology. London: W.B. Saunders, 1971.

More information

Introduction to Anatomy and Physiology - YouTube Lecture series

https://www.youtube.com/watch?v=uBGl2BujkPQ&list=PL8dPuuaLjXtOAKed_MxxWBNaPno5h3Zs8

Check out Lecture 9 for Action Potentials and 21 for Skeletal Muscle Contraction