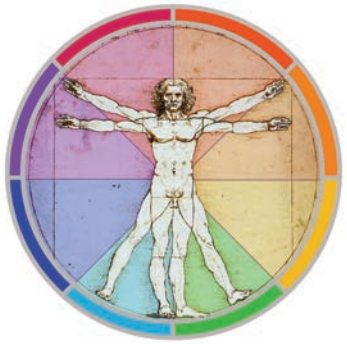
HUBS191 Lecture Material

This pre-lecture material is to help you prepare for the lecture and to assist your note-taking within the lecture,

it is NOT a substitute for the lecture !



Please note that although every effort is made to ensure this pre-lecture material corresponds to the live-lecture there may be differences / additions.

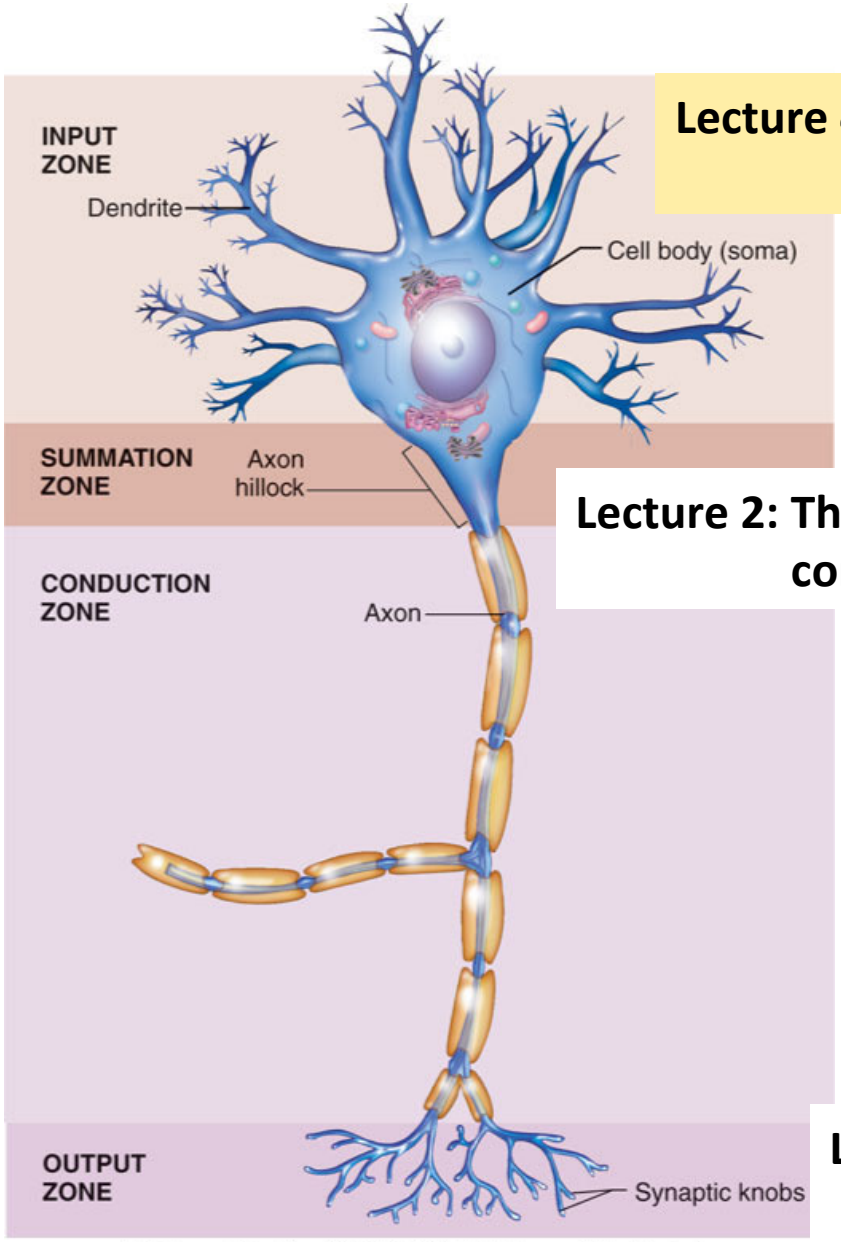
Physiological Principles of
Human Movement and Sensation

HUBS191

Lecture 24

Dr Martin Fronius
Department of Physiology
7. April 2017

Aims of Today's Lecture



Lecture 4: Synaptic Networks and Integration (input zone)

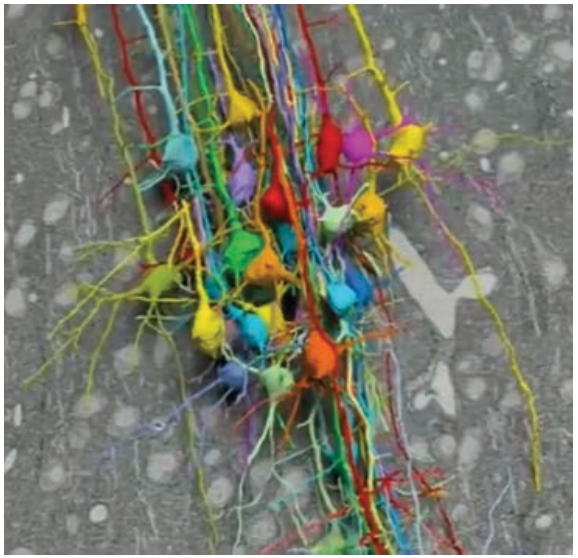
Lecture 2: The Action Potential and its conduction (axon hillock, axon)

Lecture 1: Bioelectricity and membrane potentials

Lecture 3: The Synapse – 'connecting' neurons (output zone)

Aims of Today's Lecture

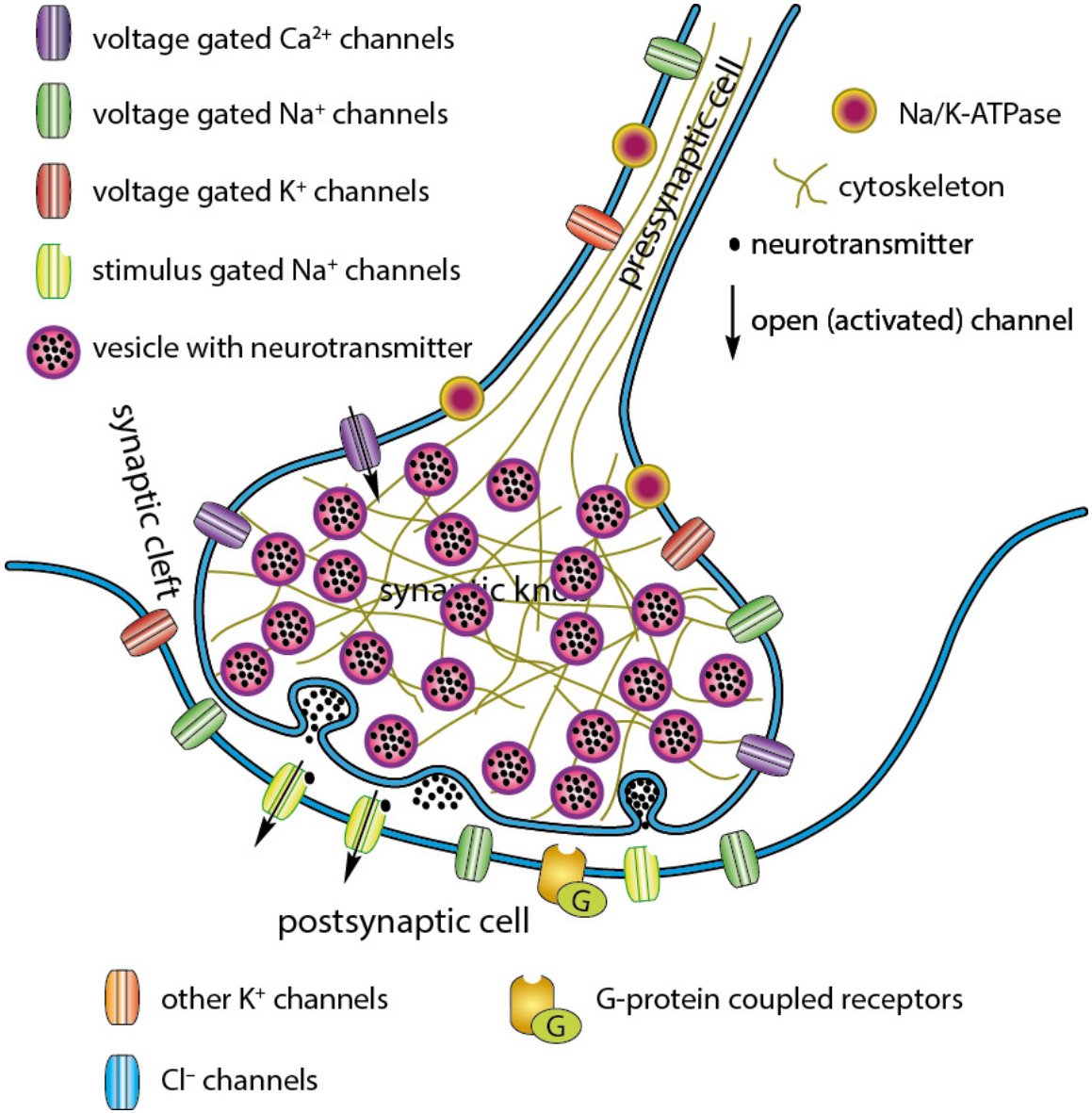
Lecture 24 – Synaptic Networks and Integration



Outline

- Recap from Lecture 24
- Excitatory and Inhibitory Transmitters and Synapses
- Synaptic Integration – Types of Summation (spatial and temporal)
- Types of neuronal network (Divergence, Convergence)

The chemical synapse



1. Presynaptic cell 'output zone'
2. Synaptic knob
3. Synaptic cleft 'the gap'
4. Postsynaptic cell 'input zone'
5. Voltage-gated Ca^{2+} channels
6. Vesicles
7. Cytoskeleton
8. Na/K-ATPAse
9. Mitochondria (not shown)

The process of synaptic transmission – form and function

1. Action potential propagates down the axon – to the pre-synaptic knob

2. Pre-synaptic knob is depolarised – voltage gated Ca^{2+} channels open

3. Ca^{2+} ions enter and TRIGGER the release of the neurotransmitter from the vesicles

4. Neurotransmitter is released INTO the synaptic cleft

5. Neurotransmitter diffuses across the cleft and binds to its SPECIFIC receptors (stimulus gated channels) on the POST SYNAPSE

6. If Na^{+} channels open – LOCAL depolarisation of post synaptic cell

7. Net depolarisation – called the

EXCITATORY POST SYNAPTIC POTENTIAL – or **EPSP**

7'. Net hyperpolarisation (opening of Cl^{-} or K^{+} channels) – called the

INHIBITORY POST SYNAPTIC POTENTIAL – or **IPSP**

HOW IS A SYNAPSE SWITCHED OFF ?

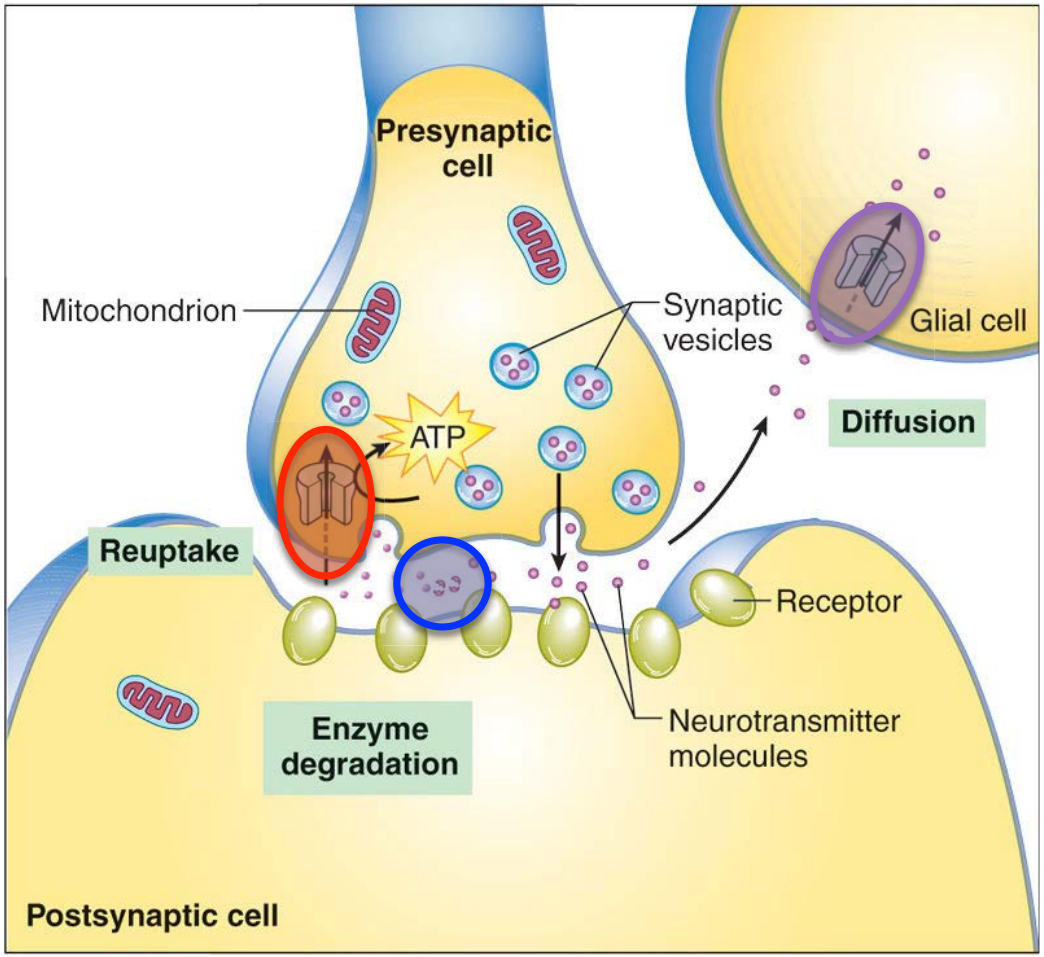


Fig. 13-26, Patton & Thibodeau, 8th Ed p. 402

→ Excess transmitter released into the cleft.

- Excess transmitter must be removed
  a. **Degradation** – by enzymes

  b. **Reuptake** into the knob

  c. Reuptake (diffusion) into **glia cells**

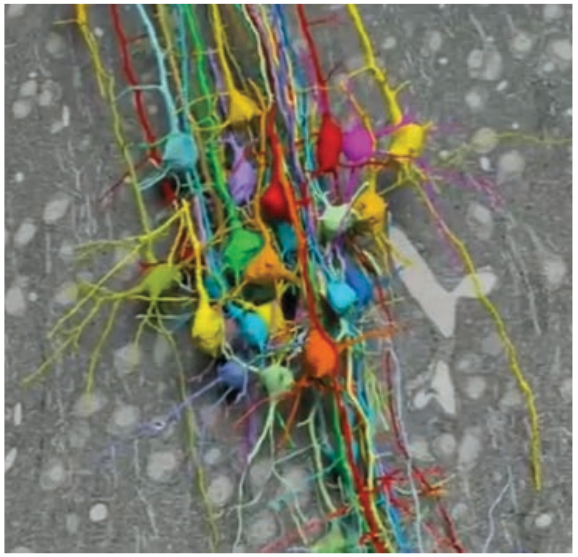
  (GLM3 – revisit)

- Removal requires ATP – energy
- Mitochondria in synaptic knob …

Glia – the supporting cells – and revisit p. 384 T&P 8th Ed.

Aims of Today's Lecture

Lecture 24 – Synaptic Network



http://www.nature.com/news/

Outline

- Recap from Lecture 24
- Excitatory and Inhibitory Transmitters and Synapses
- Synaptic Integration – Types of Summation (spatial and temporal)
- Types of neuronal network (Divergence, Convergence)

Objectives

- List the main types of neurotransmitter and name some examples
- Explain the different types of synaptic integration
- Know the two types of synaptic network and explain their different advantages

Types of Neurotransmitters

<u>Some Neurotransmitters:</u>

- Acetylcholine (**EPSP**)
- Glutamate (**EPSP**)
- GABA (**IPSP**)
- Norepinephrine /Noradrenaline
- Dopamine
- Serotonin

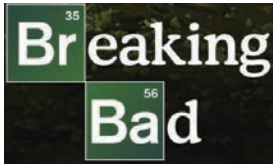
See p. 407 P&T 8th Ed

A classical neurotransmitter is released from vesicles from within the presynaptic knob in response to Ca^{2+} influx

Drugs of abuse & neurotransmitter

from google.com

Drugs of abuse & neurotransmitter



- Methamphetamine – P
  aka as ‘crystal meth’ or ‘speed’
- Increases levels of
  → noradrenaline,
  → dopamine,
  → serotonin
- Blocks **reuptake**

Pervitin tablet container
used in WW2 (en.wikipedia.org)

Obetrol: diet pill in the 1959/60
in America

Stimulates fight, flight, fright response

Acts in reward centres → **highly addictive**

Highly Neurotoxic!!!

Image from http://www.webinfo-net.com

Drugs of abuse & neurotransmitter

Almost all drugs target (highjack) endogenous neurotransmitter systems!

- Nicotine → nicotinic acetylcholine receptors (in the brain)
- Heroin → opioid receptors (endogenous endorphins peptides)
- Tetrahydrocannabinol → Cannabioid receptors (brain)

Types of Neurotransmitters

EXCITATORY – cause DEpolarisation

- Acetylcholine – neuromuscular junction & brain,
  → activates stimulus-gated Na^+ channels (ionotropic receptors)

- Glutamate – most common excitatory neurotransmitter in CNS
  → activates stimulus-gated Na^+ channels
  → activates stimulus gated Ca^{2+} channels

EXCITATORY POST SYNAPTIC POTENTIALS - EPSPs

…due to the inflow of positive charged ions (Na^+ and Ca^{2+})!

Types of Neurotransmitters II

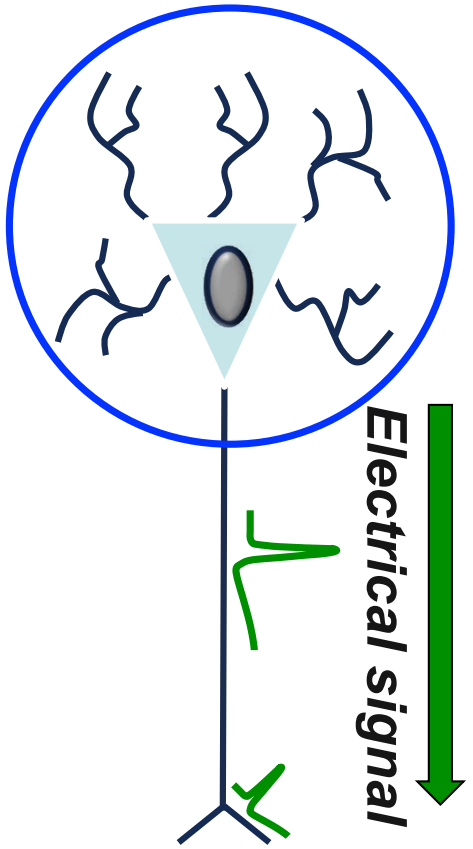
INHIBITORY – cause HYPERpolarisation

- GABA – gamma amino butyric acid,
  most common inhibitory neurotransmitter in brain.
  → activates Cl^- channels (ionotropic receptor)
  → activates K+ channels (metabotropic receptor)

INHIBITORY POST SYNAPTIC POTENTIALS - IPSPs

…due to the inflow of Cl^- or outflow of K^+!

Recap – Cells of the nervous system:
Neuron, basic structure



Input zone (dendrites)

Summation zone (axon hillock)

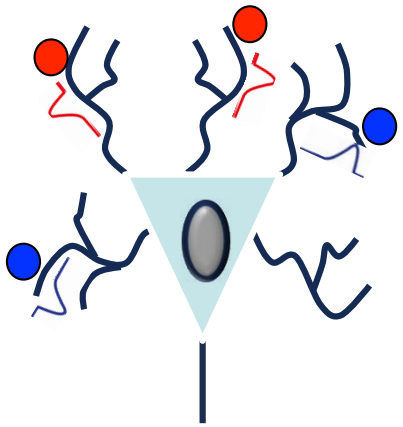
Conduction zone (axon)

Output zone (synapse)

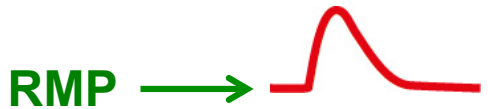
See also: Patton & Thibodeau 8th ed Fig 13-5 (7th ed Fig 12-5)

REMEMBER --- From A/Prof Jasoni's Lecture

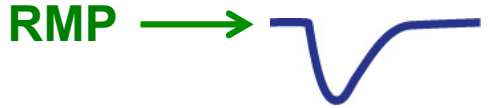
Input zone – electrical signals in the postsynaptic neuron are EPSPs or IPSPs



- **Exicatory synapse**
  - → **excitatory neurotransmitter (presynaptic)**
  - → **a lot of Na^+ channels (postsynaptic)**
  - → **local depolarisation**
  - → **EPSP**

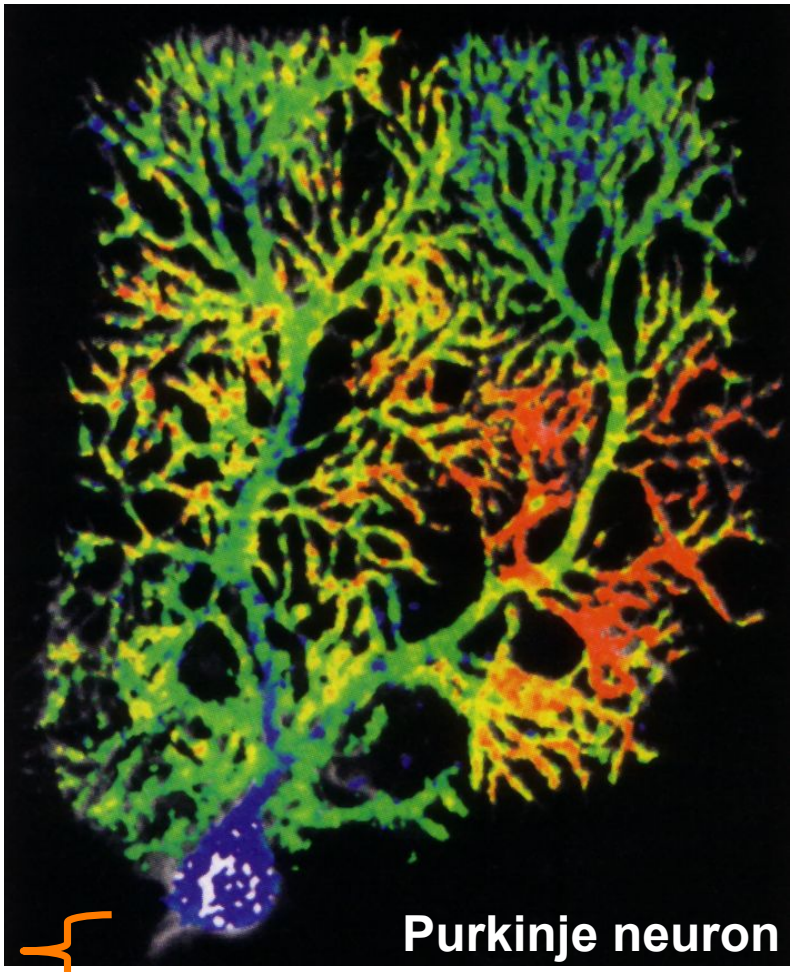


- **Inhibitory synapse**
  - → **inhibitory neurotransmitter (presynaptic)**
  - → **Cl^- and K^+ channels (postsynaptic)**
  - → **local hyperpolarisation**
  - → **IPSP**



EPSPs and IPSPs are 'Local' potentials!
And are caused by stimulus gated channels!

Input Zone - Synaptic Summation



Input ZONE
DENDRITES

> 50,000 synapses per neuron

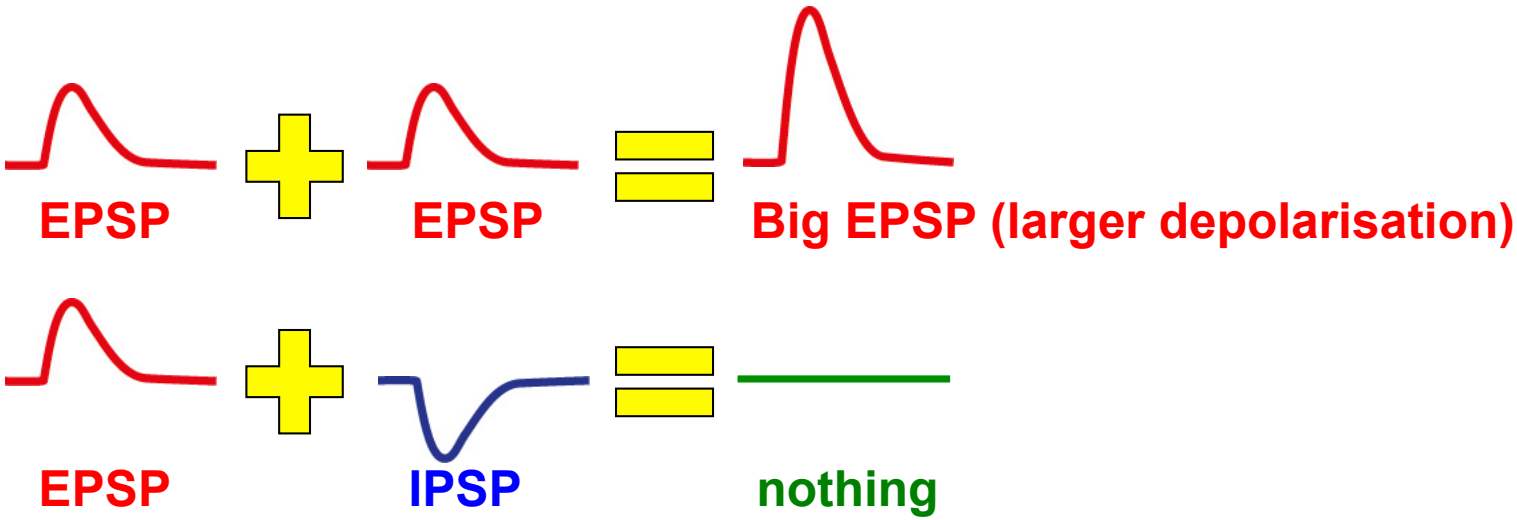
Humans
86,000,000,000 neurons!

ouput ZONE
AXON

Local Synaptic Potentials (EPSPs and IPSPs) ADD UP
– or SUMMATE within the Dendrites

Two types of summation

Basic concept of summation (simple math):



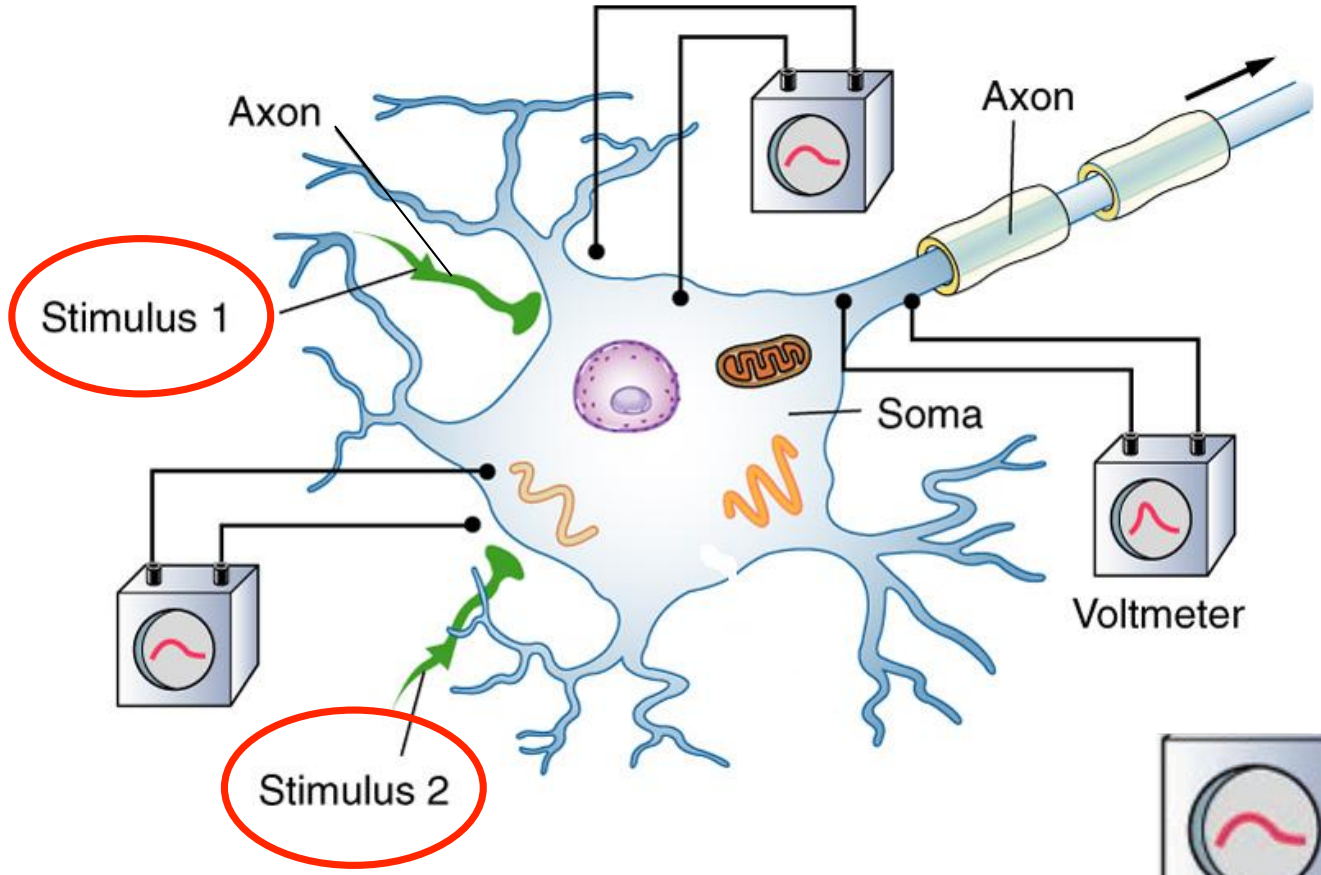
Spacial Summation

Spatial: latin – space, engl. space
Integration of inputs from different synaptic knobs (different localisation)

Temporal Summation

Time dependent – integration of inputs within a short time
at the same synaptic knob

Spatial Summation of synaptic inputs

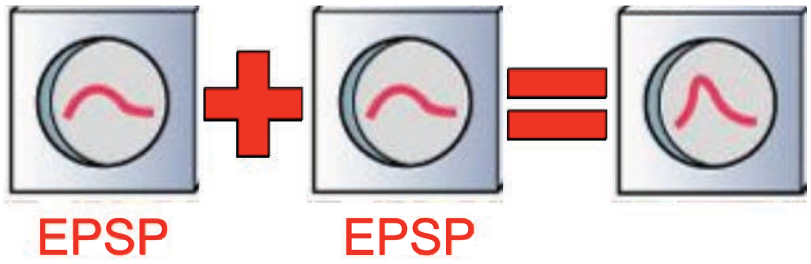


A Spatial Summation

Fig. 13-28, Patton & Thibodeau, p.403

Integration if input at AXON HILLOCK

→ "starting line for action potential"



Integration of inputs from different synaptic knobs
→ <u>different localisations</u> of the input zone

AP generated and transmitted when neuron is above threshold…

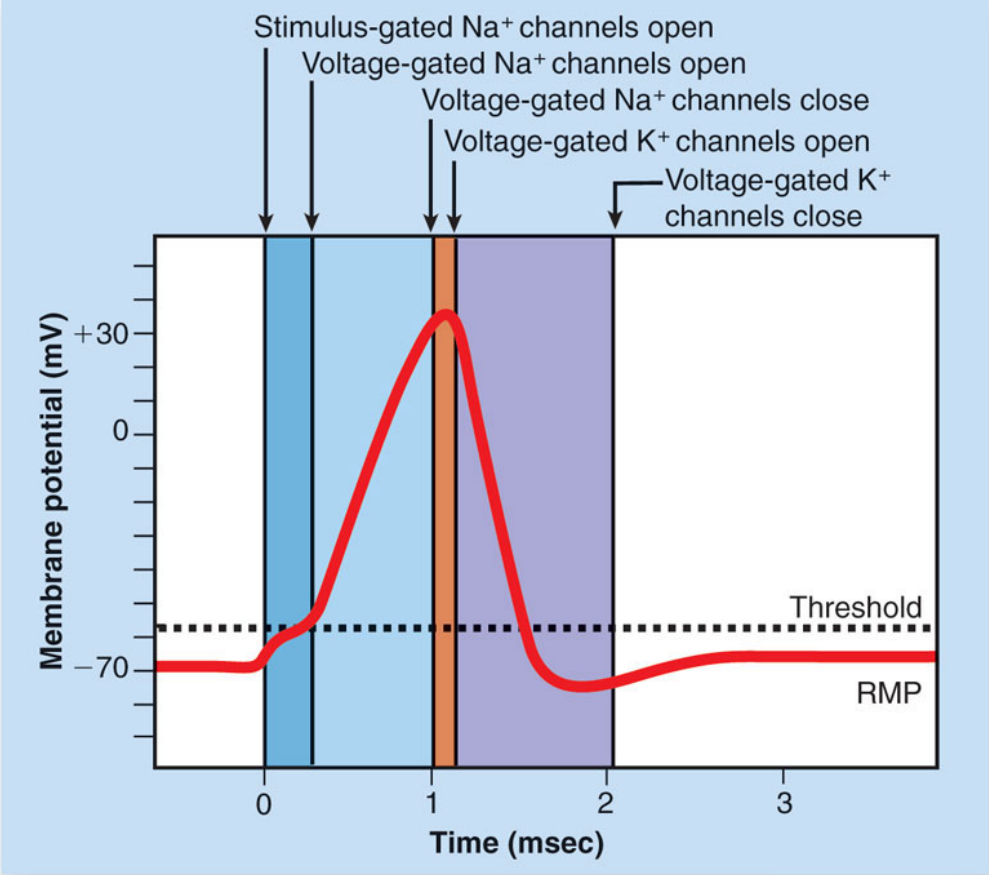


Fig. 13-19 Patton & Thibodeau, 8th Ed p.396

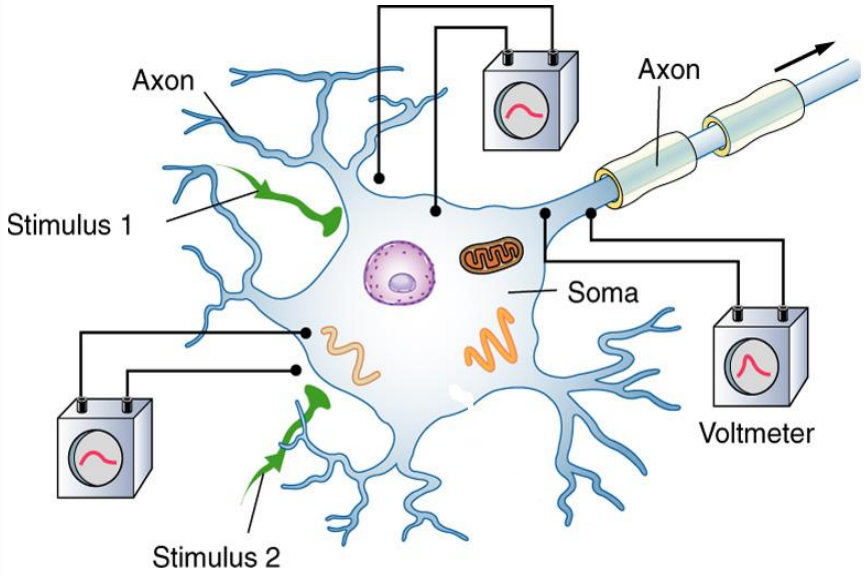
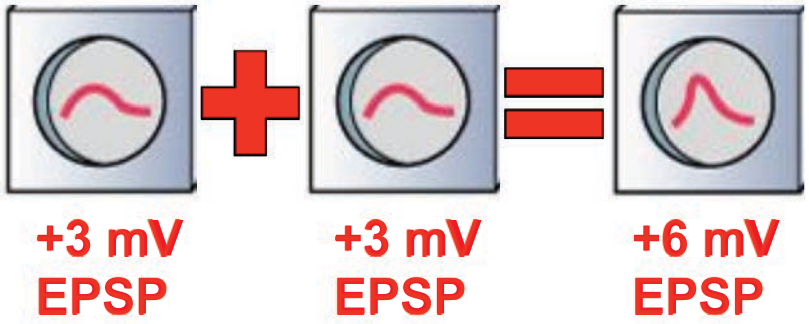
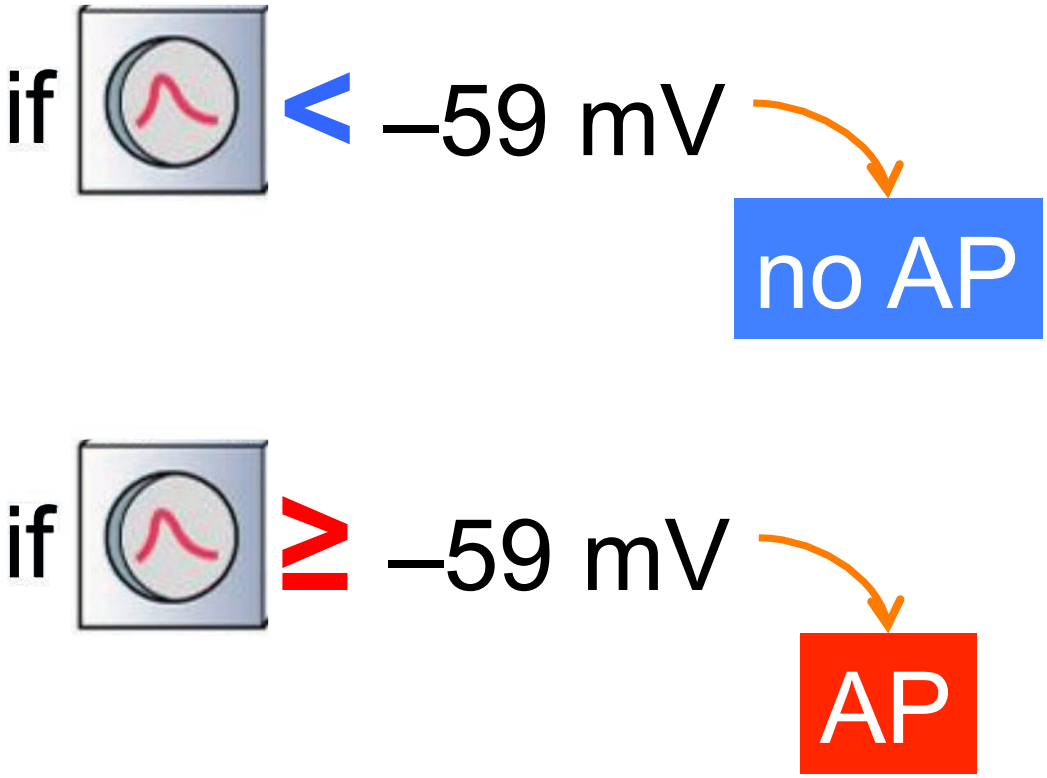


Fig. 13-28, Patton & Thibodeau, p.403

…at the AXON HILLOCK

Action potential (AP) transmitted when neuron is above threshold…





…at the AXON HILLOCK

Temporal Summation of Synaptic Inputs

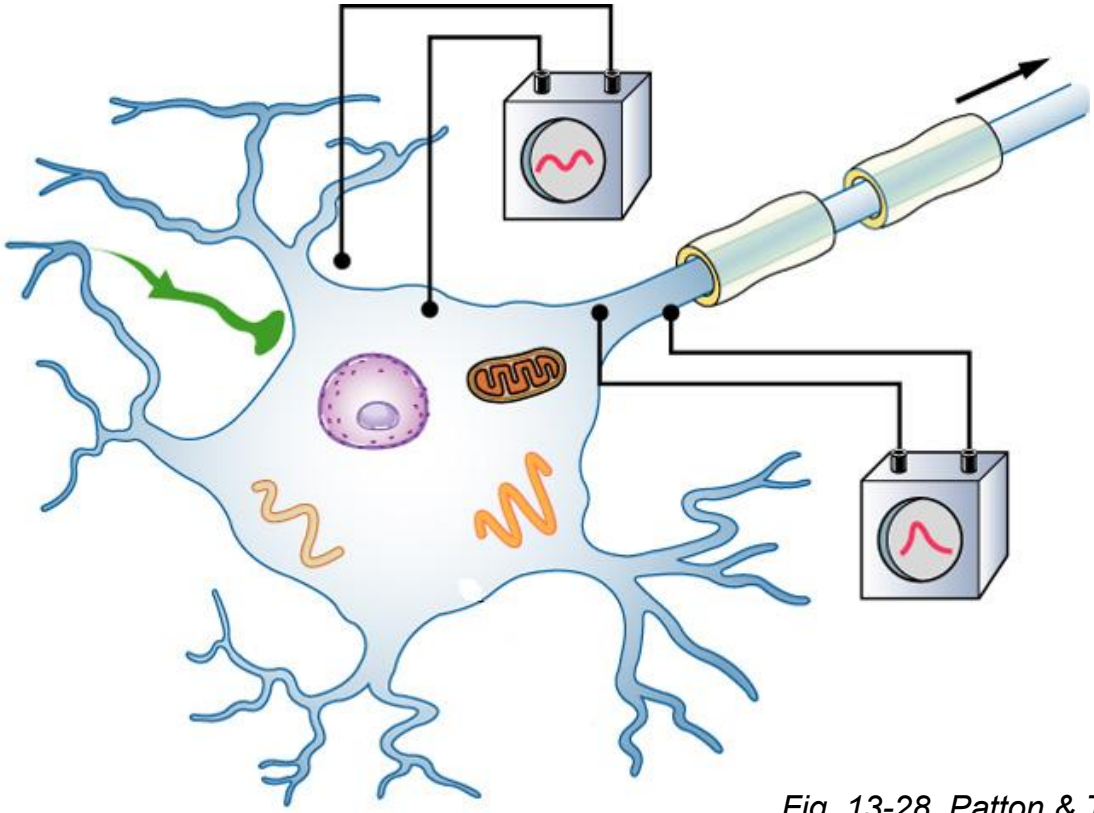
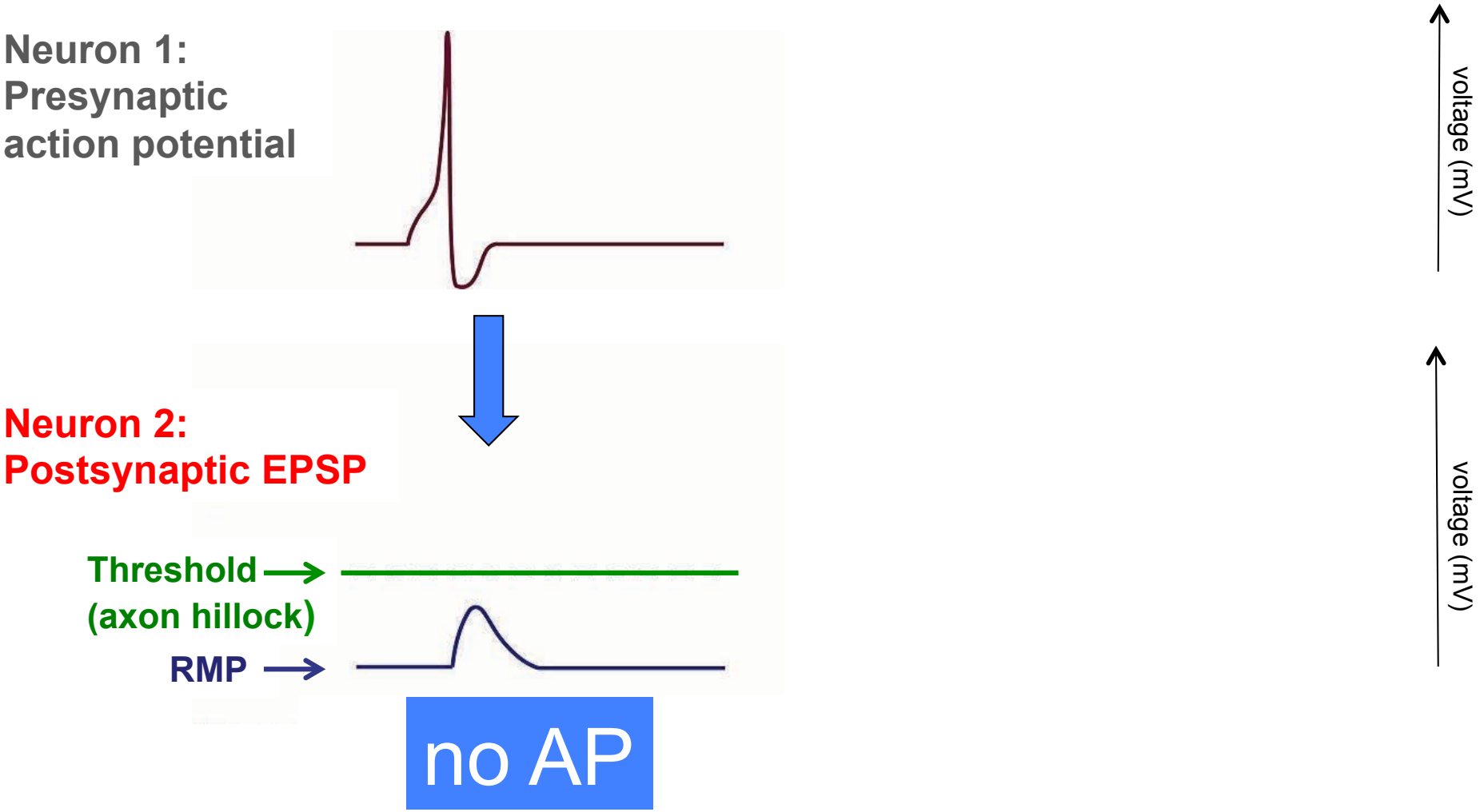


Fig. 13-28, Patton & Thibodeau, p.403

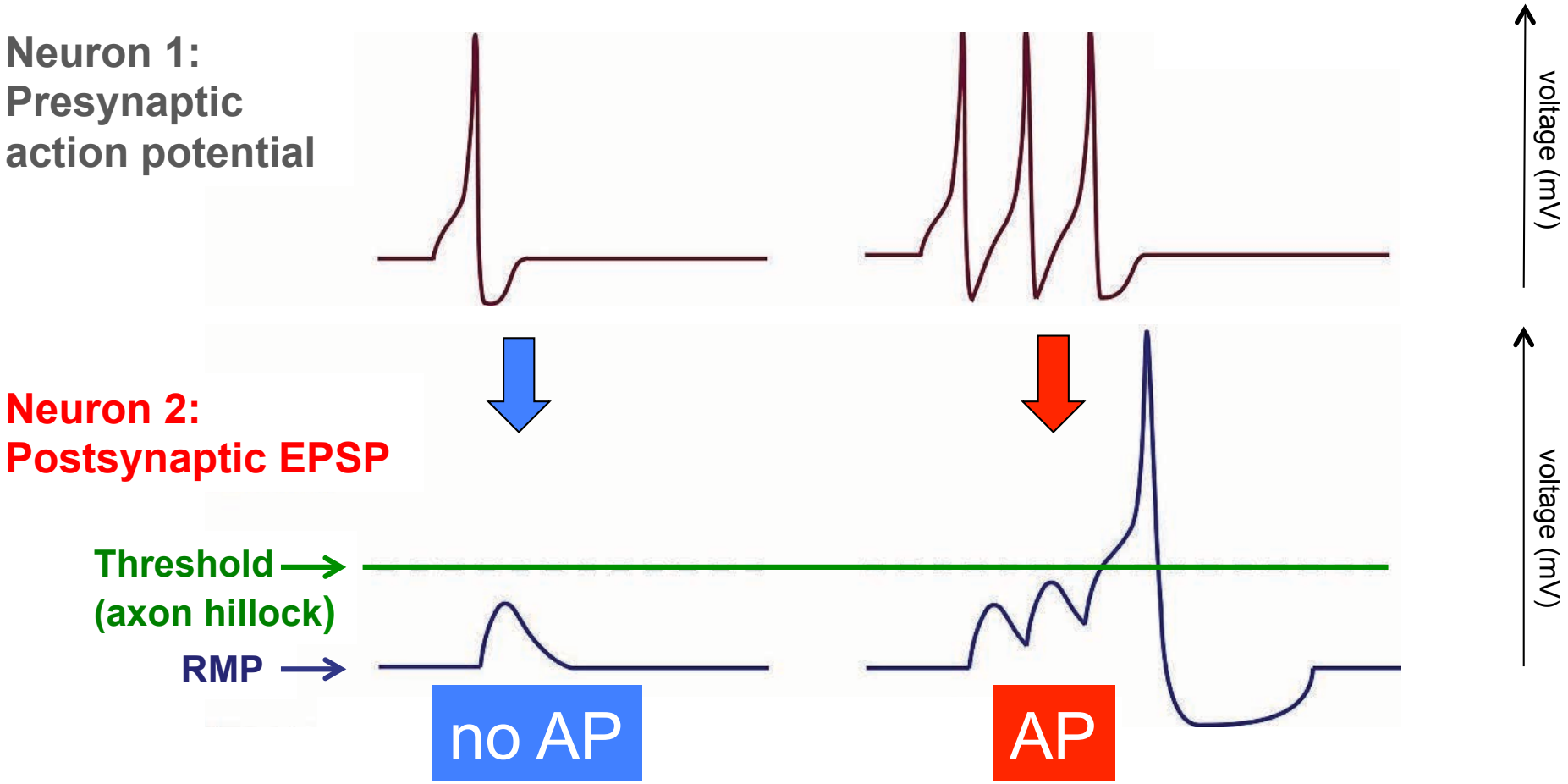
B Temporal Summation

Time dependent – integration of inputs within a short time at the same synaptic knob (identical place)

Temporal Summation of Synaptic Inputs

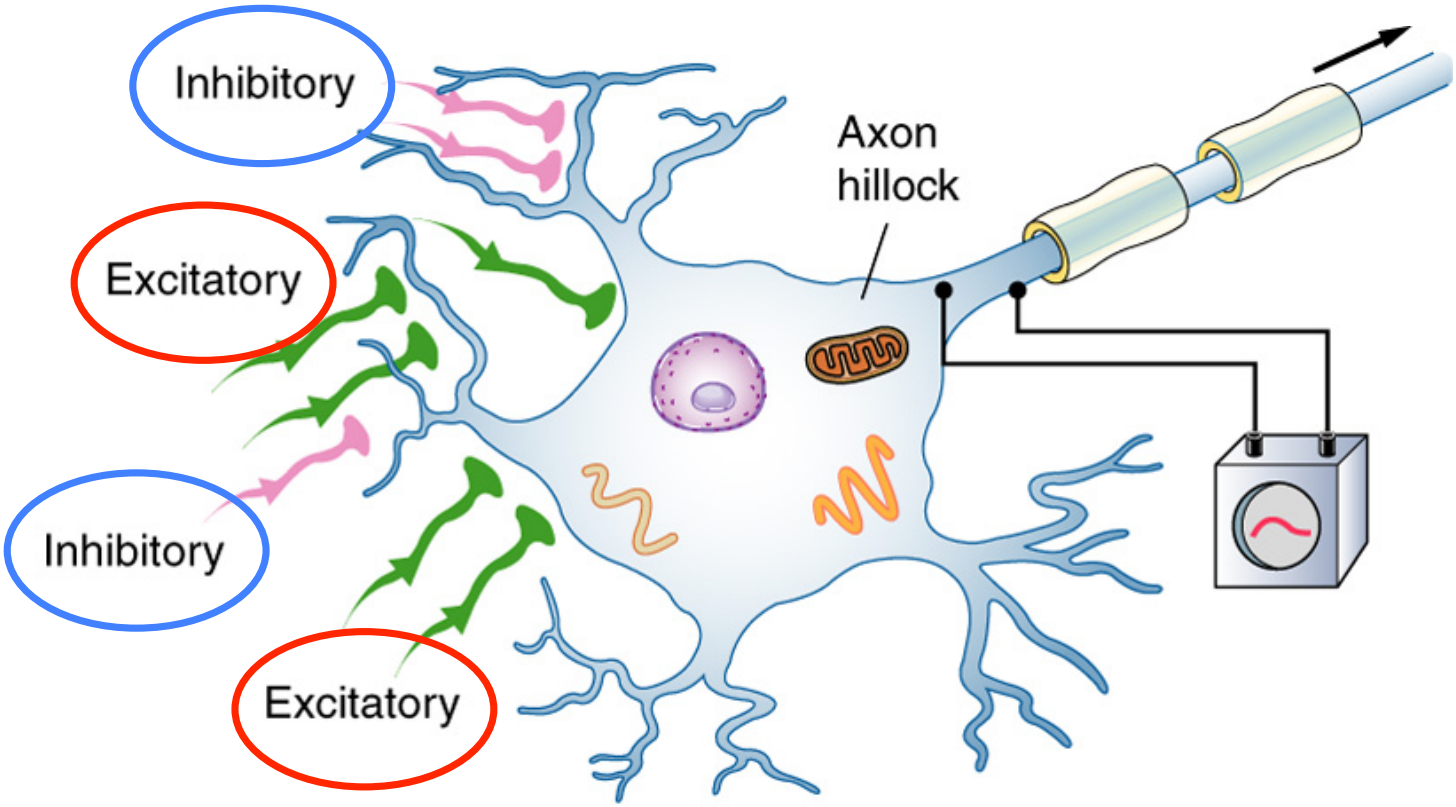


Temporal Summation of Synaptic Inputs



- Time dependent – integration of inputs within a short time at the same synaptic knob
- EPSP last longer than a AP!

Excitation & Inhibition

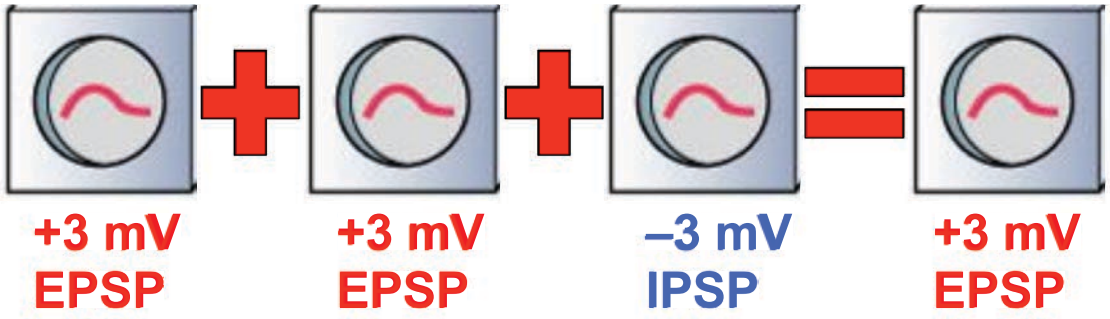


C Summation of Excitatory and Inhibitory Signals

Fig. 13-28, Patton & Thibodeau, p.403

☺ *More of these in GLM3* ☺

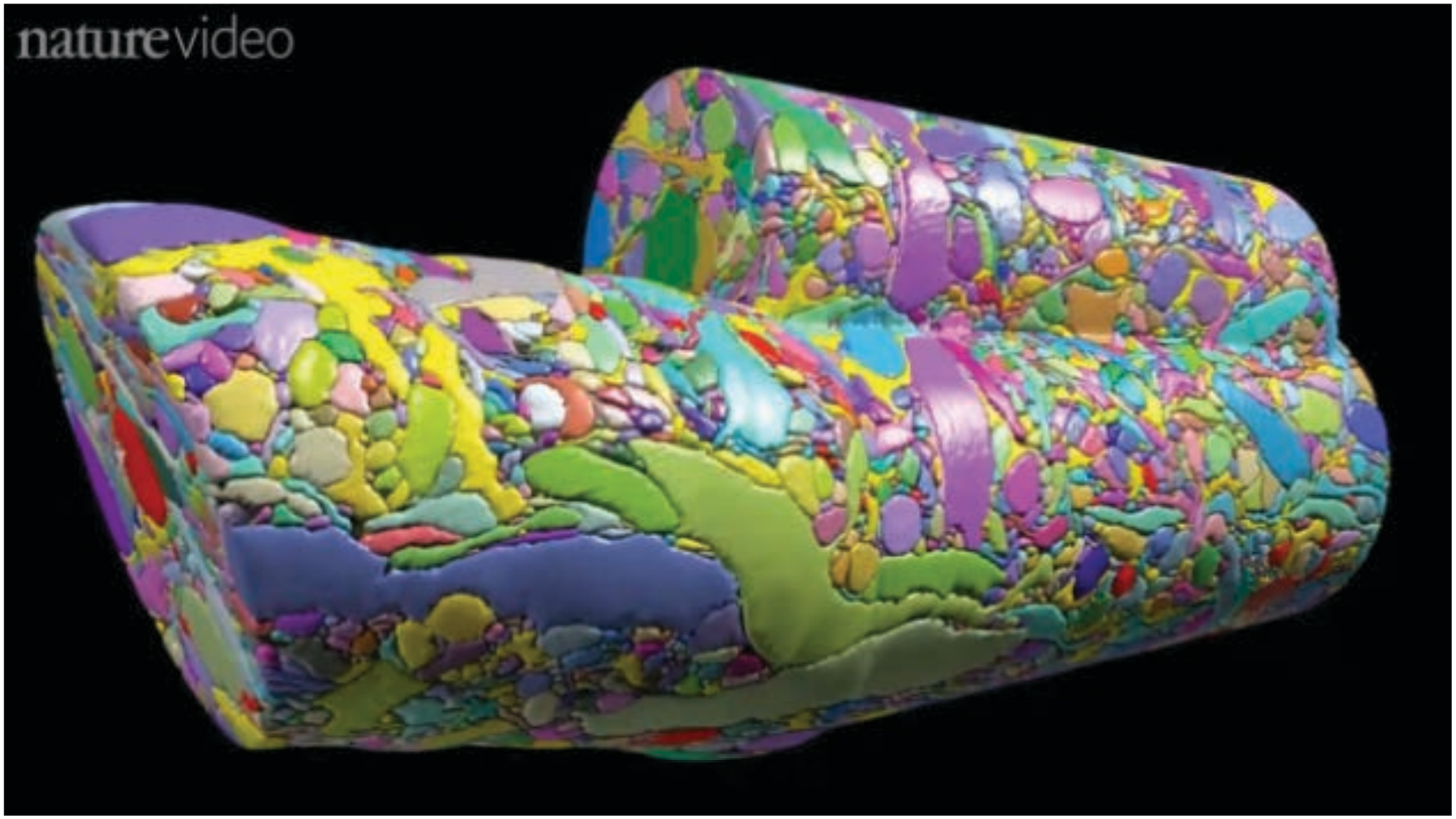
Excitation & Inhibition



if  ≤ –59 mV → no AP

if  ≥ –59 mV → AP

Neurones work in Networks



http://www.nature.com/news/crumb-of-mouse-brain-reconstructed-in-full-detail-1.18105

Types of Network - Divergence

Dictionary

diverge

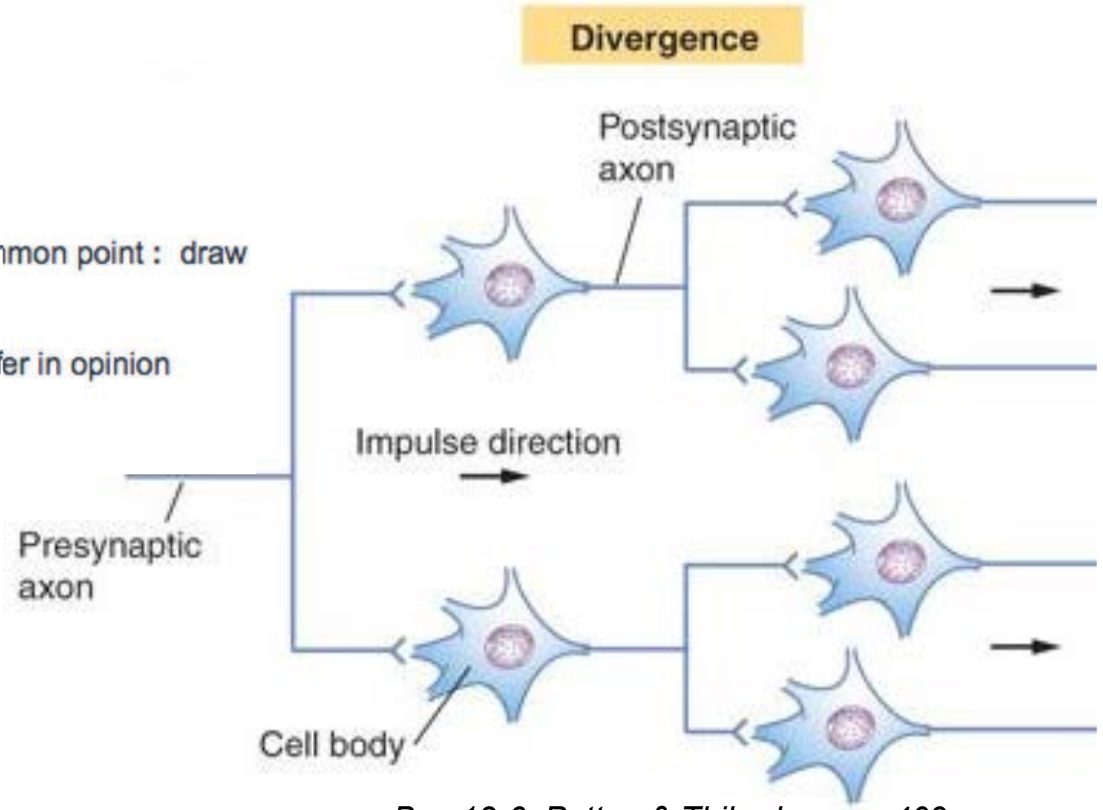
verb | di·verge | \də-'vərj, dī-\

1 **a :** to move or extend in different directions from a common point : draw apart <*diverging* roads>

b : to become or be different in character or form : differ in opinion

2 : to turn aside from a path or course : deviate

From http://www.merriam-webster.com



Box 13-6, Patton & Thibodeau, p. 409

Information from a single neuron may **DIVERGE** to different brain regions (multiple neurons) or different body parts

Provides…

1. … opportunity to **amplify** signals (multiple reactions in response to one stimulus)
2. … few control points (precise coordinated control of muscles)

Types of Network - Convergence

Dictionary

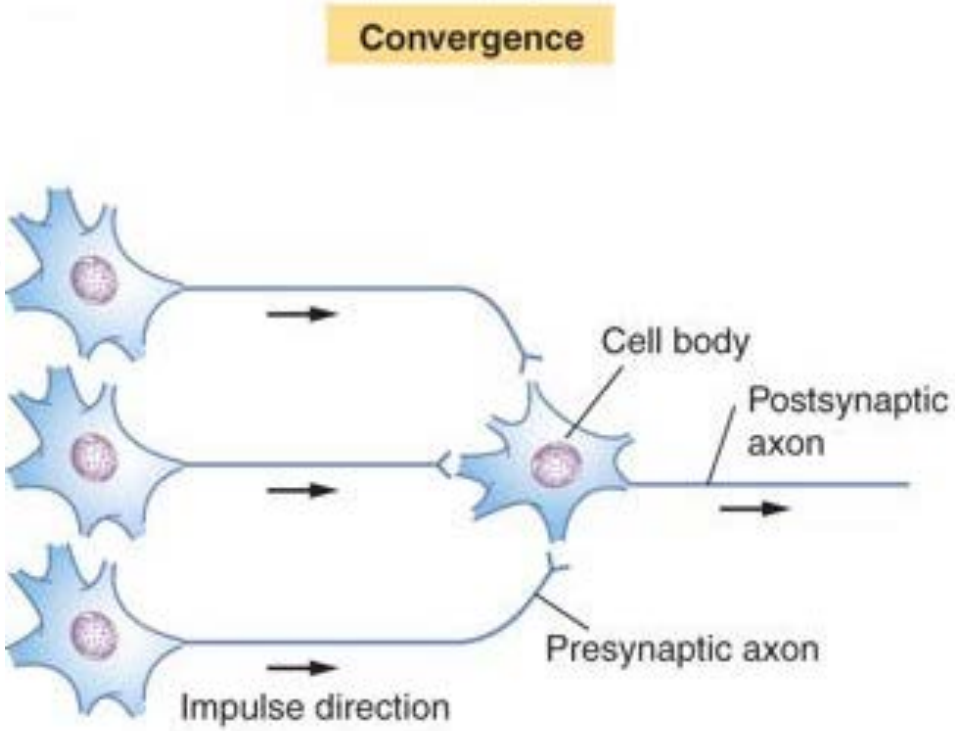
converge

verb | con·verge | \kən-'vərj\

1 : to tend or move toward one point or one another : come together
<*converging* paths>

2 : to come together and unite in a common interest or focus

From http://www.merriam-webster.com



Box 13-6, Patton & Thibodeau, p. 409

Information from multiple neurons may CONVERGE on one single neuron (Summation!) that initiates a single response

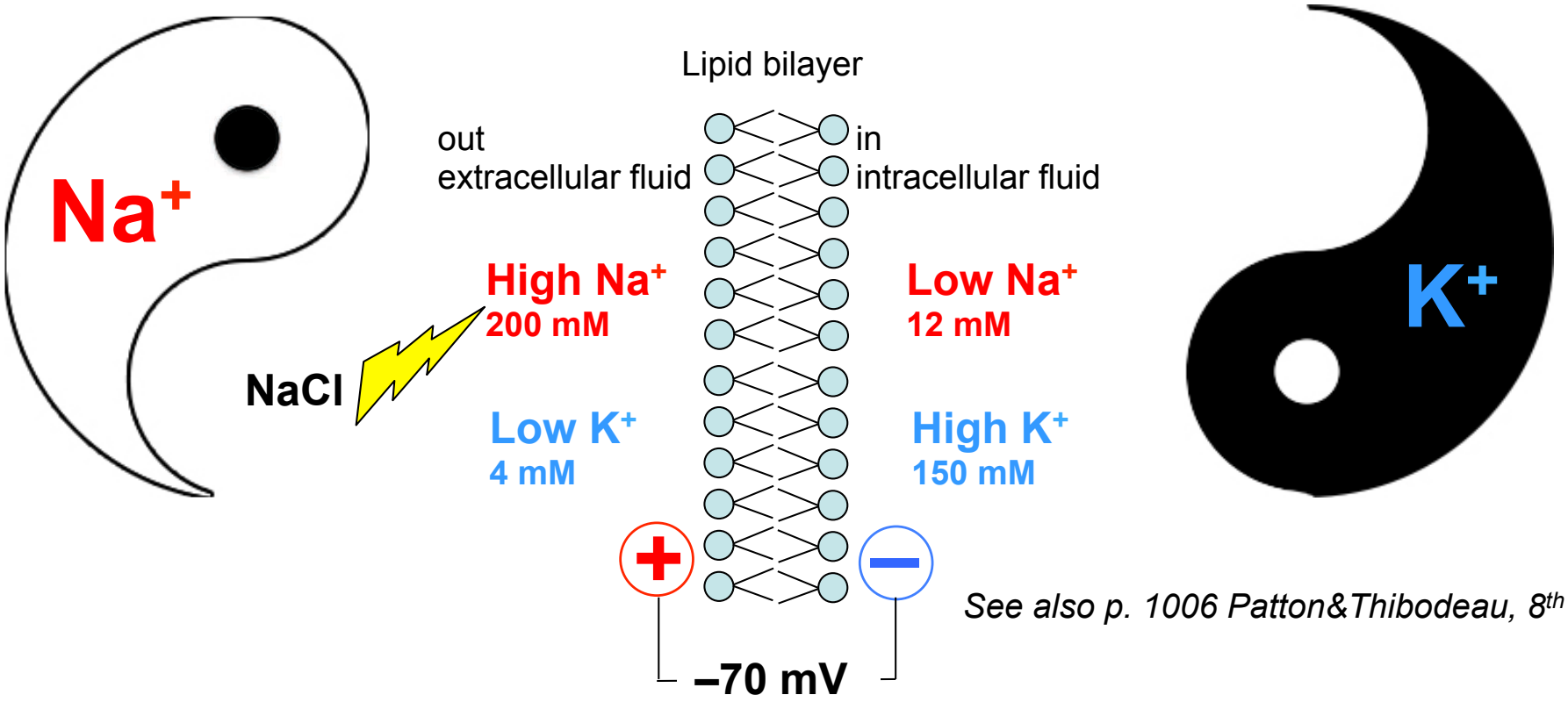
Provides…

…redundancy → 'Back-up' route for the transmission of signals

"system design that duplicates components to provide alternatives in case one component fails"

Except from YouTube Frog Legs Dancing With A Little Salt
Uploaded by thearchipelagos on 2 Jun 2009

What happens in the frog legs?



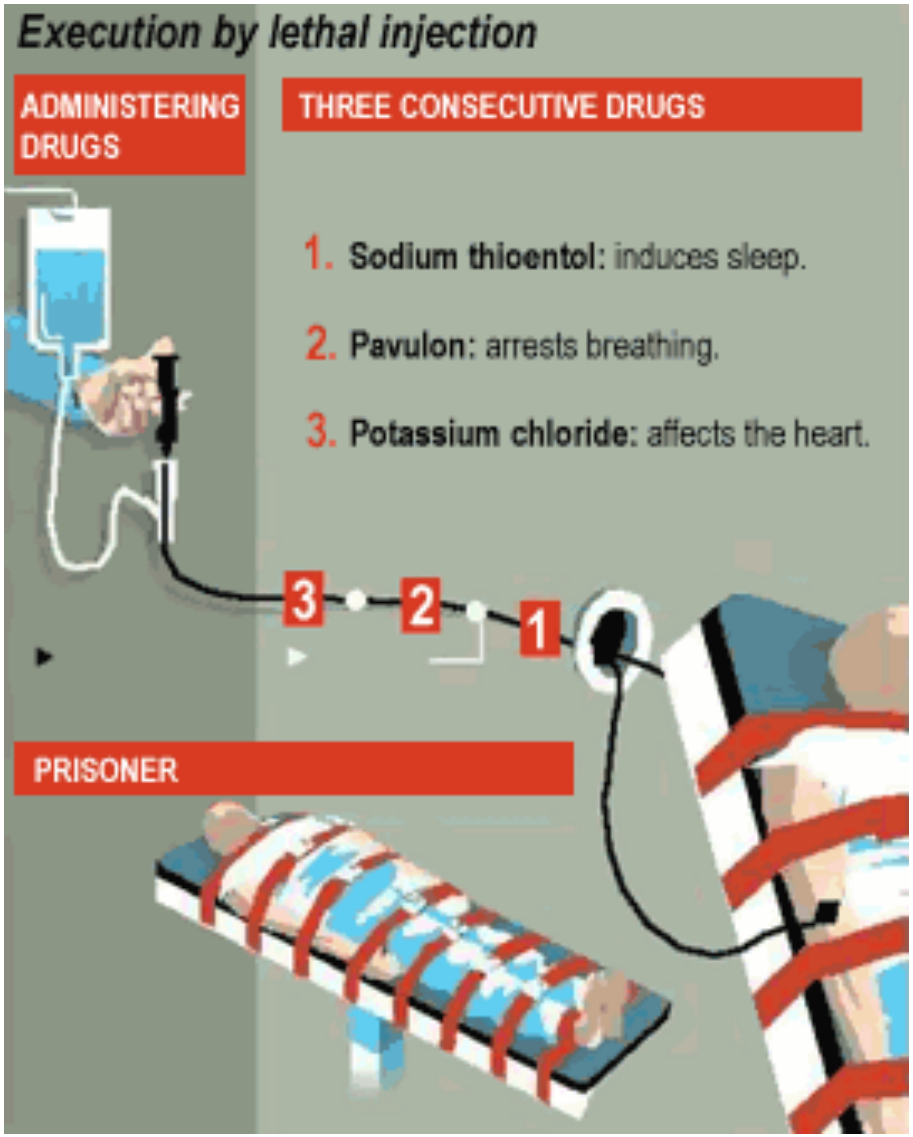
See also p. 1006 Patton&Thibodeau, 8th Ed.

Increased external [Na^+] by the addition of salt – makes neuron cell membrane more excitable (as well as the muscle cells)

→ driving force for Na^+ entry will be greater drives local EPSP's

if EPSP >-59 mV → AP → contraction (twitching)

Something to think about

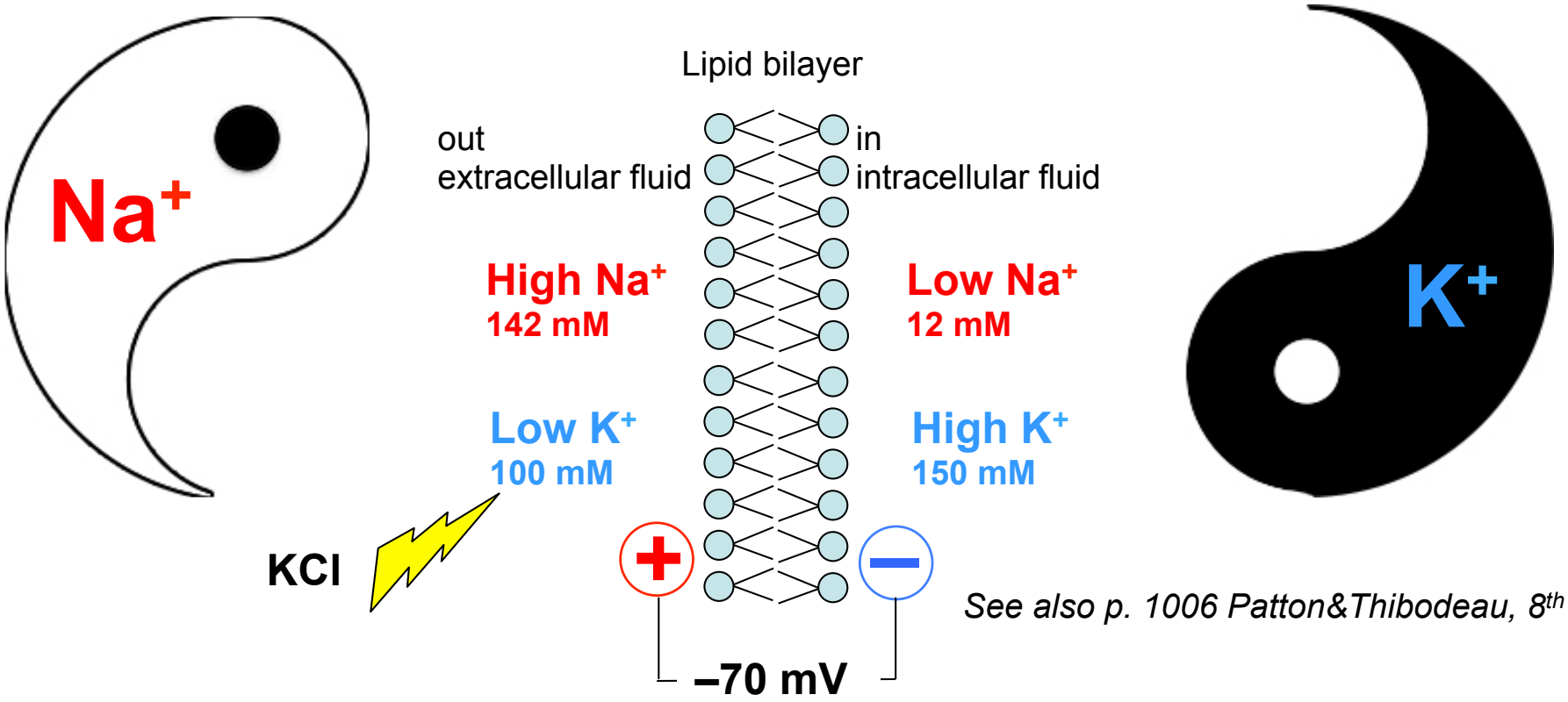


Why is KCl lethal ?

WHY ?????

From http://www.chm.bris.ac.uk/webprojects2006/Macgee/Web%20Project/lethal_injection.htm

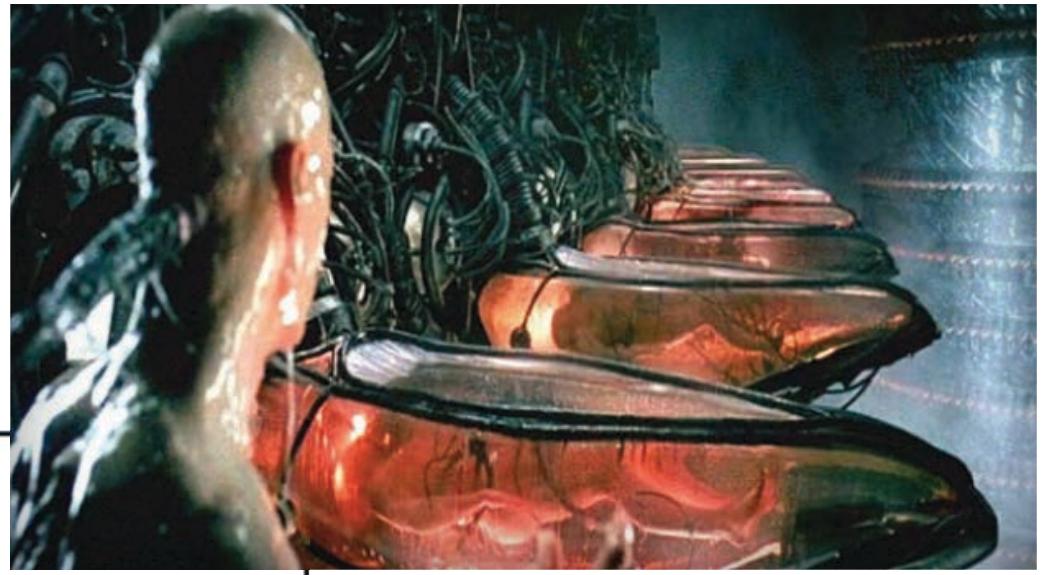
Why is KCl lethal
→ disrupts ionic (K^+) homeostasis!



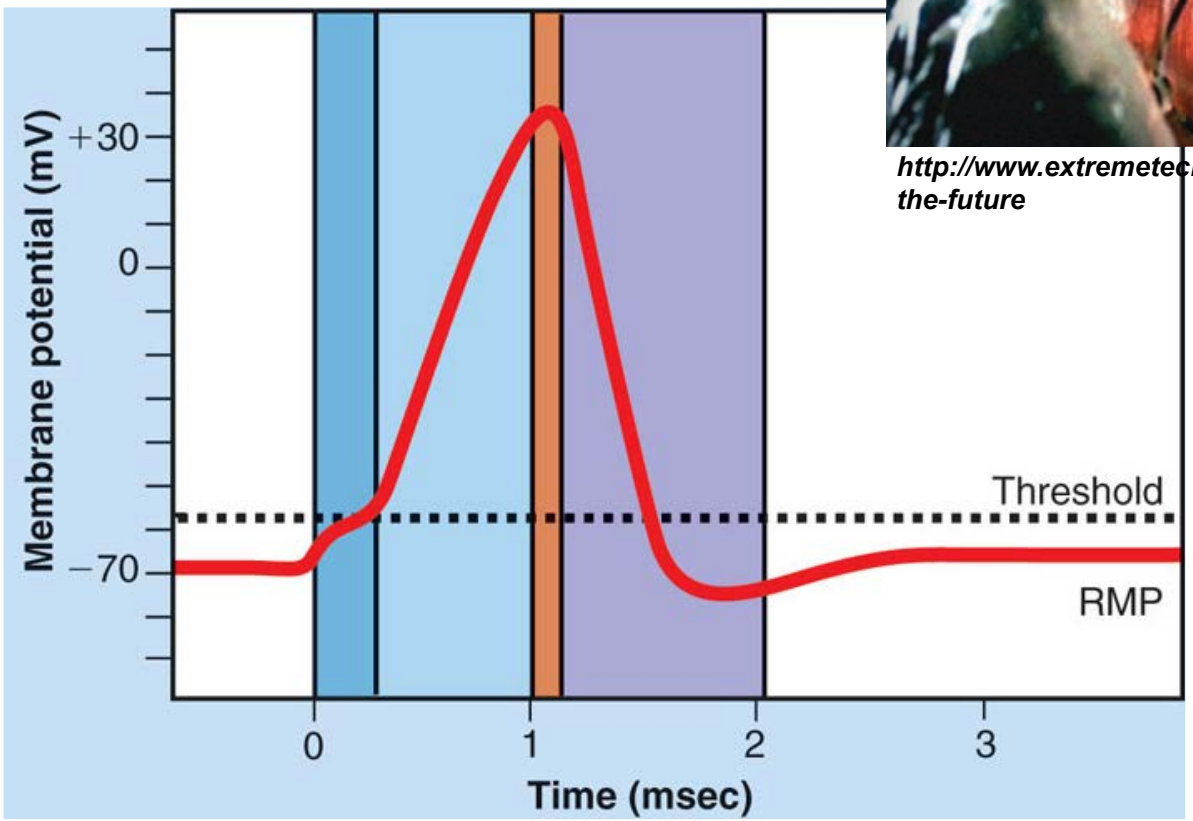
See also p. 1006 Patton&Thibodeau, 8th Ed.

Raise K^+ levels outside the cell → high K^+ inside and **high K^+ outside** – no K^+ movement through the channels will be possible
→ **cells do not repolarise, not enough K^+ leaves the cell** (cardiac cells → no contraction, cardiac arrest)

Bio–electricity!!!



http://www.extremetech.com/extreme/135481-will-your-body-be-the-battery-of-the-future



Brief summary

Lecture 1. Bioelectricity, ion distribution, ion channels and pumps,
membrane potential, depolarisation, repolarisation, hyperpolarisation

Lecture 2. Action potential, propagation/conduction of the action potential

Lecture 3. Synapses, signal transmission at chemical synapses

Lecture 4. Transmitters, synaptic integration (EPSP, IPSP), neuronal network types

Reminder → online feedback questionnaire

Thank you for you interest and attention!

Bio–electricity!!!

HUBS191