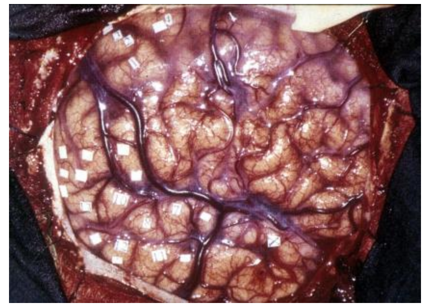
CROWN 85: Visual Perception:
A Window to Brain and Behavior
Lecture 1

Crown 85: Visual Perception:
A Window to Brain and Behavior

Lecture 1: Neurons and How They Communicate

1



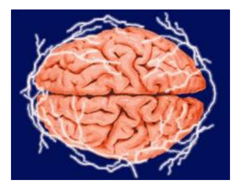
2

brain factoids (from: __University of Washington)__

weight of human brain	1300-1400 g (3 lbs)
neurons in brain	100 x 10^9
length of neurons	less than 1mm greater than 1m (spinal cord to foot)
speed of electrical transmission	0.5 m/sec 120 m/sec (268 mi/hr)

3

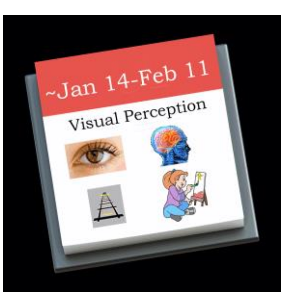
the language of the brain is ??? electricity



Your brain is electric.
It generates 10 to 12 watts of electricity – enough to power a flashlight.

http://www.morphonix.com/software/education/science/brain/game/specimens/electric_brain.html

4



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Prelude to Lectures
on Visual Perception

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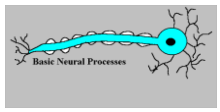
Today:

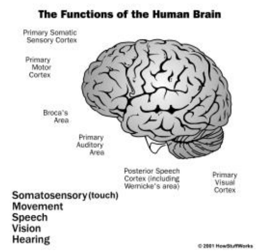
the Neuron and Electrical Potentials



http://bioserv.fiu.edu/~walterm/Fund_Sp2004/nervous/neuronanim.gif

7

different regions of the brain are ≈associated with specific behaviors



8

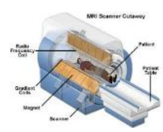
Thursday:

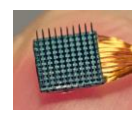
Neuroanatomy

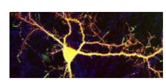
Prof/Provost Camps

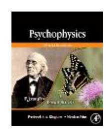
9

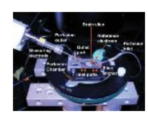
how does one investigate brain activity and the correlated behavior ??











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next Tuesday:

techniques of neuroscience research

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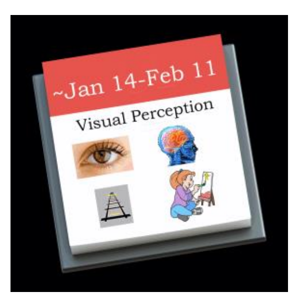

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CROWN 85: Visual Perception:
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Lecture 1

the class objectives:

- **Gain a basic understanding of**
  - ✓ neurons and how they communicate
  - ✓ structure of the brain
  - ✓ techniques used to investigate brain function

- *In order to understand (in some detail)*
  VISION: How the eye and brain
  - ✓ capture the properties of brightness, form, and color from the outside world
  - ✓ change light to electrical signals
  - ✓ extract and process visual information
  - ✓ enable visual behavior (the perception of form, color, depth, motion, illusion)

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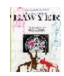
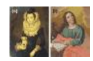
the objectives (continued):

- So that **YOU** can read and **REPORT** on contemporary topics in Brain and Behavior
  e.g.
  - ✓ Neuroscience and the Law
  - ✓ Neuroscience and magic
  - ✓ Neuroscience and art
  - ✓ Neurotransmitters and drugs
  - ✓ Visual development and amblyopia
  - ✓ Mindreading
  - ✓ Yadda
  - ✓ Yadda
  - ✓ Yadda





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the obligations:

moi:
- organize and ~PRESENT material on vision and brain
- **appropriate for SI requirement** *(and hopefully interesting)*

you:
- class participation and OFFICE HOURS
- midterm on vision and brain lectures
- short class (oral) report on assigned lecture subtopic
- interview with UCSC neuroscientist and class report on interview
- capstone research project and report

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Crown 85 Winter 2016

Visual Perception: A Window to Brain and Behavior

Lecture 1- Neurons, Synapses, Neurotransmitters, Action Potentials

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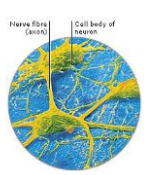
anatomy of a neuron

1. Be able to identify the following morphological features of the neuron and to describe the role they play in receiving and transmitting neural impulses.

   ✓ a. neuron
   b. cell body (soma)
   c. dendrite
   d. axon
   e. axon hillock
   f. presynaptic bulb (axon terminal)
   g. synapse
   h. myelin sheath
   i. node of Ranvier



This magnified image shows two neurons. The nerve fibre of one neuron links to the cell body of the other.
http://www.aviva.co.uk/health-insurance/home-of-health/medical-centre/medical-encyclopedia/entry/structure-and-function-nerve-cells/

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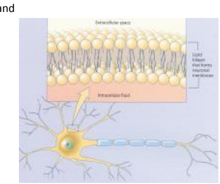

The cell wall is a lipid bilayer membrane which separates the intracellular fluid from the extracellular space.
http://fourier.eng.hmc.edu/e180/lectures/signal1/node2.html

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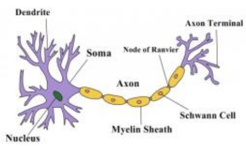

http://hubpages.com/education/Structure-of-a-Neuron

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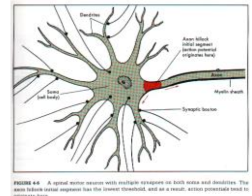

http://www.apsubiology.org/anatomy/2010/2010_Exam_Reviews/Exam_3_Review/CH_11_Histology_of_the_Neurons_Axon.htm

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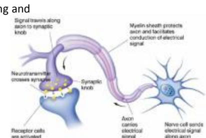

Where and axon terminal makes a functional connection, or synapse, with another cell is called a postsynaptic cell. If the postsynaptic cell is another neuron then the synapse is normally made with a dendrite or the cell body of a postsynaptic neuron. In the most common synapse there is a tiny space, called the synaptic cleft, this separates the axon terminals from the postsynaptic cell.

https://jordan-tesch.wikispaces.com/Chapter+four

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functions of parts of a neuron

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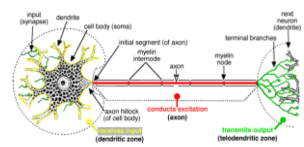

http://vanat.cvm.umn.edu/neurHistAtls/pages/neuron1.html

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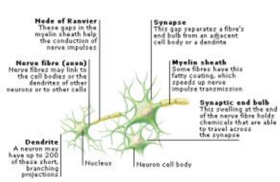

http://www.aviva.co.uk/library/images/med_encyclopedia/cfhg464nercel_003.gif

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summary

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Lecture 1

understand the basic functioning of the neural action potential

2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:
   a. ion concentrations inside and outside the neuron (how do they give rise to the membrane potential ?)
   b. resting potential
   c. depolarization and hyperpolarization
   d. action potential

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understand the basic functioning of the neural action potential

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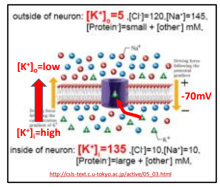

http://csls-text.c.u-tokyo.ac.jp/active/05_03.html

Simple Picture

1. ion concentrations, $[K^+]$, $[Na^+]$, $[Cl^-]$, $[A^-]$ differ between intracellular and extracellular fluids
2. in resting state cell membrane is permeable only to $[K^+]$ (slightly permeable through 'leak' channels)
3. $[K^+]_i$ **high** *inside* diffuses *(only a little)* to $[K^+]_o$ **low** *outside (Cl^- and other$^-$ don't go along !!)*
4. leaves net – *inside* ≈–70mV=resting potential

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understand the basic functioning of the neural action potential

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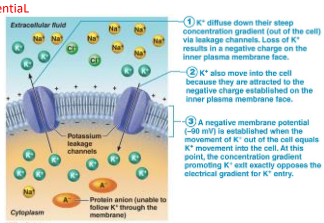
   b. resting potentiaL



http://classes.midlandstech.edu/carterp/Courses/bio210/chap03/lecture1.htm

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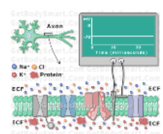
***more:** understand the basic functioning of the neural action potential*

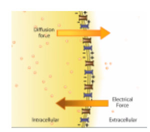
2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:
   a. ion concentrations inside and outside the neuron (how do they give rise to the membrane potential ?)
   b. resting potential

https://www.youtube.com/watch?v=JApn3gRr8Q8

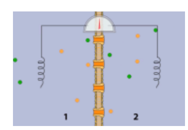
Additional Excellent Material



http://www.getbodysmart.com/ap/nervoussystem/neurophysiology/restingpotentials/menu/menu.html



http://sites.sinauer.com/neuroscience5e/animations02.01.html



http://sites.sinauer.com/neuroscience5e/animations02.02.html ADVANCED=CHEM 1C

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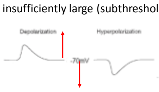
understand the basic functioning of the neural action potential

2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:
   a. ion concentrations inside and outside the neuron (how do they give rise to the membrane potential ?)
   b. resting potential
   c. depolarization and hyperpolarization

- **depolarization:** membrane potential becomes more positive
  if sufficiently large will create an action potential (suprathreshold)
  or may be insufficiently large (subthreshold depolarization)



- **hyperpolarization:** membrane potential becomes more negative
  can 'counteract' (i.e. cancel, sum with) depolarization but in itself will not lead to action potential

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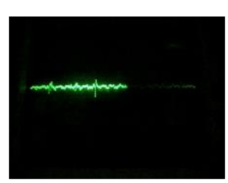
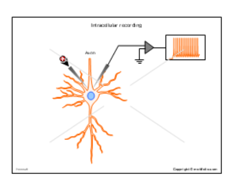
neural action potential

2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:
   c. action potential (or 'spike')



https://faculty.washington.edu/chudler/flash/son1.html



http://ep.yimg.com/ca/I/yhst-31600583429934_2260_31723678

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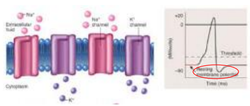
CROWN 85: Visual Perception: A Window to Brain and Behavior Lecture 1

action potential

2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:

   c. action potential (or 'spike')

Simple Picture



http://bioserv.fiu.edu/~walterm/Fund_Sp2004/nervous/sp06_exam2_nervous_review.htm

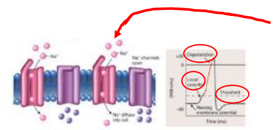
1. **Neuron is at resting potential only K^+ leakage channels open -70mV**

neural action potential

2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:

   c. action potential

Simple Picture



http://bioserv.fiu.edu/~walterm/Fund_Sp2004/nervous/sp06_exam2_nervous_review.htm

2. **Depolarizing input (e.g. synaptic transmission) opens local Na^+ 'voltage gated' channels. Na^+ ions flow in depolarizing the neuron (less negative voltage)**

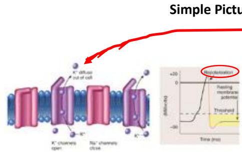
3. **If local depolarization reaches a threshold (≈–55mV) neuron fully depolarizes ('spikes') to a fixed level (≈ +40mV)**

action potential

2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:

   c. action potential. d. refractory period

Simple Picture

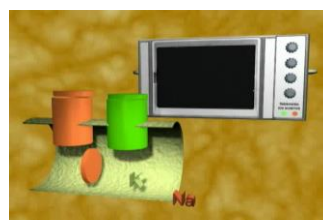


http://bioserv.fiu.edu/~walterm/Fund_Sp2004/nervous/sp06_exam2_nervous_review.htm

4. **The K^+ 'voltage gated" channels then open . K^+ ions flow out [re]hyperpolarizing the neuron, returning to the resting potential**

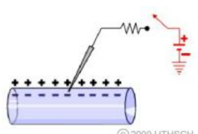
5. **The return to the resting potential and 'recovery' of the voltage-gated Na^+ channels requires a ≈ 3-4ms refractory period during which the neuron can not 'fire' again**

action potential animation (Werblin, UCB)

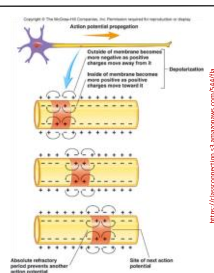


https://mcb.berkeley.edu/courses/mcb64/action_potential.html

propagation of action potential



http://neuroscience.uth.tmc.edu/s1/chapter03.html

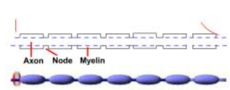


https://classconnection.s3.amazonaws.com/544/flashcards/666544/png/app1317789045502.png

propagation of action potential (myelinated neurons; salutatory conduction)

2. Understand the basic functioning of the neural action potential and be familiar with the following terms and concepts:

   e. propagation of action potential



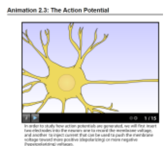
//neuroscience.uth.tmc.edu/s1/chapter03.html

http://www.uic.edu/classes/bios/bios100/lectures/myelinated_neurons.jpg

other resources for action potential propagation

https://mcb.berkeley.edu/courses/mcb64/action_potential.html

https://mcb.berkeley.edu/courses/mcb64/propagation.html



http://sites.sinauer.com/neuroscience5e/animations02.03.html

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summary of membrane and action potentials

2. Understand the basic functioning of the neural membrane and action potentials and be familiar with the following terms and concepts:
   a. ion concentrations inside and outside the neuron (how do they give rise to the membrane resting potential ?)

$[Na^+]_{inside}$ < $[Na^+]_{outside}$; $[K^+]_{inside}$ > $[K^+]_{outside}$; $[Cl^-]$ and $[A^-]$ $_{\text{proteins and other negative ions}}$ balance +charges

   b. resting potential

at 'rest' only $[K^+]$ 'leaks' inside ➡ outside ; leaving – ions inside with -70mV resting potential

   c. depolarization and hyperpolarization

depolarization: membrane potential becomes more positive
hyperpolarization: membrane potential becomes more negative

   d. action potential

$[Na^+]$ rushes inside ⬅ outside causing a spike of depolarization (*increase of membrane potential to ≈+40mV*)

   e. refractory period

3-4 msec period after action potential where neuron is unresponsive to further polarizing input

   f. propagation of action potential

local action potential opens adjacent Na^+ voltage-gated channels and spike of depolarization moves down axon

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communication among neurons (passing the message along !!)

3. Understand the role each of the following plays in the transmission of electrical signals (information) between neurons
   a. neurotransmitter
   b. synaptic vesicle
   c. synaptic cleft
   d. postsynaptic receptor
   e. excitatory and inhibitory synaptic transmission

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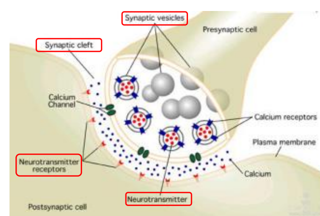
the structure of the synapse



a. neurotransmitter

b. synaptic vesicle

c. synaptic cleft

d. postsynaptic receptor

http://www.apsubiology.org/anatomy/2010/2010_Exam_Reviews/Exam_3_Review/CH_11_Histology_of_the_Neurons_Axon.htm

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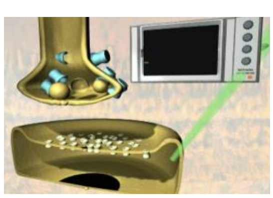
animation of synaptic transmission



https://mcb.berkeley.edu/courses/mcb64/synapse.html

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synaptic transmission (simple picture)

- action potential comes down presynaptic axon causing synaptic vesicles to migrate towards presynaptic membrane
- vesicles fuse with presynaptic membrane and release neurotransmitter
- neurotransmitter travels through synaptic cleft to postsynaptic receptors
- interaction of neurotransmitter with postsynaptic receptor causes
  - depolarization of postsynaptic membrane (excitatory synapse)
    or
  - hyperpolarization of postsynaptic membrane (inhibitory synapse)

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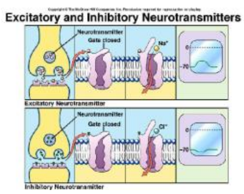
excitatory vs inhibitory synapses



http://faculty.southwest.tn.edu/rburkett/A&P1%20Muscle%20Physiology.htm

- **EXCITATORY SYNAPSE:**
  release of some neurotransmitters results in **depolarization** of postsynaptic neuron (e.g. epinephrine, glutamate)
- **INHIBITORY SYNAPSE:**
  release of other neurotransmitters results in **hyperpolarization** in postsynaptic neuron (e.g. GABA, glycine)
- In addition to the neurotransmitter the nature of the postsynaptic receptors can determine whether a synapse is excitatory or inhibitory

communication among neurons (passing the message along !!)

3. Understand the role each of the following plays in the transmission of electrical signals (information) between neurons

✓ a. neurotransmitter — chemicals released from synapse that cause postsynaptic neuron to depolarize or hyperpolarize

✓ b. synaptic vesicle — 'containers' holding neurotransmitters in presynaptic bulb

✓ c. synaptic cleft

✓ d. postsynaptic receptor — interaction of neurotransmitter with receptor results in depolarization or hyperpolarization of postsynaptic dendrite

✓ e. excitatory and inhibitory synaptic transmission

	excitatory synapse (+)		Inhibitory synapse (-)	
presynaptic	depolarizing	hyperpolarizing	depolarizing	hyperpolarizing
postsynaptic	depolarizing	hyperpolarizing	hyperpolarizing	depolarizing

neurotransmitters

4. "Recognize" the names of the major neurotransmitters and their primary 'effect'
   a. acetylcholine [Ach]
   b. norepinephrine (noradrenaline) [NE,NAd]
   c. dopamine [DA]
   d. serotonin (5-hydroxytryptamine) [5-HT]
   e. GABA (gamma-aminobutyric acid)

common neurotransmitters

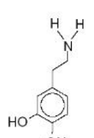
Table 11.1 Actions of Common Neurotransmitters

Neurotransmitter	Sites Where Released	Principal Actions
Acetylcholine	Brain Neuromuscular junctions Autonomic nervous system	Excitatory on skeletal muscles Excitatory or inhibitory on internal organs
Norepinephrine	Areas of brain and spinal cord Autonomic nervous system	Excitatory or inhibitory, depending on receptors Plays a role in emotions
Serotonin	Areas of brain Spinal cord	Usually inhibitory Involved in moods, sleep cycle, appetite
Dopamine	Areas of brain Parts of peripheral nervous system	Excitatory or inhibitory, depending on receptors Plays a role in emotions
Glutamate	Areas of brain Spinal cord	Usually excitatory Major excitatory neurotransmitter in brain
Endorphins	Many areas in brain Spinal cord	Usually inhibitory Natural opiates that inhibit pain
Gamma-aminobutyric acid	Areas of brain Spinal cord	Usually inhibitory Principal inhibitory neurotransmitter in brain
Somatostatin	Areas of brain Pancreas	Usually inhibitory Inhibits release of growth hormone

"recognize" know:

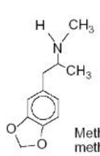
http://bioserv.fiu.edu/~walterm/Fund_Sp2004/nervous/sp06_exam2_nervous_review.htm

natural neurotransmitters and psychoactive drugs



Dopamine

natural neurotransmitter

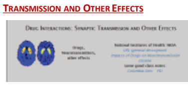


ECSTASY

Methylenedioxy-methamphetamine (MDMA)

chemically similar psychoactive drug

POSSIBLE CAPSTONE **PROJECT**:
DRUG INTERACTIONS: SYNAPTIC TRANSMISSION AND OTHER EFFECTS



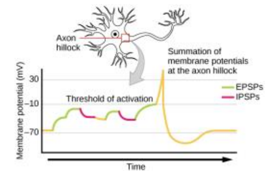
neurotransmitters (summary)

4. "Recognize" the names of the major neurotransmitters and their primary 'effect'
   ✓ a. acetylcholine [Ach] — neuron to muscle excitatory
   ✓ b. norepinephrine (noradrenaline) [NE,NAd]
   ✓ c. dopamine [DA] — excitatory or inhibitory , role in emotions
   ✓ d. serotonin (5-hydroxytryptamine) [5-HT] — inhibitory , role in moods
   ✓ e. glutamate — primary excitatory transmitter in brain
   ✓ f. GABA (gamma-aminobutyric acid) — primary inhibitory transmitter in brain

how a neuron integrates and signals information

5. Understand the following properties of a neuron's response
   a. Summation of excitation and inhibition
   b. Stimulus strength versus firing rate

integration of neuronal signals



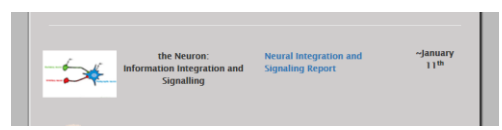
Signal summation at the axon hillock
A single neuron can receive both excitatory and inhibitory inputs from multiple neurons. All these inputs are added together at the axon hillock. If the EPSPs are strong enough to overcome the IPSPs and reach the threshold of excitation, the neuron will fire.
https://www.boundless.com/biology/textbooks/boundless-biology-textbook/the-nervous-system-35/how-neurons-communicate-200/signal-summation-764-11997/

how a neuron integrates and signals information

5. Understand the following properties of a neuron's response
   a. Summation of excitation and inhibition
   b. Stimulus strength versus firing rate

the first student **REPORT:** January 11

short report by: William Yates



how a neuron integrates and signals information

5. Understand the following properties of a neuron's response
   a. Summation of excitation and inhibition
   b. Stimulus strength versus firing rate

overview hhmi | BioInteractive

http://www.hhmi.org/biointeractive/molecular-mechanism-synaptic-function

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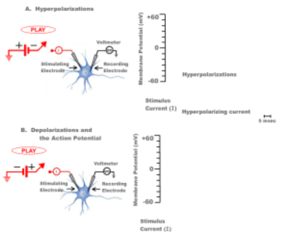
hyperpolarization and depolarization (http://neuroscience.uth.tmc.edu/s1/chapter01.html) figure 1.3



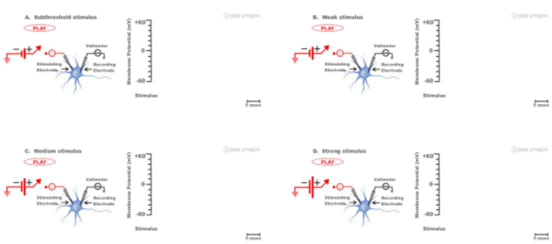
hyperpolarization and depolarization

'take home' implications:

a. as hyperpolarizing stimulus increases, neuron become more hyperpolarized as "graded" potentials; NO ACTION POTENTIALS

b. as depolarizing stimulus increases subthreshold "graded" depolarization increases until threshold is reached and an action potential is generated

spike properties vs strength of input (http://neuroscience.uth.tmc.edu/s1/chapter01.html) figure 1.4



spike rate vs intensity of stimulation

what could the 'stimulus' be :

a. inputs from other neurons via dendrites that are summed at axon hillock
b. inputs from 'sensory transduction"
c. input from an artificial electrode (pictured)

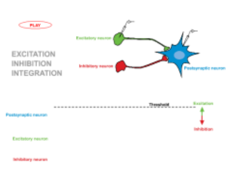
what is observed:

a. stimulus too small ⇒ subthreshold depolarization
b. weak stimulus ⇒ one spike
c. medium stimulus ⇒ moderate spike rate
d. strong stimulus ⇒ high spike rate

'take home' implications:

a. very weak stimuli that do not cause neuron to reach threshold will not lead to action potentials
b. amplitude of action potential depolarization is fixed, does not depend on strength of stimulus
c. strength of suprathreshold stimuli coded in firing-rate of neuron
   strong stimulus ⇒ many spikes per second   weak stimulus ⇒ few spikes per second

combining excitatory and inhibitory signals http://neuroscience.uth.tmc.edu/s1/introduction.html



http://neuroscience.uth.tmc.edu/s1/introduction.html figure 5

combining excitatory and inhibitory signals

take home message:

a. action potentials in presynaptic neuron at excitatory synapse will depolarize postsynaptic neuron with resulting postsynaptic spikes (if excitation is above threshold)

b. action potentials in presynaptic neuron at inhibitory synapse will hyperpolarize postsynaptic neuron

c. if excitation and inhibition arrive sufficiently simultaneously, they will cancel in postsynaptic neuron

Finis

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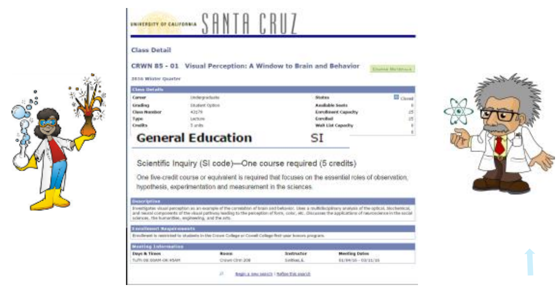

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