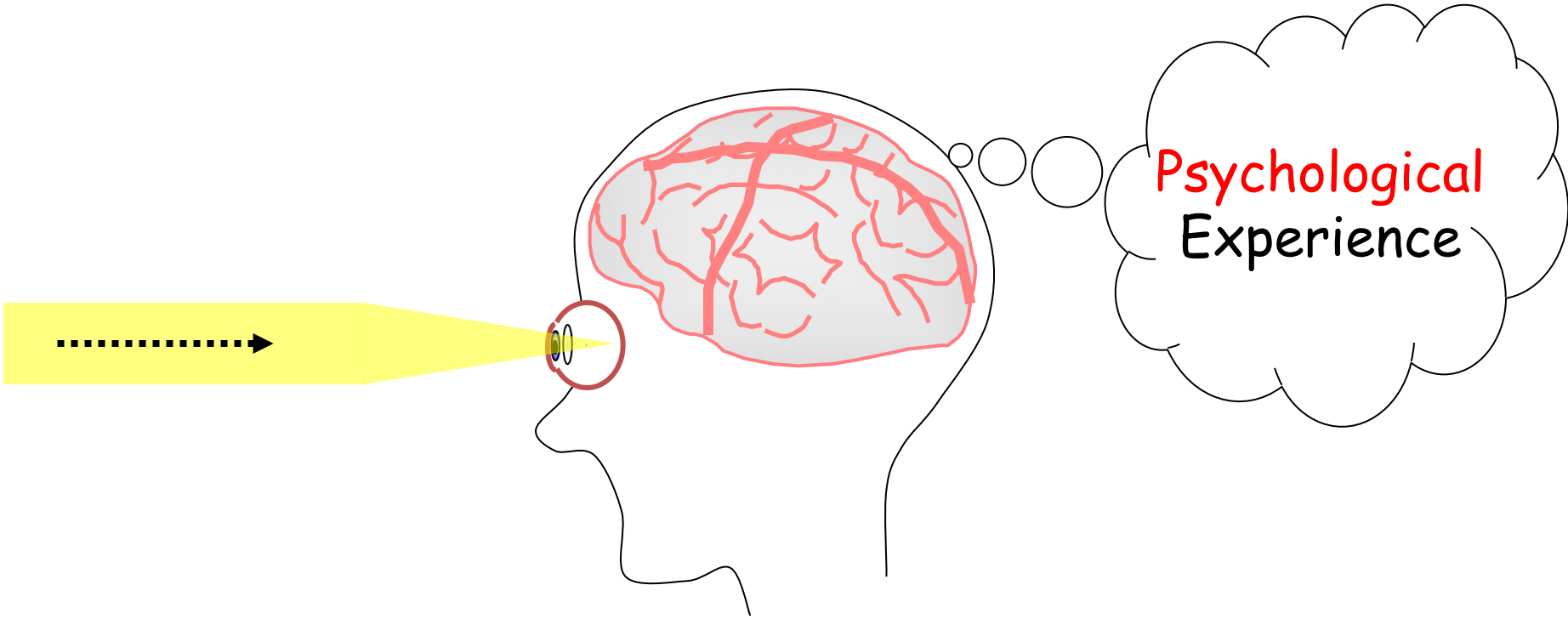
COGS 269

Lecture 1

Spring 2018


Psychological
Experience

Methods of Cognitive Neuroscience

- Dissociation experiments (patients with brain damage)
- Neuroimaging experiments
- Computational modeling

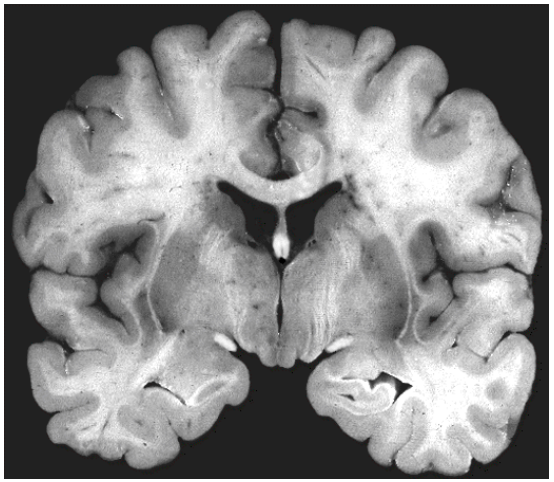
Brain damage & Cognitive Neuroscience

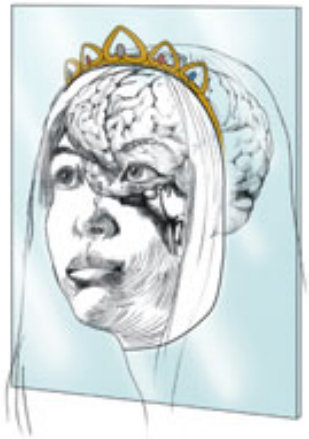
Da Brain

- Brain = 100 billion neurons
- Synapses = It has been estimated that there are 1 quadrillion synapses in the human brain. That's 10^{15} or 1,000,000,000,000,000 synapses!
- Number of connections = 100 billion X $10^{15.}$
- Number of possible behaviours -> ∞

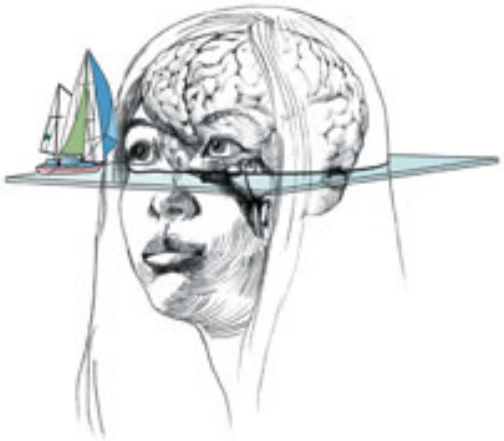
Tools: Directions

Coronal

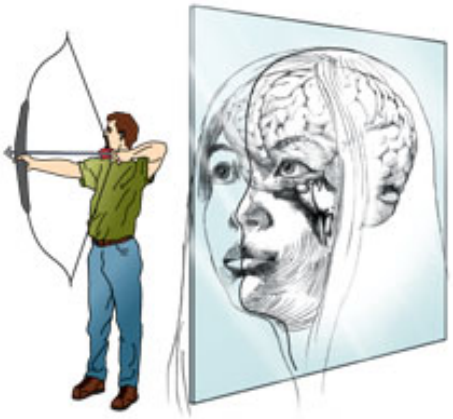




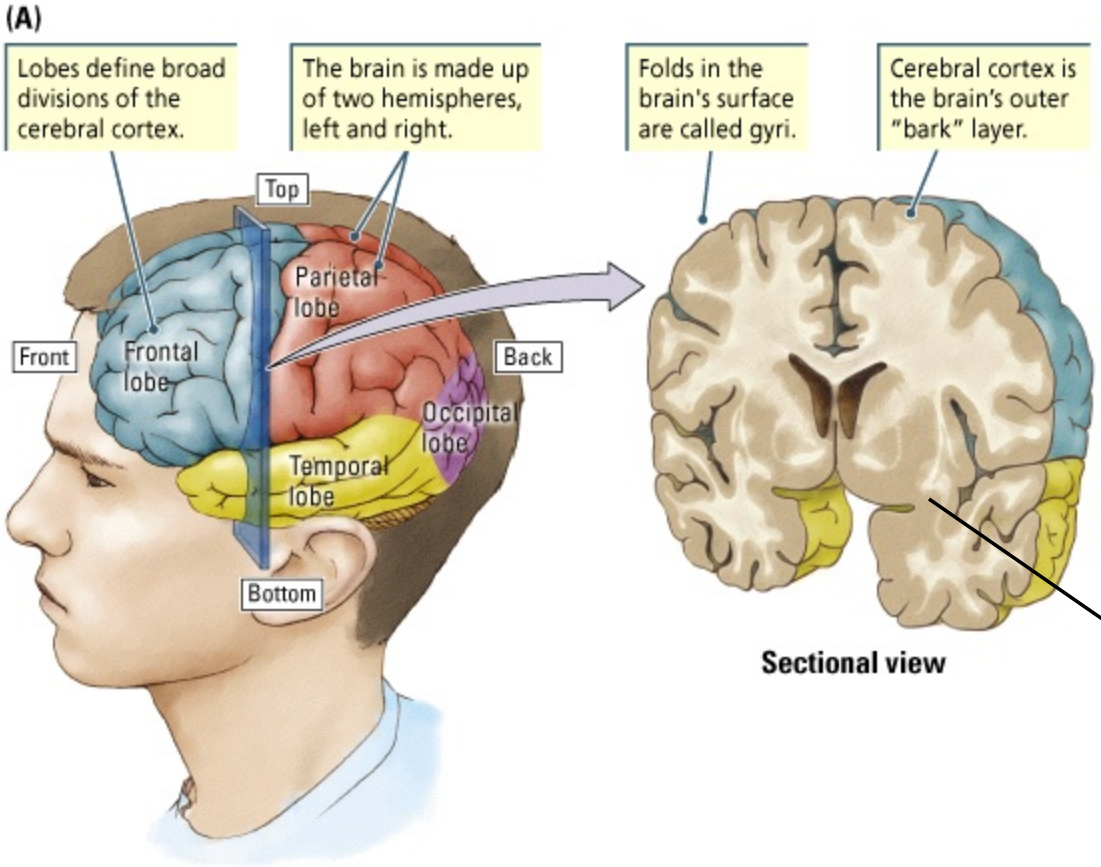
Horizontal



Sagittal

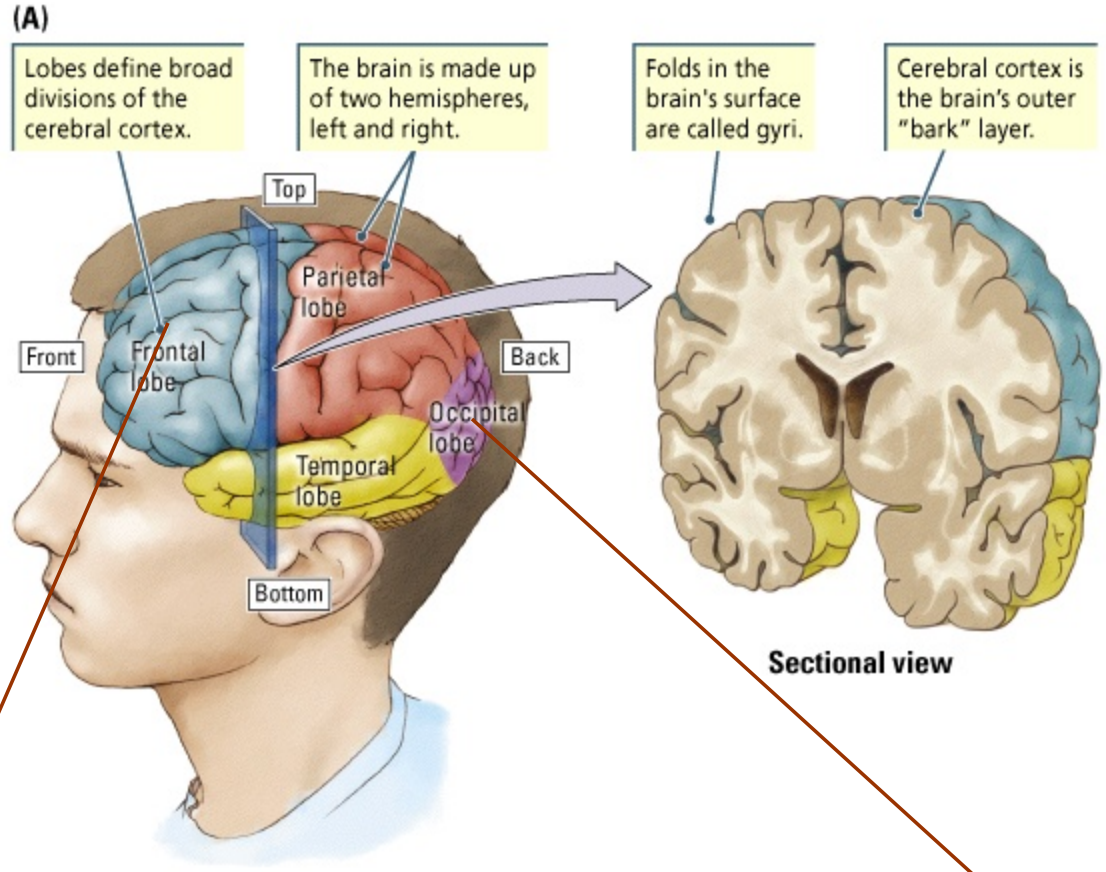


I'd rather have a bottle in front of me, than a ….



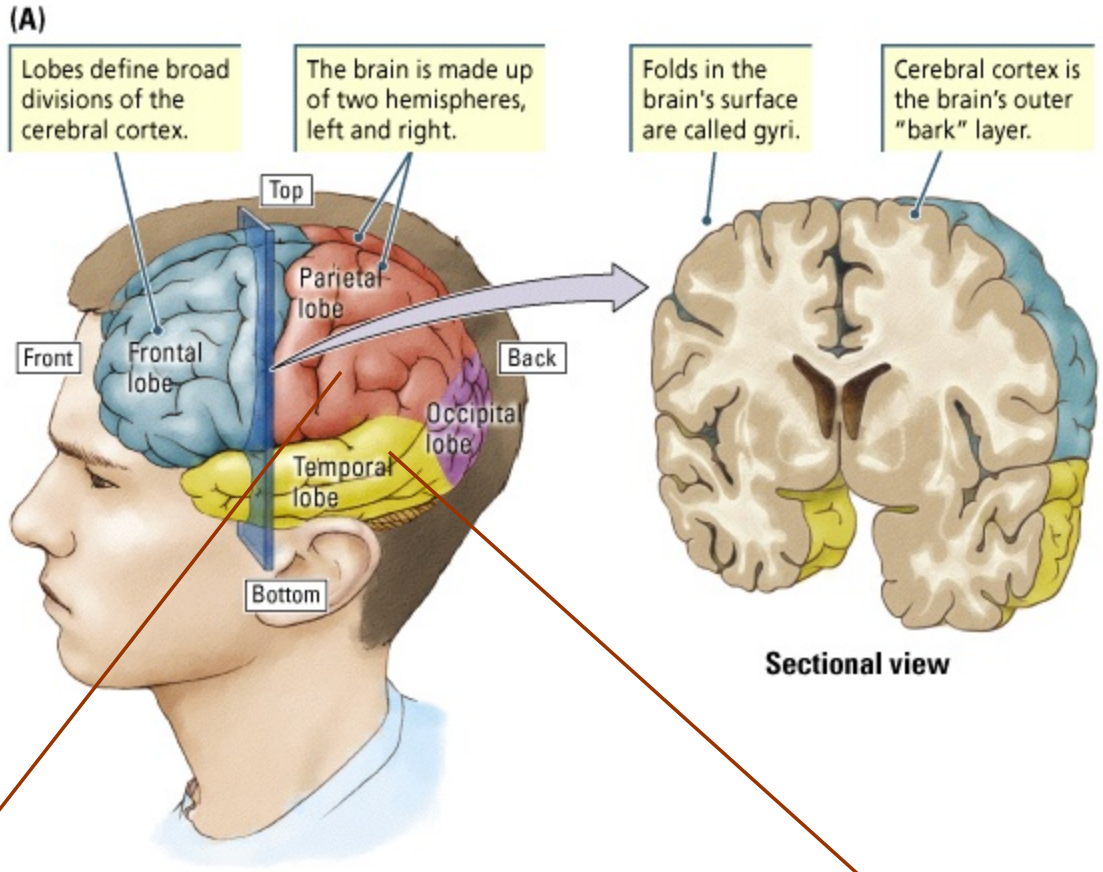
Frontalobotomy

What kind of section is this?



FRONTAL LOBE: contains MOTOR CORTEX
Planning, reasoning,
movement (map of the body)
some aspects of speech (like TULIP)

OCCIPITAL LOBE:
Seat of the visual cortex
Deals with visual information



PARIETAL LOBE:
Handles skin based proprioceptive information (heat, cold, pressure & pain)
Works closely with the motor areas.

TEMPORAL LOBE
Speech, hearing and Language

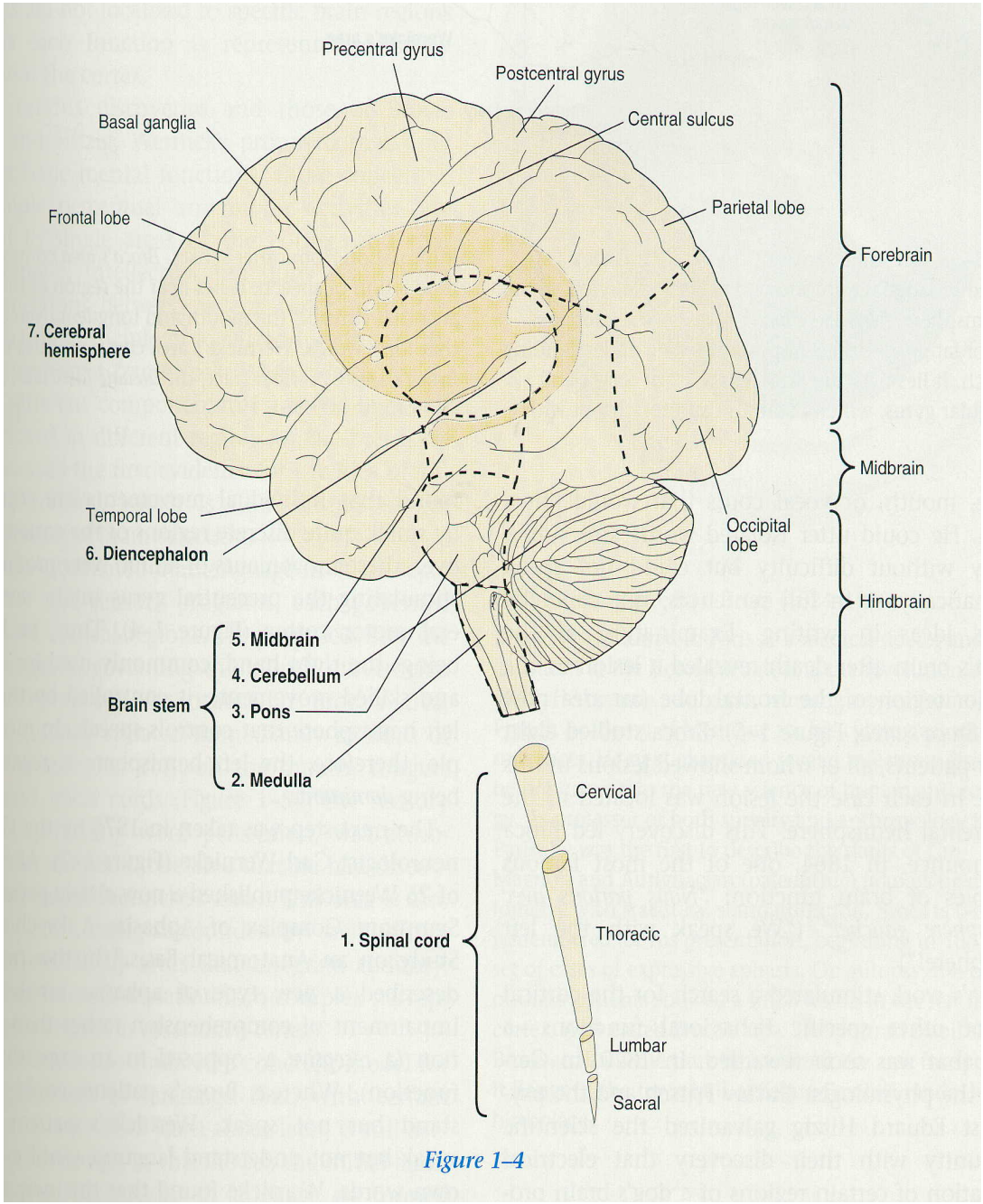


Figure 1–4

The evolved brain

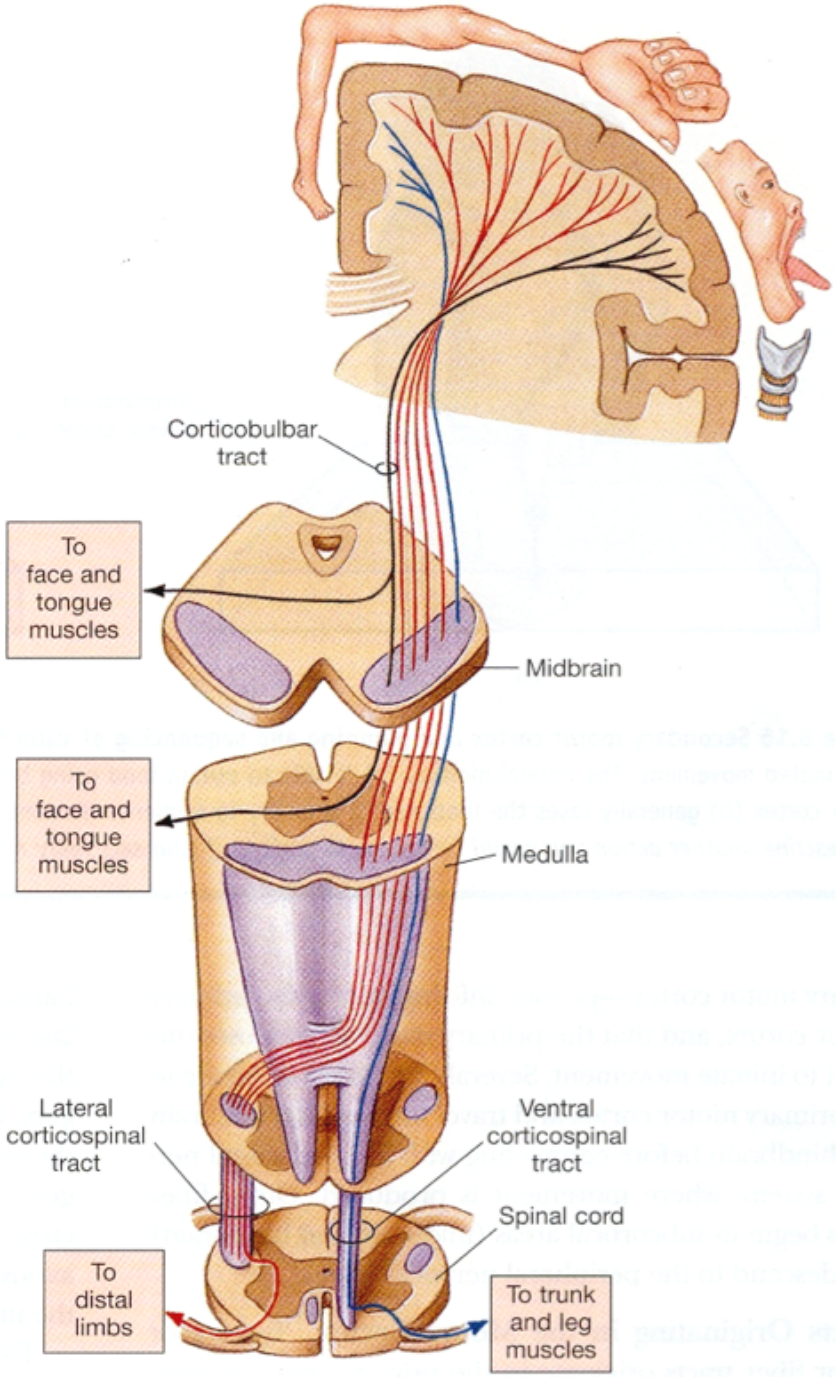
Neo-Mammalian brain

Paleo-mammalian brain

Reptilian brain

Netherbrain

BRAIN + spinal cord =
Central Nervous system



CORTEX

MIDBRAIN

& BRAIN STEM

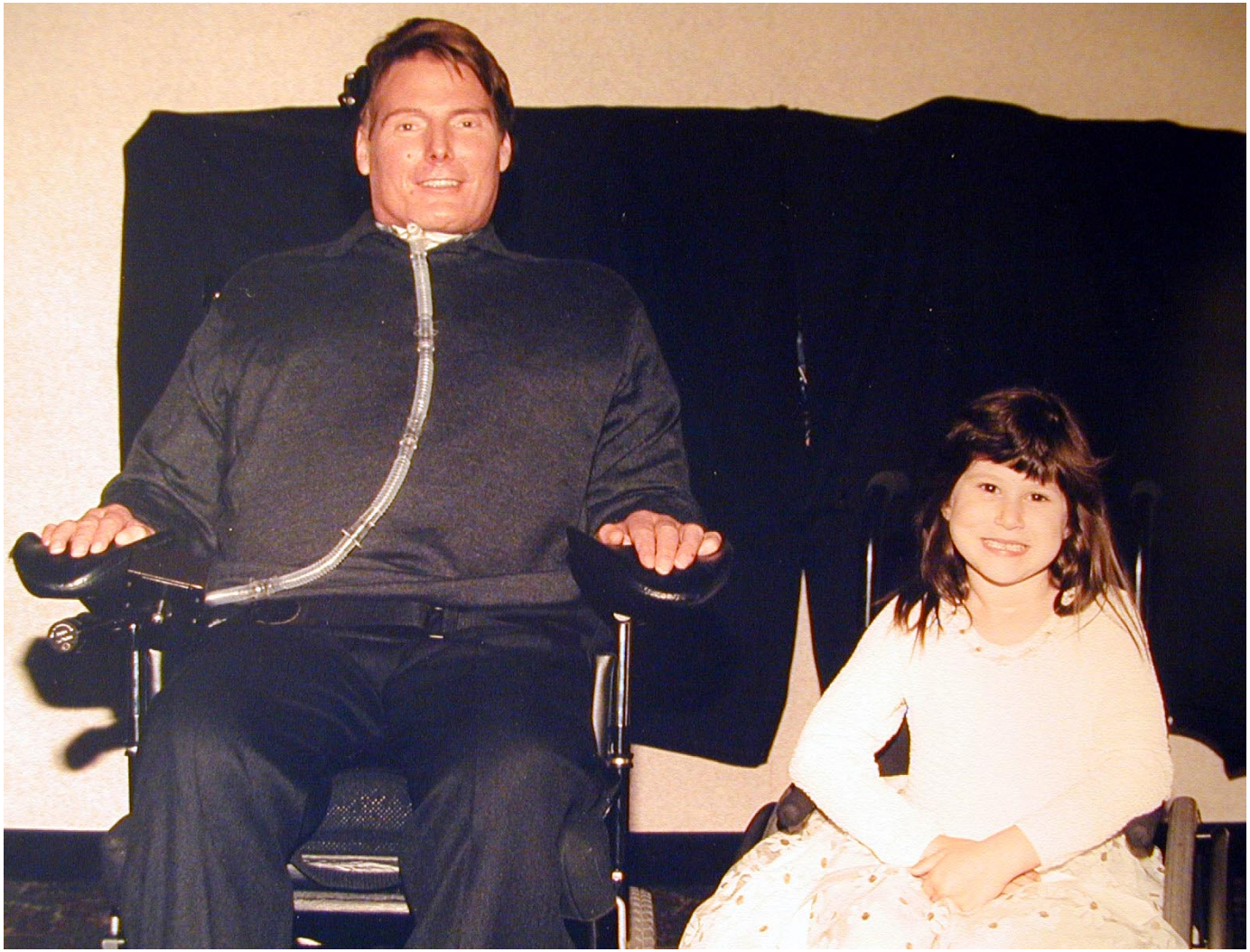
SPINAL CORD
Final common pathway

Spinal cord damage

- Spinal cord injury (SCI) occurs when a traumatic event results in damage to cells within the spinal cord or severs the nerve tracts that relay signals up and down the spinal cord.

- Most common are Lacerations (severing or tearing of some nerve fibers, such as damage caused by a gun shot wound /football injury/car accident).

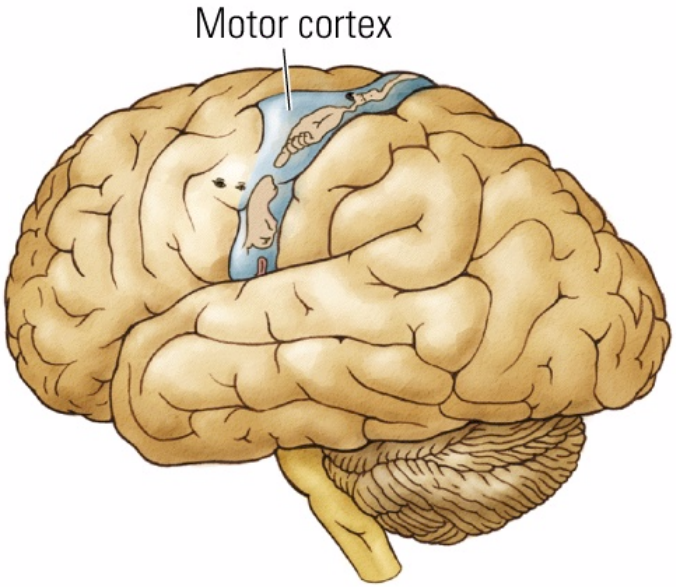
- Severe SCI often causes paralysis (loss of control over voluntary movement and muscles of the body) and loss of sensation and reflex function below the point of injury, including autonomic activity such as breathing and other activities such as bowel and bladder control.



SCI, deafferentation & Neuropathy

- Only afferent pathways are affected (no feedback going to the brain)
- Can come from accidents or even diabetes
- The role of proprioception: case study of Ian Waterman.

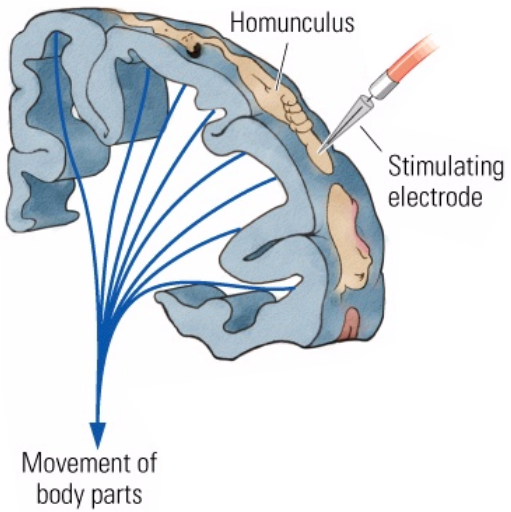
http://www.bbc.co.uk/music/dancersbody/body/proprioception.shtml

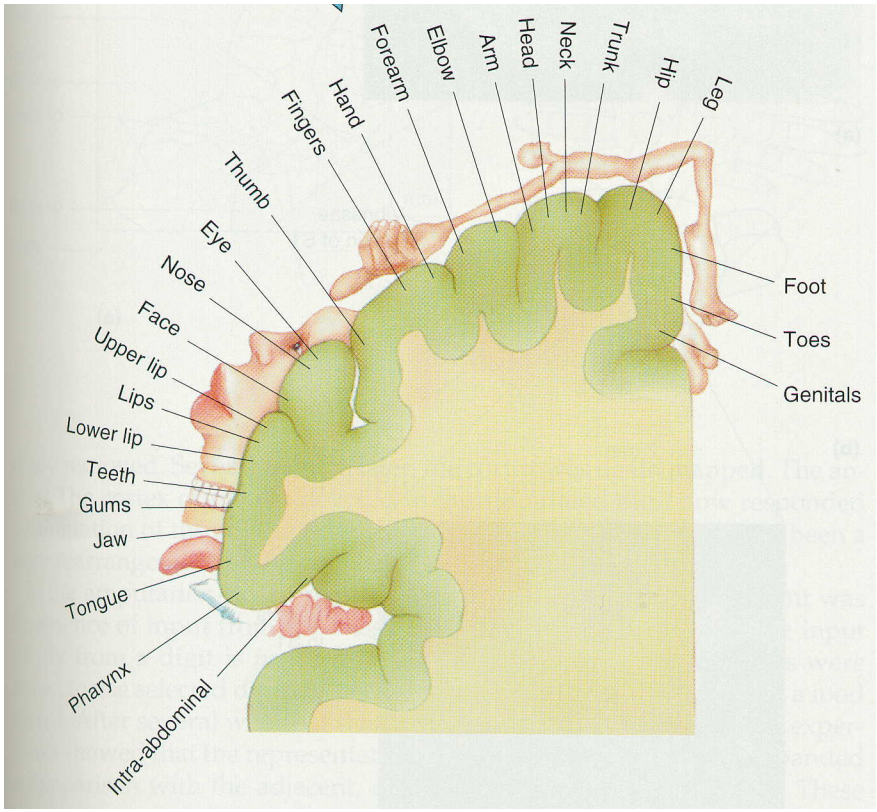


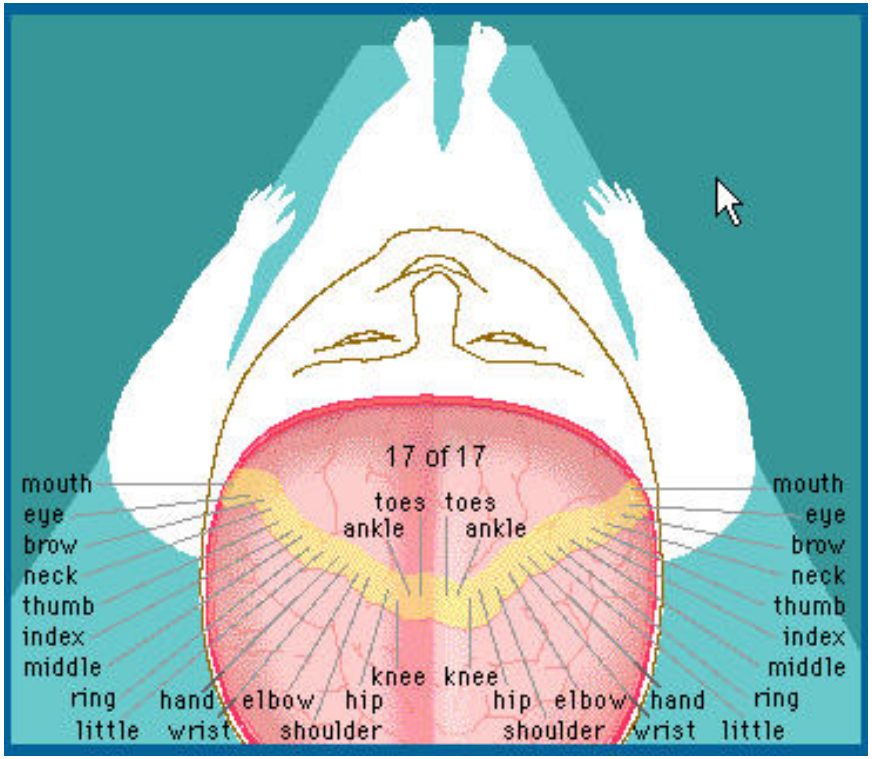
Motor homonculus

- **Organization of motor cortex reveals a map of the body**

- **Wilder Penfield aka Docteur Penfield**







This is what we would look like if we used the image from the motor cortex

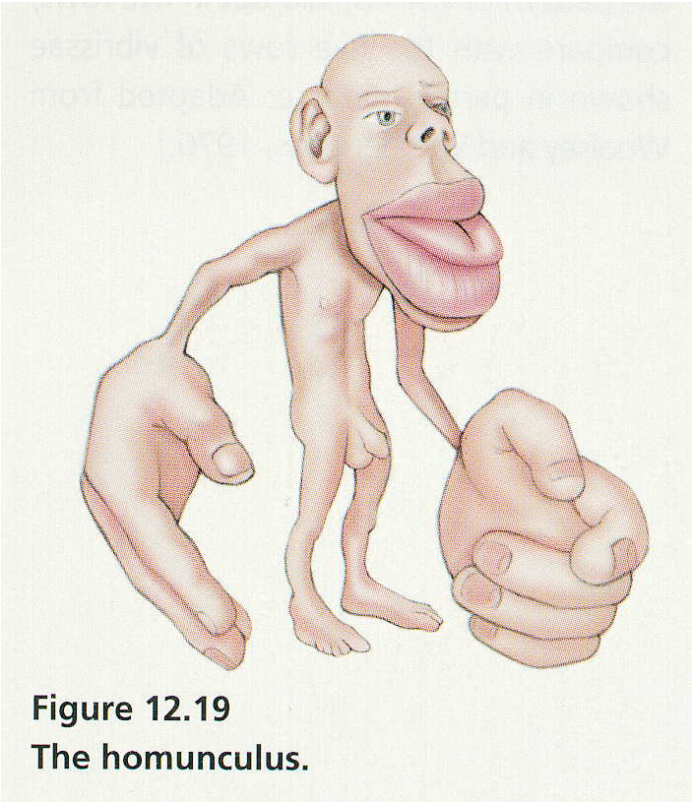


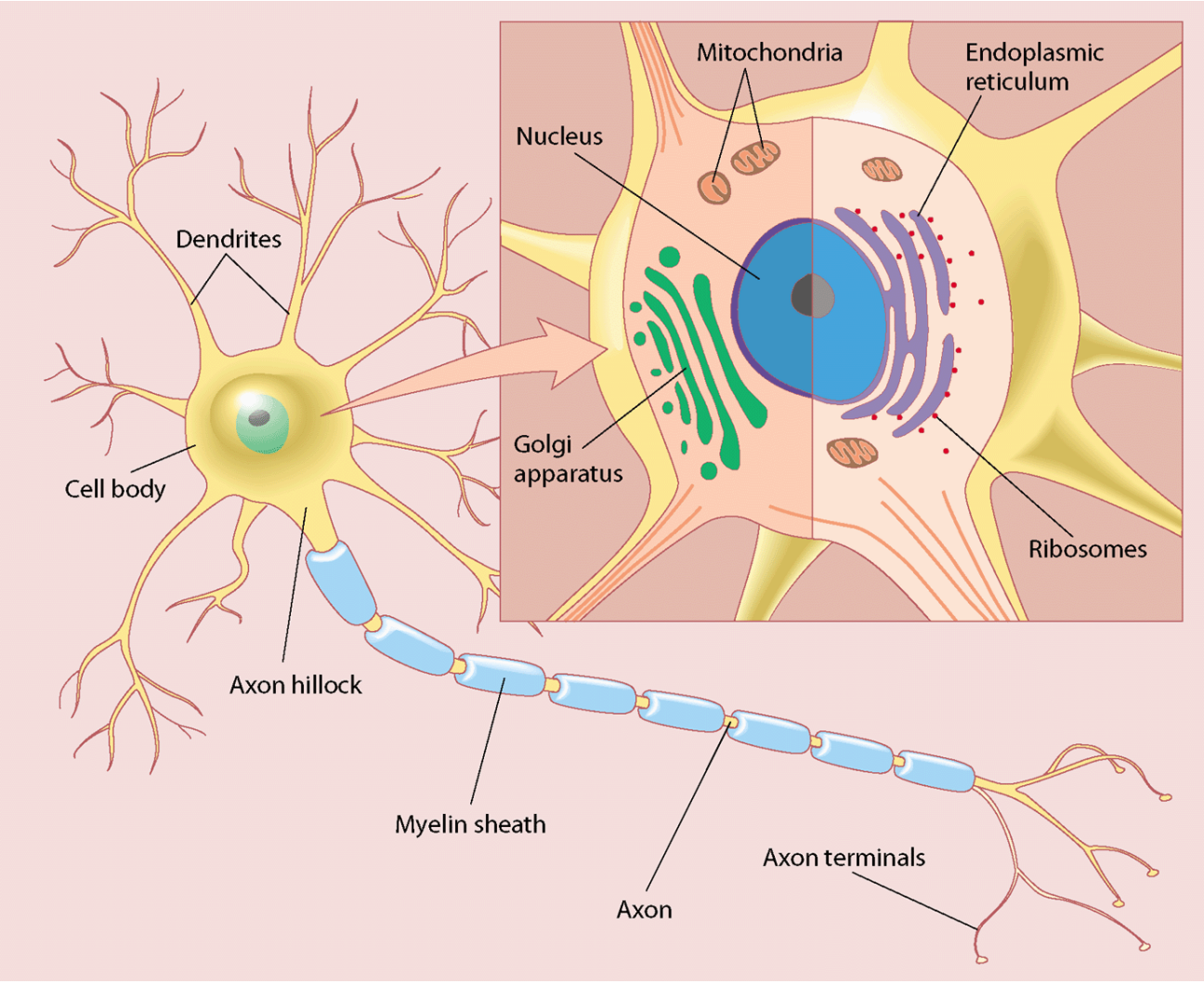
Figure 12.19
The homunculus.

Recap

- Brain and spinal cord
- Corticospinal (lateral & ventral), corticobulbar
- Structure of motor cortex (somatotopic map)
- Spinal cord damage
- Deafferentation and Neuropathy

The Anatomy of a Neuron

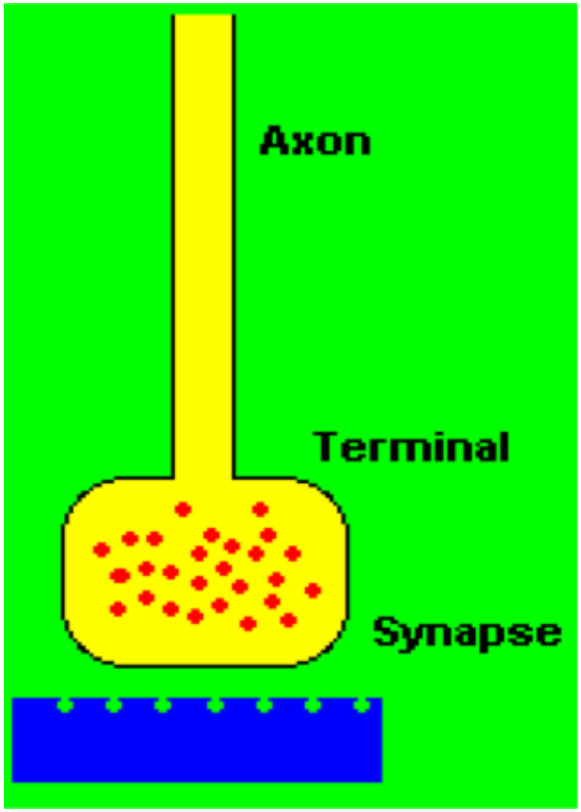
– cell body (or soma),
– dendrites,
– axon



Neuron Physiology

- neurons perform computations, they transform information.
- the functional components of a neuron.
  - an input component (dendrites)
  - an integration component (axon hillock)
  - a transmission component (axon)
  - an output component (synapse)
- passive vs. active conductance
- electrical vs. chemical transmission

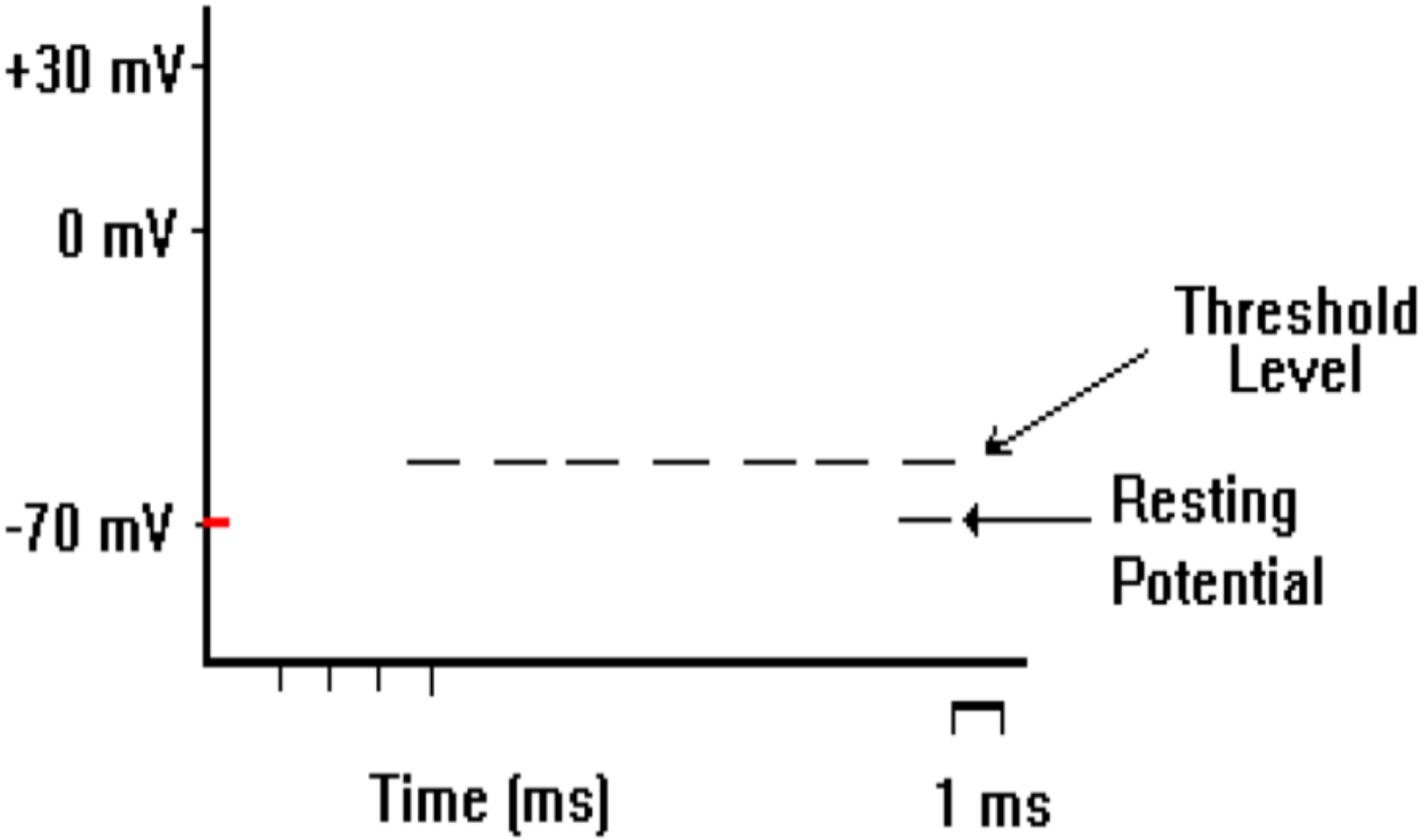
The Synapse



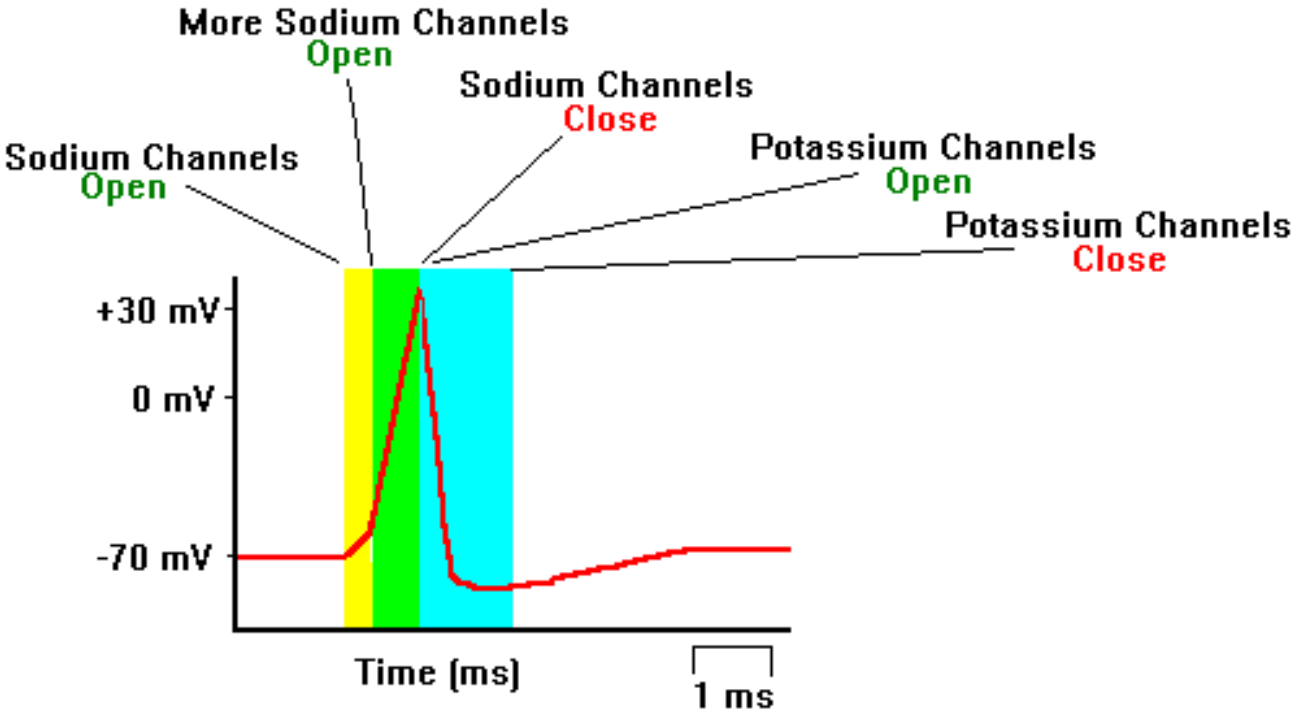
- Axon terminal releases neurotransmitters
- Neurotransmitters cross the synapse and bind to receptors on another neuron
- Neurotransmitters released, taken up again by first neuron

Neural Communication

- Neural messages reflect membrane potential changes
- A cell excited (stimulated) from its resting potential state fires an ACTION POTENTIAL → release neural message
- The neural message => Neurotransmission from one neuron to another neuron across a synapse.


+30 mV
0 mV
-70 mV
Threshold
Level
Resting
Potential
Time (ms)
1 ms

Action Potential



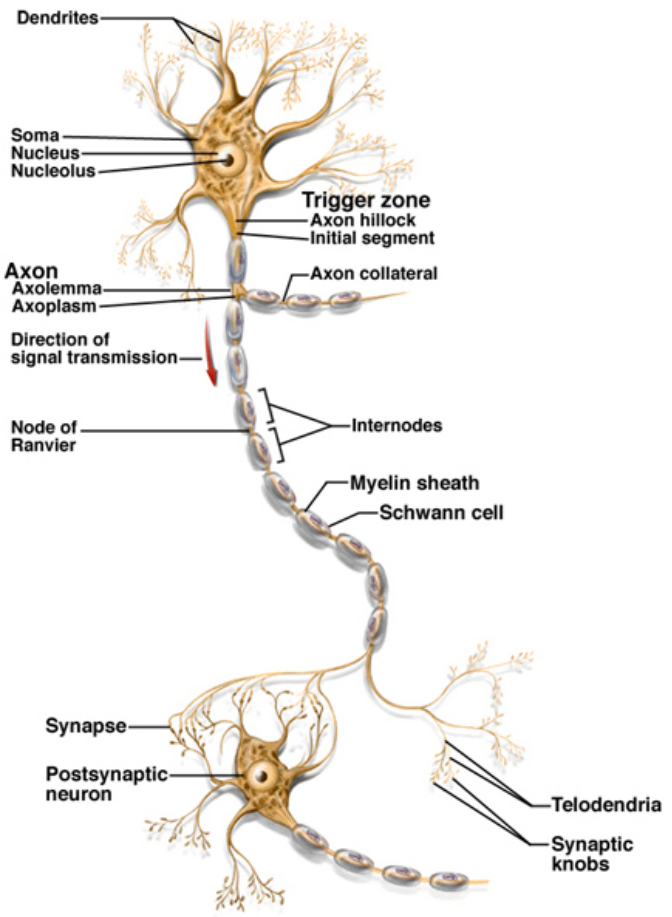
- **Involves the action of voltage-gated channels**
- **Massive, rapid exchanges of ions in and out of the cell**

Action Potentials

- How neurons transfer information
- Changes neuron's membrane potential
- Rising phase – membrane depolarizes
- Overshoot
- Falling phase – membrane repolarizes
- Undershoot
- Restoration of resting potential

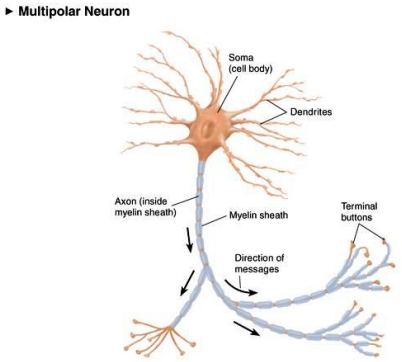
The Propagation of Action Potential

- Long-distance traveling:
  Eg. from the motor cortex
  to the spinal cord of giraffe.
- Loss-free and Fast
- The natural solution:
  - myelination
  - regeneration



Synaptic Transmission

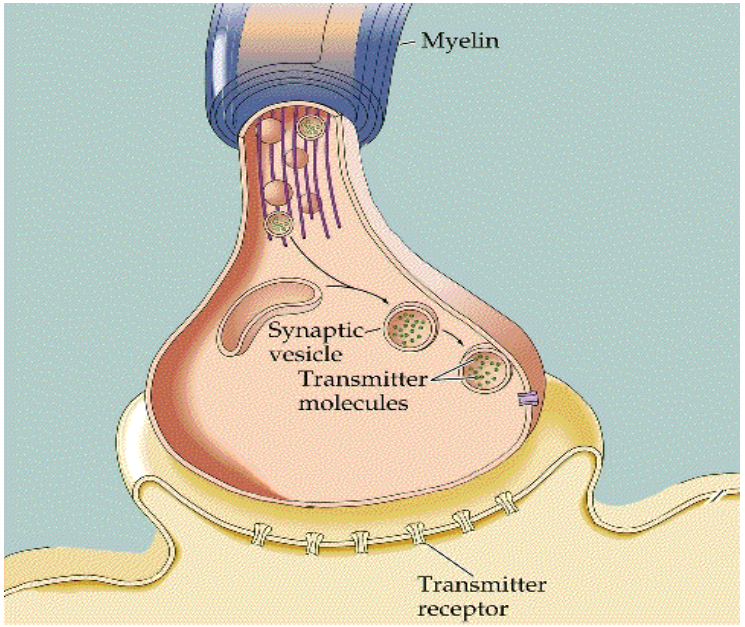
- When an action potential reaches the terminal button, synaptic vesicles release neurotransmitter (NT) into the synaptic cleft
- NT diffuses over the cleft
- At least three possible scenarios after this:
  - NT molecules do not attach to a postsynaptic receptor
  - NT released in an area with no immediate receptors
  - NT "keys into" a receptor site
- The latter scenario leads to change in the ionic permeability of the postsynaptic membrane
  - Excitatory postsynaptic potential (EPSP)
  - Inhibitory postsynaptic potential (IPSP)



Neuronal Interaction

- Chemical synapses and neurotransmitters

• Synapses: the contact sites between neurons
•Pre- and post- synaptic neurons
•Action potential triggers the release of neurotransmitter
•Neurotransmitters drift across the synaptic cleft
•Neurotransmitter-gated channels open, generating electrical current (or postsynaptic potential (PSP))
•Dependent on the sign of PSP, synapses are clarified as excitatory and inhibitory ones.



Neurotransmitters (NT)

Probably 100's

Neurons often classified by the NT it releases

Effect of NT depends on nature of receptor site

Neurotransmitters … Basic Concepts

- **Biosynthesis**: All NT - synthesized in the cell

- **General role of NT**:
  - Different NT seem to be important for different aspects of behaviour
  - Many drugs that affect behavior and experience do so by their effects on synaptic transmitters or on receptors

Glutamate

- Possibly, among the first NT type to have evolved

- Principal excitatory NT in the brain

- Produced in abundance in cells

- Biosynthesis: ά ketaglutarate

amino transferase

glutamate

- Stored in synaptic vesicles released at terminal buttons

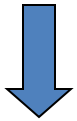
Gamma Amino-Butyric acid (GABA)

Principal inhibitory NT in the brain

- Produced in cells that contain glutamic acid decarboxylase

- Biosynthesis:

glutamate



glutamic acid decarboxylase

GABA

-Stored in synaptic vesicles released at terminal buttons
- Responsible for most of inhibitory information transmitted
    - Most neurons receive GABA types of input

- Alcohol facilitates (agonist) GABA receptors

Acetylcholine (ACh)

- First neurotransmitter discovered
- Generally Facilitative Effects
- Biosynthesis in the cell

- ***Functions in muscular contractions***
  - Secreted by efferent axons at muscular junctions - Initiates all voluntary actions

The Black widow spider (Latrodectus) and Cottonmouth are so toxic because they trigger massive release of acetylcholine from neurons.

Catecholamines

- Two important catecholamines:
  - Dopamine (DA)
  - Norepinephrine (NE)

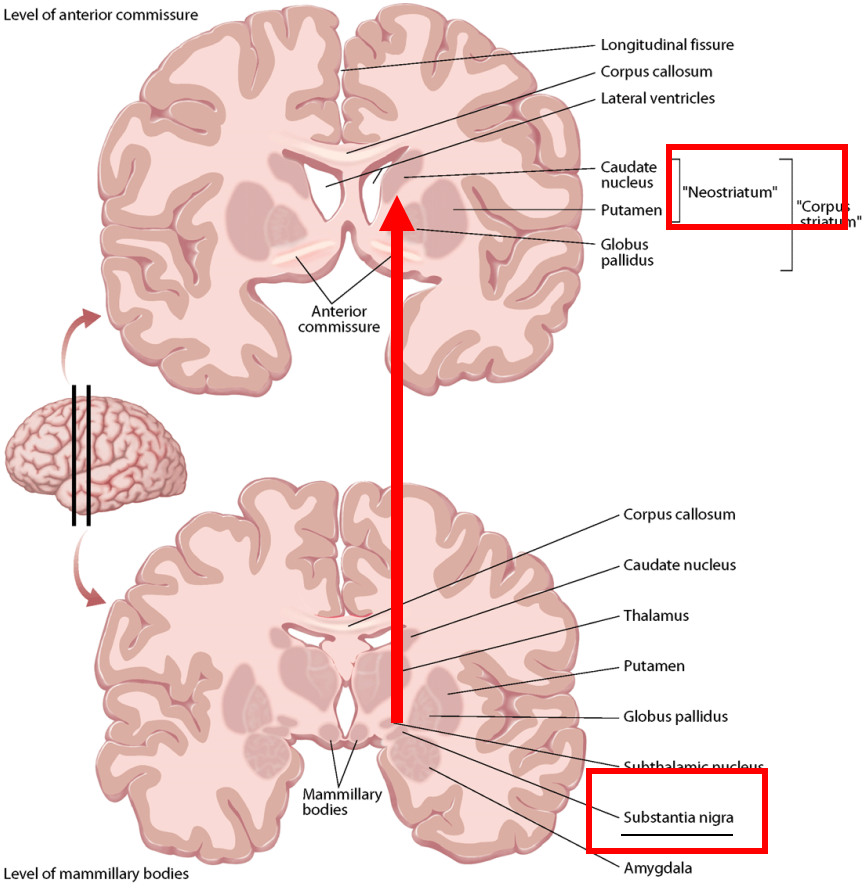
Produce both inhibitory and excitatory post synaptic potentials depending on the receptor

Essential function of catecholamines is to mobilize

- Stored in synaptic vesicles released at terminal buttons

DA

- *Involved in the control of movements*



Major DA Circuits & Nuclei

- The nigrostriatal system
- DA nuclei in the substantia nigra (SN).

SN -> striatum of the basal ganglia

Addictive drugs

- Nicotine, morphine, etc. Produce their effect by causing dopamine to be released.
- And dopamine can cause release of endocannabinoids (present in all neural systems).
- Glutamate and acetylcholine also initiate endocannabinoid synthesis and release.

Norepinephrine

- *Involved in attention and readiness to act; involved in the alarm reaction (a-k-a adrenalin)*
  - Transmitted to almost every brain region
  - Major cell bodies located in locus coeruleus of the pons, medulla, and thalamus

Indoleamine: Serotonin

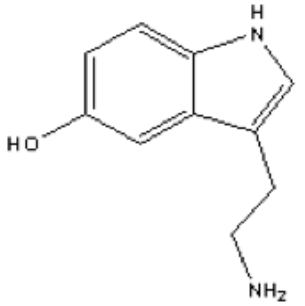
Functions: regulation of mood and pain; involved in eating, dreaming, and arousal

- Major Cell nuclei located in the raphe nucleus
- Raphe nucleus -> cerebral cortex, basal ganglia, dentate gyrus of hippocampus

LSD interacts with the 5HT transmission; LSD alters visual perceptions

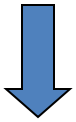
Overview of Serotonin

- Serotonin (5-hydroxytryptamine, or 5-HT) is a monoamine neurotransmitter synthesized in serotonergic neurons in the central nervous system.
- The functions of serotonin are numerous and appear to involve control of appetite, sleep, memory and learning, temperature regulation, mood, behavior (including sexual), cardiovascular function, muscle contraction, endocrine regulation, and depression



Serotonin (5HT) Biosynthesis

Tryptophan (an dietary amino acid)



tyrosine hydroxylase

5-hydroxytryptopahn (5-HTP)

5HT decarboxylase

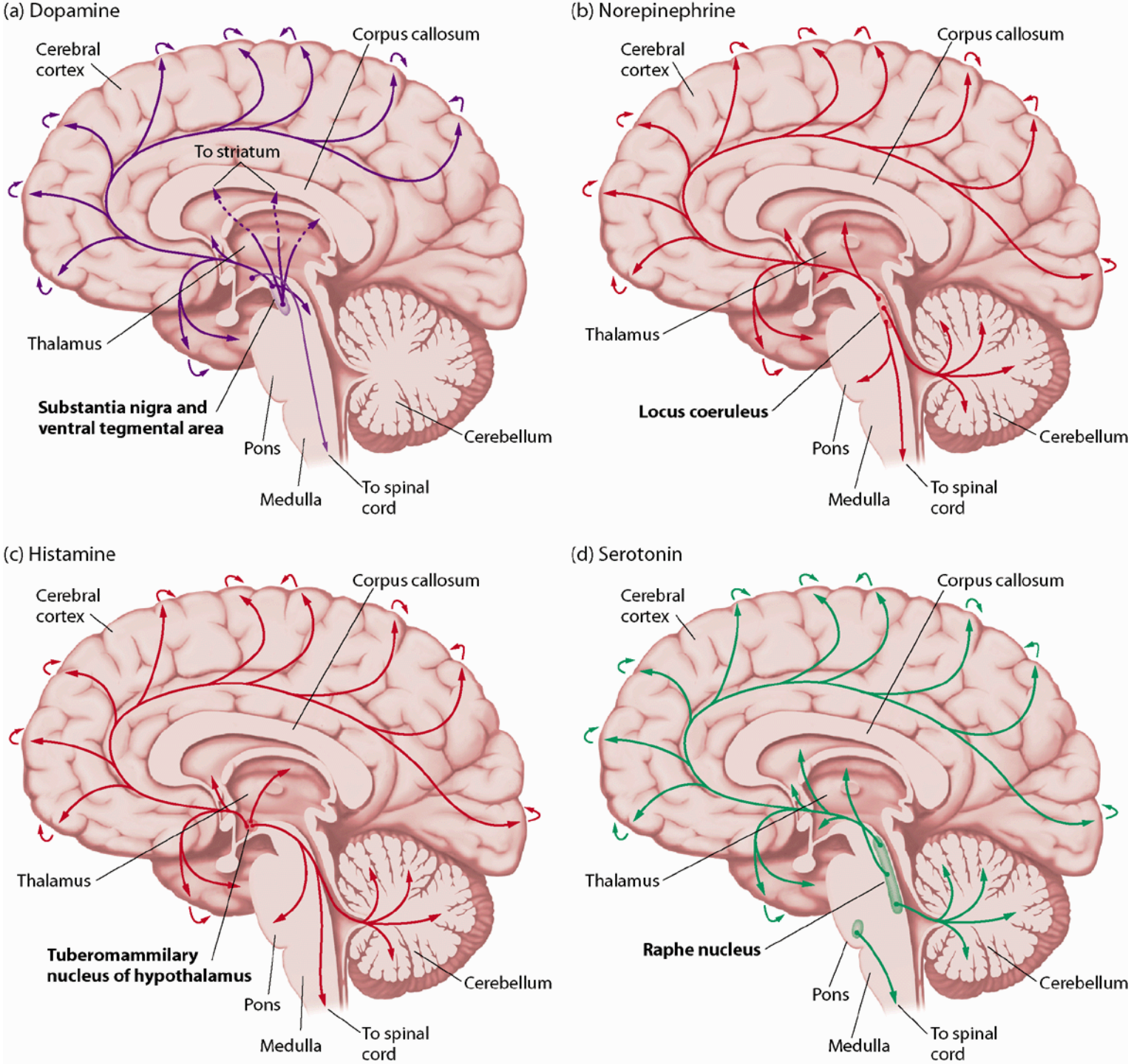
5–HT (5-hydroxytryptamine)

Tryptophan (an dietary amino acid) -> obtained from bananas, corn, meats (turkey),
Meals can alter synthesis of 5HT: chocolate and sugars boost up synthesis of 5HT

Recap

- Neurons : Structure
- Action potential
- Electrical vs chemical activity
- Neurotransmitters
- How they relate to brain functioning

Class	*Examples*
Amino Acids	Glutamate GABA
Acetylcholine	Acetylcholine
Monoamines	Serotonin Dopamine Norepinephrine Epinephrine
Purines	Adenosine
Gases	Nitric Oxide (NO)
Peptides	Endorphins


(a) Dopamine
Cerebral cortex
Corpus callosum
To striatum
Thalamus
Substantia nigra and ventral tegmental area
Pons
Cerebellum
Medulla
To spinal cord
(b) Norepinephrine
Cerebral cortex
Corpus callosum
Thalamus
Locus coeruleus
Pons
Cerebellum
Medulla
To spinal cord
(c) Histamine
Cerebral cortex
Corpus callosum
Thalamus
Tuberomammilary nucleus of hypothalamus
Pons
Cerebellum
Medulla
To spinal cord
(d) Serotonin
Cerebral cortex
Corpus callosum
Thalamus
Raphe nucleus
Pons
Cerebellum
Medulla
To spinal cord

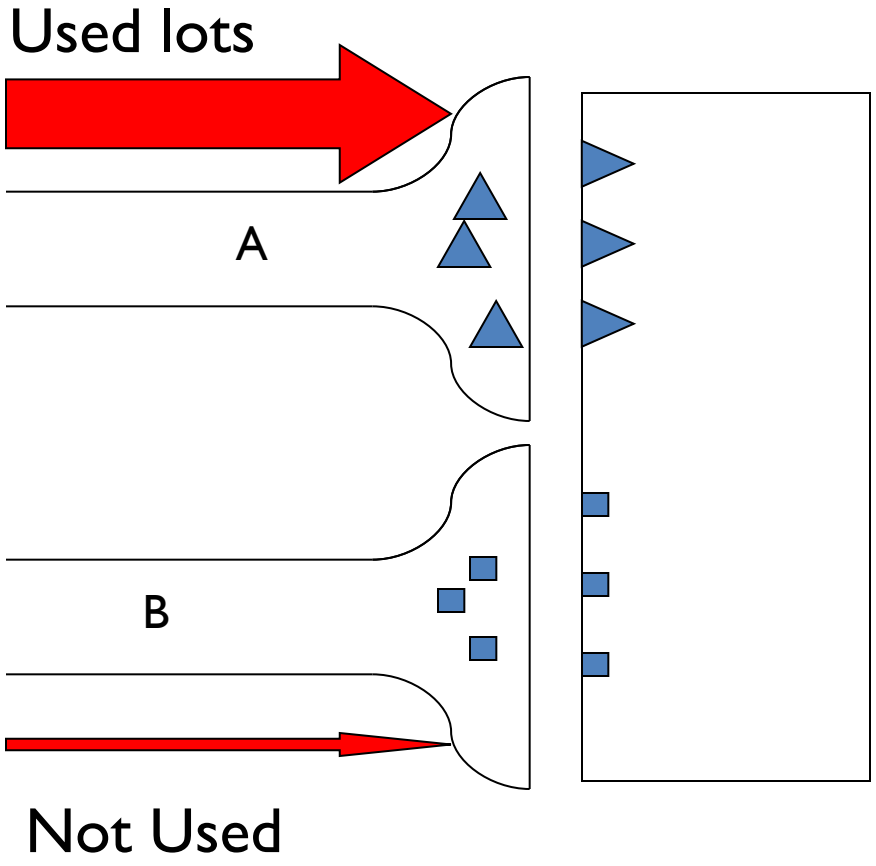
How do Neurons compute?

- By changing conduction and ion potentials.
- Made possible by Neurotransmitters.
- Strengthening and weakening of synapses

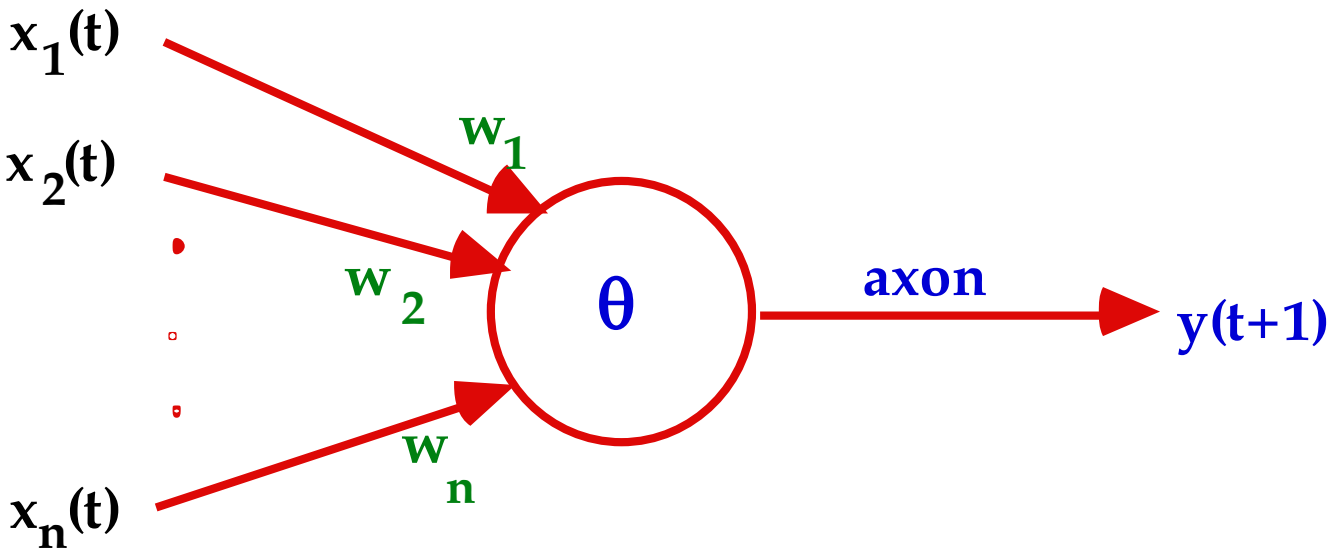
(Hebbian learning rule).

Strengthening synapses

- Synapses used often are strengthened (A)
- Those not used are weakened and can become ineffective (B)



Neurons that fire together, wire together

Learning Rule:

When two connected neurons are both excited, the connection between them is strengthened