Biology of the Mind

Neural and Hormonal Systems

Worth/Palgrave/Macmillan Publishers

Neural Communication

- Biological Psychology
  - branch of psychology concerned with the links between biology and behavior
  - Other titles for biological psychologists include: *behavioral neuroscientists, neuropsychologists, behavior geneticists, physiological psychologists,* or *biopsychologists*
- Neuron
  - a nerve cell
  - the functioning unit of the nervous system
  - Specialized to receive, integrate, and transmit information.

Neural Communication: Parts of a Neuron

- Dendrite
  - the bushy, branching extensions of a neuron that receive messages and conduct impulses toward the cell body
- Axon
  - the extension of a neuron, ending in branching terminal fibers, through which messages are sent to other neurons or to muscles or glands
- Myelin [MY-uh-lin] Sheath
  - a layer of fatty cells segmentally encasing the fibers of many neurons
  - enables vastly greater transmission speed of neutral impulses

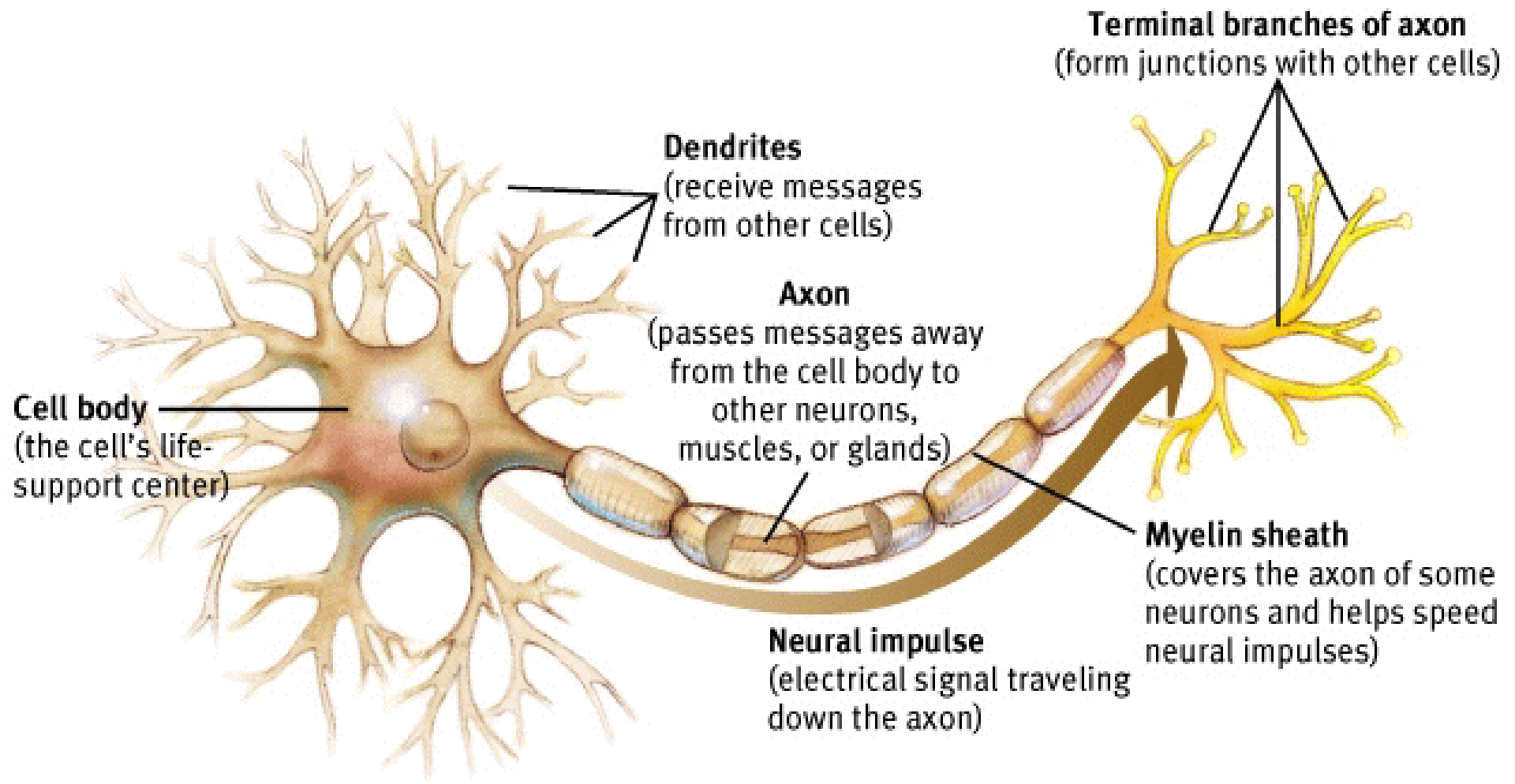
Neural Communication: Parts of a Neuron

- Soma (cell body)
  - Contains the nucleus; may be in the middle, along the main line of the neuron(bipolar neuron), or on a branch of a nerve cell (multipolar neuron)
- Node of Ranvier
  - The small constricted part of the neuron's myelin sheath that separate the axons along the cell's length.
- Schwann Cells
  - Wrap themselves around each segment of myelin sheath covering each axon segment of the nerve cells and constrict at the Nodes of Ranvier.
  - The neurons of the brain and spinal cord do not have such a cell layer covering their myelin sheaths.

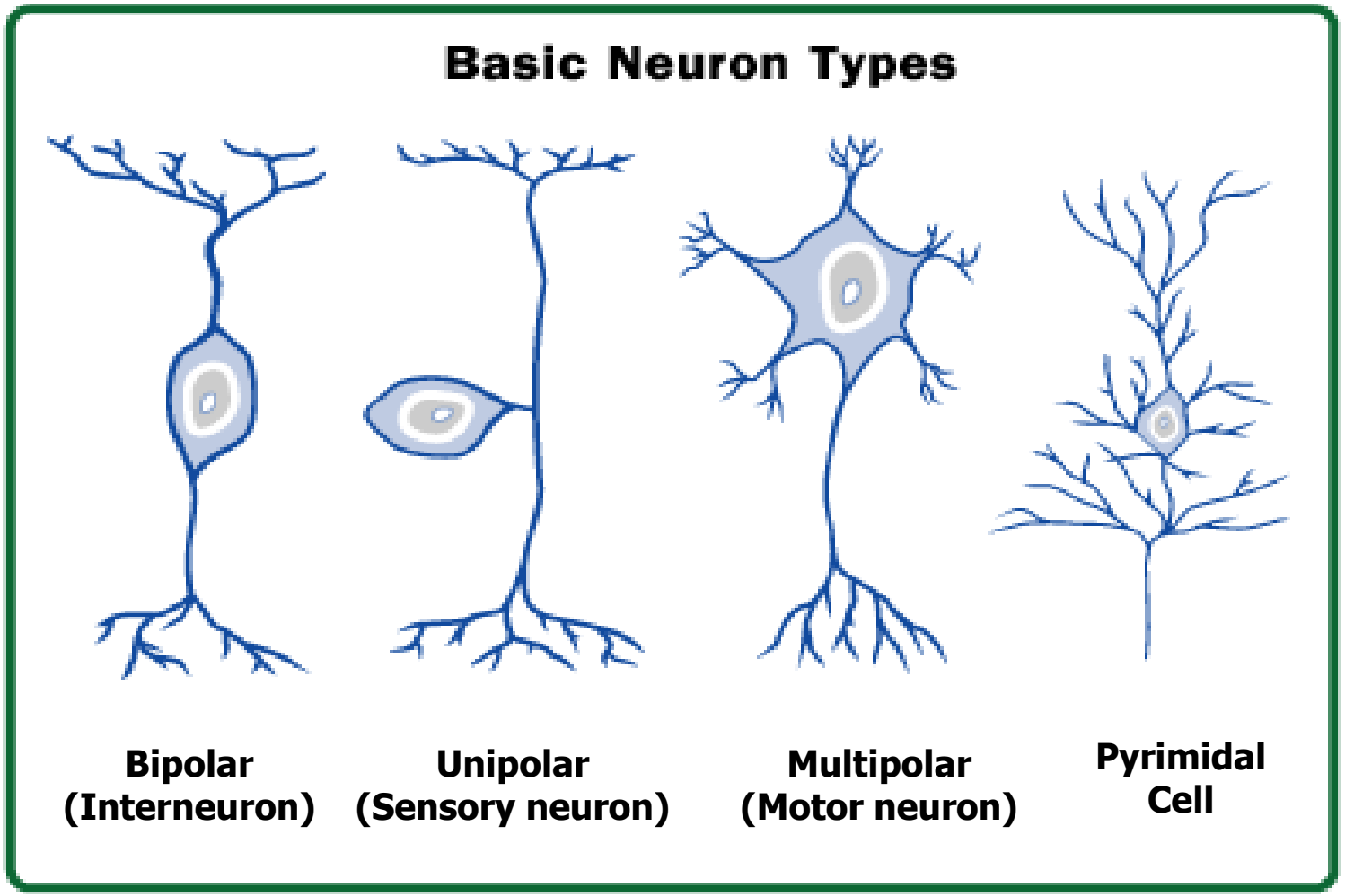
Neural Communication: Parts of a Neuron

- Terminal Branches
  - Hair-like ends of axons that transport synaptic vesicles containing neurotransmitters to the terminal buttons where they are secreted into the synaptic gap
- Terminal Button
  - Knob-like structures that release chemicals, i.e., neurotransmitters, into the space between the neurons, i.e., synaptic cleft (synaptic gap).

Neural Communication: Parts of a Neuron



Neural Communication: Identifying Differen Neurons



Neural Communication

- Action Potential
  - a neural impulse; a brief electrical charge that travels down an axon
  - generated by the movement of positively charged ions in and out of channels in the axon's membrane
- Threshold
  - the lowest level of stimulation required to trigger a neural impulse

Neural Communication

- Neurons vary with respect to their function:

Sensory neurons: (Afferent) Carry signals from the outer parts of your body (periphery) toward the central nervous system.

Motor neurons: (motoneurons) (Efferent) Carry signals away from the central nervous system to the outer parts (muscles, skin, glands) of your body.

Receptors: Sense the environment (chemicals, light, sound, touch) and encode this information into electrochemical messages that are transmitted by sensory neurons.

Interneurons: (a.k.a. association neuron, connecting neuron) - these neurons connect one neuron with another. For example in many reflexes interneurons connect the sensory neurons with the motor neurons

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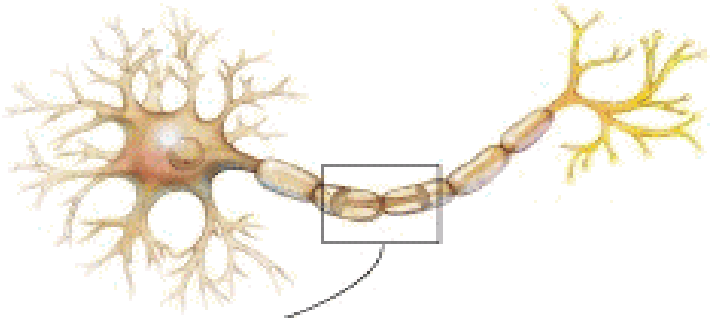
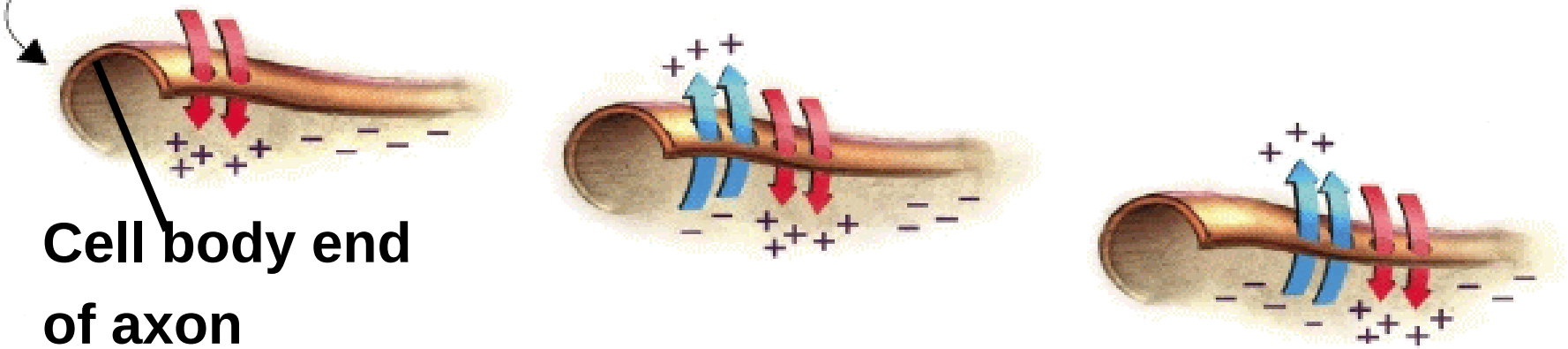
Neural Communication





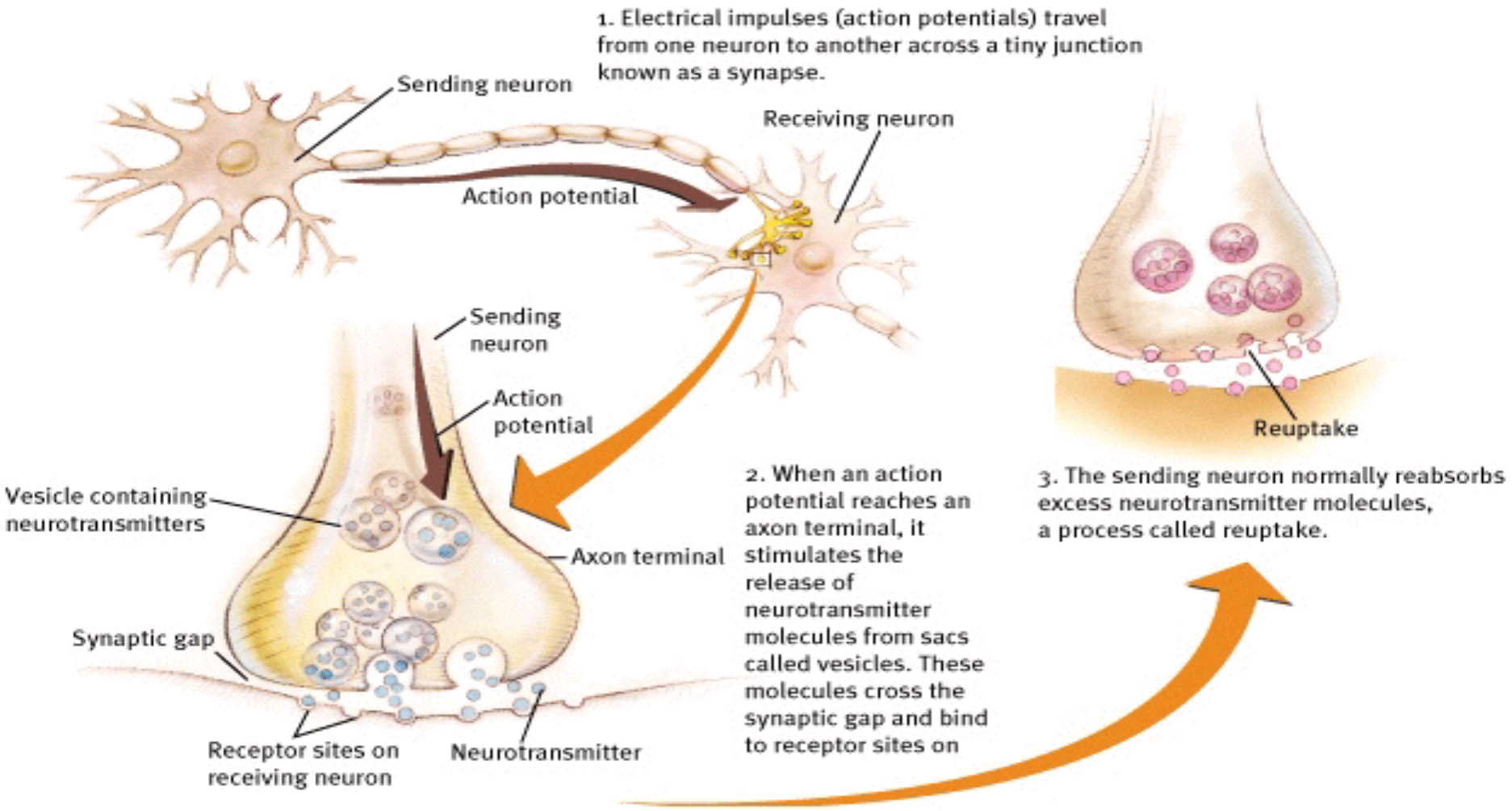
Cell body end of axon

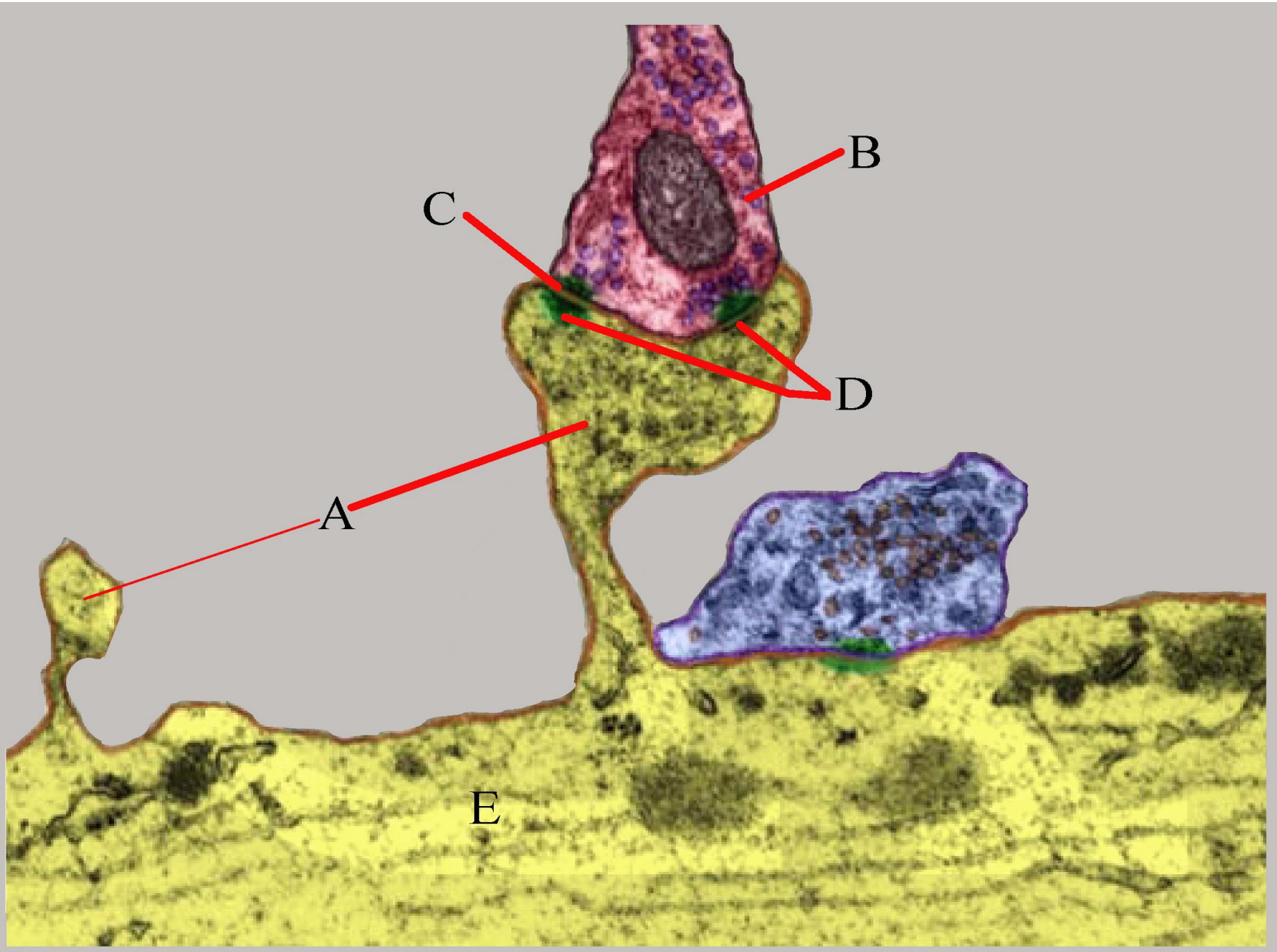
Direction of neural impulse: toward axon terminals

Neural Communication

- Synapse [SIN-aps]
  - junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron
  - tiny gap at this junction is called the *synaptic gap* or *cleft*
- Neurotransmitters
  - chemical messengers that traverse the synaptic gaps between neurons
  - when released by the sending neuron, neurotransmitters travel across the synapse and bind to receptor sites on the receiving neuron, thereby influencing whether it will generate a neural impulse

Neural Communication

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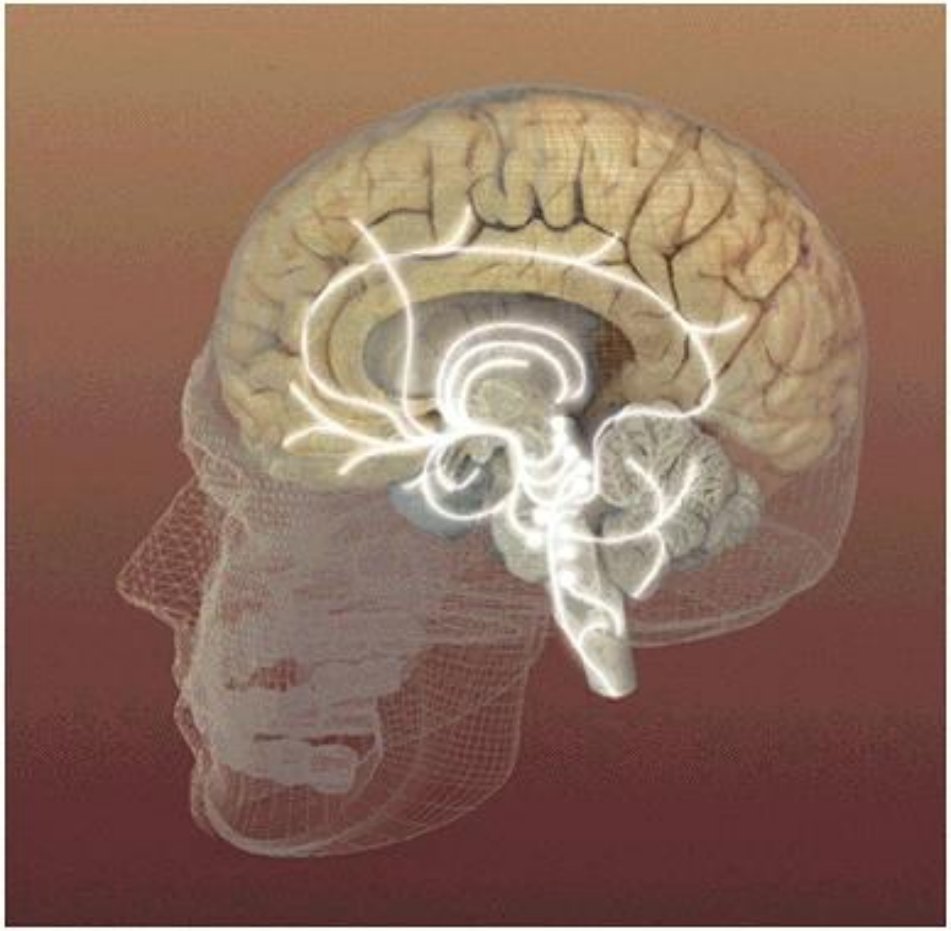
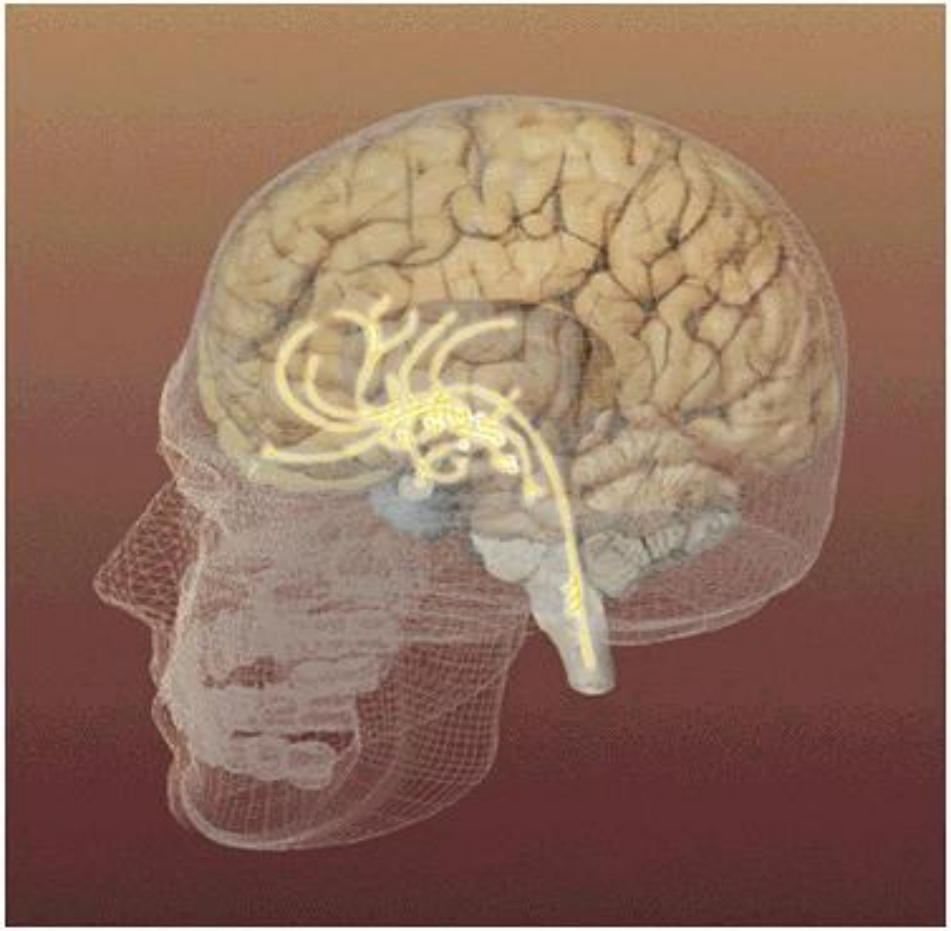
Neural Communication



Serotonin pathways

Serotonin Pathways



Dopamine pathways

Dopamine Pathways

Neural Communication

TABLE 2.1

SOME NEUROTRANSMITTERS AND THEIR FUNCTIONS

Neurotransmitter	Function	Examples of Malfunctions
Acetylcholine (ACh)	Enables muscle action, learning, and memory	Undersupply, as ACh-producing neurons deteriorate, marks Alzheimer's disease
Dopamine	Influences movement, learning, attention, and emotion	Excess dopamine receptor activity linked to schizophrenia; starved of dopamine, the brain produces the tremors and decreased mobility of Parkinson's disease
Serotonin	Affects mood, hunger, sleep, and arousal	Undersupply linked to depression; Prozac and some other antidepressant drugs raise serotonin levels
Norepinephrine	Helps control alertness and arousal	Undersupply can depress mood
GABA (gamma-aminobutyric acid)	A major inhibitory neurotransmitter	Undersupply linked to seizures, tremors, and insomnia
Glutamate	A major excitatory neurotransmitter; involved in memory	Oversupply can overstimulate brain, producing migraines or seizures (which is why some people avoid MSG, monosodium glutamate, in food)

Chemical Messengers in the NS

- **Neurotransmitters**
- **Endorphins**
- **Hormones**

Neurotransmitters

- Neurotransmitters travel from one neuron to another. Changes occur in the receiving neuron's membrane,
- The ultimate effect is either:
  - **Excitatory:** the probability that the receiving neuron will fire increases
  - **Inhibitory:** the probability that the receiving neuron will fire decreases

Neurotransmitters

Serotonin

Sleep, appetite, sensory perception, temperature regulation, pain suppression, and mood

Dopamine

Voluntary movement, learning, memory, and emotion

Acetylcholine

Muscle action, cognitive functioning, memory, and emotion

Neurotransmitters

Norepinephrine

Increased heart rate and the slowing of intestinal activity during stress, learning, memory, dreaming, waking from sleep, and emotion

GABA

(gama-aminobutyic acid)

The major inhibitory neurotransmitter in the brain

Neural Communication

- Acetylcholine [ah-seat-el-KO-leen]
  - a neurotransmitter that, among its functions, triggers muscle contraction; when inhibited, paralysis occurs
- Endorphins [en-DOR-fins]
  - Short for endogenous (produced within) morphine
  - natural, opiate-like neurotransmitters
  - linked to pain control and to pleasure

Endorphins

1. They have an effect similar to that of opiates.
2. They reduce pain and promote pleasure.
3. They play a role in appetite, sexual activity, blood pressure, mood, learning, and memory.
4. Some endorphins function as neurotransmitters.

Endorphins
Neuromodulators

Most endorphins act as **neuromodulators,** which alter the effect of neurotransmitters by limiting or prolonging their effects.

How Drugs and Other Chemicals Alter Neurotransmitters

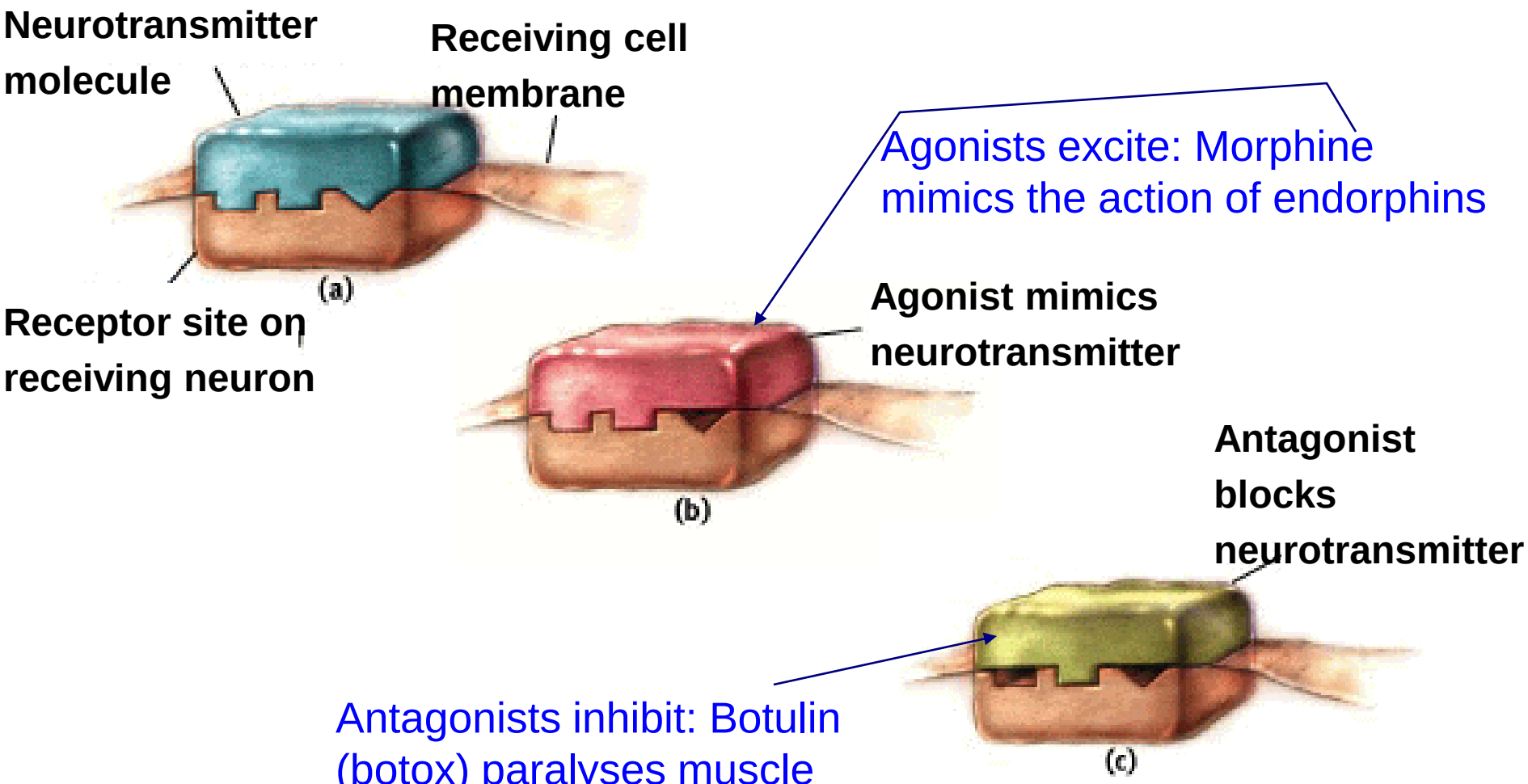
The agonist molecule excites. It mimics the effects of a neurotransmitter on the receiving neuron.

Morphine mimics the action of neurotransmitters by stimulating receptors in the brain involved in mood and pain sensation.

The antagonist molecule inhibits by blocking the neurotransmitters or by diminishing their release.

Botulin poison causes paralysis by blocking receptors for acetylcholine (a neurotransmitter that produces muscle movement)

Neural Communication



Neurotransmitters & Hormones

Acetylcholine

Shortage in acetylcholine may be associated with Alzheimer's disease

Dopamine

The degeneration of brain cells that produce and use another neurotransmitter, dopamine, appears to cause symptoms of Parkinson's disease.

Low levels of dopamine may cause ADHD

Neurotransmitters & Hormones

Serotonin

Decrease in norepinephrine and serotonin is associated with depression. Elevated levels along with other biochemical and brain abnormalities have been implicated in childhood autism.

Norepinephrine

Norepinephrine, epinephrine, and adrenaline are associated with excitement and stress.

Neurotransmitters & Hormones

Cortisol

Cortisol is associated with stress. Increase in cortisol damages the brain and may be associated with posttraumatic stress.

GABA

Abnormal GABA levels have between implicated in sleep and eating disorders and in compulsive disorders.

Glutamate

Glutamate, serotonin, and high levels of dopamine have been associated with schizophrenia

Hormones

Insulin

Produced by the pancreas

Regulates the body's use of glucose & affects appetite

Melatonin

Secreted by the pineal gland

Helps to regulate daily biological rhythms and promotes sleep.

Hormones

Sex Hormones

Are secreted by the gonads and by the adrenal glands

Androgens

Masculinizing Hormones

Estrogens

Feminizing Hormones

Is the brain capable of reorganizing itself if damaged?

Neuroplasticity

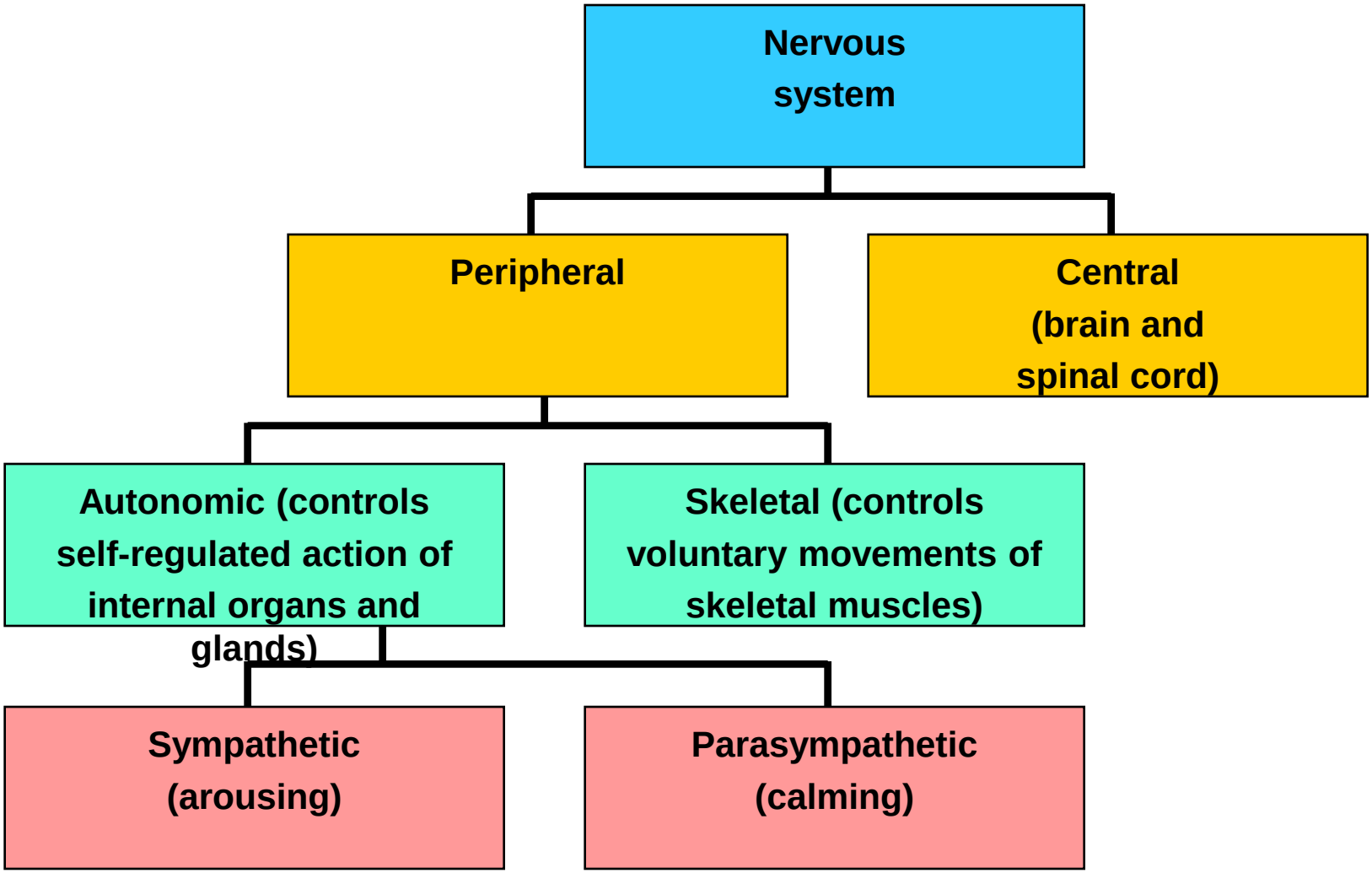
- When one brain area is damaged, other areas may in time reorganize and take over some of its functions.
- If neurons are destroyed, nearby neurons may partly compensate for the damage by making new connections that replace the lost ones.
- **Examples:**
  a) How the sense of touch in blind men invades the visual part of the brain.
  b) How the brain struggles to recover from a minor stroke.

Can damaged neurons in the central nervous system multiply and grow back?

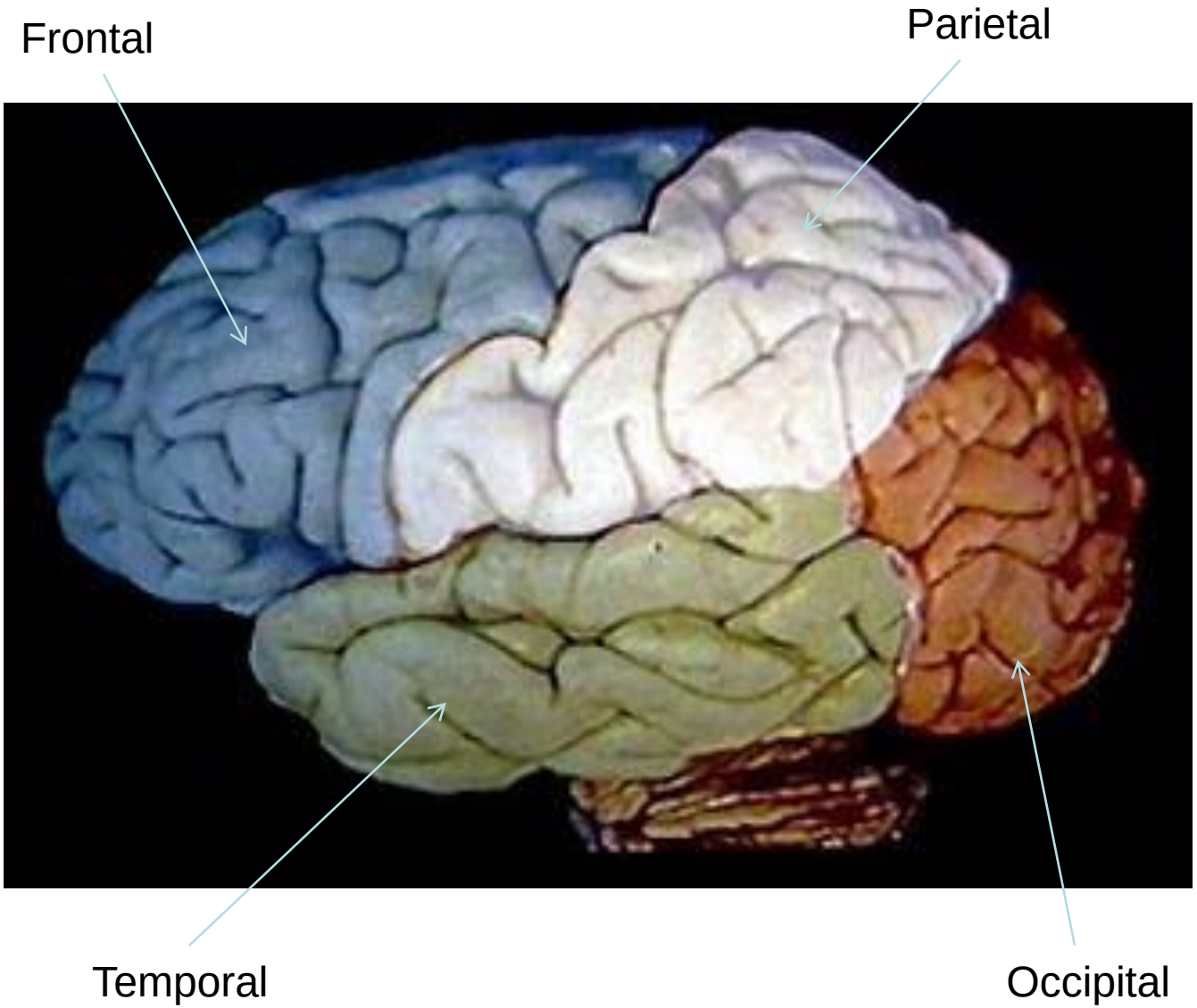
Precursor Cells (Immature Cells)

- Precursor cells can give birth to new neurons when immersed in a **growth-promotion protein**
- **Physical and mental exercise** promote the survival and the production of new precursor cells
- **Stress** can prohibit the production of new cells
- **Nicotine** can kill precursor cells

The Nervous System



Lobes of the Brain



The Nervous System

- Nervous System
  - The body's fast and efficient, electrochemical communication system
  - Consists of all the nerve cells of the peripheral and central nervous systems
  - The human brain has approximately 100 billion neurons

The Nervous System: Structural Divisions

- Central Nervous System (CNS)
  - the brain and spinal cord
- Peripheral Nervous System (PNS)
  - the sensory and motor neurons that connect the central nervous system (CNS) to the rest of the body

The Nervous System: Functional Divisions

- Voluntary Nervous System (a.k.a. Somatic)
  - Responsible for the willful control of skeletal muscles and conscious perception
  - Mediates voluntary reflexes

The Nervous System: Functional Divisions

- Autonomic Nervous System (ANS)
  - Responsible for the self-regulating aspects of the body's nervous network
  - Regulates involuntary smooth muscle movement, heart, glands
  - Comprised of 2 sub-systems:
    - Sympathetic
    - Parasympathetic

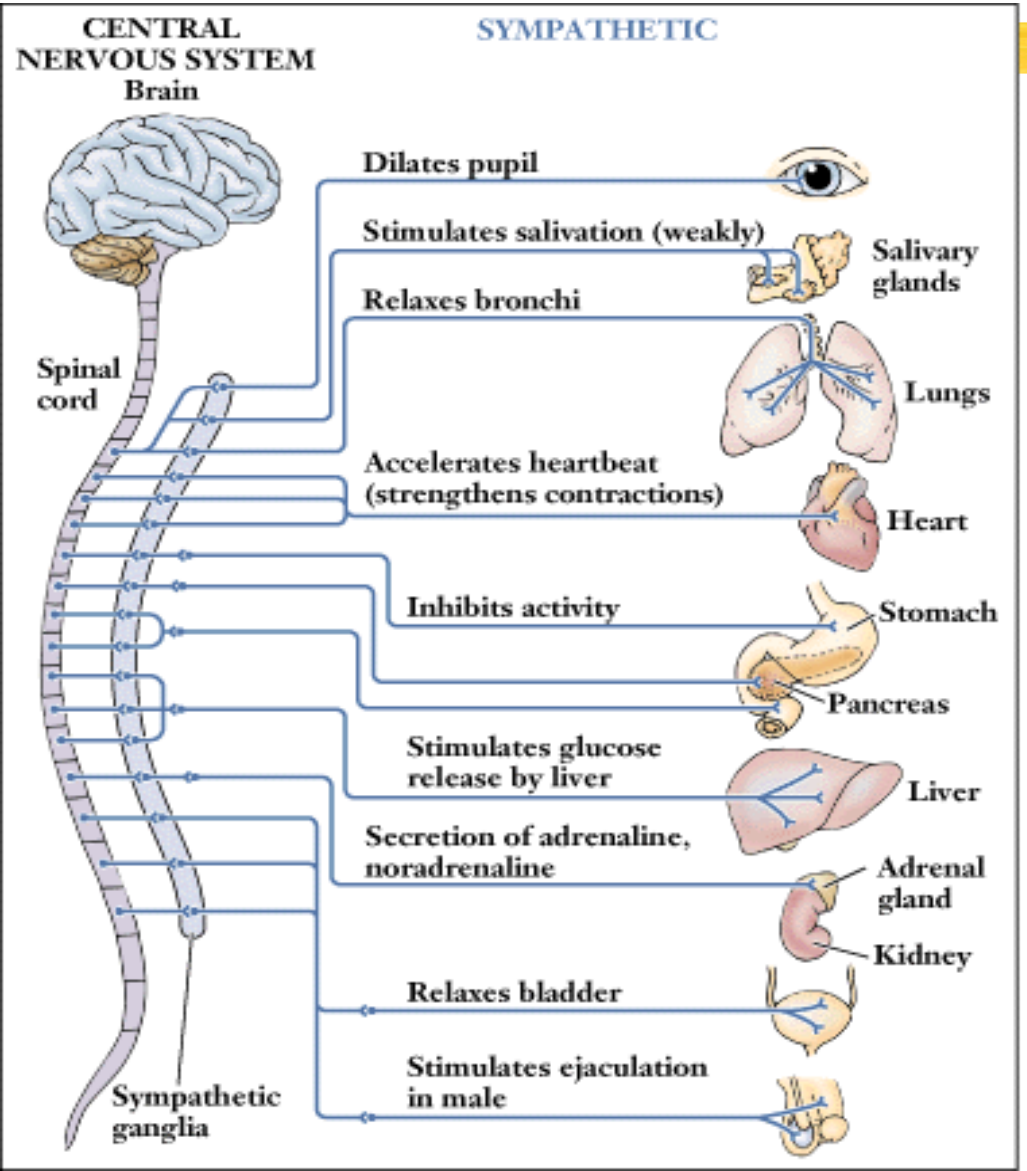
The Nervous System: Functional Divisions

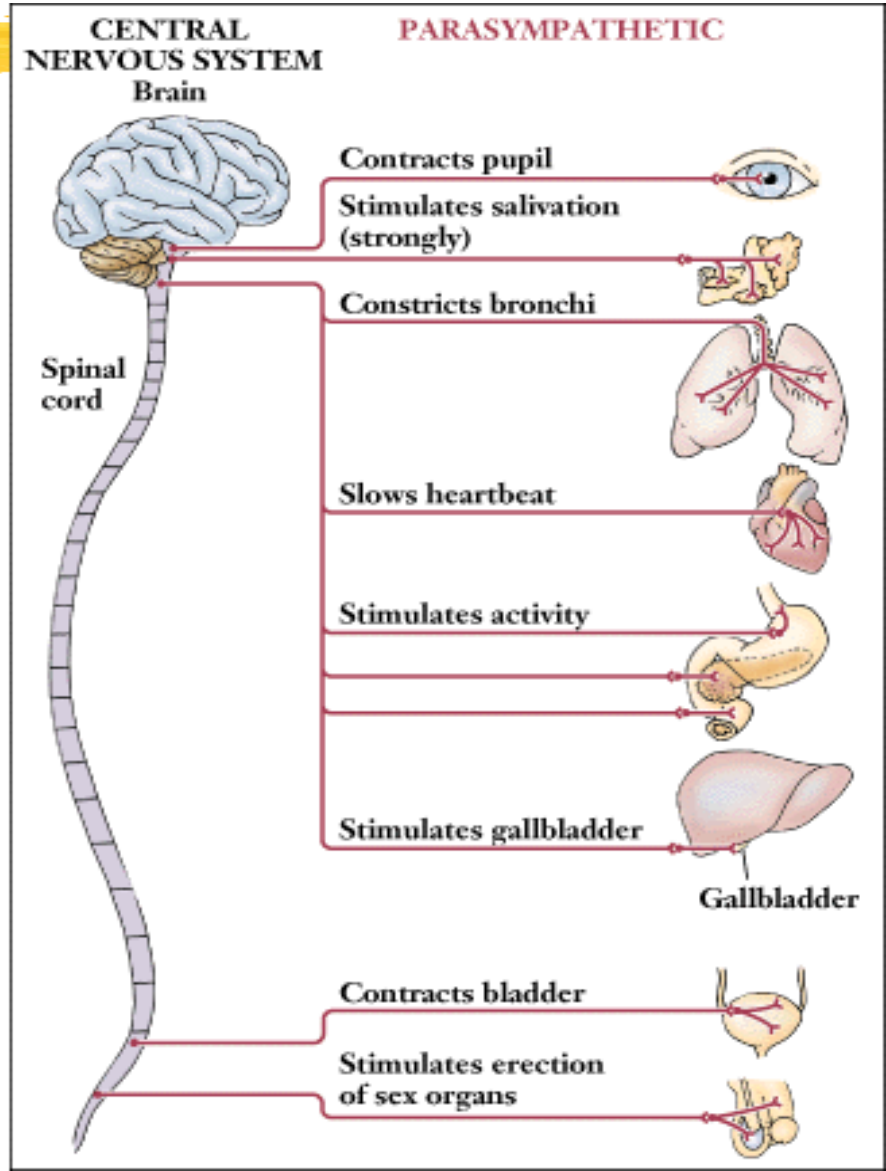
- Sympathetic Nervous System (SNS)
  - Causes the "fight or flight" responses in moments of stress or stimulus
    - Increasing heart rate
    - Saliva flow
    - Perspiration
    - Constriction of blood vessels and pupils
    - Contraction of involuntary smooth muscle
    - Dilating bronchial tubes
  - Excitatory

The Nervous System: Functional Divisions

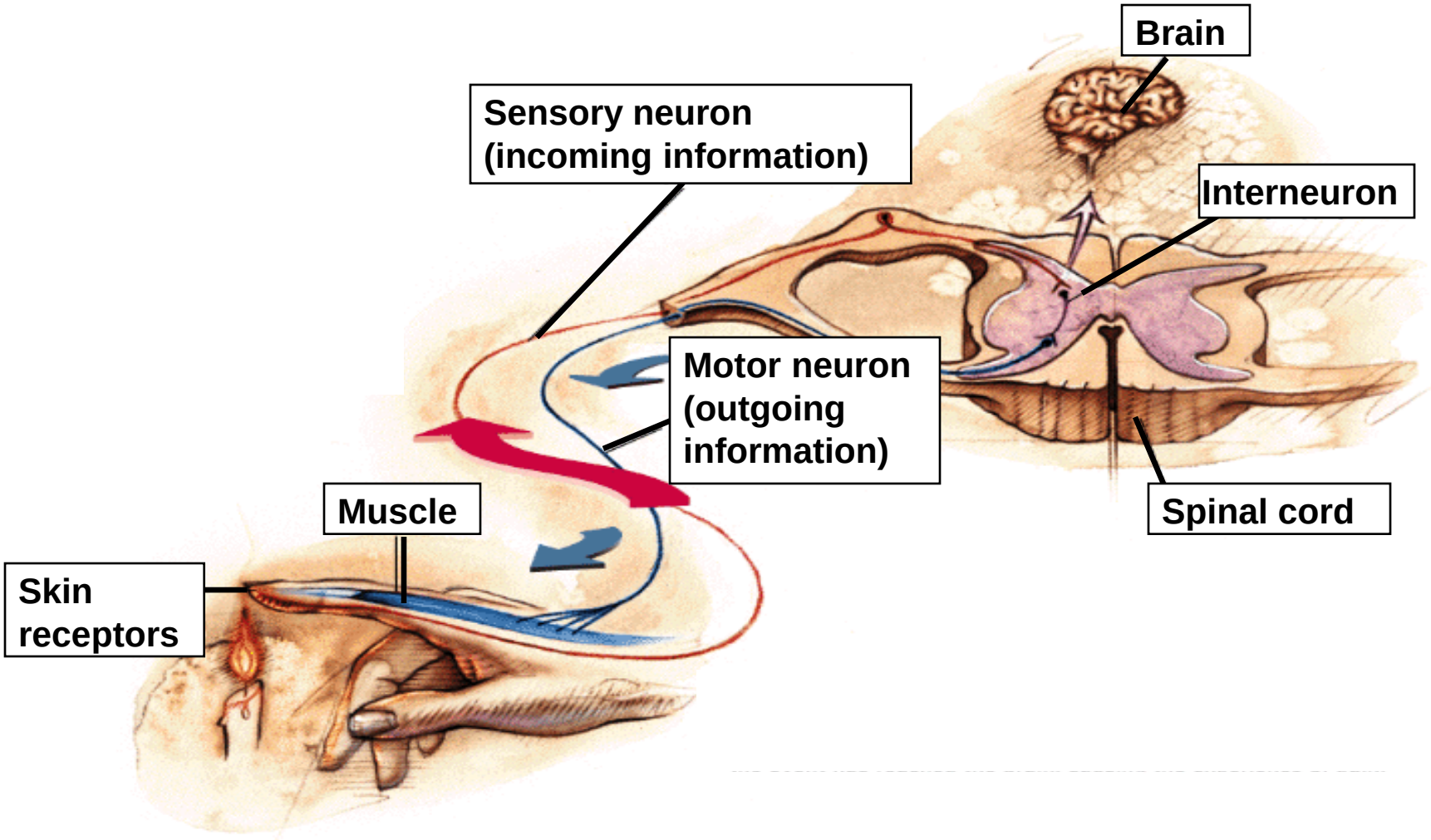
- Parasympathetic Nervous System (PNS)
  - Responsible for counter-balancing the effects of the SNS
    - Slows heart and respiration rates
    - Dilates blood vessels
    - Relaxes smooth involuntary muscles
  - Responsible for conserving and restoring energy in the body following a sympathetic response to stress
  - Inhibitory

The Nervous System

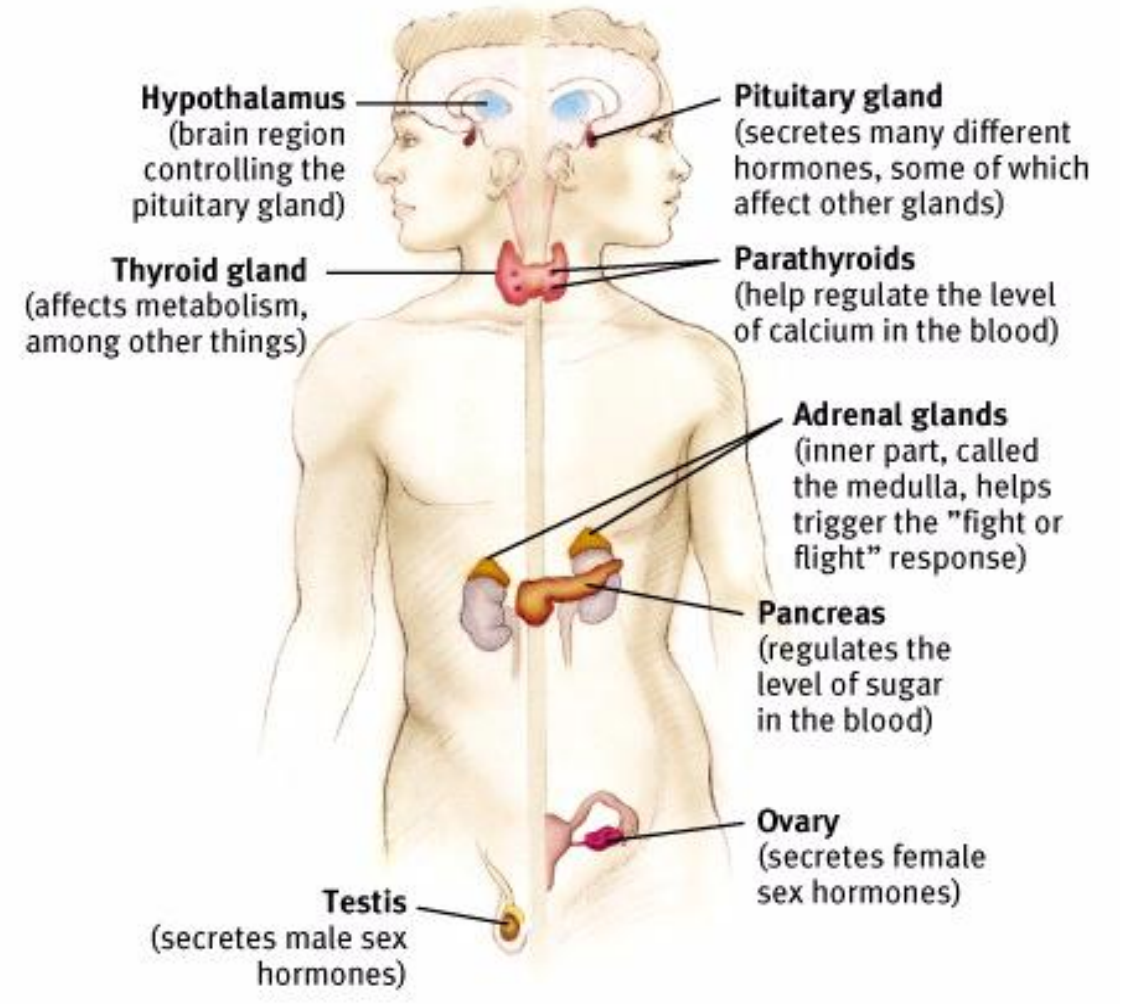




The Nervous System



The Endocrine System



Neural and Hormonal Systems

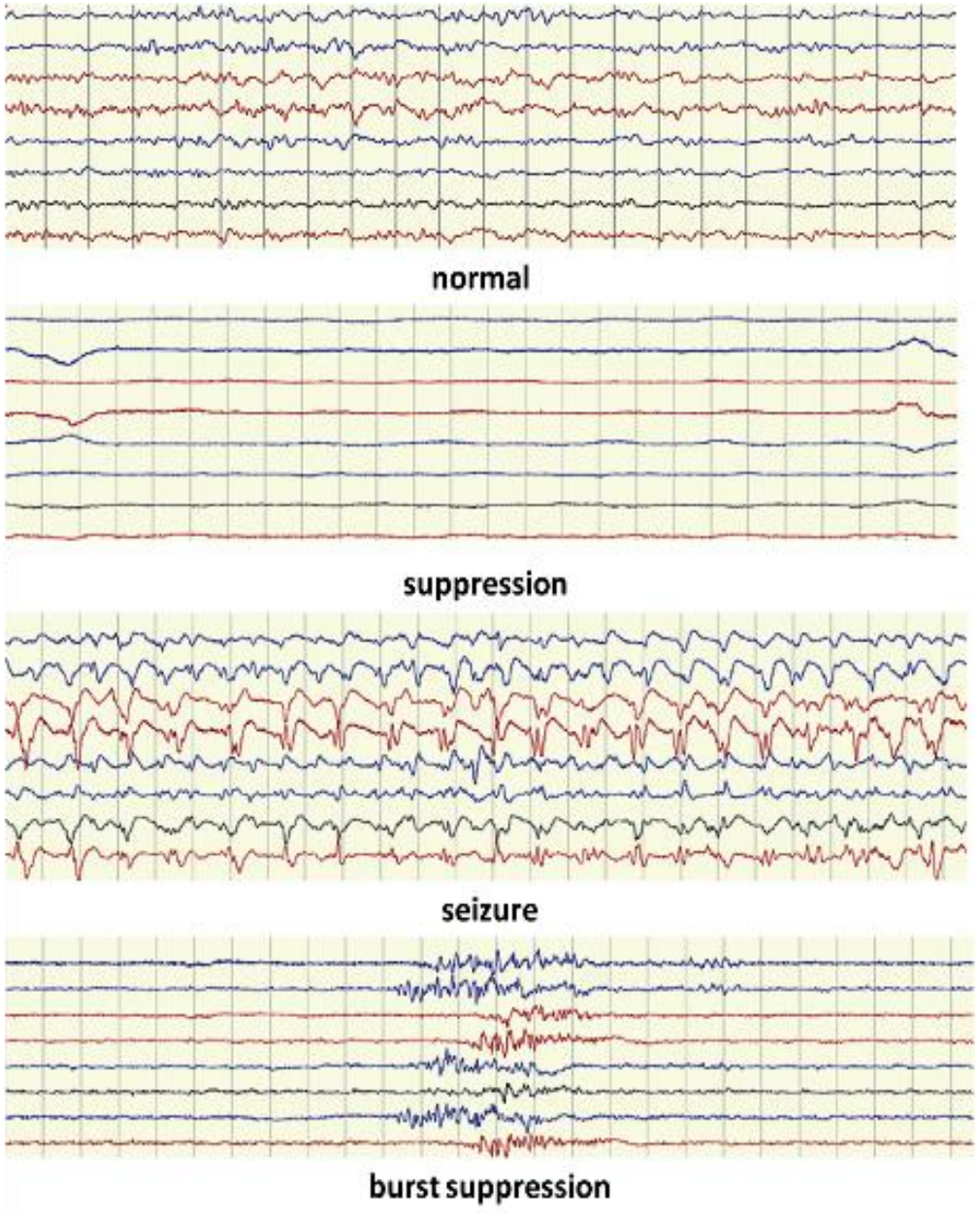
- Hormones
  - Chemical messengers, mostly those manufactured by the endocrine glands, that travel through the blood stream and affect other tissues (including the brain).
  - Some are chemically identical to neurotransmitters
  - Influences growth, reproduction, metabolism, mood, response to stress, response to exertion, and response to one's own thoughts.

Neural and Hormonal Systems

- Adrenal [ah-DREEN-el] Glands
  - A pair of endocrine glands just above the kidneys
  - Secrete the hormones epinephrine (adrenaline) and norepinephrine (noradrenaline), which help to arouse the body in times of stress
  - Produces corticosteroids (cortisol and aldosterone) that help the body reduce stress
    - Cortisol helps to generate energy; regulates conversion of carbs into glucose; suppresses inflammation
    - Aldosterone regulates mineral and water balance in the body; maintains the balance of sodium and potassium in the blood

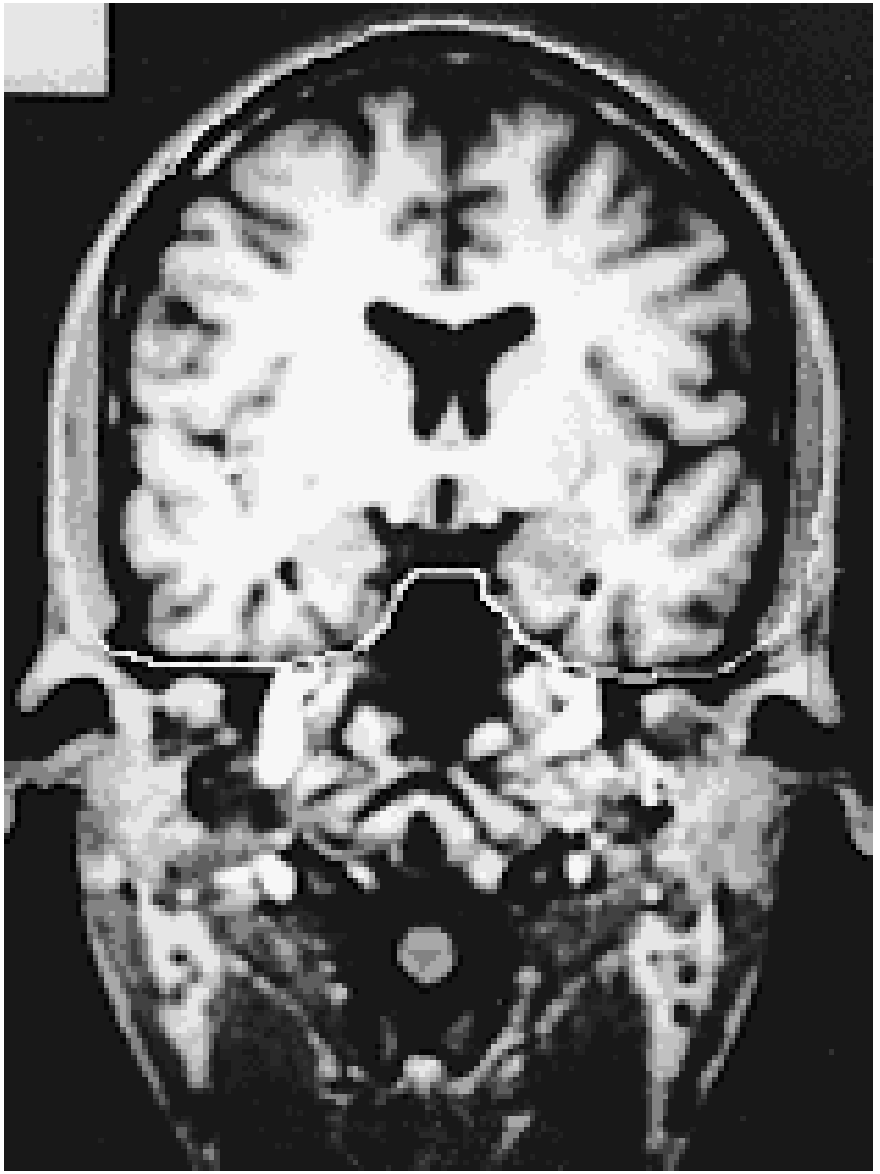
This signal that is picked up by each electrode is then amplified, stored and displayed on a monitor. We also measure several other physiological signals in conjunction with the EEG such as the ECG (heart function), respiration (lung function) and EMG (muscle function), as these recordings can influence the EEG.

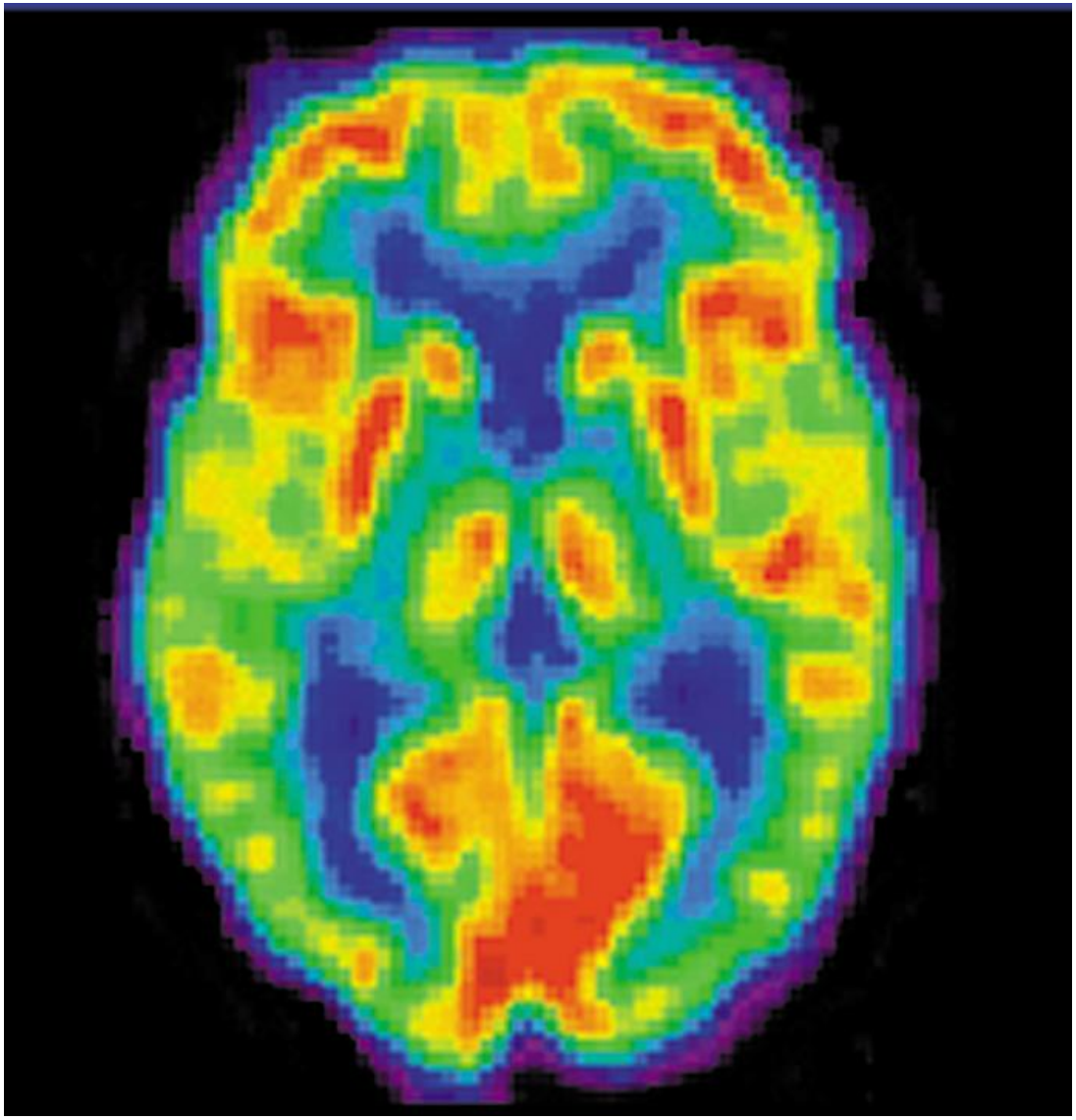
We then analyse the EEG by visual inspection to assist in the diagnosis and prognosis of the newborn. Our analysis usually involves locating abnormal EEG in a recording. The normal EEG appears to be a random signal without any obvious pattern. The EEG becomes abnormal when certain patterns appear in the EEG and it loses the underlying randomness of a normal recording. The normal EEG pattern and several abnormal EEG patterns are shown in this figure .



fMRI – saggital view

MRI scan of patient with incipient Alzheime's Disease: Notable neural atrophy of the right hemisphere





P.E.T Scan

http://webanatomy.net/anatomy/neuro_notes.htm

Further reading on neonatal EEG can be found in,

1. G.B. Boylan, "Principles of EEG and CFM" in *Neonatal Cerebral Investigation*, Chapter 2, Eds: J.M. Rennie, Robertson and Hagmann. Cambridge University Press, UK, 2008.
2. G.B. Boylan, J.M. Rennie, and D.M. Murray. "The normal neonatal EEG" in *Neonatal Cerebral Investigation*, Chapter 6, Eds: J.M. Rennie, N.J. Robertson and C.F. Hagmann. Cambridge University Press, UK, 2008.
3. G.B. Boylan, "Neurophysiology in the Neonatal Period", in *Neonatal and Paediatric Clinical Neurophysiology*, Eds: R.M. Pressler, C.D. Binnie, R. Cooper and R. Robinson, Churchill Livingstone Elsevier, The Netherlands, 2007