CAMPBELL BIOLOGY: CONCEPTS & CONNECTIONS,
NINTH EDITION, GLOBAL EDITION
PowerPoint Lectures

Chapter 28
Nervous Systems

潘建源 Chien-Yuan Pan
生命科學系
神經細胞生理研究室
生科館 Rm730

Introduction

- More than 20 million Americans are affected by depression in a given year. 台灣 ~10%，女性是男性2倍，其中約2.3%就醫
- Depression is a psychiatric disorder characterized by
  - persistent sadness,
  - loss of interest in pleasurable activities,
  - changes in weight and sleep patterns,
  - diminished energy, and
  - suicidal thoughts over a continuous period. TW 87%的自殺為患者
- Drugs that treat medically diagnosed depression, antidepressants, are the third most commonly prescribed class of drugs in the USA.
  - The most widely prescribed subclass of antidepressants, selective serotonin reuptake inhibitors (SSRIs), block the reabsorption of a particular mood-regulating chemical called serotonin into brain cells.
  - However, SSRIs are most effective for the severely depressed and offer little or no benefit to the moderately depressed.

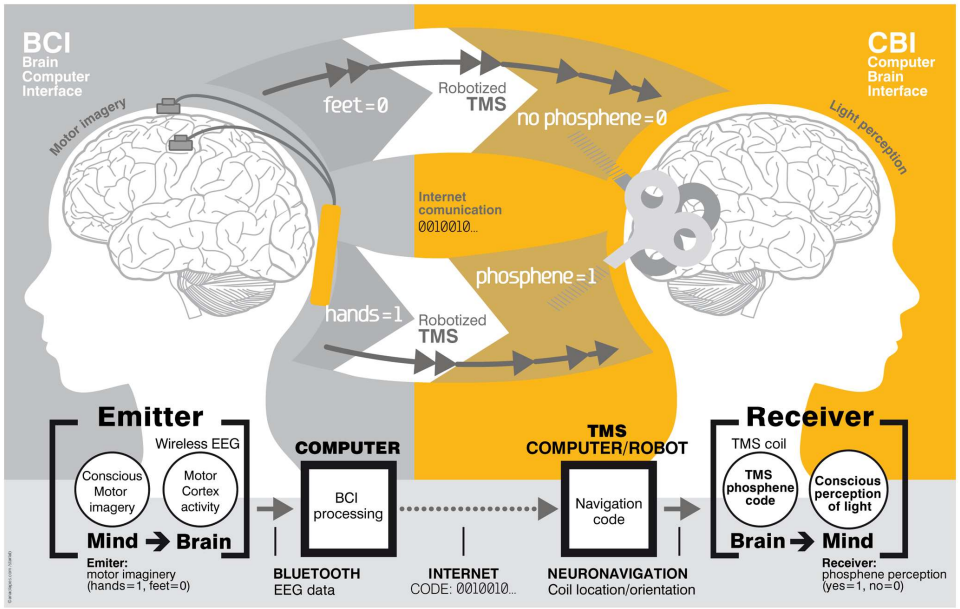
A problem? Enhanced Creativity? Just a “condition”?

Depressed people:

1. process information more deeply.
2. are more accurate at complex tasks.
3. make better judgements on detail-oriented information.
4. make more accurate cost-benefit analyses.

http://www.spring.org.uk/2014/11/4-surprising-advantages-of-being-depressed.php

From Brain-Computer Interface (BCI) to Brian-Brain Interface



https://www.extremetech.com/extreme/188883-the-first-human-brain-to-brain-interface-has-been-created-in-the-future-will-we-all-be-linked-telepathically

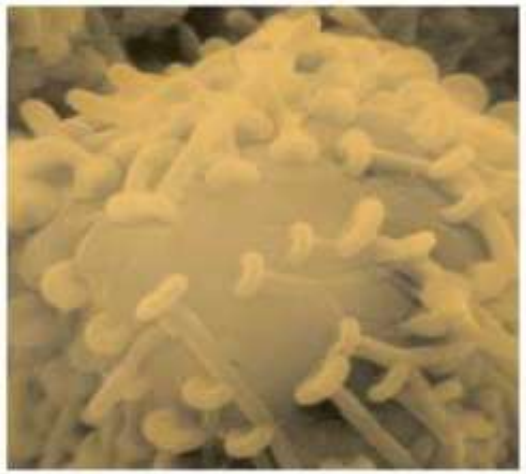
The BCI reads the sender’s thoughts — in this case, the sender thinks about moving his or her hands or feet. Thinking about feet is equivalent to binary 0, while hands is binary 1. With a little time/effort, whole words can be encoded as a stream of ones and zeroes. These encoded words are then transmitted (via the internet or some other network) to the recipient, who is wearing a TMS. The TMS is focused on on the recipient’s visual cortex. When the TMS receives a “1” from the sender, it stimulates a region in the visual cortex that produces a phosphene — the phenomenon whereby you see flashes of light, without light actually hitting your retina (when you rub your eyes, for example). The recipient “sees” these phosphenes at the bottom of their visual field. By decoding the flashes — phosphene flash = 1, no phosphene = 0 — the recipient can “read” the word being sent.

TMS: transcranial magnetic stimulation

Figure 28.0_1

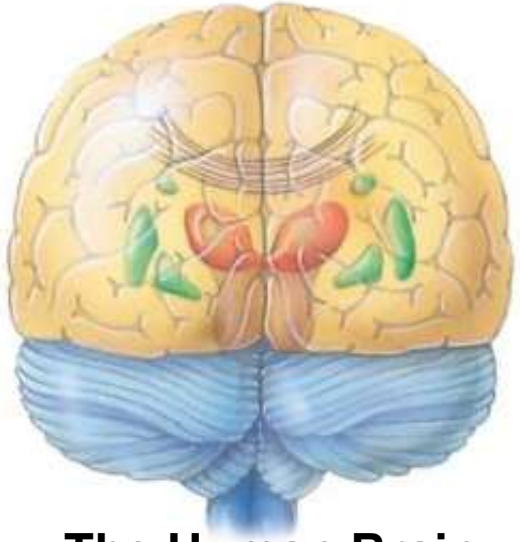
Chapter 28: Big Ideas

Nervous System Structure and Function 28.1-28.2



Nerve Signals and Their Transmission 28.3-28.9

An Overview of Animal Nervous Systems 28.10-28.13



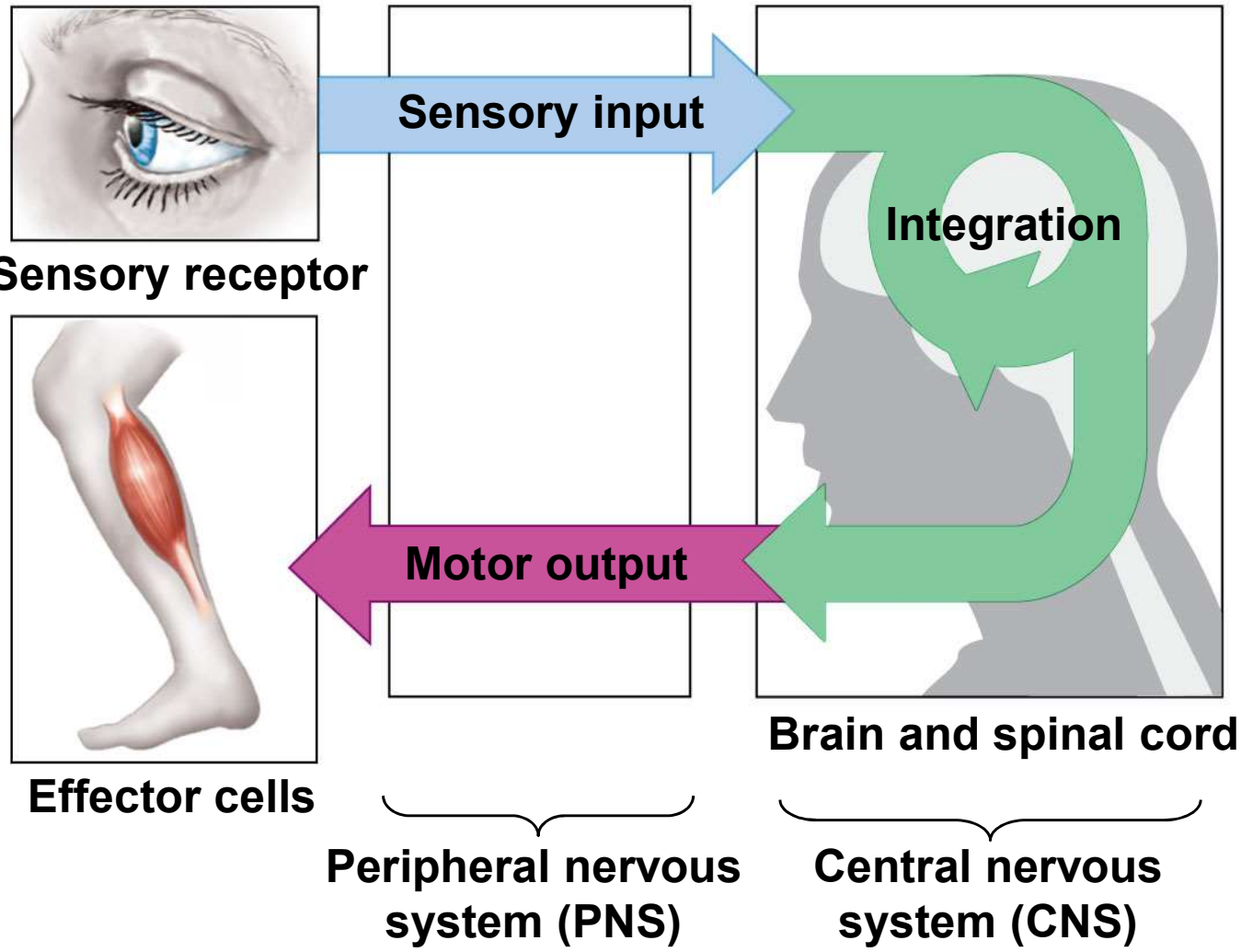
The Human Brain 28.14-28.20

NERVOUS SYSTEM STRUCTURE AND FUNCTION

28.1 Nervous systems receive sensory input, interpret it, and send out appropriate commands

The **nervous system**

- obtains sensory information, **sensory input**,
- processes sensory information, **integration**, and
- sends commands to effector cells (muscles) that carry out appropriate responses, **motor output**.



Integration of several systems!

Kobe jump over a speeding car
https://www.youtube.com/watch?v=BIWeEFV59d4

Discovery Channel: Kobe Bryant jumps car
https://www.youtube.com/watch?v=slxBNCzUmuM

Car travels at 88 km/hr

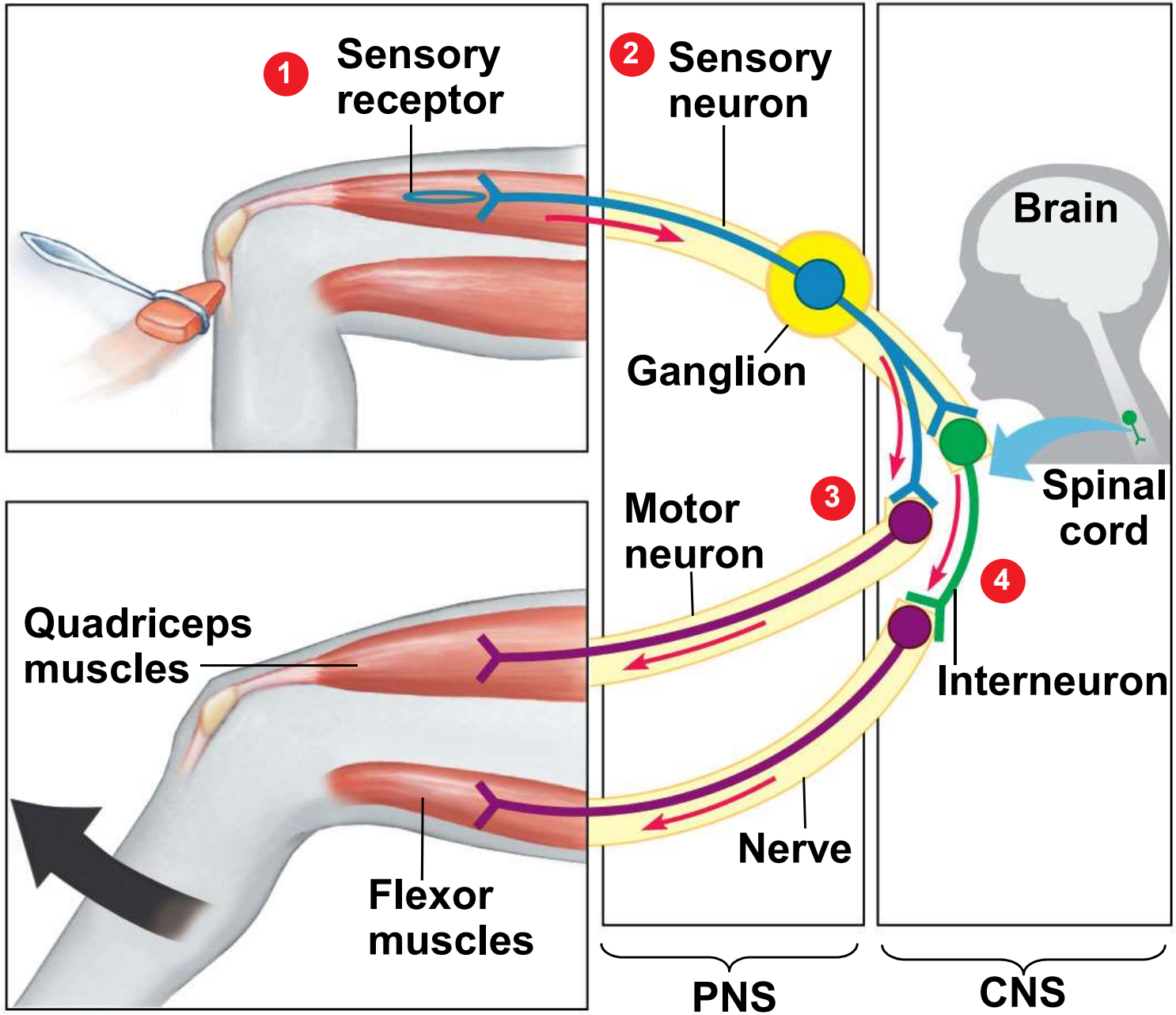
- Two major organ systems are responsible for coordinating functions of the animal body:
  1. the endocrine system, with slower and more sustained responses, and
  2. the **nervous system**, with faster and less sustained responses.
- Communication within the nervous system relies on **neurons**, nerve cells that transmit information via electrical and chemical signals.
- A neuron consists of
  - a **cell body**, containing the nucleus and other cell organelles, and
  - long, thin extensions that convey signals.

- The **central nervous system** (**CNS**) consists of the
  - brain and
  - spinal cord (vertebrates).
- The **peripheral nervous system** (**PNS**)
  - is located outside the CNS and
  - consists of
    - **nerves** (bundles of neurons wrapped in connective tissue) and
    - **ganglia** (clusters of neuron cell bodies). 神經結

- A nervous system has three interconnected functions:
  1. **Sensory input** is the conduction of signals from sensory receptors.
  2. **Integration** is the analysis and interpretation of the sensory signals in the brain and spinal cord and the formulation of appropriate responses.
  3. **Motor output** is the conduction of signals from the integration centers through the PNS to **effector cells**, such as muscle cells or gland cells, which perform the body's responses.

  The relationship between neurons and nervous system structure and function can be seen in **reflexes**, or automatic responses to stimuli.

Figure 28.1B



四頭肌

屈肌

28.2 Neurons are the functional units of nervous systems

- Neurons have two unique extensions arising from the neuron cell body.
  1. **Dendrites** are highly branched, often short, extensions that *receive* signals from other neurons and convey this information toward the cell body.
  2. **Axons** are typically a much longer extension that *transmits* signals to other cells, which may be other neurons or effector cells.
- To function normally, neurons of all vertebrates and most invertebrates have supporting cells called **glia**.
- A Schwann cell, a type of glia found in the PNS, often wraps an axon along most of its length in a thick insulating material called the **myelin sheath**, analogous to the plastic insulation that covers many electrical wires.

- The gaps between Schwann cells are called **nodes of Ranvier**, an adaptation that increases the speed of signals along an axon.
- To function normally, neurons of all vertebrates and most invertebrates have supporting cells called glia.

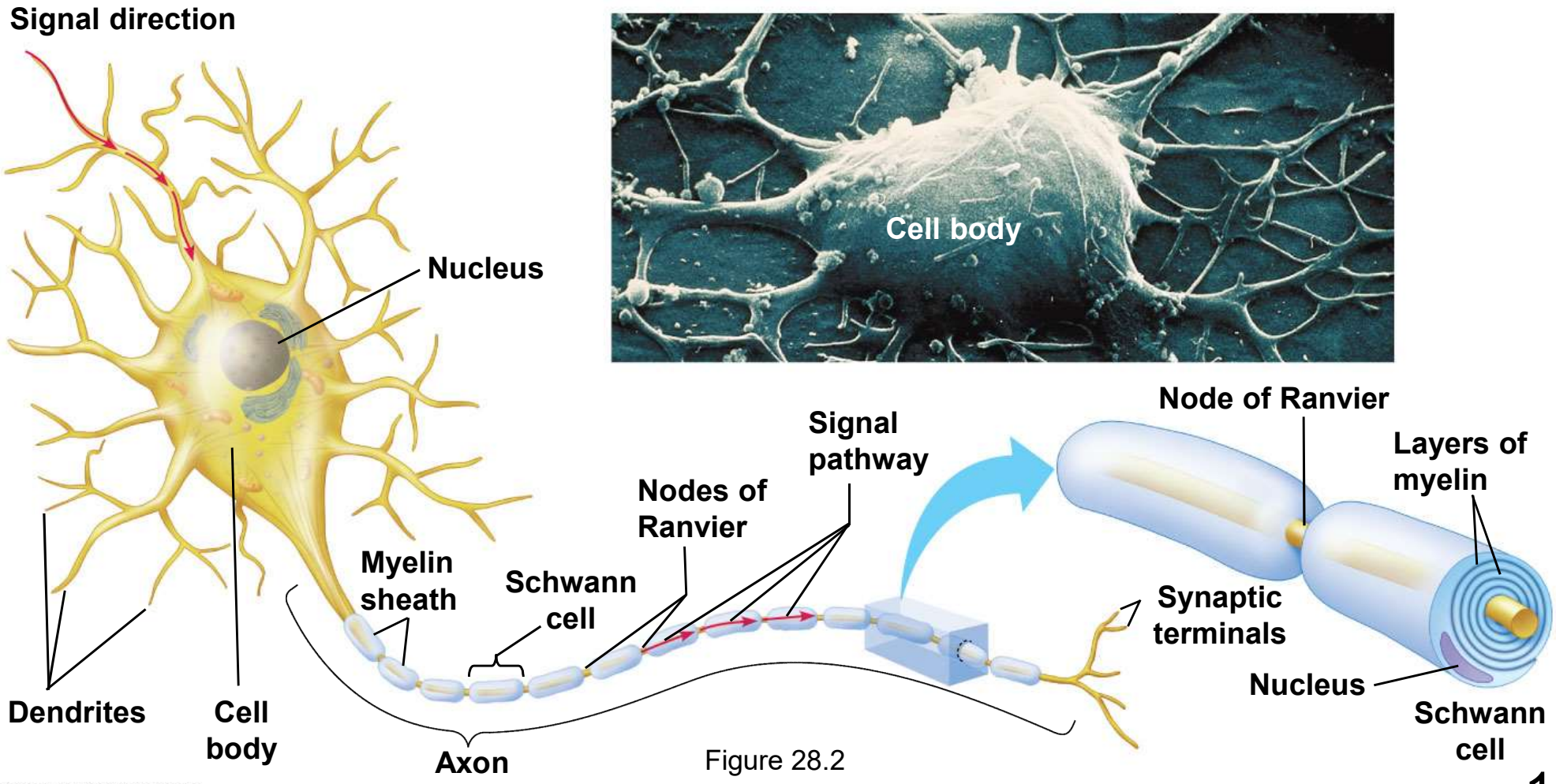


Figure 28.2

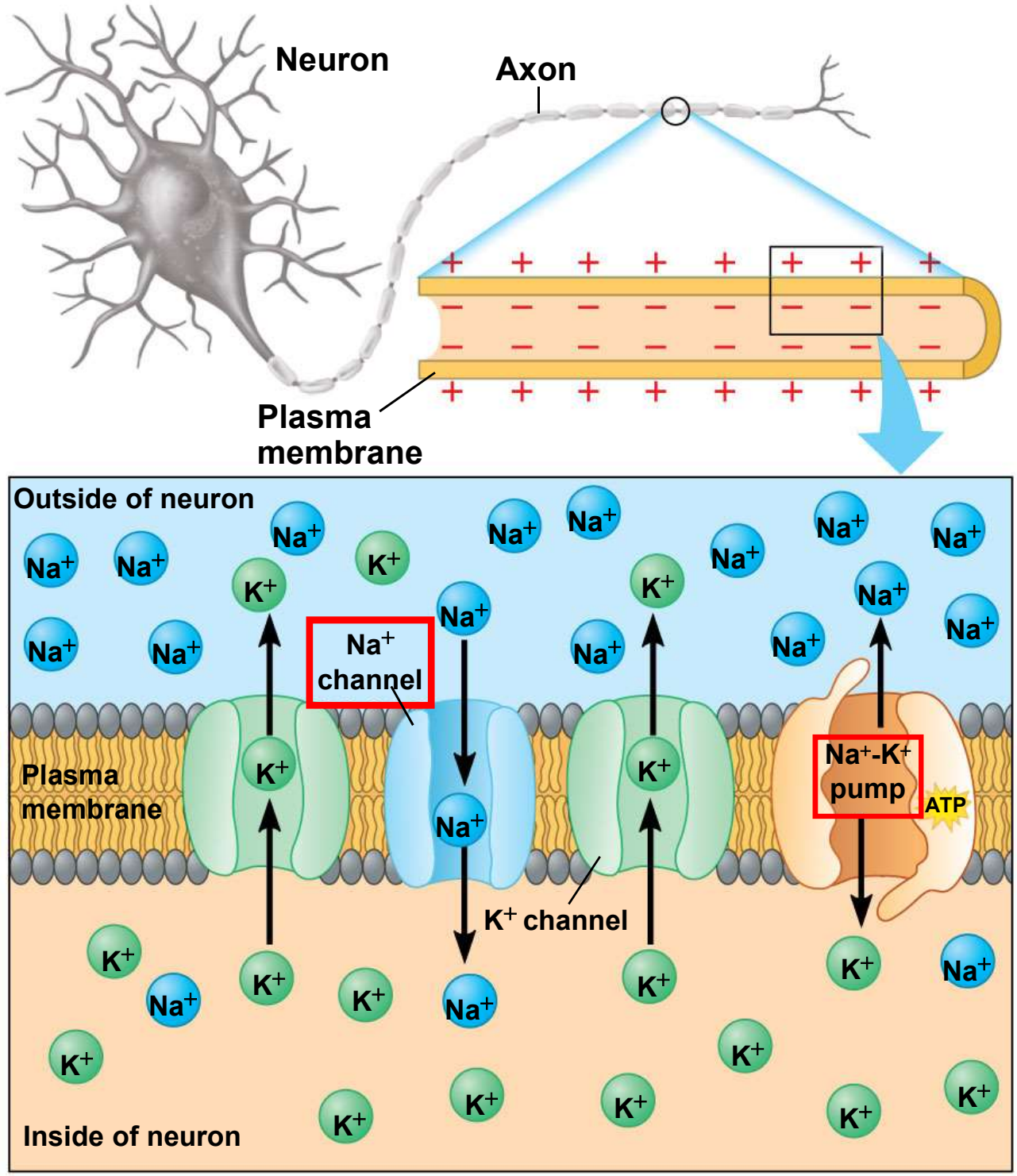
NERVE SIGNALS AND THEIR TRANSMISSION

28.3 Nerve function depends on charge differences across neuron membranes

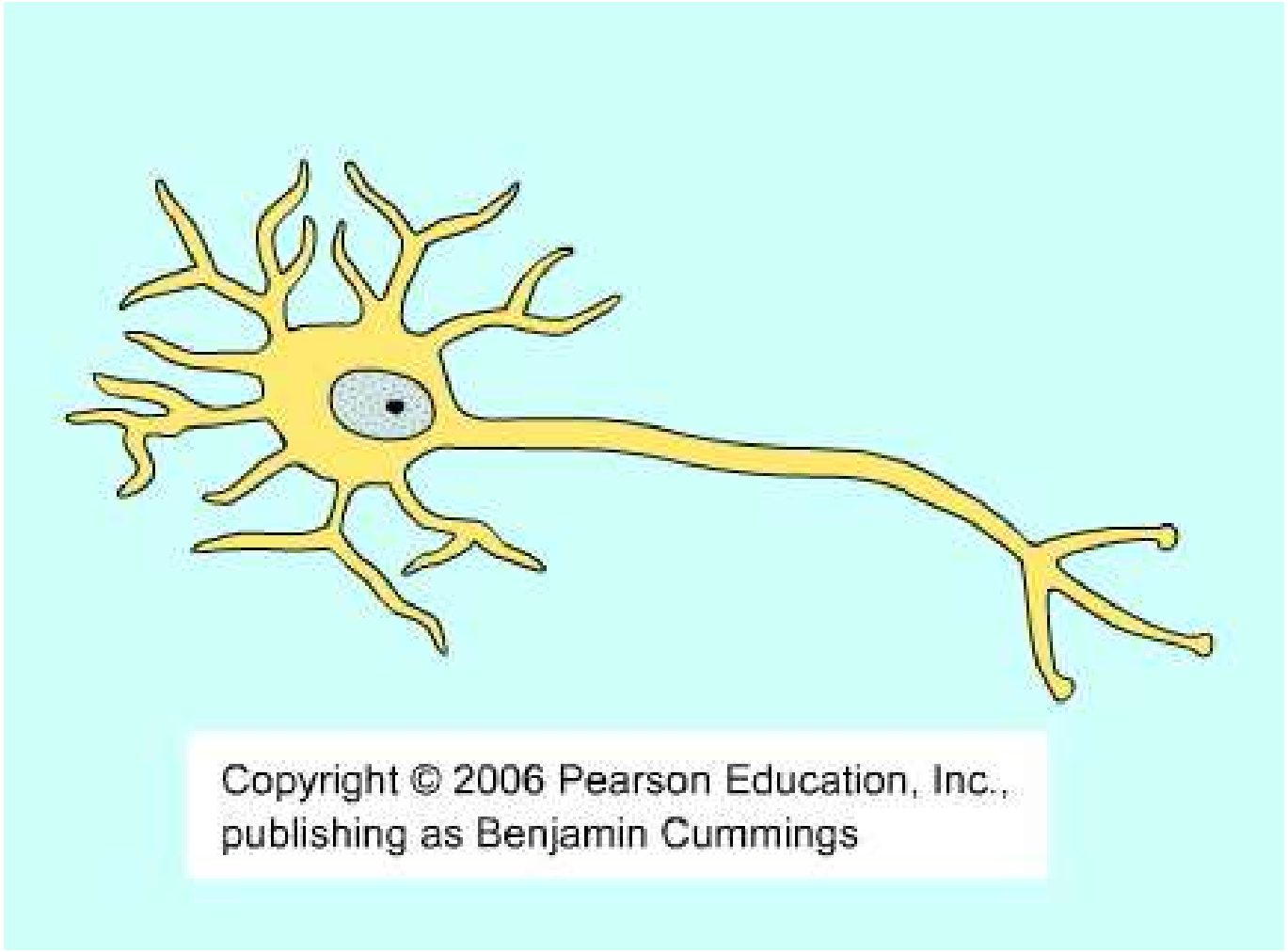
- At rest, a neuron's plasma membrane has potential energy—the **membrane potential**, in which
  - just inside the cell is slightly negative and
  - just outside the cell is slightly positive.
- The **resting potential** is the voltage across the plasma membrane of a resting neuron.
- The resting potential exists because of differences in ion concentration of the fluids inside and outside the neuron.
  - Inside the neuron, K^+ is high and Na^+ is low.
  - Outside the neuron, K^+ is low and Na^+ is high.

Sodium-potassium (Na^+-K^+) pumps use energy from ATP to actively move Na^+ out of the neuron and K^+ into the neuron.

Figure 28.3



3 Na^+ out
2 K^+ in



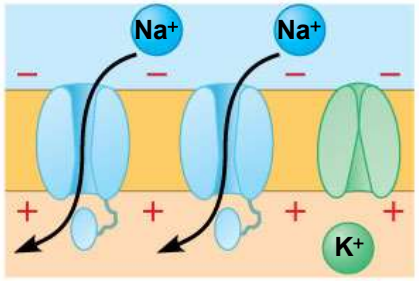
Animation: Resting Potential

Right click on animation / Click play

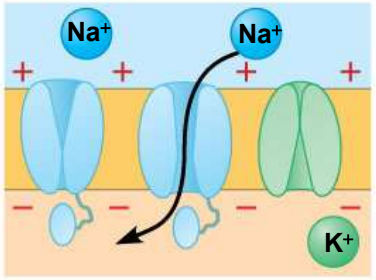
28.4 A nerve signal begins as a change in the membrane potential

- A **stimulus** is any factor that causes a nerve signal to be generated.
- A stimulus
  - alters the **permeability** of a portion of the membrane,
  - allows ions to pass through, and
  - changes the membrane's voltage.
- A nerve signal, called an **action potential**, is
  - a change in the membrane voltage,
  - from the resting potential,
  - to a maximum level, and
  - back to the resting potential.
  - that transmits a nerve signal along an axon.
- The rapid flip-flop of the membrane potential is
  - a result of the rapid movements of ions across the membrane
  - at Na^+ and K^+ ***voltage-gated channels***,
  - that open and close in response to stimuli.

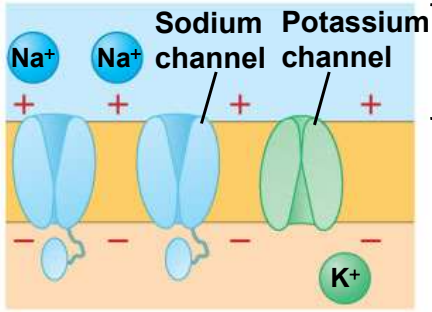
Figure 28.4



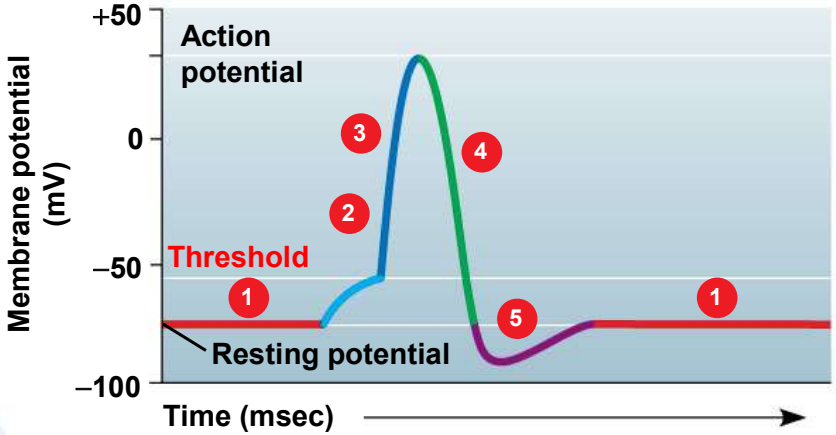
3 Additional Na^+ channels open, K^+ channels are closed; interior of cell becomes more positive.

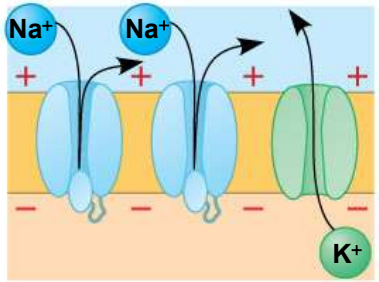


2 A stimulus opens some Na^+ channels; if threshold is reached, an action potential is triggered.



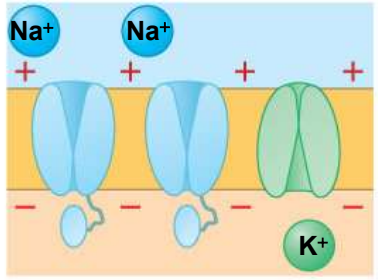
1 Resting state: Voltage-gated Na^+ and K^+ channels are closed; resting potential is maintained by ungated channels (not shown).





4 Na^+ channels close and inactivate; K^+ channels open, and K^+ rushes out; interior of cell is more negative than outside.

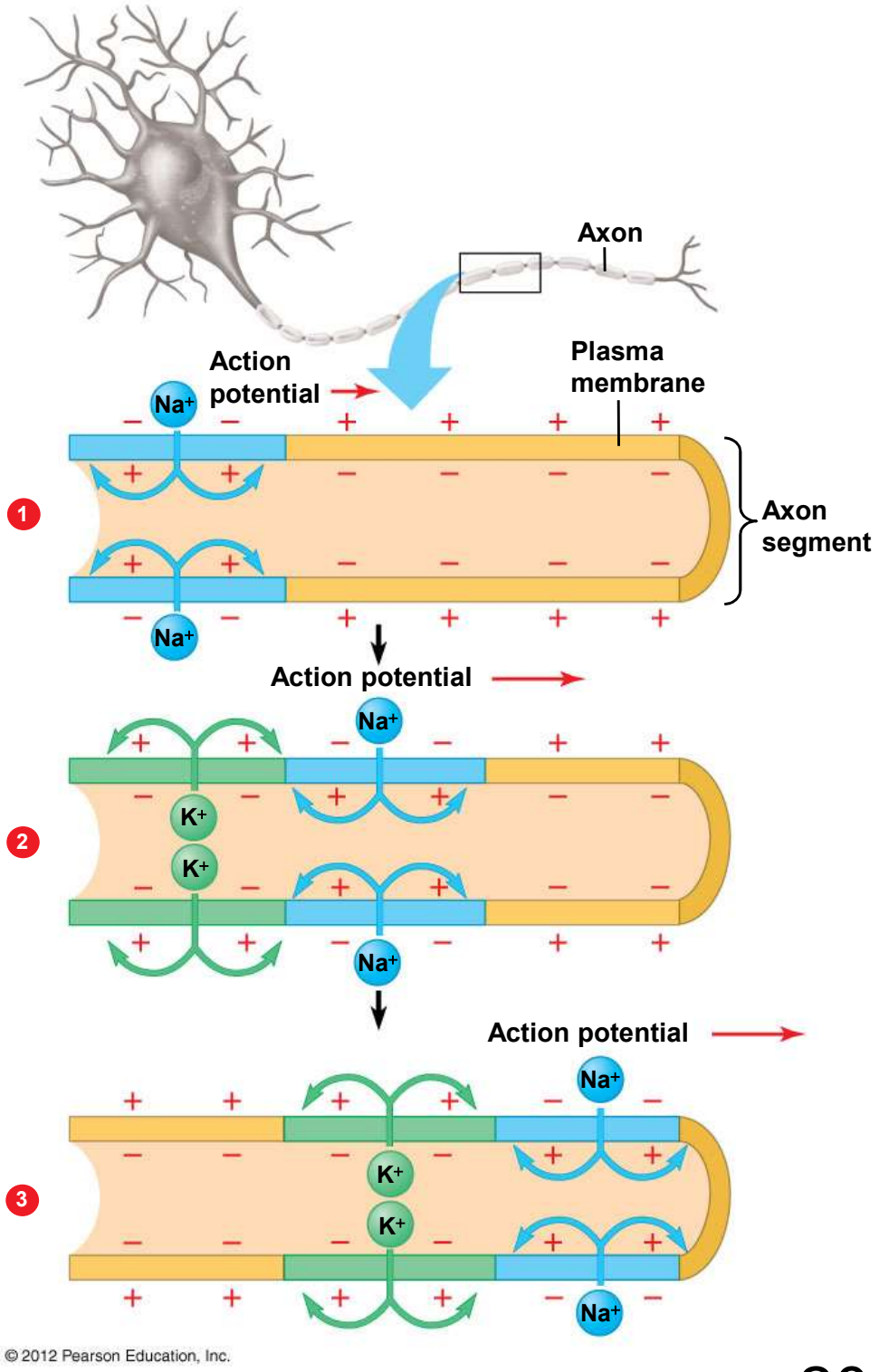
5 The K^+ channels close relatively slowly, causing a brief undershoot.

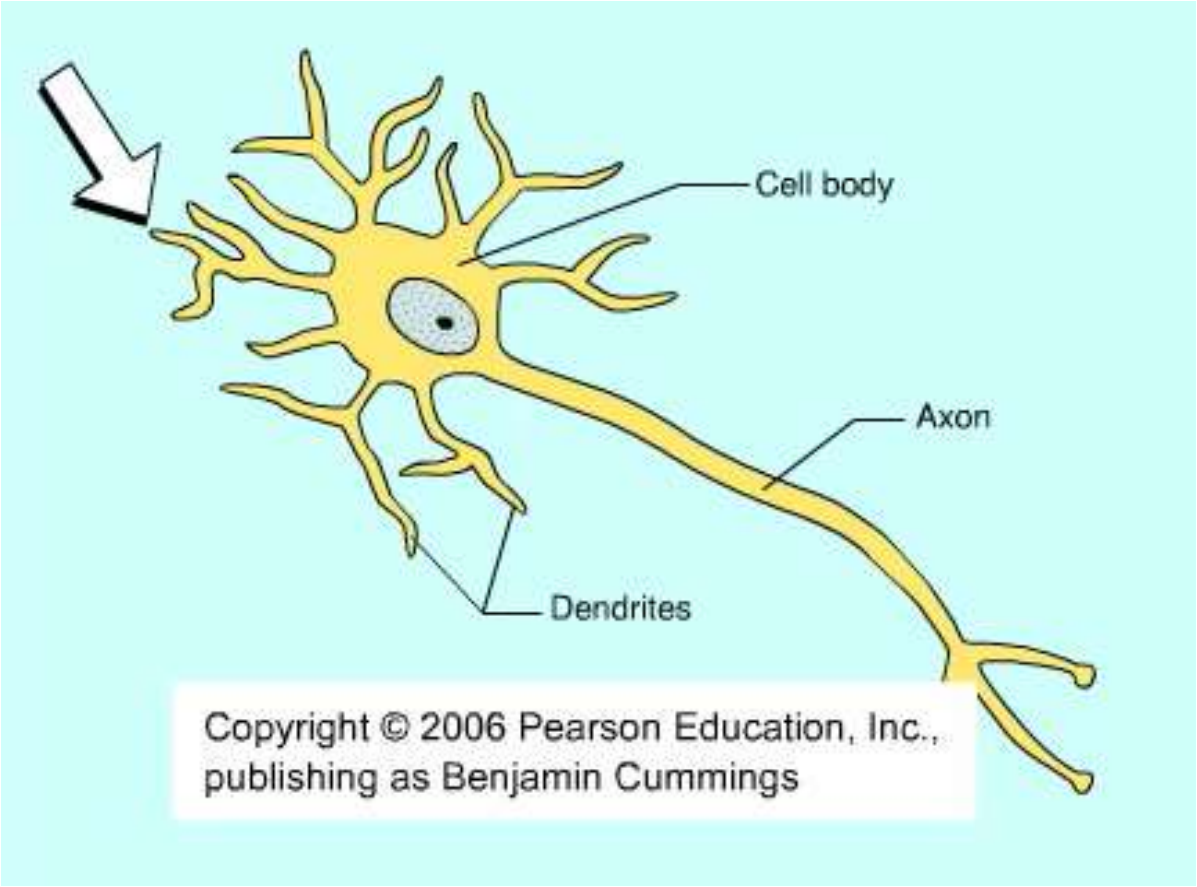


1 Return to resting state.

28.5 The action potential propagates itself along the axon

- Action potentials are
  - self-propagated in a one-way chain reaction along a neuron and
  - **all-or-none** events.
  - The **frequency** of action potentials (but not their strength) changes with the strength of the stimulus.





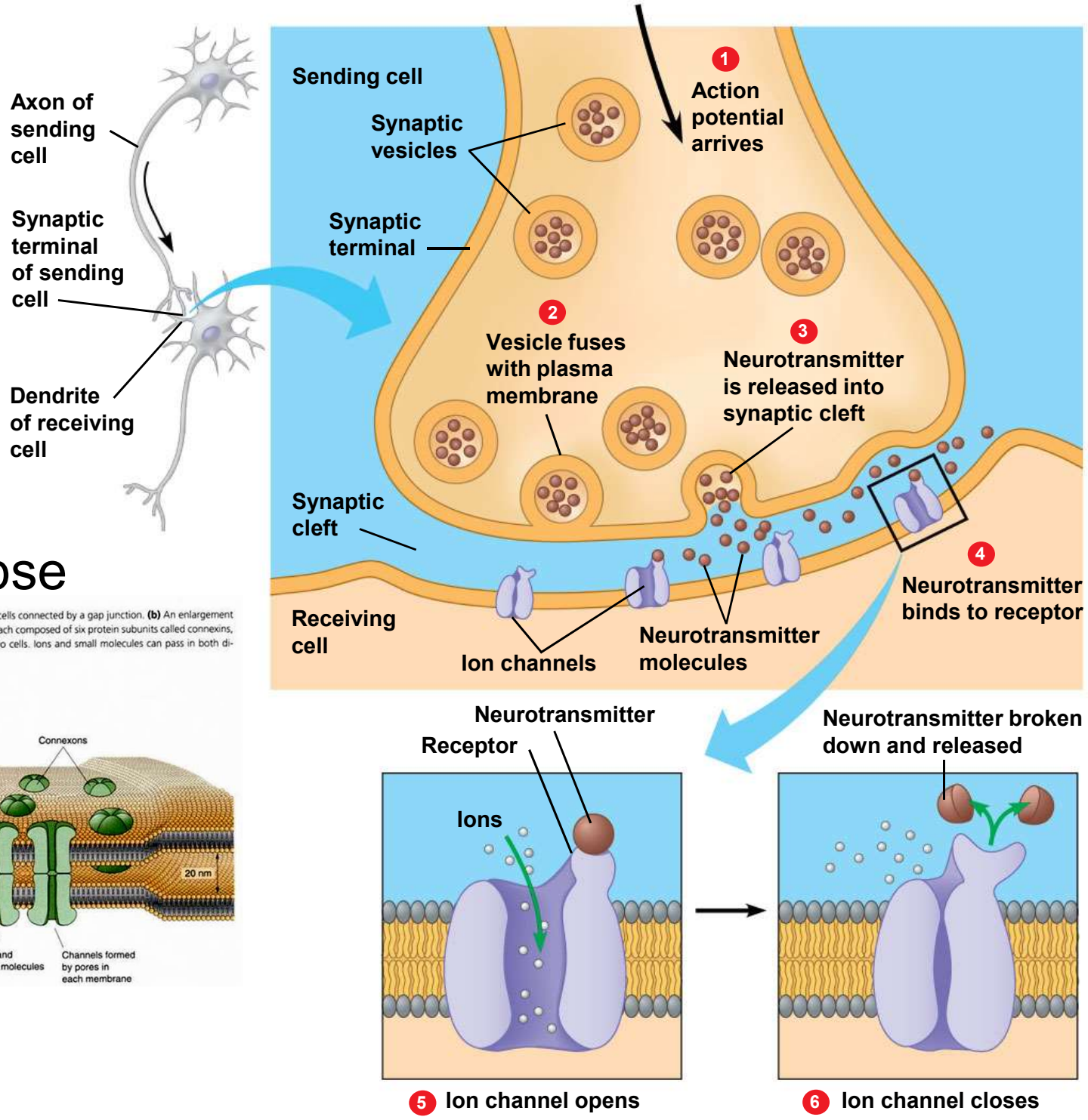
Animation: Action Potential

Right click on animation / Click play

28.6 Neurons communicate at synapses 突觸

- **Synapses** are relay points between a synaptic terminal of a sending neuron and a receiving cell.
- The receiving cell can be
  - another neuron or
  - an effector cell such as a muscle cell or endocrine cell.
- Synapses come in two varieties:
  1. In an electrical synapse, electrical current flows directly from a neuron through gap junctions.
  2. At chemical synapses, the sending (presynaptic) cell secretes a chemical signal, a **neurotransmitter**, which crosses the **synaptic cleft**, and the neurotransmitter binds to a specific receptor on the surface of the receiving (postsynaptic) cell.

Figure 28.6



Electric synapse

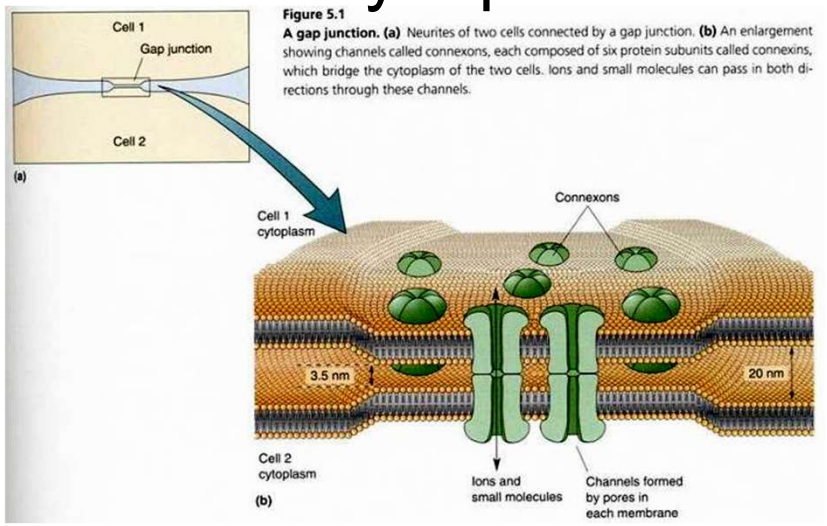
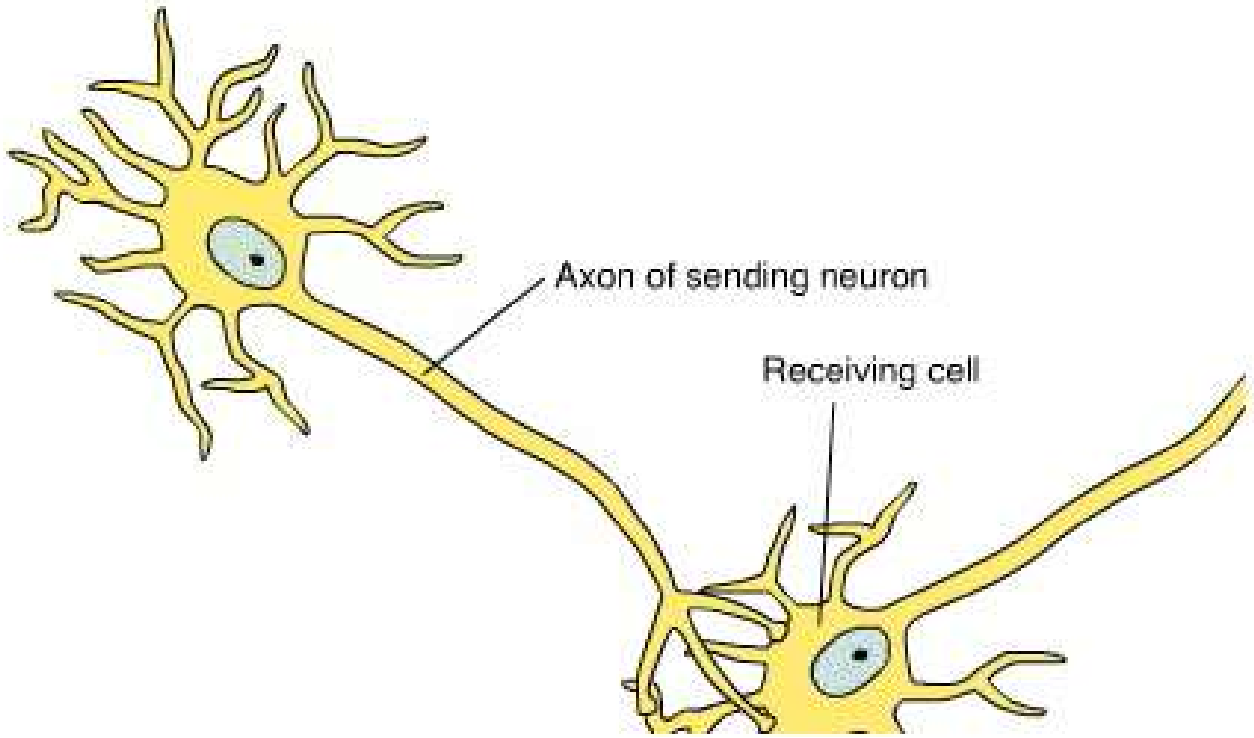


Figure 5.1
A gap junction. (a) Neurites of two cells connected by a gap junction. **(b)** An enlargement showing channels called connexons, each composed of six protein subunits called connexins, which bridge the cytoplasm of the two cells. Ions and small molecules can pass in both directions through these channels.



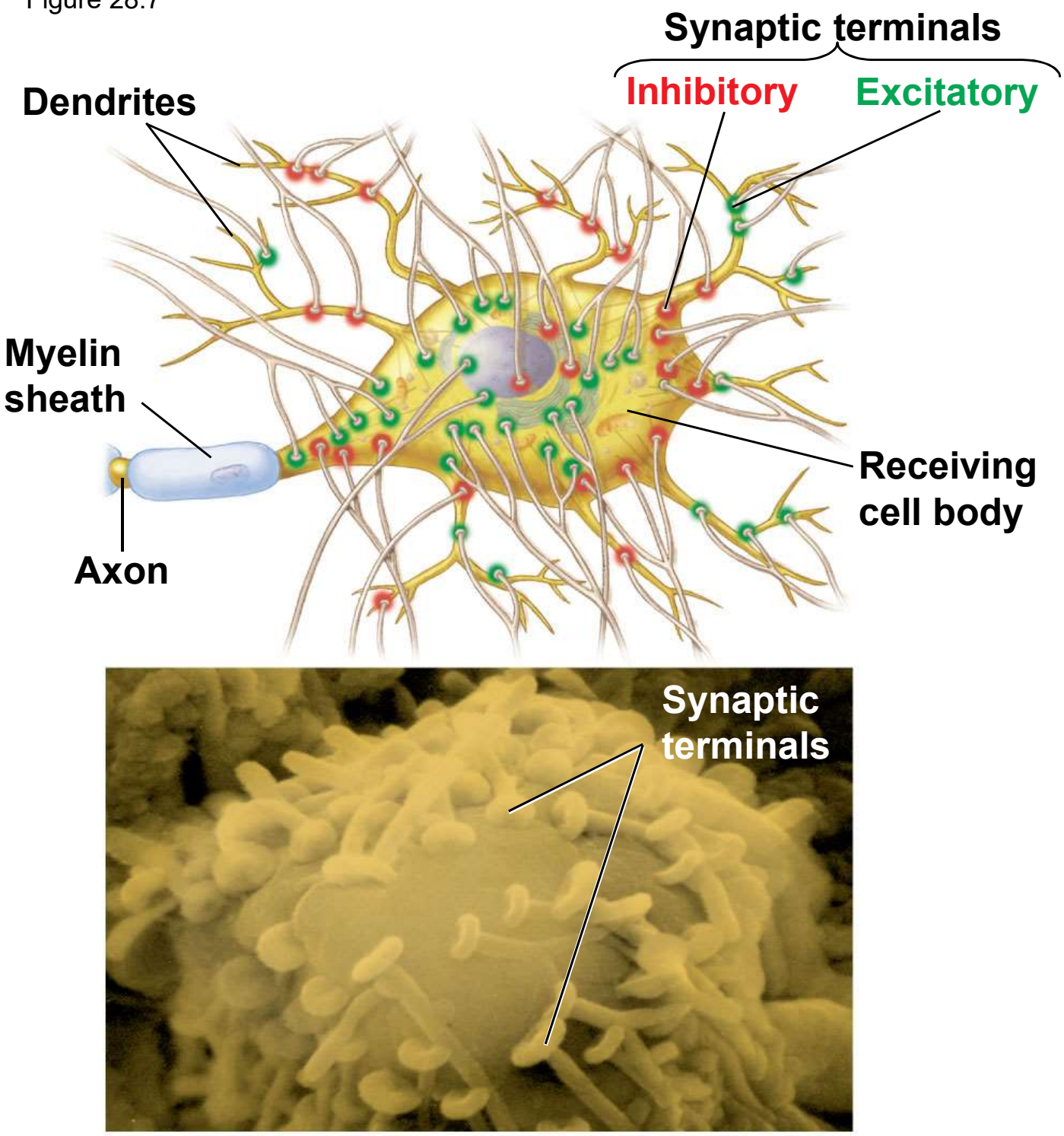
Animation: Synapse

Right click on animation / Click play

28.7 Chemical synapses enable complex information to be processed

- Some neurotransmitters
  - excite a receiving cell, and
  - others inhibit a receiving cell's activity by decreasing its ability to develop action potentials.
- A receiving neuron's membrane may receive signals
  - that are both excitatory and inhibitory and
  - from many different sending neurons.
- The summation of excitation and inhibition determines if a neuron will transmit a nerve signal.

Figure 28.7



A neuron may receive information via neurotransmitters from hundreds of other neurons, connecting at thousands of synaptic terminals, to any areas that are not myelinated, including dendrites and cell bodies.

The inputs can be highly varied because each sending neuron may secrete a different quantity or kind of neurotransmitter.

28.8 A variety of small molecules function as neurotransmitters

- Many small, nitrogen-containing molecules are neurotransmitters.
  - **Acetylcholine** is released 乙醯膽鹼
    - by PNS motor neurons to activate skeletal muscles,
    - by other PNS neurons that affect internal organs and glands, and
    - by neurons in the CNS that affect memory, learning, and alertness.

生物胺

  - **Biogenic amines** are neurotransmitters derived from amino acids and function in the CNS. They include
    - serotonin and dopamine, which affect sleep, mood, and attention, and learning, and 血清素…多巴胺
    - norepinephrine, which along with serotonin seems to be linked with some types of depression.

正腎上腺素

- Many neuropeptides, which are relatively short chains of amino acids, also serve as neurotransmitters.
  - Endorphins　腦內啡、內嗎啡
    - are peptides that decrease our perception of pain during times of physical or emotional stress and
    - may be released in response to a wide variety of stimuli, including traumatic injury, muscle fatigue, and even eating very spicy foods.
  - Nitric oxide　一氧化氮　NO
    - is a dissolved gas and
    - triggers erections during sexual arousal in men.

28.9 CONNECTION: Many drugs act at chemical synapses

- Many psychoactive drugs
  - act at synapses and
  - affect neurotransmitter action.
- Caffeine counters the effect of inhibitory neurotransmitters.
- Nicotine acts as a stimulant by binding to acetylcholine receptors. 尼古丁
- Alcohol is a depressant.

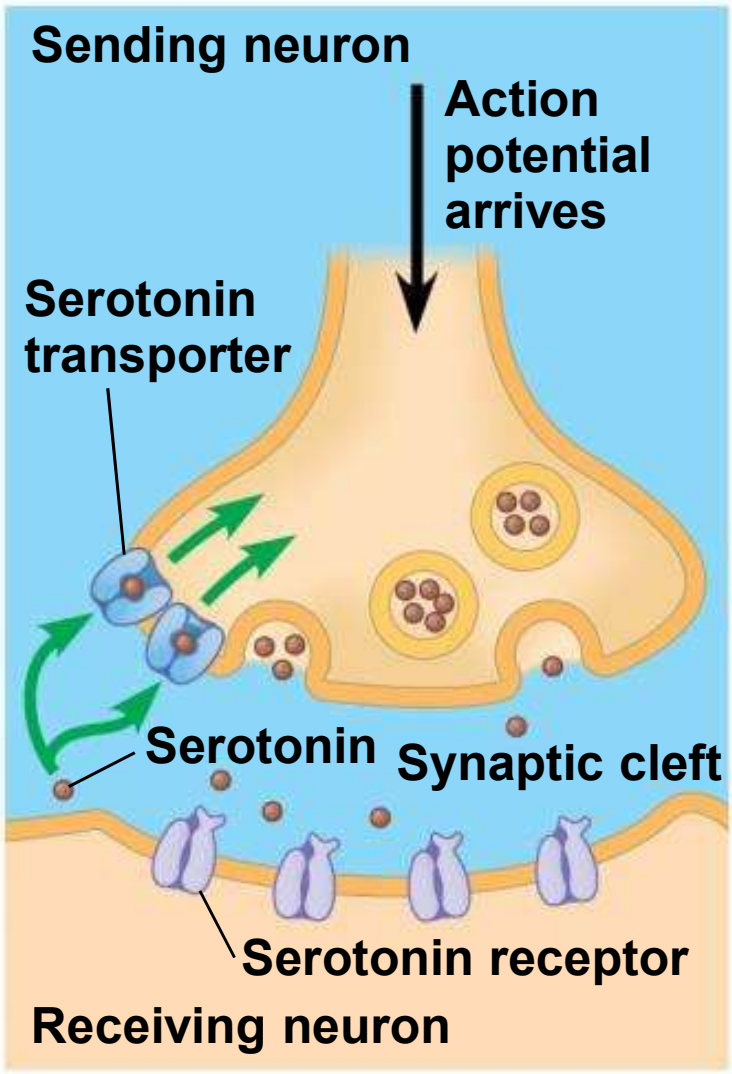
中國餐館症???

Attention deficit hyperactivity disorder (ADHD): methylphenidate (Retalin), block dopamine reuptake (inhibitory neurotransmitter)

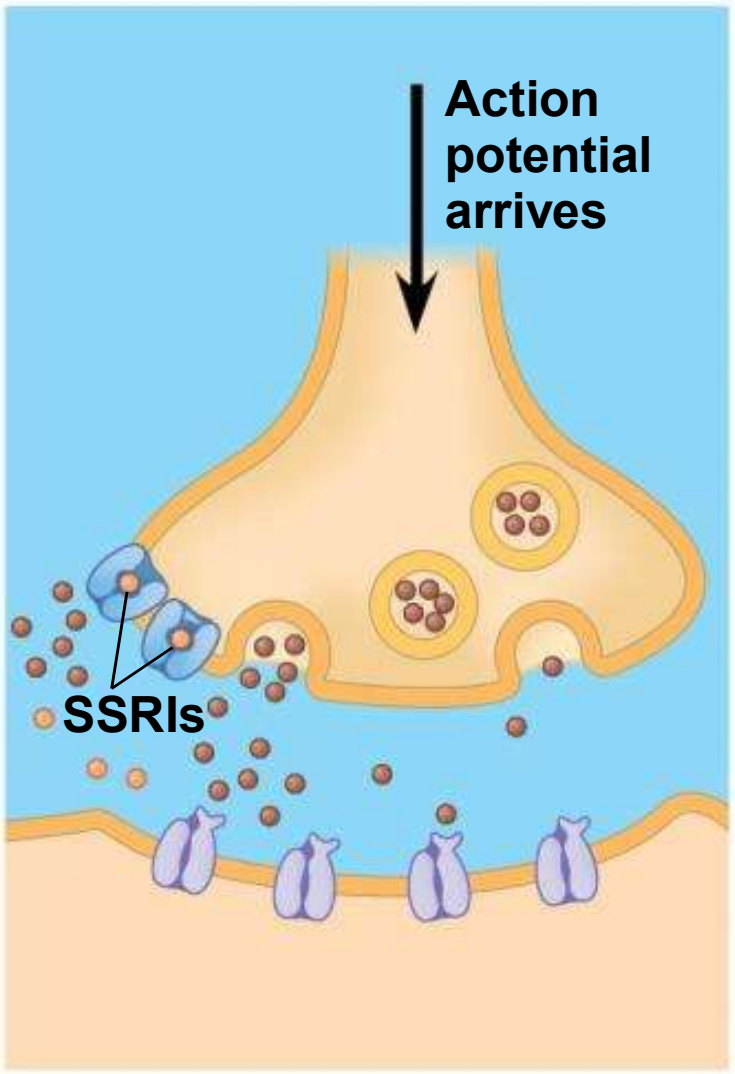
Illegal drugs, club drugs

常見濫用藥物分類
https://drug-prevention.fda.gov.tw/AntiPoison/DrugList.aspx?code=6030&nodeID=391

- Many prescription drugs used to treat psychological disorders alter the effects of neurotransmitters.
  - Tranquilizers such as diazepam (Valium) and alprazolam (Xanax) activate the receptors for the neurotransmitter GABA, increasing its effect at inhibitory synapses.
  - A drug may bind to and block a receptor, reducing a neurotransmitter's effect.
  - Still other drugs, such as the selective serotonin reuptake inhibitors (SSRIs) used to treat depression, act by inhibiting neurotransmitter "reuptake."



Reuptake of serotonin



Inhibition of serotonin reuptake by SSRI

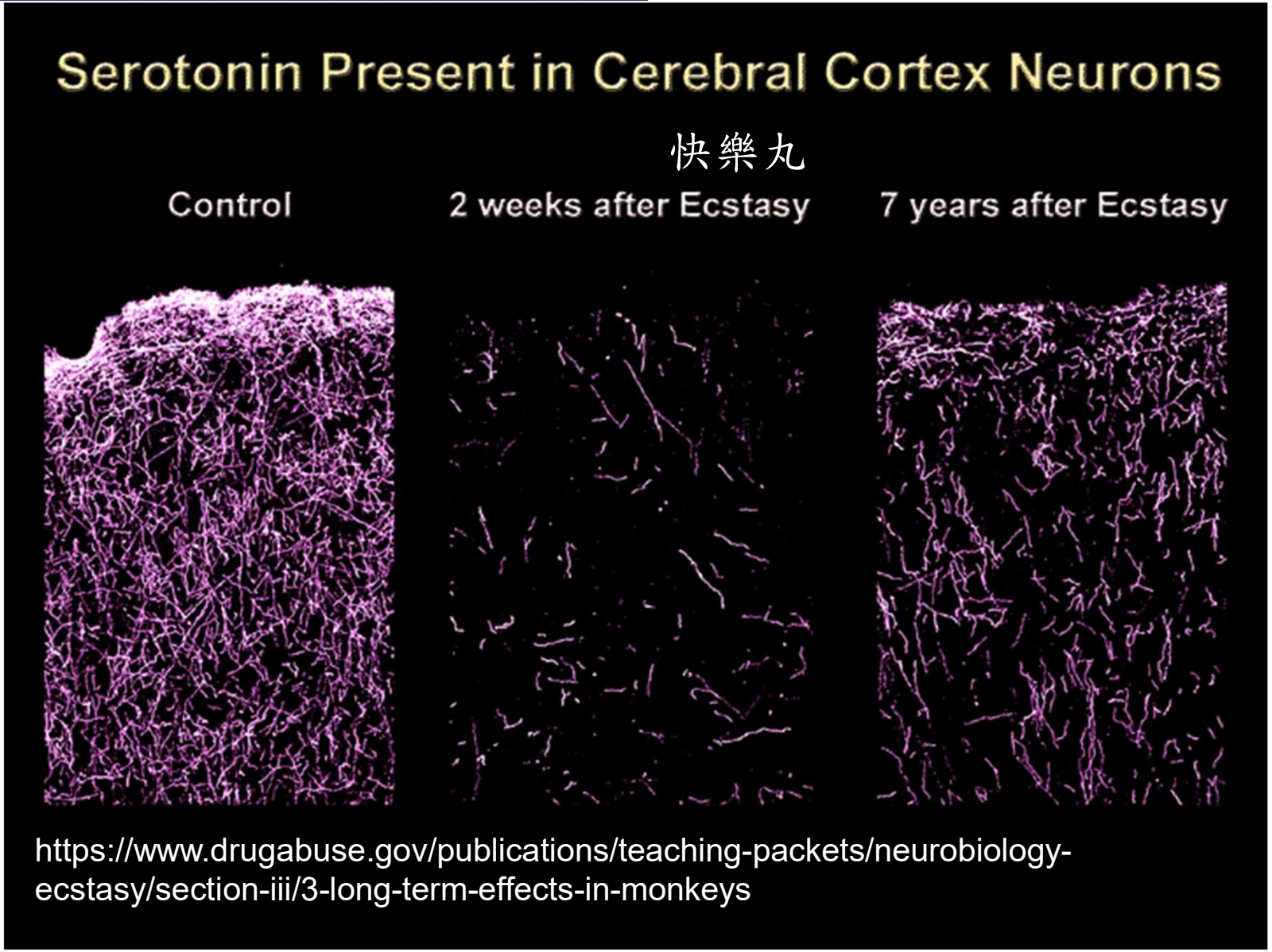
Addiction

Figure adapted from "Antidepressants Prevent Hierarchy Destabilization Induced by Lipopolysaccharide Administration in Mice: A Neurobiological Approach to Depression" by Daniel W. H. Cohn, et. al., from ANNALS OF THE NEW YORK ACADEMY OF SCIENCES, July 2012, Volume 1262. Copyright © 2012 by The New York Academy of Sciences. Reprinted with permission of Wiley Inc.

NIDA NATIONAL INSTITUTE ON DRUG ABUSE
The Science of Drug Abuse & Addiction
NATIONAL INSTITUTES OF HEALTH

http://www.nida.nih.gov/

MDMA



https://www.drugabuse.gov/publications/teaching-packets/neurobiology-ecstasy/section-iii/3-long-term-effects-in-monkeys

28.10 SCIENTIFIC THINKING: Published data are biased toward positive findings

- Depression is a prevalent mood disorder in the United States.
  - Antidepressants are widely prescribed for this common illness, and SSRIs are popular antidepressant medications.
  - The hypothesis underlying the use of SSRIs is that depression is caused by a deficiency in the brain of serotonin, a regulator of mood.
  - But how effective are drugs like this?
- Researchers set up clinical studies with individuals who are depressed. Well-designed studies
  - include large sample sizes,
  - use randomized assignments of the drug or control (placebo) to participants,

  - may also be double-blind, meaning that neither the depressed patient nor the researchers know who has been assigned to the drug or placebo, and
  - are published in professional journals that are peer-reviewed by other scientists.
- In **Figure 28.10**, we can see that scientists examined data from 74 clinical trials with antidepressants between 1987 and 2004. Of these, the FDA deemed
  - about half to be positive (that is, they demonstrated the effectiveness of the drug) and
  - half negative or questionable.
- However, the positive studies were much more likely to be published.

74 clinical trials

38 positive
(as judged by FDA)

37 published
as positive

1 unpublished

38 negative or unclear
(as judged by FDA)

3 published
as negative

22 unpublished

11 published
as positive

- The FDA put policies in place that require
  - all studies to be registered when they are initiated and
  - new studies to be accessible to the general public and free of charge within a year or so of publication.

抗憂鬱劑類別	代表藥物	說　明
三環抗鬱劑（TCA）	imipramine amitriptyline doxepin	效果不錯，但是副作用和過量時毒性較大，因此已逐漸減少使用頻率。
單胺氧化酶抑制劑（MAOI）	moclobemide	
選擇性血清素再吸收抑制劑（SSRI）	fluoxetine sertraline paroxetine	效果與傳統藥物差不多，但是副作用較小，是較常被採用的藥物。
血清素及正腎上腺素再吸收抑制劑（SNRI）	venlafaxine duloxetine	
其他	trazodone bupropion mirtazapine	

http://blog.sina.com.tw/dodolee2007/article.php?entryid=610211

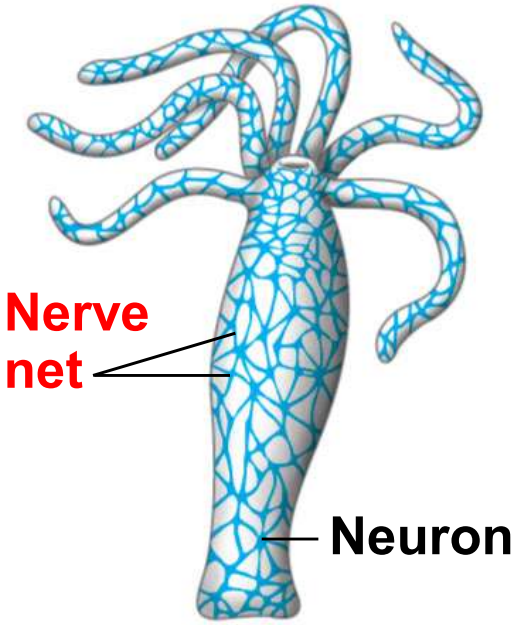
- The evidence seems to be mounting that SSRIs
  - provide only negligible benefit for patients with mild or moderate depression but
  - are helpful to the most severely depressed patients.

AN OVERVIEW OF ANIMAL NERVOUS SYSTEMS

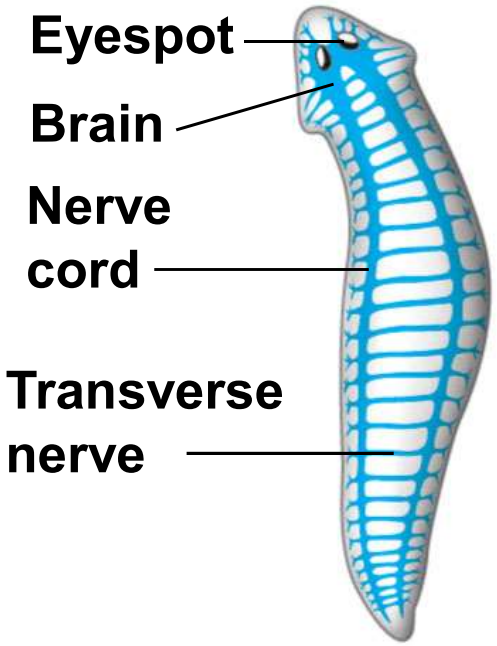
28.11 EVOLUTION CONNECTION: The evolution of animal nervous systems reflects changes in body symmetry

- There is remarkable uniformity throughout the animal kingdom in the way nerve cells function.
- But during subsequent animal evolution, great diversity emerged in the organization of nervous systems as a whole.
- Animals on the earliest branches of the animal evolutionary tree, such as sponges, lack a nervous system.
- Radially symmetrical animals have a nervous system arranged in a weblike system of neurons called a nerve net.
- Most bilaterally symmetrical animals evolved
  - **cephalization**, the concentration of the nervous system at the head end, and
  - **centralization**, the presence of a central nervous system distinct from a peripheral nervous system.

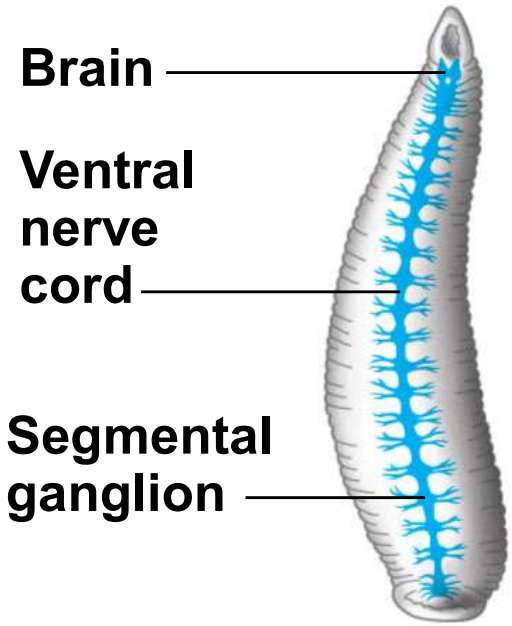
Figure 28.11A



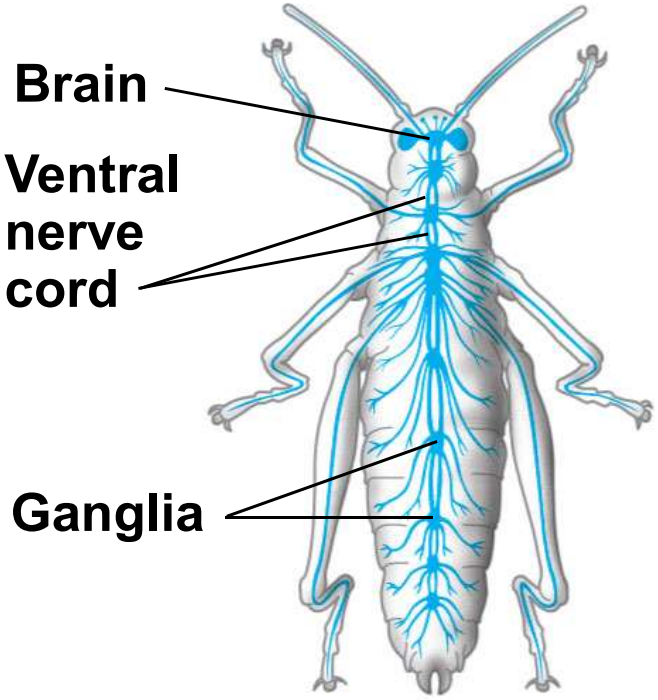
Hydra (cnidarian)



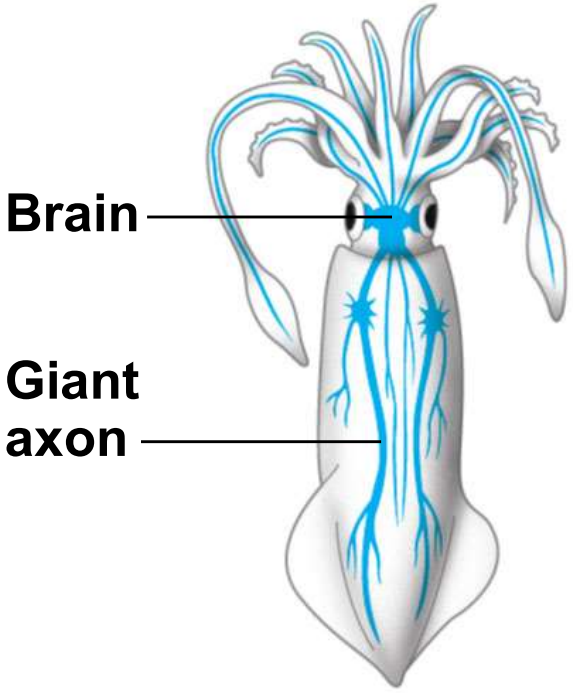
Flatworm (planarian)



Leech (annelid)



Insect (arthropod)

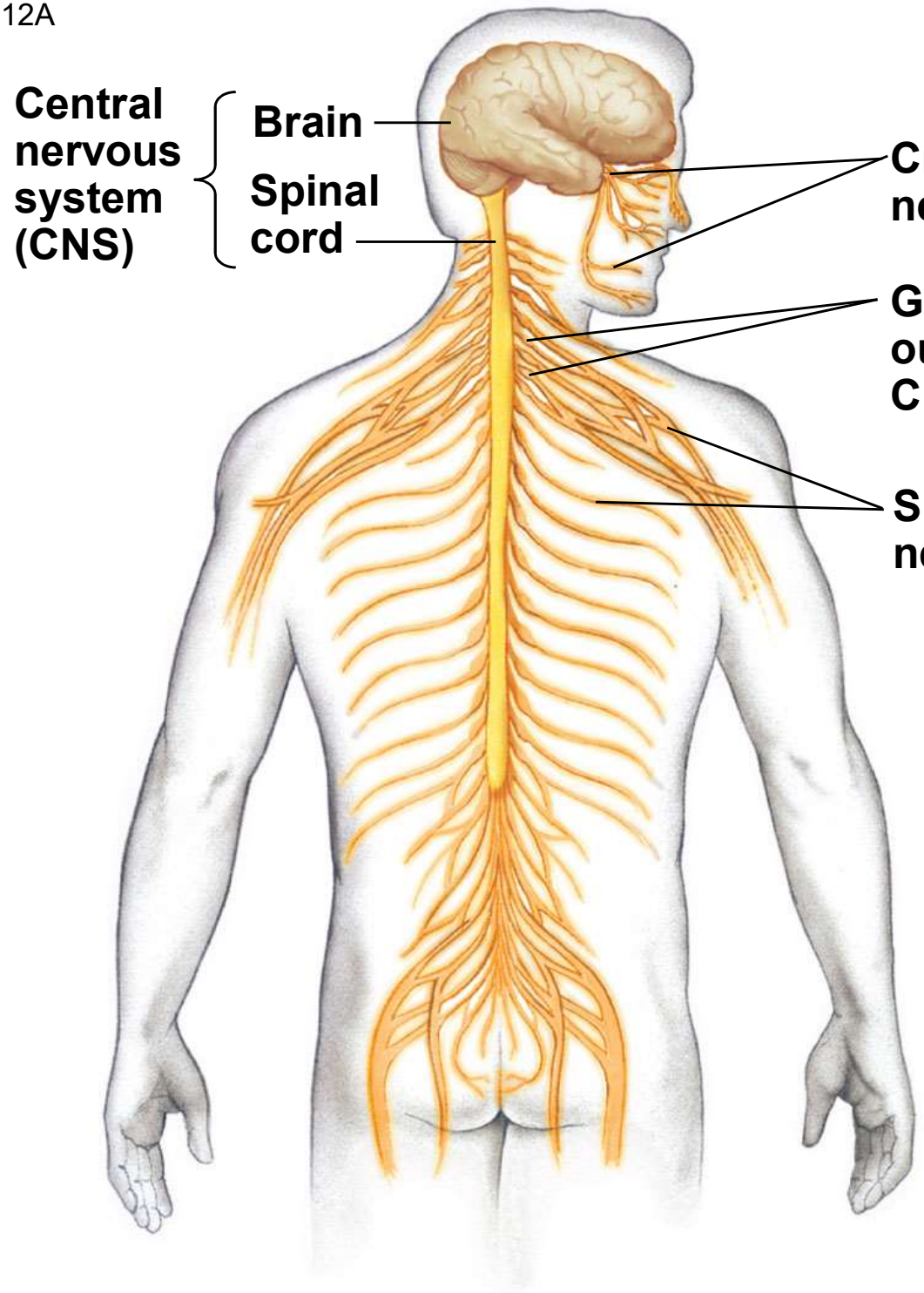


Squid (mollusc)

28.12 Vertebrate nervous systems are highly centralized

- In all vertebrates, the central nervous system (CNS)
  - consists of the **brain** and **spinal cord** and
  - includes spaces filled with cerebrospinal fluid
    - forming **ventricles** of the brain, 腦室
    - forming the **central canal** of the spinal cord, and
    - surrounding the brain. 神經管
- The vertebrate peripheral nervous system (PNS) consists of
  - cranial nerves, 顱神經、共12對
  - spinal nerves, 脊神經
  - ganglia

Figure 28.12A



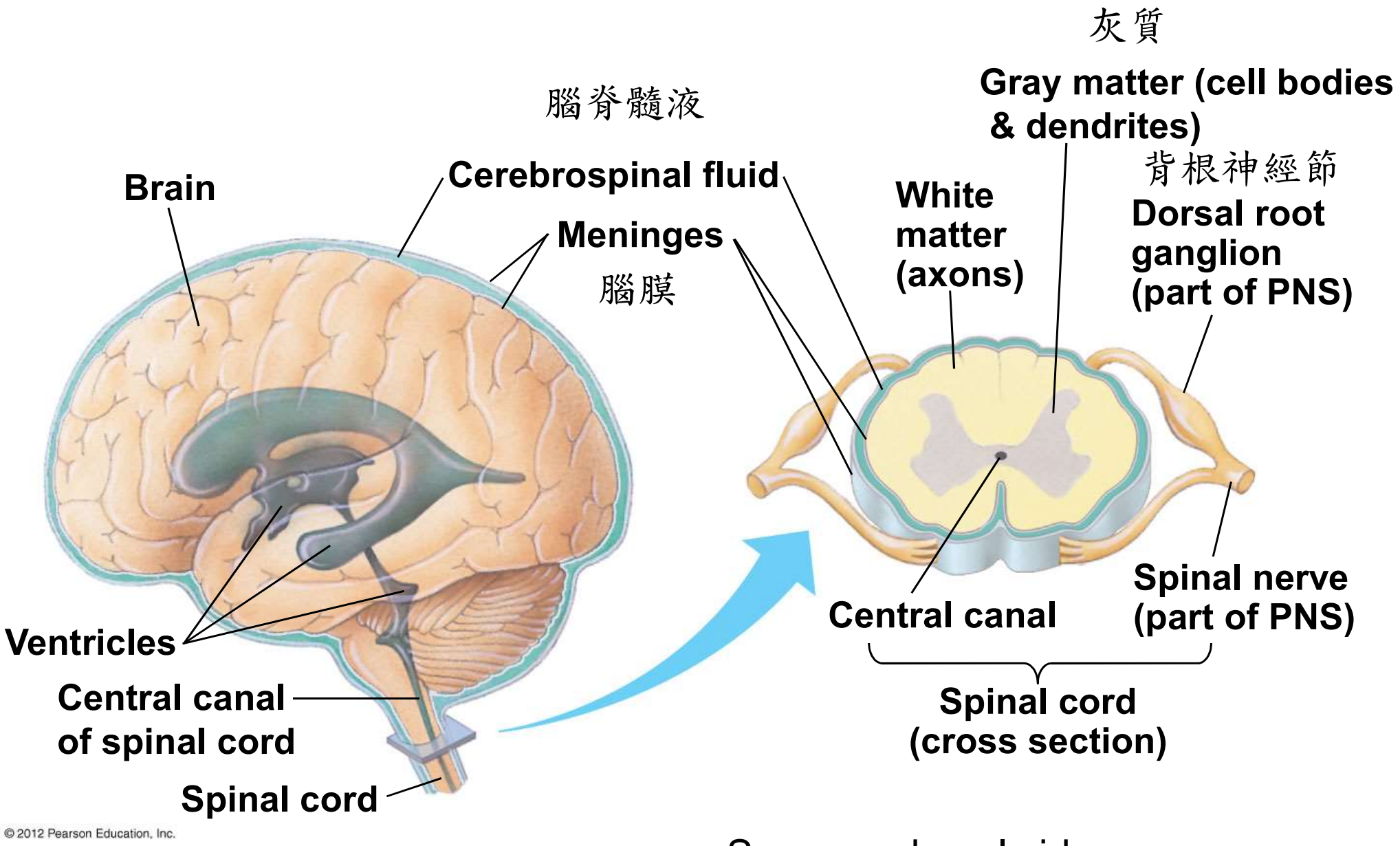
椎間盤（軟骨）突出

http://www.spine-online.com.tw/chest.php?act=view&no=42&idx=004

28.12 Vertebrate nervous systems are highly centralized

- A vast network of blood vessels services the CNS, but a selective mechanism, called the **blood-brain barrier**, maintains a stable chemical environment for the brain.
- **Cerebrospinal fluid** is found in and around the brain and spinal cord.
  - **Ventricles** are spaces in the brain filled with cerebrospinal fluid.
  - Ventricles are continuous with the narrow **central canal** of the spinal cord.
- Also protecting the brain and spinal cord are layers of connective tissue called **meninges**.

Figure 28.12B

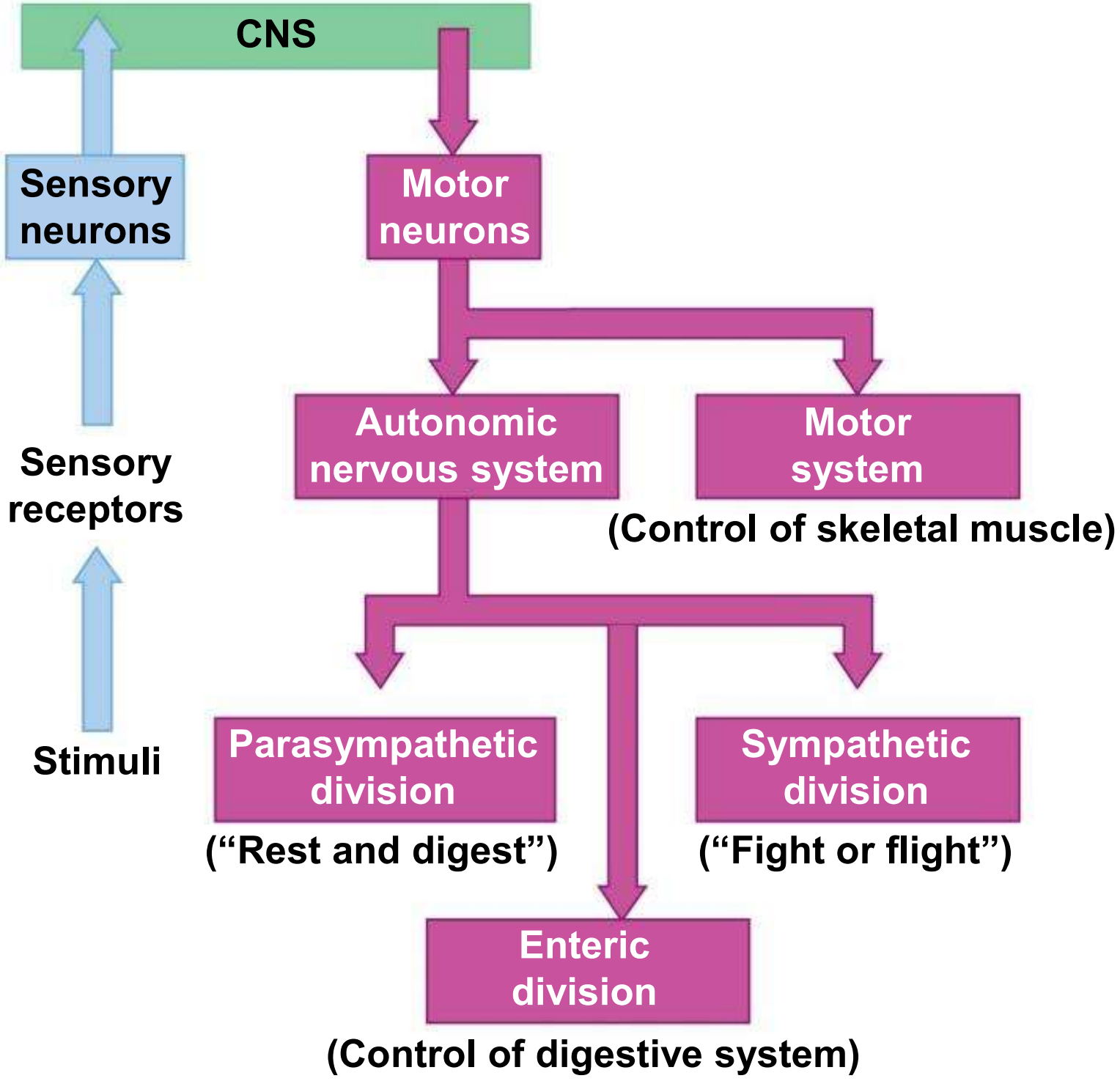


Sensory: dorsal side
Motor: ventral side

28.13 The peripheral nervous system of vertebrates can be divided into functional components

- The Motor neurons can be divided into two functional components:
  1. The **motor system**
     - carries signals from the CNS to skeletal muscles, mainly in response to external stimuli, and
     - is mostly voluntary.
  2. The **autonomic nervous system**
     - regulates the internal environment by controlling smooth and cardiac muscles and the organs and glands of the digestive, cardiovascular, excretory, and endocrine systems and
     - is mostly involuntary.

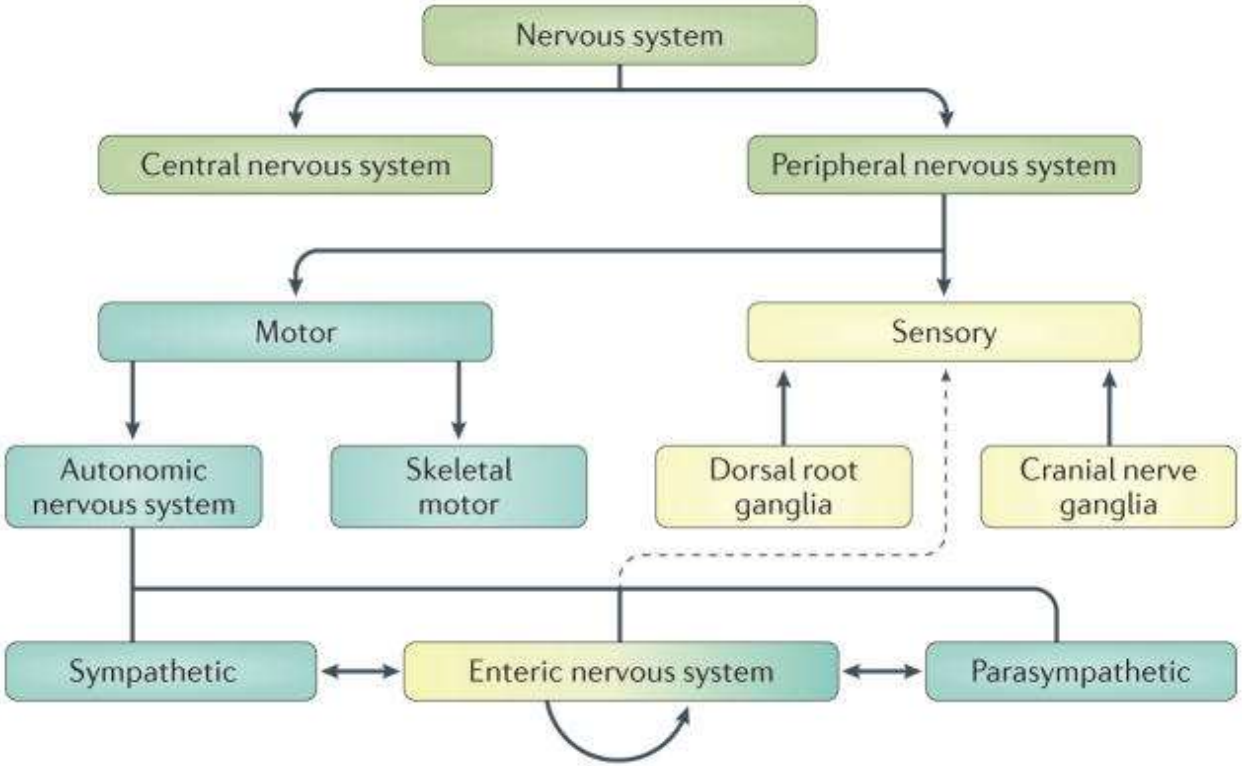
- The autonomic nervous system is composed of three divisions.
  1. The **parasympathetic division** primes the body for activities that gain and conserve energy for the body.
  2. The **sympathetic division** prepares the body for intense, energy-consuming activities.
  3. The **enteric division** consists of networks of neurons in the digestive tract, pancreas, and gallbladder that control secretion and peristalsis.
- The motor nervous system
  - carries signals to and from skeletal muscles and
  - mainly responds to external stimuli.
- The autonomic nervous system 自主神經系統
  - regulates the internal environment and
  - controls smooth and cardiac muscle and organs and glands of the digestive, cardiovascular, excretory, and endocrine systems.


CNS
Sensory neurons
Motor neurons
Sensory receptors
Autonomic nervous system
Motor system
(Control of skeletal muscle)
Stimuli
Parasympathetic division
("Rest and digest")
Sympathetic division
("Fight or flight")
Enteric division
(Control of digestive system)

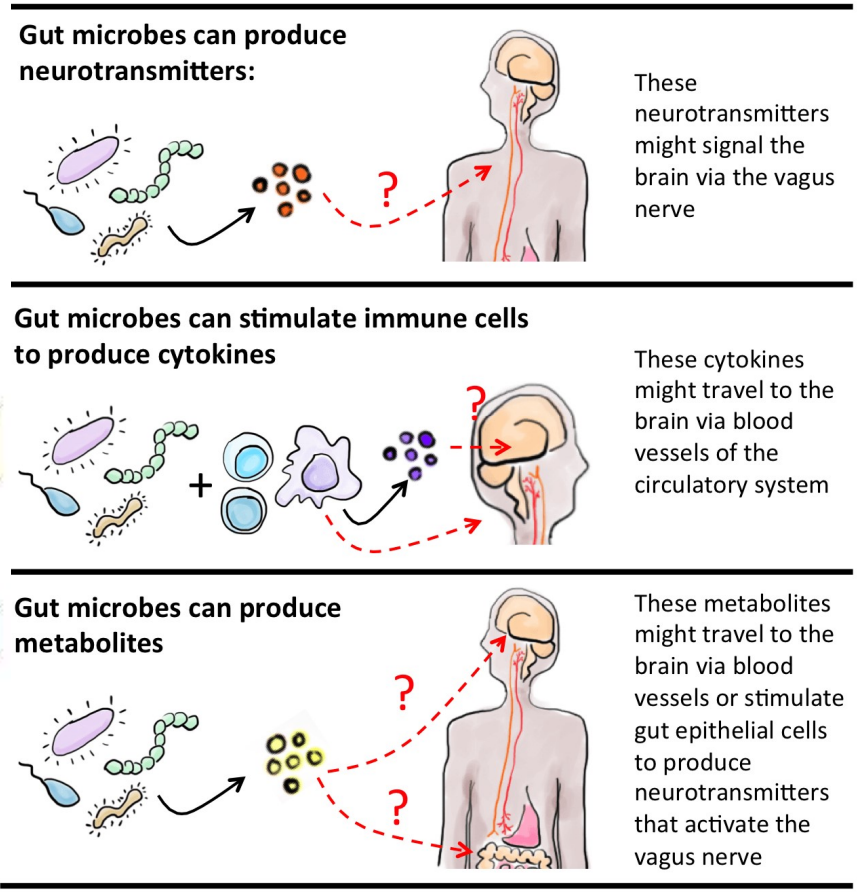
Enteric system

The bowel and beyond: the enteric nervous system in neurological disorders

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5005185/



Hypotheses about the gut-brain axis

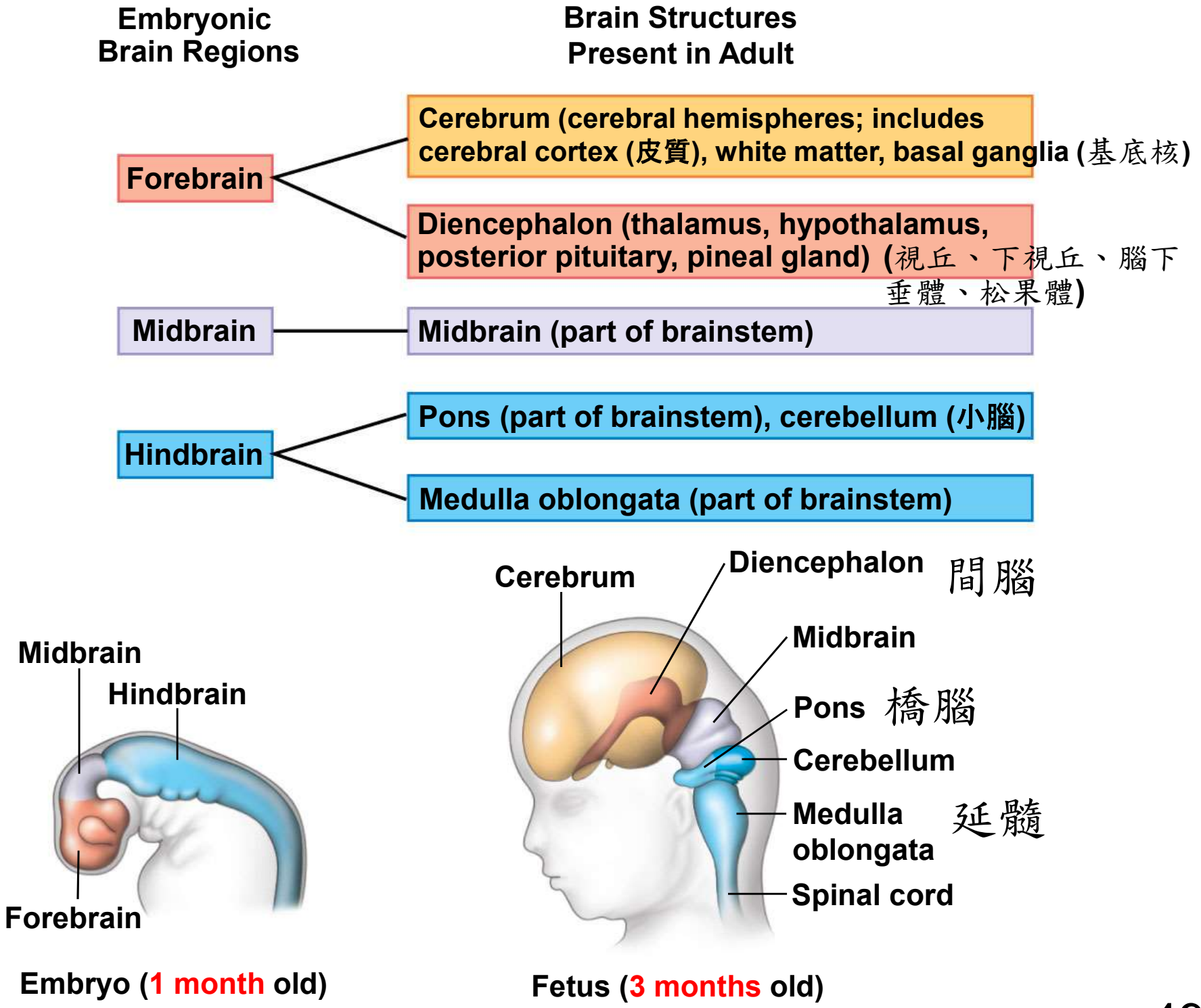


http://www.wildculture.com/article/gut-feelings-parkinson%E2%80%99s-and-depression/1651

28.14 The vertebrate brain develops from three anterior bulges of the neural tube

- The vertebrate brain evolved by the enlargement and subdivision of the
  - **forebrain**,
  - **midbrain**, and
  - **hindbrain**.
- In the course of vertebrate evolution, the forebrain and hindbrain gradually became subdivided
  - structurally and
  - functionally.
- In birds and mammals the **cerebrum**
  - is much larger and
  - correlates with their sophisticated behavior.

Figure 28.13



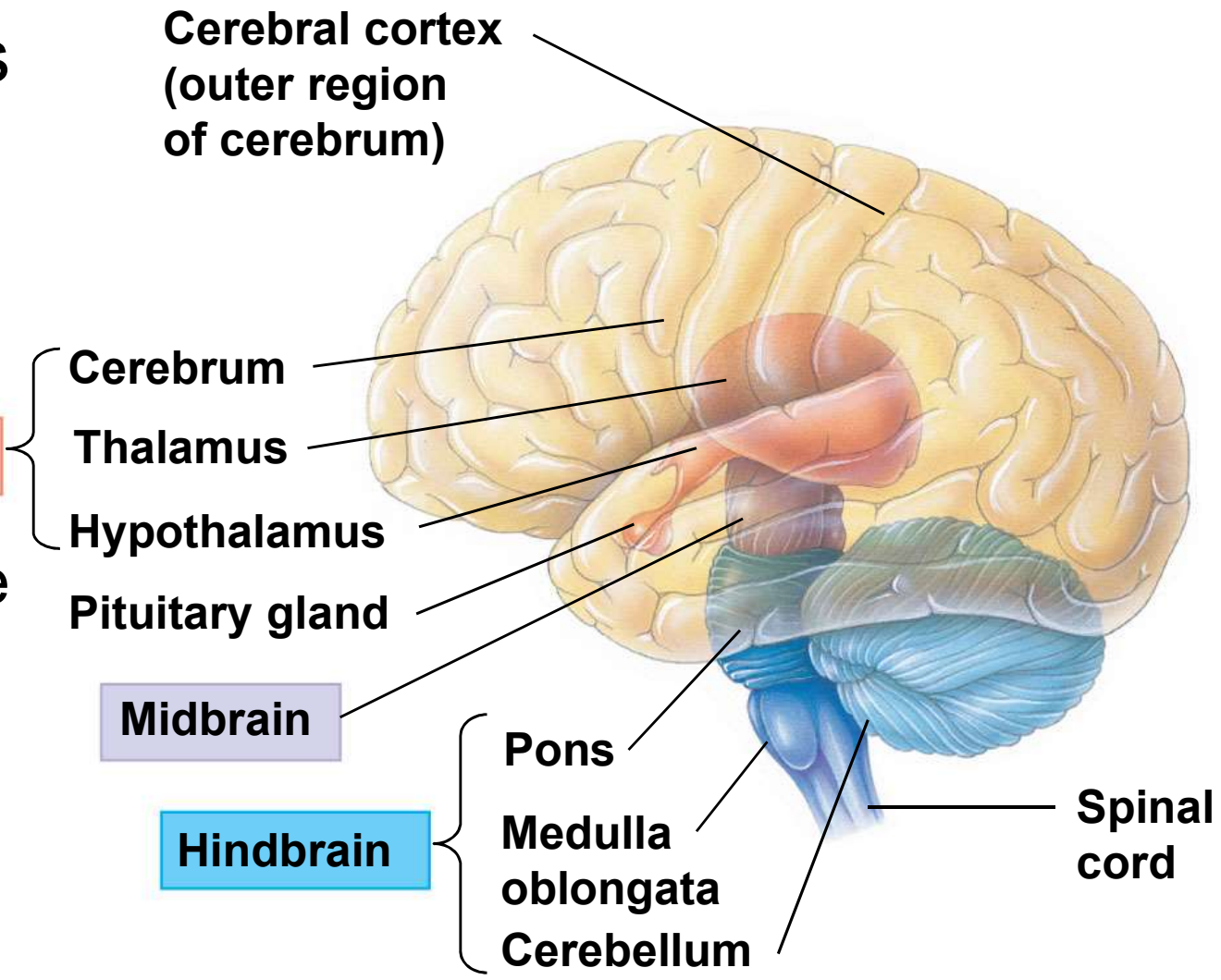
THE HUMAN BRAIN

Humans have the largest brain surface area, relative to body size, of all animals

Genes to cognition
3D Brain http://www.g2conline.org/

28.15 The structure of a living supercomputer: The human brain

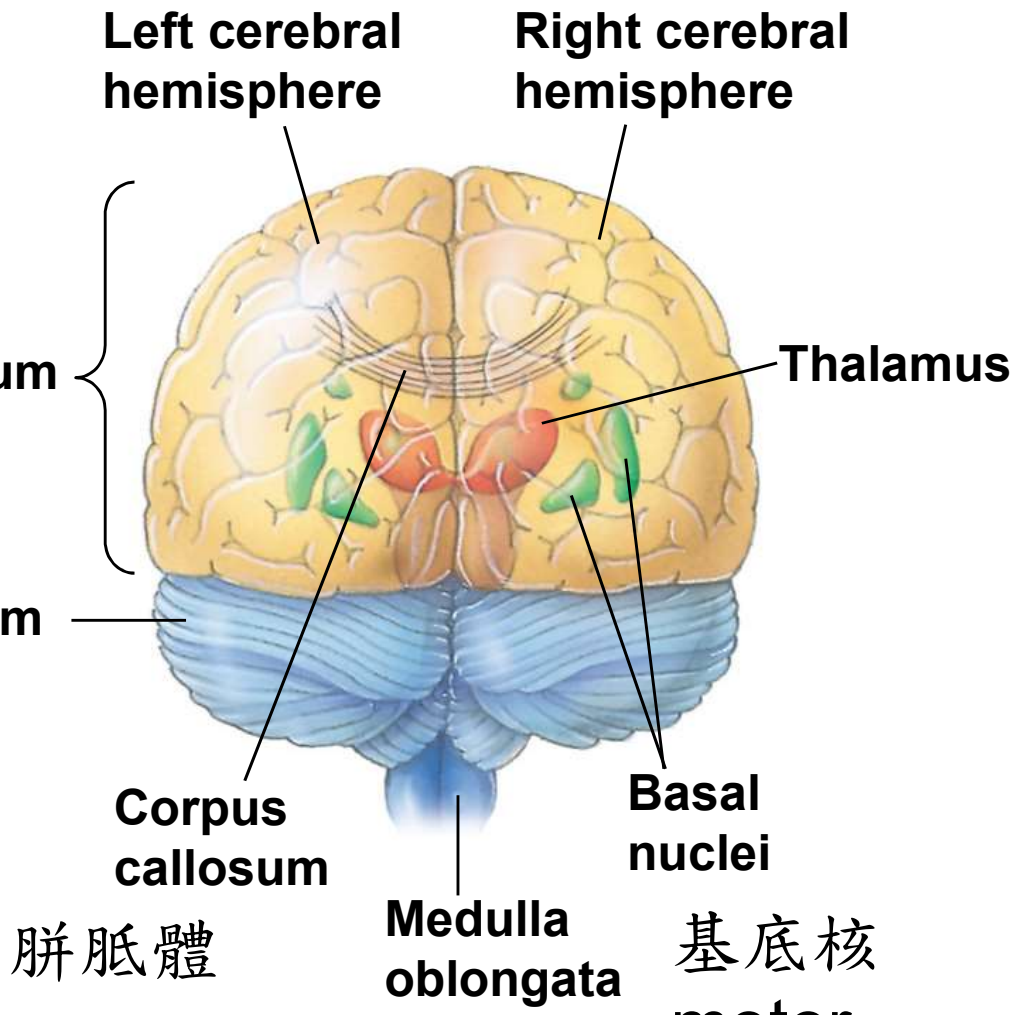
- The human brain is
  - more powerful than the most sophisticated computer
  - composed of three main parts:
    1. forebrain,
    2. midbrain, and
    3. hindbrain.



28.15 The structure of a living supercomputer: The human brain

The midbrain, subdivisions of the hindbrain, the thalamus, and the hypothalamus

- conduct information to and from higher brain centers,
- regulate homeostatic functions, (hormones, ch26)
- keep track of body position, and
- sort sensory information.



昏迷：意識狀態(昏迷指數)
腦死：無腦幹和脊髓反射
植物人：無有意義的反應

TABLE 28.15 MAJOR STRUCTURES OF THE HUMAN BRAIN

Brain Structure	Major Functions
Brainstem	Conducts data to and from other brain centers; helps maintain homeostasis; coordinates body movement
Medulla oblongata	Controls breathing, circulation, swallowing, digestion
Pons	Controls breathing
Midbrain	Receives and integrates auditory data; coordinates visual reflexes; sends sensory data to higher brain centers
Cerebellum	Coordinates body movement; plays role in learning and in remembering motor responses
Thalamus	Serves as input center for sensory data going to the cerebrum; sorts and groups all incoming sensory data for cerebrum
Hypothalamus	Functions as homeostatic control center; controls pituitary gland; serves as biological clock
Cerebrum	Performs sophisticated integration of information; plays major role in memory, learning, speech, emotions; formulates complex behavioral responses

Pleasure center
Circadian rhythms

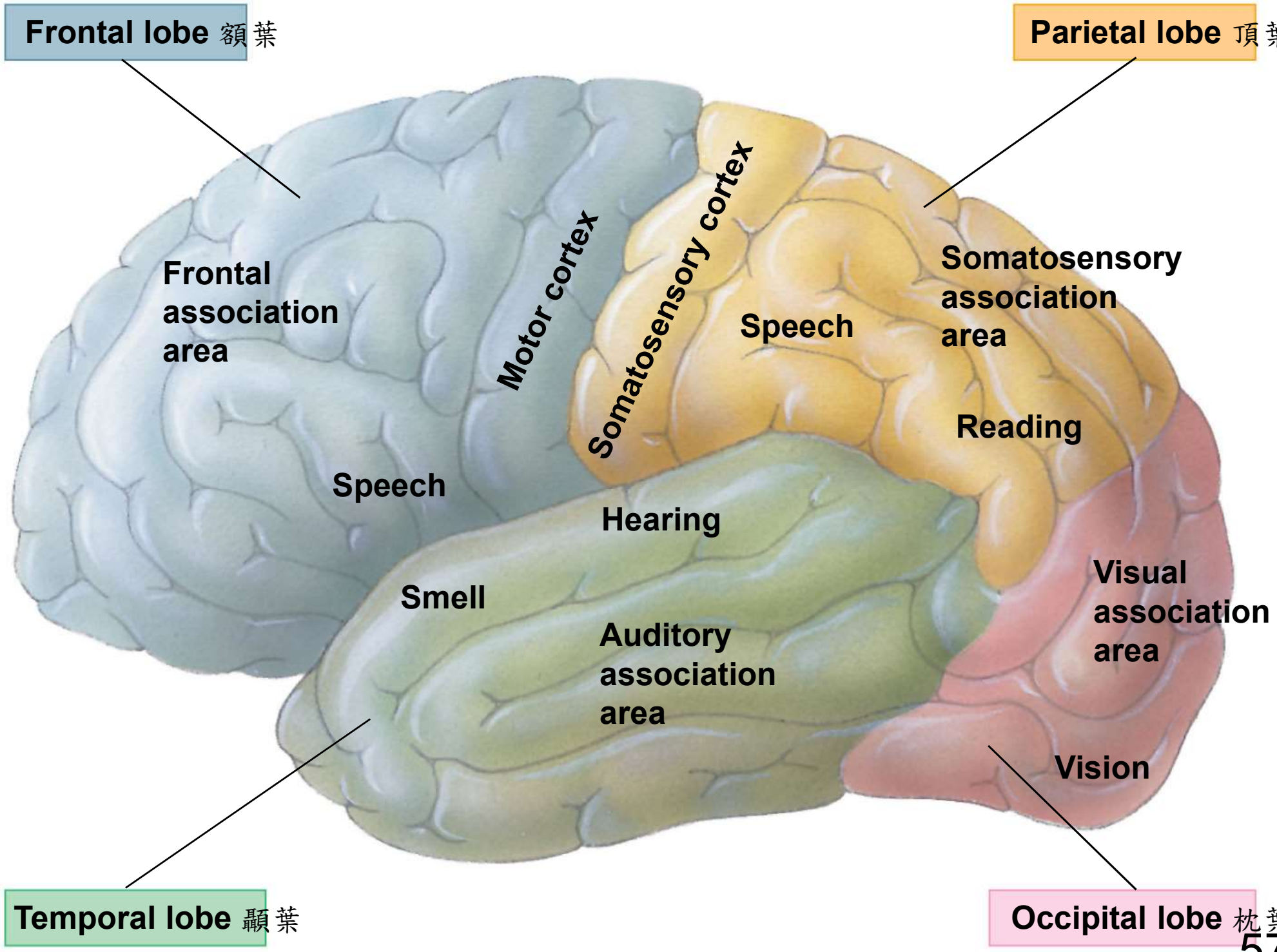
- A pair of hypothalamic structures called the suprachiasmatic nuclei function as an internal timekeeper, our **biological clock**.
  - They receive visual input from the eyes (light/dark cycles, in particular).
  - The clock maintains our **circadian rhythms**—daily cycles of biological activity—such as the sleep/wake cycle.
- The cerebrum, the largest and most complex part of our brain, consists of right and left **cerebral hemispheres**.
  - A thick band of nerve fibers called the **corpus callosum** facilitates communication between the hemispheres.
  - Under the corpus callosum, groups of neurons called the **basal nuclei** are important in motor coordination.

28.16 The cerebral cortex is a mosaic of specialized, interactive regions

- The cerebral cortex
  - is less than 5 mm thick and
  - accounts for 80% of the total human brain mass.
- Researchers have identified a number of functional areas within each lobe.
- Two areas of known function form the boundary between the frontal and parietal lobes.
  1. The motor cortex mainly sends commands to skeletal muscles, signaling appropriate responses to sensory stimuli.
  2. The somatosensory cortex receives and partially integrates signals from touch, pain, pressure, and temperature receptors throughout the body.

- The cerebral cortex also has centers that receive and begin processing sensory information concerned with vision, hearing, taste, and smell.
- The motor cortex directs responses.
- **Association areas**
  - are concerned with higher mental activities such as reasoning and language and
  - make up most of the cerebrum.
- The right and left cerebral hemispheres tend to specialize in different mental tasks, a phenomenon known as **lateralization**.

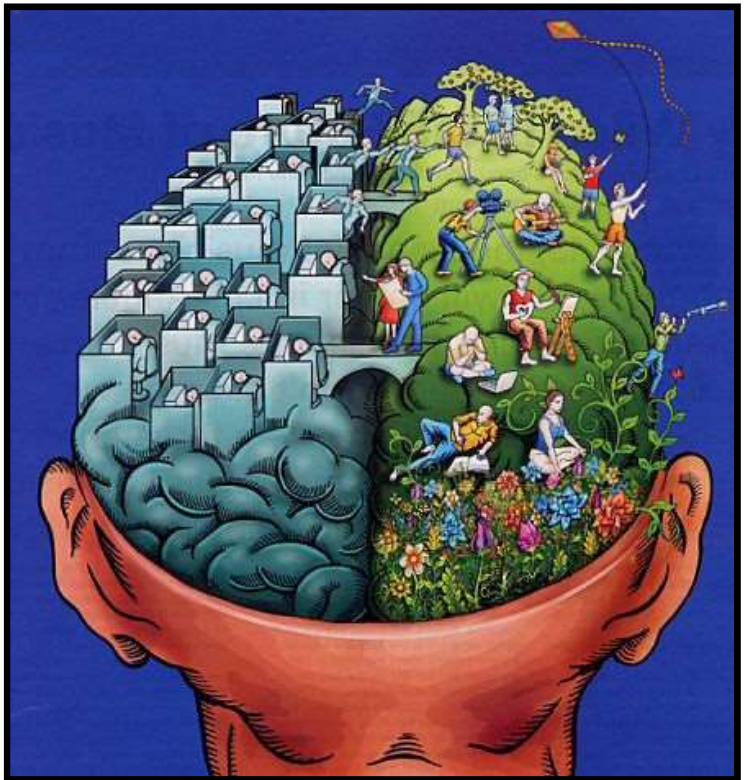
Figure 28.15



28.17 CONNECTION: Injuries and brain operations provide insight into brain function

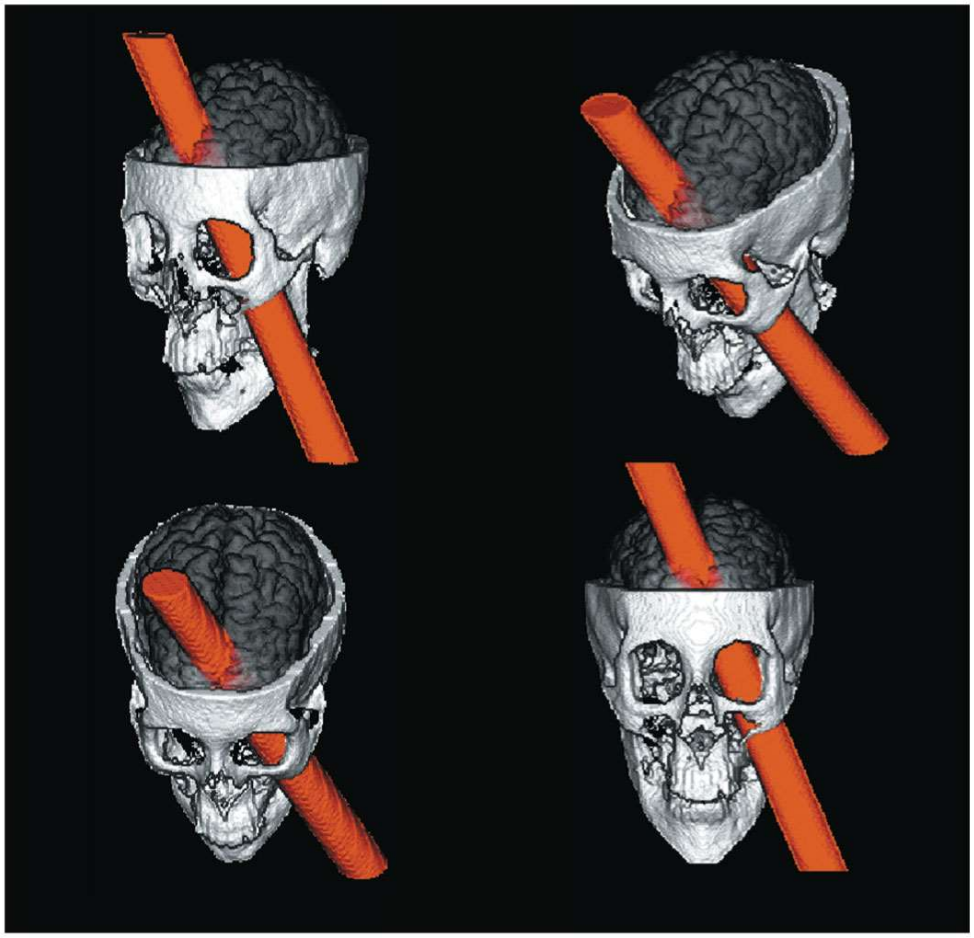
- Brain injuries and surgeries reveal brain functions.
  - After a 13-pound steel rod pierced his skull, Phineas Gage appeared to have an intact intellect but his associates noted negative changes to his personality.
  - Stimulation of the cerebral cortex during surgeries caused patients to recall sensations and memories.
  - Cutting the corpus callosum revealed information about brain lateralization.

胼胝體

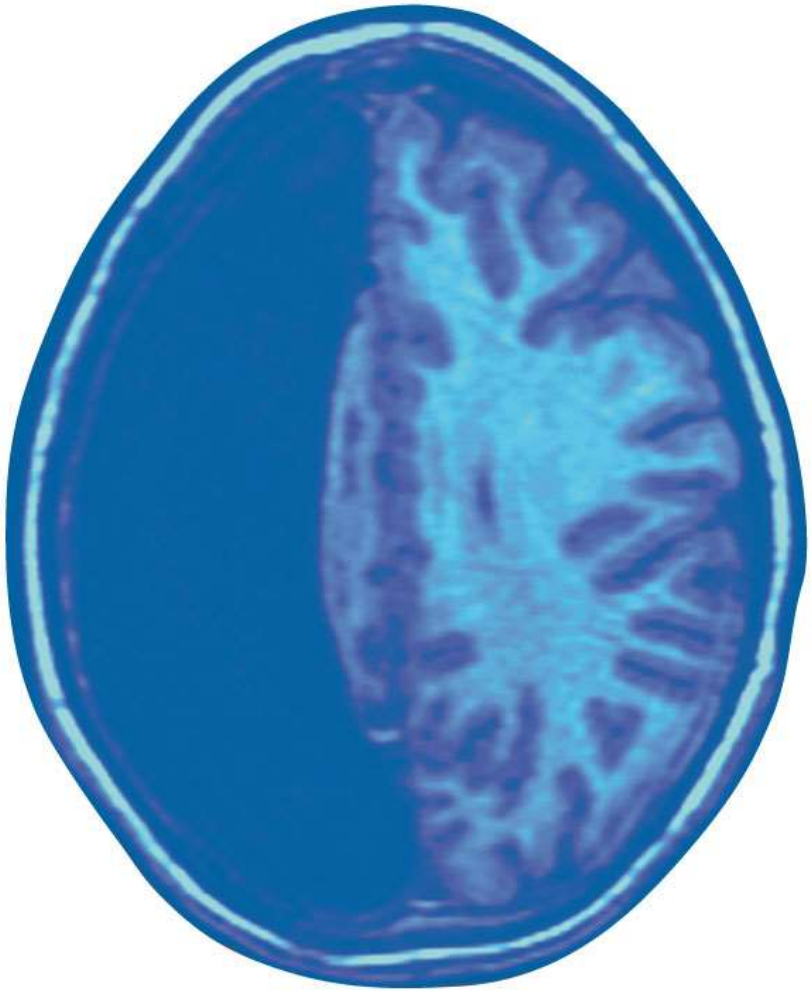


http://www.squidoo.com/braintest/

Figure 28.16A



1848 Phineas Gage

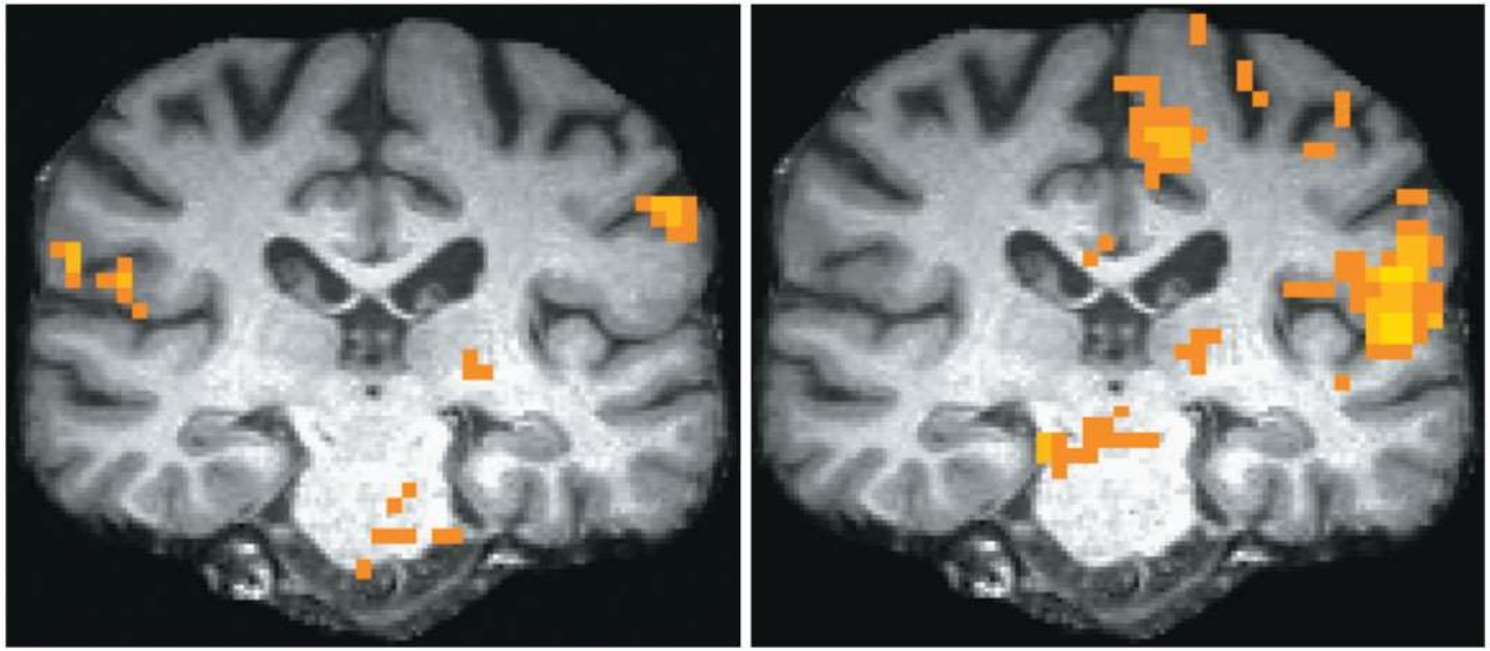


Hemispherectomy
For severe epilepsy

Half a Brain is Enough: The Story of Nico (Cambridge Studies in Cognitive and Perceptual Development) (English)

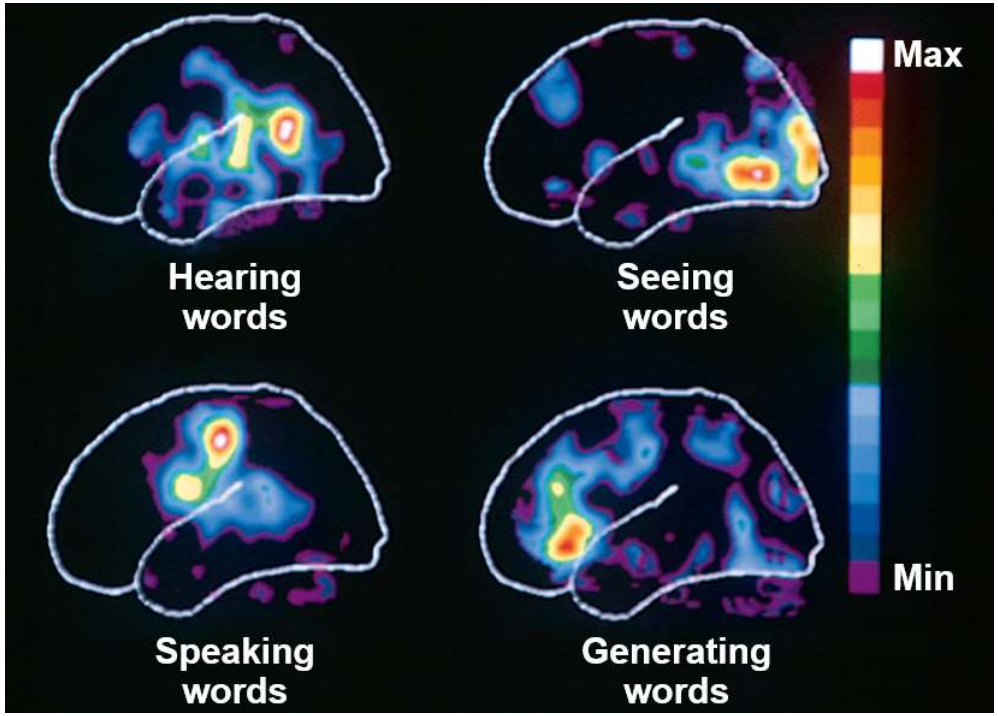
28.18 CONNECTION: fMRI scans provide insight into brain structure and function

- Functional magnetic resonance imaging (fMRI) is
  - a scanning and imaging technology used to study brain functions,
  - used on conscious patients,
  - monitors changes in blood oxygen usage in the brain, and
  - correlates to regions of intense brain function.



Healthy veteran Veteran with Gulf War syndrome

- Studies using fMRI confirm hypotheses based on older technologies about the roles of specific brain areas in movement and intention.
- Researchers have applied such techniques to correlate specific brain regions with nearly every aspect of human cognition, consciousness, and emotion.



Positron Emission Tomography (PET)

Accumulation of radioactive isotopes in active neurons (the half life is very short, ~hrs)

28.19 The reticular formation is involved in arousal and sleep

- The *reticular formation* is one example of a functional brain system that regulates alertness.
  - Attentiveness and mental alertness can change rapidly.
  - Arousal is a state of awareness of the outside world.
  - Its counterpart is sleep, a state when external stimuli are received but not consciously perceived.
  - The reticular formation is a diffuse network of neurons that extends through the core of the brainstem.
- The alertness that is maintained by the reticular formation is inhibited by a region of the hypothalamus that induces and regulates sleep.
- Sleep is essential for survival and is an active state, at least for the brain.
- Understanding the function of sleeping and dreaming remains a compelling research problem.

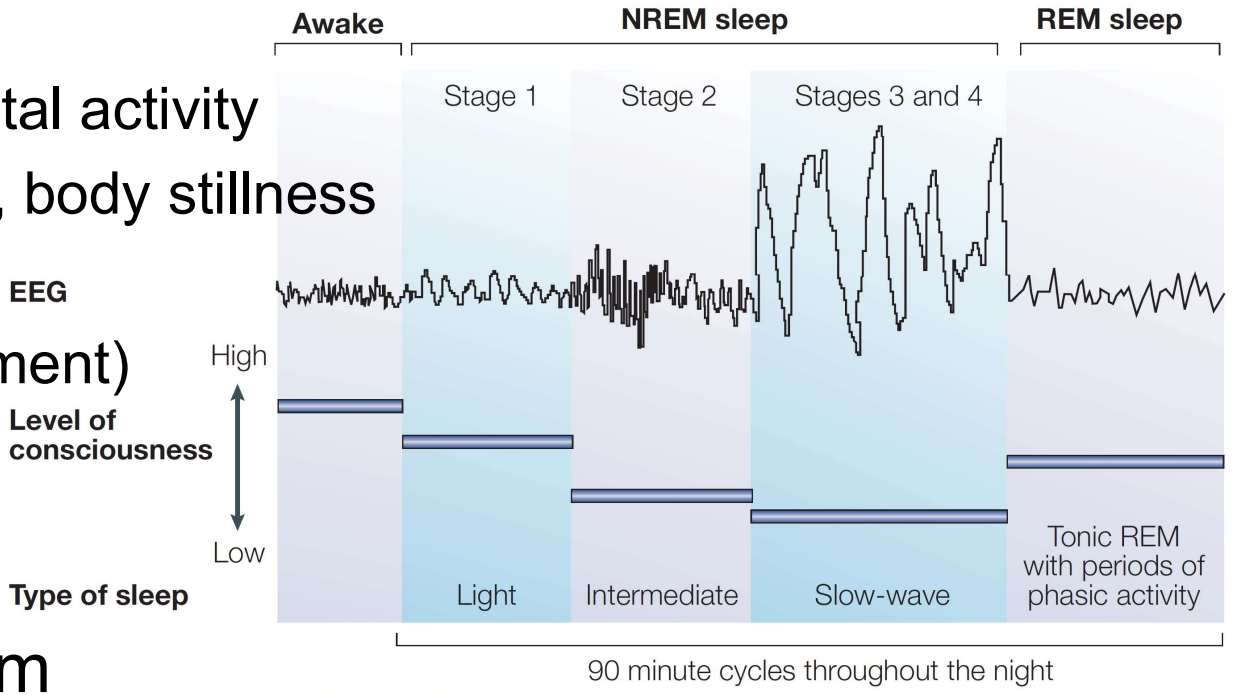
Gamma wave: >40 Hz, high mental activity

Sensorimotor rhyme: 12 ~ 16 Hz, body stillness

Why do we need sleep?

REM --- Dream (rapid eye movement)

Consolidation



EEG: electroencephalogram

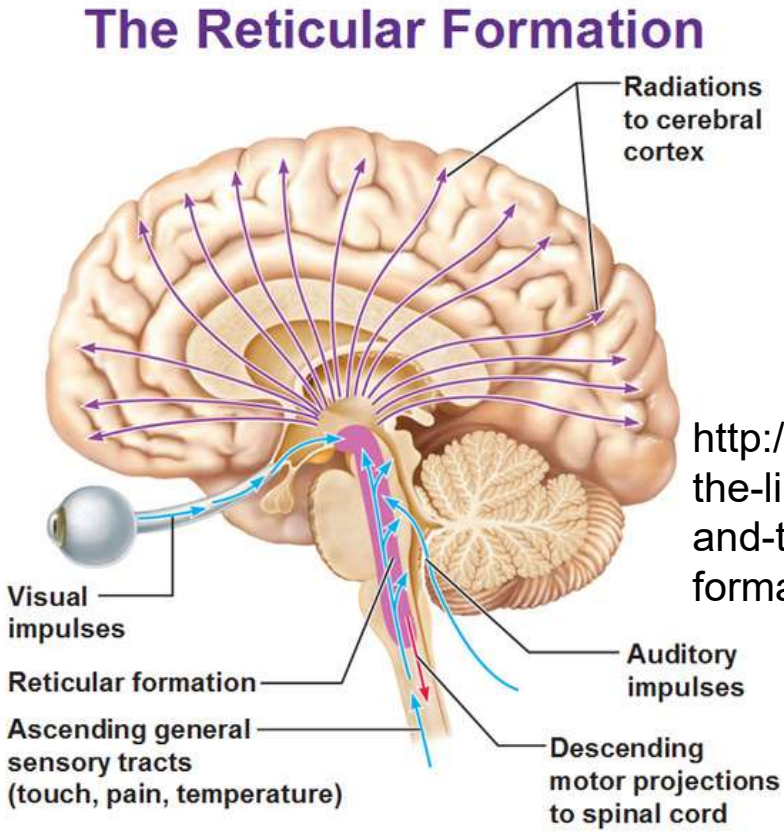
90-120 min, 4~6 cycles

http://emedicine.medscape.com/article/1140322-overview#a1

Chronic sleep deprivation suppresses immune system

https://www.sciencedaily.com/releases/2017/01/170127113010.htm

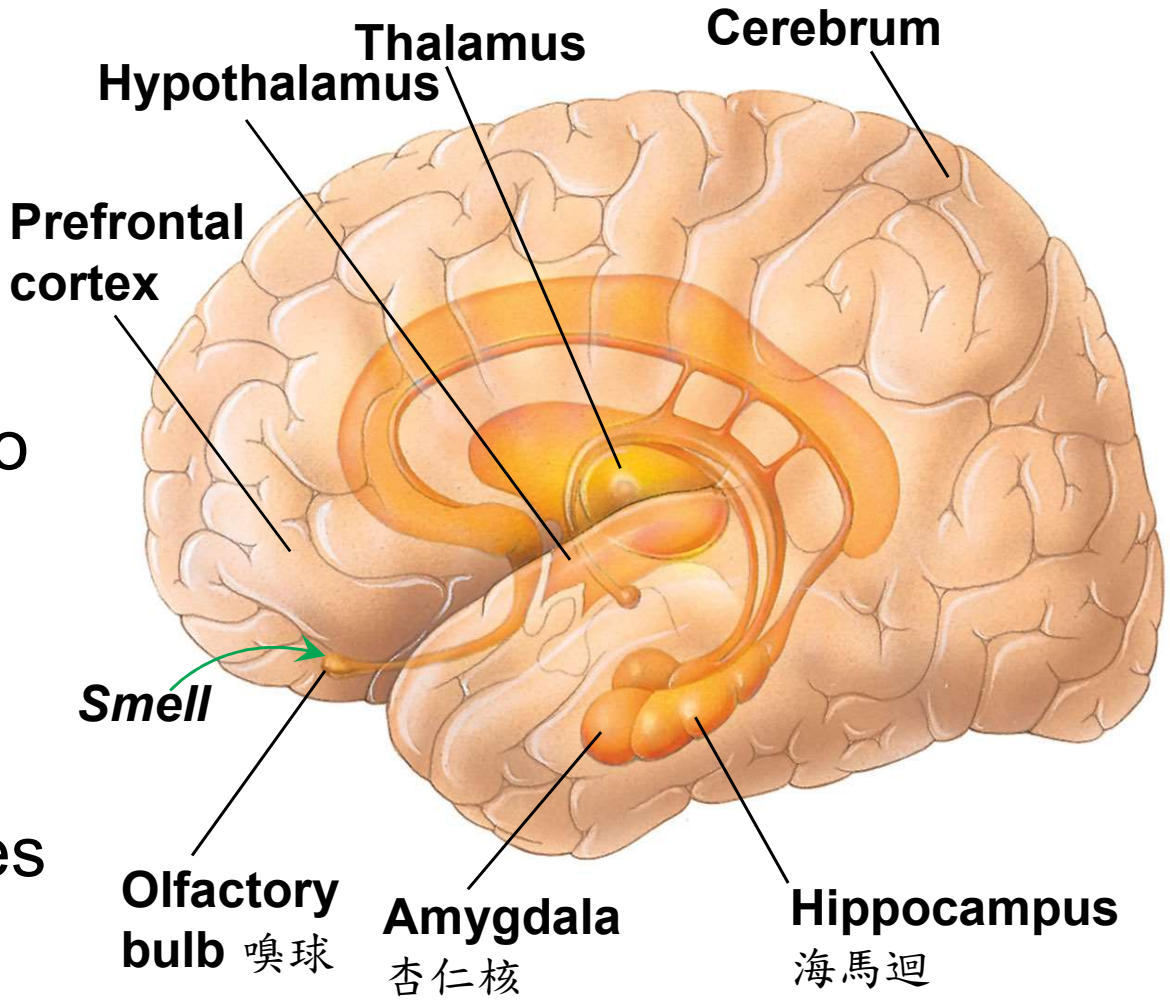
blood samples from 11 pairs of identical twins with different sleep patterns



http://antranik.org/the-limbic-system-and-the-reticular-formation/

28.20 The limbic system is involved in emotions, and memory 邊緣系統

- The **limbic system** is involved in
  - emotions, such as nurturing infants and bonding emotionally to other people,
  - motivation, and
  - memory.
- The limbic system includes
  - parts of the thalamus and hypothalamus and
  - two partial rings around them formed by portions of the cerebral cortex.



Amygdala: emotional memories; link facial expression

Hippocampus: formation and recall Long- and Short-term Memories Factual & Skill Memories

記憶中的味道

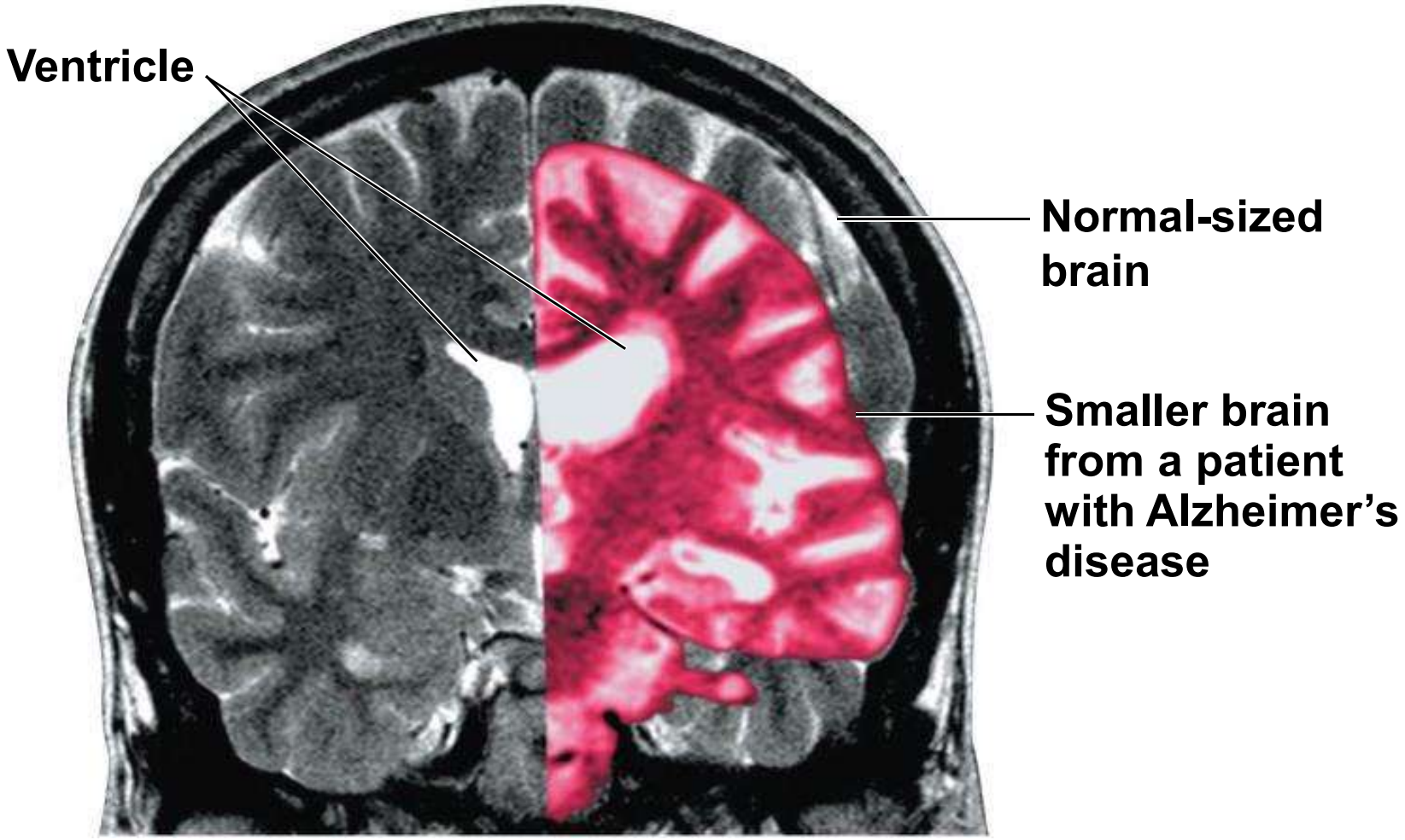
- **Memory**, which is essential for learning, is the ability to store and retrieve information derived from experience.
  - The **hippocampus** is involved in both the formation of memories and their recall.
  - The **amygdala** is central in laying down emotional memories.
- **Short-term memory**, as the name implies, lasts only a short time.
- **Long-term memory**
  - lasts much longer and
  - is enhanced by
    - rehearsal,
    - positive or negative emotional states mediated by the amygdala, and
    - the association of new data with data previously learned and stored in long-term memory.
- **Skill memories**
  - usually involve motor activities that are learned by repetition without consciously remembering specific information and
  - include tying your shoes, riding a bicycle, or hitting a baseball.

28.21 CONNECTION: Changes in brain physiology can produce neurological disorders

- Many neurological disorders can be linked to changes in brain physiology, including
  - schizophrenia, 1% 精神分裂症 思覺失調症
  - major depression,
  - Alzheimer's disease, and
  - Parkinson's disease.

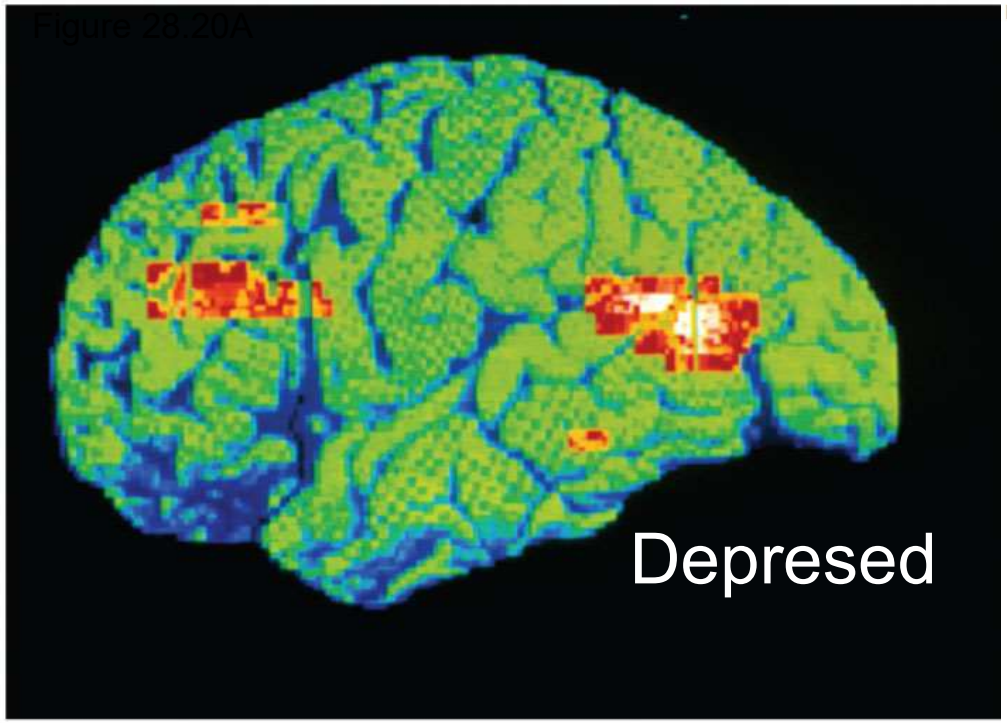
電影題材：美麗境界 A Beautiful Mind；
血色孤語 The Voices

- **Schizophrenia** is a severe mental disturbance characterized by psychotic episodes in which patients have a distorted perception of reality.
- The physiological causes of schizophrenia are unknown, although the disease has a strong genetic component.


Ventricle
Normal-sized brain
Smaller brain from a patient with Alzheimer's disease

- **Bipolar disorder**, or manic-depressive disorder, is characterized by extreme mood swings.
  - The manic phase is marked by high self-esteem, increased energy, and flow of ideas.
  - In its milder forms, this phase is sometimes associated with great creativity.
  - The depressive phase is characterized by lowered ability to feel pleasure, loss of motivation, sleep disturbances, and feelings of worthlessness.
  - Treatments may include selective serotonin reuptake inhibitors (SSRIs), which increase the amount of time serotonin is available to stimulate certain neurons in the brain.
- **Alzheimer's disease** 35% at age 85
  - Its incidence increases dramatically with age.
  - Diagnosis of AD is made with a combination of neuropsychological clinical tests and brain imaging.

Figure 28.20A



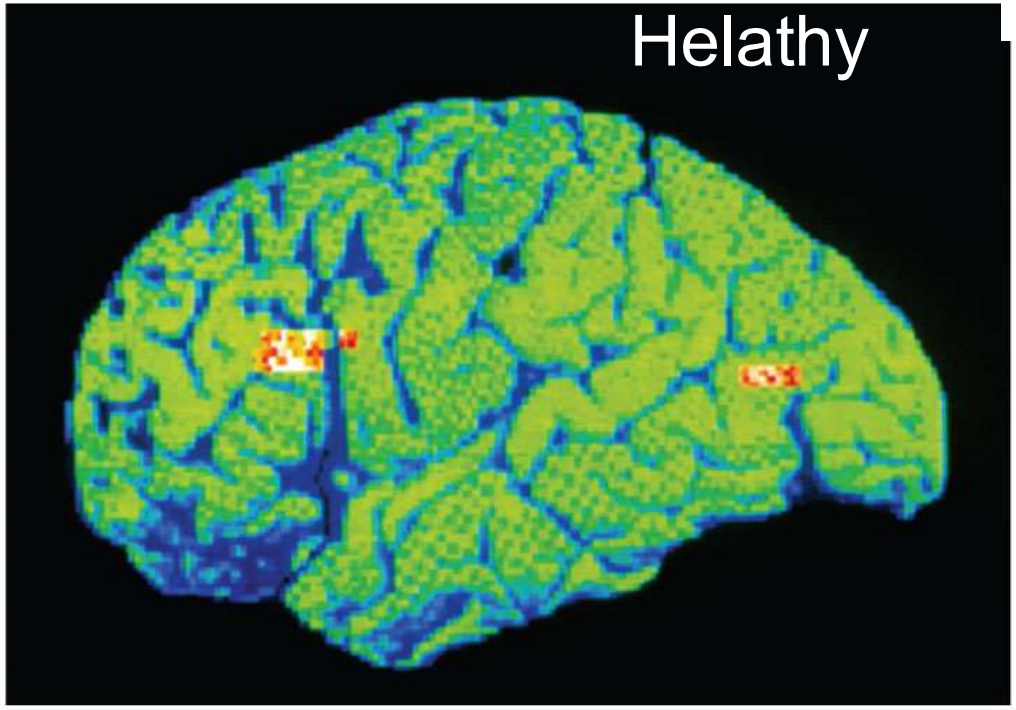
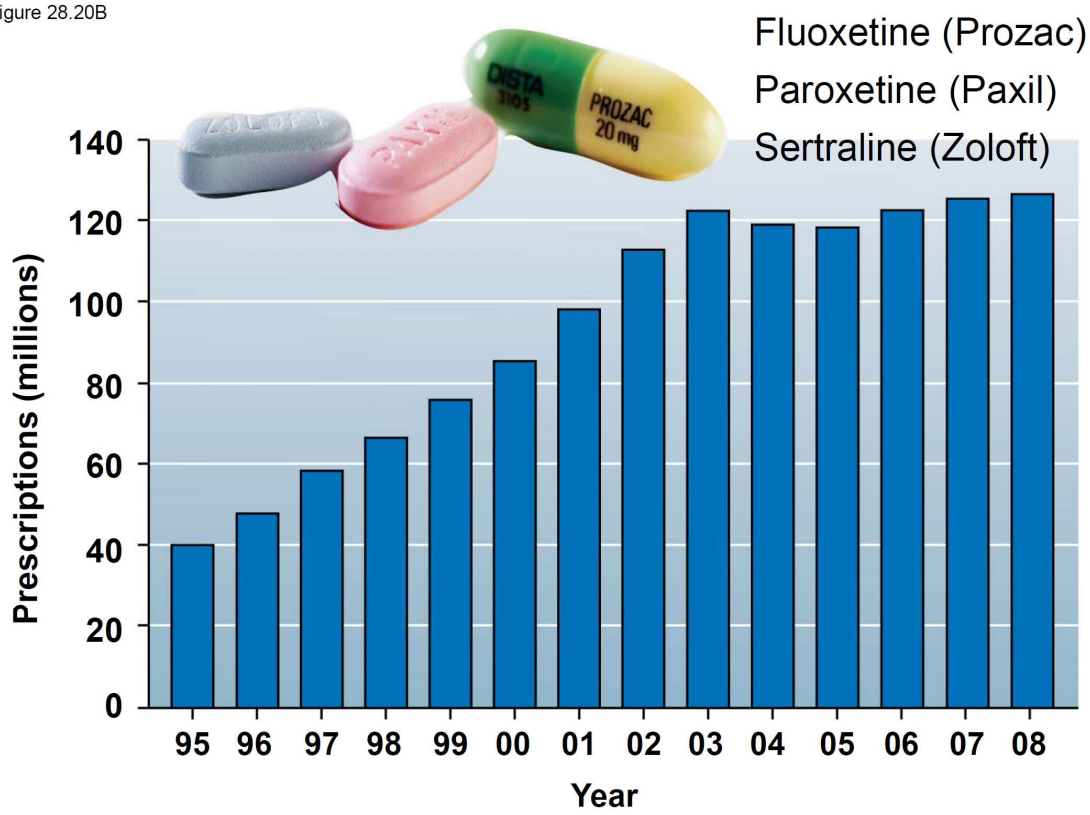


Figure 28.20B



PET Color: low activity

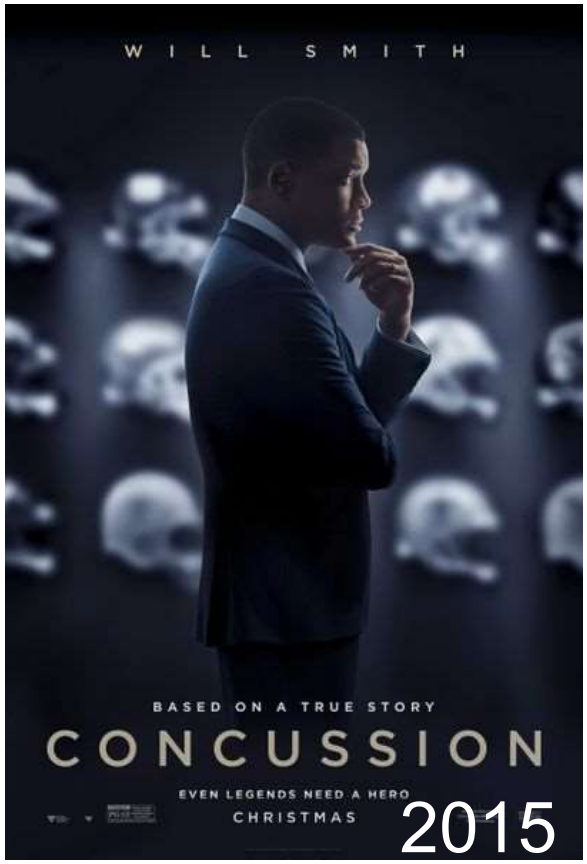
Parkinson's disease 5% at age 85

- a motor disorder and
- characterized by
  - difficulty in initiating movements
  - slowness of movement
  - rigidity.

Muhammad Ali Michael J. Fox

Neuron death at basal nuclei
Dopaminergic neurons
Dopamine supplement
Neuron implant
Deep stimulator implant

- **Chronic traumatic encephalopathy** (**CTE**) is a form of dementia caused by repeated brain trauma, particularly concussions.
  - Early symptoms include depression and loss of impulse control.
  - Eventually, symptoms lead to those of Parkinson's disease, memory loss, and dementia.



Chris Henry / Cincinnati Bengals receiver / Died at 26 in a car accident in 2009, the youngest NFL player diagnosed with CTE

Dr. Bennet Omalu, paper published in 2006 suggesting CTE in football player; β-amyloid deposition as an old man

CTE, late 1920s described in boxers

Can this helmet make football safer?

VICIS has designed a new helmet that can reduce the impact of blows to the head, but can it make football safer?

http://money.cnn.com/2016/09/08/news/nfl-football-concussions-vicis/

https://www.bostonglobe.com/business/2014/09/14/startup-seeks-better-ways-test-sports-helmets-for-safety-prevent-concussions/V797DSjlyo7hGpjp3e1JdK/story.html

http://nohuddles.blogspot.tw/2012/07/aprendiendo-football-las-faltas.html

You should now be able to

1. Describe the structural and functional subdivisions of the nervous system.
2. Describe the three parts of a reflex, distinguishing the three types of neurons that may be involved in the reaction.
3. Describe the structures and functions of neurons and myelin sheaths.
4. Define a resting potential and explain how it is created.
5. Explain how an action potential is produced and the resting membrane potential restored.
6. Compare the structures, functions, and locations of electrical and chemical synapses.
7. Compare excitatory and inhibitory neurotransmitters.
8. Describe the types and functions of neurotransmitters known in humans.
9. Explain how drugs can alter chemical synapses.
10. Describe bias in the reporting of scientific results.
11. Describe the diversity of animal nervous systems and provide examples.
12. Describe the general structure of the brain, spinal cord, and associated nerves of vertebrates.
13. Compare the functions of the motor nervous system and autonomic nervous system.

14. Compare the structures, functions, and interrelationships of the parasympathetic, sympathetic, and enteric divisions of the peripheral nervous system.
15. Explain how the vertebrate brain develops from an embryonic tube.
16. Describe the main parts and functions of the human brain.
17. Explain how injuries, illness, and surgery provide insight into the functions of the brain.
18. Explain how fMRI scans help us understand brain functions.
19. Explain how the brain regulates sleep and arousal.
20. Describe the structure and functions of the limbic system.
21. Describe the causes, symptoms, and treatments of schizophrenia, depression, Alzheimer's disease, Parkinson's disease, and chronic traumatic encephalopathy.