<u>Chapter 2 - The Biology of Mind</u>

Everything psychological is simultaneously biological.
-- Your every idea, every mood, every urge is a biological happening.

Phrenology: studying bumps on the skull

- The "science" of phrenology remains known today as a reminder of our need for critical thinking and scientific analysis.
- Phrenology succeeded in focusing attention on the *localisation of function*- the idea that various brain regions have particular functions

Biological perspective: concerned with the link between biology and behaviour, includes psychologists working in neuroscience, behaviour genetics, and evolutionary psychology. These researchers may call themselves *behaviour neuroscientists, neuropsychologists, behaviour geneticists, physiological psychologists or biopsychologists.*

- Those working from the biological perspective are announcing discoveries about that interplay of our biology and our behaviour and mind at an exhilarating pace. Researchers seeking to understand the biology of the mind have discovered that:
    - <u>Among the body's cells are nerve cells</u> that conduct electricity and "talk" to one another by sending chemical messages across a tiny gap that separates them
    - <u>Specific brain systems serve specific functions</u> (though not all functions Gall supposed)
    - <u>We integrate information processed in these different brain systems</u> to construct our experience of sights and sounds, meanings and memories, pain and passion.
    - <u>Our adaptive brain is wired by our experience</u>

    - We are each a system composed of subsystems that are in turn composed of even smaller subsystems. (Tiny cells organize to form body organs, these organs form larger systems for digestion, circulation and information processing. And those systems are part of an even larger system - the individual, who in turn is a part of the family, culture and community).
    - Thus we are **biopsychosocial systems**. To understand our behaviour, we need to study how these biological, psychological, and social systems work and interact.

Neural Communication

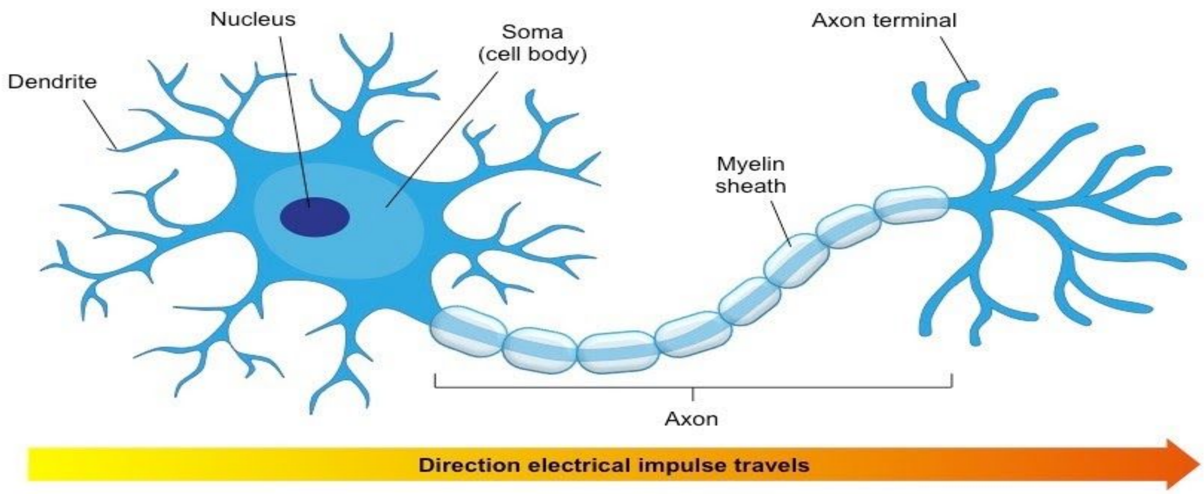
- Information systems of humans and other animals operate similarly. It allows researchers to study other mammal's brains to understand the organization of our own. Animals differ, yet their nervous systems operate similarly.

  Terms:

  1. **Neurons:**
     - To fathom our thoughts and actions, our memories and moods, we must first understand how neurons work and communicate.
  2. **Dendrites:** a neuron's bushy, branching extensions that receive messages and conduct impulses toward the cell body.
  3. **Axon:** the neuron extension that passes messages through its branches to other neurons or to muscles or glands.
  4. **Myelin:** a fatty tissue layer segmentally encasing the axons of some neurons; enables vastly greater transmission speed as neural impulses hop from one node to the next.

Neurons or nerve cells: the basic building block of the nervous system.

- Each consists of a cell body and its branching fibers, the bushy dendrite fibers receive information and conduct it towards the cell body. From there, the cell's single lengthy axon fiber passes the message through its terminal branches to other neurons or to muscles or glands. Dendrites listen. Axons speak.
- Dendrites are short, however, axons may be very long, projecting several feet through the body.
- Some axons are encased in a **myelin sheath,** a layer of fatty tissue that insulates them and speeds their impulses. If the myelin sheath degenerates, *multiple sclerosis results: Communication to muscle slows, with eventual loss of muscle control.*



Glial cells: cells in the nervous system that support, nourish and protect neurons; they may also play a role in learning, thinking and memory.

- Neurons are like queen bees, while glial cells are like worker bees.
- They provide nutrients and insulating myelin, guide neural connections, and mop up ions and neurotransmitters.
- Glia also play a role in learning and thinking. By “chatting” with neurons they participate in information transmission and memory.
- In more complex animal brains, the proportion of glia to neurons increases.

Action potential: a neural impulse; a brief electrical charge that travels down an axon.

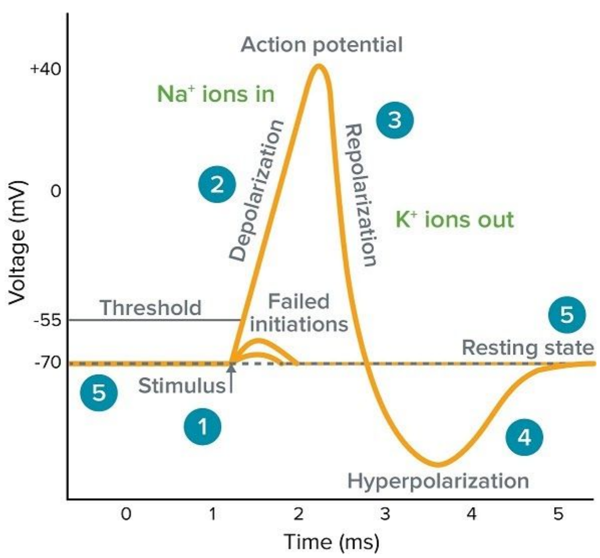
- Neurons transmit messages when stimulated by signals from our senses or when triggered by chemical signals from neighboring neurons. In response, a neuron fires an impulse, called the **action potential** - a brief electrical charge that travels down its axon.
- Neurons generate electricity from chemical events.
- In the neuron’s chemistry-to-electricity process, ions (electrically charged atoms) are exchanged. The fluid outside an axon’s membrane has mostly positively charged sodium ions; a resting axon’s fluid interior has mostly negatively charged ions. This outside-positive/negative- inside state is called the ***resting potential***.
- The axon’s surface is very selective about what it allows through its gates: the axon’s surface is ***selectively permeable***.
- When a neuron fires: the first section of the axon opens up its gates, and positively charged sodium ions flood in. The loss of the inside/outside charge difference, called ***depolarization,*** causes the next axon channel to open, and then the next, like falling dominos, each tripping the next. This temporary inflow of positive ions is the neural impulse- the action potential.

  Refractory period: a period of inactivity after a neuron has fired.
- During this resting-pause period, the neuron pumps the positively charged sodium ions back outside. Then it can fire again.

Each neuron itself is a miniature decision-making device performing complex calculations as it receives signals from hundreds, even thousands of other neurons.

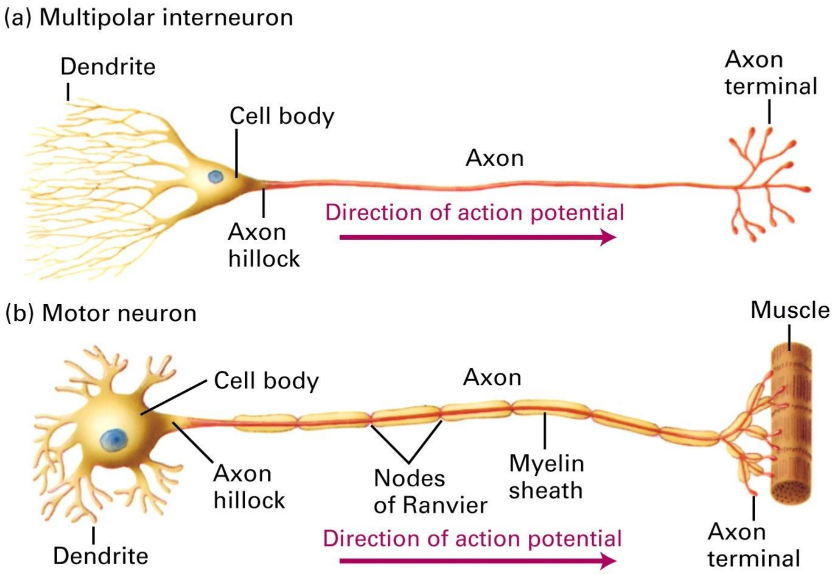
Threshold: the level of stimulation required to trigger a neural impulse.

- Most signals are excitatory (like pushing a neuron's accelerator) and some are inhibitory (more like pushing its brake). If the excitatory signals exceed the inhibitory signals by a minimum intensity, or **threshold**, the combined signals trigger an action potential. (ex: if the excitatory party animals exceed the inhibitory party poopers, the party is on). The action potential then travels down the axon, which branches into junctions with hundreds of other neurons or with the body's muscles and glands.
- Increasing the level of stimulation above the threshold will not increase the neural impulse's intensity,
- The neuron's reaction is an **all-or-none response (a neuron's reaction of either firing with a full strength response or not firing)** : Like guns they either fire or they don't. A strong stimulus can trigger more neurons to fire, and to fire more often. But it does not affect the action potential's strength or speed. Squeezing a trigger harder won't make a bullet go faster.



1. Neuron stimulation causes a brief change in electrical charge. If strong enough, this produced depolarization, momentarily changing the resting potential's negative-inside/positive-outside state, and causes an action potential.
2. This depolarization produces another action potential a little farther along the axon. Gates in this neighboring area now open, and positively-charged sodium atoms rush-in. A pump in the cell membrane (sodium/potassium pump) then transports the sodium ions back out of the cell.
3. As the action potential continues speedily down the axon, the first section has now completely recharged, returning to its resting potential.

*The action potential moves toward the axon terminals.



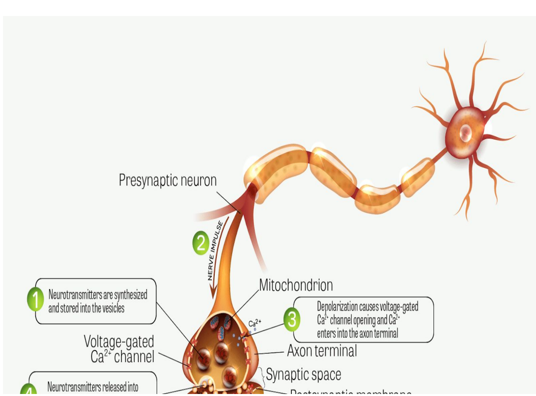
How neurons communicate

Synapse: the junction between the axon tip of the sending neuron and the dendrite or cell body of the receiving neuron. The tiny gap at this junction is called the *synaptic gap or synaptic cleft.*

- Sherrington called the meeting point between neurons a **synapse**.
- The axon terminal of one neuron is in fact separated from the receiving neuron by a synaptic gap/cleft less than a millionth inch wide.

Neurotransmitter: chemical messengers that cross 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 that neuron will generate a neural impulse.

- When an action potential reaches the knob-like terminals at an axon's end, it triggers the release of chemical messengers, called **neurotransmitters**.
- The neurotransmitter molecules cross the synaptic gap and bind to receptor sites on the receiving neuron. For an instant, the neurotransmitter unlocks tiny channels at the receiving site, and electrically charged atoms flow in, exciting or inhibiting the receiving neuron's readiness to fire. The excess neurotransmitters then drift away, are broken down by enzymes or are reabsorbed by the sending neuron-a process called **reuptake**. (**Reuptake**: a neurotransmitter's reabsorption by the sending neuron.)



How neurons communicate : Figure 2.4

1. Electrical impulses (action potentials) travel down a neuron's axon until reaching a tiny junction known as a synapse.
2. When an action potential reaches an axon's end (terminal), it stimulates the release of neurotransmitter molecules. These molecules cross the synaptic gap and bind to receptor sites on the receiving neuron. This allows electrically charged atoms to enter the receiving neuron and excite or inhibit a new action potential.
3. Excess neurotransmitters are reabsorbed (a process called reuptake), drift away, or are broken down by enzymes.

How neurotransmitters influence our motions and our emotions:

- A particular brain pathway may only use one or two neurotransmitters and particular neurotransmitters may affect specific behaviours and emotions.
- But neurotransmitter systems don't operate in isolation; they interact, and their effects vary with the receptors they stimulate.
- Acetylcholine (ACh) plays a role in learning and memory. In addition, it is the messenger at every junction between motor neurons (which carry information from the brain and spinal cord to the body's tissues) and skeletal muscles. When ACh is released to our muscle receptors, the muscle contracts. If ACh transmission is blocked, as happens during some kinds of anesthesia and with some poisons, the muscles cannot contract and we are paralyzed.

Figure 2.1

Neurotransmitter	Function	Examples of Malfunctions
Acetylcholine (ACh)	Enables muscle action, learning and memory.	With Alzheimer's disease, ACh-producing neurons deteriorate.
Dopamine	Influences movement, learning, attention, and emotion.	Oversupply linked to schizophrenia. Undersupply linked to tremors and loss of motor control in Parkinson's disease.
Serotonin	Affects mood, hunger, sleep and arousal.	Undersupply linked to depression. Some drugs that raise serotonin levels are used to treat depression.
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 stimulate the brain, producing migraines or seizures (which is why some people avoid MSG, monosodium glutamate, in food).

The brain does indeed produce its own naturally occuring opiates.

- Our body releases several types of neurotransmitter molecules similar to morphine in response to pain and vigorous excercise. These **endorphins** help explain good feelings. Endorphins: “morphine within” -natural, opiate-like neurotansmitters linked to pain control and to pleasure.
- When flooded with opiate drugs such as heroine and morphine, the brain, to maintain its chemical balance, may stop producing its own natural opiates. When the drug is withdrawn, the brain may then be deprived of any form of opiate, causing intense discomfort.

  Drugs and other chemicals affect brain chemistry, often by either causing exciting or inhibiting neurons' firing.

Agonist: a molecule that increases a neurotransmitter's action

- Agonist molecules increase a neurotransmitter's action.
- Agonists may increase the production or release of neurotransmitters, or block reuptake in synapse.
- Other agonists may be similar enough to a neurotransmitter to bind to its receptor and mimic its excitatory or inhibitory effects.
- Some opiate drugs are agonists and produce a temporary "high" by amplifying normal sensations of arousal or pleasure.

Antagonist:a molecule that inhibits or blocks a neurotransmitter's action

- Antagonists decrease a neurotransmitter's action by blocking production or release.
- Ex: Botulin, a poison that can form in improperly canned food, causes paralysis by blocking ACh release.
- These antagonists are enough like the natural neurotransmitter to occupy its receptor site and block its effect, but are not similar enough to stimulate the receptor (like foreign coins that will fit into, but won't operate, a candy machine).

The autonomic nervous system serves two important functions:

1. **Sympathetic nervous system: arouses the body, mobilizing its energy.**
   - If something alarms or challenges you, your sympathetic nervous system will accelerate your heartbeat, raise your blood pressure, slow your digestion, raise your blood sugar, and cool you with perspiration, making you alert and ready for action.
2. **Parasympathetic nervous system: calms the body, conserving its energy.**
   - When the stress subsides, your parasympathetic nervous system will produce the opposite effects, conserving energy as it calms you.

The sympathetic and parasympathetic nervous systems work together to keep us in a steady internal state called **homeostasis**.

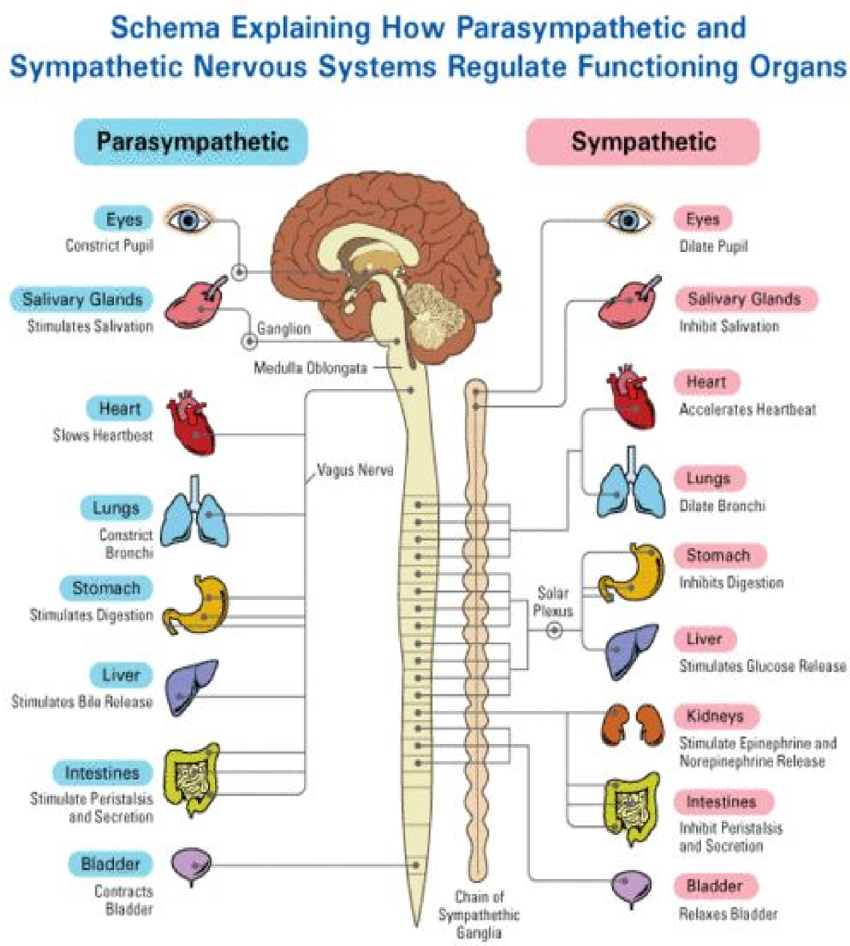


Figure 2.8
The autonomic nervous system controls the more autonomous (or self-regulating) internal functions. Its sympathetic arouses and expends energy. Its parasympathetic division calms and conserves energy, allowing routine maintenance activity. Ex: sympathetic stimulation accelerates heartbeat, whereas parasympathetic stimulation slows it.

The Central Nervous System (CNS) - The Brain and Spinal Cord.

1. The Brain.

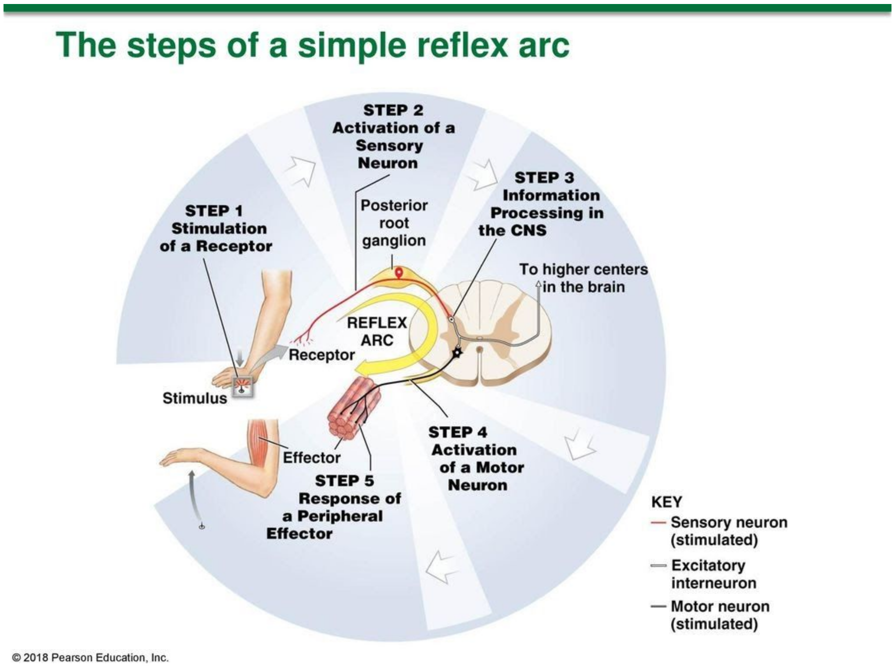
- It is the brain that enables our humanity- our thinking, feeling and acting.

- The brain's neurons cluster into work groups called neural networks:

Neurons network with nearby neurons with which they can have short, fast connections. Each layer's cells connect with various cells in the neural network's next layer.

2. The Spinal cord.

- The spinal cord, is a two-way information highway connecting the peripheral nervous system and the brain. Ascending neural fibers send up sensory information, and descending fibers send back motor-control information.
- Reflexes: our automatic response to stimuli illustrate the spinal cord's work. Ex: the knee jerk
- A simple spinal reflex pathway is composed of a single sensory neuron and a single motor neuron. These often communicate through an interneuron.



- When your finger touches a flame, neural acitivity (excited by the heat) travels via sensory neurons to interneurons in your spinal cord. These interneurons respond by activating motor neurons leading to the muscles in your arm. Because the simple pain-reflex pathway runs through the spinal cord and right back out, your hand jerks away from the flame *before* your brain receives and responds to the information that causes you to feel pain.

***Information travels to and from the brain through the spinal cord**. With your spinal cord severed, you would not feel pain or pleasure from your paralyzed body below. With your brain literally out of touch with your body, you would lose all sensation and voluntary movement in body regions with sensory and motor connections to the spinal cord below its point of injury. To produce bodily pain or pleasure, the sensory information must reach the brain.

The Endocrine System

Endocrine: a system; the body's "slow" chemical communication system; a set of glands that secrete hormones into the bloodstream.

Hormones: chemical messengers that are manufactured by the endocrine glands, travel through the bloodstream, and affect other tissues.

Interconnected with your nervous system, is a secondary system called the Endocrine system:

- The endocrine system's glands secrete another form of chemical messengers, **hormones**, which travel through the bloodstream and affect other tissues, including the brain.
- When hormones act on the brain they influence our interest in sex, food and aggression.
- Some hormones are chemically identical to neurotransmitters (the chemical messengers that diffuse across the synapse and excite or inhibit an adjacent neuron).

The nervous system and the endocrine system both produce molecules that act on receptors elsewhere

- The speedy nervous system zips messages from eyes to brain to hand in a fraction of a second.
- The endocrine messages trudge along in the bloodstream, taking several seconds or more to travel from gland to the target tissue.
  Conclusion: the nervous system is much faster that the endocrine system.
- ***Endocrine messages tend to outlast neural messages**

Adrenal glands: pair of endocrine glands that sit just above the kidneys and secrete hormones (epinephrine and norepinephrine) that help arouse the body in times of stress.

- In a moment of danger, the ANS orders the adrenal glands on top of the kidneys to release epinephrine and norepinephrine (also called adrenaline and noradrenaline). These hormones increase heart rate, blood pressure, and blood sugar, providing a surge of energy. When the emergency passes, the hormones -and the feelings- linger for a while.

Pituitary gland: the endocrine system's most influential gland. Under the influence of the hypothalamus, the pituitary regulates growth and controls other endocrine glands.

- The pituitary gland is a pea-sized structure located in the core of the brain where it is controlled by the hypothalamus.
- Among the hormones released by the pituitary is a growth hormone that stimulates physical development.
- Another is oxytocin which enables contractions associated with birthing, milk flow during nursing, and organsm. It also promotes pair bonding, group cohesion and social trust.
- Pituitary secretions also direct other endocrine glands to release their hormones.
- Ex: Under the brain's influence, the pituitary triggers your sex glands to release sex hormones. These in turn influence your brain and behaviour.

  Feedback system: **brain→pituitary→other glands→hormones→body and brain**
  -reveals the intimate connection between the nervous and endocrine systems. The nervous system directs endocrine secretions, which then affect the nervous system.

Tools of Discovery and Older Brain Structures

The brain enables the mind- seeing, hearing, smelling, feeling, remembering, thinking, speaking, dreaming. Moreover, it is the brain that self-reflectively analyzes the brain.
Brain + Body = Mind, the mind is what the brain does. Brain, Behaviour and Cognition are an integrated whole.

Tools of Discovery: Having our head examined

- Early case studies helped localize some brain functions. Damage to the back of the brain disrupted vision, and to the left-front part of the brain produced speech difficulties.
- Scientists can selectively lesion (destroy) tiny clusters of brain cells, leaving the surrounding tissue unharmed.
- Today's neuroscientists can also stimulate various brain parts-electrically, chemically or magnetically- and note the effect.

1. **EEG- Electroencephalogram: an amplified recording of the waves of electrical activity sweeping across the brain's surface. These waves are measured by electrodes placed on the scalp.**
    - Right now, your mental activity is emitting telltale electrical, metabolic, and magnetic signals that would enable neuroscientists to observe your brain at work.
    - Electrical activity in your brain's billions of neurons sweeps in regular waves across its surface. An EEG is an amplified readout of such waves. Researchers record the brain waves through a shower-cap-like hat that is filled with electrodes covered with a conductive gel.

2. **PET (Positron emission tomography) scan: a visual display of brain activity that detects where a radioactive form of glucose goes while the brain performs a given task.**
    - The PET scan depicts brain activity by showing each brain area's consumption of its chemical fuel: the sugar glucose. Active neurons are glucose hogs.
    - After a person receives temporarily active glucose, the PET scan can track the gamma rays released by this "food for thought" as a task is performed.
    - PET-scans "hot spots" show the most active brain areas as the person does mathematical calculations, looks at images of faces or daydreams.

3. **MRI (magnetic resonance imaging): a technique that uses magnetic fields and radio waves to produce computer-generated images of soft tissue. MRI scans show brain anatomy.**
    - In MRI scans, the person's head is put into a strong magnetic field, which aligns the spinning of the atoms of brain molecules. Then, a radio wave pulse momentarily disorients the atoms. When the atoms return to their normal spin, they emit signals that provide a detailed picture of soft tissues, including the brain.

- MRI scans have revealed enlarged ventricles(fluid-filled brain areas) in some patients who have schizophrenia, a disabling psychological disorder.

3.1 fMRI (functional MRI): a technique for revealing bloodflow and, therefore, brain activity by comparing successive MRI scans. fMRI scans show brain function as well as structure.

- It can reveal the brain's functioning as well as its structure. Where the brain is especially active, blood goes.
- By comparing successive MRI scans, researchers can watch as specific brain areas activate, showing increased oxygen-laden blood flow.
- Recent fMRI studies suggest which brain areas are most active when people feel pain or rejection, listen to angry voices, think about scary things, feel happy or become sexually excited.
- "Neuro Skeptics" caution against overblown claims about any ability to predict customer preferences, detect lies and foretell crime.
- We can credit brain imaging with illuminating the brain's structure and activity, and sometimes helping us test different theories of behaviour.

Summary:
fMRI can: tracks successive images of brain tissue to show brain function.
MRI scan: uses magnetic fields and radio waves to show brain anatomy.
PET scan: tracks radioactive glucose to reveal brain activity.

Older Brain Structures

Animals capacities come from its brain structures. A not-so-complex brain primarily regulates basic survival functions: breathing, resting, and feeding. A more complex brain enables emotion and greater memory. In advanced mammals, such as humans, a brain that processes more information enables increased foresight as well.

The Brainstem

Brainstem: the oldest part and central core of the brain, beginning where the spinal cord swells as it enters the skull; the brainstem is responsible for automatic survival functions.

- The **brain stem** controls the flow of messages between the brain and the rest of the body, and it also controls basic body **functions** such as breathing, swallowing, heart rate, blood pressure, consciousness, and whether one is awake or sleepy. The **brainstem** consists of the midbrain, pons, and medulla oblongata.

Medulla: the base of the brainstem; controls heartbeat and breathing.

- The brainstem begins where the spinal cord swells slightly after entering the skull. This slight swelling is the medulla.
- Just above the medulla sits the pons, which helps coordinate movements and control sleep
- The brainstem is a crossover point, where most nerves to and from each side of the brain connect with the body's opposite side

The Thalamus : sitting atop the brainstem, thalamus, is a pair of egg-shaped structures that act as the brain's sensory control center.

- The thalamus receives information from all the senses except smell and routes it to the higher brain regions that deal with seeing, hearing, tasting and touching. The higher brain replies, which it then directs to the medulla and the cerebellum.

The Reticular Formation : Inside the brainstem, between your ears, lies the reticular formation. A neuron network extending from the spinal cord right up through the thalamus. As the spinal cord's sensory input flows up to the thalamus, some of it travels through the reticular formation, which filters incoming stimuli, relays important information to other brain areas and controls arousal.

The Cerebellum: Extending from the rear of the brainstem is the baseball-sized cerebellum, meaning "little brain" which is what two wrinkled halves resemble.

- The cerebellum (along with the basal ganglia, deep brain structures involved in motor movement) enables nonverbal learning and skill memory. It also helps us to judge time, modulate our emotions, and discriminate sounds and textures. And with assistance from the pons, it coordinates voluntary movement.
    - Under alcohol's influence, coordination suffers.
- If you injured your cerebellum, you would have difficulty walking, keeping your balance, or shaking hands. Your movements would be jerky or exaggerated.

***These older brain structures all occur without any conscious effort. *Our brain processes most information outside of our awareness.*

The Limbic System : neural system (including the hippocampus, amygdala and hypothalamus) located below the cerebral hemispheres; associated with emotions and drives.

- *Cerebral hemispheres : two halves of the brain.*

a. Hippocampus :

Processes conscious, explicit memories for storage. Humans or animals who lose their hippocampus to surgery or injury, also lose their ability to form new memories of facts and events.

b. Amygdala :

Two lima-bean sized neural clusters in the limbic system,linked to emotion specifically to aggression and fear. Amygdala lesions often display reduced arousal to fear- and anger-arousing stimuli. The amygdala activates in response to the angry faces.

c. Hypothalamus :

Just below the thalamus is this structure. Some neural clusters in the hypothalamus influence hunger; others regulate thirst, body temperature, and sexual behaviour. Together, they help maintain a steady (homeostatic) internal state. As the hypothalamus monitors the state of your body, it tunes into your blood chemistry and any incoming orders from other brain parts.

The Brain influences the endocrine system, which in turn influences the brain.

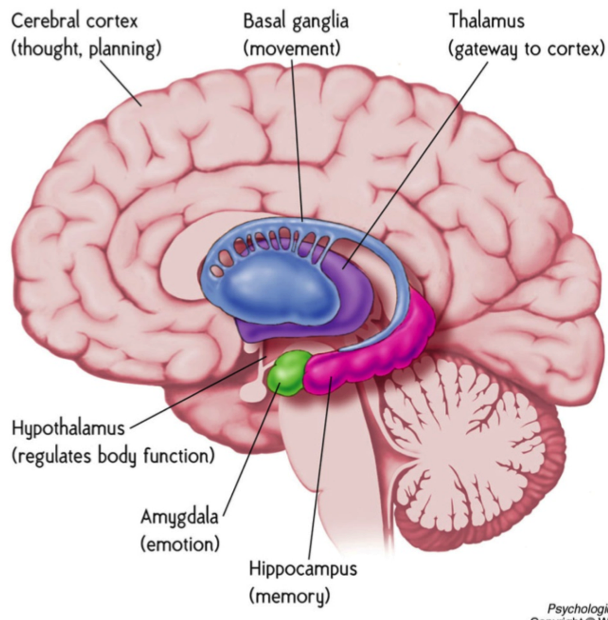


FIGURE 4.6

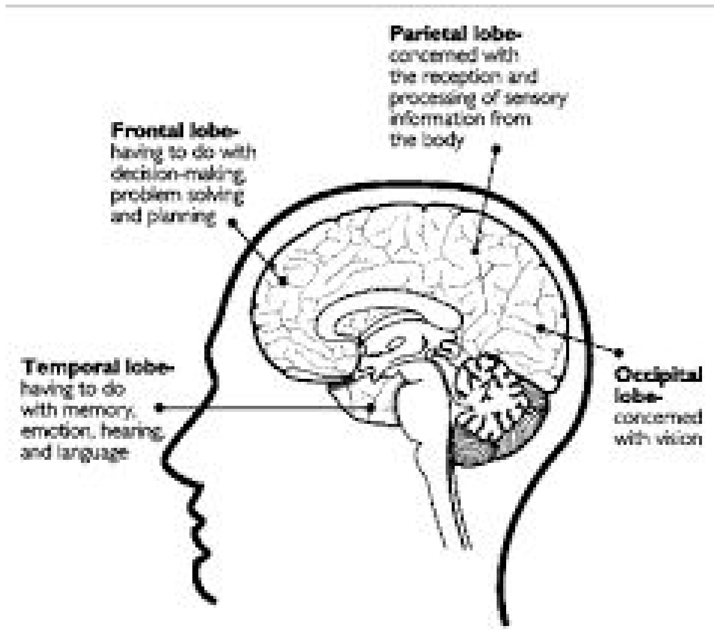
The Cerebral Cortex and Our Divided Brain

The cerebral cortex : the intricate fabric of interconnected neural cells covering the cerebral hemispheres; the body's ultimate control and information-processing center.

- A thin surface layer of interconnected neural cells. It is your brain's thinking crown, your body's ultimate control and information-processing center.
- The larger cortex of mammals offers increased capacities for learning and thinking, enabling them to be more adaptable. What makes us distinctively human mostly arises from the complex functions of our cerebral cortex.

Structure of the Cortex :

- Each hemisphere's cortex is subdivided into four lobes separated by prominent fissures or folds: **frontal lobes** (behind your forehead), **parietal lobes** (at the top and to the rear), **occipital lobes** (at the back of your head) and **temporal lobes** (just above your ears).



Frontal lobes: portion of cerebral cortex lying just behind the forehead; involved in speaking and muscle movements and in making plans and judgements.

Parietal lobes: portion of cerebral cortex lying at the top of the head and toward the rear; receives sensory input for touch and body position.

Occipital lobes: portion of cerebral cortex lying at the back of the head; includes areas that receive information from the visual fields.

Temporal lobes: portion of cerebral cortex lying roughly above the ears; includes auditory areas, each receiving information primarily from the opposite ear.

Motor Functions

Motor cortex: an area at the rear of the frontal lobes that controls voluntary movements.
Somatosensory cortex: processes sensory information from the body. Neurons from different parts of the body that receive environmental stimuli all send their information to the somatosensory cortex.

- Stimulating parts of this region in the left or right hemisphere caused movements of specific body parts on the *opposite* side of the body.
- The brain has no sensory receptors.

Output: Motor cortex (left hemisphere section Controls body's right side)	Input: Somatosensory cortex (Left hemisphere section receives input from the body's right side)

*Left hemisphere tissue devoted to each body part in the motor cortex and the somatosensory cortex.