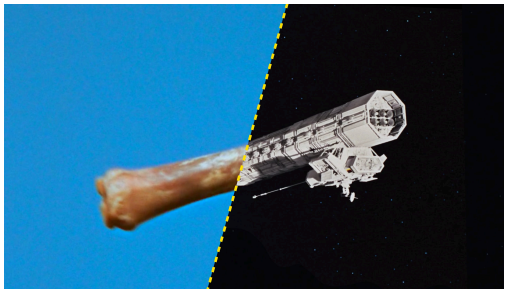


Chapter 1: Origins

Page 13 | 2020 May 29

Abstract

Perspectives from fossil hominins and *2001: A Space Odyssey* pose the question of who we really are in relation to reality, consciousness, and mental experience.

Outline

I. Cave paintings (13)
   - A. Chauvet Cave
   - B. Importance of darkness
   - C. Visual stimulus, internal mental exploration
   - D. Animals and shamans

II. *2001: A Space Odyssey* (15)
   - A. First use of weapon by hominin
   - B. Does Hal have a mind?

III. Hominins (see anthro notes for more) (16)
   - *A. Ardipithecus, Australopithecus, Homo*
   - B. Expansion of brain size leads to complex behaviors

IV. Brain and behavior (16)
   - A. Kindness, trust, love, compassion
   - B. Murder
   - C. Definition of mind and consciousness
   - D. Dreaming and consciousness
   - E. Freudian unconscious
   - F. Mind-body problem

Key Terms

Mind: The collection of mental experiences (17)
Consciousness: The capacity to be aware (17)
Mind-body problem: The question of the relationship between mental experience and physiology (18)
Compassion and kindness: One of the strongest and most natural of behavioral tendencies (17)
Conspecific killing: The killing of one's own species (15)

Diagrams

None!

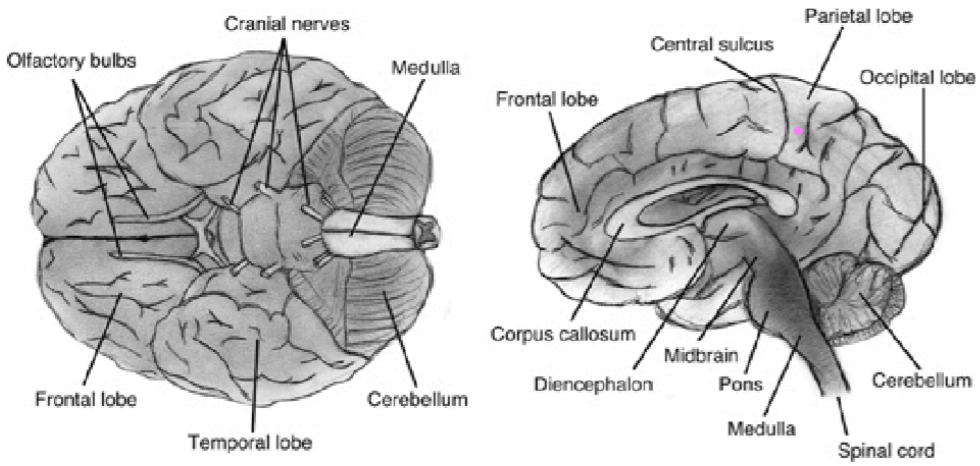


Figure 2.8. Human brain: ventral (left) and medial (right) views.

Chapter 2: Nervous Systems and Brains

Page 19 | 2020 May 29

Abstract

The structure and nature of the brain are put into the context of historical neurological discoveries and models of perception.

Outline

I. The human brain (19, 22)
   A. Association with mental functioning
   B. Complexity of connections
   C. Material makeup
II. Structure of human brain
   1. Cerebral cortex
      a) Four lobes
   2. Landmark grooves

a) Central sulcus (frontal-parietal)
b) Lateral fissure (temporal-frontal/parietal)
c) Longitudinal fissure (right-left hemispheres)

3. Protection and connections

III. Brains of other animals (21)
   A. Jellyfish
   B. Roundworm (Caenorhabditis elegans)
   C. Insects
   D. Vertebrate brains

IV. History of neuroscience (25)
   A. Vesalius
   B. Rene Descartes (perception)
   C. Luigi Galvani (electricity)
   D. Golgi, Cajal (neurons)

V. Structure of a nerve cell (29)
   A. Axons and dendrites
   B. Golgi staining

Key Terms

William James: 1890: wrote *The Principles of Psychology*. A pioneer of modern study of mind, hypothesized that consciousness depended solely on the brain (19)
Nervous system: a network in the body that functions to manipulate external and internal information, specialized for rapid communication and centered around the brain (19)
nerve cell, neuron: a type of brain cell responsible for signal transmission (20).
glial cell, glia: another type of brain cell that aids in signal transmission and appears in similar numbers as neurons- 10^{11} (20.
nervous system complexity across species

- Jellyfish and hydra: very simple neural networks
- Roundworm (C. elegans): 302 neurons that are well-researched
- Insects: complex brains with small size but large number of neurons

vertebrate brain structure

- Larger cerebrum

Cerebrum: the front of the brain (21)
Cerebellum: the back of the brain (21)
Brain stem: the section of the brain comprising of the medulla, pons, and midbrain
cerebral cortex: a 3mm thick, 2.5 sqft sheet of neural tissue that is folded up to make the brain (22)
Sulci: grooves in the cerebrum (22)
Gyri: bumps in the cerebrum (22)
corpus callosum: a bundle of ~200m nerve fibers connecting the left and right

hemispheres (23)
cerebral lobes: occipital, parietal, temporal, frontal (22)
Nerve fibers: thread-like structures connecting the brain to other parts of the body
Andreas Vesalius: 1543: Published an illustrated physiology book “On the Fabric of the Human Body”; known for dissections of human body (EX)
meninges: The covering of the brain, consisting of the dura mater, pia mater, and arachnoid (24)

- **Dura:** Skin-like, tough sheet of tissue
- **Arachnoid:** delicate, spider web-like layer of tissue
- **Pia:** soft, tender layer

Meningitis: The condition of the meninges becoming inflamed (24)
cerebrospinal fluid (CSF): A liquid that cushions the skull and is located in the subarachnoid space (between arachnoid and pia) (24)
René Descartes: 1630s: Published “Treatise on Man” about perception and mental experience in relation to the body (EX). Speculated about how physical sensations lead to mental perception (27)
Luigi Galvani: 1791: Frog leg experiment, hypothesized that muscles are electrically stimulated (EX)
Camilio Golgi: 1873: Developed the **Golgi stain,** a technique of staining neurons (EX).
Golgi Stain Equation: Potassium dichromate (K_2CrO_4) + Silver nitrate ($AgNO_3$) = Silver chromate (Ag_2CrO_4) (31)
Santiago Ramón y Cajal: 1900: studied Golgi-stained brain tissues in great detail (EX)

Diagrams

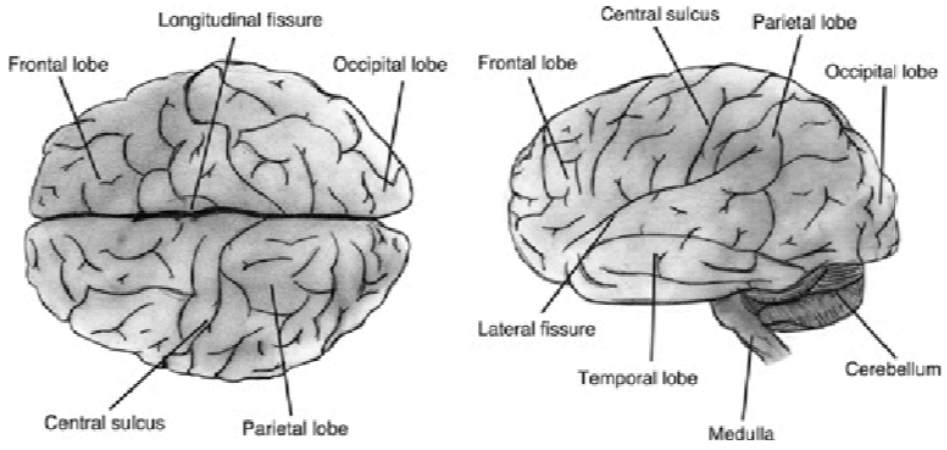


Figure 2.7. Human brain: dorsal (left) and lateral (right) views.

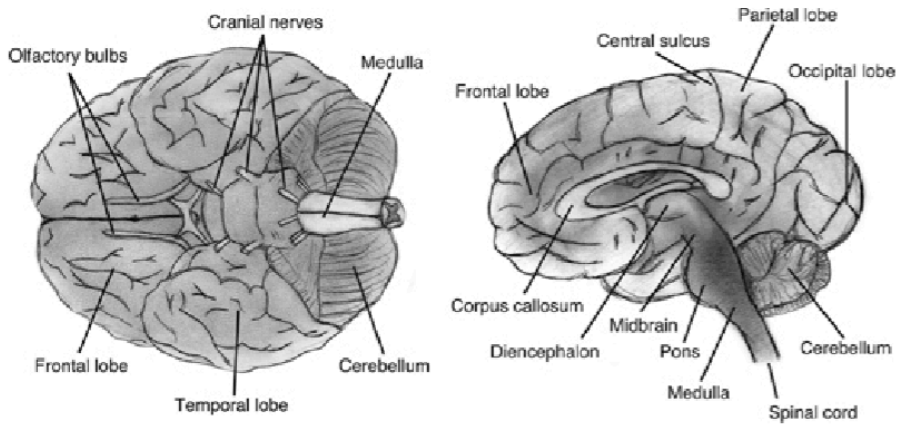


Figure 2.8. Human brain: ventral (left) and medial (right) views.

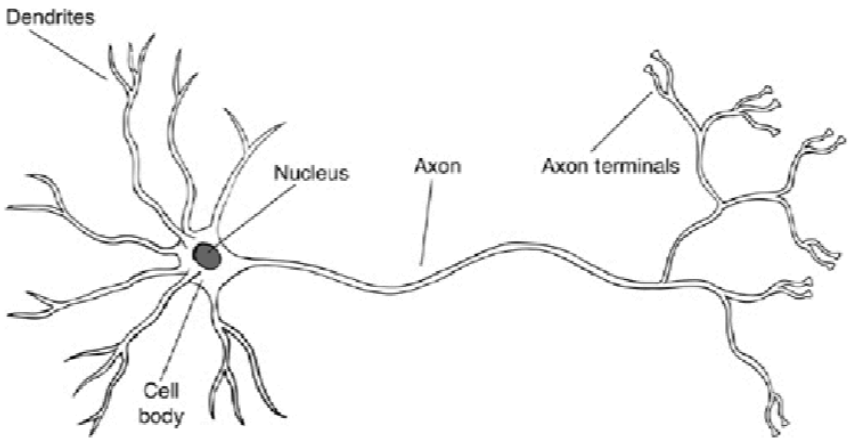
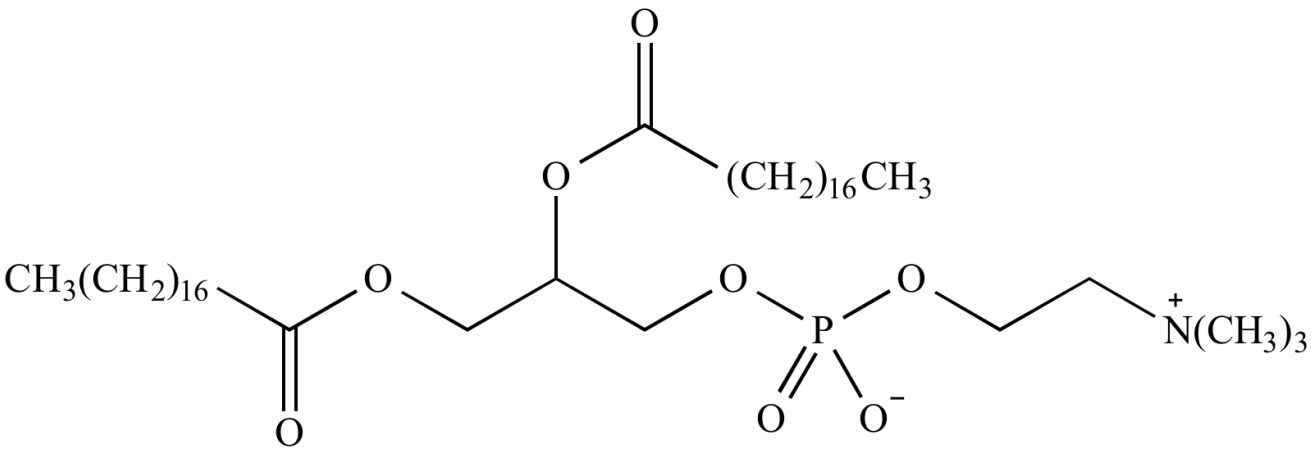


Figure 2.15. Nerve cell, with axon and dendrites.



Chapter 3: Chemistry and Life

Abstract

A brief introduction to organic chemistry, including the four major structures of life: lipids, carbohydrates, proteins, and nucleic acids.

Outline

I. Origin of chemistry
   - A. Alchemy
   - B. Early chemists (1600s-1700s) - Boyle, Newton
   - C. Transition away from alchemy (1700s) - Lavoisier, Priestley
     1. Difficulties with early studies
   - D. Mendeleev and the Periodic Table (1869)

II. Living matter
   - A. Composition
   - B. Importance of hydrogen, oxygen, carbon
   - C. Importance of water

III. Atoms
   - A. Cations and anions
   - B. Noble gases

IV. Diagramming molecules
   - A. Basic rules
     1. Carbon is the scaffold
     2. Hydrogen is attached only to a single carbon atom
     3. Oxygen has two bonds
     4. Nitrogen has three bonds

5. Carbon and hydrogen atoms are not shown - assume molecule has full bonds

B. Hydrocarbons (only hydrogen and oxygen)
C. Double bonds
D. Cyclic carbon molecules (benzene, cyclohexane…)
E. Neurotransmitters (dopamine, serotonin)

V. Water
A. Polarity
B. Hydrogen bonding (noncovalent)
C. Properties of water
1. Noncovalence allows molecules to slip past one another
2. Polarity allows ease of dissolving ions
3. Hydrophilic vs hydrophobic substances

VI. Cells
A. Shared features
1. Boundary membrane (phospholipid bilayer)
2. Genetic material (nucleic acids)
3. Ribosomal structures (protein synthesis)
4. Protein receptors, pumps, channels (transportation)

VII. Four fundamental types of molecules
A. Lipids
1. Fatty acids
2. Phospholipids
B. Proteins
1. Amino acids
2. R-groups and alpha amino acids
3. Catalyzing amino acids to form proteins and peptide chains
4. Structure of proteins
C. Carbohydrates
1. Sugars
D. Nucleic acids
1. Nucleotides
2. Double helix

Key Terms

Chemistry: the science of matter and its transformations

- Derived from **alchemy -** the process of extraction, conversion, fermentation, distillation, and other transformations of matter

Periodic table: a way of organizing known chemical elements that predicted now-discovered elements

- Formulated in 1869 by **Dmitri Mendeleev**

Elemental composition of the human body:

- 65% oxygen (due to water content)
- 18.5% carbon (most of the solid mass)
- 9.5% hydrogen (most common molecule, but very light)
- 3.2% nitrogen, 1.5% calcium, 1% phosphorus (next most common solids)
- .4% K, .3% S, .2% Na, .2% Cl

Ions: cations are positively charged (lost electron)**, anions** are negatively charged (gained electron)

Covalent chemical bonds: sharing of electrons between atoms in a molecule

Organic molecules: molecules largely made of carbon and hydrogen that make up living organisms

Hydrocarbons: Organic molecules solely composed of carbon and hydrogen; are combustible in oxygen

- Becomes thicker and more waxy with more carbon
- Can be cyclic or folded

Polarity: when different atoms in a molecule have different charges

Hydrogen bonds: when a negative molecule is attracted to a positive hydrogen (i.e. in water molecules)

Hydrophobic / lipophilic: a molecule that can bind to lipids but is not attracted to water

Hydrophilic / lipophobic: a molecule that is attracted to water and not lipids

Lipids / fats: Medium-sized carbon and hydrogen chains

- 16-24 carbon atoms
- Energy storage, signaling, hormones, membranes
- **Fatty acids** have a **carboxylic acid group** at one end (COOH)
- Lipids are **saturated** if all carbon atoms are fully bonded
- **Unsaturated** lipids may have carbon double bonds
    - Omega number is how far this double bond is away from the end (omega-9)
- **Phospholipids** are two chains joined together at one end with oxygen, phosphorus, nitrogen, etc (polar)
    - One end is hydrophobic (tails), the other end is hydrophilic (head)

Phospholipid bilayer membrane: An exterior coating on a cell consisting of two sets of phospholipid lines with the hydrophilic heads on the exterior

Quaternary amine: when a nitrogen atom has four bonds instead of three, causing it to have a positive charge. Often found at the end of phospholipids

Amino acids: a molecule containing an **amine group** (NH_2) and a **carboxylic acid group**

(COOH)

- **Alpha amino acids** have an R-group, amine group, carboxylic acid group, and hydrogen atom linked to the same carbon atom
- Different amino acids are identified by their differing R-groups
- **Polypeptides** are chains of amino acids joined by **peptide bonds** (covalent chemical bonds). Have fewer amino acids than proteins
- **Proteins** are large molecules built from a large number of amino acids

Levels of description for protein structure:

- **Primary:** the linear sequence of amino acids that form the protein
- **Secondary:** The interactions of nearby amino acids to produce folding
- **Tertiary:** Overall 3D shape of the entire protein molecule
- **Quaternary:** Subunits consisting of hundreds of amino acids

Alpha helix: a famous protein secondary structure that is similar to twisted ribbons

Carbohydrates: comprised of carbon and water, built from **sugars**

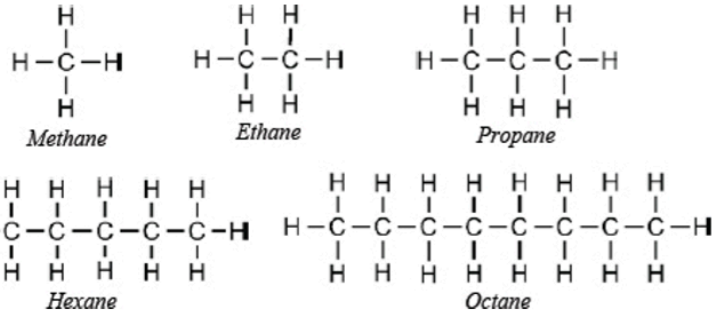
- **Starches** are polymers of many sugar molecules linked together by covalent bonds
- Energy is stored in the bonds and can be used as fuel

Nucleic acids: contain information to construct cells and other hereditary structures

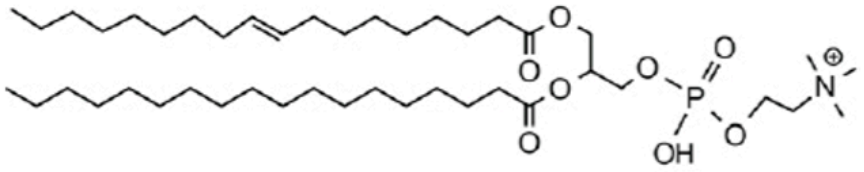
- Composed of **nucleotides** adenine, cytosine, guanine, thymine and **deoxyribose sugars with phosphate groups**
- **deoxyribonucleic acid (DNA), ribonucleic acid (RNA)** are two types

Diagrams

and nothing else. Organic molecules composed solely of carbon and hydrogen are called *hydrocarbons*.



Among the most abundant phospholipids in the cells of animals and plants are the phosphatidylcholines, an example of which is shown here:



Phosphatidylcholine

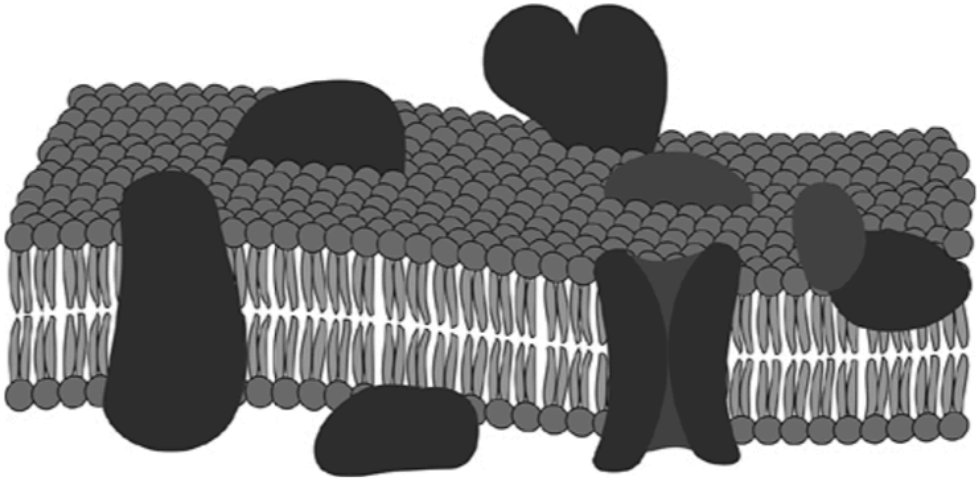
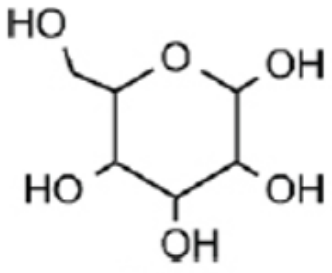
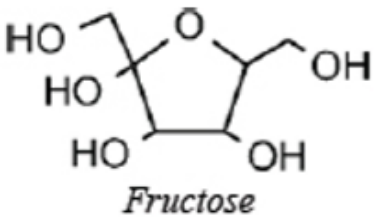


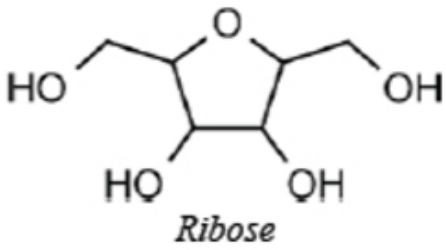
Figure 3.3. Phospholipid bilayer forming a biological membrane. Membrane proteins are here depicted as amorphous, potato-like structures. In actuality, proteins have a great deal of internal structure.



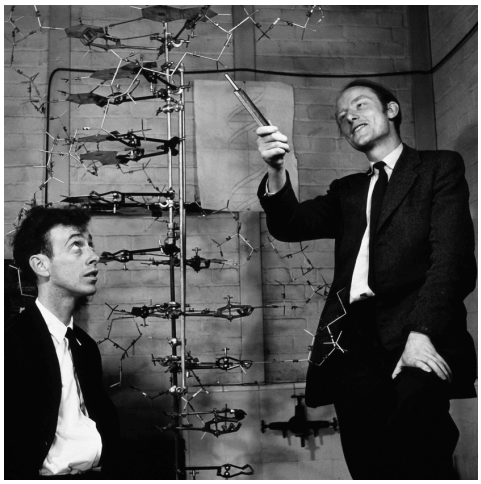
Glucose



Fructose



Ribose



Chapter 4: Genes and the History of Molecular Biology

Page 59 | 2020 May 31

Abstract

A brief history of the chemists and physicists that shaped our current understanding of genetic structures, and the functions of those structures in allowing cells to replicate.

Outline

I. History of molecular biology (59-64)
   A. Charles Darwin (evolution)
   B. Gregor Mendel (genetics)
   C. Albert Einstein (relativity)
   D. Max Planck (quantum mechanics)
   E. Bohr (quantum mechanics of cellular structures)
   F. Delbruck (molecular structure of biology, radiation)
   G. Schrodinger (publicized the problem of the physical basis of life)
   H. Avery (importance of DNA)
   I. Hershey-Chase Experiment (proved that DNA carried genetic information)

II. DNA
   A. Structure (Watson and Crick)
   B. Transcription and Translation - DNA replication

Key Terms

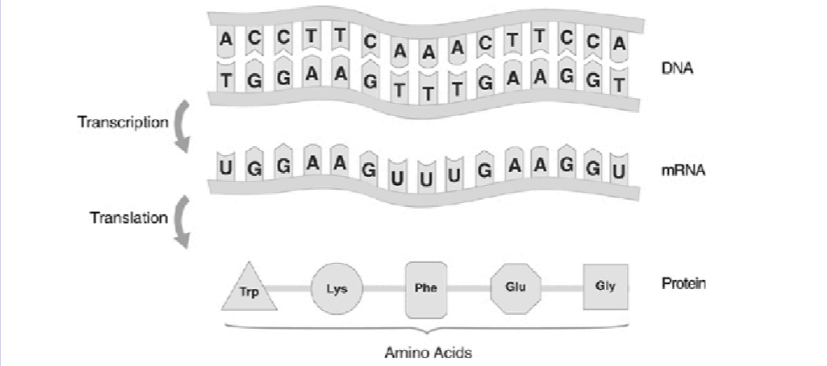
Charles Darwin: 1809-1882: introduced the theory of evolution, and that all life is related and has developed over common origins (59)
Gregor Mendel: 1822-1884: inheritance in pea plants and the idea of genes. One of the earliest geneticists
Gene: A large molecule that contains genetic information
Niels Bohr: 1885-1962 proposed that not-yet-discovered quantum mechanics knowledge was required to understand organisms at the subcellular level (61)
Max Delbrück: 1906-1981: proposed that genes were large molecules that could be rearranged using radiation such as X-rays. Investigated bacteria (e. coli) and viruses

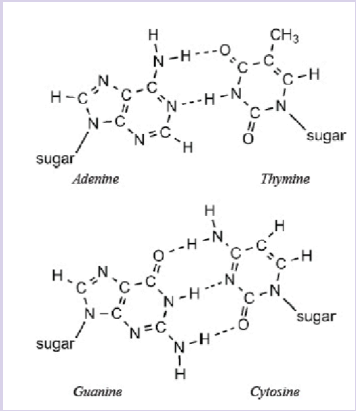
- Viruses are made of only proteins and nucleic acids (62-63)

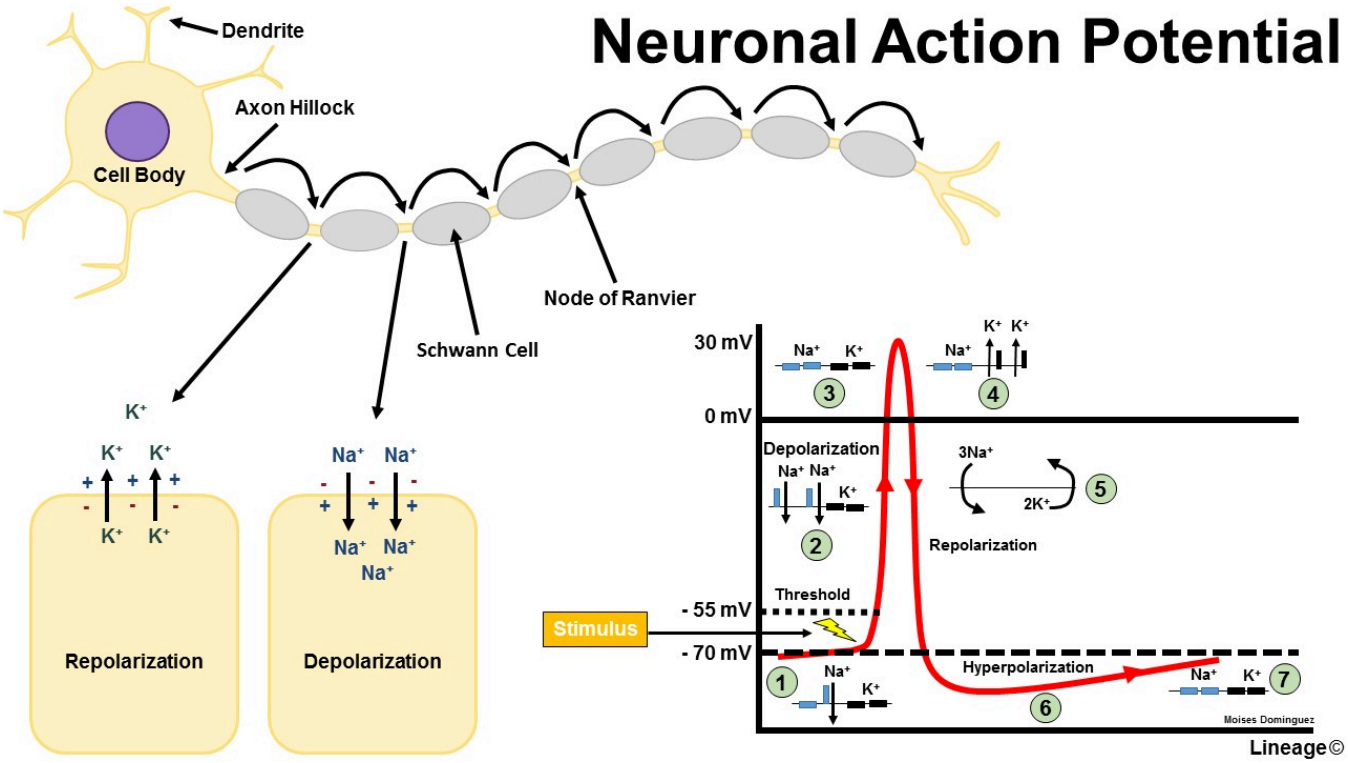
Erwin Schrödinger: 1887-1961: publicized the problem of the physical basis of life
Oswald Avery: 1877-1955: Designed experiments to prove that DNA carries genetic information between cells. Largely ignored in the early stages of his research (64)
Hershey-Chase experiment: Virus phage T2 was grown in 2 ways (radioactive sulfur vs. radioactive phosphorus). Since proteins contain sulfur and DNA contains phosphorus, this could determine how radioactivity was transferred when the viruses infected a cell (65)
Francis Crick (1916-2004) and **James Watson** (1928-) proposed that the DNA molecule was a double helix composed of ATCG bases joined by covalent bonds to phosphates. The individual strands are then connected by hydrogen bonds (66)
DNA structure and function: DNA encodes for amino acids using sequences of 3 nucleotides called **codons**. DNA is replicated using this process (67-68):

- DNA is unwound
- One of the strands is used to create a strand of **messenger RNA** (U instead of T) - **gene transcription**
- **Transfer RNA** matches mRNA triplets with amino acids to create a protein - **translation**

Diagrams







Chapter 5: How Neurons Generate Signals

Page 70 | 2020 June 1

Abstract

The subcellular processes that allow neurons to transmit electrical signals, including an exploration of ion transportation across the cell membrane and the action potential.

Outline

I. The microscopic nature of neural signaling
   A. Frankenstein, Galvani, and the wonder of electricity (70)
   B. Electrical properties of neurons (70)
      1. Ions Ca^{++}, Cl^{-}, K^{+}, Na^{+}
      2. Diffusion
      3. Neuronal boundary (70-71)

a) Transportation devices

4. Energy requirements (72)
5. Na/K Pumps (73)
6. Powering transmissions (74)
7. Hyperpolarization and depolarization (75)\
8. Action potentials (77)

C. Myelin (80)

Key Terms

Diffusion: The process where particles distribute uniformly over a volume of fluid (70)
Neuronal boundary: a phospholipid bilayer membrane around the neuron that is impermeable to ions due to being hydrophobic (70-71)
Ion channels: controllable openings where certain ions can pass through; uses diffusion to move ions until they equalize (71)
Ion pumps: transporter proteins that use energy to move ions across the membrane

- Example: Na/K pump moves sodium and potassium ions into the neuron (71)

ATP: adenosine triphosphate, an adenine molecule connected to a ribose sugar and three phosphate groups linked by covalent bonds. When these bonds are broken, the stored energy is released (72)
Energy consumption by human brain: (72-73)

- Basal metabolic rate: 1 kcal/min to maintain body at rest (1440 kcal/day)
- Brain uses about 25% of basal consumption: 360 kcal/day
- Na/K pumps use about 60% of brain energy usage (220 kcal/day)

Major ions for neural function: Na+, K+, Cl-, Ca++
Ion concentration differences inside and outside a neuron

- Na+ is much higher outside than inside, whereas K+ inside is greater (73)

Membrane potential and resting potential (74)

- The voltage across a nerve membrane is about 65 mV
- Inside of cell is more negative than outside

Hyperpolarization: when the opening of ion channels causes a greater separation of charge across a cell membrane. Caused by K+ and Cl- channels (75)
Depolarization: when the opening of ion channels causes the magnitude of charge difference to decrease. Caused by Na+ and Ca++ channels (positive ions flow inside cell)
Alan Hodgkin, Andrew Huxley: directly measured voltage changes across an axon membrane during action potential in 1939. Predicted the existence of voltage-gated ion channels (77)
Action potential: a spike in membrane potential caused by a signal passing through an axon. This is the result of ions moving across the membrane and takes place over 1 millisecond. Action potentials get triggered at -50 mV (up from the resting potential of -65

mV) (76)
Voltage-gated ion channels: Sodium and potassium channels that open and close depending on membrane voltage. Na+ channels open at -50 mV and closes at +30 mV. K+ channels open at +30 and close at -65 (77)
Soma: the nerve cell body (79)
Action potential propagation along axon: occurs without new input of energy when an action potential is started. Charge moves across the length of the axon without stopping (79)
Axon hillock: The axon initial segment of the nerve cell with a large density of voltage-gated channels (79)
Refractory period: A time of several milliseconds after a channel is closed where it cannot be opened again (79)
Myelin: A coating around axons formed when glial cells wrap around an axon. 70% of dry weight is lipid, and 25% is cholesterol (80)
Oligodendrocytes, Schwann cells: glial cells that form myelin in the brain and peripheral nervous system, respectively (80)
Nodes of Ranvier: the observation made by Louis-Antoine Ranvier in the 8970s that myelin is separated by small gaps to allow ions to pass through (81)
Saltatory conduction: the propagation of action potential from one node of Ranvier to the next as positive charge moves along an axon. This allows for much faster communication between cells (200 mph) (82)

Diagrams

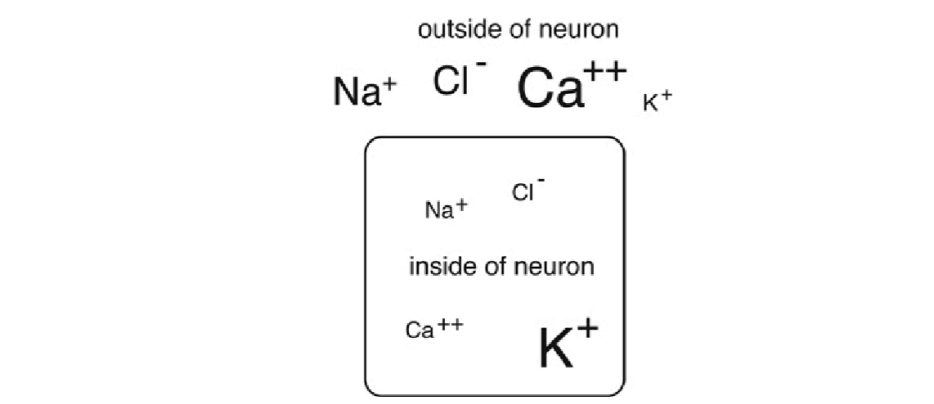


Figure 5.2. Relative ion concentrations inside and outside a nerve cell, represented by the relative sizes of the chemical symbols of the ions.

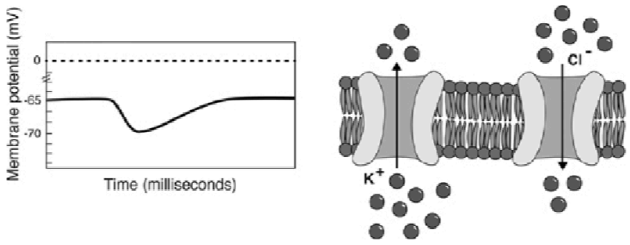


Figure 5.4. Hyperpolarization (left) may result from opening potassium channels or chloride channels (right).

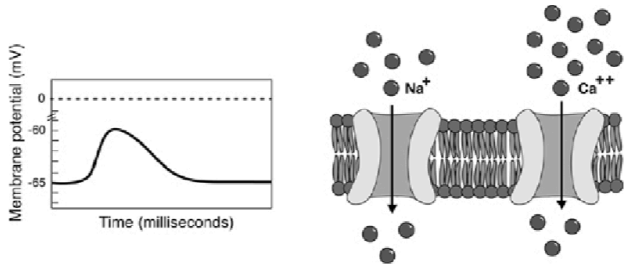


Figure 5.5. Depolarization (left) may result from opening sodium channels or calcium channels (right).

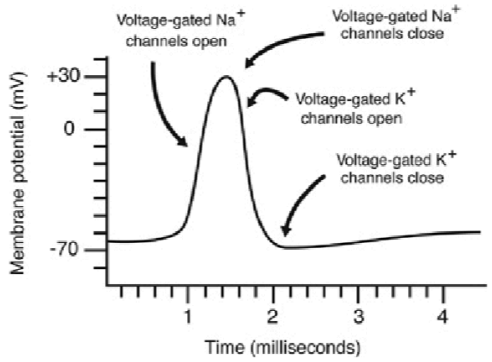


Figure 5.7. Actions of voltage-gated ion channels during an action potential.

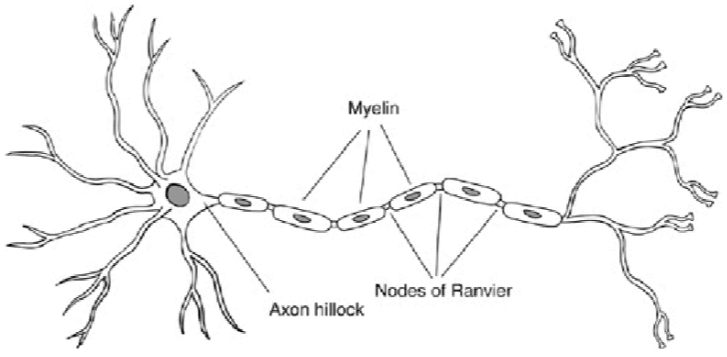
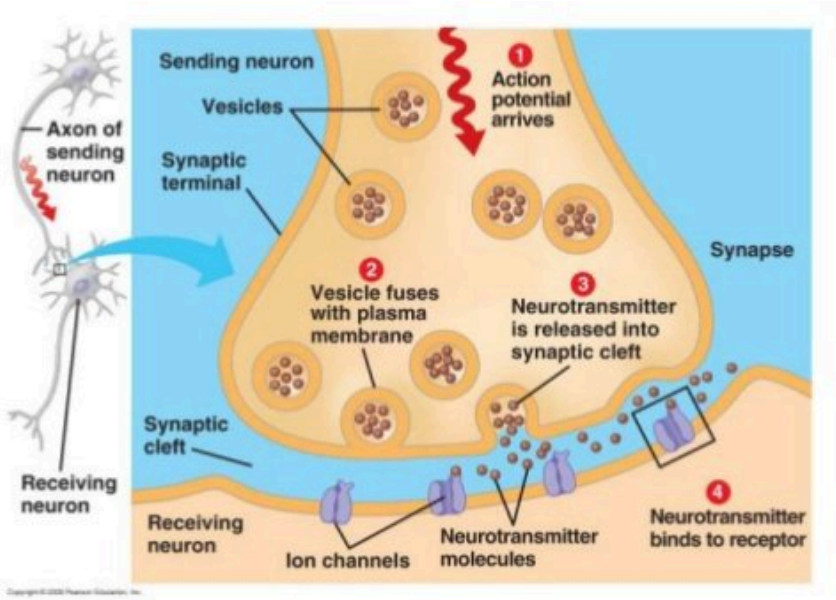


Figure 5.9. Neuron with myelinated axon.



Chapter 6: Synapses, Neurotransmitters, and Receptors

Page 84 | 2020 June 2

Abstract

An overview of how synapses aid in neurotransmission, and how different neurotransmitters affect ion channels and other cell functions.

Outline

I. Synapses
   - A. Electrical synapses (84)
   - B. Chemical synapses
     1. Structure (84)
     2. SNARE complex and ion processes (85)
     3. Neurotransmission (85)
        - a) Ionotropic
          - (1) Summation of EPSPs and IPSPs (90)
        - b) Metabotropic (93)

II. Neurotransmitters

A. Vagusstoff (88)
B. Glutamate (88)
C. GABA (90)

Key Terms

Synapse: syn = together, haptein = fasten: the points of contact between neurons.
- Synaptic connections involve glial cells and come in two varieties

Electrical synapse (gap junction): clusters of proteins forming channels in the membranes of two adjacent cells. These channels are called **connexons** which is made up of proteins called **connexins** (84)
- Connexons form an electrical synapse when they pair up to allow ions to pass between cells
- Channels are large enough to support all ions as well as glucose/ATP

Chemical synapse: A structure that allows a neuron to communicate with another through releasing **neurotransmitters** (84-85)
- The standard type of synapse
- More complex than electrical synapses
- Allows for more types of regulation
- A **synaptic cleft** separates the neurons: a gap of about 20nm

Synaptic vesicle: a storage unit containing neurotransmitters that is present at the axon terminal

SNARE complex: N-ethylmaleimide-sensitive factor attachment protein receptor: proteins in the lipid membrane of synaptic vesicles that attach vesicles to other proteins in the boundary membrane (85)

Neurotransmission: The process of transferring neurotransmitters across a synaptic cleft: (86)
- Action potential reaches axon terminal and opens a Ca++ channel
- Calcium binds to SNARE complex proteins
- Vesicular membrane fuses with boundary membrane
- Contents of vesicle enter the synaptic cleft, releasing neurotransmitters
- Neurotransmitters reach the **neurotransmitter receptor proteins** at the **postsynaptic neurons,** only binding if the proteins match (87).
- The neurotransmitters are removed from the synaptic cleft:
    - **Reuptake transporter proteins** bind to neurotransmitters and move them into the cell interior
    - When acetylcholine is the neurotransmitter, acetylcholinesterase enzymes break up the molecule (enzymatic inactivation)

Dendritic spine: a bulge on a dendrite that increases its surface area (85)

Otto Loewi (1873-1961): In 1920, ran an experiment that showed how a substance he

called **Vagusstoff** was released from the **vagus nerve,** causing a frog heart to slow down its beating when introduced. Vagusstoff is later identified as the first known neurotransmitter, **acetylcholine** (88)

Ionotropic receptor: A major type of neurotransmitter receptor that opens when a specific neurotransmitter is bound to the receptor protein. This is also known as a **ligand-gated channel receptor** (88)

- Contrasted by **metabotropic receptors** (93) which affect the intracellular chemistry. May cause events other than ion channel openings. See **GPCR**

Ligand: a smaller molecule that binds to a larger molecule (88)

Glutamate: Glutamic acid, the most common neurotransmitter molecule discovered as a product of breaking down gluten (88)

- The nonionized form is glutamic acid, and the ionized form is glutamate
- Primary **excitatory neurotransmitter** that initiates an inward flow of Ca++ and Na+
- Stored in **glutamatergic cells**

GABA: gamma-amino-butryic acid: a major **inhibitory neurotransmitter** that allows Cl- to flow inward to induce hyperpolarization (90)

Glutamic acid decarboxylase (GAD): an enzyme that converts glutamic acid to GABA. Only present in GABAergic neurons (91)

EPSP, IPSP: excitatory/inhibitory postsynaptic potentials: the measured sum inputs of all excitatory/depolarizing and inhibitory/hyperpolarizing signals received by the neuron (90)

- **Spatial and temporal summation of neuronal input:** inputs from further away are much weaker; repeated temporal sequences from inputs enhance the signal (90)

GPCR: G-protein-coupled receptors, another way of referring to **metabotropic receptors.** (95)

- **GPCR signaling:** done by the transmission of **G-proteins** (93)
    - Upon binding, it becomes activated
        - Split into **GDP** (guanosine diphosphate) and **GTP** (guanosine triphosphate) that then bind to other receptors to cause different events
        - **Adenylate cyclase** catalyzes the formation of cAMP (cyclic adenosine monophosphate) molecules that alter enzymatic activity
        - **Protein kinases** catalyze attachment of phosphate groups through **phosphorylation** to other proteins to change their behaviors
        - **Transcription factors** change the rate of transcription of specific genes
        - **Intracellular messengers** such as IP_3 and DAG activate other processes inside the cell **(95)**

Diagrams

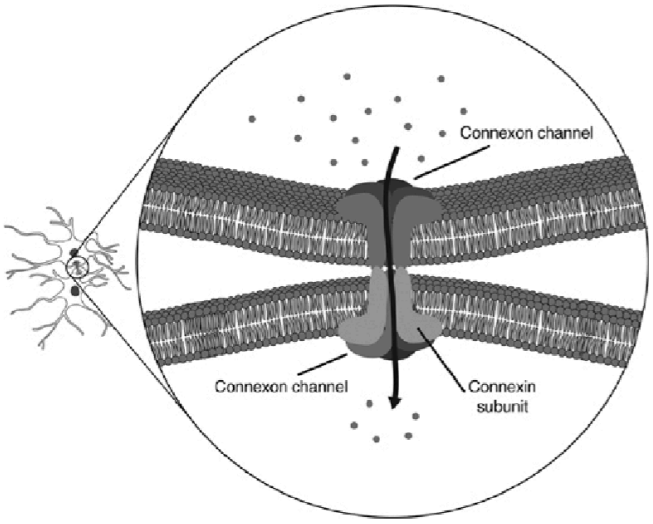


Figure 6.1. Electrical synapse. Connexon channels from two cells join together, forming a pore connecting the cells. Where the two connexons join, the membranes of the two adjacent cells are separated by a gap of about 3 nm. Each connexon channel is formed from six connexin subunit proteins, joined in a doughnut-like fashion with a hole in the center.

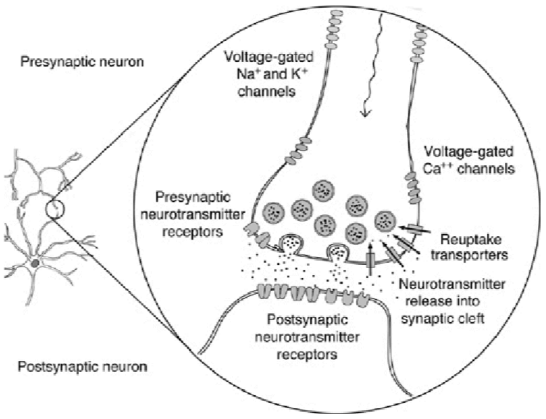


Figure 6.2. Chemical synapse between the terminal of a presynaptic neuron's axon and a dendrite of a postsynaptic neuron.

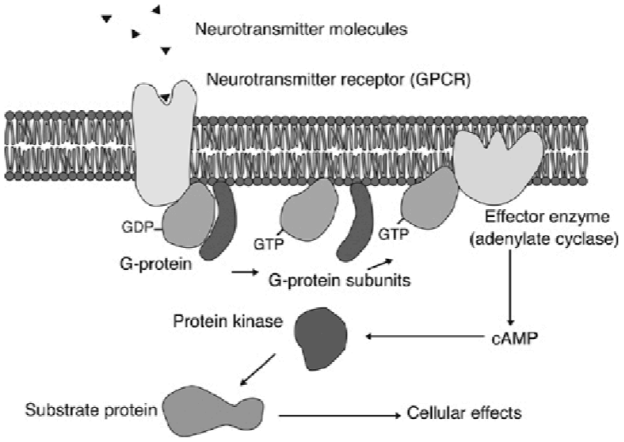
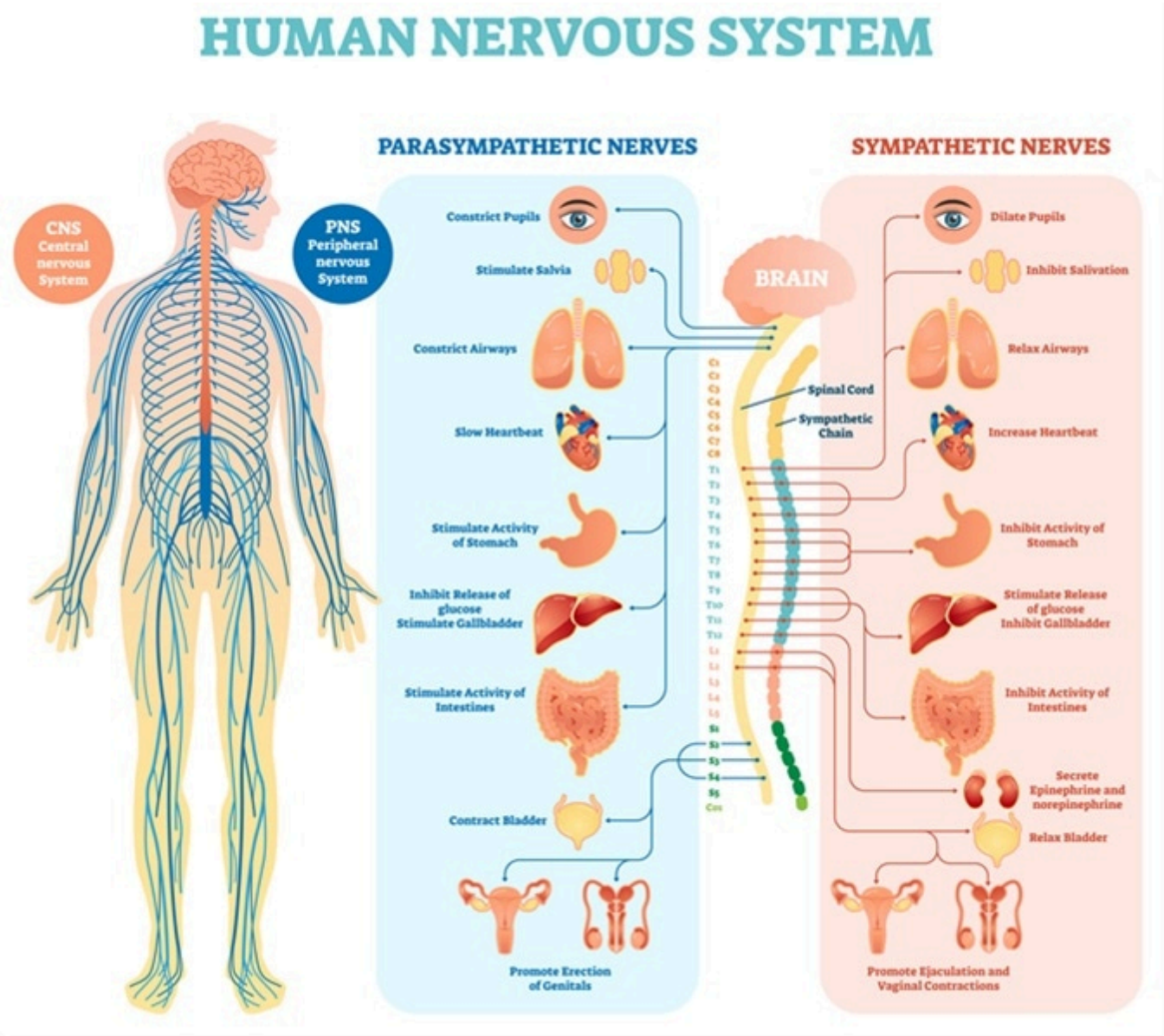


Figure 6.6. An intracellular cascade resulting from activating a G-protein-coupled receptor (GPCR), with adenylate cyclase as the effector enzyme. Substrate proteins are targets of phosphorylation by protein kinases. Examples of substrates are channel proteins (which would be located in the cell membrane) and transcription factor proteins.



Chapter 7: Neuroanatomy and Excitability

Page 96 | 2020 June 3

Abstract

Nervous systems, more types of neurotransmitters, and the delicate balance of excitation and inhibition.

Outline

I. Acetylcholine (96, 101)
II. The nervous system
    A. Central nervous system (96)
    B. Peripheral nervous system
        1. Autonomic nervous system (96)
            a) Sympathetic and parasympathetic nervous systems
        2. Enteric nervous system (97)
    C. Connections and functions (97)
        1. The interconnectivity of the human body
        2. Neural fibers and sympathetic ganglia
        3. Opposing effects of sympathetic and parasympathetic systems (98)
    D. Drugs (98)
        1. Agonists (99)
        2. Dilation (100)
        3. Inhalers (100-101)
III. Monoamines (102)
    A. Serotonin (102)
    B. Phenylalanine (103)
    C. Properties of monoamines (106)
IV. Polypeptides (106)
    A. Opioids
    B. Neuropeptides
V. Categories of neurotransmitters (106)
VI. Seizures (108)

Key Terms

Neuromuscular junction: the connection between nerves and skeletal muscles, mediated by **AChRs** (ionotropic acetylcholine receptors) (96)
Central nervous system (CNS): the brain and spinal cord (96)
Peripheral nervous system (PNS): neural networks in all other parts of the body (96)

- Includes sensory systems and receptors
- Includes **autonomic nervous system:** automatically regulates internal functions, and is divided into the **sympathetic** and **parasympathetic** nervous systems
    - Neural fibers emerge from spinal cord to form connections with **sympathetic ganglia** (clusters of nerve cells) (97)
    - Parasympathetic ganglia are located further away
    - Sympathetic and parasympathetic systems have opposite functions: stress vs. relaxation (98)

    - Sympathetic uses norepinephrine, parasympathetic uses acetylcholine (**autonomic neurotransmitters)**
- Includes **enteric nervous system** that regulates digestion within the gastrointestinal system (98)

Cranial nerves: 12 pairs for different muscle/sensory groups; connect the CNS and PNS (97)
Sympathomimetic, sympatholytic: drugs that activate/disrupt the sympathetic nervous system (99)
Parasympathomimetic, parasympatholytic: drugs that activate/disrupt the parasympathetic nervous system (99)
Agonist: a molecule that binds to a neurotransmitter receptor, activating it (98)

- Neurotransmitters are agonists for its own receptor
- Other molecules can act as agonists if they are similar to a neurotransmitter

Antagonist: a molecule that binds to a neurotransmitter, blocks it from being activated (99)
Choline acetyltransferase: an enzyme that catalyzes the synthesis of ACh from acetate and choline
Acetylcholinesterase: enzyme that breaks ACh down back into acetate and choline
Basal forebrain nuclei, midbrain pontine nuclei: two clusters of cells that release acetylcholine (102)

Serotonin: a monoamine (contains amine/nitrogen group at the end of carbon chain) that is released from **raphe nuclei** in the brainstem (103)
dopamine: ventral tegmentum, substantia nigra (105)
norepinephrine: locus coeruleus (106)
Biosynthesis of monoamine neurotransmitters: 104
Peptide neurotransmitters: 5-31 amino acids including opioids, endorphins, other neuropeptides that are relatively unknown (106)
Seizure: a condition caused by an excess of excitation (107)

- Disturbances in perception
- Involuntary muscle movements
- Memory loss or loss of consciousness
- Can be caused by tumors, infections, and fevers
- **Idiopathic seizures** are not associated with any causes and can appear at any point

Epilepsy: chronic, recurring seizures (108)
Antiseizure medications reduce the amount of excitation or increase the amount of inhibition in the brain **(108)**
Excitotoxicity: the phenomenon of cell death caused by an excess of glutamate, allowing large amounts of Ca++ to enter cells (109)

Diagrams

1. Olfactory (nose; smell)
2. Optic (retina of eye; vision)
3. Oculomotor (eye muscles; eye movement, pupil constriction)
4. Trochlear (eye muscles; eye movement)
5. Trigeminal (face; facial sensation and movement)
6. Abducens (eye muscles; eye movement)
7. Facial (face; facial sensation and movement, salivation, lacrimation)
8. Auditory-vestibular (inner ear; hearing and balance)
9. Glossopharyngeal (tongue and pharynx; taste and movement)
10. Vagus (pharynx, larynx, internal organs of chest and abdomen; taste, heart rate, respiration)
11. Accessory (neck muscles; movement)
12. Hypoglossal (tongue; movement, swallowing, speech)

Sympathetic	Parasympathetic
increases heart rate	decreases heart rate
dilates lung airways	constricts lung airways
dilates pupils of eyes	constricts pupils of eyes
inhibits salivation	stimulates salivation
inhibits bladder from voiding	stimulates bladder to void
decreases intestinal motility	stimulates intestinal motility

Chapter 8: Poison, Medicine, and Pharmacology

Page 110 | 2020 June 6

Abstract

Poisons are medicines, and medicines are poisons: an exploration of toxic substances and how they are used.

Outline

I. Pharmacology intro (110)
   A. Drugs
   B. Medicines are also poisons
II. TTX (103)
   A. Made by bacteria
   B. Why it is poisonous (Na+ Blocker)
III. Blood-Brain Barrier (112)
   A. Implications
   B. Crossing the barrier (2 ways)
IV. STX (113)
   A. Similarities to TTX
   B. PSP
   C. Sensitivity of protein functions
V. BTX (113)
   A. Similarities and differences to TTX/STX

VI. Anesthetics (115)
    A. Cocaine
VII. Nicotine (116)
    A. Effects on acetylcholine
    B. Properties of molecule
    C. SEE CH9 FOR MORE INFO
VIII. Atropine (118)
    A. Medicinal uses
    B. Parasympatholytic effects (anticholinergic effects)
    C. Psychoactive effects
    D. Chemical structure
IX. 5 most used psychoactive drugs (120)
X. Plants, drugs, and ethnobotany (122)

Key Terms

Drug: a molecule that has a significant impact on body function (110)
Pharmacology: the study of drugs (110)
- Originated from pharmakon (both medicine and poison at the same time)
- **Paracelsus** originally thought of the idea that all substances are poison, and their lethality depends on the dose (110)

Tetrodotoxin (TTX): a chemical found in pufferfish and other animals that blocks voltage-gated Na+ channels, causing paralysis (110-112)
- Temporary effects but can cause suffocation
- Does not affect the heart or brain due to blood-brain barrier (not hydrophobic)

Blood-brain barrier: cells that make up the CNS are packed tightly together, so that there are no gaps for molecules to cross easily (112)
- 2 ways to cross:
    - Transporter proteins for important molecules such as ATP, amino acids
    - Dissolve through cell walls (since they are phospholipid bilayers)

TTX resistance: certain animals are not affected to TTX due to having a different structure of voltage-gated Na+ channels (113)
Saxitoxin (STX): found in dinoflagellates and acts very similarly to TTX (113)
- Typically caused by the consumption of shellfish: results in **PSP** (paralytic shellfish poisoning)

Batrachotoxins (BTX): A group of poisons found in tropical frogs; prevent Na+ channels from closing, resulting in similar paralytic conditions as TTX/STX (114-115)
- Different because they do not block Na+ channels, resulting in anesthetic effects

Cocaine: the first local anesthetic, purified from coca plant (115)**. local anesthesia** causes loss in sensation in a specific part of the body.
AChRs: acetylcholine receptors. Two types:

- **Nicotinic:** an ionotropic receptor activated by binding nicotine. Blocked by tubocurarine (found in curare plant extract) (116)
    - Tubocurarine is not absorbed, so it must enter bloodstream directly
- **Muscarinic:** Activated by the muscarine molecule and antagonized by atropine

Atropine: a parasympatholytic drug found in the nightshade plant **(atropa belladonna).** In small quantities, treats gastrointestinal problems and dilates pupils; in large quantities, paralyzes the body

- Crosses blood-brain barrier

Top 5 psychoactive drugs

1. Caffeine
2. Alcohol (ethanol)
3. Nicotine
4. Areca nut (relaxation, mental stimulation)
5. Cannabis (THC)

Diagrams

None!

Chapter 9: Psychoactive Drugs

Page 124 | 2020 June 7

Abstract

An overview of some common types of *psychoactive drugs*, which alter the state of the mind by affecting certain chemical synapse processes such as antagonizing receptors.

Outline

I. Caffeine (124)
   - A. Source
   - B. Chemical structure
   - C. Effects
   - D. Antagonization of adenosine receptors

II. Nicotine (126)
   - A. Source
   - B. Antagonist to nAChRs
   - C. Poisonous qualities

III. Alcohol (127)
   - A. Ethanol and fermentation
   - B. Sedative-hypnotics
   - C. Barbiturates

D. Benzodiazepines
E. General anesthetics
F. Common neurochemical mechanisms

IV. Opioids (129)
A. Origins
B. Positive effects of opium
C. Isolation of chemical and its importance
D. Aspirin
E. Diacetylmorphine
F. Synthetic opioids
G. Effects on body (bind to GPCRs)
H. Neuropeptides

V. Cocaine (132)
A. Origins and uses (Coca plant)
B. Similarities to caffeine
C. Neurochemical effect of blocking reuptake transporters for norepinephrine and dopamine
D. Poisonous qualities: overstimulation

VI. Amphetamine stimulant drugs (134)
A. Similar behavior to cocaine, but different structures
B. Effects on norepinephrine and dopamine reliant synapses
C. Medicinal uses

VII. Psychedelics (135)
A. Complex effects
B. Set and setting
C. LSD and other examples
D. Effects of chemical signaling on CNS function
E. Psychedelic mushrooms
F. DMT
G. Medicinal uses and unpredictability

VIII. Cannabinoids (139)
A. Prevalence in human societies
B. THC
C. Cannabinoid receptor
D. Anandamide
E. Endocannabinoids and retrograde neurotransmitters

Key Terms

Caffeine
- Origin: coffee, cacao, kola, guarana, yerba mate

- Most used psychoactive drug in the world
- Stimulant drug that increases wakefulness and alertness
    - Affects cardiovascular and CNS
- Molecular structure: very similar to adenine and guanine (the counterparts are **theophylline** and **theobromine** which are synthesized from A and G)
- **Adenosine:** a molecularly similar neurotransmitter that mediates slower heart rates and vasodilation (opposite effects of caffeine)
    - Caffeine antagonizes adenosine receptors, resulting in the blocking of G-protein activation and preventing hyperpolarization

Nicotine

- Origin: tobacco
- Agonizes **nicotinic acetylcholine receptors** (nAChRs)
- Increases relaxation, alertness, attention in small quantities but poisoning creates disruptions in heart, blood pressure, respiration

Alcohol

- Human consumption is of **ethyl alcohol (ethanol)** that has 2 carbons
- Formed by metabolism of yeast on sugar (fermentation)
- Is a type of **sedative-hypnotic drug:** in small quantities it is a sedative, in high doses it is hypnotic or sleep-inducing
    - Most sedative-hypnotics work by increasing CL- flow into cells, increasing GABA-ergic inhibition
- **Barbiturates** are another type of sedative-hypnotic drug
    - Some of the first synthetic drugs to be introduced
    - Used to treat anxiety and insomnia
- **Benzodiazepines:** another type of sedative-hypnotic drug that include xanax, librium, and valium. Very widely used drugs
- **General anesthetics:** another type of sedative-hypnotic drug that interfere with voltage-gated sodium channels to locally alter nerve signals

Opioids

- Originated from the opium poppy (*Papaver somniferum*)
- Reduces the perception of pain, cough suppression, and to slow down intestinal movements
- Morphine was isolated in 1804 by **Friedrich Wilhelm Sertürner** (first time a chemical substance was isolated and shown to have medicinal properties)
- Mixed with acetic acid to produce diacetylmorphine (heroin), salicylic acid for acetylsalicylic acid (aspirin) (**semisynthetic opioids)**
    - Heroin is more potent because acetyl groups cross the blood-brain barrier more readily due to having less polarity
- Fully synthetic opioids: methadone, fentanyl (100x), carfentanil (10,000x)
- GPCRs (mu, delta, kappa opioid receptors) bind opioids
    - These receptors are agonized by **endorphins** which are a type of neuropeptide

Cocaine

- Isolated from *Erythroxylum coca* (the coca plant)
- Increases wakefulness and stamina by stimulating the sympathetic nervous system
- Effect: inhibits reuptake transporters for norepinephrine and dopamine
    - These neurotransmitters will then have an enhanced effect at the synapse
- Poisonous due to overarousal, resulting in **psychosis** (a detachment from perception of reality through delusions and hallucinations)
- Sympathomimetic effects due to enhanced noradrenergic synapses

Amphetamine stimulant drugs

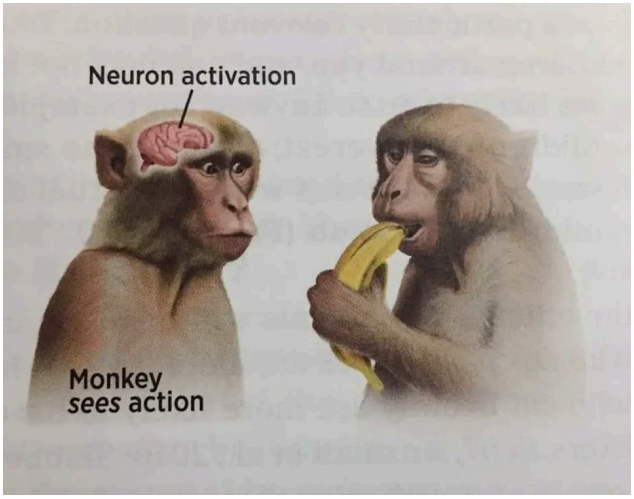
- Very similar effects to cocaine, but structurally different
- Originates from khat plant
- Makes norepinephrine and dopamine intake transporters leaky- neurotransmitters leak out into the synaptic cleft and result in overstimulation

Psychedelics

- Complex effects on mind (alters perception)
- **Set-and-setting effect:** influences memories, experiences, mood, physical environment perception
- **Arthur Heffter:** discovered **mescaline** in 1897**,** a psychedelically active chemical that originates from peyote cactus in Mexico and Texas
- **Albert Hofmann:** discovered **LSD** in 1943, derived from ergotamine in ergot fungi
    - Important because it indicated that thought was associated with chemical signalling
- **Maria Sabina:** a Manzatec healer who shared information about psychedelic mushrooms (*Psilocybe*), which reached **Gordon Wasson**, who identified **psilocybin** and **psilocin** which are very similar to serotonin
- **DMT:** dimethyltryptamine, can be synthesized from tryptophan
    - Naturally catalyzed by the ayahuasca vine
    - Bind to agonists of serotonin receptors
- **MDMA** and **MDA** have relatively unknown effects and are different from other psychedelics in structure

Cannabinoids

- Cannabis has been used for many purposes throughout human history
- Main active chemical: **tetrahydrocannabinol (THC)**
    - Hydrophobic molecule that dissolves easily into phospholipid bilayers
    - Binds to cannabinoid (CB) receptors, the most abundant GPCR receptor
- **Anandamide:** endogenous agonist of CP receptor and a type of **endocannabinoid** (similar effects to THC, but different structures)
- Important for **retrograde signalling** that propagates in the opposite direction of most other signals



Chapter 10: Neural Development and Neuroplasticity

Page 142 | 2020 June 8

Abstract

An overview of some common types of *psychoactive drugs*, which alter the state of the mind by affecting certain chemical synapse processes such as antagonizing receptors.

Outline

I. Overview of the human genome (142)
II. Human development
    A. Transcription factors and cell differentiation (143)
    B. Neurogenesis and gliogenesis
    C. Neural tube
    D. Cajal and developing neurons (144)
    E. Growth cone (145)
    F. Microfilaments and microtubules
III. Sperry's experiments: optic nerve regeneration (147)
    A. Eye rotation
IV. Neurotrophin, the first nerve growth factor (148)
V. Neuroplasticity (149)

A. Hippocampus and its role in the formation of neurons (150)
B. Importance of childhood

Key Terms

The human genome
- 46 chromosomes: 2 pairs of 23
- 3 billion nucleotide base pairs
- < 3% is functional protein; > 85% is used for RNA transcription

Transcription factors: proteins that regulate **cell differentiation-** the idea that different cells have different processes for transcription and translation that must be determined (142-143)

Embryonic stem cells: general purpose cells with the capacity to differentiate into any type of cell, including **neural progenitor cells** (143)
- **Neurogenesis** and **gliogenesis**: the conversion of neural progenitor cells into nerve cells and glial cells respectively

Neural tube: a structure formed 3 weeks into conception that eventually develops into the central nervous system (144)

Santiago Ramón y Cajal: studied how axon tips sought out connections with other neurons; hypothesized that the **growth cone** allowed a growing axon to make connections
- Made up of fingerlike structures (**filopodia)**
- **Cytoskeleton:** ordered arrays of protein polymers that make up the internal structure of the cell
- **Microfilaments and microtubules** are long strands that help with growth, movement of cell processes, movement of materials, and insertion and removal of membrane proteins (ion channels, transporters, etc) (145)
    - Made up of polymers **actin** and **tubulin**

Roger Sperry: Investigated neural connections in 1930s (147)
- If a frog's eyeball was severed and rotated, the frog would reform the same connections as it did before, creating the **chemoaffinity hypothesis:** nerve cells use chemical signals to guide development and regeneration

Neurotrophin: the first nerve growth factor to be discovered (148)
- Promotes the survival of neurons: otherwise, large proportions of neurons are eliminated during early development

Synaptic pruning: synapses that are not used are eliminated (149)

Neuroplasticity: processes of strengthening, weakening, and overall development of synapses (149)
- Prolonging state of depolarization to increase release of neurotransmitter (strengthening)
- Retrograde signals such as endocannabinoids can be released from postsynaptic cells

- Influence the number of neurotransmitter receptors created during gene transcription

Hippocampus: a bilateral structure under the temporal lobe that is associated with memory formation (150)

- Inside the hippocampus, **neurogenesis** occurs throughout a lifespan
- Brain plasticity is highest in early stages of life

Diagrams

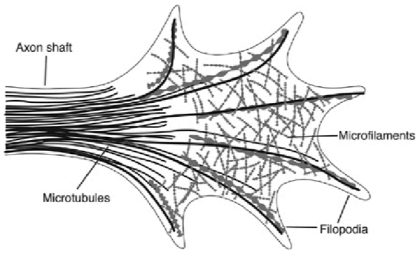


Figure 10.4. Internal cytoskeleton of an axon's growth cone. The shaft of the axon contains numerous microtubules (black lines), with some branching out into the filopodia. The tips of the filopodia are filled with microfilaments (gray lines), some of which are meshlike and some of which are larger bundles.

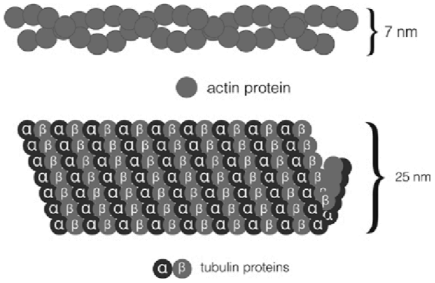
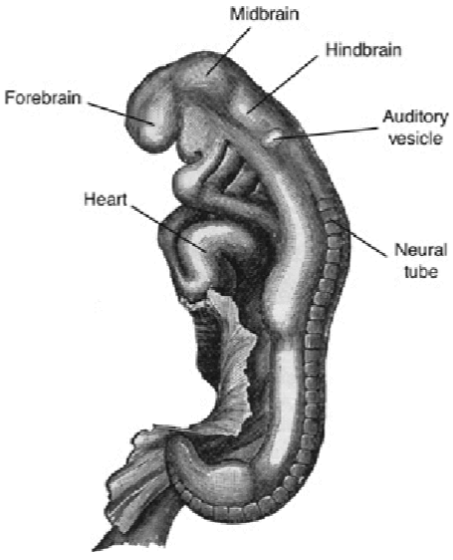


Figure 10.5. Microfilaments (top) are long polymers of actin proteins. Each actin protein is composed of about 375 amino acids. Microtubules (bottom) are long polymers of alpha-tubulin and beta-tubulin proteins. Each tubulin protein is composed of around 450 amino acids. Microtubules are cylindrical, with a hollow core. Microfilaments and microtubules can grow to be hundreds of times longer than their diameters and are composed of millions of atoms.



Chapter 11: Sensory Perception

Page 152 | 2020 June 12

Abstract

A brief overview of sensation and perception and examples of how they affect both humans and animals.

Outline

I. Sensory perception (152)
   A. Collection of information (sensation)
   B. Analysis and interpretation of information (perception)
II. Sensation in bacteria (152)
   A. Chemotaxis
   B. Phototaxis
   C. Example: Phycomyces fungus
III. Ontology and the nature of reality (154)
   A. Naive realism
IV. Overview of human sensory perception (155)
   A. Example: vision
      1. Honeybees vs. humans
      2. Snakes and pit organs (158)
      3. Animal abilities that humans do not possess
         a) Polarization

b) Electroreception
c) Ultrasound

Key Terms

Sensation: the collection of information via sensory organs/receptors (152)
Perception: the analysis and interpretation of sensory information (152)
Chemotaxis: a behavior where bacteria move towards areas where nutrients are present
- **Tumbles:** occur when bacteria flops around, reversing direction randomly
- **Runs:** occur when bacteria move in one direction for about a second
- Together, they create a **random walk**

Phototaxis: when an entire organism moves towards a light (like bacteria) (153)
Phototropism: when an organism bends/grows towards a light (like plants) (153)
Naive Realism: the epistemological notion that what we perceive is identical to what actually exists. This has many limitations and is not always true (154-155)

Vision
- A response to the **electromagnetic spectrum** (155)
  - 10^{18} (quintillion) difference in energy between lowest and highest levels
  - Humans can only perceive visible light (400-700 nm)
  - **Karl von Frisch:** demonstrated that honeybees have color vision, proving that humans are not the only animals that can see in color. (156)
    - Honeybees can also sense UV light
  - Pit vipers (such as rattlesnakes) have **pit organs** that can detect infrared radiation, allowing them to sense warm objects in complete darkness (158)
  - **Polarization:** the vibration of electromagnetic fields along a specific angle. Can be sensed by insects, birds and reptiles (158)

Other Perception
- Animals can hear in ranges that humans cannot: for example, elephants can hear 20 Hz **infrasound** while dogs and cats can hear 40 kHz **ultrasound** and bats can sense >100kHz sonar (160)
- **Electroreception:** the detection of electric fields generated by living organisms (160)
- Birds, fish, etc. can sense the geomagnetic field to navigate

Diagrams

None!

Chapter 12: Nose and Smell

Page 163 | 2020 June 12

Abstract

An overview of the olfactory system and the process of how odorants are captured and interpreted by the brain.

Outline

I. Olfactory sensory perception (163)
   - A. Odorants
   - B. Olfactory epithelium
   - C. Olfactory stem cells
   - D. Olfactory receptors (GPCRs)
     1. Pseudogenes

II. Aromas (165)
   - A. Perfume and essential oils

B. Examples: cinnamon, cardamom, black pepper, flowers (jasmine), lemon, asparagus, durian, truffles

III. Pheromones (173)

Key Terms

Olfaction (163)

- Occurs when **odorants** enter nasal passages and are captured in the **olfactory epithelium** lining
  - Nasal epithelium contains **olfactory stem cells** that replace receptor cells every couple months
  - Made up of **cilia** that are connected to olfactory receptor proteins
  - Olfactory receptors are GPCRs. Humans have about 350 different olfactory receptor proteins (164)
    - Humans also have nonfunctional code for **pseudogenes** (about 600)
    - Each different scent activates a different pattern of olfactory GPCRs

Aromas

- **Aroma** derives from the Greek word for spice (165)
- **Essential oil:** oily concentrate of aromatic molecules from a plant (165)
  - Aroma carrying particles are often hydrophobic
  - Cinnamaldehyde, cinnamyl acetate, cinnamyl alcohol, copaene, eugenol, ethyl cinnamate, guaiene
- Plant aromas are composed of dozens of different molecules
- Cardamom: limonene, menthone, eucalyptol, terpineol, terpinyl acetate, myrcene, sabiene, phellandrene
- Pepper: sabinene, linalool, piperine, limonene, caryophyllene, pinene, carene
- Rose: citronellol, geraniol, nerol, linalool, citral, phenyl ethanol
  - Linear chain of eight carbons, two methyl CH_3, hydroxy OH group in common
- Jasmine flowers have indole, which is normally pungent but makes aromas more complex (169)
- Thiols all contain sulfur-hydrogen SH groups that are often smelly (170)
  - Also methanethiol and dimethyl sulfide
- **Anosmia:** loss of sensitivity to a specific kind of smell (171)
  - Opposite: hyperosmia
  - **Specific anosmia** = one particular type of smell is lost, **general anosmia =** can't smell a large variety of scents

Activation of olfactory GPCRs (171)

1. An olfactory GPCR is activated
2. cAMP is synthesized
3. Depolarization occurs as Ca++ and Na+ enter the cell

4. Olfactory receptor cells send axons into the **olfactory bulb** forming synapses with mitral cells (triangular shape)
5. Mitral cells send axons to pyriform cortex and amygdala
6. Pyriform cortex sense axons to the thalamus and orbitofrontal cortex

Pheromones: chemicals that carry social communication information between members of the same species (173)

- The **vomeronasal system** response to pheromone molecules
- Pheromones are also detected by the main olfactory pathway

Diagrams

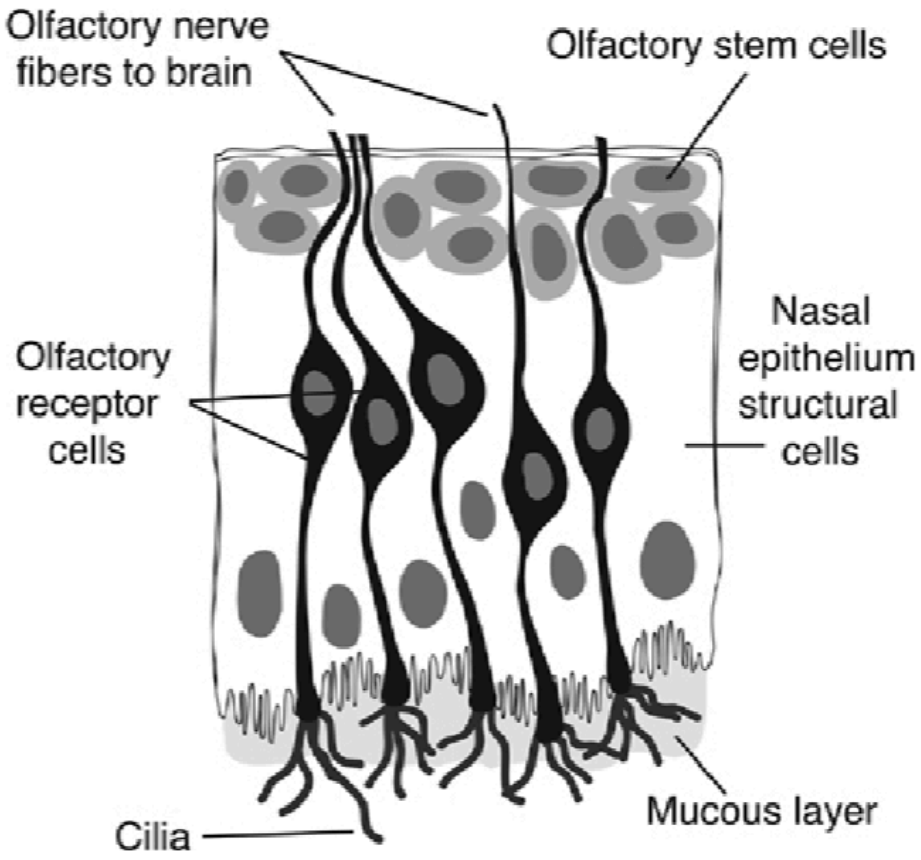
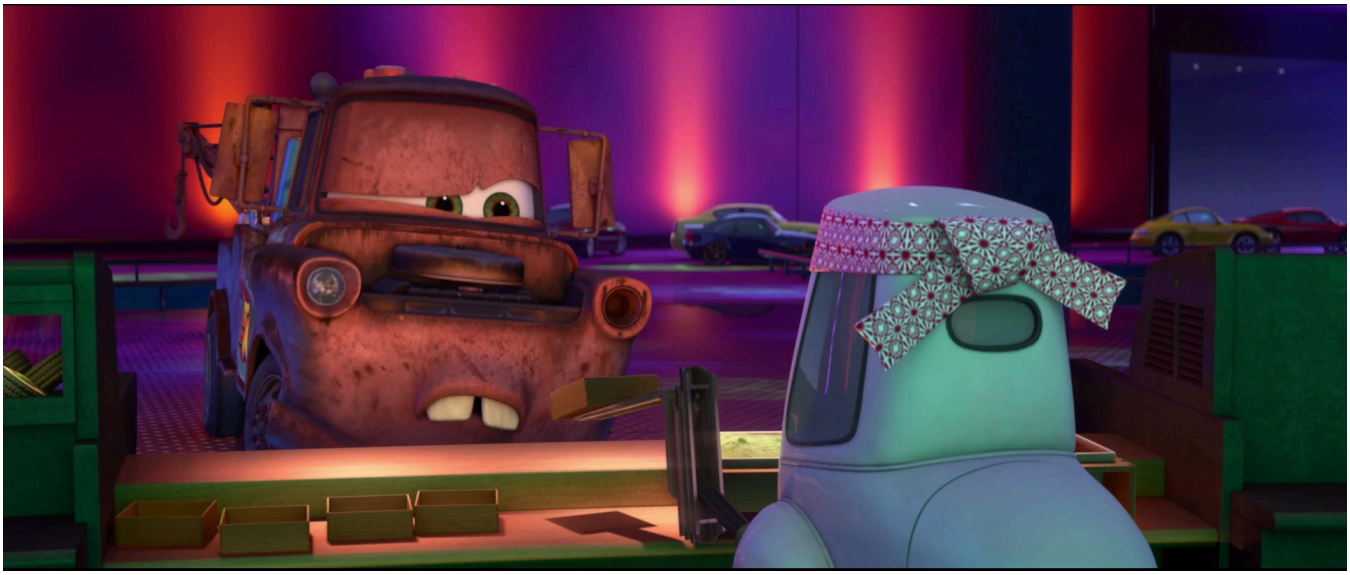


Figure 12.1. Olfactory epithelium.



Chapter 13: Tongue and Taste

Page 175 | 2020 June 14

Abstract

A brief overview of the gustatory system, the five types of taste receptors, and the broader experience of flavor.

Outline

I. Gustation overview (175)
   A. Similarities with olfaction
   B. Gustatory receptor
II. Five types of taste receptor cells (176)
   A. Salt
   B. Sour
   C. Bitter
   D. Sweet (177)
      1. Natural sweeteners
      2. Synthetic sweeteners (saccharin, aspartame)
   E. Umami (180)
      1. Glutamate
III. Taste as a mental experience (181)

IV. Other taste sensations
    A. Spiciness/capsaicin (182)
    B. Mint/menthol (184)
    C. Pungent (isothiocyanates) (184)
V. Flavor (185)

Key Terms

Taste Bud: clusters of receptor cells located on the mouth (175)
- Contains about 100 receptor cells each
- About 1 million taste receptor cells total

Microvilli: functionally similar to cilia, but are smaller and are used to increase sensory surface area (175)
- Made of actin (cilia have microtubules instead)

Similarities to olfactory system (175)
- Stem cells are present to replace taste receptor cells continually, as they are frequently damaged

Salt (176)
- Taste receptor proteins not yet identified
- Na+ ions from salt flow through sodium ion channel (readily dissolved in mouth)

Sour (176)
- Originates from H+ ions release from acids
- Captured in hydrogen-sensitive ion channels

Bitter (177)
- Associated with more than 30 GPCRs
- Bitter substances are often toxic

Sweet (177)
- Sugar molecules bind as ligands to GPCRs
- Sweet receptor protein is a **dimer** - two GPCRs are linked to form a functional receptor protein
- Synthetic sweeteners bind to sweet GPCRs more readily than natural sugar
    - Saccharin is 300x sweeter than sucrose
    - Most widely used is aspartame (200x sweeter)

Umami (180)
- Savory taste that is a response to metabotropic glutamate receptors
- Aids with detection of protein containing foods

Processing taste (181)
- Cranial nerves carry information to the lower brain stem
- First connection is the **nucleus solitarius**
- Next: thalamus -> insula -> somatosensory cortex in parietal lobe

- Second branch: hypothalamus -> amygdala
- (gustatory receptor cells release NT; activation of cranial nerves; information relayed to thalamus; activation of primary gustatory cortex)

Spiciness: experienced due to the presence of **capsaicin (182)**
- Chili plant: Capsicum annuum
- Capsaicin binds to receptor proteins, changing the protein shape and opening Ca++ channels (leads to depolarization -> excitability)
- Experiencing heat is the same molecular and cellular mechanism
- Capsaicin receptor: TRPV1 (transient receptor potential)

Mint: experienced through the presence of **menthol** (184)
- Opens Ca++ channel due to binding of menthol
- The same receptors respond to cold temperatures
- Menthol receptor: TRPM8

Isothiocyanates: pungency (184)
- Sulfur, carbon, nitrogen components
- Activates Ca++ channel TRPA1

Flavor: a combination of many channels of sensory information (taste, texture, aroma) (185)

Diagrams

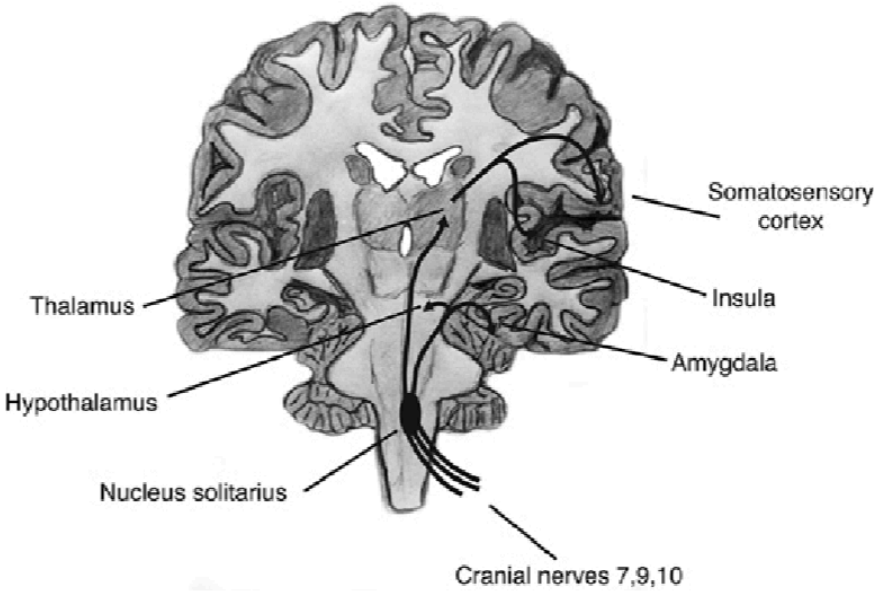
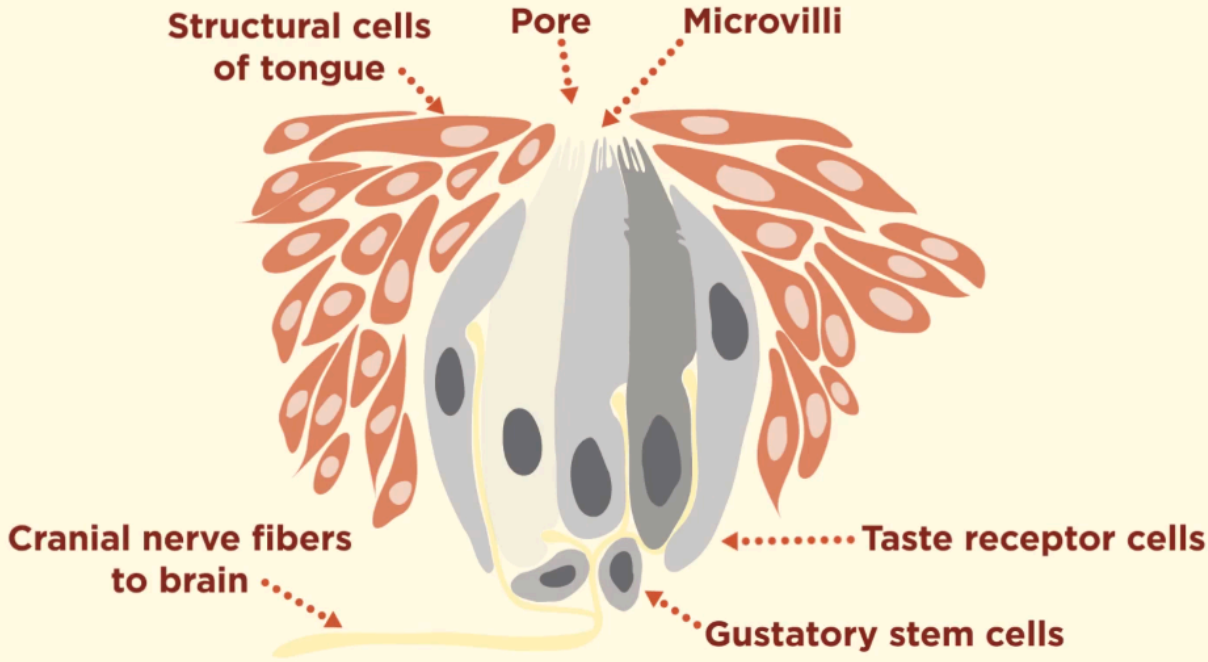


Figure 13.2. A coronal or frontal slice through the brain showing neural pathways associated with taste. The insula is a region of the cerebral cortex deep within the lateral sulcus, at the juncture of the parietal and temporal lobes.

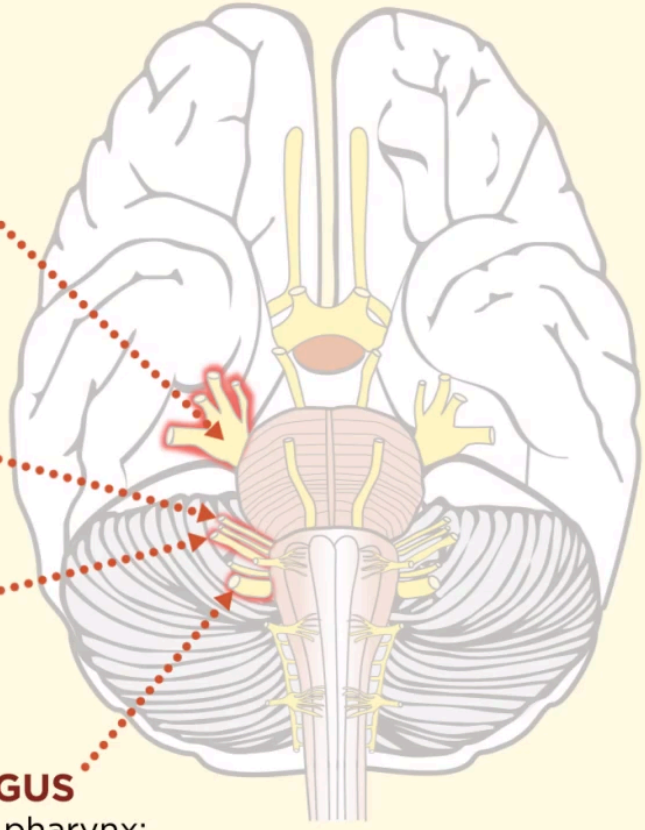


5. TRIGEMINAL
Mouth, teeth, and nasal cavity; sensation and chewing

7. FACIAL
Face; facial sensation and movement, salivation, lacrimation

9. GLOSSOPHARYNGEAL
Tongue and pharynx; taste and movement

10. VAGUS
Tongue and pharynx; taste and movement



Chapter 14: Eyes and Vision

Page 186 | 2020 June 16

Abstract

An overview of the structure of the eye and how visual information is collected and processed.

Outline

I. Electromagnetic radiation (186)
II. Anatomy of the eye (187)
III. Retina and photoreceptor cells (187)
    A. Rods and cones
    B. Rhodopsin and cone opsins
    C. Color vision
        1. Trichromatic color vision
        2. Genetic variability (189)
    D. Distribution of photoreceptor cells (190)
    E. Blind spots (191)
    F. Three layers of cells in the retina (195)
IV. Retinal (193)
    A. Carotenoids
    B. Photoisomerization (194)
V. Process of detecting light (194)
    A. Background noise (196)
VI. Melanopsin (196-197)
VII. The receptive field (197)
VIII. Brain processing of visual information (197)
IX. Lesions (199)

Key Terms

Retina: A photosensitive film at the rear of the eyeball consisting of light-sensitive photoreceptor cells, nerve cells, and blood vessels (186)

- Derives from Latin word for 'net'

Fovea: A region in the center of the retina where the concentration of photoreceptor cells is the highest (187)

Types of photoreceptor cells (187)

- **Rods:** sensitive to small amounts of light
  - very numerous and distributed throughout retina
  - Contains light-sensitive protein **rhodopsin**
  - About 100 million
  - Contain about 100 million rhodopsin molecules
- **Cones:** sensitive to different ranges and intensities of light
  - Contains light-sensitive protein **cone opsin**
  - Three types that absorb short, medium, and long wavelengths (Blue, Green, Red cones)
  - Responsible for color vision
  - About 5 million; concentrated at the fovea

Genetics of vision (188)

- Opsin proteins have 350 amino acids
- M and L opsin genes are found to be encoded in X chromosome
- **Color anomalous:** a change in light-absorbing proteins alters the ability to differentiate between different colors (189)
- **Colorblindness:** when one type of cone receptor cell is lost
- **Retinal achromatopsia:** all functional cone cells are lost, resulting in greyscale vision

Blind spot: the region near the fovea where axons form the optic nerve and exit the eyeball. No photoreceptors exist here (191)

- The brain can fill in this spot since we have two eyes and are constantly moving; alternatively, the brain can average out visual information from around the spot

Structure of photoreceptor cells (192)

- Outer segment consists of a long chain of opsin protein wound around a phospholipid bilayer membrane
- **Retinal** molecules are embedded in the membrane, covalently bonded (nitrogen-lysine) to opsin protein

Retinal: changes shape when exposed to light (**photoisomerization)**, starting a GPCR cascade that results in perception of vision **(193)**

- Synthesized from Vitamin A (retinol) and carotenoids (beta-carotene, etc)

- Shifts from the bent form (11-cis isomer) to straight form (all-trans isomer)
- When shifted, binds to opsin GPCRs, activating enzyme cGMP phosphodiesterase
    - Enzyme converts cGMP to non-cyclic GMP, keeping ion channels open and increases cell excitability

Layers of the retina (195)

- **Photoreceptor cells:** rods and cones
- **Bipolar cells:** have a synaptic connection with photoreceptor cells
    - Contains **horizontal cells** and **amacrine cells** that interconnect the photoreceptor cells with ganglion cells
- **Ganglion cells:** have a synaptic connection with bipolar cells
    - Bundle together to form optic nerve
    - About 1 million ganglion cells in the eye
    - Avoids background noise by waiting for several signals from multiple photoreceptors before sending to the brain
    - Contains protein **melanopsin** that regulates pupil size and circadian rhythm

Receptive field: a property of visual neural cells in which photoreceptors will only respond to stimuli from a specific area of visual space. This phenomenon is known as **contralateral connectivity** (197)

- Upon entering the brain from the optic nerve, signals enter the **optic chiasm** (X-shaped crossing) and separate into the left and right brain hemispheres
- ~10% connect to the midbrain **superior colliculus** (unconscious behaviors such as turning to see something in peripheral vision)
- ~90% connect to **thalamus** in diencephalon → enter **lateral geniculate nuclei (LGN)** → posterior occipital lobe → cortical neurons → visual cortex → Visual processing areas V1 through V5
- Visual areas contain a **visual map**: the relationship between locations of photoreceptor cells are linked to the locations of light in the real world. These locations are preserved when processed by the V1 (visual space processor)

Brain lesions (199)

- **Scotoma**: a blind spot resulting in a lesion in V1
- **Hemianopsia:** A large lesion that completely damages V1 in a cortex, resulting in loss of vision for half of the visual field
- **Cortical achromatopsia**: disruption of color vision caused by a lesion in V4
- **Akinetopsia:** motion blindness (unaware of movement) resulting from a lesion in V5
- **Prosopagnosia**: Inability to recognize faces resulting from a lesion in the inferior/medial temporal lobe
- **Agnosia:** a general neurological syndrome where people have difficulty recognizing visual objects

Diagrams

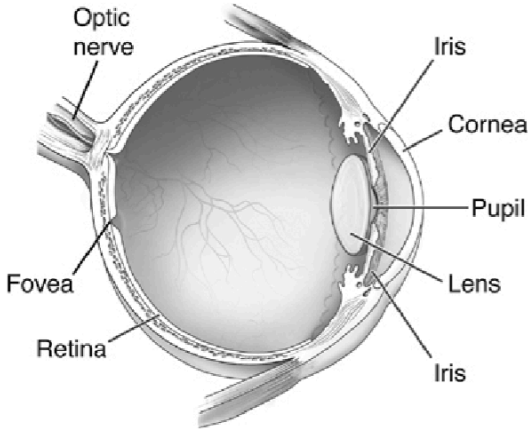


Figure 14.1. Cross section of the human eyeball, our organ of vision. The muscles of the iris regulate the size of the pupillary opening. The interior of the eyeball is filled with a transparent gelatinous fluid called vitreous humor.

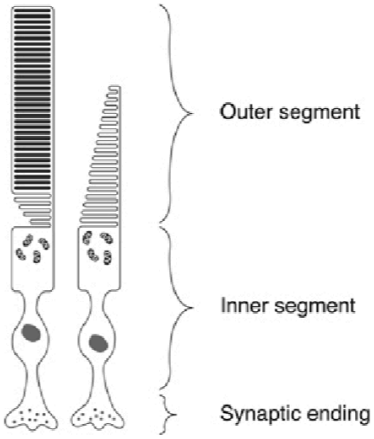
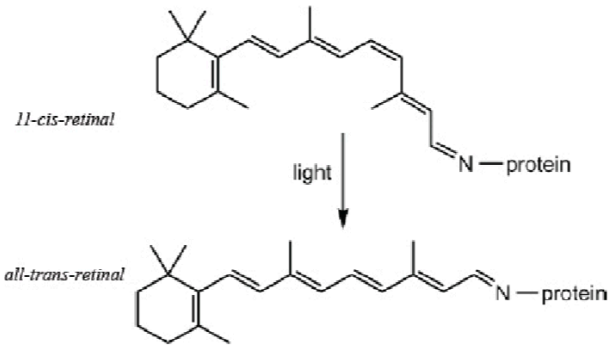


Figure 14.4. Diagram of rod cell (left) and cone cell (right). The outer segments of the cells contain the rhodopsin and cone opsin photoreceptor proteins. The inner segments contain nuclei, mitochondria, and other structures necessary for the functioning of the cell.



In straightening, the retinal pushes on the amino acids surrounding it and, in so doing, shifts the shape of the entire opsin protein. It so happens that opsin proteins are familiar friends—G-protein coupled receptors (GPCRs). Thus, when they change shape, a cascade of intracellular events is initiated. In the case of neuronal signaling at synapses, the binding of a neurotransmitter molecule shape-shifted the GPCR; here, the light-induced isomerization of the retinal changes the shape. Opsin GPCRs are light detectors.

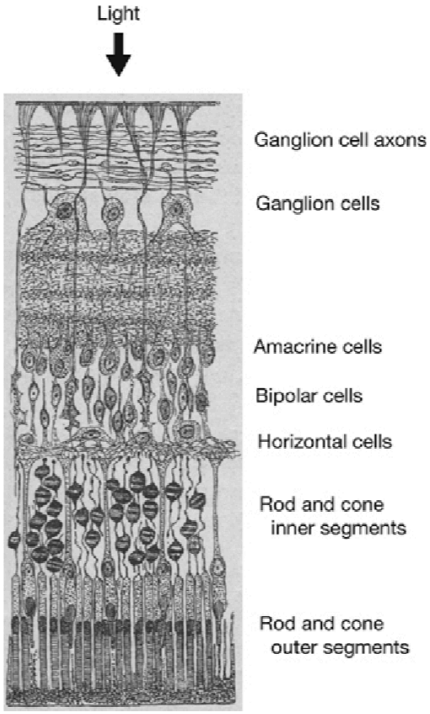


Figure 14.6. Drawing by Ramón y Cajal of the cell layers in a vertebrate retina. The top of this drawing is the part of the retina closest to the interior of the eyeball and the vitreous humor. Light enters the retina from the top and passes through several layers of cells before interacting with the rod and cone photoreceptors. At the fovea, these other cell layers are folded back, allowing incoming light to have unobstructed access to the photoreceptor cells—the pit structure of the fovea.

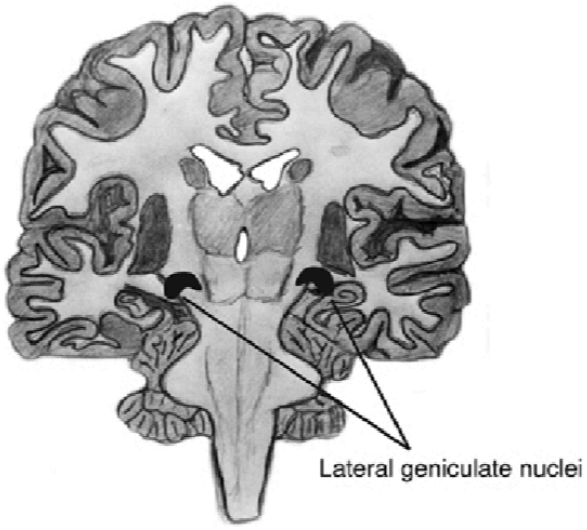


Figure 14.7. Coronal section showing location of the lateral geniculate nuclei.

$$F(j\omega) = \int_{-\infty}^{\infty} f(t)e^{-j\omega t}dt$$

Chapter 15: Ears and Hearing

Abstract

Properties of sound and how they are perceived through the structure of the ear.

Outline

I. What is sound (201)
   A. Sound waves and frequencies
   B. Timbre (204)
II. Anatomy of the ear (207)
   A. Basilar membrane
   B. Hair cells (209-210)
   C. Cochlear fluid and K+ ions
III. Skull vibration (210)
IV. Auditory signalling (211)
V. Hearing loss (212)
   A. Acoustic trauma
   B. Improving hearing
      1. Amplification
      2. Cochlear implants (214)
VI. Functions of the inner ear (214)

Key Terms

Sound: both a physical and mentally perceived concept (201)

- **Physical properties:**
  - Speed of propagation is about 335 m/s or 750mph
  - Rhythmic pattern of compression and rarefaction
  - **Timbre:** the complexity of the waveform (204)
- **Perception:**
  - Humans can perceive 20 Hz - 20kHz
  - Loudness of a sound is the amplitude
  - Pitch of a sound is the frequency

Anatomy of the ear (206)

- External structure: **pinna** functions as funnel for focusing sound into the ear canal
- At the end of the canal is the **tympanic membrane** (eardrum) that vibrates from sound. This separates the outer ear from the middle ear
- Middle ear: a cavity occupied by three bones (**ossicles**) → hammer, anvil, stirrup
- **Oval window** separates the middle ear from the inner ear
- Inner ear: consists of **cochlea** (a spiral structure that contains a fluid) and the bony labyrinth
  - The cochlear fluid has K+ ions to make the concentration greater outside of the cell
  - The cochlea is lined by **basilar membrane** that vibrates when the fluid vibrates in the cochlea
    - Basilar membrane is thickest at the oval window, and thinnest at the other end. The thickness is associated with resonant frequency
    - Consists of about 3500-12000 (inner vs. outer) **hair cells** which have a bundle of cilia on one end and a synapse at the other end (209)
      - When cilia are bent, ion channels open, causing K+ ions to flow into the cell, depolarizing it
      - Voltage-gated Ca++ channels open and release neurotransmitters into the synaptic cleft
      - Outer hair cells contain **prestin** protein that stretches based on membrane potential
  - The bony labyrinth consists of 3 orthogonal canals with two bulbs: **utricle** and **saccule** (214)
    - Part of the **vestibular system** - detects orientation
    - Movement of fluid is detected and translated into information about orientation and position
    - Ear stones (**otoliths)** are suspended in fluid and amplify signals in the ear that contribute to balance

Skull vibration: an alternative method of sound perception that often occurs when

perceiving one's one voice (210)

- Typically does not occur for most sounds, except for sounds coming very close to the ear structure
- Has a differing frequency composition when compared to normal sounds

Auditory signaling: when neurotransmitter is release from hair cells, a signal is generated in cranial nerve 8 (211)

- **Bipolar neurons** carry signals in both directions
- Signal is carried to the brainstem **medulla** where signals are sent to the **cochlear nucleus** → **superior olive** and **lateral lemniscus** in the pons
- Brainstem auditory centers are connected to the **inferior colliculus** in midbrain → **medial geniculate nucleus** (MGN) in thalamus → temporal lobe → **primary auditory cortex (A1)**
- Brainstem auditory nuclei are interconnected, even when on opposite sides of the brain. This allows for comparison of sound between the two ears.

Hearing loss (212)

- Infection of inner ear may cause damage to hair cells
- Genetics may affect the cochlea
- Mutation for connexin 26 may result in imbalance of ions in cochlea
- **Acoustic trauma** may occur, damaging hair cells due to excitotoxic overstimulation

Diagrams

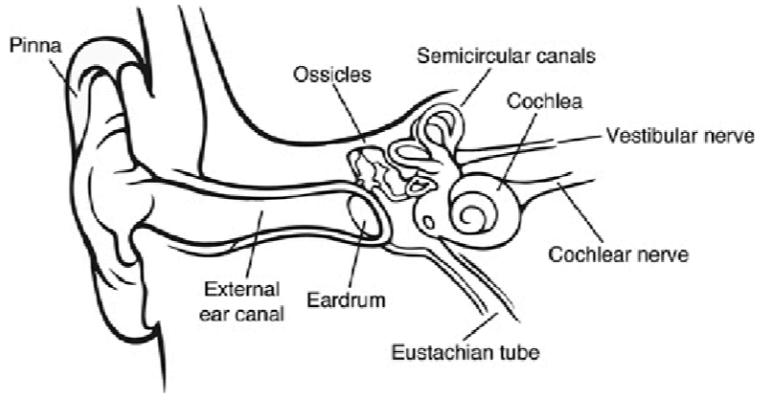


Figure 15.10. The human ear. The external ear is the pinna, ear canal, and eardrum; the middle ear is the chamber containing the ossicles; the inner ear is the cochlea and semicircular canals. The cochlear and vestibular nerves form cranial nerve 8. The Eustachian tube connects the middle ear with the nasopharynx and allows for equalization of air pressure between the middle-ear chamber and the external atmosphere. The Eustachian tube is named after sixteenth-century Italian anatomist Bartolomeo Eustachi, a contemporary of Vesalius.

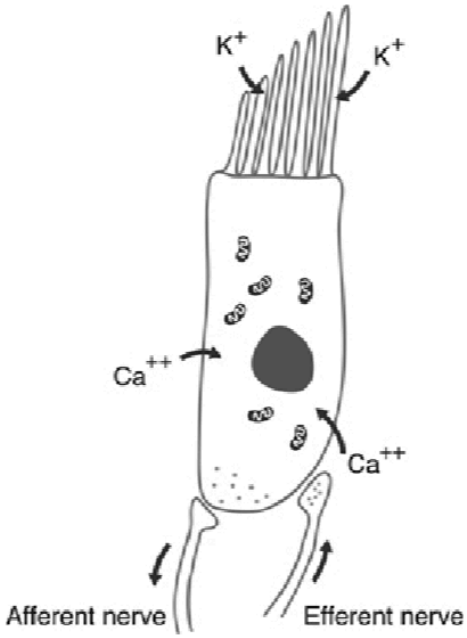


Figure 15.12. Inner-ear hair cell. Afferent fibers (Latin *af* = toward, *ferre* = carry) carry signals from the body's periphery to the brain; efferent fibers (Latin *e* = out) carry signals from the brain to the periphery. Afferent signals convey sensory information to the brain; efferent signals at least in part function to adjust the sensitivity of the inner ear to sound.

Chapter 16: Skin, Touch, and Movement

Page 216 | 2020 June 18

Abstract

An exploration of how touch and movement are handled by the somatosensory system, and the neural pathways that connect our skin to our brain.

Outline

I. Anatomy of the skin (216)
   A. Touch receptors
   B. Somatosensory neurons
II. The somatosensory body (217)
   A. Somatosensory cortex
   B. Body map
   C. Sensitivity differences in areas
III. Mouse studies (220)
   A. Lost body parts results in higher sensitivity in other areas
   B. Phantom arm phenomenon
IV. Penfield and movement (222)
   A. Primary motor cortex
   B. Role of the cerebellum
V. Anosognosia (224)

Key Terms

Somatosensory receptors: found in neurons at the top layers of skin. Receptor proteins respond to touches via mechanically gated ion channels (216-217)
Dorsal-root ganglion: a collection of nerve fiber cell bodies (217)
- Receptor proteins generate action potentials that propagate towards the DRG
- DRG functions in the opposite manner of an axon (propagation is towards cell body)

Somatosensory body map: the representation of spatial receptive fields in the brain (217)
- Contained within the **primary somatosensory cortex S1** in the occipital lobe
- Contralaterally connected
- **Wilder Penfield** discovered the somatosensory map in the 1930s by stimulating

different parts of the brain in surgery patients
- Represented by the **cortical map** that places different parts of the body in different sections of the brain (219)
- Related to differing amounts of sensitivity- neurons in fingers and lips are more dense than in arm/back
    - Sensitivity can be measured using the **two-point discrimination test** (how far apart can two points of contact be when they can be perceived as two rather than one)

Posterior somatosensory cortex (S2, S3, etc): contain more vague maps than S1; process information passed through from S1 (220)

Neglect syndrome: when touch sensation is intact but not perceived unless attention is drawn to it. Caused by lesions in the posterior somatosensory cortex (220)
Phantom limb: the perception of touch from a missing limb. Caused by the neurons for that limb reconnecting to neural pathways from the opposite limb (221)

Primary motor cortex (M1): located immediately anterior to the central sulcus in the frontal lobe. Contains a map of skeletal muscles, allowing us to move our muscles (222)
- Muscles contract when acetylcholine is released
- Connected to s**upplementary motor / premotor areas** that activate before M1 and are involved with planning muscle movements
    - Lesions in this area result in problems with executing a sequence of motor movements, but does not damage the ability to make those movements. This is known as an **apraxia:** a disorder in the organization of movement
- Sends an **efference copy** of signals to the sensory cortex in order to allow the brain to plan based on movements

Mirror neurons: collections of neurons in premotor areas that fire when you observe other people making similar movements (223)
- Associated with empathy and language

The **cerebellum** is responsible for the timing and coordination of movement (223)
- Densely packed with >50 billion nerve cells, including Purkinje cells that have several hundred thousand dendrites

Anosognosia: a lack of knowledge of one's own disease. Often results from lesions in the somatosensory system in one hemisphere (224-225)

Diagrams

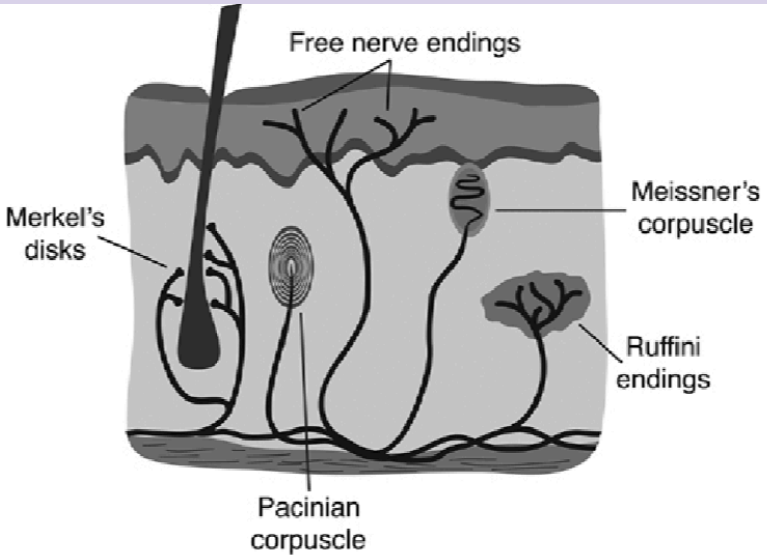


Figure 16.1. Cross section of skin showing dendrites of somatosensory neurons.

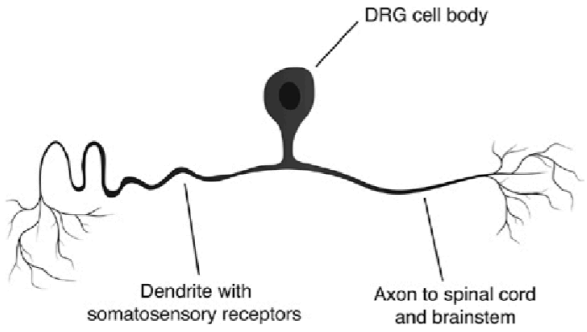


Figure 16.2. Dorsal root ganglion cells, with dendrite nerve fibers innervating the skin and axons that send signals into the central nervous system.

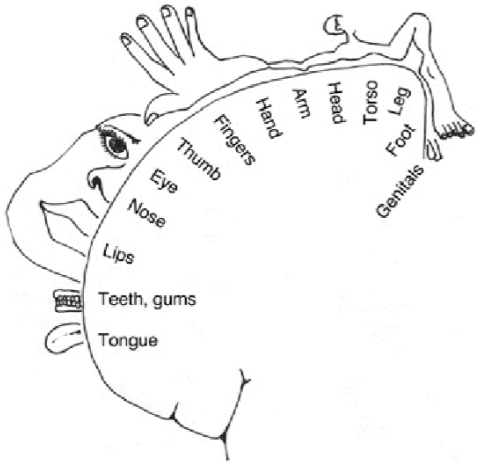
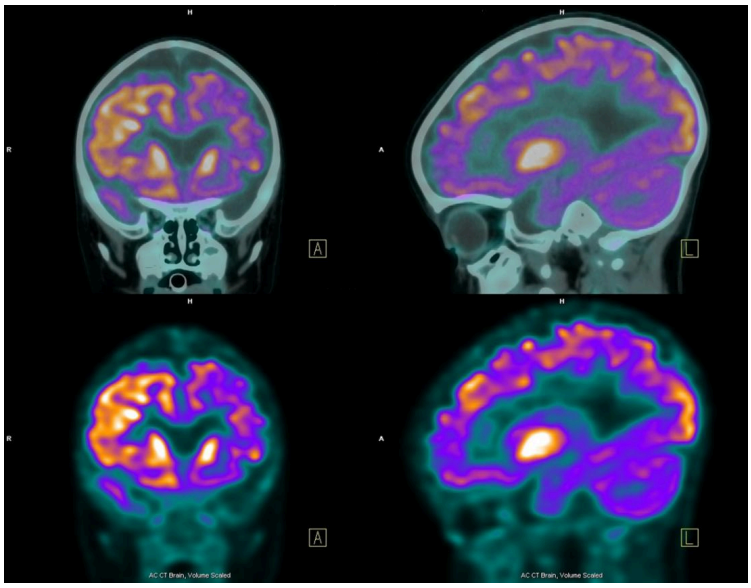


Figure 16.4. Frontal section through one hemisphere of the anterior parietal lobe, showing the somatosensory map. Following Penfield, the drawing of the figure draped over the surface of the brain gives an approximation of the proportional representation for various parts of the body.



Chapter 17: Imaging the Brain

Page 226 | 2020 June 18

Abstract

An overview of the common methods in which both static images of the brain and dynamic neural activities are captured.

Outline

I. Lesions, strokes and tumors (226)
II. X-rays and imaging (227)
    A. Rontgen and the discovery of x-rays
    B. CT scans
    C. Damage caused by x-rays
    D. MRI
        1. Development and NMR
III. Measuring neural activity (230)
    A. EEG
        1. Hans Berger (231)
        2. Wilder Penfield and ECoG
    B. MEG (233)
    C. PET (233)
        1. Limitations of PET (radioactive isotopes, difficulty)

D. fMRI (236)

Key Terms

Lesion: a general term for an injury or abnormality (226)

- **Stroke:** part of the brain gets abnormal blood flow (blockage or hemorrhage), resulting in cell death and loss of function
- **Tumor:** a proliferation of anomalous cells in the brain that often disturbs normal neural tissues
- **Traumatic Injuries:** closed (e.g. concussion) vs. penetrating (skull is compromised)
- **Parkinson's Disease:** neuronal death in substantia nigra

X-ray technology (227)

- Discovered by **Wilhelm Rontgen** in 1901
- Provides the ability to image and detect bone fractures as well as brain lesions
- **C[A]T Scan** (Computed [Axial] Tomography): taking multiple x-rays along a central axis and combining them to create a 3D representation
- X-ray radiation can break covalent bonds, which can damage cells and DNA

MRI (magnetic resonance imaging): creates a 3D reconstruction of the body by measuring quantum spin as it interacts with an imposed magnetic field (228)

- Early MRI was **NMR** (nuclear magnetic resonance) developed in 1940s
- Magnets are ~1 Tesla in strength (10k Gauss)
- Allow for the differentiation of different molecules which have differing resonant frequencies

Dynamic/functional brain imaging:

Electroencephalography (EEG): a method of generating a graph of neural activity in the brain based on changes in the magnetic field (230)

- Not the most precise, since fields can get distorted due to folds in the brain
- Requires electrodes attached to the head
- Limited spatial resolution, but excellent time resolution (ms scale)
- First designed by Hans Berger in 1920s

Electrocorticography (ECoG): A technique of recording neural activity directly during brain surgery, allowing for much higher spatial resolution (232)

- First done by **Wilder Penfield** in the 1940s, who studied **epileptogenic tissue** (seizure-generating) and determined the relationship between regions of the cortex and their corresponding functions
- Commonly used to pinpoint and remove epileptogenic tissue

Magnetoencephalography (MEG): A technique of measuring magnetic fields induced by electric currents of neural activity (233)

- Magnetic fields measured are extremely small, at 1 picotesla (10^{-12})
- Brain must be shielded from external magnetic fields. Additional cancelling fields may also be generated
- Uses SQUID detectors (superconducting quantum interference device)
- Very expensive

Positron emission tomography (PET): a method for imaging dynamic brain activity involving accelerating positrons into the brain and detecting gamma rays resulting from radioactive emissions during particle collision (234)

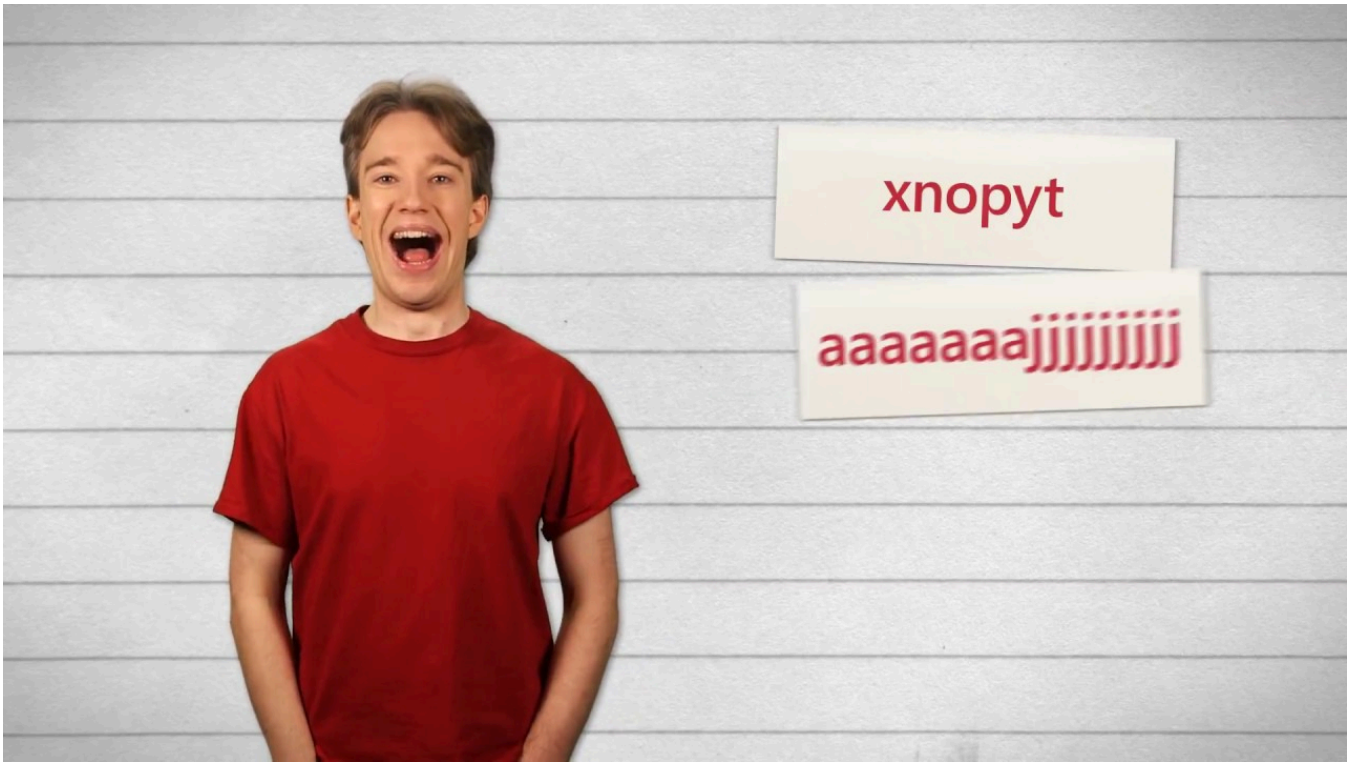
- Uses radioactive carbon-11, oxygen-15, fluorine-18 that undergo beta decay, emitting a positron
- Glucose is made radioactive and injected into the body, which then can be detected as it accumulates into the cell
    - Due to short decay times, cyclotrons are used to generate radioactive isotopes rapidly
        - Cyclotrons were created by **Ernest Lawrence** around 1930
- **Dark Energy:** the mystery of what the brain consumes most of its energy for

fMRI: functional magnetic resonance imaging: uses MRI technology over time, taking a series of images that can be used to detect neural activity (237)

- Detects the **BOLD signal:** blood-oxygen-level dependence: the change in blood oxygenation resulting in the fact that areas of higher neural activity have a greater influx of oxygenated hemoglobin

Diagrams

None!



Chapter 18: Connectivity, Language, and Meaning

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Abstract

How the brain is connected, and how these connections enable us to navigate perception using movement and language.

Outline

I. Interconnectivity of the brain (238)
II. Language
    A. As a hemispheric specialization (238)
    B. Aphasias (239)
    C. Broca's and Wernicke's areas (240)
III. Role of language in brain surgery (241)
    A. Wada test
IV. Primary auditory cortex A1 (242)
V. Roger Sperry and lateralization (242)

A. Split-brain patients

VI. Awareness and the neural correlates of consciousness (245)

VII. Neurodynamics (247)

A. Ephaptic coupling

B. Hypotheses: global oscillation, phase transitions

Key Terms

Cortical layers: layers of neural circuitry that are similar and interconnected (238)

Cerebral cortex is about 2,000 square centimeters in area

Hemispheric asymmetry: the two hemispheres of the brain are slightly different (238)

- For example, language is specialized in **Broca's area** (left frontal premotor area) and **Wernicke's Area** (posterior left temporal lobe)
  - Broca's area is responsible for organizing mouth and tongue movements to produce language
  - Wernicke's area is responsible for the interpretation of language
  - **Aphasia:** an impairment in ability to speak, write, or understand language

Wada test: developed in 1940s by Juhn Wada; used to determine if a surgery patient is properly sedated (241)

- Ability to speak is not totally impaired if sedative-hypnotic barbiturate is injected into the non language-dominant hemisphere

Language lateralization: the association between language perception and the hemisphere of the brain that is dominant (241)

- Right handed: 97% left dominant, 3% right dominant
- Non right handed: 70% left dominant, 15% right dominant, 15% both

Levels of understanding (242)

- Sound activates A1
- If the sound is of any language, Wernicke's area activates
- If the sound is of a language understood by the listener, Broca's area activates
  - Broca's area consists of premotor mirror neurons

Roger Sperry: studied lateralization in the 1960s (242)

- Studied patients who underwent **corpus callosotomy,** where the corpus callosum is severed and the brain is split into two, resulting in a reduction of the frequency and intensity of seizures
- Auditory, visual information etc. cannot move between hemispheres, so they

sometimes cannot be used to inform motor or language responses

Neural correlates of consciousness (NCC): the neural conditions sufficient for conscious awareness (245)

- Subjectively determined
- Hypothesis: NCC is allowed by gamma waves

Cortical neuropil: a densely packed region of neurons and glia

Ephaptic coupling: the influence of local field potentials on nearby neurons (247)

Diagrams

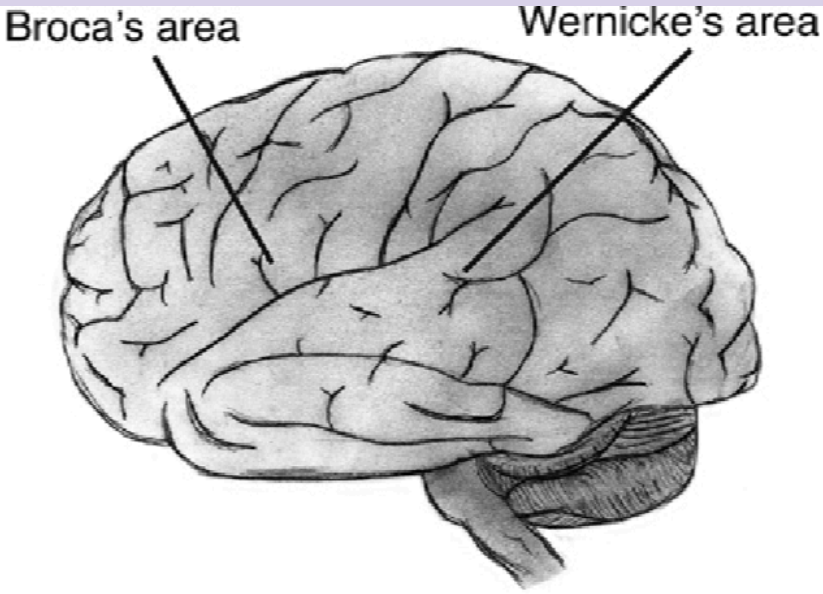

Figure 18.2. Cortical language areas.

Chapter 19: Memory

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Abstract

How we form and retain memories, the types of memories, and how memory can become impaired.

Outline

I. Pi and memorization (250)
II. Memory (251)
    A. Our reliance on memory
III. The Mind of a Mnemonist (252)
    A. Synesthesia
IV. The components of memory (253)
    A. Working memory (short term)
    B. Long term memory
        1. Storage and retrieval
V. Amnesia and other memory pathologies (254)
    A. Retrograde amnesia
    B. Anterograde amnesia
    C. Dementia
        1. Vascular
        2. Alzheimer's
VI. Drugs and memory impairment (255)
    A. Sedative hypnotics
    B. Benzodiazepines

C. Other medications and drugs
D. Nootropic drugs

VII. Where memory is stored (257)
A. Karl Lashley, rat mazes
B. Donald Hebb, distributed memory
C. Henry Molaison, the memory patient

VIII. Declarative and nondeclarative memory (260)
A. Semantic and episodic memory
B. Procedural memory
C. Priming

IX. Eric Kandel and the sea slug (262)
A. Release of serotonin in gill withdrawal

Key Terms

The Mind of a Mnemonist: a famous 1965 book by Alexander Luria detailing patient S and his **synesthesia** (ability to blend perception between different senses) (252)

Short term (working) memory: lasts from a few seconds to a few minutes (253)
- Limited capacity, temporary

Long term memory: relatively permanent memory (253)
- Can be acquired through repetition
- Items of significant meaning are more easily stored
- Involves **storage** and **retrieval**
    - Structural change in nervous system
    - New memories become more stable over time (**consolidation)**
    - Memories may decay over time if not exercised, but related information can prompt the memory to awaken

Amnesia: pathological memory problems (254)
- **Retrograde:** inability to recall events before amnesia
- **Anterograde:** inability to recall events after amnesia
- Associated with physical brain injury from strokes, seizures, tumors, infections, or traumatic injuries
- Symptom of **dementia** - global loss of cognitive abilities
    - **Vascular dementia:** cellular damage in brain due to impaired blood circulation
    - **Alzheimer's dementia:** senile plaques and neurofibrillary tangles

Memory impairment drugs (255)
- Sedative-hypnotics such as alcohol, benzodiazepines
    - Midazolam is used during surgery to allow patients to forget painful experiences
- **Nootropic** drugs such as lecithin enhance memory and attention

Karl Lashley (1890-1958) studied rats in mazes when lesions were made in the cerebral cortex. Concluded that memory is not localized to any one part of the cerebrum (257)
Donald Hebb: 1904-1985: suggested that memory is distributed over networks of many neurons

Patient H.M: had his medial temporal lobe removed, resulting in anterograde amnesia (258)

- Fully functional working memory
- Could still learn motor skills but could not remember anything else
- Formed the distinction between **declarative** and **nondeclarative** memory
    - Declarative = words or describable images
        - Includes semantic memory (facts) and episodic memory (time/place)
    - Nondeclarative = procedural memory, classical conditioning, priming
        - Associates stimuli with responses

Aplysia californica: the sea slug. Studied by Eric Kandel to learn how memory was associated with molecular mechanisms through gill withdrawal behaviors (262)

- Sensory signal releases serotonin → GPCR receptors activated → cAMP activated → increased cAMP synthesis → Activate protein kinase → increased excitation through changes in the timing of ion channel opening and closing

Diagrams

None!

Chapter 20: Rhythms, Sleep, and Dreams

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Abstract

An overview of circadian rhythms, particularly that of the sleep cycle; what sleep is, the stages of sleep, dreaming, sleep conditions, and benefits of sleep.

Outline

I. Introduction to sleep (267)
II. Circadian rhythms (267)
    A. Periodic variation in melatonin synthesis
    B. Other rhythms in birds and mammals
    C. The circadian (endogenous) clock (270)
        1. SCN
        2. PER gene transcription
III. Retinal-hypothalamic pathway (271)
    A. Jetlag
IV. Stages of sleep (271)
    A. NREM
        1. Levels of EEG activity (stages 1 to 4)

B. REM
    1. Dreaming (273)
        a) Acetylcholine and cortical activation
        b) Lucid dreaming
        c) Meditation

V. Sleep conditions (274)
    A. Insomnia
    B. Sleep apnea
    C. Narcolepsy
    D. Sleep paralysis
    E. Chronic sleep deprivation

VI. Benefits of sleep (276)

Key Terms

Sleep: a period of reduced activity that exists for vertebrate animals (267)

Circadian rhythms: biological cycles that repeat approximately once every 24 hours (267)

- Example: sleep is a circadian rhythm that depends on the synthesis of **melatonin** in the pineal gland
    - Melatonin synthesis is high at night and low in the day

Circ-annual rhythms: periodic patterns in behavior that do not follow a daily cycle like circadian rhythms (268)

- Example: bird migration is regulated by an internal clock that cycles once every 6 months and tells a bird to migrate even without external signals such as temperature or light
- **free-running rhythm:** when a period becomes longer or shorter and is decoupled from environmental factors (269)

Suprachiasmatic nucleus (SCN): a cluster of ~20k neurons in the hypothalamus of the diencephalon at the top of the brainstem that fires periodically (270)

- Believed to drive the internal biological clock
- Synchronizes with environmental factors when available

PER: short for period, a gene mutation in the fruit fly that affects the fly's circadian rhythm (270). First genetic insight into the biological clock in 1970s

- Analogous genes have been found in humans

Retinal-hypothalamic pathway: the connection between 1% of optic nerve axons and the SCN that synchronizes circadian rhythm with the environment (271)

- Has an intrinsic photoreceptor protein **melanopsin** that is analogous to rhodopsin
- Impaired performance when endogenous and environmental time do not match up (i.e. jet lag)

The Stages of Human Sleep

- **NREM:** 1, 2, 3, 4: in order from high to low frequency EEG activity (271)
- **REM:** rapid eye movement sleep that is close to waking
    - Periods become more frequent later in sleep
    - Found in mammals and birds, but not in reptiles, amphibians, or fish
    - Results in excitation due to transmission of acetylcholine
    - Results in vivid dreaming due to sensory perception being activated despite lack of input
    - Cholinergic drugs such as nicotine results in more vivid dreams
    - Dreams are **ephemeral:** not remembered

Lucid dreaming: when awareness occurs while dreaming (273)

- An extension of this is **dream yoga,** in which meditation allows for being completely conscious during sleep

Sleep Disorders (274)

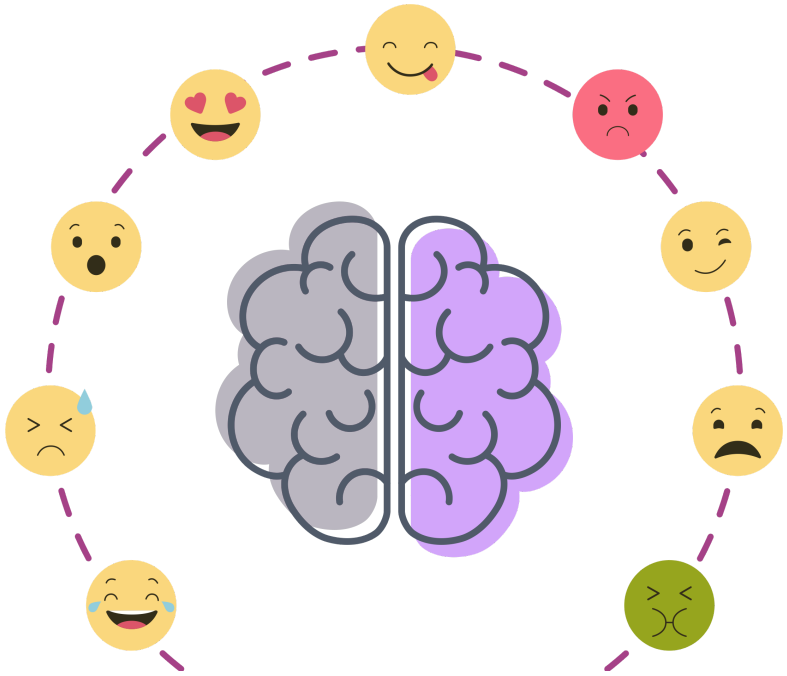
- **Insomnia:** difficulty sleeping
    - May be caused by drugs (e.g. caffeine), jet lag, discomfort, excitation
- **Sleep apnea:** breathing stops while sleeping, resulting in repeatedly waking up
    - Occurs in 5% of adults
- **Narcolepsy:** excessive daytime sleepiness
    - Caused by abnormalities on orexin
- **REM behavior disorder:** impairment of motor inhibition in REM sleep, causing motor movement and often wakes up the individual
- **Sleep paralysis:** partial awakening during REM sleep, causing awareness but inability to move the body
- **Sleepwalking (somnambulism):** person is unaware but performs everyday tasks while asleep
- **Chronic sleep deprivation:** caused by widespread inadequacy in amount or quality of sleep
    - Increased usage of caffeine contributes to the problem
    - Results in impaired performance and poor decision making

Benefits of sleep (276)

- Initiates restorative processes, removing free radicals and oxidants and repairing cell damage
- Encodes new information in long-term memory and consolidates existing memory

Diagrams

None!



Chapter 21: Emotion

Page 277 | 2020 June 21

Abstract

Human and nonhuman emotions, theories about emotion, and mood disorders.

Outline

I. HAL (277)
II. Thoughts, feelings, and perception (277)
    A. Sentience and the association between emotion and consciousness
    B. Emotion vs. mood
III. Darwin and *The Expression of the Emotions in Man and Animals* (278)
    A. Nonhuman animals and emotion
IV. Constructivist vs. evolutionary perspectives (279)
    A. Cultural factors
V. Duchenne and muscle activation for facial expressions (280)
    A. Vagus nerve and emotion
VI. Brain regions and emotions (282)
    A. Amygdala
    B. Hypothalamus
    C. Oxytocin and vasopressin

VII. Mood disorders (285)
    A. Depression
        1. MAOIs and TCAs
        2. SSRIs
            a) Cosmetic psychopharmacology
    B. Mania
VIII. Human nature (287)
    A. Fear and dread as dominant emotions
    B. Born to Be Good and prosocial emotions

Key Terms

Feeling: the mental experience component of emotions that are intuitive and nonlinguistic (277).
Emotion: an experience in both the mind and body that result in different responses (278)

- comes from French/Latin roots for excite, move
- Associated with consciousness
- Spontaneous and may reveal inner experiences to others
- Mood vs. emotion - while emotions are short, moods are prolonged

The Expression of the Emotions in Man and Animals (279)

- Book published by Darwin in 1872
- Put emotions in evolutionary context- evolved as adaptive behaviors and exist in other animals
- Argued that emotions are universal throughout primates
- Differed from **constructivist view** that emotion was developed and rely heavily on cultural factors
    - Refuted by **Paul Ekman** who observed that facial expressions were similar across different cultures (280)

Guillaume Duchenne: studied facial muscles and facial expressions (280)

- Activating muscles can trigger their corresponding emotions
- Other aspects of body signatures related to emotions include changes in heart rate, blood pressure, posture, tone, hormone release

Vagus nerve: cranial nerve 10 that consists of connections from brain to many of the body's major organs (281)

- Activates the parasympathetic system, so action (vagal tone) is correlated to relaxed and positive emotions

Amygdala: a group of nuclei at the base of the temporal lobes that is involved with the perception of fear and anger (282)

- Associated with responses to stressful events

Hypothalamus: produces neuropeptides that regulate the release of hormones from the pituitary gland (282)
- Releases cortisol (threat/stress response)
- Releases oxytocin (childbirth, production of milk)
- Releases vasopressin (antidiuretic that slows transfer of water to urine)
- Oxytocin and vasopressin are related to prosocial actions such as parental bonding

Reward pathways: regions of the brain that are associated with reward behaviors (283)
- Dopaminergic neurons
- Serotonin: positive emotions
- **James Olds:** discovered regions of the brain in rats that stimulated pleasure

Mood disorders: mood becomes stuck for extended periods of time (285)
- Depression: prolonged dysphoric mood
- Mania: prolonged euphoric mood
- Bipolar disorder: periods of depression followed by mania

Antidepressant medications reduce symptoms of depression (286)
- MAOIs: monoamine oxidase inhibitors - blocks the enzyme that inactivates norepinephrine and serotonin, keeping them in synapses for longer
- TCAs: tricyclic antidepressants - blocks/slows norepinephrine and serotonin uptake
- SSRIs: selective serotonin reuptake inhibitors - fewer side effects

Diagrams

None!

Chapter 22: Mind, Consciousness, and Reality

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Abstract

An exploration of the concept of intelligence, and how we can go by redefining it.

Outline

I. Intelligence (290)
   A. Understanding
   B. Computers and the technological singularity
II. Conditions for mental experience (291)
   A. Body and brain physiology
   B. Reductionism
III. Reality and perception (293)
   A. Primordial biological structures
   B. Astronomy and reality
   C. Explanatory gap between physical and subjective
IV. Metaphysical frameworks (296)
   A. Continued direct investigation
   B. Refined analysis of mental experience
   C. Radically empirical approach
   D. Physics and consciousness

Key Terms

Intelligence: the ability to acquire and retain knowledge (290)
- Derived from **intelligentum** (to discern or comprehend)
- Includes **understanding:** a capacity to discern relationships and connections
- May not include sentience or awareness
- **Artificial intelligence**
  - **Technological singularity:** the state of affairs in which computational intelligence will exceed human intelligence
  - Different from question of whether computers have a mind- can be intelligent without being conscious

Reductionism: the concept of explaining a structure or science by a more fundamental set of structures (e.g. explaining chemistry with physics, and physics with math) (291)

Quantum measurement problem: the unsolved problem of how superpositions of potentialities collapse into a discrete value (292)

SETI: Search for Extraterrestrial Intelligence - agency that studies signals that may lead to the discovery of alien civilizations (294)

Metaphysics: describes how we interpret scientific analyses (295)

- Contemporary science can be described as **physical materialism** or **physicalism**
- **Explanatory gap / hard problem of consciousness:** how subjective mentality is related to objective physical reality

Metaphysical Trajectories for the mind-body problem

- **Continued Direct Investigation:** continuing to observe the body in greater detail, resulting in greater knowledge of potentially undiscovered processes (296)
- **Refined Analysis of Mental Experience:** studying meditation, emotion, and religion to figure out how to analyze one's own mind (297)
- **Radically empirical approach:** Studying phenomena such as telepathy that are often dismissed by science (298)
- **The next big scientific revolution:** may occur when scientific exploration of physics allows us to better understand our mind in ways that completely overshadow current understanding (299)

Diagrams

None!