8 Nervous System

Competencies

AN2.6: Explain the concept of nerve supply of the joint and Hilton's law.

AN7.3: Describe the parts of a neuron.

AN7.4: Describe the structure of a typical spinal nerve.

AN7.7: Describe the various types of synapse.

Q1. Describe briefly: Neuron. (AN7.3)

a. Name the parts of a neuron.

b. Describe the structure of a neuron.

c. Describe the constituents of a nerve cell body.

a. The neuron has two main parts (**Fig. 8.1**):

1. *Cell body* (*soma/perikaryon*).
2. *Processes* (*neurites*), which are of two types:
   - *Dendrites:* numerous in number and are short.
   - *Axon:* a single long process.

b. Cell Body (Soma/Perikaryon)

- Expanded portion of the neuron.
- Cell bodies of the majority of neurons are located in the gray matter of the brain and spinal cord, but cell bodies of the spinal ganglia are located outside the central nervous system (CNS).
- These are 5 to 100 μm in diameter.
- They are of different shapes: pyramidal, fusiform, stellate, flask shaped, etc.

c. Constituents of Cell Body

The constituents of a cell body are the following (**Fig. 8.2**):

- *Cell membrane*: trilaminar.
- *Nucleus*: large, vesicular, and centrally placed. It is eccentric in healthy sympathetic ganglia and in case of injury to a neuron. In females, sex chromatin or Barr body is present close to the nuclear membrane.
- Cytoplasm: contains the following organelles:
  - Nissl bodies: These are basophilic bodies of rough endoplasmic reticulum. They are present in the cytoplasm and in dendrites. They are *absent at the axon hillock and axon*. They take part in protein synthesis. Their number is more in motor neurons than in sensory neurons.

Clinical importance

In case of injury (mechanical or chemical) or fatigue of the nerve cell, the Nissl bodies disappear and the nucleus moves to the periphery (eccentric). This process is known as chromatolysis. When the nerve cell is recovering from stress in a reasonable time, the Nissl bodies reappear.

  - Golgi bodies: These are located close to the nucleus and extend into the dendrites.
  - Mitochondria: These are present in the cytoplasm and extend into all the processes.
  - Lysosomes: These are thick-walled membranous vesicles and contain hydrolytic enzymes and acid phosphatase.

Clinical importance

They phagocytose the foreign particles and hydrolyze the Nissl granules during chromatolysis.

  - Neurofibrils: These are filaments of protein that form a network.
  - Lipofuscin: A golden brown pigment seen in cell bodies of aged neurons. It is a wear-and-tear pigment.

Note: *Centrosomes and centrioles are absent in neurons. Their absence is the reason for the inability of the neuron to divide. In case of damage to the neuron, the neuroglial cells replace it.*

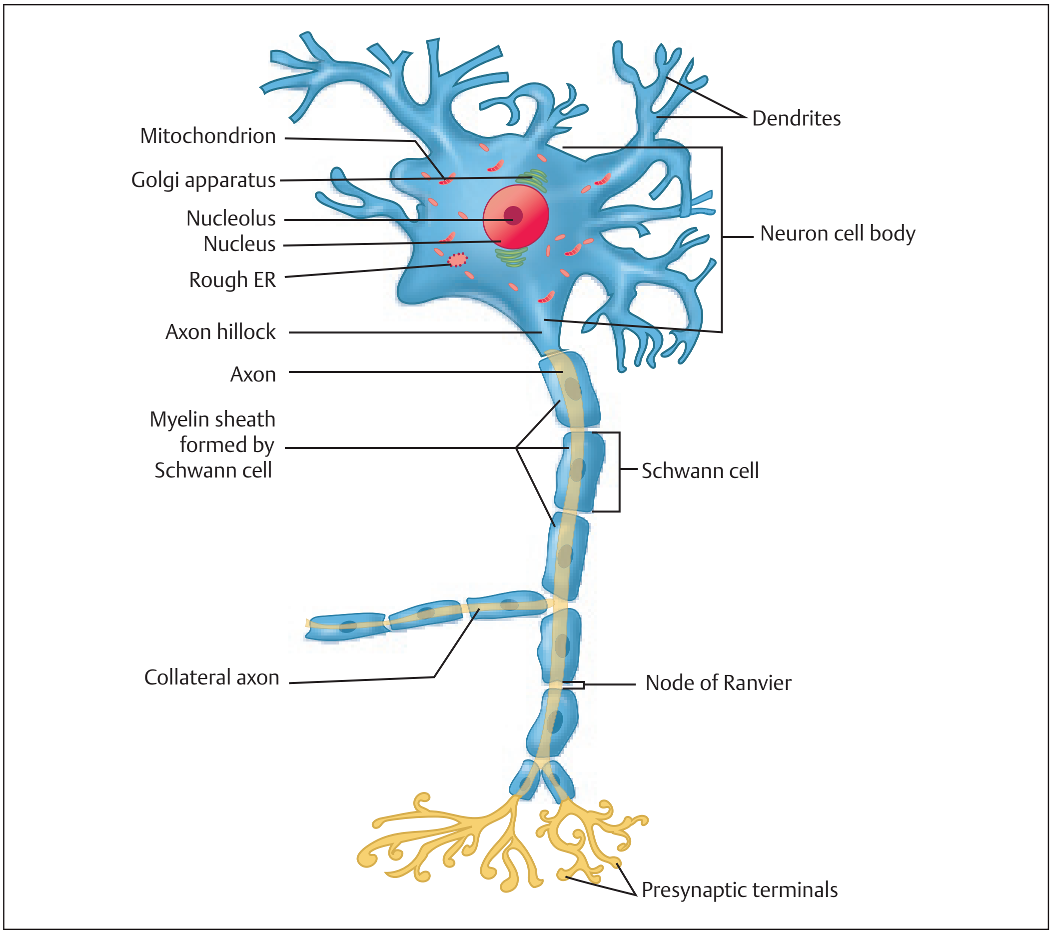

Fig. 8.1 Structure of a neuron (ER, endoplasmic reticulum).

Dendrites

- Dendrites are short multiple processes arising from the cell body and each of them presents extensive branching, forming dendritic tree.
- They contain all the cytoplasmic contents of the cell body.
- They provide structural support for the neurons in the central nervous system (CNS).
- In the peripheral nervous system (PNS), they form myelin sheath for the axons and are nutritional.
- They are capable of mitotic division throughout their life.
- The terminal arborizations of dendrites are thornlike and are called dendritic spines or gemmules. The dendrites convey the nerve impulse from the periphery to the cell body.

The axon is described in question number 3 of the same chapter.

Q2. What is the difference between nuclei and ganglia? (AN7.3)

- Nuclei: *Collections of nerve cell bodies within the CNS.*
- Ganglia: *Collections of nerve cell bodies outside the CNS.* Examples are dorsal root ganglia of spinal nerves, ganglia in relation with certain

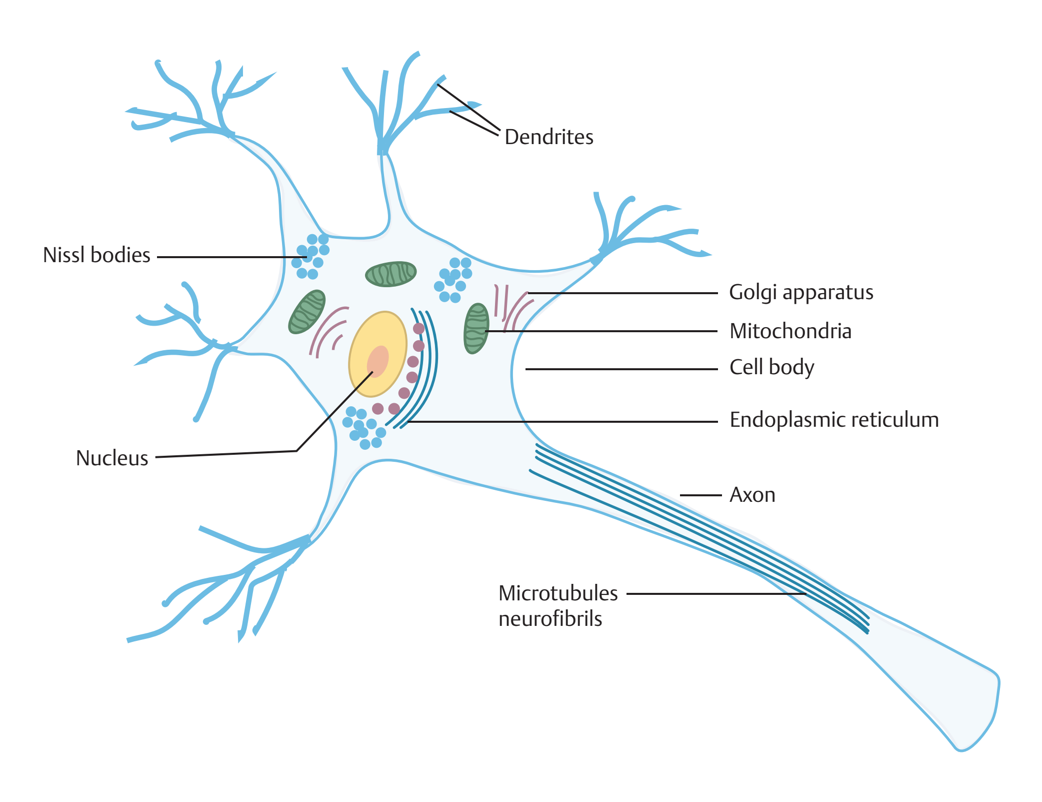

Fig. 8.2 Constituents of a nerve cell body.

cranial nerves (facial), and ganglia in the autonomic nervous system.

Q3. Describe the structure of axon.

Axon

- Each neuron has a single axon, which is a long process (**Fig. 8.3**).
- The length of axons is variable, but the diameter is constant.
- All axons originate in a short pyramid like structure called the axon hillock, which lacks Nissl substance.
- The plasma membrane of the axon is termed the **axolemma**, and the cytoplasm of the axon is termed the **axoplasm**. The axoplasm contains neurofilaments and microtubules but lacks the Golgi apparatus and Nissl substance.
- The thicker axons have concentric wrappings of the enveloping Schwann cell in the PNS and oligodendrocyte in the CNS that forms the myelinated sheath. The nerve fibers wrapped with myelinated sheaths are called **myelinated fibers**.
- The myelin sheaths increase the velocity of conduction of an impulse. Myelin also forms an insulating sheath around the axons in the CNS and PNS.
- In myelinated axons, the initial portion, between the axon hillock and the starting of the myelin sheath, is called the **initial segment**. Axons sometimes have right-angled branches, which are called the **axon collaterals**.
- Outside the myelin sheath in the PNS, a thin layer of Schwann cell cytoplasm and its cell membrane persists forming an additional sheath known as the Schwann cell sheath or the *neurilemmal sheath*.
- The neurilemmal sheath plays an important role in regeneration of a peripheral nerve after

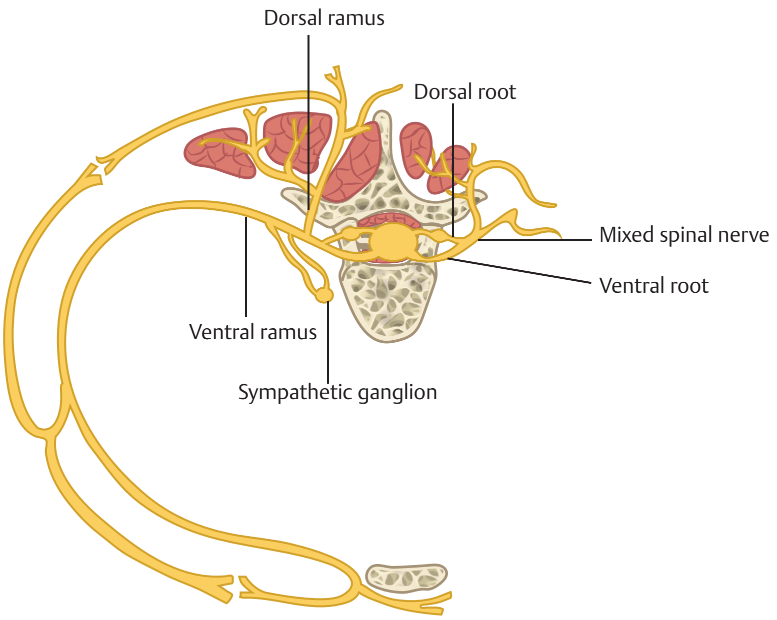

Fig. 8.3 A typical spinal nerve.

injury. The neurilemmal sheath is not found in the CNS.

- Each unit of an axon is myelinated by the Schwann cell or the oligodendrocyte. A gap occurs where an axon is not covered by the myelin. This gap is known as the *node of Ranvier*.
- The segment of an axon between two nodes of Ranvier is called an *internode*, which is covered by a single Schwann cell whose nucleus is seen at the periphery.
- At the nodes of Ranvier, a number of collaterals arise from the axon.
- Near the termination, the axon divides into smaller branches called telodendria.
- The terminal parts of the axon forms synapses with other neurons, muscle fibers, and secretory units of the exocrine glands.
- At the synapse, the collaterals and terminals of axons form small bulbous expansions called boutons terminaux. Motor end plate is the specialized terminal of axon in a skeletal muscle.
- Bundles of axons form the peripheral nerve. In the CNS, the axon forms the nerve fiber.
- An *endoneurial connective tissue sheath* surrounds each fiber.

Clinical Importance

Regeneration of an axon after injury is not possible in the CNS because of absence of neurilemmal sheath in the CNS neurons.

Q4. Describe a typical spinal nerve. (AN7.4)

There are 31 pairs of spinal nerves (**Fig. 8.3**). They are classified according to the regions of vertebral column. They are the following:

- Cervical (8 pairs).
- Thoracic (12 pairs).
- Lumbar (5 pairs).
- Sacral (5 pairs).
- Coccygeal (1 pair).

Each spinal nerve is connected to the spinal cord by two roots: a ventral root, which is motor, and a dorsal root, which is sensory.

The motor root consists of bundles of nerve fibers that carry impulses away from the spinal cord that stimulate contraction of a muscle (skeletal/cardiac/smooth) or secretion of a gland. Hence, they are called efferent fibers. The cell bodies of these nerve fibers are in the anterior gray horn of the spinal cord.

The sensory root consists of bundles of nerve fibers that carry information about various sensations from a specific body part to the spinal cord. They are called afferent fibers. On the dorsal root lies an enlarged structure, the dorsal root ganglion, which is a collection of nerve cell bodies. The dorsal root ganglion is placed in the intervertebral foramen.

The dorsal and ventral roots unite in the intervertebral foramen to form a mixed spinal nerve. Hence, a typical spinal nerve contains both motor and sensory fibers.

The four functional components of a typical spinal nerve are the following:

- Somatic efferent, which innervates the skeletal muscles.
- Visceral efferent, which contains sympathetic and parasympathetic fibers and innervates organs.
- Somatic afferent, which receives information from the skin, joints, and muscles.
- Visceral afferent, which receives sensory information from the organs.

After emerging from the intervertebral foramen, the spinal nerve gives a recurrent branch and divides into a small dorsal and a large ventral ramus. The recurrent branch enters the vertebral canal and supplies the meninges. The dorsal ramus supplies the skin and muscles on the back. The ventral ramus supplies the skin and muscles of the limb or the anterolateral body wall. The ventral ramus is connected to the sympathetic ganglion by gray and white rami communicantes.

Formation of Nerve Plexuses: Except T3–T11 spinal nerves, the ventral rami of all other spinal nerves join with one another and divide and branch into an intricate fashion and form a network of nerves called plexuses that innervate the muscles and skin of the neck (C1–C4 spinal nerves: cervical plexus), upper limb (C5–T1 spinal nerves: brachial plexus), and lower limb (L1–S5 nerves: lumbosacral plexus). The branches arising from the plexus are called peripheral nerves.

Clinical Importance

- Compression of the spinal nerve occurs as it passes through the intervertebral foramen.
- Intervertebral disc protrusion or herniation of the nucleus pulposus causes compression of the spinal nerve.
- Narrowing of the vertebral canal (spinal stenosis) due to age-related degeneration can cause compression (impingement) of the nerve. This causes weakness of muscles innervated by the impinged spinal nerve and sensory disturbances (pain, numbness, etc.) in the associated dermatome. For example, in the case of the lower limb, the common condition called sciatica results.

Q5. Explain Hilton's law with examples. (AN2.6)

- The articular branches of a nerve supplying the joint are branches supplying the muscles acting on the joint and the skin overlying the joint. This is called Hilton's law (**Fig. 8.4**).
- According to Hilton's law, nerves crossing a joint supply the following:
  - Muscles acting on the joint.
  - Skin over the joint.
  - Joint itself.
- Example: Axillary nerve. It supplies the following:
  - Joint: shoulder joint—capsule.
  - Muscles acting on the joint: deltoid.
  - Skin of the upper lateral part of the arm: lateral cutaneous nerve of the arm.

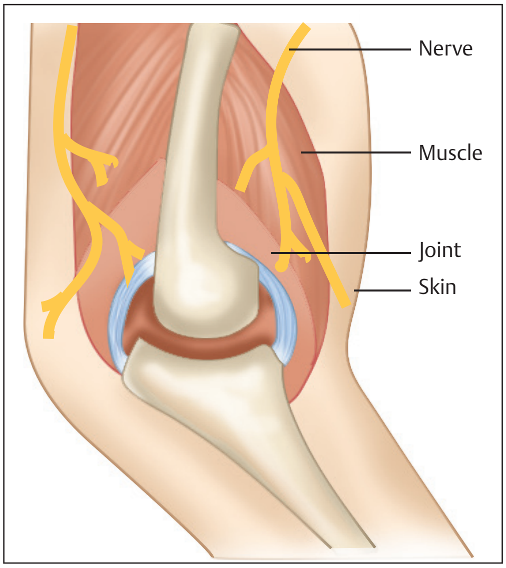

Fig. 8.4 Hilton's law.

Exceptions for Hilton's law: There are two exceptions:

- The buccinator muscle in relation to the temporomandibular joint: It is pierced by the buccal branch of the mandibular nerve, but it is supplied by the facial nerve (nerve of the second branchial arch). The joint and the skin over it is supplied by the buccal branch of mandibular nerve (branch of the trigeminal nerve).
- The piriformis muscle in relation to the hip joint: The sciatic nerve is close to this muscle and sometimes some of its fibers pierce the muscle, but it will not supply the muscle. The piriformis receives its motor supply from the sacral plexus.

Q6. Define synapse and describe the different types of synapses. (AN7.7)

Definition: A specialized junction between two neurons for transmission of information.

It is not an anatomical continuation. It is only a physiological continuity between two neurons (**Figs. 8.5** and **8.6**).

Parts:

- Presynaptic neuron.
- Synaptic cleft.
- Postsynaptic neuron.

The signal coming from the presynaptic axon or dendrite is transmitted to the postsynaptic dendrite or the axon through the synaptic cleft.

Classification

They are classified into two types: anatomical and physiological.

Anatomical/Structural Classification

- Usually, the axon of one neuron will be ending on the cell body, axon, or dendrite of the adjacent neuron. Depending on the ending of the axon, the synapses are classified as the following:
  - Axoaxonic synapse.
  - Axodendritic synapse.
  - Axosomatic synapse.

Physiological/Functional Classification

Based on mode of transmission of impulse, they are divided into the following:

- Electrical: There is direct contact between the neurons. These contain pores and the passage of information is fast.
- Chemical: It is the junction between a nerve fiber and a muscle fiber or between two nerve fibers. Small gaps or synaptic clefts will be present between the two neurons for diffusion of chemicals that are released from the presynaptic neurons to the postsynaptic neurons. There will be release of neurotransmitters stored in vesicles on one neuron into these gaps. These neurotransmitters will be received by the other neuron. The passage of information is slow.

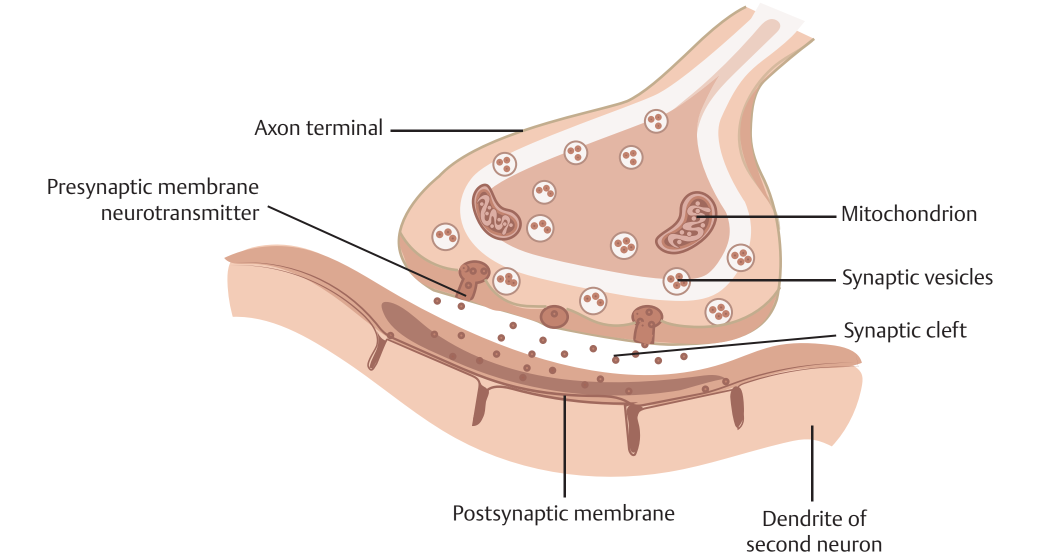

Fig. 8.5 Structure of a synapse.

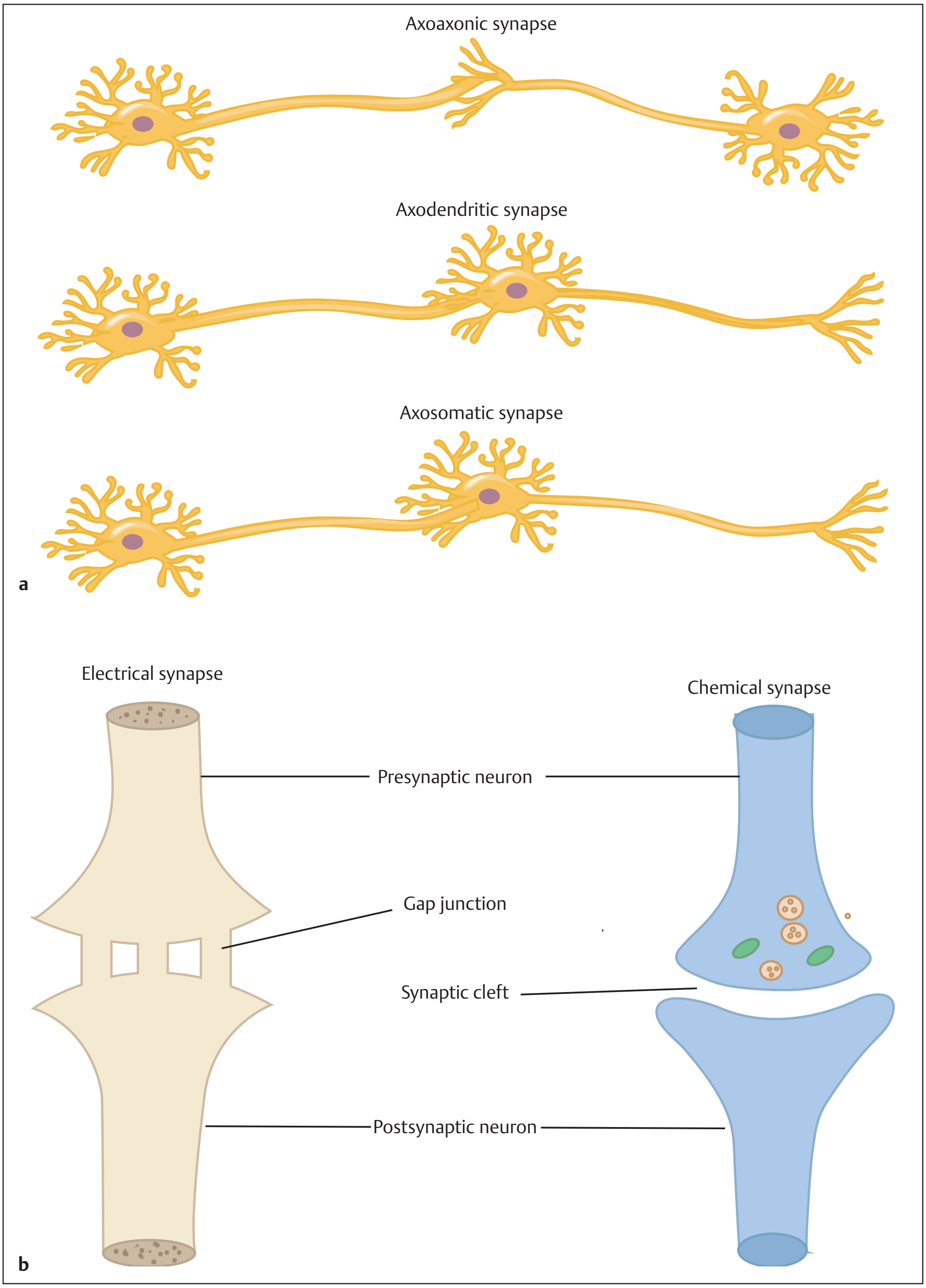

Fig. 8.6 Classification of synapses. **(a)** Anatomical. **(b)** Physiological.