

Anatomy and Physiology of the Nervous System

The nervous system is divided into two parts: the central nervous system (CNS) and the peripheral nervous system (PNS).

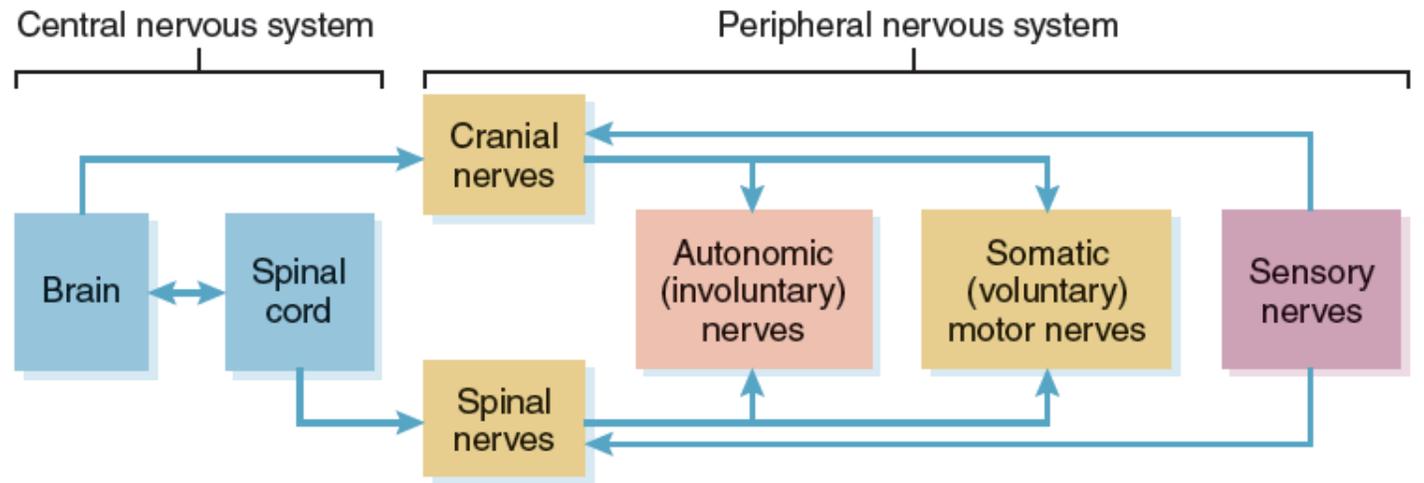


The ability of the human body to maintain a state of balance is chiefly the result of the nervous system's ability to coordinate and regulate the body's activities.



A total of 43 pairs of nerves originate from the CNS to form the PNS, including 12 pairs of cranial nerves originating from the brain and 31 pairs of spinal nerves originating from the spinal cord.

the Nervous System



- **Cells of the Nervous System**

- Cells of the nervous system include neurons and connective tissue cells known as neuroglia.
- Each neuron has three main parts:
 - The cell body, which has a single, relatively large nucleus with a prominent nucleolus
 - One or more branching projections, called dendrites
 - A single, elongated projection, known as an axon
- Synapses connect neurons and allow the impulses to be transmitted.
- Axons are also surrounded by Schwann cells in the PNS.



Cells of the Nervous System

- In the PNS, bundles of axons and their sheaths are called nerves. Collections of nerve cells are gray matter and are called gray matter.
- Gray matter is the site of integration in the nervous system.
- The outer surface of the cerebrum and the cerebellum consists of gray matter, which forms the cerebral cortex and the cerebellar cortex.

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Types of Neurons

- Neurons are classified according to their structure, shape, and function, and the direction in which they transmit impulses.
- Sensory neurons transmit impulses to the spinal cord and brain from all parts of the body, and respond to stimuli such as touch, sound, or light.
- Motor neurons transmit impulses away from the brain and spinal cord, and transmit impulses only to muscle and glandular epithelial tissue.
- Interneurons conduct impulses from sensory neurons to motor neurons.

Impulse Transmission

- The transmission of nerve impulses in the nervous system is similar to the conduction of electrical impulses through the heart.
- In its resting state, the neuron is positively charged on the outside and negatively charged on the inside. When the neuron is stimulated by pressure, temperature, or chemical changes, the cell membrane's permeability to sodium ions increases. As a result, positively charged sodium ions rush into the interior of the neuron.



Impulse Transmission (cont.)

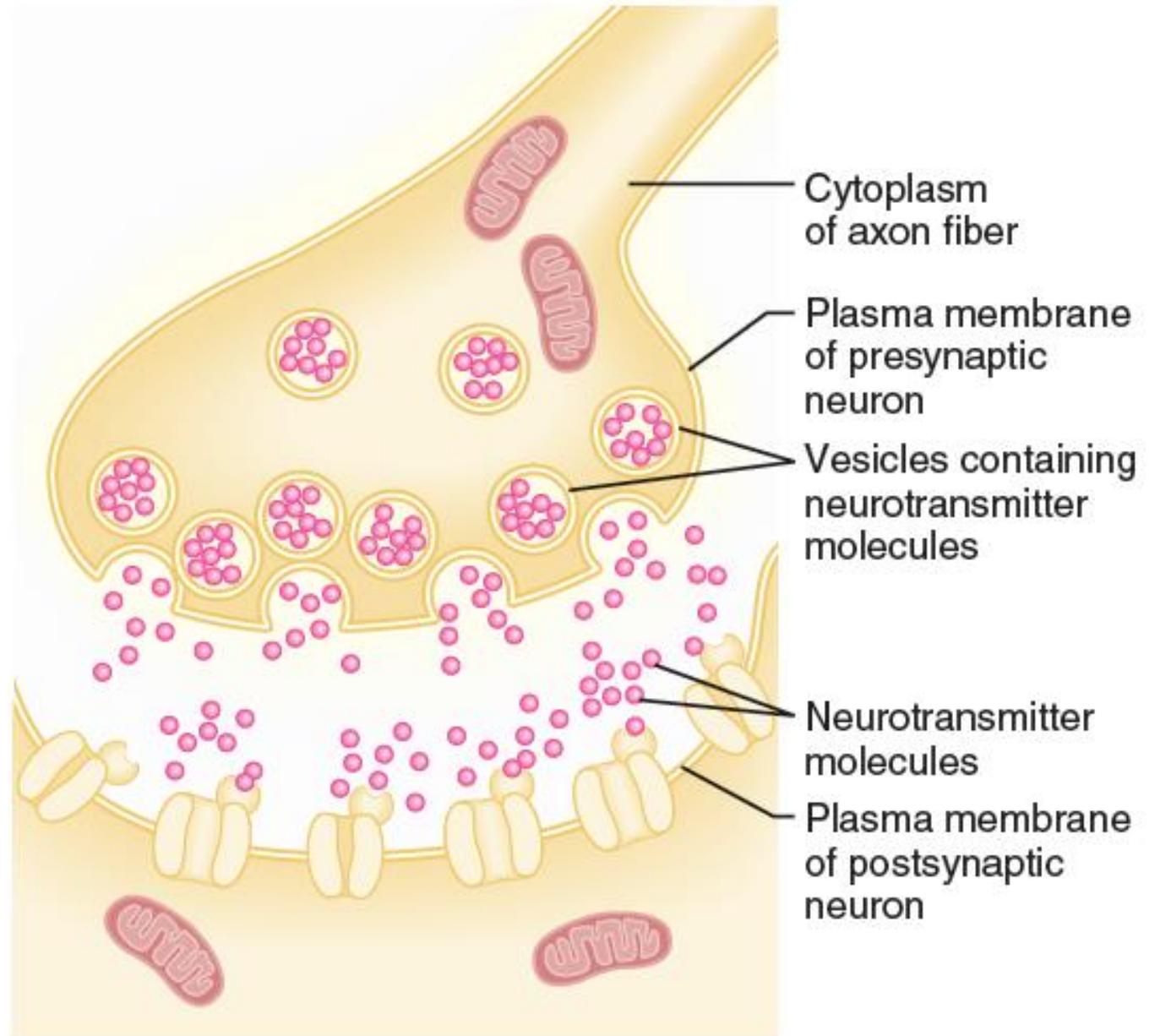
- In unmyelinated axons, action potentials are spread along the entire axon membrane.
- Myelinated axons have interruptions, known as nodes of Ranvier, that allow nerve impulses to “jump” from one node to the next without spreading along the entire length of the cell.
- Myelinated axons, therefore, conduct action potentials faster than do unmyelinated axons.



Synapses

- The membrane-to-membrane point of contact between the axon endings of one neuron and the dendrites of another neuron is known as a synapse.
- The structures that compose a synapse are the presynaptic terminal, the synaptic cleft, and the plasma membrane of the post-synaptic neuron.
- Within each presynaptic terminal are synaptic vesicles that contain neurotransmitter chemicals.

Components of a Synapse



Synapses

- Each action potential arriving at the presynaptic terminal initiates a series of specific events which result in the release of the neurotransmitter.
- The neurotransmitter rapidly diffuses the short distance across the synaptic cleft, then binds to specific receptor molecules on the postsynaptic membrane.
- After an impulse has been generated and conducted by the postsynaptic neurons, neurotransmitter activity ends quickly.



Reflexes

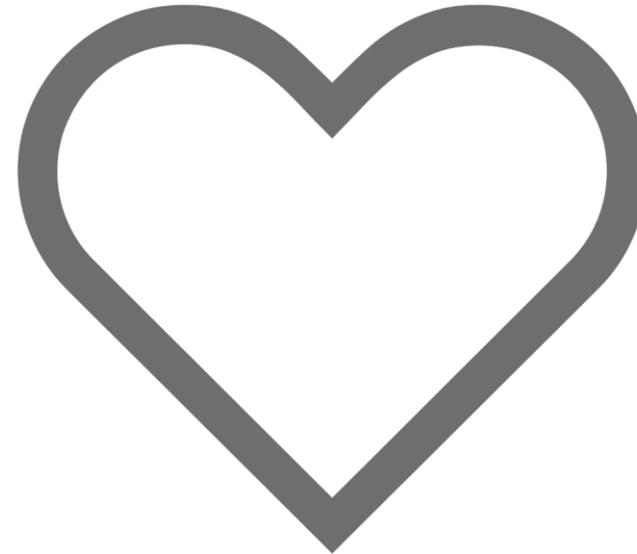
- A reflex is the basic unit of the nervous system capable of receiving a stimulus and generating a response. They allow conduction of impulses over a short arc.
- Have several basic components:
 - Sensory receptor
 - Sensory neuron
 - Interneurons
 - Motor neuron
 - Effector organ

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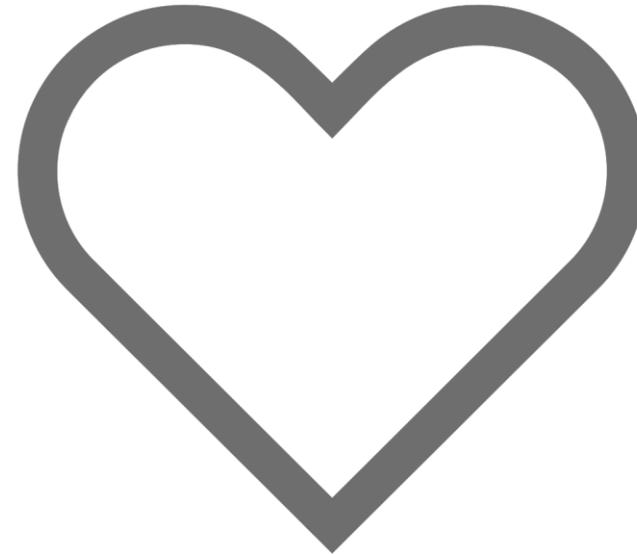
Blood Supply

- The membrane-to-membrane point of contact between the axon endings of one neuron and the dendrites of another neuron is known as a synapse.
- The internal carotid arteries enter the cranial vault through the carotid canals and give rise to the anterior cerebral arteries which supply blood to the frontal lobes of the brain.
- The two posterior cerebral arteries are connected at their common origin from the basilar artery.



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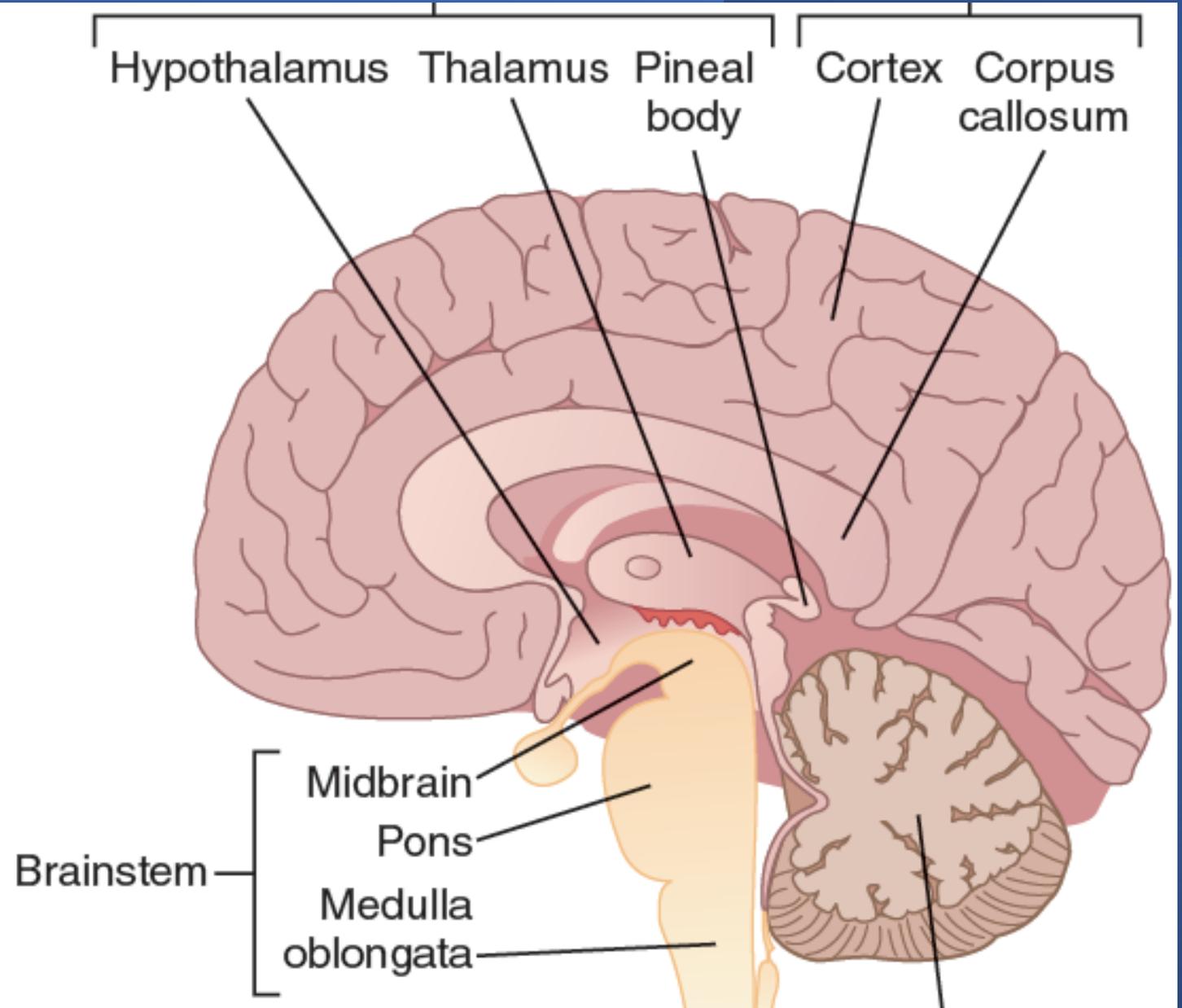
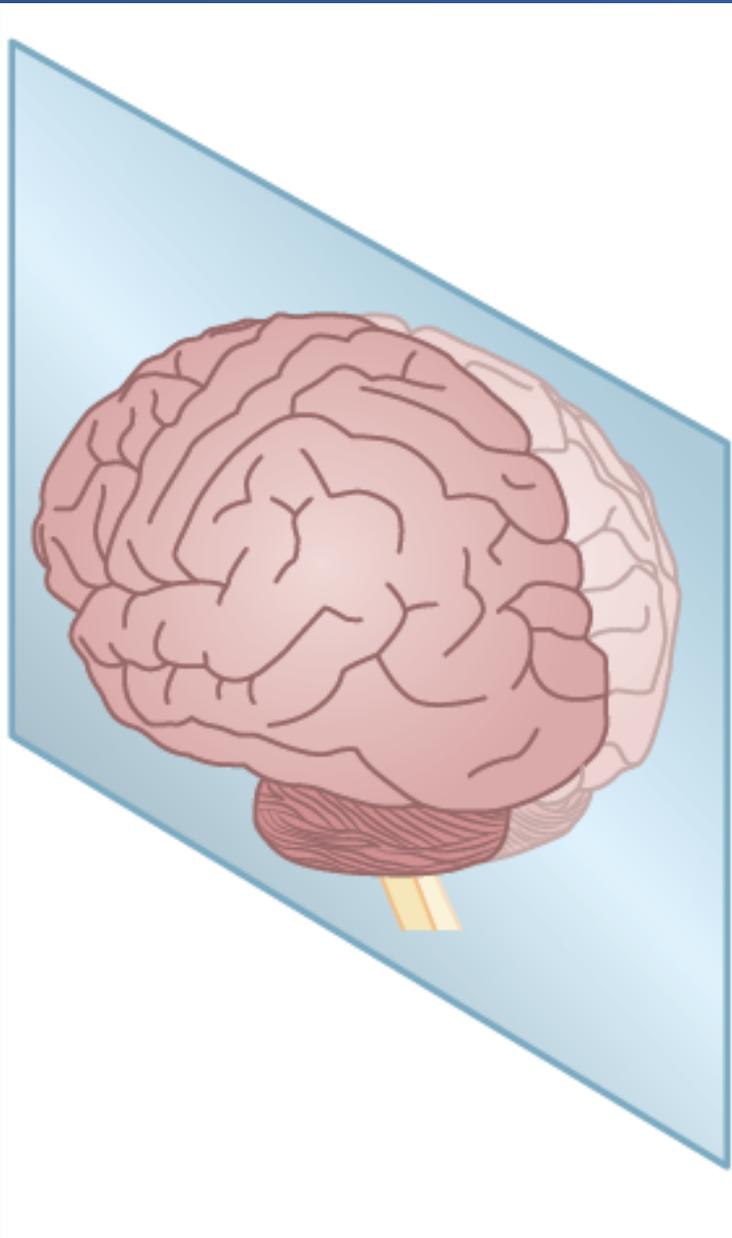


Ventricles

- Each cerebral hemisphere contains a large space filled with cerebrospinal fluid, and this space is known as a lateral ventricle.
- The two lateral ventricles communicate with the third ventricle through two interventricular foramina.
- The third ventricle communicates with the fourth ventricle by way of a narrow canal, called the cerebral aqueduct.
- The fourth ventricle is continuous with the central canal of the spinal cord.

Divisions of the Brain

- The major divisions of the adult brain are the brainstem (medulla, pons, midbrain, and the site of the reticular formation), cerebellum, diencephalon (hypothalamus and thalamus), and cerebrum.



Neurologic Pathophysiology

- Some neurologic emergencies are a consequence of structural changes or damage, circulatory changes, or alternations in intracranial pressure that affect cerebral blood flow.
- Three structures occupy the intracranial space: brain tissue, blood, and CSF.



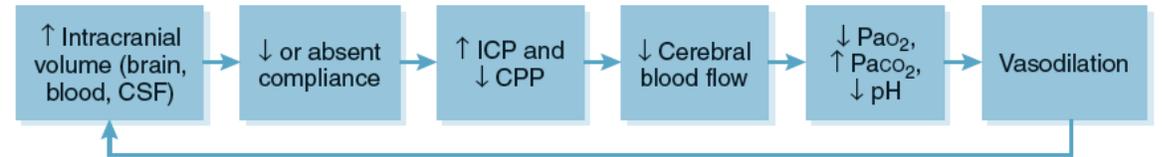
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Cerebral Blood Flow

- Cerebral blood flow (CBF) is a function of the cerebral perfusion pressure (CPP) and the resistance of the cerebral vascular bed.
- To measure the CPP, the ICP is subtracted from the mean arterial pressure (MAP). Normal CPP is 60 to 80 mm Hg.
- As the ICP rises and approaches the MAP, the CPP falls.
- As the CPP decreases, vessels in the brain dilate and this results in increased cerebral blood volume and further cerebral vasodilation.

Cerebral Blood Flow



Cerebral Perfusion Pressure

- CBF depends on the CPP, which is the pressure gradient across the brain. If the CPP falls below 40 mm HG, CBF declines, which critically affects cerebral metabolism.
- With mild to moderate elevation of the ICP, the MAP usually rises, and the rise in the MAP causes cerebral blood vessels to constrict and prevents the increase in blood volume and CBF that normally would occur.
- If mass or cerebral edema develops, an immediate reduction in the volume of one or more of these components must occur to prevent the ICP from rising and compressing brain tissue.

Assessment of the Nervous System

- Care begins with a consistent, systematic primary survey which helps to ensure that signs and symptoms that may indicate an urgent condition are not missed.
- The goals of emergency care are:
 - Patency of the airway
 - Adequate ventilation
 - Stabilization and support of the cardiovascular system
 - Intervention to limit further cerebral injury
 - Protection of the patient from further harm while at the scene and during transport

Primary Survey

- Begin by evaluating scene safety and exsanguinating hemorrhage, airway, breathing, circulation, disability, and exposure (the XABCDEs).
- Determine the patient's level of consciousness.
- Patient airway must be ensured.
- The patient's respiratory rate and minute ventilation also should be closely monitored for changes because increased ICP may result in abnormal breathing patterns and potentially respiratory arrest.
- The patient should be monitored for vomiting, which may also be associated with increased ICP.



Patient Assessment

- A patient with a neurologic illness may be difficult to assess, especially if their mental status is impaired.
- Key elements may offer clues to the cause of the neurologic emergency:
 - History
 - Vital signs
 - Respiratory patterns

Neurologic Evaluation

- A sudden or progressively decreasing level of consciousness is highly suggestive of a serious neurologic condition.
- The mnemonic AVPU (Awake and alert, responsive to Verbal stimuli, responsive to Pain, Unresponsive) can help determine the patient's baseline neurologic status.
- The Glasgow Coma Scale (GCS) should be calculated during the initial assessment.
- The paramedic should report and record patient information with descriptive terms, as this allows others involved in the patient's care to follow the progression of the condition.

Posturing, Muscle Tone, and Paralysis

- Significant neurologic emergencies may be associated with abnormal posturing, weakness, or paralysis of limb or limbs, or both.
- Abnormal flexion of the elbows with extension of the legs is called decorticate posturing and is thought to result from damage to the thalamus or cerebral hemispheres.
- Abnormal extension at the elbow with internal rotation of the shoulders and leg extension is called decerebrate posturing and implies both cerebral and midbrain dysfunction.

Pupillary Reflexes

- Examination of the pupils can be helpful in an unconscious patient.
- Illicit substance use may be suspected based on the appearance and reaction of the pupils.
- Pupillary constriction is controlled by parasympathetic fibers which originate in the midbrain and accompany the oculomotor nerve.

Extraocular Movements

- The evaluation of extraocular movements may identify abnormalities in cranial nerve in their course from the brainstem to the orbit, in the brainstem nuclei, or finally, in the higher-order centers and pathways in the cortex and brainstem that control eye movements.
- A conscious patient should be able to move the eyes in six directions without moving the head.
- Prehospital stroke scales that include the gaze deviation sign may be useful in clinical practice.

Pathophysiology and Management of Specific CNS Disorders

Coma

- An abnormally deep state of unconsciousness from which the patient cannot be aroused by external verbal or physical stimuli
- Produced by structural lesions or toxic/metabolic states
- Structural lesions depress consciousness by affecting the reticular activating system in the brainstem.
- Toxic/metabolic conditions involve the presence of toxins or the lack of oxygen or glucose.

Six General Causes of Coma

BOX 24-2 Six General Causes of Coma

Structural Origin

Intracranial bleeding
Head trauma
Brain tumor or other space-occupying lesion

Metabolic System

Anoxia
Hypoglycemia
Diabetic ketoacidosis
Thiamine deficiency
Kidney and liver failure
Postictal phase of seizure

Toxidromes

Anticholinergic
Cholinergic
Opiate
Hallucinogenic
Sedative-hypnotic
Sympathomimetic

Cardiovascular System

Hypertensive encephalopathy
Shock
Dysrhythmias
Stroke

Respiratory System

Chronic obstructive pulmonary disease
Toxic inhalation (eg, carbon monoxide poisoning)

Infection

Meningitis
Sepsis

Mnemonic
for Common
Causes of
Coma:
AEIOUTIPS

BOX 24-3 Mnemonic for Common Causes
of Coma: AEIOUTIPS

Alcohol (or acidosis)

Epilepsy, endocrine, electrolytes

Insulin

Opiates and other drugs (overdose)

Uremia (kidney failure)

Trauma, temperature

Infection

Poisoning, psychogenic causes

Shock, stroke, seizure, syncope, space-occupying lesion,
subarachnoid hemorrhage

Differentiation of Structural and Toxic/Metabolic Causes of Coma

- In coma of structural origin, the neurologic signs often are one-sided, or asymmetrical.
- In toxic/metabolic coma, the neurologic findings often are the same on the two sides of the body. This is often slow in onset.
- Equal pupil responses suggest that the coma has a toxic/metabolic cause; unresponsive or asymmetrical pupils suggest a structural cause.
- Structural coma follows a progressive pattern of deterioration.

Assessment and Management

- Prehospital care is directed at supporting vital functions, preventing further deterioration of the patient's condition, establishing vascular access to administer medications and intravenous fluids, and managing potentially reversible causes.
- Airway maintenance and ventilator support with supplemental oxygen are the first priorities.
- Transport should not be delayed for IV access in a critical patient or patient with acute stroke.

Stroke and Intracranial Hemorrhage

- A stroke, or cerebrovascular accident, is a sudden interruption in blood flow to a portion of the brain, resulting in a neurologic deficit.
- The fifth-leading cause of death in the United States.
- Has potentially devastating permanent neurologic consequences



Modifiable Stroke Risk Factors

- Hypertension
- Cigarette smoking
- Heart disease
- Atrial fibrillation
- Diabetes mellitus
- Hyper coagulopathic states
- Carotid artery disease
- Peripheral artery disease
- Sickle cell disease
- Diet
- Obesity
- Hypercholesterolemia



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Other Factors That May Play a Role in Stroke Risk

- Geographic location
- Low income
- Alcohol or drug abuse
- Poor sleep quality

Pathophysiology

- There is no collateral circulation in the depths of the brain, therefore occlusion of any one of the more distal vessels may result in ischemia and infarction.
- Vessel occlusion or hemorrhage causes a sudden cessation of circulation to a portion of the brain. Autoregulatory mechanisms cannot readily correct this problem.
- The uncorrected ischemia that results within a short period leads to neuronal dysfunction and death.
- The onset and symptoms of the stroke depend on the area of the brain involved.

- **Types of Stroke**

- “Stroke” is a general term that refers to the neurologic manifestations of a critical decrease in blood flow to a portion of the brain, regardless of the cause.
- Determining the origin of a stroke frequently is difficult and is generally unnecessary in the prehospital setting.

TABLE 24-3 Differentiation of Ischemic and Hemorrhagic Stroke

Ischemic Stroke	Hemorrhagic Stroke
Most common	Least common
Usually the result of atherosclerosis or embolism caused by a cardiac dysrhythmia, such as atrial fibrillation	Usually the result of cerebral aneurysms, arteriovenous malformations, hypertension
Disease develops over time, symptoms develop abruptly	Develops abruptly
Long history of vessel disease	Can occur during stress or exertion, or other causes of abrupt increase in blood pressure
May be associated with valvular heart disease and atrial fibrillation	May be associated with use of cocaine and other sympathomimetic amines
History of angina, previous strokes	May be asymptomatic before rupture

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Differentiation of Ischemic and Hemorrhagic Stroke

Ischemic Stroke

- 85% fall into this category, some of which are caused by cerebral thrombosis
- The thrombosis occurs as a result of atherosclerotic plaques or pressure from a mass in the brain, and is usually associated with a long history of blood vessel disease.

Hemorrhagic Stroke

- 13% of all strokes, may occur anywhere in the brain and its structures
- The most common causes are cerebral aneurysms, arteriovenous malformations, and hypertension.

Transient Ischemic Attacks

- An episode of cerebral dysfunction that appears to last minutes to several hours
- Thought to be the most important indicator of impending stroke
- Signs and symptoms of a TIA are the same as those that characterize stroke: weakness, paralysis, numbness of the face, and speech disturbances.
- Most patients are hospitalized by close observation, evaluation, and treatment of vascular disease.



Role of Paramedics in Stroke Care

- The paramedic's role is to identify a stroke event quickly, determine how much time has elapsed since the stroke symptoms began or since the patient was last seen to be in his/her normal state so transport to the appropriate destination can be initiated, notify medical direction, and transport the patient rapidly for evaluation and treatment.

Eight Ds of Stroke Management

BOX 24-4 Eight Ds of Stroke Management

The first three Ds are the responsibility of the public and EMS providers. The fourth and fifth Ds are the responsibility of EMS, and the last three Ds are performed in the hospital.

Detection. A patient, family member, or bystander recognizes the signs and symptoms of a stroke or TIA.

Dispatch. Someone calls 9-1-1, and EMS dispatchers dispatch the appropriate EMS team with high transport priority.

Delivery. EMS providers respond rapidly, confirm the signs and symptoms of stroke, and transport the patient.

Door. The patient is transported to a stroke center that can provide fibrinolytic therapy within 1 hour of arrival at the ED door for eligible patients.

Data. A computed tomographic scan and appropriate laboratory work are obtained.

Decision. The center determines whether the patient is a candidate for fibrinolytic therapy or other interventions.

Drug. Eligible patients are treated with fibrinolytic therapy or endovascular treatment.

Disposition. The patient is rapidly transferred to a stroke or critical care unit.

Modified from: American Heart Association. 2015 Handbook of Emergency Cardiovascular Care for Healthcare Providers. Dallas, TX: American Heart Association; 2015.



Assessment

- The primary survey of a patient who may have suffered a stroke or TIA follows the same sequence as that for any other ill/injured patient in the emergency setting.
 - Cincinnati Prehospital Stroke Scale
 - Los Angeles Prehospital Stroke Screen
 - Los Angeles Motor Scale
 - Face-Arm-Speech-Time Test (FAST Test)
 - Other signs and symptoms

Management

- Once the diagnosis of stroke is suspected, time in the field must be reduced because limited time is available to begin therapy.
- The risk of complications, such as intracerebral hemorrhage versus benefit to the patient, increases as time elapses.
- The paramedic needs to manage:
 - Airway
 - Breathing
 - Circulation
 - Other supportive measures



In-Hospital Treatment

- Once at the hospital, the patient is evaluated as a possible candidate for fibrinolytic therapy.
- This assessment is aided by the use of GCS and other standardized scales.

Seizure Disorders

- A seizure is a brief alteration in behavior or consciousness caused by abnormal electrical activity of one or more groups of neurons in the brain. Recurrent seizures is called epilepsy.
- The underlying cause of seizures is not well understood but is believed to result from a structural lesion or problems with brain metabolism that result in changes in the brain cell's permeability to sodium and potassium ions.
- When these changes occur, the neurons' ability to depolarize and emit an electrical impulse sometimes results in seizure activity.

Causes of Seizures

- Stroke
- Head trauma
- Toxins
- Hypoxia
- Hypoperfusion
- Hypoglycemia
- Infection
- Metabolic abnormalities
- Brain tumor or abscess
- Vascular disorders
- Eclampsia
- Drug overdose



Focal Onset Seizure

- Seizure that begins within networks of one hemisphere of the brain
- Usually arise from identifiable lesions in the motor or sensory cortex and may spread in an orderly way to surrounding areas
- Divided into categories by the types of symptoms a patient experiences
 - Focal aware seizure
 - Focal impaired awareness seizure



Motor Onset Seizure

- Produces a change in muscle activity, such as weakness, twitching, and stiffening of body parts
- Non-motor onset seizures can affect the senses, resulting in changes in smell, taste, and hearing; visual and/or auditory hallucinations may also arise.



Generalized Onset Seizure

- Begins within both hemispheres of the brain and are divided into motor and non-motor.
- Awareness is believed to be impacted in some way.
- May include absence seizures, atonic seizures, myoclonic seizures, and tonic-clonic seizures.

Assessment

- Assessment procedure is determined by the patient's seizure state.
- If possible, should include a thorough history and physical examination, including a neurological evaluation.
- Differentiation of syncope and seizure
 - Syncope is a complete loss of consciousness caused by a temporary reduction in CBF.
 - Because syncope and seizure have similar presentations, determining whether a patient has experienced a syncopal episode or a seizure can be difficult.

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Differentiation of Syncope and Seizure

TABLE 24-5 Differentiation of Syncope and Seizure

Characteristic	Syncope	Seizure
Position	Syncope usually starts when patient is in a standing position.	Seizure may start with patient in any position.
Warning	Patient usually has a warning period of light-headedness.	Patient has little or no warning.
Level of consciousness	Patient usually regains consciousness immediately on becoming supine; fatigue, confusion, and headache last less than 15 minutes.	Patient may remain unconscious for minutes to hours; fatigue, confusion, and headache last longer than 15 minutes.
Clonic–tonic activity	Clonic movements (if present) are of short duration.	Tonic–clonic movements occur during unconscious state.
Electrocardiographic analysis	Bradycardia is caused by increased vagal tone associated with syncope in some cases.	Tachycardia is caused by muscular exertion associated with seizure activity.

Management

- The first step is to protect the patient from injury. This involves removing obstacles in the immediate area.
- The patient should not be restrained. Restraining activity may harm the patient or paramedic crew.
- Most patients with an isolated seizure can be properly managed in the postictal phase by being placed in a lateral recumbent position.
- All patients should be encouraged to seek aftercare at the emergency department. However, few patients who experience an isolated seizure require drug therapy in the prehospital setting.

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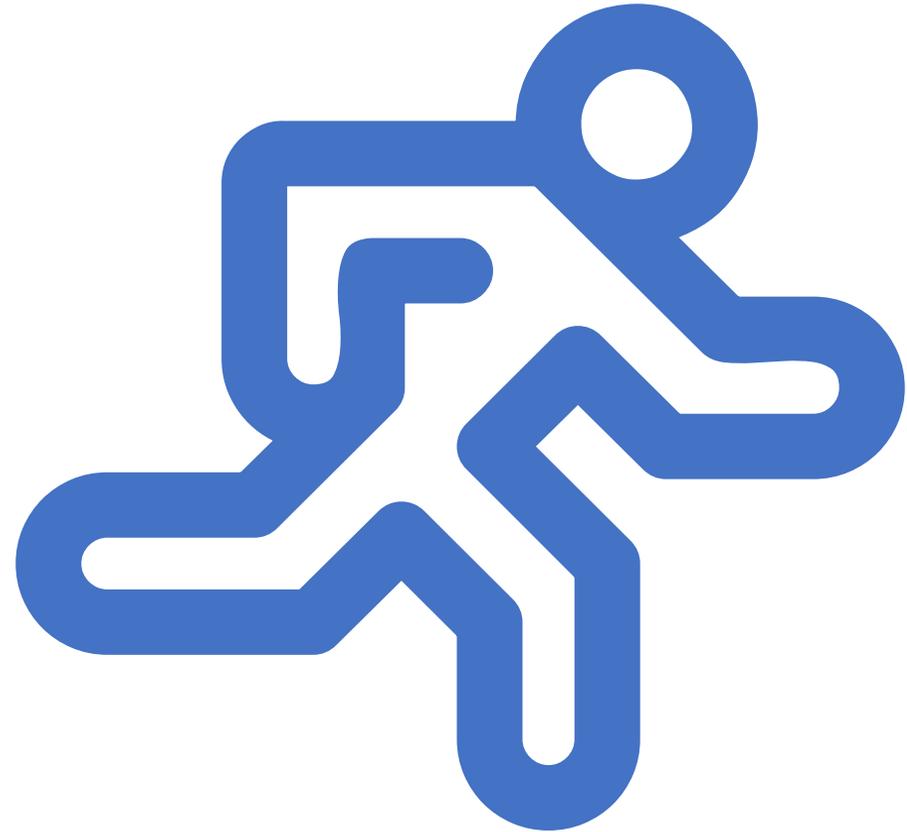
Status Epilepticus (cont.)

- Management priorities include protecting patients from injury, securing the airway, and providing supplemental oxygenation and ventilator support.
- Patients should be transported to a medical facility for physician evaluation.
- During drug administration, paramedics should be prepared for respiratory depression or arrest.

Headache

- Most are minor health concerns and are easily managed with analgesics
- Categorized according to their underlying cause
- Therapies include prescription and over-the-counter remedies, herbal remedies, meditation, acupressure, aromatherapy, and others.

-
- A tension headache is caused by muscle contractions of the face, neck, and scalp; causes include stress, persistent noise, eyestrain, and poor posture. Pain may last for days or weeks.



A migraine is a severe, incapacitating headache that is often associated with neurologic deficits and can be a stroke mimic; symptoms are associated with constriction and dilation of blood vessels brought on by an imbalance of serotonin or hormone fluctuations.

Medications prescribed include beta blockers, calcium channel blockers, antidepressants, antiemetics, anticonvulsants, and nonsteroidal anti-inflammatory and serotonin-inhibiting drugs.

A sinus headache involves pain in the forehead, nasal area, and eyes caused by allergies, inflammation, or infection of the membranes lining the sinus cavities.

Managed with medications such as analgesics, decongestants, and even antibiotics, if necessary.

Management

- Many causes of headaches can be prevented through identification of triggers.
- Seldom require prehospital emergency care
- A headache may be a sign of an aneurysm or a stroke.
- A full history should be obtained

Weakness and Fatigue

- Weakness and fatigue may be the result of multiple causes, or a specific cause may not be initially apparent.
- Paramedic should determine if the weakness is unilateral or generalized, symmetric or asymmetric, and proximal or distal.
- A thorough history should include time course of onset, distribution, exacerbating and relieving factors, associated signs and symptoms, the setting in which the problem developed, and the impact on daily activities.
- The physical examination will determine whether there is objective evidence of weakness.

Infections of the CNS

- Infections tend to cause more morbidity and mortality than do infections involving other organ systems.
- Bacteria and viruses are the most common causes of CNS infections.
- Viruses that cause CNS infection include herpesviruses, arboviruses, coxsackieviruses, echoviruses, and enteroviruses. Streptococcus and staphylococcus are usually the agents that cause bacterial infections.

Meningitis and Encephalitis

- Meningitis is inflammation of the membranes surrounding the brain and spinal cord.
- Most cases of meningitis are caused by a viral infection, but bacterial and fungal infections can also be responsible.
- Swelling triggers symptoms such as headache, fever, and nuchal rigidity.
- Some cases improve without treatment over a period of weeks; others can be life threatening and require emergent antibiotic intervention.

Meningitis and Encephalitis (cont.)

- Encephalitis is inflammation of the brain which results from the same viral or bacterial infections. Other causes can include rabies, fungus, parasites, autoimmune diseases, and certain medications.
- Some forms are contagious and can be spread through contact with saliva, nasal discharge, feces, or respiratory and throat secretions.
- Early signs mimic influenza and can develop over 1 to 2 days

Brain Abscess

- An accumulation of purulent material surrounded by a capsule within the brain.
- Develops from a bacterial infection that often begins in the nasal cavity, middle ear, teeth, or mastoid cells.
- Clinical manifestations are often nonspecific and may be associated with intracranial infection and an expanding intracranial mass.



CNS Tumors

- Include brain tumors and spinal cord tumors
- A brain tumor, or neoplasm, is a mass in the cranial cavity, which may be either malignant or benign.
- Heredity may play a role in development; also associated with exposure to radiation, tobacco use, dietary habits, some viruses, and the use of some medications.
- Effects of the tumor depend on its size, location, and growth rate, and whether any evidence of hemorrhage or edema exists.
- May cause local and generalized manifestations.

Dementia

- A slow, progressive loss of awareness of time and place.
- Usually involves an inability to learn new things or recall recent events.
- Often a result of brain disease caused by strokes, genetic or viral factors, and Alzheimer disease.
- Generally considered irreversible
- Eventually results in full dependence on others because of progressive loss of cognitive functioning.
- Sudden outbursts or embarrassing conduct may be the first obvious signs of dementia.
- Some patients eventually regress to a “second childhood”

Alzheimer disease is a type of dementia condition in which nerve cells in the cerebral cortex die and the brain substance shrinks.

- Cause of Alzheimer's is unknown: possible causes include abnormalities in glutamate metabolism, chronic infection, toxic poisoning by metal, reduction in brain chemicals, and genetics.
- Early symptoms are related to memory loss, especially the ability to make and recall new memories.
- Currently has no cure.

Early Signs and Symptoms of Alzheimer Disease

BOX 24-9 Early Signs and Symptoms of Alzheimer Disease

1. Memory loss that disrupts daily life
2. Challenges in planning or solving problems
3. Difficulty completing familiar tasks at home, work, or leisure
4. Confusion with events, time, or place
5. Difficulty understanding visual imagery or spatial relationships
6. New problems with words in speaking or writing
7. Misplacing things and losing the ability to retrace steps
8. Diminished or poor judgment
9. Unfounded suspicions about family, friends, caregivers
10. Withdrawal from work or social activities
11. Changes in mood or personality
12. Difficulty speaking, swallowing, or walking

Modified from: Ten early signs and symptoms of Alzheimer's. Alzheimer's Association website. <https://www.alz.org/10-signs-symptoms-alzheimers-dementia.asp>. Accessed March 26, 2018.

Please complete the online quiz for two (2) hours of continuing education unit hours