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Physiotherapy in Neurological Conditions

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Contents

Section 1: Foundational Concepts

1. Introduction to Physiotherapy in Neurological Conditions 3
Megha Sheth, Srishti Sharma, Priyasingh Rangey, Neeta Vyas
History 3
Physiotherapy in Neurological Conditions 4
Need for Evidence-based Practice 4
ICF in Neurological Conditions 5
Clinical Decision Making in Neurological Physiotherapy 6
An Integrated Framework for CDM 7

2. Basics of Neuroanatomy and Neurophysiology 10
Dhwanit Shah
Neurophysiology 10
Classification of Nervous System 10
Neurons and Neuroglia 11
Nerve Fiber 12
Synapse 13
Receptors 14
Neurotransmitters 14
Reflex Activity 15
Somatic Nervous System 19
Physiology of Pain 19
Electroencephalography 20
Higher Intellectual Functions 20
Cerebrospinal Fluid and Blood-Brain Barrier 20
Autonomic Nervous System 21
Cranial Nerves 21
Neuroanatomy 23
Spinal Cord 23
Brainstem 23
Cerebellum 25
Thalamus 26
Hypothalamus 27
Internal Capsule 29
Basal Ganglia 30
Reticular Formation 31
Cerebral Cortex 32
Limbic System 32

3. Normal Development of Fetus and Child 35
Vivek Ramanandi
Fetal Development 36
Somatic Development of the Fetus 36
Neurological Development of the Fetus 36
Behavioral Development of the Fetus 37
Development of Fetal Organs and Systems 37
Development after Birth 37
Growth of the Organ Systems 37
Milestone Development 39
Developmental Red Flags for Children Aged Birth to Five Years 54

4. Drugs Used in Neurological Diseases 62
Samidh Shah, Lav Patel
Multiple Sclerosis 62
Myasthenia Gravis 64
Parkinsonism 65
Cerebral Palsy 70

Section 2: Clinical Evaluation

5. Principles of Neurological Assessment 75
Suvarna Ganvir
Primary Survey of the Patient 76
Subjective Assessment 76
Objective Examination 77
Neurological Examination 77

6. Assessment of Balance and Gait 95
Suvarna Ganvir
Assessment of Balance 95
Assessment of Gait 99

7. Investigations in Neurological Conditions 103
Pooja Jani
Skull X-ray 103
Computerized Tomography Scanning 104
Magnetic Resonance Imaging 105
Radionuclide Imaging Techniques 106
Ultrasound 107
Cerebral Angiography 107
Electroencephalography 108
Intracranial Pressure Monitoring 108
Myelography 108
Biochemical Investigations 108
Lumbar Puncture 109
Biopsies 110
Electromyography 111
Nerve Conduction Velocity 112
Evoked Potentials 112

8. Radiological Investigations for a Neurophysiotherapist 115
Anjan Desai, Vivek Ramanandi
Regional Imaging for Neurological Structures 115

9. Electrodiagnosis 130
Shweta Maheshkumar Parikh
Classical Electrodiagnostic Tests 131
Advanced Electrodiagnostic Tests 133
Other Electrodiagnostic Tests 146

Section 3: Physiotherapy Approaches

10. Principles of Neurorehabilitation 151
Jui Dave
Neuroplasticity and Rehabilitation 152
Modern Neurorehabilitation Beliefs 152
Challenges of Neurorehabilitation 153
General Principles of Neurorehabilitation 154
Motor Issues in Neurorehabilitation 155
Overview of Techniques in Neurorehabilitation 158

11. Neural Repair and Neural Plasticity 165
Dhara Sharma 165
Neural Repair 165
Neuroplasticity 166
Synaptic Plasticity 166
Mechanism of Structural and Functional Changes in Nervous System 168
Principles of Neural Plasticity 168
Intersection of Neuroplasticity and Rehabilitation 171

Section 4: Physiotherapy Management

12. Cranial Nerve Injuries—Physiotherapy Management 175
Rushikesh K Joshi, Megha Soni
Basics of Cranial Nerves: Anatomy and their Important Functions 175
Cranial Nerve Injuries 175

13. Lesions of the Brain—Clinical 191
Disha Dalal Parikh, Dhara Sharma
Classification of Lesions of the Brain 191
Brain Infections 191
Brain Tumors 195

14. Brain Injuries 198
R Harihara Prakash
What is Traumatic Brain Injury? 199
Causes of Traumatic Brain Injury 199
Classification 199
Pathophysiology 200
Clinical Manifestations 201
Testing and Diagnostic Procedures 202
Assessment 202
Management 204

15. Stroke—Clinical 217
Ashish Kakkad
Types 218
Risk Factors 218
Prevalence 220
Clinical Anatomy 220
Pathology 221
Management Categories 221
Clinical Features 222
Diagnosis 224
Management 225
Complications 227
Impact of Stroke on the Country 228

16. Stroke—Physiotherapy 230
Ashish Kakkad
Assessment 230
Physiotherapy Treatment 232
Physiotherapy Management Strategies 235
Recent Advances 241

17. Stroke—Care at Home 245
Shyam Ganvir
Objectives for Care of Stroke Patients at Home 245
Care of Stroke Patients at Home 245

18. Cognitive Dysfunction and Physiotherapy 253
R Lakshmiprabha
Domains of Cognition 254
Sensation and Perception 257
Causes of Cognitive Dysfunction 258
Assessment of Cognition 258
Definition of Cognitive Rehabilitation Therapy 261
Attributes of Cognitive Rehabilitation Therapy 261
Factors Affecting the Effectiveness of CRT 262
Integrating Physiotherapy in Cognitive Rehabilitation 264
Aging and Cognition 266
Cognitive Behavioral Therapy and Cognitive Functional Therapy: Basic Concepts 267

19. Parkinson's Disease and Extrapyramidal Conditions 271
Asmita Karajgi
Extrapyramidal Conditions 271
Parkinsonism 272
Parkinson's Disease 272
Physiotherapy for Other Extrapyramidal Conditions 278

20. Cerebellar Dysfunction 280
Asmita Karajgi
Cerebellum: Structure and Function 280
Etiology 281
Clinical Features 282
Physiotherapy Assessment 282
Management 283
Physiotherapy Management 283
Evidence 288

21. Non-traumatic Spinal Cord Disorders—Clinical 290
Neha Christian
Anatomy 290
Myelopathy 291
Compressive Myelopathies 295
Noncompressive Myelopathies 297

22. Non-traumatic Spinal Cord Injury—Physiotherapy 302
Jaspreet Kaur Kang
Non-traumatic Spinal Cord Injury 302
Congenital NTSCI 303
Skeletal Malformations 309
Genetic Disorders 311
Acquired Abnormalities 313
Vascular Disorders 314
Inflammatory and Autoimmune Disorders 315
Neoplastic Disorders 316
Infections of Spine 318

Syringomyelia 319
Management 321
Rehabilitation 321
Physiotherapy Management 323
Complications of NTSCI 327

23. Multiple Sclerosis 332
Zarna Ronak Shah
Epidemiology 332
Pathophysiology 333
Clinical Features 333
Classification 334
Investigations 335
Differential Diagnosis 335
Medical Management 335
Physiotherapy Assessment 336
Physiotherapy Management 336
General Preventive Measures 337
Psychosocial Issues 340

24. Polyneuropathy 342
Shivani Verma Sheth, Megha Sheth, Srishti Sharma
Anatomy 342
Classification of Polyneuropathy 343
Pathophysiology of Polyneuropathy 343
Clinical Features 343
Diagnosis 344
Medical Management 344
Guillain-Barré Syndrome 344
Chronic Inflammatory Demyelinating Polyneuropathy 349
Porphyric Neuropathy 349
Toxic Neuropathy 349
Alcohol-induced Polyneuropathy 351
Polyarteritis Nodosa 351
Diabetic Neuropathy 351
Rheumatoid Polyneuropathy 352
Amyloid Neuropathy 352
Hereditary Neuropathy with Liability to Pressure Palsies 353
Hereditary Motor and Sensory Neuropathy 353
Charcot-Marie-Tooth Disease 353
Hypertrophic Interstitial Neuropathy 353

25. Motor Neuron Disease 356
Shivani Verma Sheth, Megha Sheth, Priyasingh Rangey
Classification of Motor Neuron Disease 356
Clinical Features 357
Diagnosis 357
Symptoms and their Management 358
Physiotherapy Management 360

26. Myopathy 363
R Harihara Prakash
Classification and Types of Myopathy 364
Clinical Features of Myopathies 364
Muscular Dystrophy 365
Distal Myopathies 367
Myotonic Muscular Dystrophy 368
Inflammatory Myopathy 369
Diagnosis 369
Complications of Myopathy 369
Medical Management of Myopathy 370
Physical Therapy Rehabilitation 370

27. Myasthenia Gravis 379
Chaitali Shah
Causes 380
Etiology 380
Pathology 380
Commonly Involved Groups of Muscles 381
Clinical Features 381
Classification 383
Course of Disease 383
Diagnosis 384
Medical Management 385
Myasthenic and Cholinergic Crisis 386
Physiotherapy Assessment 386
Physical Activity and Exercise in Myasthenia Gravis 387
Stress Management and Coping Skills 391

28. Vestibular Rehabilitation 394
Hutoxi S Writer
Anatomy of the Vestibular System 395
Vestibular Dysfunction 400
Vertigo 401
Assessment of the Dizzy Patient 402
Impairments due to Dizziness 405
Vestibular Rehabilitation 406
Factors Affecting Outcome Measures 413

29. Peripheral Nerve Injuries—Clinical 415
Srishti Sharma, Megha Sheth, Priya Singh Rangey
Anatomy of Peripheral Nerve 415
Peripheral Nerve Injuries 417
Pathological Changes: Degeneration and Regeneration 418
Classification of Nerve Injuries 419
Clinical Features 421
Diagnosis and Prognosis 421
Complications of Peripheral Nerve Injury 422
Surgical Management 422

30. Peripheral Nerve Injuries—Physiotherapy 426
Megha Sheth, Srishti Sharma, Priya Singh Rangey
Physiotherapy Assessment 426
Physiotherapy Management 429
Peripheral Nerve Injury in the Upper Limb 432
Peripheral Nerve Injury in the Lower Limb 443

31. Poliomyelitis and Post-polio Syndrome 449
Srishti Sharma, Megha Sheth
Poliomyelitis 449
Etiology 449
Pathogenesis 450
Clinical Features 450
Diagnosis 451
Management 451
Role of Physiotherapy 452
Post-polio Syndrome 452
Pathogenesis and Risk Factors 452

Clinical Features 454
Diagnosis and Assessment 454
Management 455

32. High-risk Infants 461
Priya Singh Rangey
Levels of Neonatal Care 462
Role of Physiotherapist in NICU 462
Theories of Motor Development 463
The NIDCAP Approach 464
Development of Sensory System in the NICU 464
Assessment of the High-risk Infant 465
Early Intervention 465
Techniques Used in the NICU 466

33. Cerebral Palsy—Clinical 470
Shraddha Diwan
Heterogeneity of the Cerebral Palsy Population 471
Epidemiology 471
Origin and Pathophysiology 471
Clinical Manifestation of Different Types of Cerebral Palsy 472
Functional Classification of Children with Cerebral Palsy (Based on their Functional Abilities) 473
Diagnosis 476
Prognosis 476
Impairments 476
Evaluation 476

34. Cerebral Palsy—Management 485
Shraddha Diwan
Teamwork 485
Pharmacological Management 485
Neurosurgical Management 486
Orthopedic Management 486
Physical Therapy Management 487
Overall Evidence 494
Orthotic Management 495
Home Management Program 498

35. Neurogenetic Conditions 500
Archana Gore
Overview of Genetics 500
Classification of Genetic Disorders 502
Clinical Features of Neurological Conditions with Genetic Etiology 503
Physical Therapy Assessment 507
Physical Therapy Management 508
Evidence-based Physical Therapy 509

36. Hydrocephalus 511
Mihirdev Jhala
Physiology of Cerebrospinal Fluid 511
Classification of Hydrocephalus 512
Causes 512
Pathophysiology 512
Clinical Features 512
Investigations 513
Medical Management 513
Surgical Management 514
Physiotherapy Assessment 514
Physiotherapy Management 515

37. Spina Bifida 518
Urvashi Jhala
Patho-embryology 518
Risk Factors 519
Types of Neural Tube Defects 519
Classification of Spina Bifida 519
Complications 521
Clinical Findings and Diagnosis 521
Surgical Management 522
Prognosis 522
Physiotherapy Assessment 522
Physiotherapy Management 524

Section 5: Neurological Rehabilitation

38. Disability Evaluation in Neurological Conditions 533
Monali Soni, Megha Sheth
Disability 534
Evaluation of Neurological Disability 534
Guidelines for Evaluation of Permanent Physical Impairment of Upper Extremities 534
Guidelines for Evaluation of Permanent Physical Impairment in Lower Extremity 536
Disability Evaluation in Multiple Disabilities 538
Disability Evaluation in Some Neurological Conditions 538
Who can Give Certificate? 540

39. Community Rehabilitation of Individuals with Neurological Conditions 542
Megha Matul Jayswal, Megha Sheth
Rehabilitation in Neurological Disorders 543
Barrier-free Environment 544
Transport System 544
Built-up Environment 545
Psychological Rehabilitation 548
Legislation/Policies 550
Employment 551
Knowledge and Awareness Among Patients 553
Public Awareness and Knowledge about Neurological Disorders 553

40. Cardiopulmonary Functioning in Neuromuscular Conditions 555
Dhruv Mehta
Neuraxis 556
Impairments due to Neuromuscular Affection 556
Challenges and Solutions in the Rehabilitation of Neurological Conditions 557

Index 563

2 Basics of Neuroanatomy and Neurophysiology

Dhwanit Shah

LEARNING OBJECTIVES

At the end of the chapter, the reader will be able to:

- Discuss the anatomy of the nervous system.
- Understand the functional importance of different parts of the nervous system.
- Be able to locate damage in the nervous system based on history, investigations and physical examination.

Chapter Outline

Neurophysiology

- Introduction to the Nervous System
- Classification of Nervous System
  - Central Nervous System
  - Peripheral Nervous System
- Neurons and Neuroglia
  - Classification of Neurons
  - Parts of Neurons
- Nerve Fiber
  - Classification of Nerve Fibers
  - Properties of Nerve Fibers
  - Degeneration and Regeneration of Nerve Fibers
- Synapse
- Receptors
- Neurotransmitters
- Reflex Activity
  - Classification of Reflexes
  - Pathological Reflexes
- Somatic Nervous System
  - Somatosensory System
  - Somatomotor System
- Physiology of Pain
  - Neurogenic Pain
- Electroencephalography
  - Significance of EEG
  - Method of Recording EEG
  - Waves of EEG
- Higher Intellectual Functions
- Cerebrospinal Fluid and Blood Brain Barrier (BBB)
  - Properties and Composition of Cerebrospinal Fluid
  - Mechanism of Formation
  - Absorption of Cerebrospinal Fluid
  - Circulation of Cerebrospinal Fluid
  - Functions of Cerebrospinal Fluid
  - Autonomic Nervous System
- Cranial Nerves

Neuroanatomy

- Spinal Cord
  - Tracts of Spinal Cord
- Brainstem
  - Medulla Oblongata
  - Pons
  - Midbrain
- Cerebellum
  - Connections
- Thalamus
  - Connections
  - Functions of Thalamus
  - Disorders
- Hypothalamus
  - Connection
  - Function
  - Disorders of Hypothalamus
- Internal Capsule
  - Location
  - Divisions
  - Applied Physiology
- Basal Ganglia
  - Components of Basal Ganglia
  - Disorders of Basal Ganglia
- Reticular Formation
  - Connections of Reticular Formation
  - Functions of Reticular Formation
- Cerebral Cortex
- Limbic System
  - Components of Limbic System
  - Functions of Limbic System

NEUROPHYSIOLOGY

INTRODUCTION TO THE NERVOUS SYSTEM

The nervous system comprises of nerves and neurons (nerve cells) and is concerned with transmission of signals throughout the body.

CLASSIFICATION OF NERVOUS SYSTEM

The nervous system controls the activities and functioning of the human body. Its functioning is faster than other physiological systems of the body. The nervous system is classified in two parts:

1. Central nervous system
2. Peripheral nervous system

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1. Central Nervous System

The central nervous system (CNS) is formed of the brain and the spinal cord. It is formed of neuroglia (non-neuronal cells) and neurons. The parts of brain and spinal cord are arranged in two layers, i.e., gray matter and white matter. The gray matter consists of neuronal cell bodies, glial cells, synapses, capillaries and the proximal parts of nerve fibers, arising from nerve cell body. White matter consists of remaining parts of nerve fibers. The white matter is placed in the inner part of the brain and the outer part is formed of the gray matter. Whereas in the spinal cord, the white matter forms the outer part and the inner part is formed of the gray matter. The brain is inside the skull and continues as spinal cord in the vertebral canal through the foramen magnum of the skull bone. Three layers of meninges surround the brain and spinal cord. The outer layer is known as dura mater, middle is arachnoid mater and inner layer is pia mater. The space between arachnoid mater and pia mater is known as subarachnoid space. It has the cerebrospinal fluid. Brain and spinal cord are suspended in cerebrospinal fluid.

Important parts of brain and segments of spinal cord are shown in **Figure 2.1.**

The brain is comprised of three parts **(Flowchart 2.1):**

1. Prosencephalon
2. Mesencephalon
3. Rhombencephalon

The brainstem is formed of midbrain, pons and medulla oblongata.

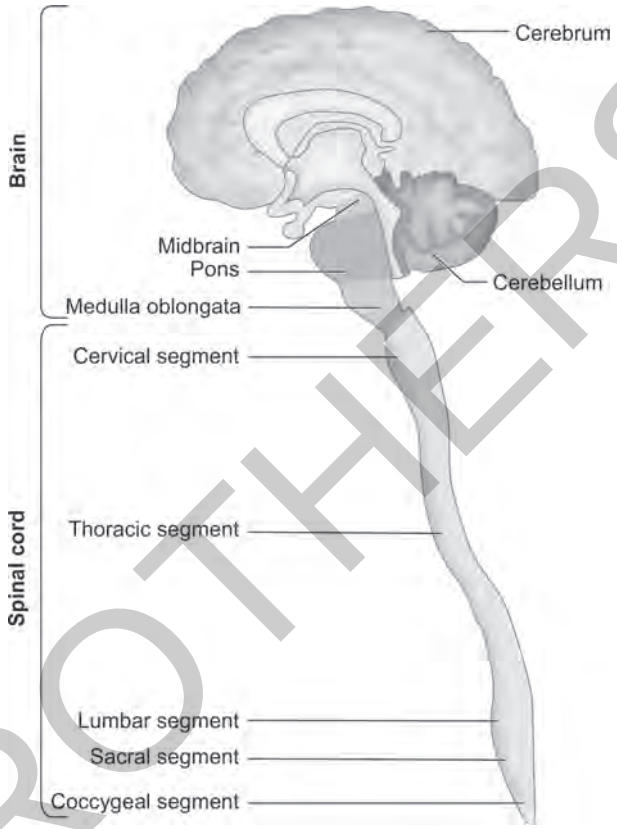


Fig. 2.1: The brain and the spinal cord.

2. Peripheral Nervous System

Peripheral nervous system (PNS) comprises of neurons and their processes present in all parts of the body along with cranial nerves (from brain) and spinal nerves (from spinal cord). This part of nervous system, which lies outside the CNS, consists of nerves extending from the brain and the spinal cord to all parts of the body. It is further divided in two subdivisions as shown in **Flowchart 2.2**.

NEURONS AND NEUROGLIA

The nerve cell which is also known as the neuron is the functional and structural unit of the nervous system. It has nucleus and like other cells of the body has all the organelles in cytoplasm **(Box 2.1)**. **Figure 2.2** shows the structure of a nerve cell.

Classification of Neurons

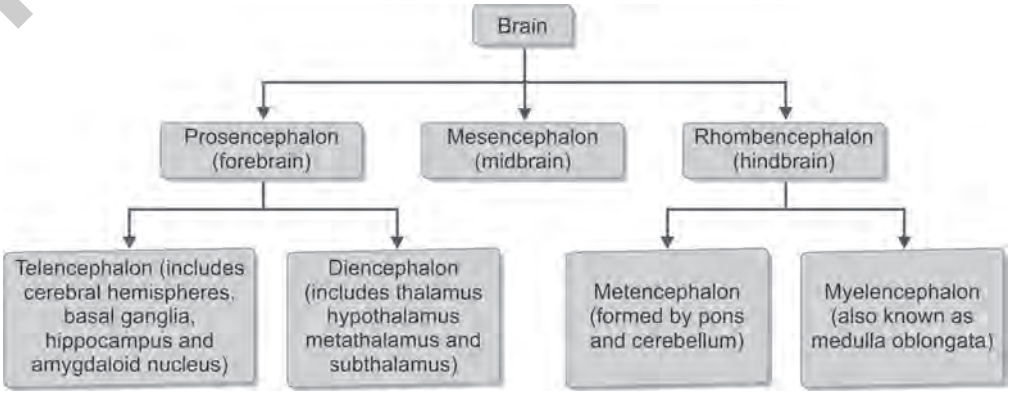
Neurons are classified by three different methods (**Flowchart 2.3**):

1. Number of poles
2. Function
3. Length of axon

Parts of Neurons

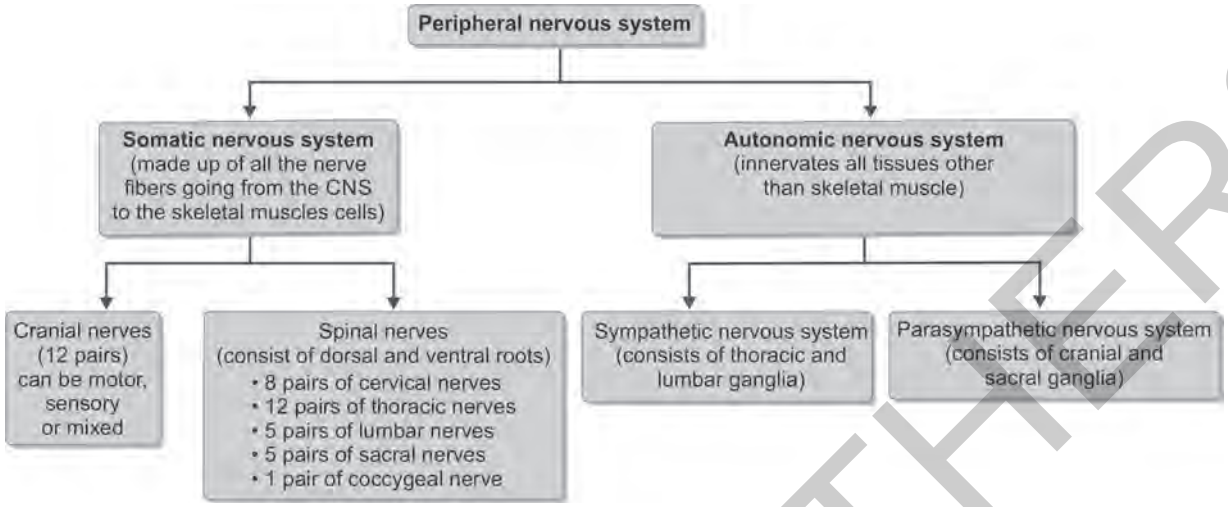
Table 2.1 presents the parts of a neuron—axon and dendrite, and their characteristics.

Flowchart 2.1: Divisions of the brain.



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Flowchart 2.2: Parts of the peripheral nervous system.



Box 2.1: Characteristic features of neurons.

1. Neuron has branches or processes called axon and dendrites.
2. Neuron does not have centrosome. So, it cannot undergo division.

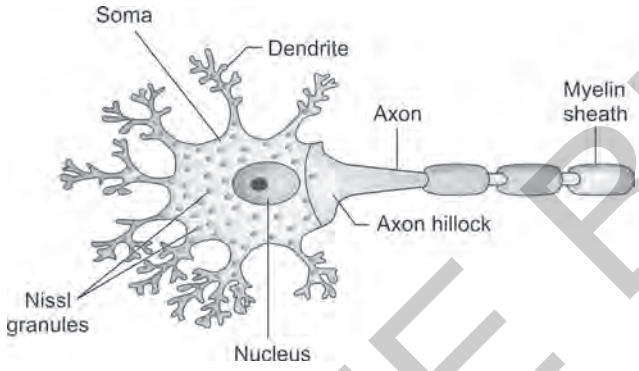


Fig. 2.2: Structure of a nerve cell.

NERVE FIBER

These are the processes which are extensions of the neurons. The classification and properties are described below:

Classification of Nerve Fibers

Nerve fibers are classified by six different methods. The basis of classification differs in each method. Different methods of classification are listed in **Box 2.2.**

1. **Based on the structure:**
   a. Non-myelinated nerve fibers
   b. Myelinated nerve fibers
2. **Based upon distribution:**
   a. Somatic nerve fibers
   b. Visceral or autonomic nerve fibers
3. **Based upon origin:**
   a. Cranial nerve fibers
   b. Spinal nerve fibers
4. **Based upon function:**
   a. Sensory nerve fibers
   b. Motor nerve fibers
5. **Based upon secretion of neurotransmitter:**
   a. Adrenergic nerve fibers
   b. Cholinergic nerve fibers
6. **Based upon diameter and conduction of impulse (Erlanger Gasser classification):**
   a. Type A nerve fibers
   b. Type B nerve fibers
   c. Type C nerve fibers

Properties of Nerve Fibers

1. **Excitability:** This property can be defined as the change of physiochemical nature which occurs in response to a stimulus.
2. **Conductivity:** Conductivity is the property of nerve fibers to transmit impulses from region of stimulation to other areas.
3. **Refractory period:** Refractory period is the phase in which no response to the stimulus occurs.
   Types of refractory period:
   Refractory period is of two types:
   1. *Absolute refractory period:* Absolute refractory period is phase in which the nerve gives no response, irrespective of the strength of stimulus.
   2. *Relative refractory period:* In this phase if a maximum intensity stimulus is given, nerve fiber would give response.
4. **Summation:** When a stimulus of subminimal intensity is given, there would no response in the nerve fiber. But, if two or more subliminal stimuli are applied within a short interval of about 0.5 millisecond, a response is produced. It is because with the summation of the subliminal stimuli leads to a strong response. This phenomenon is known as summation.
5. **Adaptation:** While stimulating a nerve fiber continuously, the excitability of the nerve fiber is greater in the beginning. Gradually, the response reduces in intensity and finally the nerve fiber shows no response at all. This phenomenon is known as adaptation or accommodation.
6. **Infatigability:** A nerve fiber does not get fatigued. This holds true even when the nerve fiber is stimulated continuously over a long period of time. This occurs as

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Flowchart 2.3: Types of neurons.

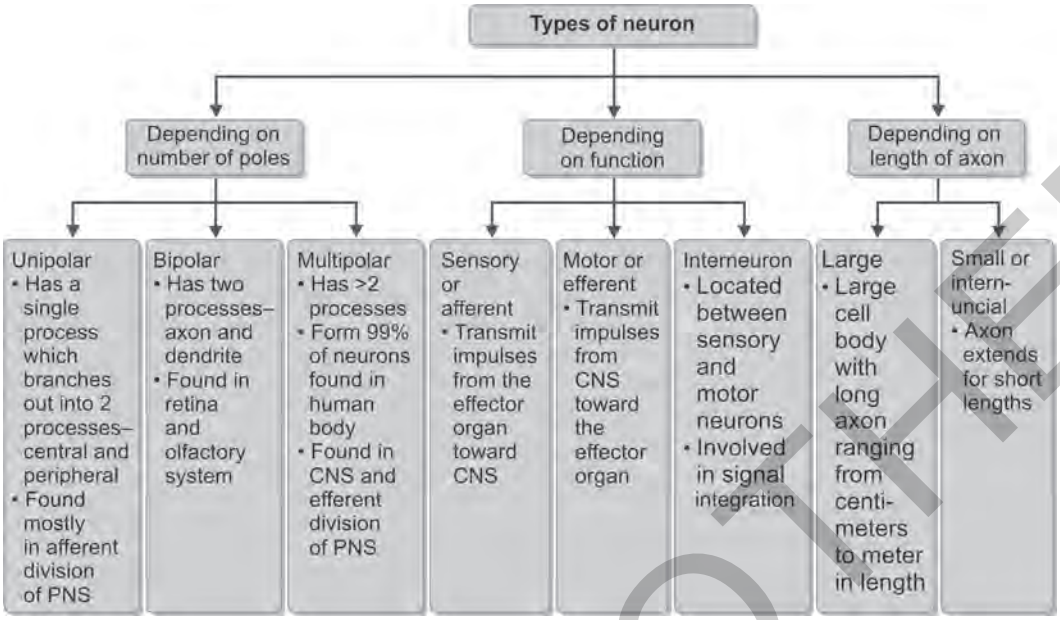


Table 2.1: Characteristics of axon and dendrite.

Axon	*Dendrite*
• The long process of the neuron is axon • Each neuron has only one axon • It arises from axon hillock of nerve cell body and is devoid of Nissl granules • It extends long beyond the nerve cell body • Its length is around 1 meter • It transmits impulses away from the nerve cell body	• Branched process of neuron is dendrite • It could be present or absent. If present, could be one or multiple • It consists of Nissl granules and neurofibrils • It transmits impulses toward the nerve cell body • It is usually, shorter than axon.

Box 2.2: Classification of nerve fibers.

1. Depending upon structure
2. Depending upon distribution
3. Depending upon origin
4. Depending upon function
5. Depending upon secretion of neurotransmitter
6. Depending upon diameter and conduction of impulse (Erlanger-Gasser classification)

nerve fiber conducts only one action potential at a time. So, it is completely refractory to other stimuli and cannot conduct another action potential.

7. **All-or-none law:** This law states that when a nerve is stimulated it either gives maximum response or gives no response at all.

Degeneration and Regeneration of Nerve Fibers

Degeneration of nerve fibers: In case of injury to the nerve fiber, various changes take place in the nerve fiber and nerve cell body which are called the degenerative changes.

Regeneration of nerve fibers: The term regeneration refers to regrowth of lost or destroyed part of a tissue. An injured or degenerated nerve fiber can regenerate. The process of regeneration begins by 4th day post injury, but it gets more effective only after 30 days. The process of regeneration is completed in around 80 days.

SYNAPSE

Synapse can be defined as the junction between two neurons. It is basically the physiological continuity between two neurons and not an anatomical continuation. **Figure 2.3** shows the structure of a synapse.

Synapse is classified by two methods:

1. Anatomical classification
2. Functional classification.

Tables 2.1 to 2.3 show the various classifications of synapses.

- **Anatomical classification:** A synapse is formed of an axon of one neuron terminating on cell body or dendrite or axon of the other neuron. Based on the part of axon which is terminating, synapse is classified in three types as shown in **Figure 2.4**, and **Tables 2.2 and 2.3:**

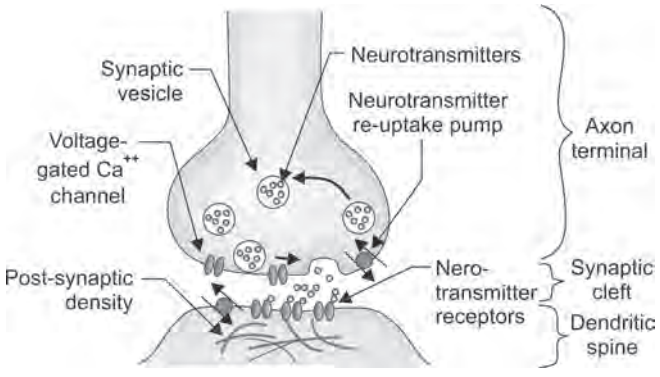


Fig. 2.3: Structure of synapse.

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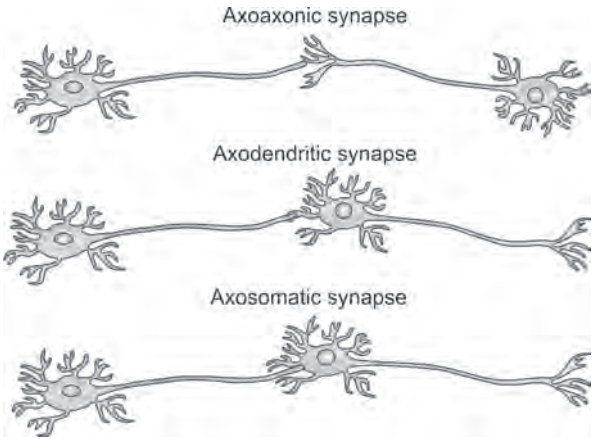


Fig. 2.4: Anatomical classification of synapse.

1. *Axoaxonic synapse:* In this axon of one neuron terminates on axon of another neuron
2. *Axodendritic synapse:* In this axon of one neuron terminates on dendrite of another neuron
3. *Axosomatic synapse:* In in this axon of one neuron ends on soma (cell body) of another neuron

- **Functional classification:** Functional classification of synapse is based on mode of impulse transmission. According to this, synapse is classified in two categories—electrical synapse and chemical synapse as shown in **Figure 2.5** and **Table 2.4.**
  - *Electrical synapse:* Electrical synapse is the synapse in which the physiological continuity between the presynaptic and the post synaptic neurons is provided by gap junction between the two neurons.
  - *Chemical synapse:* It is the junction between nerve fiber and muscle fiber or between two nerve fibers. Through this signals are transmitted with release of chemical transmitters.
- ***Functions of synapse:*** Function of synapse is mainly to transmit impulses (action potential) from one neuron to another. However, some of the synapses inhibit impulses, as a result they are not transmitted to postsynaptic neuron. On the basis of functions, synapses are classified in two types:
  1. *Excitatory synapses:* These transmit the impulses (excitatory function)
  2. *Inhibitory synapses:* These inhibit transmission of the impulses (inhibitory function).

RECEPTORS

Receptors are specialized modified sensory nerve endings which undergo depolarization (i.e., form nerve impulses) in response to specific stimulus and in turn send information to CNS. They act as transducers that convert various forms of energy into electric energy (action potential) in the neuron.

Flowcharts 2.4 and 2.5 show the classification of receptors.

NEUROTRANSMITTERS

It is a chemical substance which acts as mediator for transmission of nerve impulse from one neuron to another neuron through a synapse.

Criteria for neurotransmitter: To be considered as a neurotransmitter, a chemical must fulfill the following criteria:

1. Produced by a neuron
2. Should be found in neuron
3. Released by a neuron
4. It must act on a target area and produce some biological effect
5. Post its action, it should be inactivated.

Table 2.2: Classification of synapse.

Type of synapse	*Site of contiguity (close proximity between)*		*Main location in the nervous system*
	Part of presynaptic cell	*Part of postsynaptic cell*	
1. Axodendritic (most commonly seen)	Axon	Dendrite	a. Motor neurons in the spinal cord b. Excitatory synapse in the cerebral cortex c. Climbing fibers in the cerebellum
2. Axosomatic	Axon	Soma or perikaryon	Motor neurons in the spinal cord Basket cells of the cerebellum Autonomic ganglia
3. Axoaxonal	Axon	Axon	Spinal cord
4. Dendrodendritic (rare)	Dendrite	Dendrite	Synapse between mitral and granule cell in the olfactory bulb

Table 2.3: Anatomical classification of synapses.

Type I	*Type II*
Example: Axodendritic synapses It shows marked thickening of the subsynaptic membrane Synaptic cleft–wider (30 mm) and filled with dense extracellular material Sites (*refer* to above **Table 2.2**)	*Example:* Axosomatic synapses Subsynaptic membrane shows slight thickening which is not continuous Synaptic cleft-narrow (20 mm) and no much dense material found here Sites (*refer* to above **Table 2.2**)

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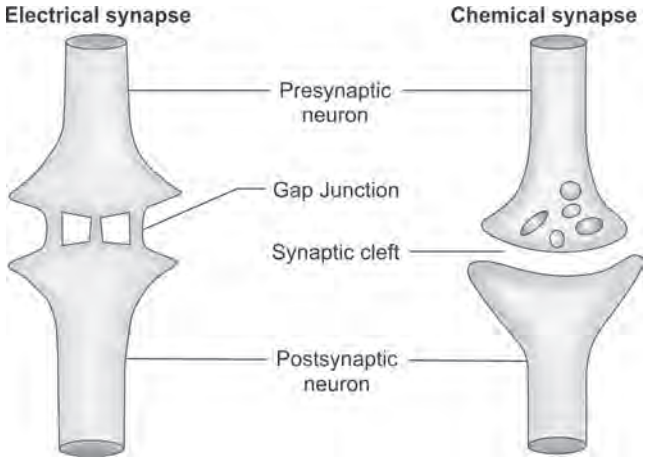


Fig. 2.5: Functional classification.

Tables 2.5 and 2.6 show some neurotransmitters and their characteristics.

REFLEX ACTIVITY

Reflex arc can be defined as the anatomical nervous pathway for a reflex action. A simple reflex arc includes five components as shown in **Figure 2.6.**

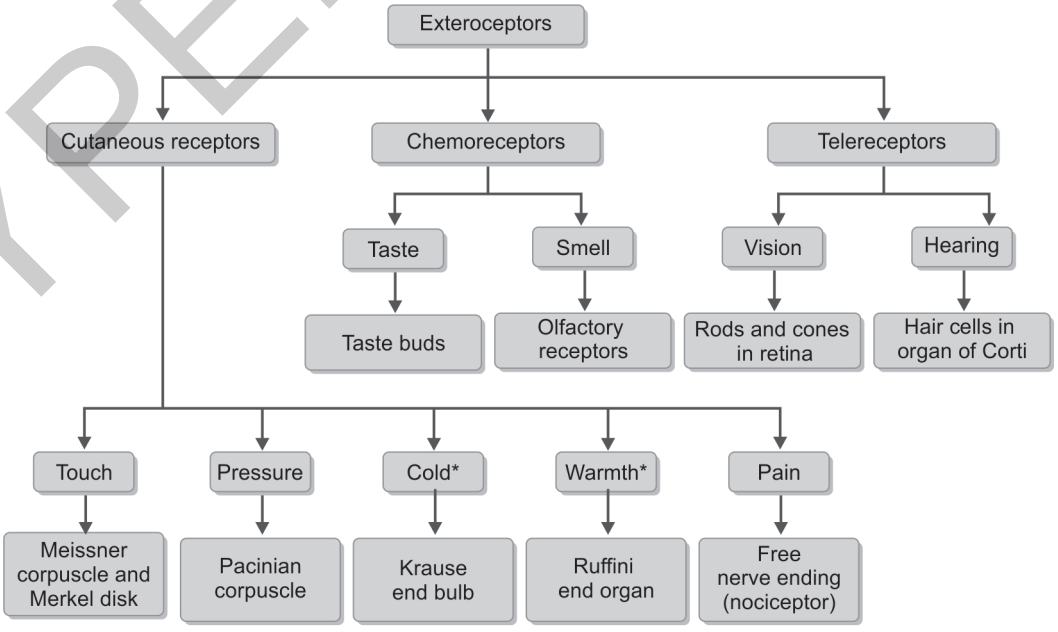
1. **Receptor:** It is the end organ that receives the stimulus. When it is stimulated, impulses are transmitted in afferent nerve.
2. **Afferent nerve:** An afferent or sensory nerve is the one which transmits sensory impulses from receptor to the center.
3. **Center:** It is located in the brain or spinal cord. It receives sensory impulses via afferent nerve fibers. It then transmits motor impulses.
4. **Efferent nerve:** An efferent or motor nerve transmits motor impulses from the center to the effector organ.
5. **Effector organ:** It is usually a gland or muscle. It is the organ where the activity occurs in response to the stimulus.

Afferent and efferent nerve fibers can be connected directly to the center. In some places, one or more neurons are interposed between the nerve fibers and the center. These

Table 2.4: Functional classification of synapses.

Chemical synapses	*Electrical synapses*
• Here transmission of impulse from pre- to postsynaptic site occurs due to liberation of chemical mediator • These are seen at most of the synaptic junctions' nervous system. They always transmit the signals in one direction, i.e., from presynaptic to post-synaptic neuron. • Synaptic cleft is present. • Synaptic delay present. • They are sensitive to hypoxia. • It allows for large number of synapses per neuron and a large amount of neurotrans-mitters. This results in infinite processing of information. This is particularly of help in the processing of learning and memory.	• Here pre- and postsynaptic membranes come very close to form gap junction. These junctions act as low resis-tance bridges through which ions can pass with relative ease. • These are seen at some of the synaptic junctions in the ner-vous system and can transmit signals in either direction (e.g., in the lateral vestibular nucleus, hippocampus and cerebral cortex). • Synaptic cleft gets replaced by low resistance bridges. • Synaptic delay is absent because of low resistance bridges. • They are insensitive to hypoxia. • There are not too many syn-apses on the same neurons. Therefore, transmission across it is rapid and efficient.

Flowchart 2.4: Exteroceptors.



*Receptors of cold and warmth are together called temperature receptors (thermoreceptors)

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Flowchart 2.5: Interoceptors.

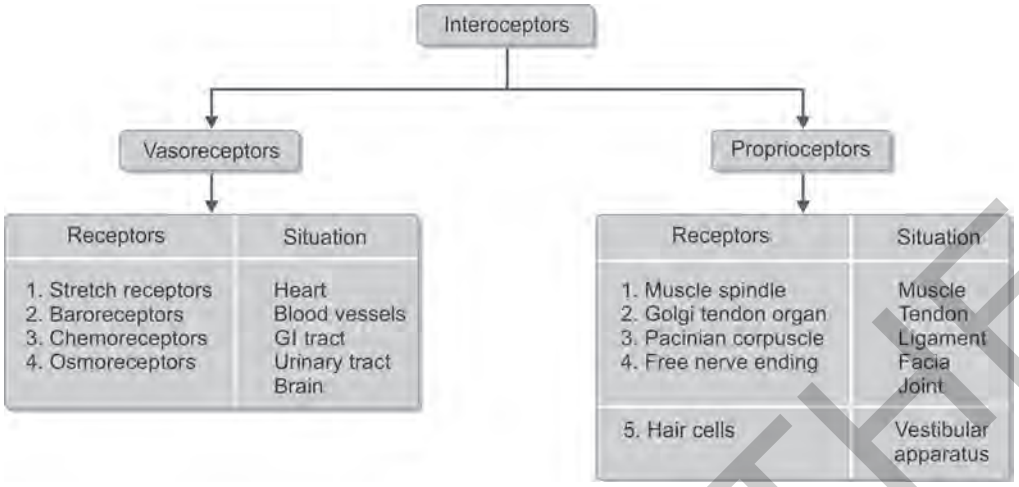


Table 2.5: Some neurotransmitters with their characteristics.

Name	*Group*	*Secretion site*	*Function*
GABA (gamma amino-butyric acid)	Amino acids	Retina, spinal cord, brain stem, cerebrum	Inhibitory
Glycine		Retina, spinal cord, brain stem and forebrain	Inhibitory
Aspartate		Retina, spinal cord and cerebellum	Excitatory
Glutamate		Brainstem, cerebellum and cerebral cortex	Excitatory
Adrenaline	Amines	Spinal cord, thalamus, hypothalamus	Excitatory and inhibitory
Noradrenaline		Spinal cord, brain stem, basal ganglia, hypothalamus, cerebral cortex	Excitatory and inhibitory
Serotonin		Platelets, lungs, retina, spinal cord, limbic system, cerebellum, basal ganglia	Inhibitory
Dopamine		Retina, limbic system, basal ganglia, hypothalamus	Inhibitory
Histamine		GI tract, hypothalamus, cerebral cortex	Excitatory
Nitric oxide	Others	GI tract, neuromuscular junction and various other parts of CNS	Excitatory
Acetylcholine		Pre and Post Ganglionic sympathetic and parasympathetic nerve endings, basal ganglia, hypothalamus, thalamus, hippocampus, cerebral cortex, neuromuscular junction	Excitatory

Table 2.6: Examples of neurotransmitters.

Inhibitory	*Excitatory*	*Both (Inhibitory and Excitatory)*
GABA	Acetylcholine	Adrenaline
Glycine	Histamine	Noradrenaline
Serotonin	Aspartate	
Dopamine	Glutamate	

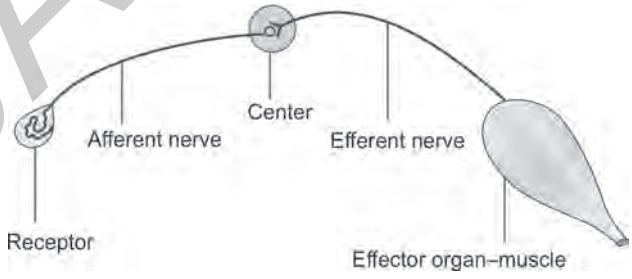


Fig. 2.6: Reflex arc.

neurons are known as connector neurons or internuncial neurons or interneurons.

Classification of Reflexes

Reflexes can be classified in six different ways based on various factors.

1. **Depending upon whether reflexes are inborn or acquired:**
   - *Inborn reflexes or unconditioned reflexes*
     - Unconditioned reflexes are the natural reflexes that are present since birth. Hence, they are also known as inborn reflexes.
     - No learning, training or conditioning is required to acquire these reflexes.
     - Best example of these types of reflexes is secretion of saliva when a drop of honey is kept in the mouth of a newborn baby for the first time. The baby does not know the taste of honey, but still saliva is secreted.

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- *Acquired reflexes or conditioned reflexes*
  - The reflexes that develop after conditioning or training are known as conditioned or acquired reflexes.
  - As the name suggests, these reflexes are not present since birth but, are acquired after birth.
  - Learning, training or conditioning is required for these reflexes.
  - Example is the secretion of saliva by sight, smell, thought or hearing of a known edible substance.

2. Depending upon situation: Anatomical classification: Reflexes can be classified based on the location of the center of the reflex.

- *Cerebellar reflexes:* These reflexes have center in cerebellum.
- *Cortical reflexes:* These reflexes have their center in cerebral cortex.
- *Midbrain reflexes:* These reflexes have their center in the midbrain.
- *Bulbar or medullary reflexes:* Bulbar or medullary reflexes are the reflexes which have their center in medulla oblongata.
- *Spinal reflexes:* Reflexes which have center in the spinal cord are known as spinal reflexes.

Based on segments involved, spinal reflexes are classified in three groups:

a. Segmental spinal reflexes
b. Intrasegmental spinal reflexes
c. Suprasegmental spinal reflexes

3. Depending upon purpose: Physiological classification: In this method, reflexes are classified based on their purpose (functional significance).

- *Protective reflexes or flexor reflexes*
  - These are the reflexes that protect the body from nociceptive (harmful) stimuli and are also known as withdrawal reflexes or flexor reflexes.
  - Protective reflexes involve flexion at different joints hence the name flexor reflexes.
- *Antigravity reflexes or extensor reflexes*
  - These are the reflexes which protect the body against gravitational force.
  - These reflexes are also called the extensor reflexes because, the extensor muscles contract during these reflexes resulting in extension at joints.

4. Depending upon the number of synapses: Based on number of synapses in reflex arc, reflexes can be classified as:

- *Monosynaptic reflexes*
  - Reflexes which are composed of only one synapse in the reflex arc are known as monosynaptic reflexes.
  - Stretch reflex is the best example for monosynaptic reflex and it is elicited due to the stimulation of muscle spindle.
- *Polysynaptic reflexes*
  - Reflexes which are composed of more than one synapse in the reflex arc are known as polysynaptic reflexes.
  - Flexor reflexes (withdrawal reflexes) are the polysynaptic reflexes.

5. Depending upon whether reflexes are somatic or visceral:

- *Somatic reflexes*
  - These reflexes have the reflex arc which is formed by somatic nerve fibers.
  - These reflexes involve the participation of skeletal muscles.
  - There may be flexion or extension at different joints during these reflexes.
- *Visceral or autonomic reflexes*
  - Visceral or autonomic reflexes are the reflexes for which at least a part of reflex arc is formed by autonomic nerve fibers.
  - These reflexes involve smooth muscle or cardiac muscle.
  - Visceral reflexes include pupillary reflexes, gastrointestinal reflexes, cardiovascular reflexes, respiratory reflexes, etc.
  - Some reflexes such as swallowing, coughing or vomiting are considered as visceral reflexes. However, these reflexes involve some participation of skeletal muscles also.

6. Depending upon clinical basis:

On clinical basis, reflexes can be classified as:
Superficial reflexes: They are described in **Table 2.7.**
Deep reflexes: They are shown in **Table 2.8**.

Pathological Reflexes

Pathological reflexes are elicited only in pathological conditions. Well-known pathological reflexes are:

1. Babinski sign
2. Clonus
3. Pendular movements.

1. Babinski sign:

- An abnormal plantar reflex is known as Babinski sign. It is also known as Babinski reflex or phenomenon. It is named after the discoverer Joseph Babinski.
- In normal plantar reflex, a gentle scratch over the outer edge of the sole of foot causes plantar flexion and adduction of toes.
- In Babinski sign, dorsiflexion of great toe along with fanning of other toes occurs.
- When Babinski reflex is present, the condition is commonly called Babinski positive sign and when it is absent, the condition is called Babinski negative sign.
- Babinski sign is present in upper motor neuron lesions.
- Physiological conditions when Babinski sign is present are infancy and deep sleep. It is also present in infants because of non-myelination of pyramidal tracts.

2. Clonus:

- It is a rapid and repeated series of involuntary and jerky movements that occur as a response to deep reflex stimulation.

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Table 2.7: Superficial reflexes.

Reflex	*Stimulus*	*Response*	*Center involved*
Scapular reflex	Stimulation of the skin on intrascapular region	Slight contraction of scapular muscles with in-drawing of scapula	C5 to T1
Upper abdominal reflex	Stroke the abdominal wall (below the costal margin)	Slight ipsilateral contraction of abdominal muscles with movement of umbilicus toward the stimulus	T6 to T9
Lower abdominal reflex	Stroke the abdominal wall at umbilical and iliac level	Slight ipsilateral contraction of abdominal muscles with movement of umbilicus toward the stimulus	T10 to T 12
Cremasteric reflex	Stroke the skin at upper and medial aspect of thigh	Elevation of testicles	L1, L2
Gluteal reflex	Stroke the skin over the buttocks	Slight gluteal muscle contraction	L4 to S1,2
Plantar reflex	Stroke the sole of foot	Plantar flexion and adduction of toes	L5 to S2
Bulbocavernosus reflex	Stroking dorsum of glans penis	Contraction of bulbocavernosus	S3, S4
Anal reflex	Stroking the perianal region	Contraction of anal sphincter	S4, S5

Table 2.8: Deep reflexes.

Reflex	*Stimulus*	*Response*	*Center-Spinal Segment involved*
Jaw Jerk	Tap downward on the chin, with the mouth slightly open	Jaw rebounds and closes	Pons- Cranial Nerve V
Biceps Jerk	Tap on the tendon, while the patient is sitting with arm flexed and supported	Slight contraction of biceps	C5, C6
Triceps Jerk	Tap just above olecranon process, on the tendon	Slight contraction of elbow extensors	C6 to C8
Supinator Jerk	Place finger on radial tuberosity and tap on the finger	Slight contraction of elbow	C7, C8
Wrist Tendon Reflex	Percuss on the palmer aspect of tendon	Slight contraction of finger flexors	C8, T1
Knee Jerk	Tap on patellar tendon	Slight contraction of knee extensors	L2 to L4
Ankle Jerk	Percuss on Achilles tendon	Plantar flexion	L5 to S2

- When deep reflex is elicited in a normal person, the contractions of a muscle or group of muscles are smooth and continuous. Clonus occurs when the responses of deep reflexes are exaggerated due to hypertonicity of muscles due to pyramidal tract lesion.
- Clonus is often present in calf muscles causing ankle clonus and in quadriceps producing patella clonus.
- *Ankle clonus* can be defined as rhythmical repeated contractions of calf muscles due to sudden dorsiflexion of foot. Repeated rhythmical contractions of calf muscles cause series of rhythmic plantar flexion at ankle joint. Sudden dorsiflexion of foot is done by supporting patient's knee in a slightly flexed position.
- *Patellar clonus* is the rhythmic jerky movements of patella produced by grasping it between thumb and index finger of the examiner and pushing it down forcibly toward the foot. It is caused by clonic contractions of quadriceps muscle.

3. Pendular movements:

- Pendular movements are slow oscillatory movements that occur during elicitation of a tendon jerk.
- Hypotonicity of muscles is found to cause pendular movements.
- Pendular movements are very common while eliciting the knee jerk or patellar tendon reflex in the individuals having cerebellar lesion.
- When leg is hanging freely, percussion of patellar tendon causes a brisk extension of leg due to the contraction of quadriceps muscle (knee jerk).
- In physiological conditions, post the extension, the leg returns to resting position immediately.
- In cerebellar lesion, the leg swings forwards and backwards several times.
- These movements can be similar to movements of clocks pendulum, hence, are known as pendular movements.

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SOMATIC NERVOUS SYSTEM

Somatosensory System

Somatosensory system is defined as the sensory system associated with different parts of the body.
Sensations are of two types:
1. Somatic sensations
2. Special sensations

1. **Somatic sensations**
   - Somatic sensations are the sensations arising from skin, muscles, tendons and joints.
   - These sensations have specific receptors, which respond to a particular type of stimulus. **Flowchart 2.6** shows the classification of somatic sensations.
2. **Special sensations:** Special sensations are the complex sensations for which the body has some specialized sense organs.

Somatomotor System

Movements of the body depend upon different groups of skeletal muscles. Various types of movements or motor activities brought about by these muscles are:
1. Execution of smooth, precise and accurate voluntary movements
2. Coordination of movements responsible for skilled activities
3. Coordination of movements responsible for the maintenance of posture and equilibrium.

The execution, planning, coordination and adjustments of movements of the body are under the influence of different parts of nervous system, which are together called motor system. Sensory system of the body also plays a vital role in the control of movements.

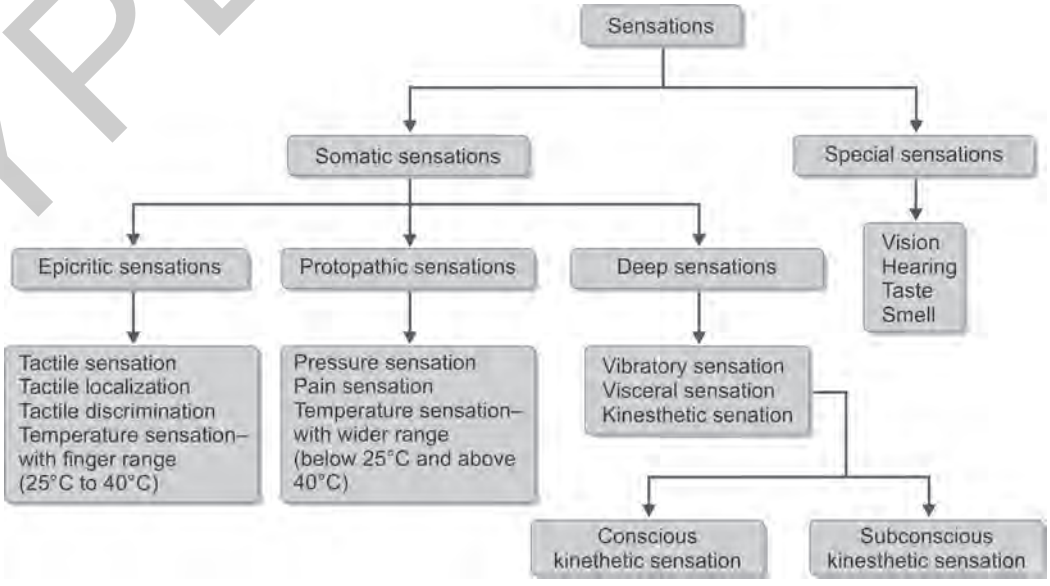
Spinal reflexes are associated with the movements that are associated with voluntary actions and posture. Apart from these reflexes, voluntary motor activities signals are also relayed from different parts of the brain, particularly cerebral cortex to spinal motor neurons.
Coordination and control of movements initiated by cerebral cortex is based on two factors:
1. The feedback signals which arise from proprioceptors (in muscle) and other sensory receptors
2. Interaction between cerebellum, brainstem, and basal ganglia.

Hence, the motor system is composed of the cerebral cortex, cerebellum, brainstem, basal ganglia, cranial nerves, and spinal cord and its nerves. Neuronal circuits present in these parts of nervous system, are responsible for motor activities. These neuronal circuits are known as motor pathways.

PHYSIOLOGY OF PAIN

- Pain is defined as an unpleasant and emotional experience associated with/without actual tissue damage.
- Pain sensation can be described as sharp, pricking, electrical, dull aching, shooting, cutting, stabbing, etc. When it is very severe in nature it can lead to crying and fainting.
- Pain can be as a result of real or potential injury to the body. Often it is expressed in terms of injury.
- For example, pain produced by fire is expressed as burning sensation; pain produced by severe sustained contraction of skeletal muscles is expressed as cramps.
- Pain can be acute or chronic in nature. Acute pain is sharp pain of very short duration and usually has an easily identified cause. Often it is localized in a small area before spreading to neighboring areas. Usually, it is treated by medications. Chronic pain can be defined as an intermittent or constant pain with different intensities and lasting for long duration of time.
- Pain in neurological disorders may be a sentinel marker of the disease itself (e.g., acute herpes zoster or acute back pain) or it may occur as secondary consequence of the disease (e.g., post-herpetic neuralgia).

Flowchart 2.6: Classification of somatic sensations.



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Neurogenic Pain

- Pain caused by a dysfunction in the CNS or PNS in absence of any nociceptive stimulation due to trauma or disease is termed as neurogenic pain.
- Physiologic pain is easy to treat and is most of the times, self-limiting. Neurogenic pain is not easily managed and is not self-limiting.
- Neurogenic pain can be caused by several agents—infectious diseases, neurological disorders, metabolic diseases, etc.
- In case of neurogenic pain, there might be an initial peripheral pain which may cause central sensitization due to ectopic neuronal activity in the spinal cord dorsal horn.
- Presentation of neurogenic pain is often vague and indescribable by the patient.
- The onset is often delayed.
- Examination may reveal mild sensory loss with allodynia, hyperalgesia and hyperpathia. Rarely, signs of sympathetic dysfunction may be observed.
- Neurogenic pain is often associated with neurological pain syndromes.

ELECTROENCEPHALOGRAPHY

- Electroencephalography (EEG) is the study of electrical activities of brain.
- Electroencephalogram is the graphical recording of electrical activities of brain.
- Electrical activity of the brain is complicated when compared to that of a single nerve fiber or neuron. It is due to the involvement of large number of neurons and synapses.
- German psychiatrist Hans Berger was the first one to analyze the EEG waves systematically and hence the EEG waves are referred as Berger waves.

Significance of EEG

- Electroencephalogram is useful in the diagnosis of neurological disorders and sleep disorders.
- EEG pattern is altered in the following neurological disorders:
  - Epilepsy, which occurs due to excessive discharge of impulses from cerebral cortex
  - Disorders of midbrain affecting ascending reticular activating system
  - Subdural hematoma during which there is collection of blood in subdural space over the cerebral cortex.

Method of Recording EEG

- Electroencephalograph is the instrument used to record EEG.
- The electrodes called scalp electrodes from the instrument are placed over unopened skull or over the brain after opening the skull or by piercing into brain.
- Electrodes are of two types, unipolar and bipolar electrodes.
- While using bipolar electrodes, both the terminals are placed in different parts of brain. When unipolar electrodes are used, the active electrode is placed over cortex and the indifferent electrode is kept on some part of the body away from cortex.

Waves of EEG

- Electrical activity recorded by EEG may have synchronized or desynchronized waves.
- Synchronized waves are the regular and invariant waves, whereas desynchronized waves are irregular and variant.
- In normal adults, EEG has three frequency bands:
  - Alpha rhythm
  - Beta rhythm
  - Delta rhythm
- In addition to these three types of waves, EEG in children shows theta waves.

HIGHER INTELLECTUAL FUNCTIONS

Various higher mental functions are very important in assessment of patient. They are described in detail in Chapter 5.

CEREBROSPINAL FLUID AND BLOOD BRAIN BARRIER (BBB)

Cerebrospinal fluid (CSF) is the clear, colorless, and transparent fluid that circulates through ventricles of brain, subarachnoid space and central canal of spinal cord. It is a part of extracellular fluid (ECF).

Properties and Composition of Cerebrospinal Fluid

Properties

- Volume: 150 mL (100–200 mL)
- Rate of formation: 0.3 mL per minute
- Specific gravity: 1.005
- Reaction: alkaline

Composition

- CSF is a part of ECF and contains more amount of sodium than potassium.
- CSF also contains some lymphocytes.
- CSF secreted by ventricle does not contain any cell.
- Lymphocytes are added when CSF flows in the spinal cord.

Mechanism of Formation

- CSF is formed by the process of secretion that involves active transport mechanism.
- Formation of CSF does not involve ultrafiltration or dialysis.

Absorption of Cerebrospinal Fluid

- CSF is mostly absorbed by the arachnoid villi into dural sinuses and spinal veins.
- Small amount is absorbed along the perineural spaces into cervical lymphatics and into the perivascular spaces.
- The mechanism of absorption is by filtration due to pressure gradient between pressure in the subarachnoid space fluid and the pressure that exists in the dural sinus blood.

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- Colloidal substances pass slowly and crystalloids are absorbed rapidly.
- Normally, about 500 mL of CSF is formed every day and an equal amount is absorbed.

Circulation of Cerebrospinal Fluid

Circulation of CSF is presented in **Figure 2.7.**

Functions of Cerebrospinal Fluid

1. **Protective function:**
   - CSF is the fluid buffer which protects the brain from shock. The specific gravity of brain and CSF is more or less same, so brain floats in CSF.
   - In case of blow to the head, CSF acts as a cushion that prevents movement of brain against the skull bone and thereby, prevents damage to the brain. However, in case high intensity blow, the brain moves forcefully and may hit against the skull bone, which can cause damage to brain tissues.
   - Brain would strike against the skull bone opposite to the point where the blow was applied. So, this type of damage to the brain is known as countrecoup injury.
2. **Regulation of cranial content volume:**
   - Regulation of cranial content volume is a very important function as functioning of the brain can be affected if increase in volume of cranial content occurs. It happens in cerebral hemorrhage and brain tumors.
   - Increase in cranial content volume can be prevented by greater absorption of CSF which would give space for the increasing cranial contents.
3. **Medium of exchange:** CSF provides the medium for exchange of many substances, particularly nutritive substances, and waste materials between blood and brain tissues.

AUTONOMIC NERVOUS SYSTEM

- The innervation of all tissues other than skeletal muscle is by way of the autonomic nervous system (ANS).
- It regulates the activities of smooth muscles, heart, glands of GIT, sweat glands, adrenal glands and of certain endocrine organs.
- Its main aim is to maintain the optimal internal environment of the body. Thus, it governs the body functions which are normally carried out without conscious control or awareness.
- This is why ANS is also called as vegetative or efferent visceral or involuntary nervous system (vegetative because it is concerned with growth, i.e., vegetative aspects of day to day living).

Divisions of ANS

From anatomical and physiological point of view, ANS is divided into two divisions:
1. Sympathetic division
2. Parasympathetic division.

Difference between Somatic and ANS

The major differences between the somatic and ANS are given in **Figure 2.8.**

The differences between the sympathetic and parasympathetic system are given in **Table 2.9.**

Table 2.10 shows the major differences between the somatic and ANS.

CRANIAL NERVES

- Cranial nerves are the nerves that emerge directly from the brain (including the brainstem), of which there are conventionally twelve pairs.
- Cranial nerves relay information between the brain and parts of the body, primarily to and from regions of the head and neck, including the special senses of vision, taste, smell and hearing.

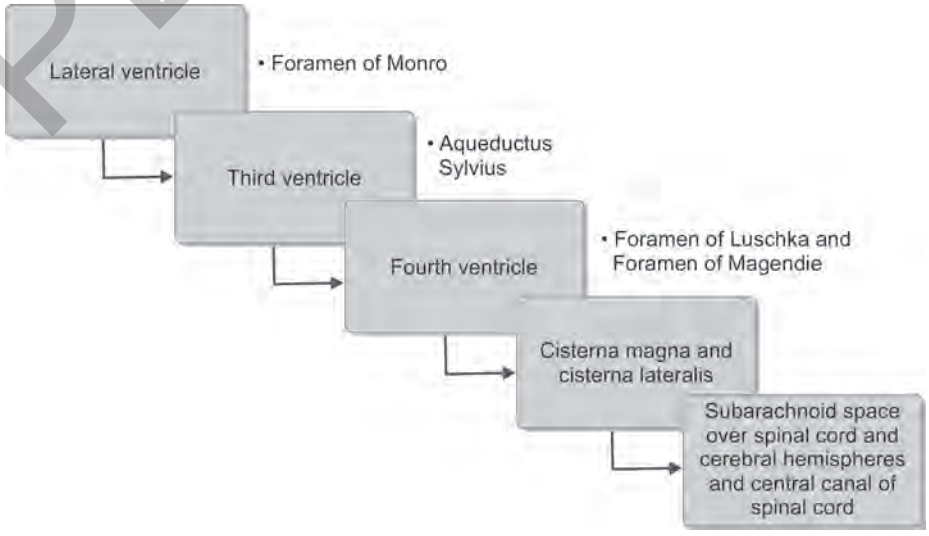


Fig. 2.7: Circulation of cerebrospinal fluid (CSF).

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Physiotherapy in Neurological Conditions

The goal of the authors when writing this book was to provide a textbook and a reference book for students, clinicians and academicians. It contains important and common neurological pathologies encountered amongst patients. The book is divided into various sections depending on the content of the chapters comprising details of foundational concepts, clinical evaluation and investigations, physiotherapy techniques used in neurological rehabilitation, common neurological pathologies and rehabilitation. Clinical examples provide a clear understanding of the assessment and management processes. It is one of a kind, depiction of all topics related to neuro-medicine and physiotherapy.

Salient Features

- The information is presented in a well-defined manner and easily comprehensible language
- Assessment process has been explained in great detail
- Detailed description of the neurological physiotherapy management and techniques to be followed
- Provides variety of photographs depicting important clinical features and management strategies
- Important information has been provided in striking boxes
- Clinical pointers have been provided for better clinical guidance
- An integration of evidence with clinical practice
- Clinical examples have been provided with suggested physiotherapy management
- Review questions for exam-going students

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