RETICULAR FORMATION
General anatomy of reticular formation

- Diffuse appearance – usually identified as the area between the brainstem nuclei
  - Neuron groups are indistinct
- Cells at raphe
- Very large neurons (gigantocellular) tend to be at paramedian location
- Smaller cells (parvocellular) tend to be lateral
- Medullary, Pontine, and Midbrain RF
Figure 17.12  Location of the reticular formation

1. Midbrain
   - Superior colliculus
   - Medial lemniscus
   - Substantia nigra
   - Cerebral peduncle

2. Lower pons
   - Fourth ventricle
   - Abducens nucleus
   - Middle cerebellar peduncle
   - Medial lemniscus
   - Corticospinal fibers

3. Middle medulla
   - Hypoglossal nucleus
   - Medullary reticular formation
   - Dorsal motor nucleus of vagus
   - Medial lemniscus
   - Medullary pyramid
   - Inferior olive
Nuclei of the reticular formation


**FIGURE 9-1** Diagram showing the positions of the larger nuclei of the reticular formation of the brain stem.
FIGURE 9-2 Transverse sections of the brain stem. The left side of each figure shows nuclei and tracts that are major anatomical landmarks. The right side shows the positions of reticular and other nuclei discussed in this chapter. Black dots indicate procerbellar nuclei; red dots indicate groups of serotonin- and catecholamine-containing neurons; and blue dots indicate other nuclei. (continued)
Lateral reticular nucleus

Hypoglossal nucleus

Gigantocellular nucleus

Parvocellular nucleus

Raphe (serotonin)

Acetylcholine

Norepinephrine

Serotonin

Nuc Ambiguus

Inferior olive
Caudal pons

Caudal pontine reticular nucleus
Raphe (serotonin)
Parvocellular reticular area
FIGURE 9-2 (continued) Transverse sections of the brain stem. The left side of each figure shows nuclei and tracts that are major anatomical landmarks. The right side shows the positions of reticular and other nuclei discussed in this chapter. Black dots indicate precerебellar nuclei, red dots indicate groups of serotonin- and catecholamine-containing neurons, and blue dots indicate other nuclei. (A) Nuclei at the level of the caudal pole of the inferior olivary nucleus, in the closed part of the medulla. (The unlabeled red dots indicate scattered adrenergic neurons.) (B) Nuclei at the level of the rostral pole of the inferior olivary nucleus, in the open part of the medulla. (The unlabeled red dots indicate groups of noradrenergic and adrenergic neurons. The blue dots dorsolateral to the inferior olivary nucleus indicate the probable position of the ventral superficial reticular area of the medulla.) (C) Nuclei in the caudal pontine tegmentum, at the level of the internal genu of the facial nerve. (D) Pontine tegmentum at a level rostral to the trigeminal motor nucleus. (E) Nuclei at the level of the caudal end of the inferior colliculus.
Mid pons

Locus coeruleus – Note the pigment

Parabrachial nucleus

Raphe

Pedunculopontine nucleus

PPRF

Acetylcholine
Norepinephrine
Serotonin
ROSTRAL MIDBRAIN
Rostral midbrain

MRF

Nuc III

riMLF

Acetylcholine
Norepinephrine
Serotonin
Reticular Formation Functions

• Short local connections
  • Cranial nerve reflexes
  • Central pattern generators
  • Cerebellum input & output
  • Gaze centers within brainstem

• Long Connections
  • Mescencephalic and rostral pontine RF modulates forebrain activity
  • Medullary and caudal pontine RF modulate somatic and visceral motor activity
Local RF Circuits for Cranial Nerve Reflexes

- Corneal blink
  - Input via 5
  - Output via 7
- Gag reflect
  - Input via 5 and 9
  - Output via 9
- Acoustic startle
  - Input via 8
  - Output via RF
Central Pattern Generator for Chewing

- Location in parvocellular RF
  - Surrounds motor trigeminal nucleus
  - Caudal to facial nuc.

- Chewing circuitry
  - Afferents
    - Trigeminal afferents from lips, oral cavity, muscle spindles in muscles that elevate mandible, & cortical masticatory area in M1
  - Central pattern generator
  - Trigeminal motor for jaw muscles
    - Jaw closing – rostral 2/3 of Motor V
    - Jaw opening – ventromedial middle 1/3 and caudal Motor V
Central Pattern Generator for Respiration

- Respiratory regions in parvocellular RF near nucleus ambiguus
- Pattern generator controls cycle of active inspiration
- Inputs modulate breathing pattern
- Outputs control diaphragm and other muscles
Motor Function: Pre-cerebellar RF Nuclei

- Inputs to cerebellum from reticular formation
  - Lateral reticular nucleus
  - Paramedian reticular nucleus
  - Pontine reticulotegmental nucleus

- Output from cerebellum
  - To Spinocerebellar tract (Vermal cortex -> Fastigial nucleus -> RF)
  - Vestibulocerebellar (Flocculus-Nodulus -> Fastigial + Vestibular -> RF)
Figure 20.11  Projections from the frontal eye field to the superior colliculus and the PPRF

Primary motor cortex  Frontal eye field

Cerebrum

Midbrain

Superior colliculus

Pons

PPRF (horizontal gaze center)
Reticular Formation Functions

- Short local connections
  - Cranial nerve reflexes
  - Central pattern generators
  - Cerebellum input & output
  - Gaze centers within brainstem

- Long Connections
  - Mespencephalic and rostral pontine RF modulates forebrain activity
  - Medullary and caudal pontine RF modulate somatic and visceral motor activity
Long Connection Circuitry of RF

- Central Medial Nuclei
- Neurons
  - Large dendritic fields
  - Dendritic fields are heavily overlapping
- Inputs
  - Many sources
  - Highly overlapping (not topographic)
  - Axons may be ascending or descending or both
- Outputs
  - Many targets
  - Long distances
Overlapping dendritic fields

Axons
- Local connections
- Long distance connections
- Usually both
- Some axons ascend and descend the neuraxis

**FIGURE 9-5** Neurons of the reticular formation. (A) Interaction between dendrites and collateral axonal branches of neurons with ascending (*blue*) and descending (*red*) projections. (B) A neuron whose axon divides into long ascending and descending branches.
Figure 15.4 *Orientation of dendrites in the reticular formation.* Sagittal section through the medulla (rat). Note the long, straight dendrites, which are typical of the neurons of the reticular formation, in contrast to the neurons of a cranial nerve nucleus (the hypoglossal) and other specific brain stem nuclei. A long axon with numerous collaterals extending ventrally in the transverse plane is also shown. Collaterals of the pyramidal tract fibers also enter the reticular formation. From Scheibel and Scheibel (1958).
Box 17D The reticular formation

Mesencephalic and rostral pontine reticular formation
Modulates forebrain activity

Caudal pontine and medullary reticular formation
Premotor coordination of lower somatic and visceral motor neuronal pools
 Whole Body Reactions And Reflexes: Central Group of Reticular Nuclei

- Reticulospinal tract (descending) – Motor pathway
- Reticulothalamic tract (ascending) – Somatosensory/pain
- Startle, muscle tone, posture, attention

**FIGURE 9-4** Major connections of the central group of reticular nuclei.
Raphe nuclei: Serotonergic neurons

tryptophan hydroxylase (TPH); TPH2 in situ shows location of serotonin
Raphe nuclei: Serotonergic neurons

- **Descending outputs**
  - Control of pain via PAG inputs and output to dorsal horn of spinal cord
  - Autonomic controls

- **Ascending outputs** goes to most forebrain regions
  - Active in deep sleep

---

**FIGURE 9-3** Major connections of the serotonergic raphe nuclei.

Kiernan JA (2009)
Chat in situ shows cholinergic cells (D) in lateral dorsal tegmental nucleus
Cholinergic neurons

- Inputs
  - RF
  - Hypothalamus
  - Basal ganglia
- Outputs
  - RF
  - Intralaminar Thalamus
  - Basal forebrain
- Consciousness and REM sleep

**FIGURE 9-6** Major connections of the cholinergic nuclei of the brain stem.

Kiernan JA (2009)
Locus Coeruleus

- Catecholamine nuclei
- Norepinephrine as a neurotransmitter
- Inputs mostly unknown
- Outputs to most parts of the CNS, especially forebrain

Tyrosine hydroxylase in situ shows location of locus coeruleus
Catecholamine nuclei

- Spontaneous activity modulated by other RF inputs
- Loculus coeruleus sends axons with many branches to forebrain
- Lateral neurons send axons descending to autonomies

**Figure 9-7** Major connections of the noradrenergic nuclei of the brain stem.
Motor Control and Emotion

Figure 29.2
Descending systems that control somatic and visceral motor effectors in the expression of emotion
Sleep and Wakefulness

A. Electrical stimulation of cholinergic neurons near junction of pons and medulla
B. Low frequency electrical stimulation of thalamus
Figure 28.11  Important nuclei in regulation of the sleep–wake cycle (Part 1)

Sleep and arousal

(A)

Cerebral cortex

Thalamus

Raphe nuclei

Cholinergic nuclei

Pons

Medulla

Corpus callosum

Thalamus

Corpus callosum

Cerebral cortex

Tuberoventricular nucleus of hypothalamus

Pons

Medulla

To spinal cord

Locus coerules
In general, less activity in RF during sleep
- REM sleep looks more like wakefulness due to cholinergic RF activity

**TABLE 28.1 Summary of the Cellular Mechanisms that Govern Sleep and Wakefulness**

<table>
<thead>
<tr>
<th>BRAINSTEM NUCLEI RESPONSIBLE</th>
<th>NEUROTRANSMITTER INVOLVED</th>
<th>ACTIVITY STATE OF THE RELEVANT BRAINSTEM NEURONS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wakefulness</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholinergic nuclei of pons–midbrain junction</td>
<td>Acetylcholine</td>
<td>Active</td>
</tr>
<tr>
<td>Locus coeruleus</td>
<td>Norepinephrine</td>
<td>Active</td>
</tr>
<tr>
<td>Raphe nuclei</td>
<td>Serotonin</td>
<td>Active</td>
</tr>
<tr>
<td>Tuberomammillary nuclei</td>
<td>Histamine</td>
<td>Active</td>
</tr>
<tr>
<td>Lateral hypothalamus</td>
<td>Orexin</td>
<td>Active</td>
</tr>
<tr>
<td><strong>Non-REM sleep</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholinergic nuclei of pons–midbrain junction</td>
<td>Acetylcholine</td>
<td>Decreased</td>
</tr>
<tr>
<td>Locus coeruleus</td>
<td>Norepinephrine</td>
<td>Decreased</td>
</tr>
<tr>
<td>Raphe nuclei</td>
<td>Serotonin</td>
<td>Decreased</td>
</tr>
<tr>
<td><strong>REM sleep</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cholinergic nuclei of pons–midbrain junction</td>
<td>Acetylcholine</td>
<td>Active (PGO waves)</td>
</tr>
<tr>
<td>Raphe nuclei</td>
<td>Serotonin</td>
<td>Inactive</td>
</tr>
<tr>
<td>Locus coeruleus</td>
<td>Norepinephrine</td>
<td>Inactive</td>
</tr>
</tbody>
</table>
Consciousness and Coma


Table 18–1. Glasgow Coma Scale. A practical method of assessing changes in level of consciousness, based on eye opening and verbal and motor responses. The response can be expressed by the sum of the scores assigned to each response. The lowest score is 3, and the highest score is 15.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Examiner's Test</th>
<th>Patient's Response</th>
<th>Assigned Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eye opening</td>
<td>Spontaneous</td>
<td>Opens eyes on own.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Speech</td>
<td>Opens eyes when asked to do so in a loud voice.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>Opens eyes when pinched.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>Does not open eyes.</td>
<td>1</td>
</tr>
<tr>
<td>Best motor response</td>
<td>Commands</td>
<td>Follows simple commands.</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>Pulls examiner’s hand away when pinched.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>Pulls a part of body away when pinched.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>Flexes body inappropriately to pain (decorticate posturing).</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>Body becomes rigid in an extended position when pinched (decarbrate posturing).</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Pain</td>
<td>Has no motor response to pinch.</td>
<td>1</td>
</tr>
<tr>
<td>Verbal response (talking)</td>
<td>Speech</td>
<td>Carries on a conversation correctly and tells examiner where and who he or she is and the month and year.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Speech</td>
<td>Seems confused or disoriented.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Speech</td>
<td>Talks so examiner can understand words but makes no sense.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Speech</td>
<td>Makes sounds examiner cannot understand.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Speech</td>
<td>Makes no noise.</td>
<td>1</td>
</tr>
</tbody>
</table>

Slightly modified and reproduced, with permission, from Rimel RN, Jane JA, Edlich RF: Injury scale for comprehensive management of CNS trauma. JACEP 1979;8:64.

Figure 18–2. Lesions that cause coma or loss of consciousness.