The Anatomy of Sea Turtles

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Illustrated by Dawn Witherington
NERVOUS SYSTEM

Nervous System

The brain or central nervous system (CNS) of sea turtles is longitudinally arranged along the midline of the skull (Fig. 187). The brain is housed in a tubular braincase, composed anteriorly of the following bones: ethmoid, epiotic, prootic, opisthotic, basisphenoid, laterosphenoid, and otic (Figs. 26 and 30). Posteriorly it is completed by the basioccipital, exoccipital, and supraoccipital. It is roofed by the parietal and frontal bones (Fig. 25).

Two tissue layers, the meninges, cover the brain.

The outer meninx (singular) is the tough dura mater. A more delicate leptomeninx (sometimes termed the pia mater) lies directly on the brain's surface (Fig. 187). There are both subdural (beneath the dura mater) and epidural (above the dura mater) spaces within the brain case. Epimeningeal veins occupy some of the epidural space. The brain is bathed in clear cerebral spinal fluid produced by the tela choroidea, a vascular region of the brain (Fig. 187).

Figs. 187a and 187b. Exposed brain and cut meninges. The anterior and posterior extent of the dura mater and a vascular portion of the leptomeninges (= pia mater) are seen in this exposed loggerhead brain. In life, both meninges would envelop the brain.
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Traditionally, the brain (Fig 189) is described by three regions that are initially demarked during development: the **forebrain**, **midbrain**, and **hindbrain**. The following combinations of external and internal landmarks roughly identify these divisions. The forebrain extends from the nose to the posterior cerebrum. The midbrain extends from the eye to the posterior aspect of the optic lobes. The hindbrain extends from the ear to the posterior cerebellum. These regions, in turn, are subdivided topographically and/or histochemically into principal divisions: **telencephalon** and **diencephalon** of the forebrain, **mesencephalon** of the midbrain, **metencephalon** and **myelencephalon** of the hindbrain (Fig. 189).

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**Fig. 188.** Parasagittal section of the brain and airways. The section though this green turtle head shows the tight epidural space and the more voluminous subdural space surrounding the brain. Because this cut is to the right of the midline, the cerebral ventricles and part of the cerebellar ventricle can be seen. The nasopharyngeal duct, part of the respiratory system, can be seen passing from the olfactory sacs to the internal choane.
Figs. 189a and 189b. Leatherback brain showing major regions and landmark structures. The brain is demarcated into its major regions and principal divisions.

The divisions of the brain and their major components are as follows.

**Telencephalon:** cranial nerve I, (olfactory nerve), olfactory bulbs, cerebral hemispheres, lateral ventricles.

**Diencephalon:** hypothalamus, thalamus, infundibulum and pituitary, pineal, optic chiasma, cranial nerves II-III (optic and oculomotor nerves).

**Mesencephalon:** optic lobes, third ventricle, cerebral aqueduct, cranial nerve IV (trochlear nerve).

**Metencephalon:** cerebellum, anterior part of medulla, fourth ventricle, cranial nerves V-X (trigeminal, abducens, facial, statoaccoustic, glossopharyngeal, and vagus, respectively).

**Myelencephalon:** most of medulla, cranial nerves XI-XII (spinal accessory and hypoglossal).
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The brain forms as a tube during sea turtle development. It then undergoes considerable regional specialization, torsion, and expansion to form the structures found in adult turtles. Remnants of the nerve tube cavity persist as the lateral ventricles of the cerebral hemispheres, the third ventricle and cerebral aqueduct, and the fourth ventricle of the cerebellum and medulla (Fig. 188).

Most of the cranial nerves arise ventrally and laterally, and are easiest to observe when the brain is removed (Figs. 189-191).

Figs. 190a and 190b. Ventral surface of a ridley brain. This brain is viewed from the posterior aspect of the skull and is reflected anteriorly and dorsally. Only the optic and olfactory nerves are still attached to the head. The cut pituitary can be seen in the sella tursica in the floor of the brain case, while the infundibulum is removed with the rest of the brain.
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Figs. 191a and 191b. Ventrolateral view of a loggerhead brain without the olfactory nerves. The size of the brain of mature and maturing turtles is remarkably small for the body size. This brain from a 72 cm SCL loggerhead is just less than 10 cm long.

Specific landmarks identifying the parts of the brain differ slightly across cheloniids and, even more when compared with Dermochelys (Figs. 192-202). Among the cheloniids, the brain is closest to the skull roof in Lepidochelys kempii. It is furthest from the skull roof in adult Caretta caretta and Eretmochelys imbricata. Scalation patterns on the lateral head and the position of the ear provide species-specific landmarks for some structures (Fig. 192). The brain of the leatherback is housed deeply, except for the pineal, which extends dorsally in a cartilaginous cone-like chamber adjacent to the pink spot on the middorsal surface of the head (Figs. 201-202).
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Fig. 192. Brain landmarks for marine turtles. Overlays of brain positions are shown for 5 species. The position of the head scales, the eye, and the ear provide some reference points for identifying the position of the brain, which varies in dorsal-ventral position with species. The brain position of the leatherback, in this drawing, is based more upon the shape of the braincase because of the poor condition of all leatherback brains examined. The landmarks shown are accurate for large turtles, however the brains of hatchlings and juveniles are disproportionately larger.
Figs. 193a and 193b. Parasagittal view of a loggerhead head. The brain, airways, oral cavity, and esophagus are exposed. The interorbital septum is intact and the optic nerve is seen passing through its foramen. There is a large subdural space, above the cerebrum and olfactory nerve, in loggerheads.
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Figs. 194a and 194b. Parasagittal cut through the head of a subadult loggerhead, close up. The positions of the brain, its parts, and the large subdural space containing cerebral spinal fluid relative to the dorsal skull are clear. The lateral ventricles are not exposed by this cut; the third ventricle and cerebral aqueduct are seen ventral to the optic lobe. The cerebellar ventricle is part of the 4th ventricle. Ventrally, the infundibulum leads to the pituitary (dorsal to the palate). The pituitary is housed in a bony socket, the sella turcica.
Figs. 195a and 195b. Parasagittal cut through an immature green turtle head. This view shows the spatial relationships of the CNS to other head structures. The brain is located close to the dorsal skull. The cut removed part of the interorbital septum so that the eye muscles are exposed dorsal to the palate and posterior to the olfactory sac. The intact olfactory nerve can be seen extending to the olfactory sac.
Figs. 196a and 196b. Parasagittal cut through a subadult green turtle head (close up). The brain is located very close to the dorsal skull in green turtles. The lateral ventricles are just exposed by the parasagittal cut; part of the cerebral aqueduct is seen within and ventral to the optic lobe. The cerebellar ventricle, part of the fourth ventricle, is exposed.
Figs. 197a and 197b. Parasagittal cut through the head of an immature Kemp’s ridley. The anterior half of the brain is flexed slightly dorsally in this species.
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Figs. 198a and 198b. Parasagittal cut near the midline of a juvenile Kemp's ridley turtle (close up). The cerebral hemispheres are closer to the skull roof bones in ridleys than in the other cheloniid species. The cut was positioned so that the optic chiasma (at the posterior end of the optic nerve) was bifurcated. The pituitary is not seen in this section.
Figs. 199a and 199b. Parasagittal section through a hawksbill head. The brain is not as closely positioned to the skull roof in hawksbills as in other cheloniids. The pineal gland is clearly exposed in this dissection. Other parts of the brain are partially decomposed so their structure is slightly collapsed. The partial collapse makes the spinal meninges more distinct. The trachea and oral cavities are clearly exposed. The esophagus is collapsed in this specimen.
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Figs. 200a and 200b. Parasagittal cut near the midline of a subadult hawksbill turtle (close up). The subdural space is relatively large in the hawksbills. In this dissection, the medulla was sliced so a portion is displaced ventrally to an abnormal position. Structures from other systems are clearly exposed in this dissection. The tongue, glottis, and trachea are shown with the supporting hyoid skeletal structure.
Figs. 201a and 201b. Midsagittal section of an adult leatherback head. The braincase is largely cartilaginous around the dorsal and anterior aspects of the forebrain and midbrain. The parietal and frontal skull bones cover this cartilaginous portion of the braincase. The brain is partially decomposed and has collapsed. The extremely hypertrophied salt gland is visible where a portion extends medial to the eye.
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Figs. 202a and 202b. A midsagittal cut of an adult leatherback head (close up). The brain is partially decomposed, however the pineal is still attached to the skull roof dorsally and the infundibulum remains attached to the pituitary ventrally. The largely cartilaginous positions of the braincase are typical of leatherbacks.
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The relative sizes of parts of the brain vary through ontogeny. The brain is proportionately larger in hatchlings and juveniles than in subadults and adults (Fig. 203). The olfactory nerves become proportionately longer and the cerebral hemispheres, optic lobes, and cerebellum are proportionately smaller in subadult and adult turtles.

Peripheral Nerves -- The spinal nerves form the peripheral nervous system. They leave the spinal cord as paired dorsal and ventral nerve roots and exit the vertebrae via intervertebral foramina. The dorsal nerves are composed of somatic and visceral sensory nerve fibers and may contain motor fibers as well; the ventral roots are generally composed of both somatic and visceral motor nerve fibers. These nerves function as the autonomic nervous system. The autonomic nervous system of turtles has both sympathetic and parasympathetic components. However, these are not anatomically segregated as "thoracolumbar" sympathetic and "craniosacral" parasympathetic regions as in mammals. Hence, nerves arising along the length of the spinal cord may have both sympathetic and parasympathetic components.

Two networks of interconnected spinal nerves, the brachial plexus and sacral (= lumbosacral) plexus, are associated with control of the limbs. They are poorly described in the literature on sea turtles. In cheloniids they are formed by ventral nerve roots and their branches. The brachial plexus (Figs. 204-206) arises at the level of cervical vertebrae VI-VIII in sea turtles. These cervical nerves form a complex network innervating the pectoral, arm (humerus), and flipper muscles (Table 1) as well as sending branches to the respiratory muscles. Most muscles receive innervation from more than one branch of the plexus. A ventral branch of nerve VI makes a large contribution to the median nerve. Nerves VII & VIII give rise to the inferior brachial nerve, which immediately divides to form the superficial radial nerve and the deep radial nerve to the anterior shoulder and dorsal flipper. Next, the supracoracoideus, subscapular, and ulnar nerves arise and travel to those pectoral muscles and the ventral side of the flipper. The deltoideus nerve arises primarily from nerves (VI and VII).

There are no descriptions available for the brachial and sacral plexuses of Dermochelys.
Fig. 204. The brachial plexus of a hawksbill. The brachial plexus arises from the most posterior cervical vertebrae. Its nerves innervate the pectoral muscles and flippers. The carapace and connective tissues have been removed to provide this posterodorsal view of the brachial plexus. Its 3 rami arise from the intervertebral foramina and immediately undergo a series of divisions and interconnections to form the nerves of the brachial plexus.

Fig. 205. Branch of the brachial plexus of a hawksbill (ventral view). The inferior brachial nerve of the brachial plexus travels along the ventral and anterior aspect of the flipper. The ulnar nerve is seen branching off. The other main nerve of the arm, the median nerve, is deep to the inferior brachial nerve and cannot be seen.
The sacral plexus (Figs. 207-208) arises as 4 (sometimes 5-6) rami (branches) from spinal nerves XVII-XXI, located on the last dorsal and sacral vertebrae. These nerves interconnect and subdivide several times as they send nerves to the inguinal, pelvic, and hind leg muscles (Table 1). Many muscles receive multiple innervations. The more posterior nerves roots give rise to the obturator nerve, going to the ventral pelvic muscles, and the ichiadicus nerve, which runs medial to the ilium and then divides to form the peroneal and sciatic nerves. The anterior two nerve roots interconnect provide major innervations (via crural, femoral, and tibial nerves) to the inguinal muscles, thigh adductors, and leg extensors.

**Fig. 206.** Diagram of the right brachial plexus based upon cheloniids. The three roots of the brachial plexus and their interconnections to the flipper and shoulder musculature are shown. Branches to ventral muscles go to the pectoralis, biceps superficialis, biceps profundus, and the deltoideus. Larger branches are shown as thicker lines. The most distal branches are not shown.
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Fig. 207. The sacral plexus of a hawksbill. This lateral view of the sacral plexus shows four roots giving rise to the interconnecting nerves that innervate the hind limb and respiratory muscles of the inguinal region. The most posterior branch of the sacral plexus extends posteriorly, medial to the ilium, and then travels along the posterior hind limb. It gives rise to the sciatic, tibial and peroneal nerves that innervate many of the distal hind limb muscles.

Fig. 208. Diagram of the right sacral plexus (lateral view) based upon chelonids. The roots of the sacral plexus and their interconnections to the pelvic, inguinal, and hind limb musculature are diagrammed. Thicker lines represent larger branches. The most distal branches are not shown. The lone branch medial to the ilium is the obturator nerve to the ventral pelvic muscles.
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#### Brachial Plexus

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Innervations</th>
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<tbody>
<tr>
<td>Inferior brachial nerve</td>
<td>Tractor radii</td>
</tr>
<tr>
<td>Superficial radial nerve</td>
<td>Latissimus dorsi</td>
</tr>
<tr>
<td>Deep radial nerve</td>
<td>Latissimus dorsi, Supracoracoideus, Testoscapularis</td>
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<tr>
<td>Supracoracoideus nerve</td>
<td>Supracoracoideus, Pectoralis major, Biceps brachii (profundus and superficialis)</td>
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<tr>
<td>Subscapular nerve</td>
<td>Subscapularis</td>
</tr>
<tr>
<td>Axillary (= Deltoideus) nerve</td>
<td>Deltoideus (ventral parts), Brachialis</td>
</tr>
<tr>
<td>Radial nerve</td>
<td>Latissimus dorsi, Teres major, Tractor radii, Triceps brachii (humeral head), Respiratory muscles</td>
</tr>
<tr>
<td>Ulnar nerve</td>
<td>Deltoideus (dorsal head), Latissimus dorsi, Subscapularis, Extensor radialis, Medial flipper muscles, Extensors of digits</td>
</tr>
<tr>
<td>Median nerve</td>
<td>Coracobrachialis, Flexor carpi ulnaris, Flexors of digits</td>
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#### Sacral Plexus

<table>
<thead>
<tr>
<th>Nerve</th>
<th>Innervations</th>
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<tbody>
<tr>
<td>Crural nerve</td>
<td>Inguinal muscles, Thigh protractors (Triceps femoris complex)</td>
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<tr>
<td>Femoral nerve</td>
<td>Puboischiofemoralis, Dorsal hip muscles</td>
</tr>
<tr>
<td>Obturator nerve</td>
<td>Ventral hip muscles, Caud-ilioformoralis, Ischirotrocantericus, Adductor femoris, Flexor tibialis (internus &amp; externus), Pubotibialis complex</td>
</tr>
<tr>
<td>Ischiadicus nerve</td>
<td>Posterodorsal hip muscles</td>
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<tr>
<td>Sciatic nerve</td>
<td>Gastrocnemius, Iliofemoralis, Ventrolateral foot extensors</td>
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<tr>
<td>Peroneal nerve</td>
<td>Triceps femoris (ambiens, femorotibialis, Iliotibialis), Gastrocnemius, Foot flexors</td>
</tr>
<tr>
<td>Tibial nerve</td>
<td>Flexor tibialis (internus &amp; externus), Ambiens, Pubotibialis inguinal muscles, Foot extensors</td>
</tr>
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**Table 1.** Major innervations by the nerves of the brachial and sacral plexuses. Nerves are named using mammalian nerve terminology.