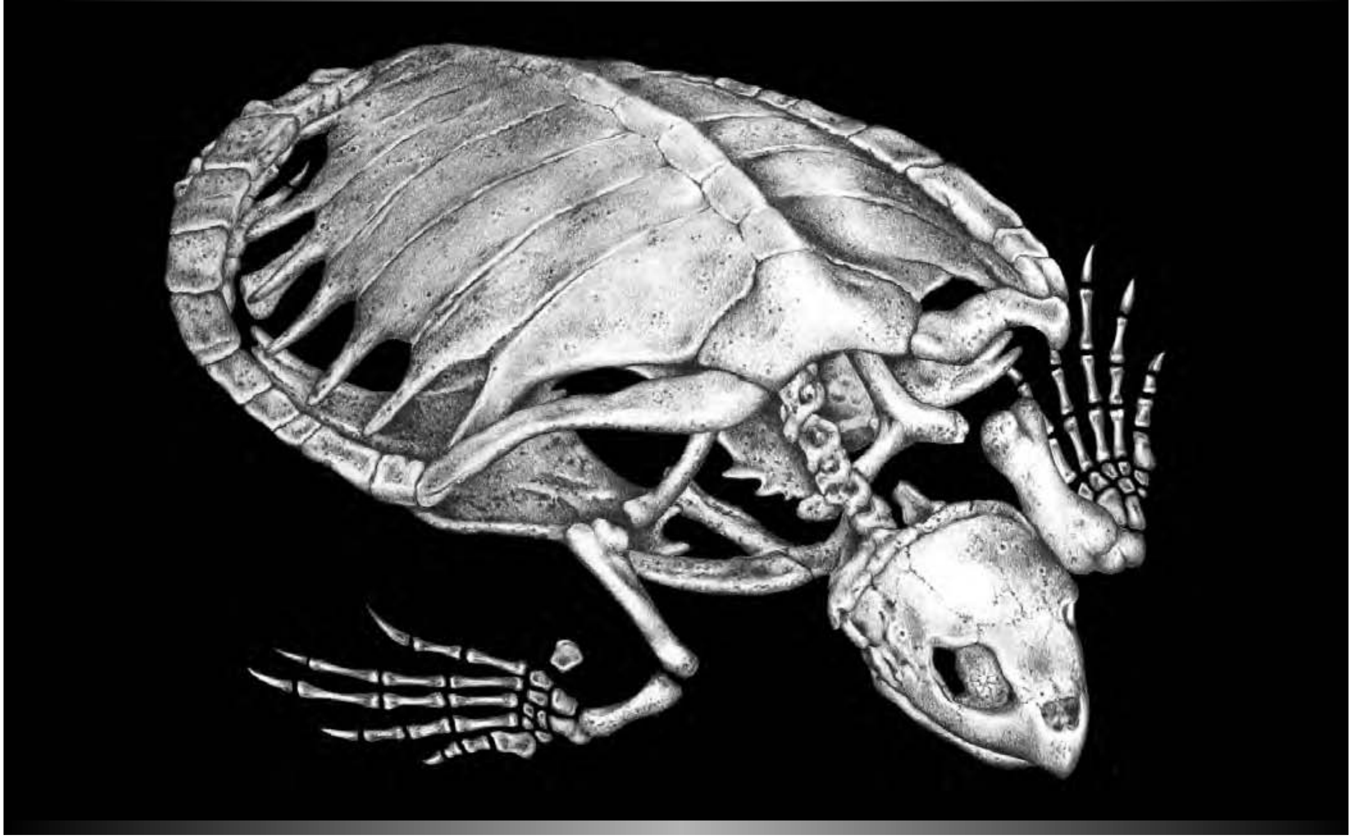
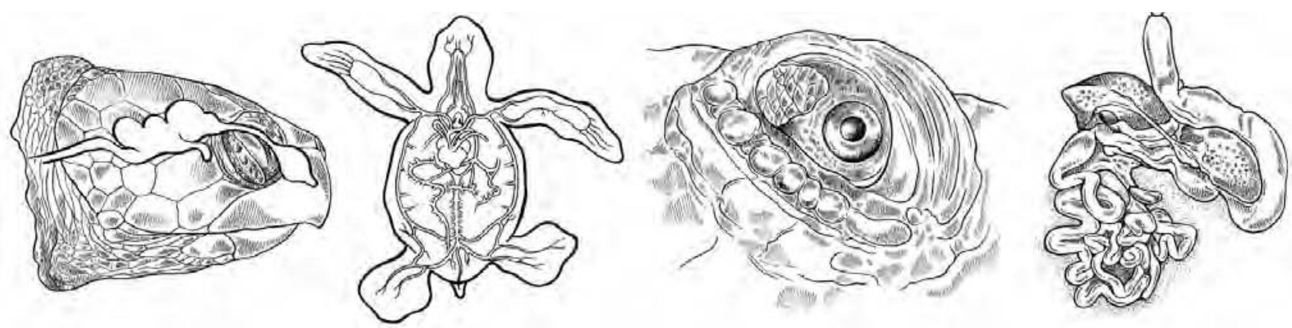
NOAA Technical Memorandum NMFS-SEFSC-470

The Anatomy of Sea Turtles





Jeanette Wyneken, Ph.D.

Illustrated by Dawn Witherington

December 2001

U. S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Fisheries Science Center, 75 Virginia Beach Drive, Miami, FL 33149

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THE ANATOMY OF SEA TURTLES

by

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NOTICE

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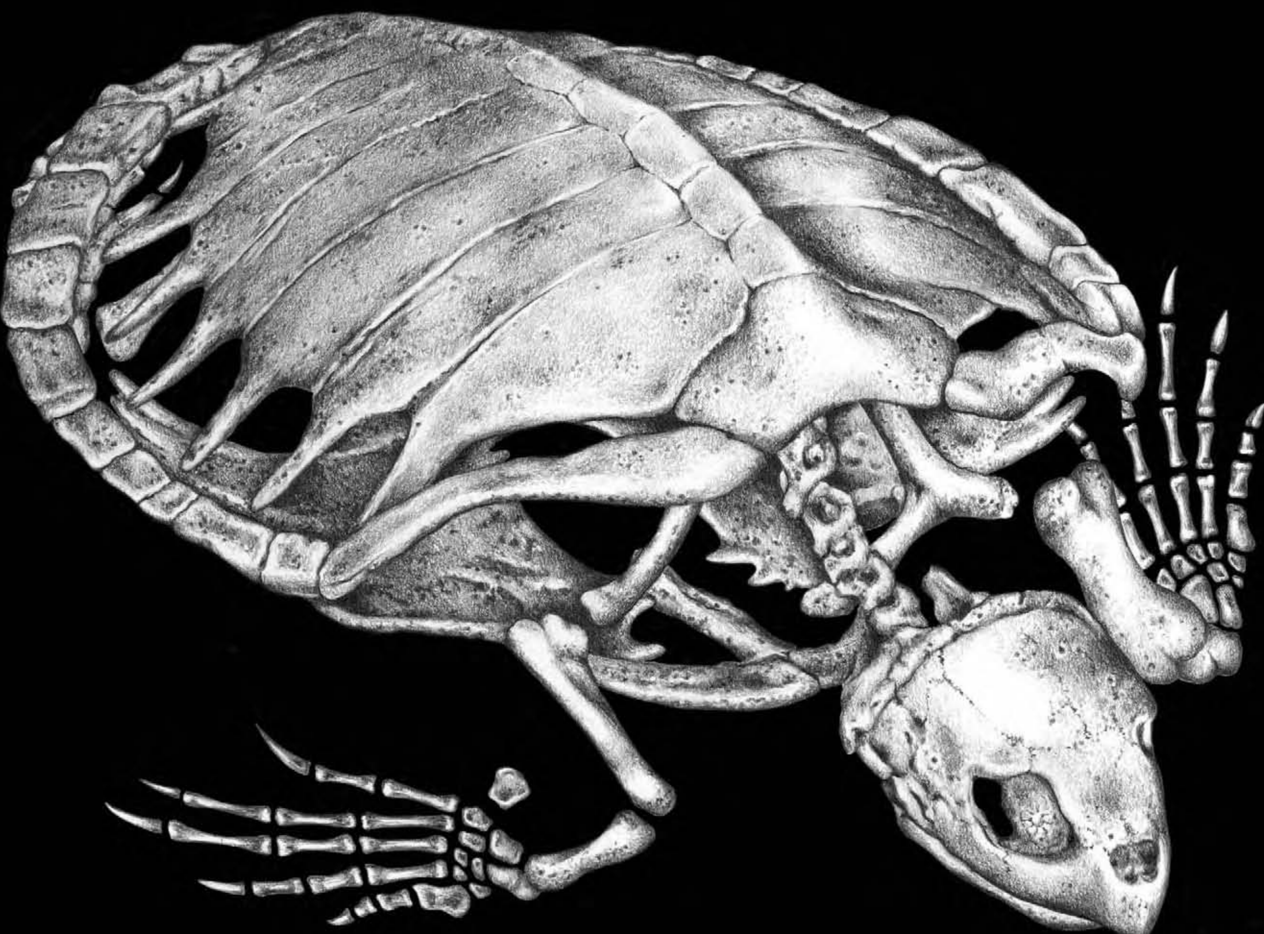

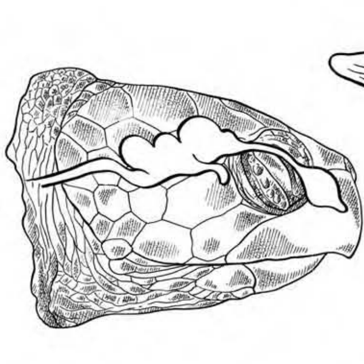

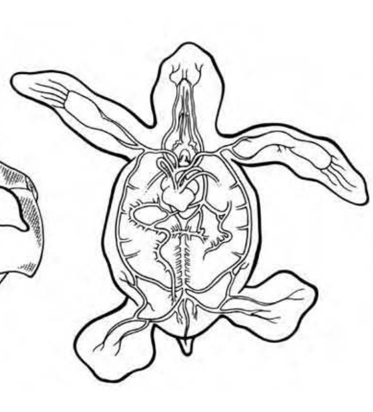

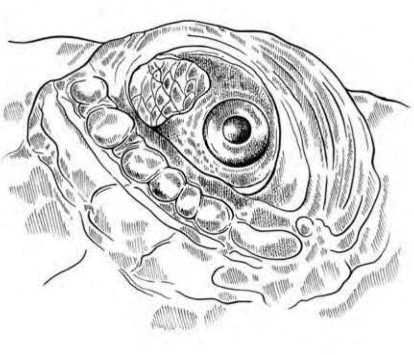

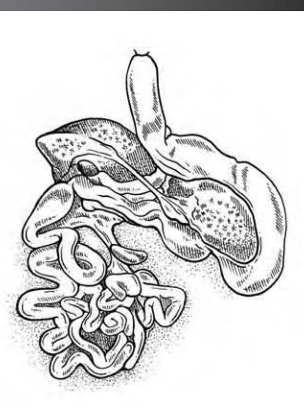

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Illustrated by Dawn Witherington

The need for an up-to-date guide to the anatomy of sea turtles became clear toward the end of the 1900s. Increasing numbers of individuals developed the interest, talents, and techniques to study the biology of sea turtles, contend with their illnesses and injuries, and address the nature of sea turtle mortalities. This manual was written in response to these needs and was designed to be accessible to a variety of users. It provides a fundamental background, reference photos of normal anatomy, and diagrams to guide novice or professional biologists, stranding personnel, and veterinarians. Species identification, standard dissection techniques, standard measurements, and basic anatomy are covered with a diverse audience in mind. While this manual does not serve as a necropsy guide, it may serve as a reference when conducting necropsies. It is designed particularly with the understanding that many users will be working with it in the field or under less-than-ideal conditions. *The Anatomy of Sea Turtles* is organized so that it can be used either as a guide to dissection or as an anatomical reference to species identification, standard methods, and dissection (pp. 1-42) or as an anatomical reference to sea turtle structures or systems.

Most of the photos in this guide are by the author. However, several individuals contributed pictures that enhanced the quality of the manual. These include Larisa Avens, George Balazs, Peter Bennett, Beth Chittick, Larry Crowder, Bill Dailey, Sheryan Epperly, Craig Harms, Eve Haverfield, Bruce Homer, Chris Johnson, Ursula Keuper-Bennett, Joanne Braun McNeill, Anne Meylan, David Owens, Denise Parker, Donna Shaver, Tom Smoyer, J. Vasconcelos, and Wendy Teas. Access to specimens, dissection assistance, and/or comments on drafts of the manual were provided by George Balazs, Ruth Boettcher, Mike Bresette, Brian Cousin, Lisa Csuzdi, Nancy DiMarco, Sheryan Epperly, Kristin Fick, Allen Foley, Jerris Foote, T.H. Frazzetta, Ellis Greiner, Craig Harms, Kristin Hart, Hector Horta, Elliott Jacobson, Chris Johnson, Ken Kardong, Jennifer Keller, Kate Kelso, Greg Lewbart, Peter Lutz, Charles Manire, Carol Hardy McFadden, Joanne Braun McNeill, Nancy Mette, Jeff Miller, Debra Moore, Steve Morreale, David Owens, Joe Parsons, Robert Prescott, Peter C. H. Pritchard, Tony Redlow, Anders Rhodin, Kurt Rusenko, Cheryl Ryder, Michael Salmon, Karrie Singel, Melissa Snover, Trish Sposato, Fred Steinberg, Kelly Stewart, Wendy Teas, Mike Walsh, James Weege, Pat Wells, Donna Weyrich, Dale Wilke, Blair Witherington, Wayne Witzell, and Larry Wood. The Cayman Turtle Farm, Chelonian Research Institute, Florida Fish and Wildlife Conservation Commission, Gumbo Limbo Environmental Center, Harbor Branch Oceanographic Institution, The Marinelife Center of Juno Beach, Mote Marine Laboratory, Philadelphia Academy of Sciences, National Marine Fisheries Service-Beaufort Laboratory, National Marine Fisheries Service-Miami Laboratory, North Carolina Wildlife Commission, University MRI, Inc., and the U.S. Fish and Wildlife Service provided access to specimens and logistical help.

Many individuals provided thoughtful discussions during the preparation of this manual and *The Anatomy of Sea Turtles* video. The quality and coverage of *The Anatomy of Sea Turtles* was greatly improved by their attention and suggestions.

This manual's illustrations and layout are by Dawn Witherington.

PHOTOGRAPHIC CREDITS

The following people contributed photos that enhanced the quality of this manual. Where known, turtle tag numbers or their identifications are also provided.

Ursula Keuper-Bennett and Peter Bennett: Figs. 11, Tutu; Fig. 20, Ake

Beth Chittick: Fig. 145

Larry Crowder: Fig. 141

Bill Dailey: Fig. 21

Craig Harms: Figs. 81, 161, 187

Bruce Homer: Fig. 176

Chris Johnson: Figs. 9, 17

Heather Kalb and David Owens: Fig. 234

Joanne Braun McNeill: Fig. 15

Anne Meylan: Fig. 77

Peter C. H. Pritchard: Fig. 189

Tom Smoyer (Harbor Branch Oceanographic Institution): Figs. 10, 12, 13, 14, 19, 31, 45, 58, 70, 71, 90, 106, 229

J. Vasconcelos: Fig. 24

TABLE OF CONTENTS

Anatomical Terminology

There are several terms used here that describe the spatial relationships of structures. Below, these are defined specifically for sea turtles (Figs. 1-2).

Dorsal is toward the top of the shell (the carapace).
Ventral is toward the plastron.
Anterior is toward the head.
Posterior is toward the tail.

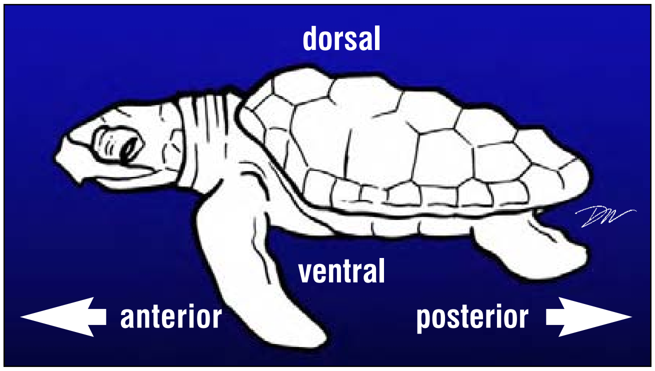


Fig. 1. *Anatomical terminology.*

Medial is toward the midline.
Lateral is away from the midline, toward the sides.
Proximal is close to the body or the start of a structure.
Distal is away from the body or main structure.
Deep to is underneath a structure

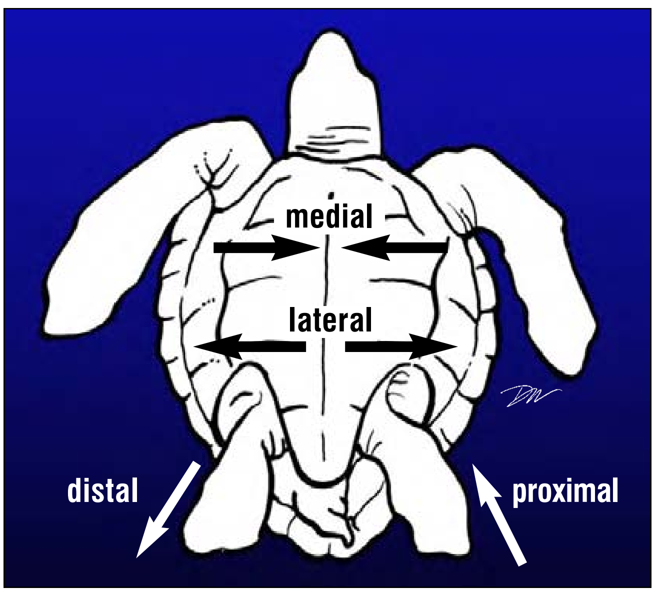


Fig. 2. *Relative anatomical position.*

Characters for Species Identification

Sea turtle identification, from external characters, is based upon the scales on the head, form of the jaws, the number of claws on the feet, and the numbers and arrangement of the plates or scutes on the shell. The scutes of the carapace (the top shell) are numbered from front to back (Fig. 3). The primary scutes (Fig. 4) used as key characteristics are the **marginals**, **laterals (costal)**, **vertebrals**, and **nuchal**, as well as the **inframarginal** or bridge scutes.

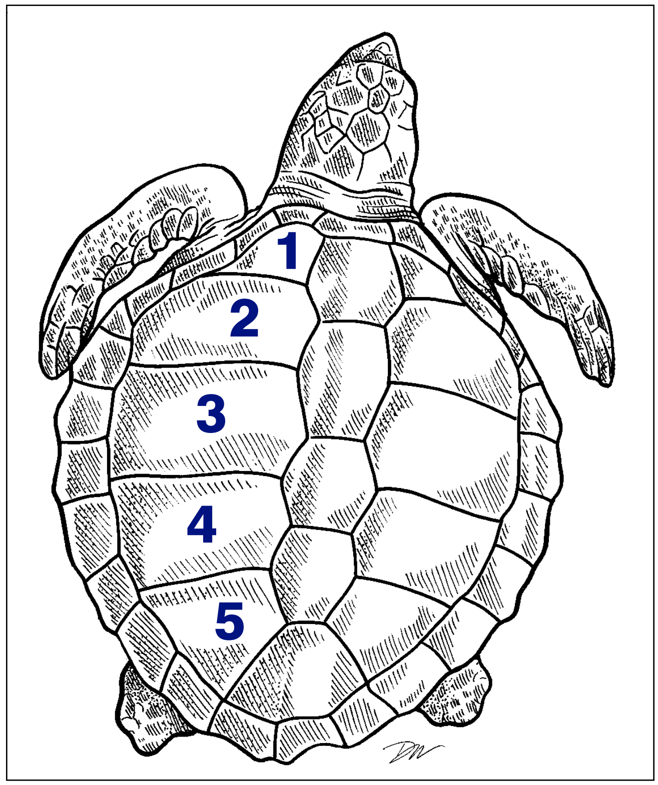


Fig. 3. *Numbering the carapace scutes.*

The bottom shell is the **plastron**. It also has distinct scute patterns, but these are used more often as landmarks for internal structures than for species identification (Fig. 5). From anterior to posterior, the **intergular** scute is closest to the neck, then (in order) are the **gular**, **humeral**, **pectoral**, **abdominal**, **femoral** and the **anal** scutes. Some individuals have a single unpaired **interanal scute** that is found between or posterior to the anal scutes.

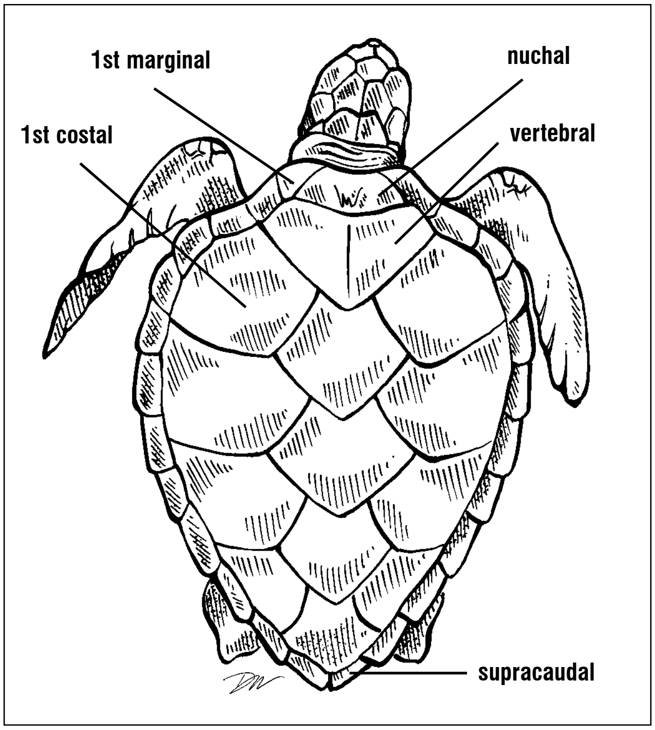


Fig. 4. *Scutes of the carapace.*

Scutes of the carapace and plastron. The lateral scutes are also known as costals or pleurals. The last marginal scutes on each side are termed supracaudals or postcentrals (Fig. 4). The scutes between the plastron and the carapace are the

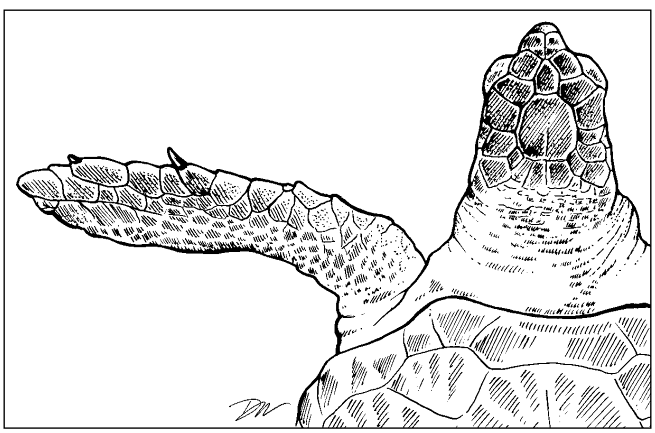


Fig. 6. *Position and numbering of claws.*

inframarginals (Fig. 5). While the number of inframarginals is somewhat variable, the most common count is often listed as a key characteristic.

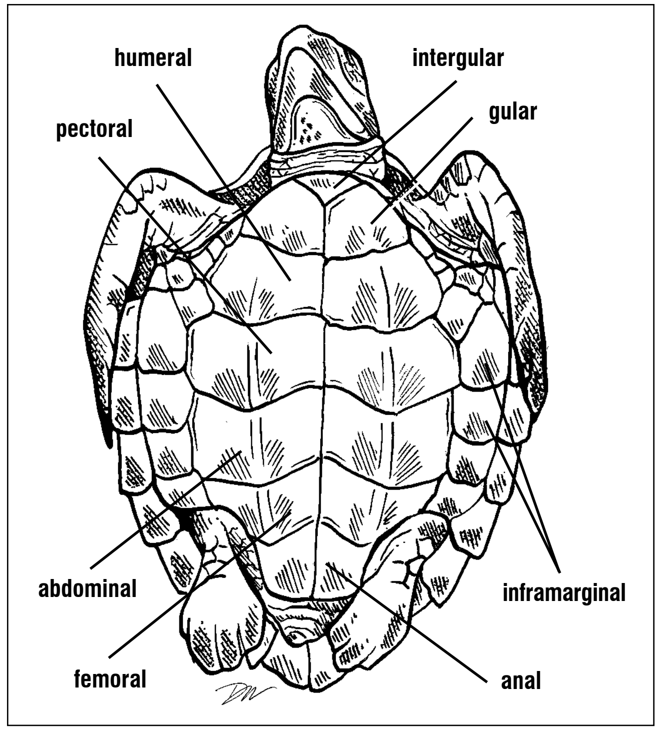


Fig. 5. *Scutes of the plastron and bridge.*

Cheloniidae (hard-shelled sea turtles) are characterized by the scales on the head, carapace, and inframarginal scute patterns and numbers, as well as the numbers of claws on the flippers (Figs. 6-7). Most species have 2 claws. Claw I is

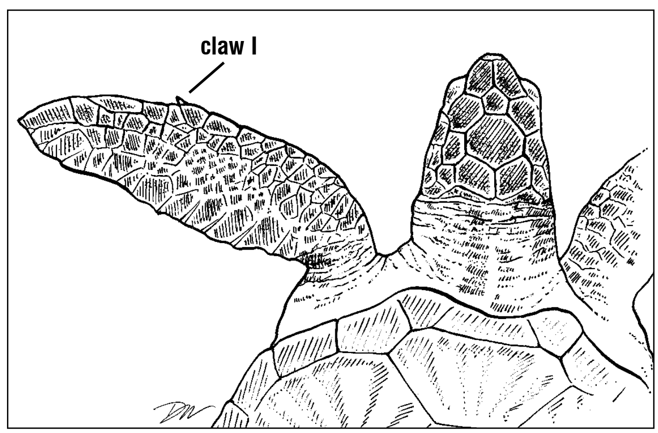


Fig. 7. *The single claw occurs on the first digit. No claw forms on the second digit.*

usually larger than claw II and becomes strongly curved in adult males. The number of claws on the front and hind limbs is the same.

Leatherbacks lack both distinctive head scales as adults and have minimal keratin covering on the jaws. The hard-shelled sea turtles have keratinous scales on the dorsal and lateral head that are used in identification of species (Fig. 8). The **prefrontal** scales occur in pairs. One or more **supernumerary** scales may occur along the midline and separate the pairs. Other head scales (**supraocular**, **postocular**, **frontal**, **frontoparietal**, **parietal**, **interparietal**, **temporal**, and **tympanic scales**) may vary slightly in form but not in position relative to one another. In some cases, individual variations in the head scales can be used to identify individual turtles.

A key to the species is found on the next page. It summarizes species identification using external characteristics.

Several internal bony and jaw (rhamphotheca) characters also may be used for species identification. These are described later (Species Identification from Skulls, pp. 13-25; Rhampotheca Structure, pp. 26-27; Skeletal Anatomy, pp. 50-51).

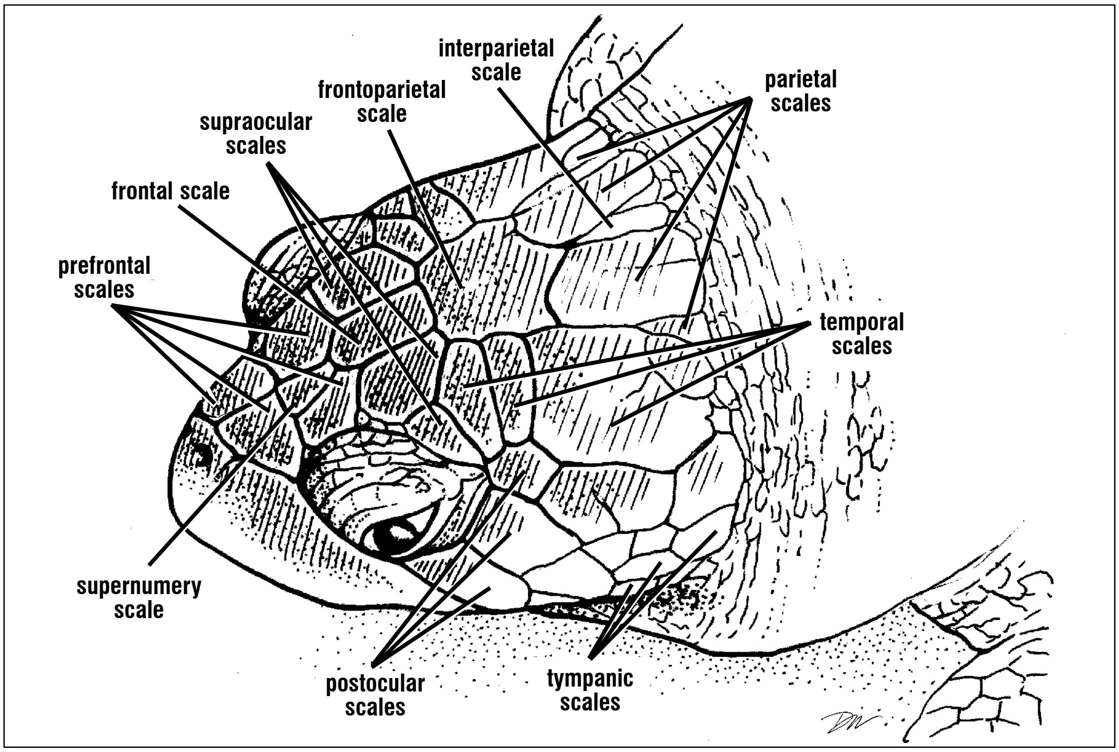
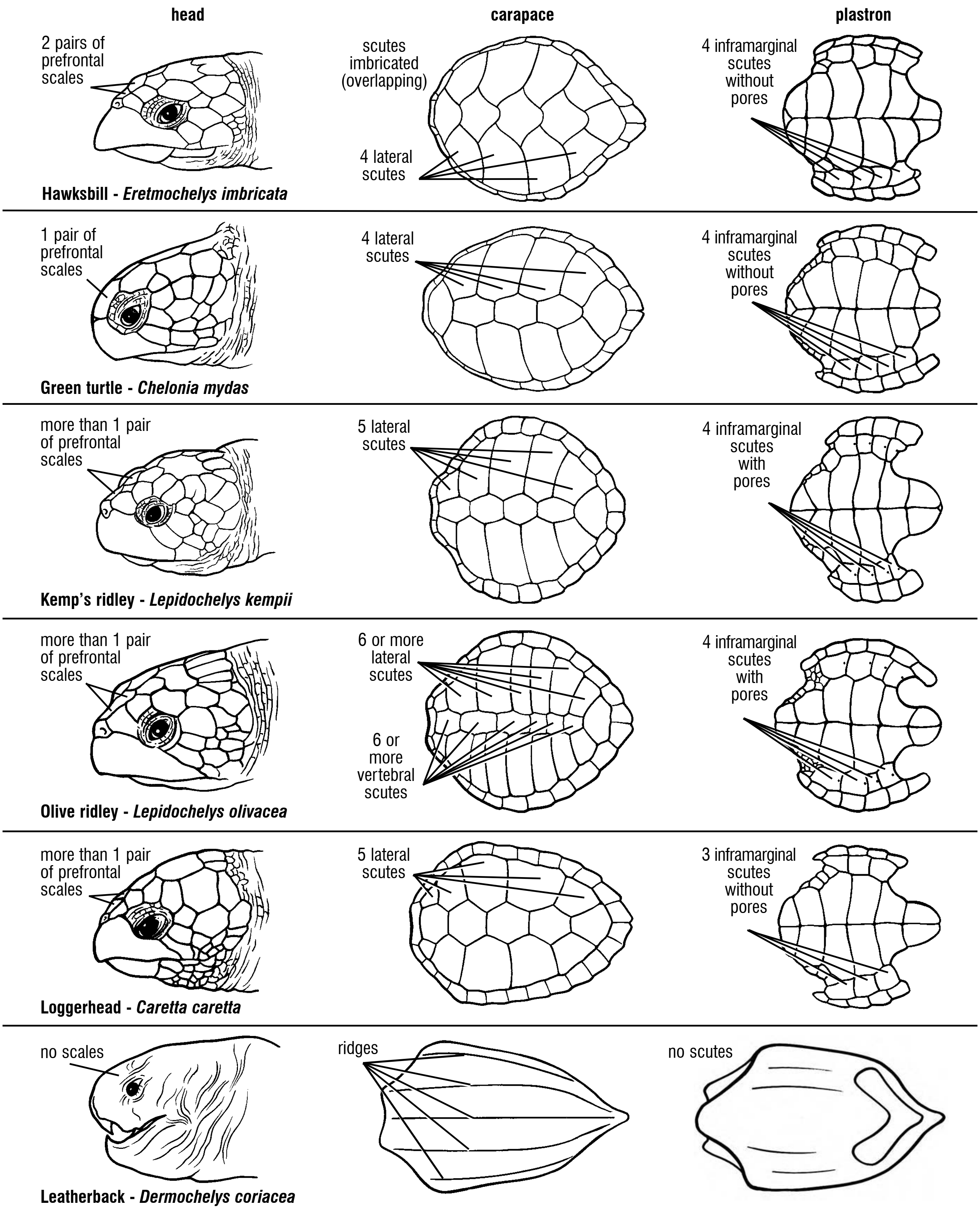


Fig. 8. *Head scales of cheloniid turtles. The major sets of scales used in species identification are the prefrontals. There are often supernumerary scales (multiple extra scales) between the prefrontals. These lack pattern and are usually small. The other labeled scales serve as landmarks.*


head
carapace
plastron
2 pairs of prefrontal scales
scutes imbricated (overlapping)
4 lateral scutes
4 inframarginal scutes without pores
Hawksbill - Eretmochelys imbricata
1 pair of prefrontal scales
4 lateral scutes
4 inframarginal scutes without pores
Green turtle - Chelonia mydas
more than 1 pair of prefrontal scales
5 lateral scutes
4 inframarginal scutes with pores
Kemp's ridley - Lepidochelys kempii
more than 1 pair of prefrontal scales
6 or more lateral scutes
6 or more vertebral scutes
4 inframarginal scutes with pores
Olive ridley - Lepidochelys olivacea
more than 1 pair of prefrontal scales
5 lateral scutes
3 inframarginal scutes without pores
Loggerhead - Caretta caretta
no scales
ridges
no scutes
Leatherback - Dermochelys coriacea

Species Identification

Sea turtles can be separated into the hard-shelled (cheloniid) and the leathery-shelled (dermochelyid) species. There is just one dermochelyid species, the leatherback, *Dermochelys coriacea* (Figs. 9-10). It is black with white speckling. Five dorsal ridges run the length of the carapace, two ridges form the margins, and few ridges occur ventrally. A notch occurs in each side of the upper jaw and the limbs lack claws.

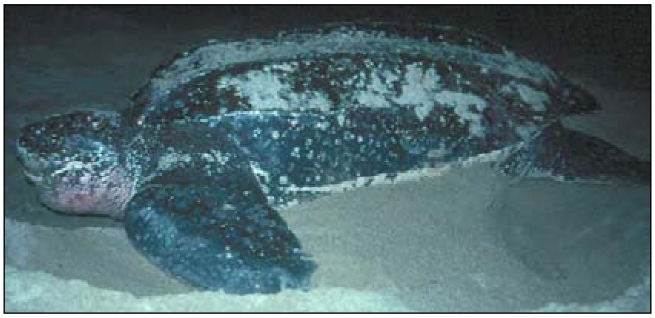


Fig. 9. *Dermochelys coriacea, adult.*

Fig. 10. *Dermochelys coriacea, hatchling.*

The cheloniids can be distinguished from one another by the scales on top of the snout, called the prefrontals and by the scutes on the carapace. The green turtle, *Chelonia mydas* (Figs. 11-13), has one pair of prefrontal scales (Fig. 12). The carapace is smooth with 4 pairs of lateral scutes. Carapace color changes with age. It is black in hatchlings, then turns brown and tan in juveniles, and in adults, it is olive or gray-green, sometimes with speckles of yellow and brown. The plastron is white in hatchlings. It turns creamy yellow, sometimes temporarily pink or gray depending on the population. Adults have a creamy yellow plastron except in the more melanistic green turtles (referred to as black turtles) found in some Pacific waters. The green turtle has one claw on each limb. There are 4 inframarginal scutes on each side and two Rathke's pores, one each in the axillary and inguinal scales (see Glands, pp. 122-123).

Fig. 11. *Chelonia mydas, adult.*

Fig. 12. *Chelonia mydas, juvenile.*

Fig. 13. *Chelonia mydas, hatchling.*

The remaining species have 2 pairs of prefrontal scales (Fig. 8) and, as young, they have keels (ridges) on their shells. The loggerhead, *Caretta caretta* (Figs. 14-17), has a large head and brown carapace with 5, or sometimes 4, lateral scutes. The nuchal scute (the marginal just dorsal to the neck) is in contact with the first lateral scute. In hatchlings, the carapace is brown with various shades of grey (Fig. 14). The plastron of hatchlings is creamy to brown. In juveniles to adults it is creamy and tan. The carapaces of juveniles (Fig. 16) develop streaks of yellow and tan. Sometimes the scutes of juveniles slightly overlap one another at their margins. In adults, there is no overlap of scutes. The carapace is primarily brown with occasional individuals retaining some tans or even black (Fig. 17). The shells of loggerheads often host large epibiont communities. Loggerheads have two claws on each limb.

Fig. 14. *Caretta caretta, hatchling.*

Fig. 15. *Caretta caretta, plastron. Loggerheads often have 3 inframarginals however, this characteristic is variable.*

Fig. 16. *Caretta caretta, immature. Immature loggerheads often have sharp keels on their vertebral scutes and posterior marginal. These recede with larger size and age so that loggerheads found in coastal waters often bear little of or no signs of the keels.*

Fig. 17. *Caretta caretta, adult. The jaws have thick, robust rhampotheca (beak-like structures) for crushing food.*

The hawksbill, *Eretmochelys imbricata*, as a hatchling, is dark mahogany brown on both the carapace and the plastron (Fig. 18). As the turtle grows, the head elongates and the carapace develops a distinctive pattern of yellow, black, tan and brown radiating through the scutes (Fig. 19). This color persists though adulthood. The nuchal scute does not touch the first lateral scute in hawksbills. This distinguishes the hawksbill carapace from the loggerhead pattern. The head of the hawksbill is nearly twice as long as it is wide and has a long narrow beak or **rhamphotheca** (Fig. 20). Hawksbills have two claws on

Fig. 18. *Eretmochelys imbricata hatchling (left) and Caretta caretta hatchling (right). Note that the nuchal scute touches the first lateral in loggerheads but not in hawksbills.*

Fig. 19. *Eretmochelys imbricata, immature. The narrow head and imbricate (overlapping) scutes of the hawksbill are clear.*

Fig. 20. *Eretmochelys imbricata, adult.*

The last two species that occur in U.S. waters are the ridleys (Figs. 21-24). These turtles are mostly gray in color. The Kemp's ridley, *Lepidochelys kempii*, occurs in east coast waters. The olive ridley, *Lepidochelys olivacea* occurs in Pacific and South Atlantic waters (but occasionally strays into tropical North Atlantic regions). The hatchlings of both species are gray-brown.

Fig. 21. *Lepidochelys kempii, adult*

The carapace assumes a nearly round appearance as the turtle grows and the marginal scutes become wide (Fig. 21). There are 4 (sometimes 3) inframarginal scutes. Characteristic pores are found within each inframarginal scute (Fig. 22) in both ridley species. Ridley turtles have two claws on each limb.

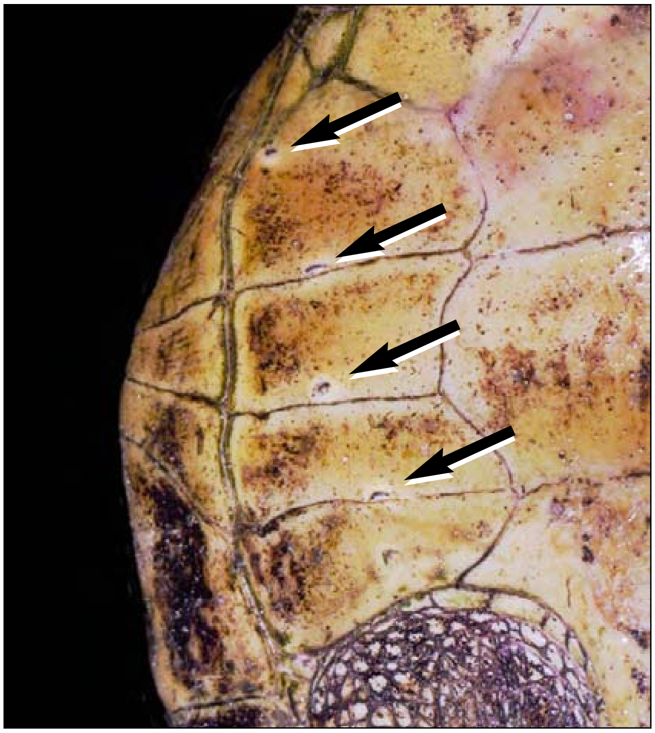


Fig. 22. *Lepidochelys inframarginals with Rathke's pores.*

Kemp's ridley turtles are dark grey to grey-green in color. They have 5 lateral scutes (4-6 is common).

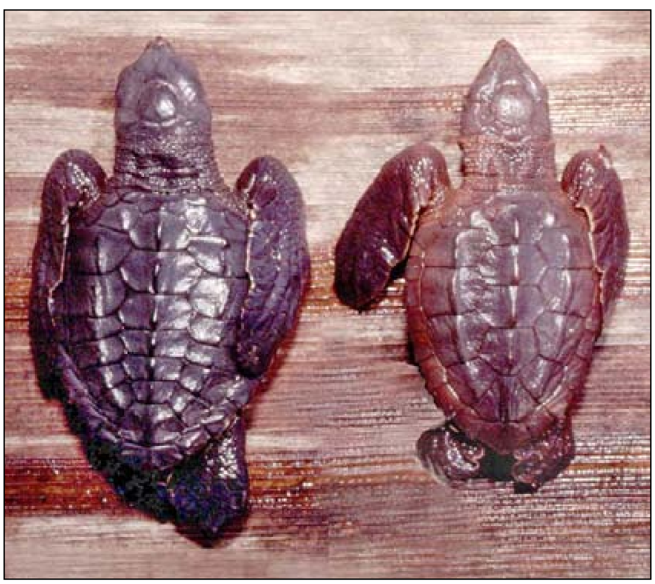


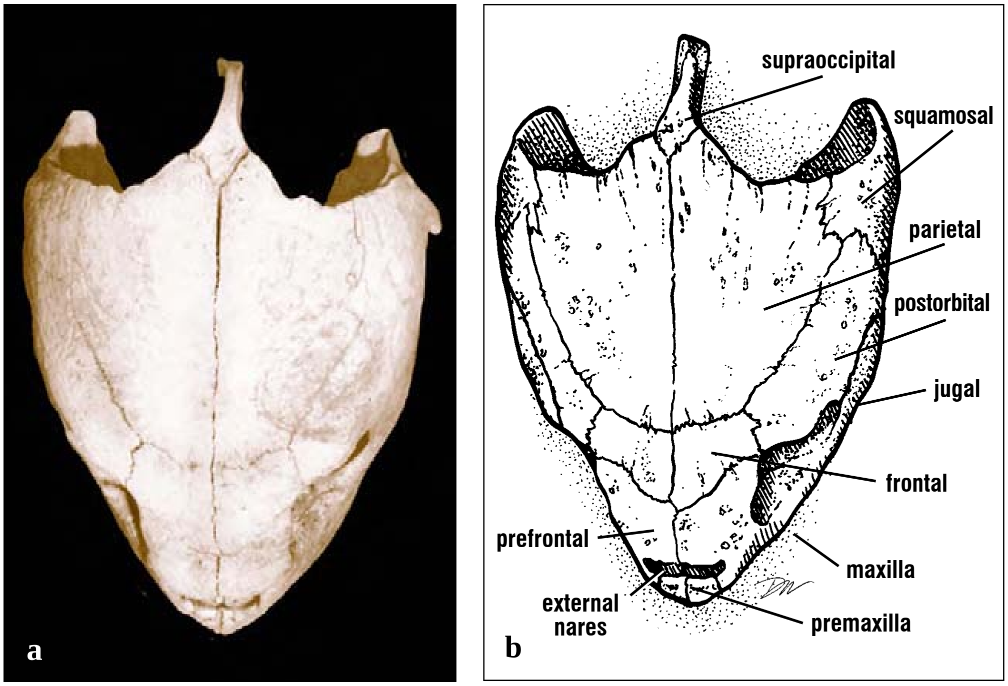
Fig. 23. *Lepidochelys hatchlings. L. kempii (right) has just 5 lateral and vertebral scutes while L. olivacea (left) has 6 or more lateral and vertebral scutes.*

Olive ridleys turtles are dark grey. They typically have more than 6 normally aligned lateral scutes, 6 or more normally aligned vertebral scutes (Fig. 23) and many supraoccular scales (Fig. 24).

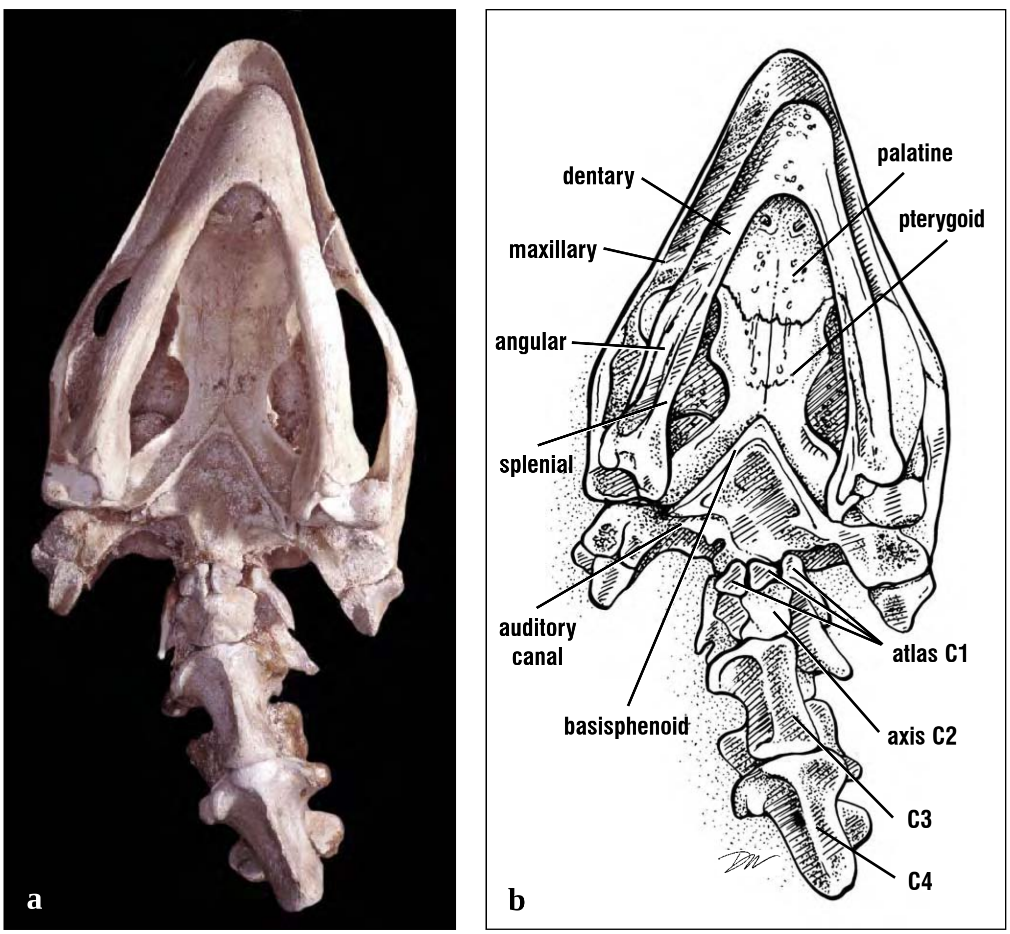
Fig. 24. *Lepidochelys olivacea, adult*

Skull Anatomy

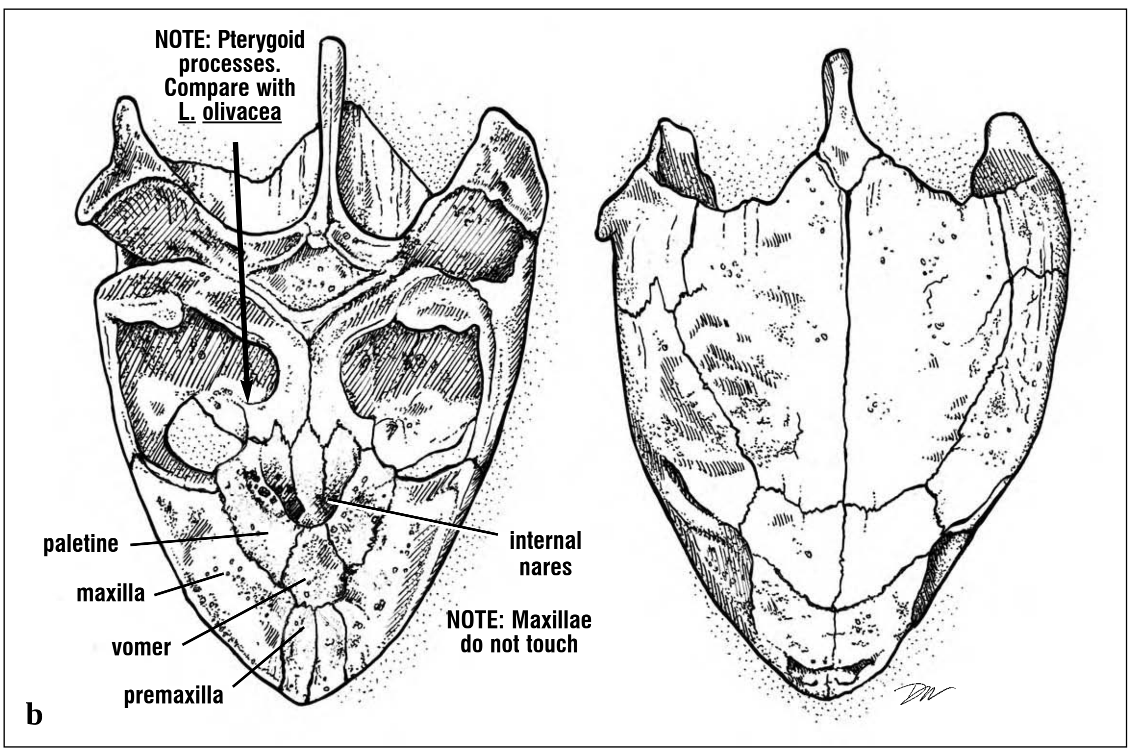
The skull is organized into an inner braincase, the **neurocranium,** which houses the brain and an outer bony superstructure, the **splanchnocranium**. The anterior splanchnocranium along with the mandibles form the jaws. The splanchnocranium also houses the sense organs and provides the muscle attachment sites for jaw, throat and neck muscles. The braincase is found along the midline, internal to the skull roof, snout, and jaw bones of the splanchnocranium. The external bones of the splanchnocranium (Fig. 25) are the same in all species, however their specific form and some articulations differ. Skull shape and the patterns of bones of the palate (roof of mouth; Figs. 26-27) are diagnostic for species identification. Lateral bones (Fig. 28) are important landmarks for locating internal structures. The jaws (Fig. 26) and the neurocranium (Fig. 29), also are composites of several bones.



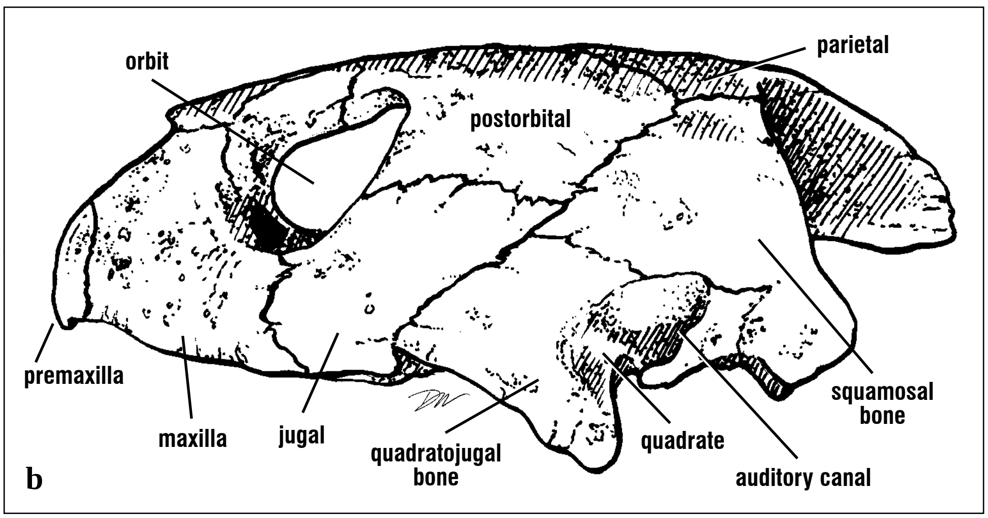
Figs. 25a and 25b. *The dorsal and lateral bones are identified here. With the exception of the supraoccipital, these are bones of the splanchnocranium.*



Figs. 26a and 26b. *Ventral bones of the skull (with the hyoid skeleton of the throat removed) are shown with the lower jaw and anterior neck vertebrae articulated. Both the upper and lower jaws are composed of multiple bones. The posterior braincase, part of the neurocranium, articulates with the cervical vertebrae. The vertebrae are composed of several parts: a vertebral body or centrum located ventrally and dorsal arch elements. C1 - C4: Cervical vertebrae.*



Figs. 27a and 27b. *The specific articulations and forms of the bones are characteristic of each species. The bones that make up the palate are frequently used as key characteristics. For example, in this ridley skull, the vomer prevents the maxillae from touching. In the loggerhead, a grossly similar skull, the vomer does not reach the premaxillae, so the maxillaries articulate. The pterygoid process shape and position are also key characteristics.*



Figs. 28a and 28b. *The lateral bones, identified on this cheloniid skull, vary in form with species. The eye would be housed in the orbit and the auditory canal (ear) would occupy the notch posterior to the quadratojugal.*

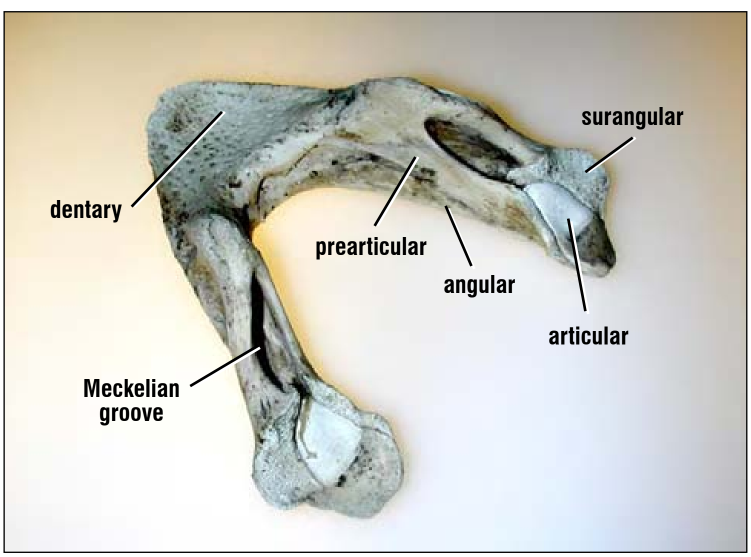
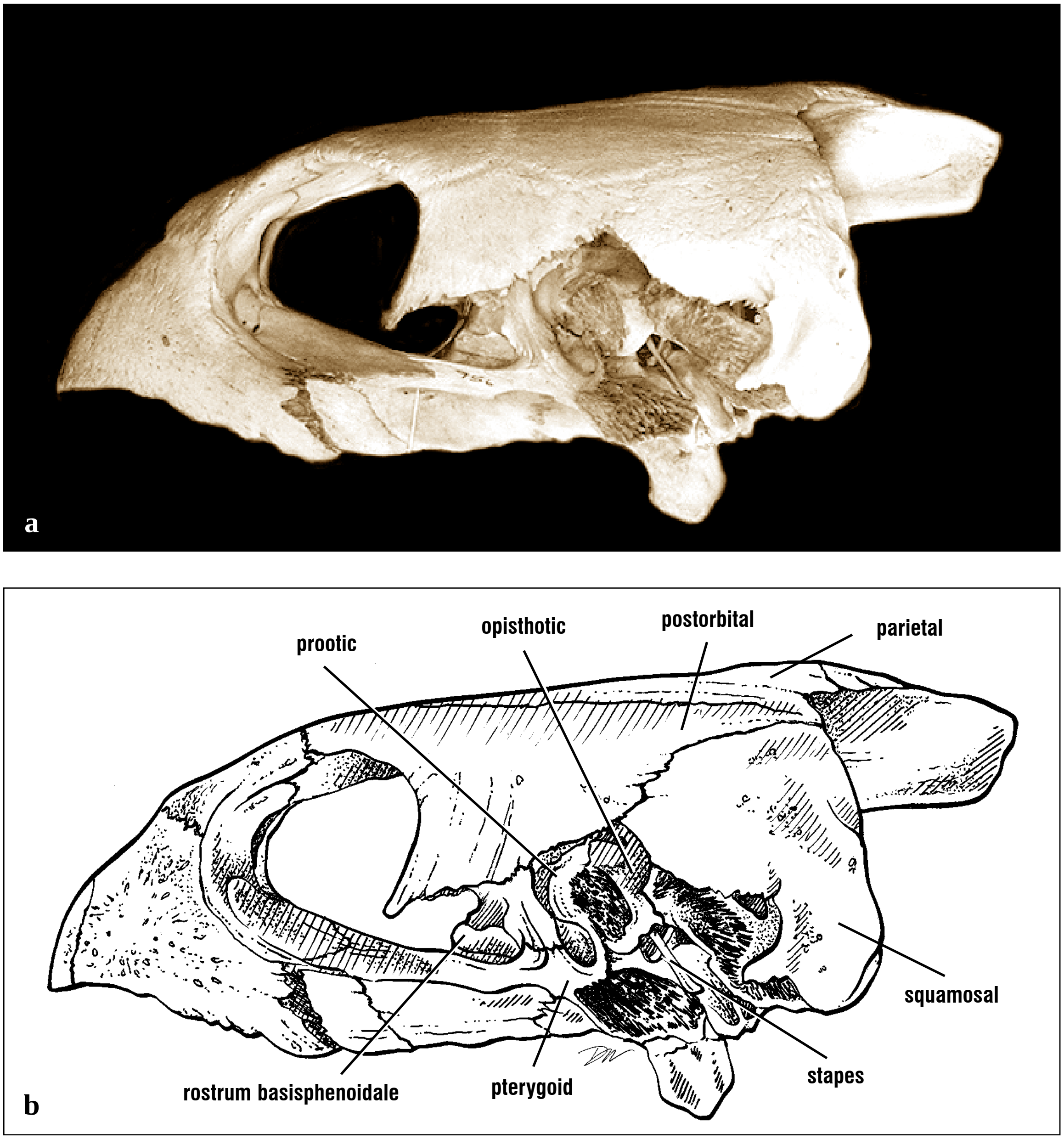


Fig. 29. *The lower jaw is a composite of the dentary, angular, surangular, prearticular, splenial (not shown) and articular bones. The cartilaginous portion is Meckel's cartilage; it is found in the Meckelian groove in life.*

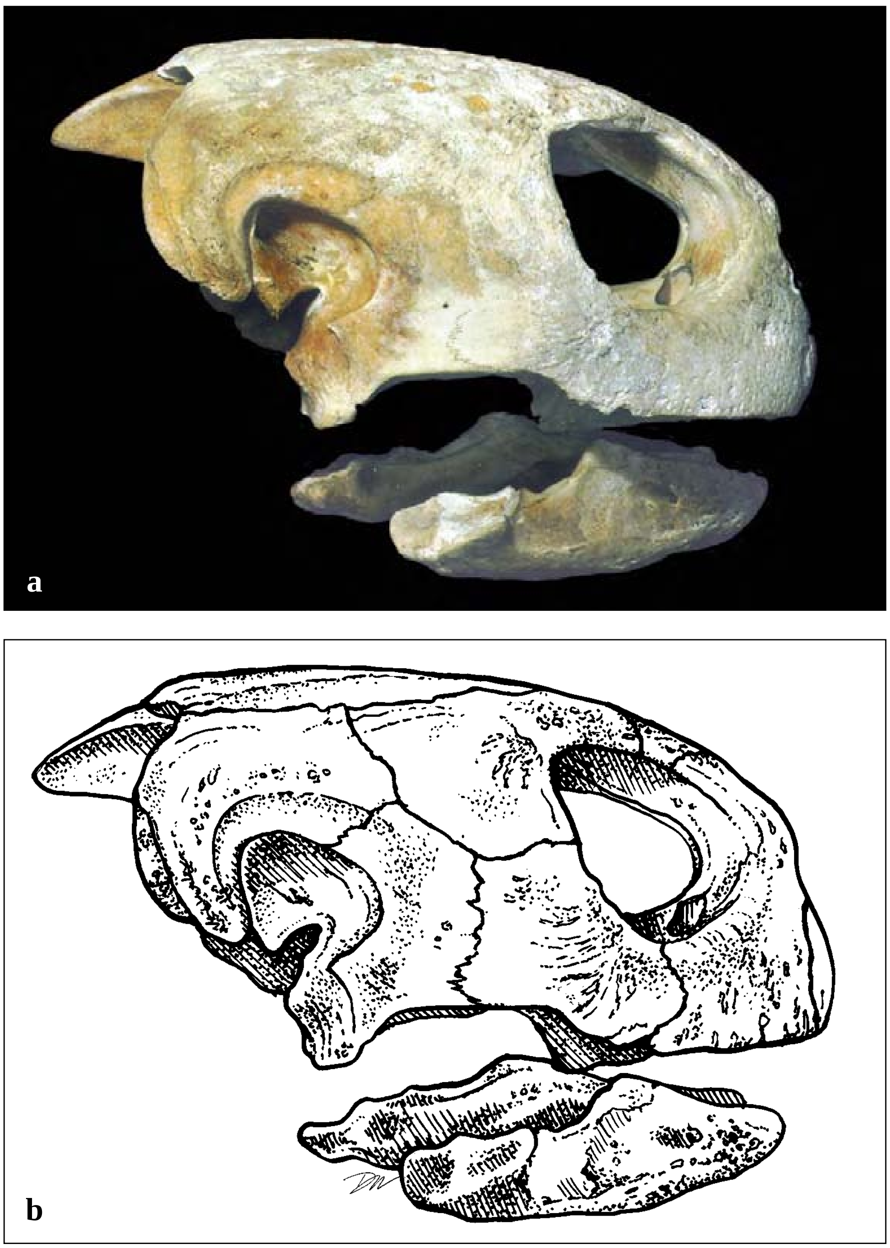


Figs. 30a and 30b. *The neurocranium is partially exposed by the removal of the jugal, quadratojugal, and quadrate of a hawksbill skull. The braincase is small and housed internal to the skull roof. Anterior bones (rostrum basisphenoidale and pterygoid) and lateral bones (prootic and opisthotic) form walls of the braincase.*

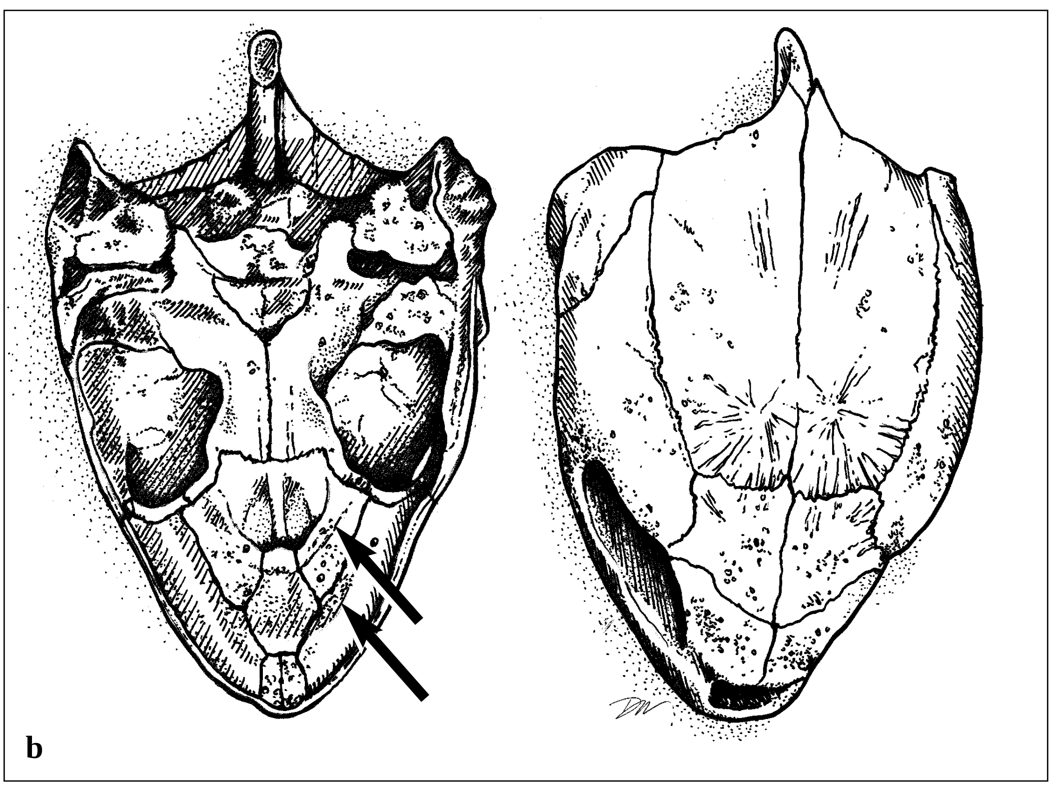
Species Identification from Skulls

The following descriptions are based upon bony characteristics alone and do not include other diagnostic features of the scales or the form of the rhampotheca (keratinaceous beak, see Rhamphotheca Structure, pp. 26-27).

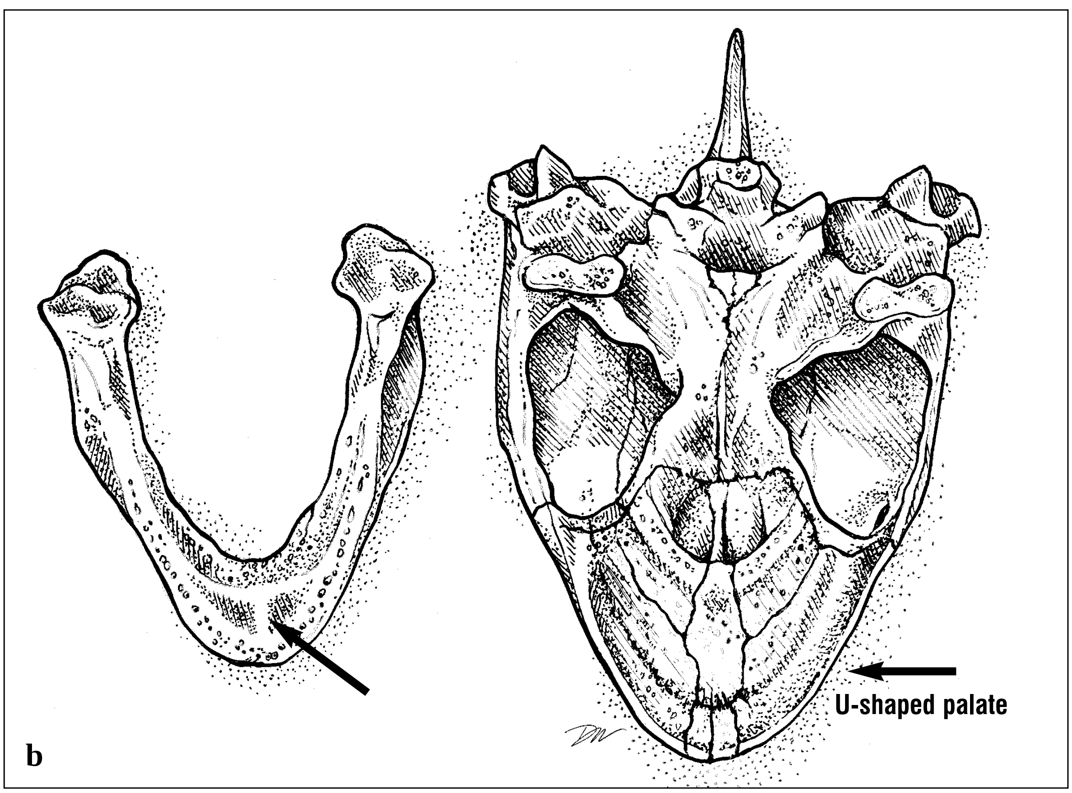
***Chelonia mydas* (Figs. 31 - 33).** The skull is rounded with a short snout and shallow parietal notches (Fig. 31). The upper jaw is described by a smooth U-shaped outline; the palate between the margins of the upper jaw and the internal nares (the alveolar surface) has a pair of ridges that run parallel to the outer edge of the jaw (Fig. 32). The lower jaw, has a ridge running parallel to the inner surface (Fig. 33) and a midline cusp.



Figs. 31a and 31b. *Chelonia mydas, lateral view.*

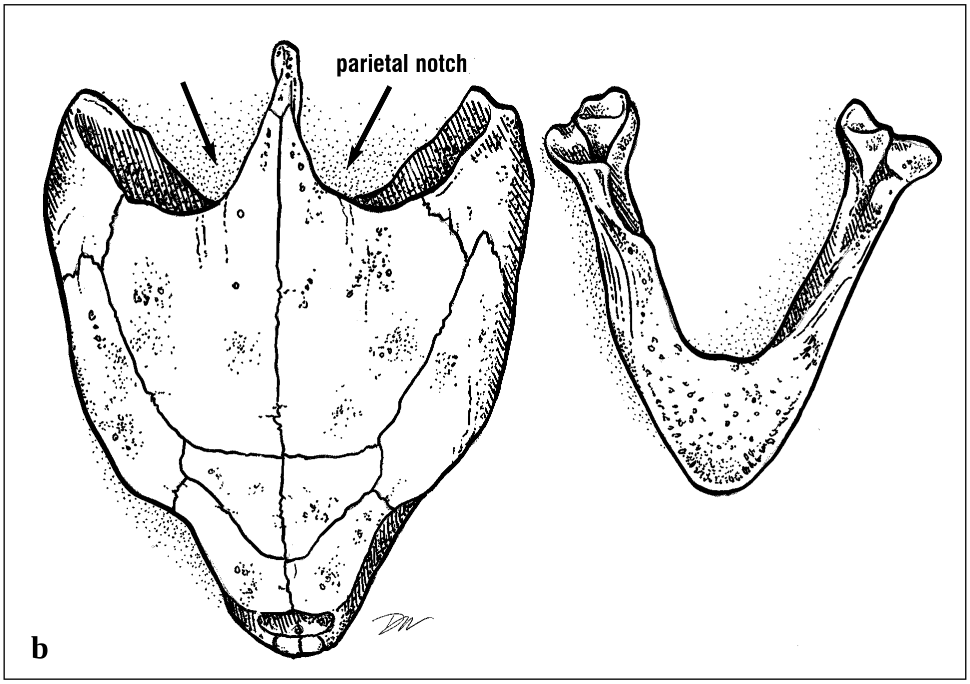


Figs. 32a and 32b. *Chelonia mydas, dorsal and ventral skull. Note ridges on palate at arrows.*

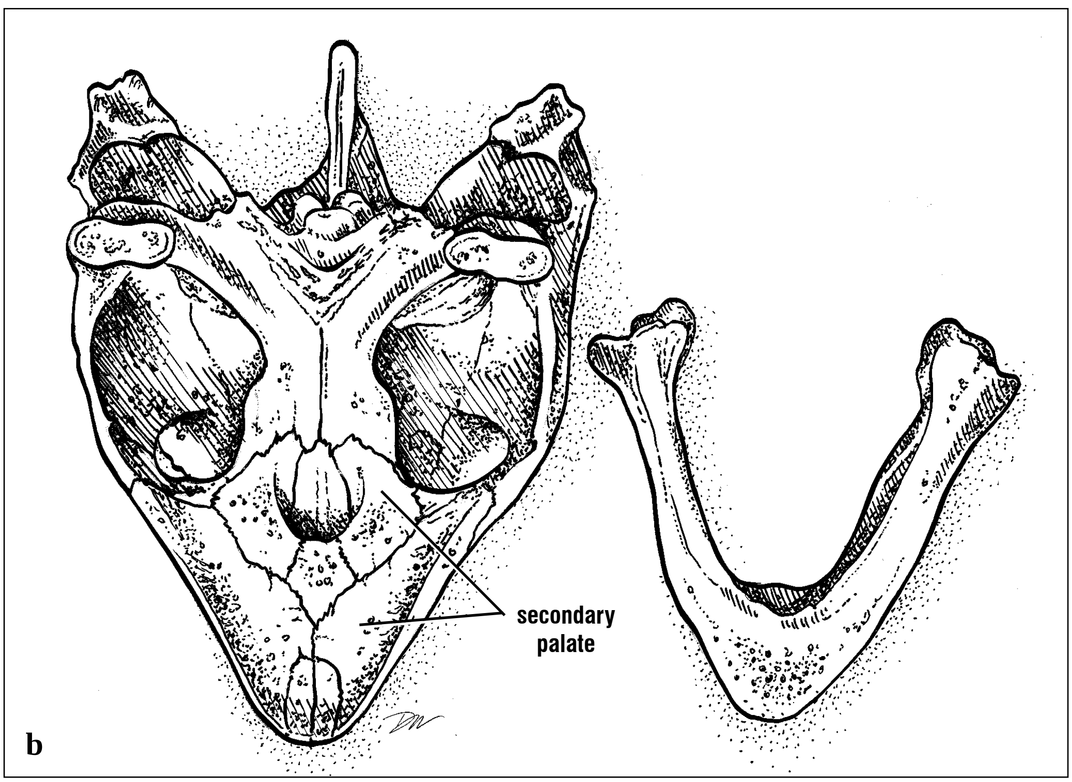


Figs. 33a and 33b. *Chelonia mydas, ventral skull and lower jaw. Midline cusp of lower jaw at arrow.*

***Caretta caretta* (Figs. 34 and 35).** The head of the loggerhead is relatively large, wide posteriorly, and the snout tapers anterior to the orbits. The parietal notches (wide U-shape emarginations formed by the posterior borders of the squamosal, parietal and supraoccipital bones) are large (Fig. 34). The jaws are robust and shaped like a wide V. Loggerheads have a relatively long secondary palate. (The secondary palate is the shelf of bone that separates or partially separates food and air passages.) The palate lacks alveolar ridges and the two maxillary bones contact one another posterior to the premaxillary bones (Fig. 35).

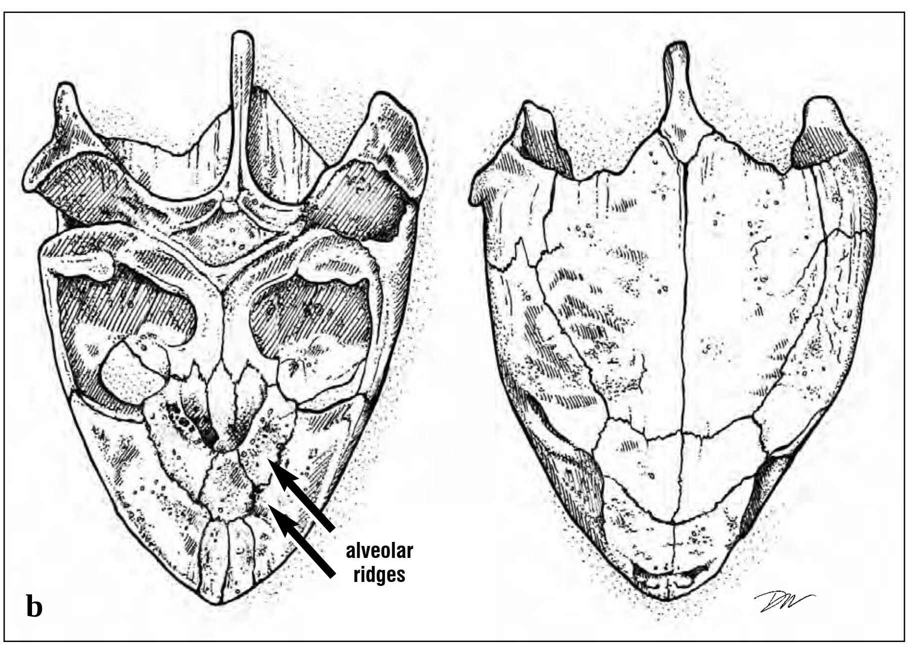


Figs. 34a and 34b. *Caretta caretta, dorsal skull and lower jaw. Parietal notches are at arrows.*



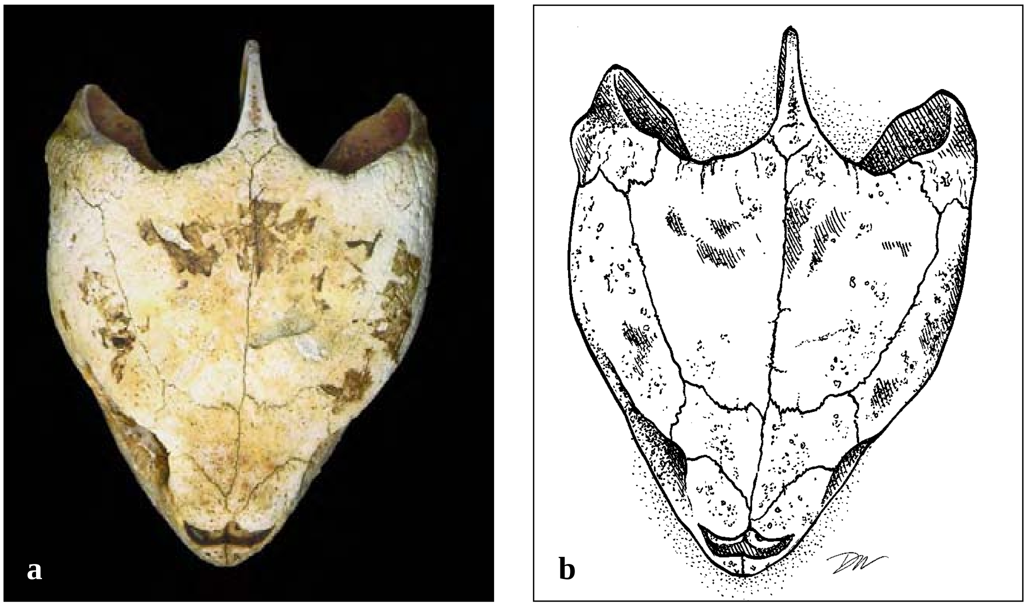
Figs. 35a and 35b. *Caretta caretta, ventral skull and lower jaw. Note that the two maxillary bones touch at the middle of the palate.*

***Lepidochelys kempii* (Fig. 36).** The skull is similar in overall shape to that of the loggerhead but can be distinguished from the loggerhead by the features of the palate. The Kemp's ridley skull is roughly triangular in shape. The parietal notches are well developed (Fig. 36). The snout tapers anterior to the orbits. The jaws are shaped like a wide curved V and there is a relatively long secondary palate. The palate has longitudinal alveolar ridges and the two maxillary bones are separated by the vomer which extends anteriorly to articulate with the premaxillary bones (Figs. 27 and 36). The orbits are relatively small when compared with other species and each has a ridge of bone along its dorsal margin that extends laterally from the anterior portion of the postorbital bone.

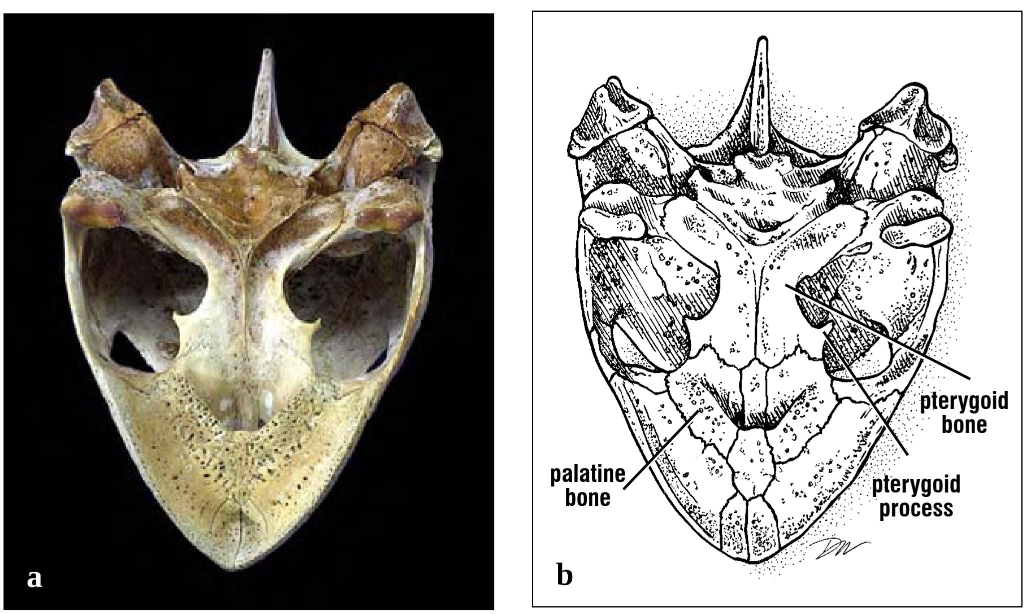


Figs. 36a and 36b. *Lepidochelys kempii, dorsal and ventral skull.*

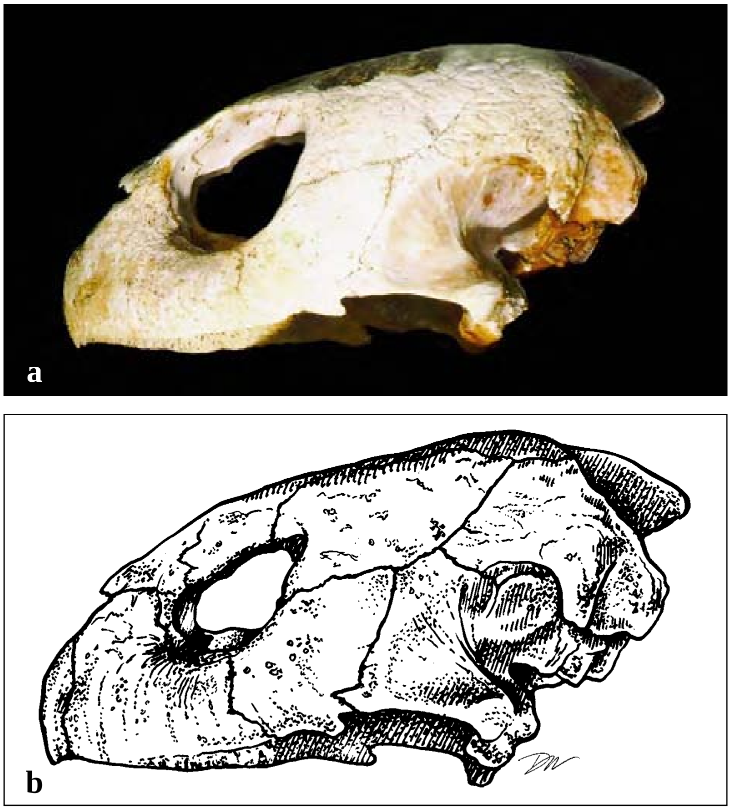
Lepidochelys olivacea **(Figs. 37-39).** The olive ridley skull is similar in shape to skulls of the loggerhead and Kemp's ridley. It is roughly triangular in shape, wide posteriorly, and has deep parietal notches. The jaws are shaped like a wide V. The palate lacks alveolar ridges. The two maxillary bones are separated by the vomer which articulates with the premaxillary bones. The orbits are larger than in *L. kempii* (Figs. 39-40) and the pterygoid bones are broad at their narrowest point when compared with other species.



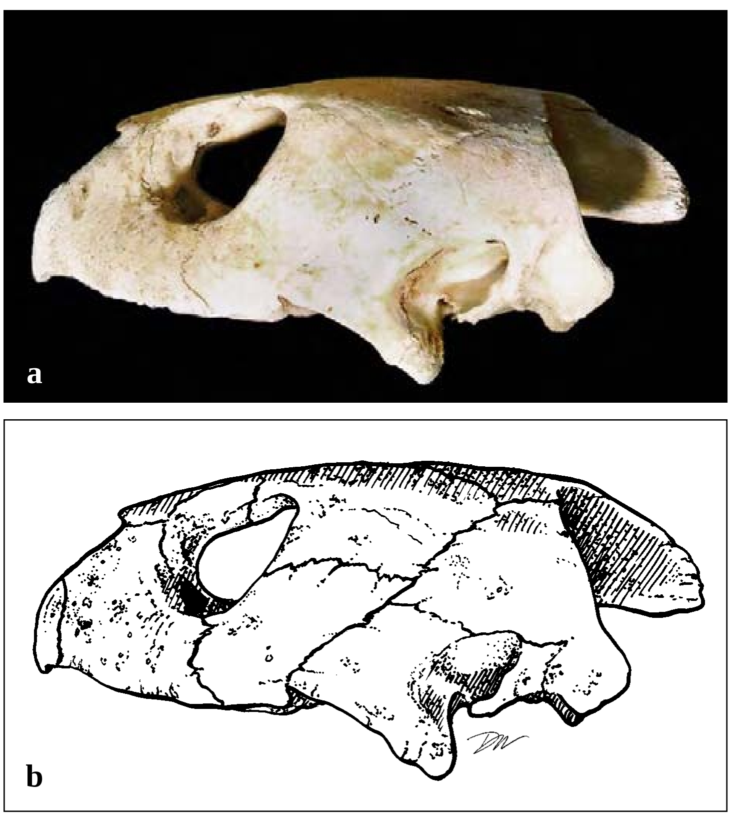
Figs. 37a and 37b. *Lepidochelys olivacea, dorsal skull*



Figs. 38a and 38b. *Lepidochelys olivacea, ventral skull. The pterygoid bone of the olive ridley is proportionately wider and the pterygoid processes are more pronounced than in the Kemp's ridley.*

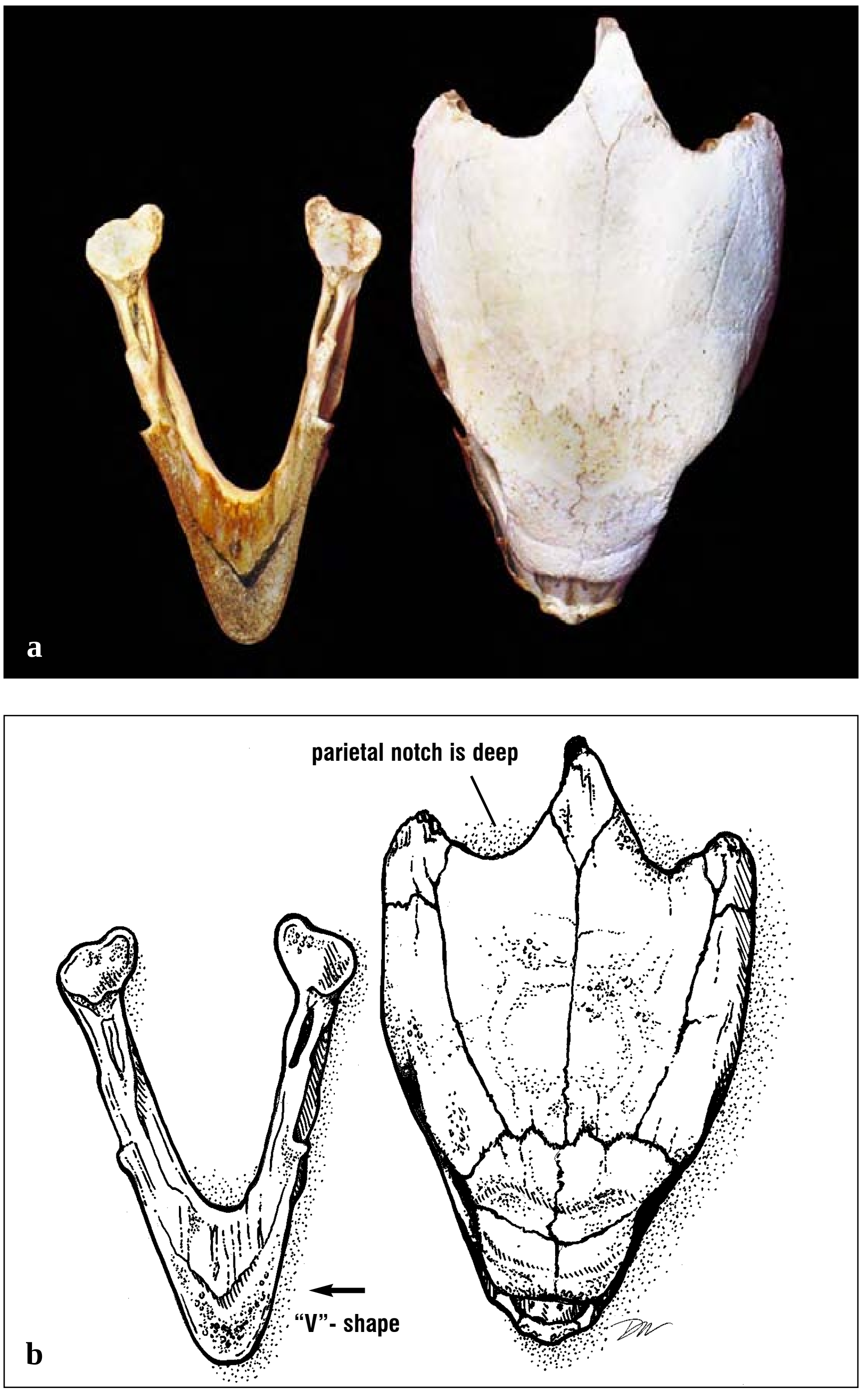


Figs. 39a and 39b. *Lepidochelys olivacea, lateral skull. When measured across its longest axis, the orbits of L. olivacea are proportionately larger than those of L. kempii.*

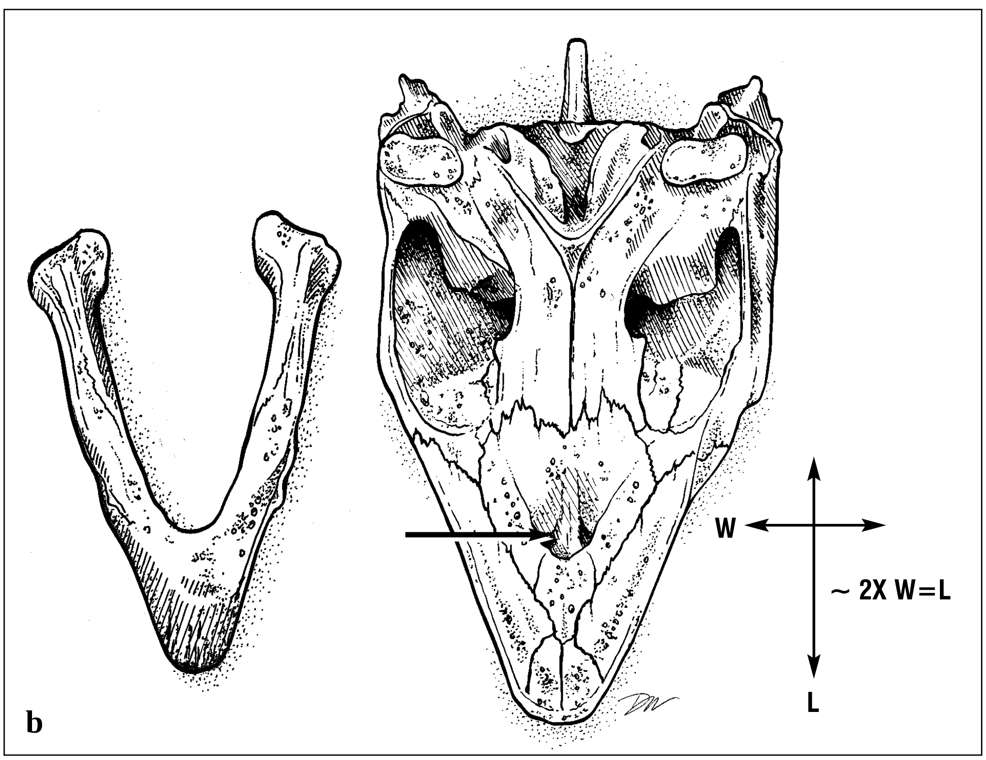


Figs. 40a and 40b. *Lepidochelys kempii, lateral skull. Note the proportionally smaller orbit and slightly more hooked snout.*

***Eretmochelys imbricata* (Figs. 41-42).** The hawksbill skull is long and narrow in all but the youngest turtles (hatchlings). The length is approximately equal to twice the width (measured at the skull's widest part; Fig. 42). Hawksbill skulls have deep parietal notches and the snout tapers to a point. The jaws are V-shaped and narrow (Fig. 41). The secondary palate is well developed and the internal nares are situated in the anterior third of the mouth. The two maxillary bones are separated by the vomer which extends anteriorly to articulate with the premaxillary bones (Fig. 42).



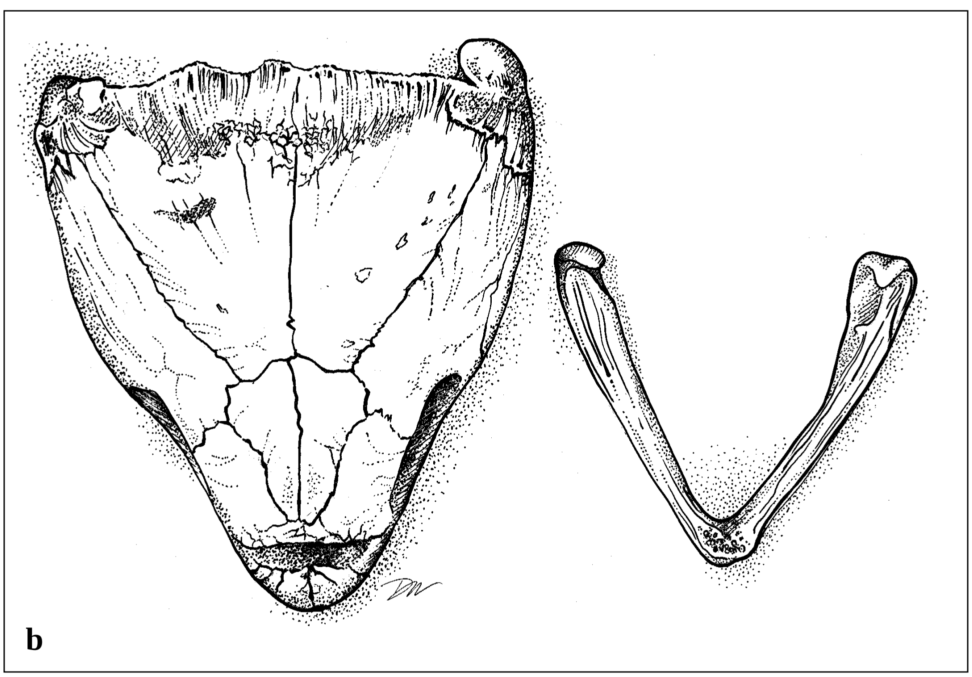
Figs. 41a and 41b.
Eretmochelys imbricata, dorsal skull and lower jaw with rhampotheca. The jaws are very narrow and V-shaped.

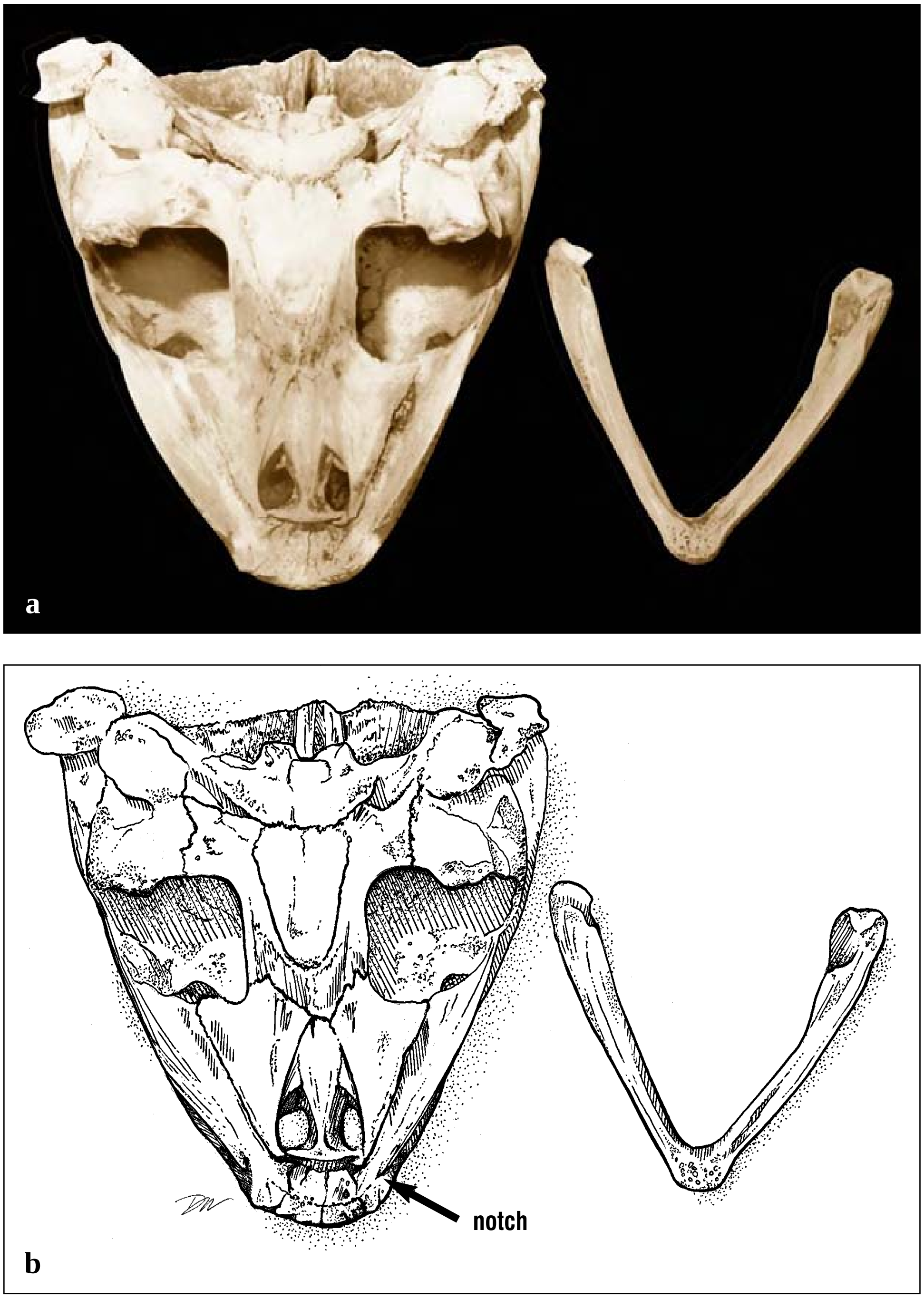


Figs. 42a and 42b. *Eretmochelys imbricata, ventral skull and lower jaw. The skull is longer and narrower than that of any other species. The secondary palate is long so that the internal nares (arrow) are relatively far back.*

Dermochelys coriacea **(Figs. 43 - 44).** Leatherback skulls are unlikely to be mistaken for those of any other species. The skull is wide and rounded anteriorly with large orbits; there are no parietal notches (Fig. 43). The bones articulate loosely; there is little or no secondary palate (Fig. 44). The margins of the jaws are sharp and possess notches. There are pointed cusps on the anterior maxillary bones. The lower jaw comes to a dorsally directed point at the mandibular symphysis (where the two halves of the lower jaw join). The lower jaw has a cartilaginous portion medial to the dentary.

Figs. 43a and 43b.
Dermochelys coriacea, dorsal skull and lower jaw. The bones fit together more loosely than in other species. The leatherback skull and skeleton has been described as neotenic (having embryonic characteristics) in form because of the lack of bony fusions.





Figs. 44a and 44b. *Dermochelys coriacea, ventral skull and lower jaw. Note the lack of a secondary palate and the loose articulations of the bones.*

Fig. 45. *Skulls of all the species found in US waters. Clockwise from top right: Dermochelys coriacea (a), Eretmochelys imbricata (b), Chelonia mydas (c), Lepidochelys olivacea (d), Lepidochelys kempii (e), Caretta caretta (f). The hawksbill, green turtle and Kemp's ridley skulls are from immature animals, others are from adults.*

Rhamphotheca (beak)

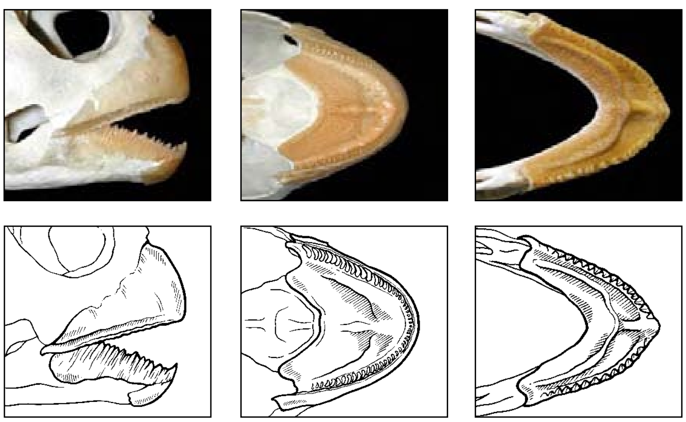
The rhamphotheci are the keratinous beaks of the upper and lower jaws in cheloniids. They cover the maxillary, premaxillary, and vomer bones of the upper jaw, and the dentary of the lower jaw. They differ with diet and can be used to identify species.

Several terms are used to describe the positions of parts of the mouth or rhamphotheci. Alveolar refers to the surfaces and edges of the jaws where teeth would be found in nonchelonian reptiles. Palatal refers to the horizontal surface forming the roof of the mouth. Buccal refers to the portion of the lower plate next to the tongue.

Below, species-specific characteristics of the rhamphotheci (Fig. 46), useful in species identification, are illustrated and described.

Fig. 46. *Rhamphotheca characteristics by species.*

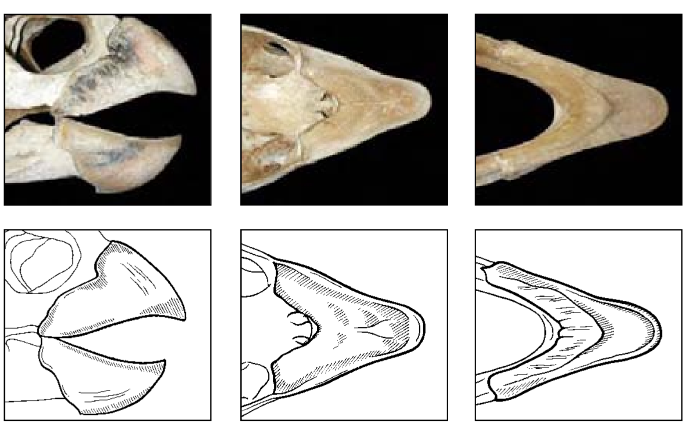
Chelonia mydas



Rhamphotheci   Upper Rhamphotheca   Lower Rhamphotheca

- *Snout rounded, outer keratin smooth and delicately built.*
- *Edges are outlined by serrations and spike-like cusps.*
- *Upper rhamphotheca serrated, short, pointed cusps.*
- *Inner surface with vertically aligned ridges.*
- *Lower rhamphotheca is serrated with vertical spike-like processes.*
- *Parallel inner ridge with row of smaller cusps.*
- *Midventral ridge without spikes connects the two.*
- *Alveolar surface has two depressions to either side of the midline ridge.*

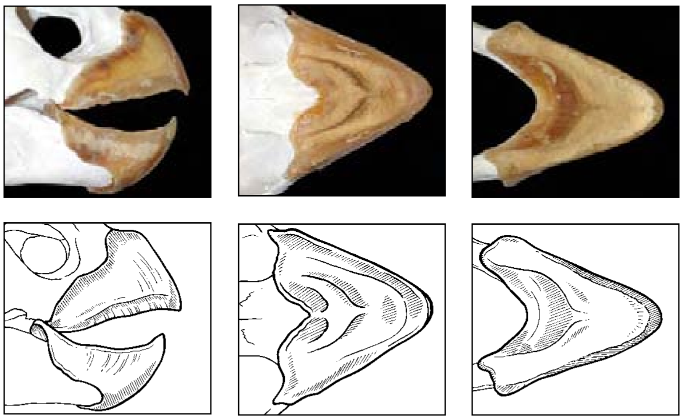
Eretmochelys imbricata



Rhamphotheci   Upper Rhamphotheca   Lower Rhamphotheca

- *Rhamphotheca moderately built.*
- *Snout narrow and pointed with sharp alveolar edges.*
- *Upper rhamphotheca's palatal portion is mostly smooth.*
- *Slight ridge, parallel to the maxillae; ridge may wear in older turtles.*
- *Lower rhamphotheca is narrow and smooth.*
- *Triangular process extends anteriorly from the buccal (posterior) margin.*

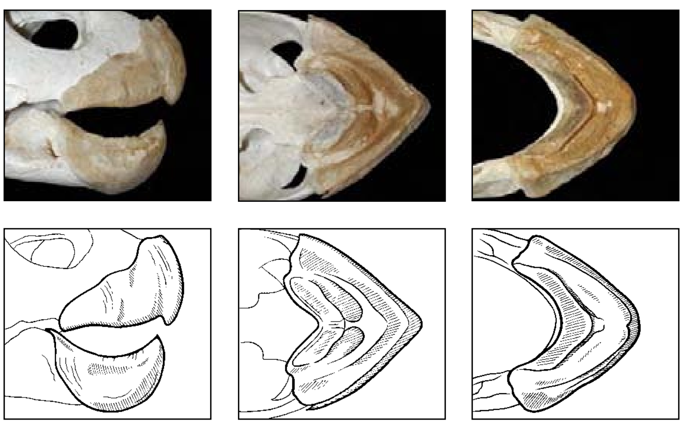
Caretta caretta



Rhamphotheci | Upper Rhamphotheca | Lower Rhamphotheca

- *Rhamphotheci robustly constructed with sharp alveolar edges.*
- *In young, upper and lower jaw come to a point.*
- *Upper rhamphotheca: palatal portion is wide and forms crushing surface inside mouth.*
- *Two V-shaped palatal ridges are found in young turtles; worn smooth in older animals.*
- *Lower rhamphotheca is trough-like with a thick crushing surface.*
- *U-shaped cutting surface is found along the posterior margin.*

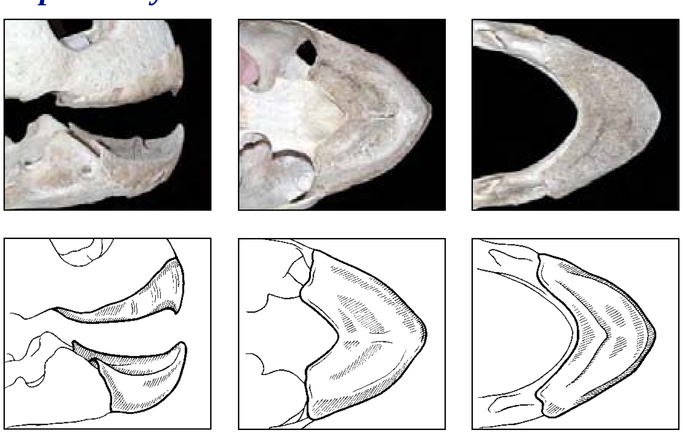
Lepidochelys kempii



Rhamphotheci | Upper Rhamphotheca | Lower Rhamphotheca

- *The rhamphotheci are heavily constructed with thick alveolar surfaces.*
- *Both upper and lower jaws come to anterior hook-like points.*
- *Upper rhamphotheca: forms wide crushing surface with sharp-edged alveolar margins.*
- *The palatal portion has large cusps bilaterally.*
- *Lower rhamphotheca is trough-like with two depressions that receive the palatal cusps.*
- *Sharp U-shaped ridge marks the posterior border.*

Lepidochelys olivacea



Rhamphotheci | Upper Rhamphotheca | Lower Rhamphotheca

- *Rhamphotheci are heavily constructed with thick alveolar surfaces.*
- *Both the upper and lower rhamphotheci are pointed at the anterior midline.*
- *Upper rhamphotheca forms a wide plate with a sharp-edged alveolar surface.*
- *Palatal portion has a ridge bilaterally extending just anterior to the internal choanae.*
- *Lower rhamphotheca has a sharp, wide, V-shaped ridge running posteriorly along the buccal margin.*

Standard Measurements

Several different lengths are measured when describing turtle size (Fig. 47). Each measurement is taken in order to ensure that comparative data are available to share with other programs world-wide. Over-the-curve measurements are taken with a non-stretching tape measure while straightline measurements are taken with calipers. The following are the standard measurements and their landmarks.

Standard Length **(SCL** and **CCL)** are measured from the mid-point of the nuchal scute to the posterior-most tip of the carapace in cheloniids (Figs. 48-49). Standard carapace length is a straightline measurement from the anterior-most point on the midline of the nuchal scute to the posterior-most tip of the last marginal (supracaudal or postcentral) scute. Curved carapace length uses the same landmarks but is taken over the curve of the carapace with a tape measure. If the tape crosses epibionts, notation should be made describing this aberration in the measurement. In leatherbacks, SCL is measured from the middle of the nuchal notch to the posterior-most tip of the caudal peduncle. To measure the CCL of a leatherback, pull the tape tight between the middle of the nuchal notch and the terminal tip of the caudal peduncle, without forcing the tape along the ridge.

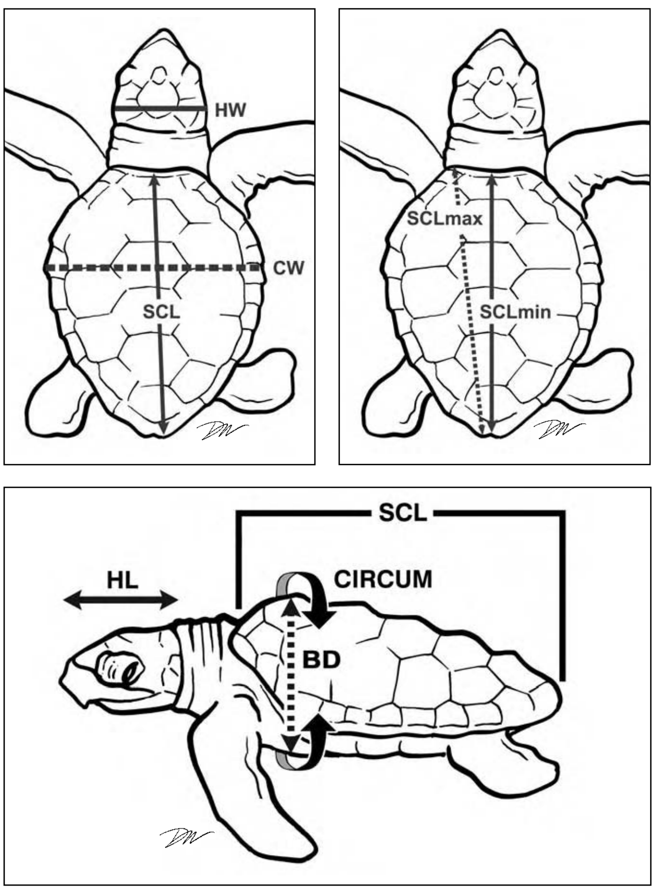


Fig. 47. *Landmarks for standard measurements. Each is described in detail in the text.*

Fig. 48. *Straightline Standard Length:* ***SCL****.*

Fig. 49. *Over-the-Curve Standard Length:* ***CCL****.*

Minimum Carapace Length **(SCLmin** and **CCLmin)**, also known as notch-to-notch length, is measured from the mid-point of the nuchal scute to the notch where the two most posterior marginal scutes meet (Figs. 50-51).

Fig. 50. *Minimum Straightline Carapace Length (Notch-to-Notch):* ***SCLmin****.*

Fig. 51. *Minimum Carapace Length Over-the-Curve (Notch-to-Notch):* ***CCLmin****.*

Maximum Carapace Length **(SCLmax** and **CCLmax)**, also sometimes called greatest length, is from the anterior-most part of the carapace to the posterior-most tip of the carapace on the same side (Figs. 52-53).

Fig. 52. *Maximum Straightline Carapace Length:* ***SCLmax****.*

Fig. 53. *Maximum Over-the-Curve Carapace Length:* ***CCLmax****.*

Carapace Width **(SCW** and **CCW)** is measured at the widest part of the carapace (not at specific scutes). In leatherbacks, carapace width is at measured the widest points, typically on the most lateral ridges. Care should be taken to ensure that the calipers and/or tape measure are perpendicular to the animal's long axis. The maximum width taken using a tape measure will not always fall on the same location as that measured with calipers (Figs. 54-55).

Fig. 54. *Straightline Width:* ***SCW****.*

Fig. 55. *Over-the-Curve Width:* ***CCW****.*

Maximum Head Width **(HW)** is measured using calipers at the widest part of the head (Fig. 56).

Fig. 56. *Maximum Head Width* ***(HW)*** *is measured at the widest part with the calipers perpendicular to the long axis of the skull. This position varies with species so that, in some, it is near the jaw joint and in others, it is found more posteriorly.*

Maximum Head Length **(HL)** is measured along the midline from the anterior-most part of the upper jaw to the posterior-most bone of the skull - the supraoccipital crest (Fig. 57). This bone is identified by feeling for the landmark (palpating).

Fig. 57. *Maximum Head Length* ***(HL)*** *is measured from the posterior tip of the supraocciptal crest (found by palpating) to the anterior-most part of the head, often the rhamphotheca (beak) of the upper jaw.*

Body Depth **(BD)** is recorded with the animal propped on its side or by digging a trench for the caliper jaws under an adult animal on land. This measurement is taken with calipers at the point of maximum carapace height when the bottom jaw of the calipers is held parallel to the plastron (Fig. 58).

Fig. 58. *Body Depth **(BD)** measurements are taken at the body's maximum height. On a live turtle, an average of at least 3 measurements should be taken between breaths because the depth changes during breathing.*

When measuring the animal, be sure to look for tags or tag scars on the front and hind flippers and, in the leatherback, near the tail (Fig. 59).

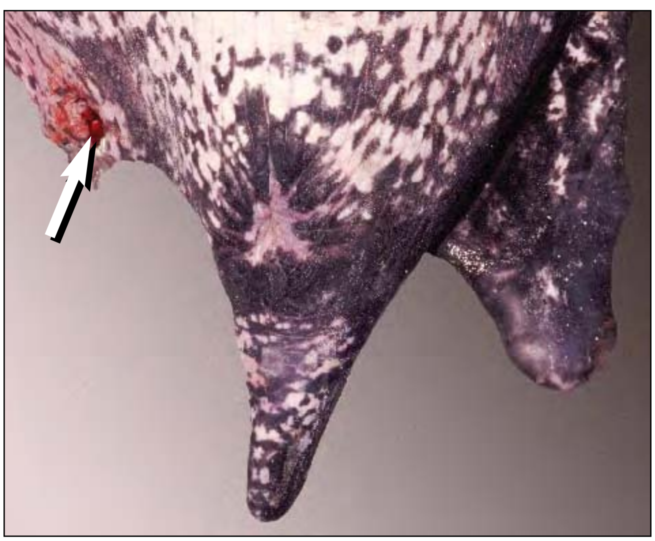


Fig. 59. *Tag tear-out scar on a leatherback.*

Plastron Length **(SPL),** straightline or curved **(CPL)**, is defined by the posterior-most part of the plastron hard structure to its anterior-most hard structure. These points may extend beyond the intergular or gular scute at the ventral base of the neck and the anal or interanal scute of the plastron (Figs. 60-61).

Fig. 60. *Plastron Length **(SPL)** is measured with calipers extended from the anterior-most end of the plastron to the posterior-most end. These landmarks may occur beyond the scutes.*

Fig. 61. *Plastron Length **(CPL)** is measured with an aligned tape measure. This method gives a slightly longer measurement than one obtained with calipers.*

Total Tail Length **(TTL)** is measured from the posterior-most point of the plastron to the tail tip. The ***Plastron-to-Vent Length*** **(PVTL)**, a separate measurement, is from the middle of the cloaca, or vent, to the posterior-most tip of the plastron. The ***Vent-to-Tip*** **(VTTL)** measure is taken from the middle of the vent to the tip of the tail or it can be calculated by subtraction (Figs. 62-63).

Fig. 62. *Tail Length* ***(TTL)*** *is typically measured with a tape measure extending from the posterior-most part of the plastron to the tip of the tail. The tape measure is allowed to follow the curl in the tail. Caliper measures tend to be slightly shorter.*

Fig. 63. *The Vent-to-Tip measurement* ***(VTTL)***, *shown here, is taken from the middle of the cloaca (vent) to the tip of the tail.*

Circumference **(CIRCUM)** is the greatest circumference taken perpendicular to the turtle's long axis (excluding the flippers; Figs. 64-65).

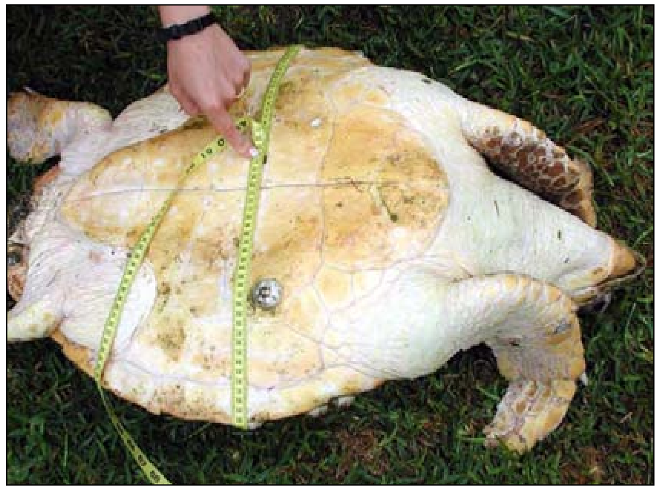


Fig. 64. *Circumference* ***(CIRCUM)*** *is taken with a tape measure. It can be measured with the turtle lying on its carapace.*

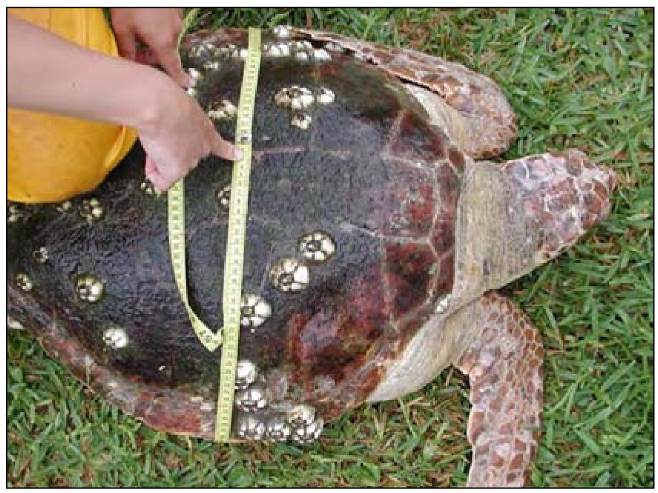


Fig. 65. *Circumference also can be taken with the turtle on its plastron. For very large animals, it may be necessary to dig under the turtle in order to get the tape aligned properly. When the tape is stretched over epibionts, such as barnacles, this should be noted.*

Methods of Dissection

Tools and Preparation. Before beginning your dissection, make sure you have all necessary tools, data sheets, pens, and pencils. Tools should include large and small calipers, a tape measure (Fig. 66), a camera, one or more saws, snips (metal or bone shears), one or more sharp knives, scalpel blades and handles, a sharpening stone or steel, and hemostats or pliers (Fig. 67). Other useful tools are blunt probes, forceps with and without teeth, scissors, pipettes and/or syringes for removing fluid. Bowls, plastic bags or jars and string or rubber bands are also useful. Protective gear should minimally include gloves; boots, coveralls or aprons are recommended. Access to towels will be important. Be sure to start with sharp instruments and be prepared to sharpen them frequently. Turtle skin can be tough and dulls knives and scalpel blades quickly. For clean up, herbal and anti-bacterial soaps are good for neutralizing odors and disinfecting, respectively. A 10% chlorine bleach (sodium hypochlorite) solution will help disinfect floors, bowls, or trays. Mix 1 part liquid chlorine bleach with 9 parts water. Check stock solution concentrations; some brands are stronger than others. Bleach solution is too harsh for use on most good tools.

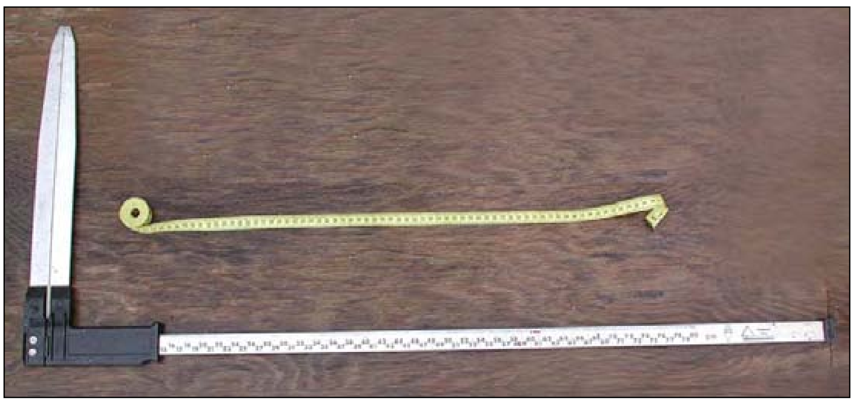


Fig. 66. *Tools used to measure the animal: a nonstretching tape measure and large sliding calipers (tree calipers).*

Fig. 67. *Examples of tools used for the dissection (left to right): Metal snips, blunt scissors, pointed scissors, hemostatic forceps, forceps without teeth, blunt probes, and scalpels. A syringe and knife (at the top) are particularly useful.*

Instructions for use of this guide.
Dissections typically proceed by body region while investigators tend to look-up structures by system. Hence, the dissection will be briefly described by region. The more complete description of each structure, should it be needed, will be found in sections dedicated to the details of organ systems.

The following are instructions for the most common dissections. Individuals differ in the order in which they proceed. There is no one correct way, however, all dissections should start with a thorough external examination and verification of the species. Photographs are helpful for verifying species, documenting anomalies, and addressing questions.

In most cases, it is easiest to work with a carcass that is placed on its back (Fig. 68). Working with very large animals may require the assistance of heavy equipment to move the carcass.

Fig. 68. *Carcasses should be placed on their backs for access to most viscera.*

When positioning the carcass for dissection, pay attention to proximity to buildings, drainage and tides. Before beginning a dissection, consider the time of day as dissections may take hours. In some cases, packing the animal or some parts of the animal in ice is a good strategy to minimize decomposition.

External examination. A complete description of the carcass should start with an external examination. Species, size, and sex, (if mature) should be noted. Foreign materials, anomalies, and healed or fresh wounds should be described including their locations. Tumors are common in some species, especially green turtles, and should also be described by size, color, texture and location.

Starting the dissection. Start by removing the plastron. Make a cut through the skin of the neck then extend it laterally (Fig. 69). Cut around the axillary regions near the plastron and along the seam made by the marginal and inframarginal scutes (Fig. 70). Bony processes from the plastron bones extend into the peripheral bones near the anterior and posterior inframarginal scutes. Hence, the cut cannot follow the seam completely. The skin and muscle near the hind limbs are thin, so care should be taken here to avoid cutting into the body cavity. The cut should follow along the plastron's posterior margin.

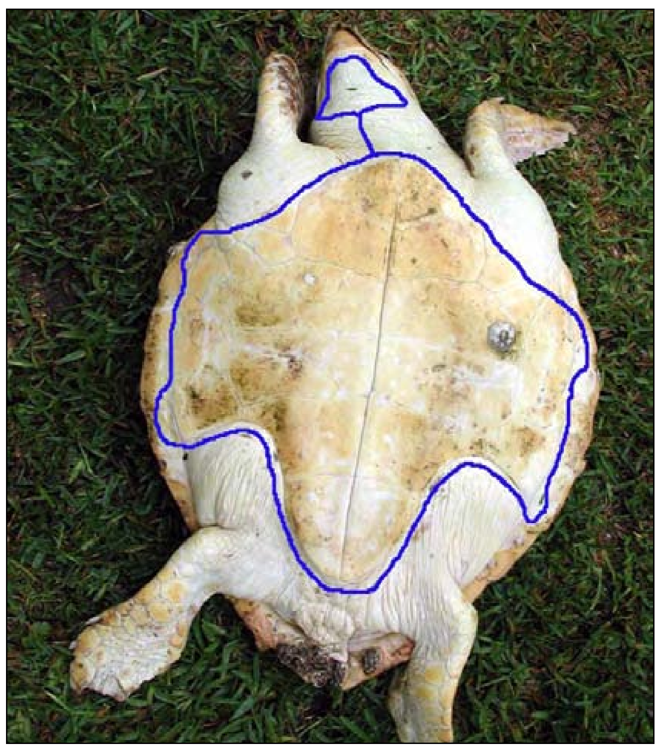


Fig. 69. *An outline is shown to trace the path of the initial cut needed to successfully remove the plastron.*

Fig. 70. *The cut may be made with a knife or scalpel blade. When using a knife, be sure the point is kept very near to the plastron so that it does not cut the viscera.*

The anterior part of the plastron is attached to the pectoral apparatus (the shoulder bones) via thick connective tissue. (In cheloniids, this is near the midline at the margins where the humeral and gular scutes meet). This connection must be cut close to the plastron (Fig. 71) in both hard-shelled and leatherback sea turtles to avoid damaging the heart, great vessels, or thyroid gland (Figs. 72-73). Once this attachment is free, lift the plastron while separating muscle and blood vessels from the shell by blunt dissection and careful cutting. Blunt dissection, the use of the hands or blunt instruments to separate structures, will often free the shoulder muscles from the plastron and from the peritoneum (the translucent connective tissue covering the organs).

Before removing the plastron completely from both sides, locate the greenish gray Rathke's glands in green turtles and ridley turtles. They are located deep to the Rathke's pores (Fig. 22) and embedded in fat. The gland feels denser than the fat when palpated. If a sample is needed, section the gland, and like most organs, if dropped in water, it will sink whereas fat will float, making it possible to distinguish the two.

Internal Landmarks. Once the plastron is removed, you will see that the ventral surface of the body is mostly covered by muscles (Figs. 72-73). There are 3 major groups of muscles that must be cut or dissected away to expose the viscera. These are the longitudinal muscles along the neck, the large pinnate (feather-shaped) "chest" muscles used for swimming, and the fan-shaped pelvic muscles that were attached to the plastron (Fig. 73).

Fig. 71. *To free the plastron, the attachment from the acromion processes to the plastron (at arrow) must be cut.*

Good landmarks that you can use to find organs are the **acromion processes** (Fig. 73) and the long triangular **coracoid processes** (procoracoids; see Skeletal Anatomy, p. 51; Muscle Anatomy, p. 61) on each side of the body. The two acromion processes cross the anterior body just posterior to the neck and extend to the shoulder joint. They attach medially, via ligaments, to the plastron. The coracoid processes extend posteriorly from the shoulder joint toward the abdomen. These two parts of the shoulder girdles serve as attachments for many of the large muscles that move the flippers (Fig. 73; see Skeletal Anatomy Figs. 112-115). The space defined within the borders of the right and left acromion and coracoid process serves as a landmark for the heart, great vessels, and thyroid gland. The major blood vessels will also act as guideposts for locating the thyroid and thymus glands.

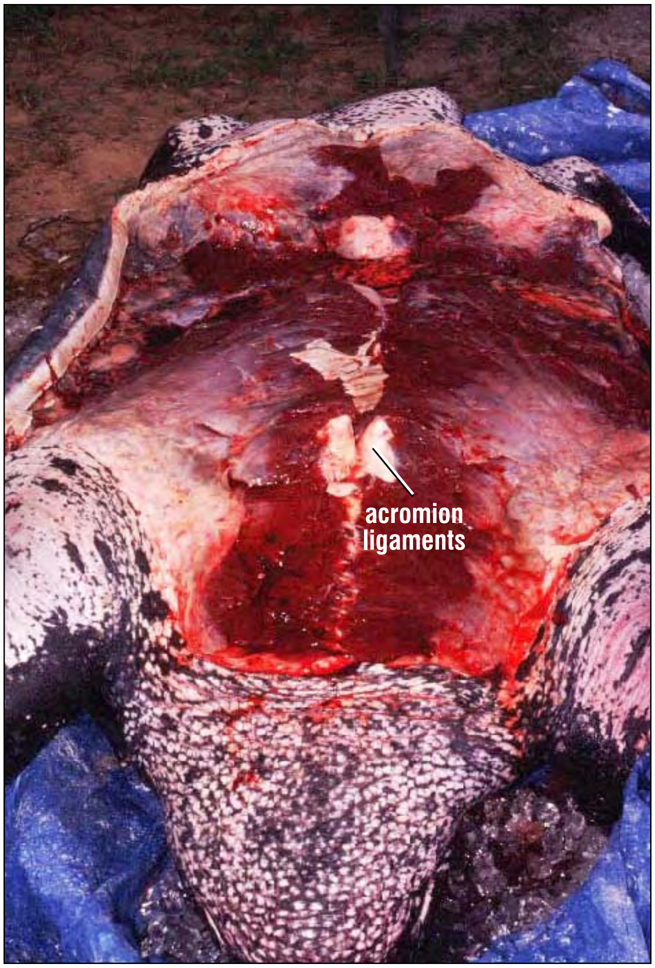


Fig. 72. *The massive pectoral and pelvic musculature can be seen in this leatherback. The two white patches on the anterior body are the cut ligaments of acromion processes. The head is toward the bottom of the picture.*

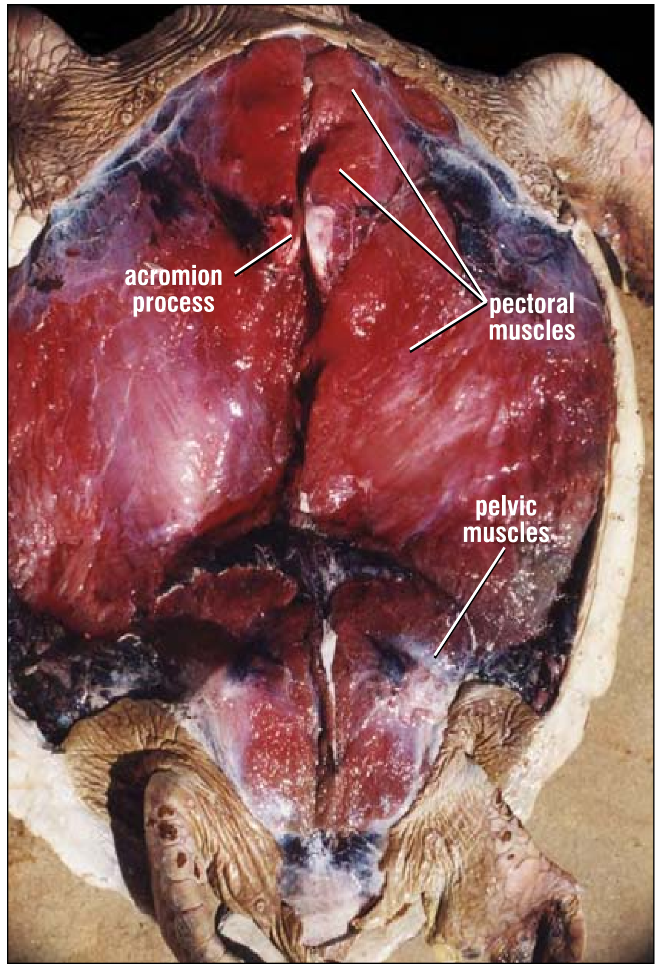


Fig. 73. *The ventral pectoral and pelvic musculature covers most of the peritoneum and organs. These must be removed to expose the peritoneal cavity. The paired acromion processes are visible adjacent to the midline but the fan-shaped coracoids are covered by the pectoral muscles. Anterior is toward the top of the picture.*

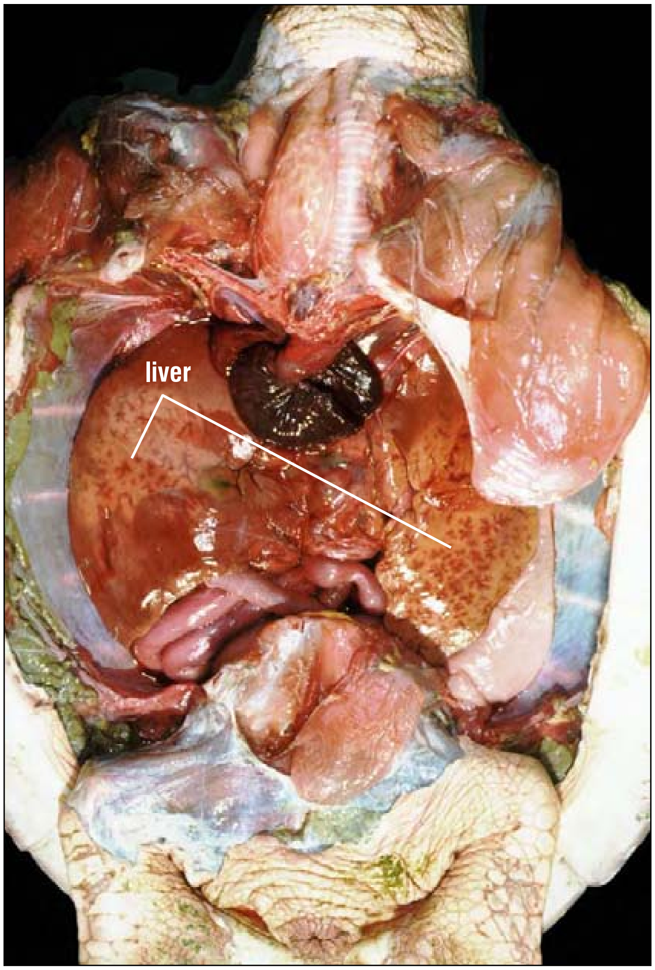


Fig. 74. *The peritoneum has been removed to expose the layout of the organs. The heart is centrally located, posterior to the trachea. The liver is to each side of the heart. The pectoral girdle was removed from the animal's right side (left in photo) and reflected laterally on the animal's left side.*

Rotating the acromion and coracoid anteriorly will help separate the muscles from the peritoneum (encasing the viscera). The heart, liver, and major blood vessels (Fig. 74) usually can be seen through this layer. To expose the viscera, remove the flippers and shoulder girdles by breaking the attachments of the scapula to the carapace. Free the shoulder muscles attached to the shell and neck (cut or break them). Twist the acromion and coracoid until the scapula, which extends from the shoulder joint to the anterior carapace, is free. Use blunt dissection to remove the remaining attachments then lift the shoulder girdle and flipper out of the body.

Cardiovascular anatomy. Open the **pericardium** (Fig. 75) to reveal the heart. The pericardial cavity will often contain fluid, particularly in specimens that have been frozen and thawed.

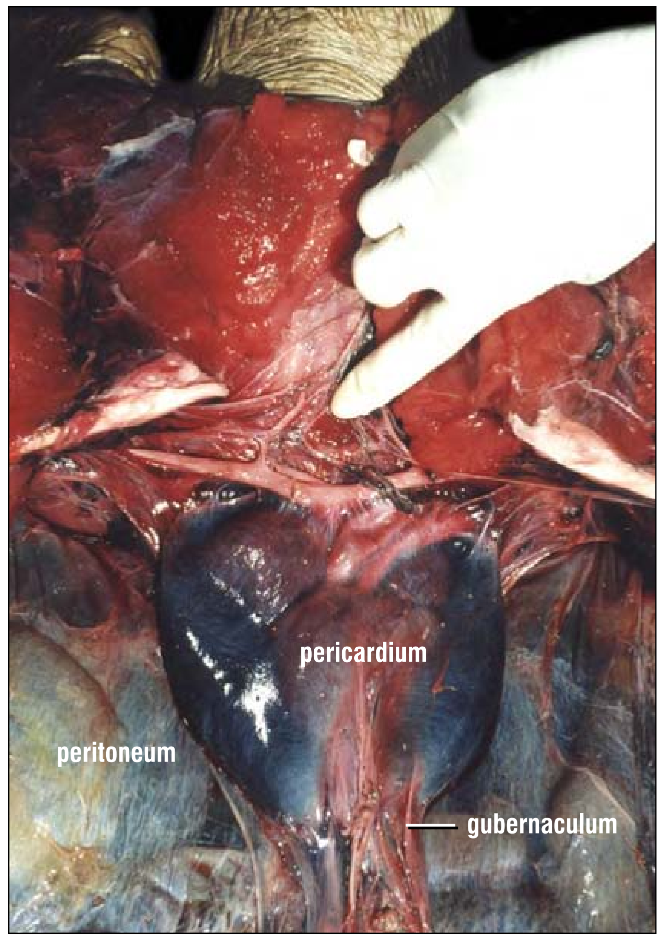


Fig. 75. *The pericardium contains the heart and pericardial fluid. The great vessels (aortas and pulmonary arteries) are seen posterior to the thyroid, at the fingertip, and the horizontal arteries. The heart is attached posteriorly via the gubernaculum, a cord of tissue at the base of the pericardium. The peritoneum, a translucent fibrous membrane surrounding the organs, is seen to either side of the pericardium.*

Upon opening the pericardium, 3 of the chambers of the heart are visible: the single **ventricle, left atrium** and **right atrium** (Fig. 76). The ventricle is attached to the pericardium via a fibrous connective tissue cord called the **gubernaculum cordis** (Fig. 75). After the gubernaculum is cut, the heart can be rotated anteriorly to reveal the fourth chamber, the **sinus venosus**. The sinus venosus is thin-walled; it collects venous blood from the head, ventricle, lungs and body (see Circulatory Anatomy, Fig. 129).

The great vessels (pulmonary artery, left aorta, and right aorta) arise from the anterior and ventral part of the heart. The right aorta gives off a branch almost immediately, the **brachiocephalic trunk** (Fig. 76) which then branches to the left and right. Small thyroid arteries arise from the brachiocephalic trunk and drain the single thyroid gland. The thyroid gland feels like a round gelatinous mass. Careful trimming of fat and connective tissue will reveal the red to brown thyroid (Fig. 75). The brachiocephalic trunk then forms subclavian arteries laterally, which become axillary arteries as they pass toward the flippers. The right and left thymus glands can be found by following the brachiocephalic trunk to the subclavian and axillary arteries. Feel for the thymus glands along the subclavian and axillary arteries before trying to locate them visually. After you have identified the thymus and thyroid glands, you can remove the heart for detailed examination by cutting through all the vessels and the sinus venosus. You may tie off the vessels before cutting if you want to minimize blood draining into the body cavity.

Gastrointestinal Tract and Related Structures. Next examine the gastrointestinal (GI) tract. Expose the **esophagus** leading to the stomach and the **trachea** to the lungs with a midventral cut in the neck skin. Open the neck skin and muscle as deep as the **hyoid** (the skeletal structures that support the tongue and some neck muscles). Cut along the inner surface of the lower jaw to free the tongue, glottis, trachea, and esophagus. The trachea and esophagus will exit posterior to the hyoid apparatus. The esophagus is deep and slightly to the (turtle's) right of the trachea. Cartilaginous rings characterize the trachea. The esophagus is a collapsed muscular tube. If you have difficulty finding the esophagus, you can run a blunt instrument or tube down the throat and locate the structure by moving your probe.

In the body cavity, the esophagus makes a sharp curve to the left to join to the stomach. The stomach leads to the small intestine with its digestive glands (liver and pancreas). The large intestine joins the distal small intestine and the GI tract ends with the rectum (Fig. 77).

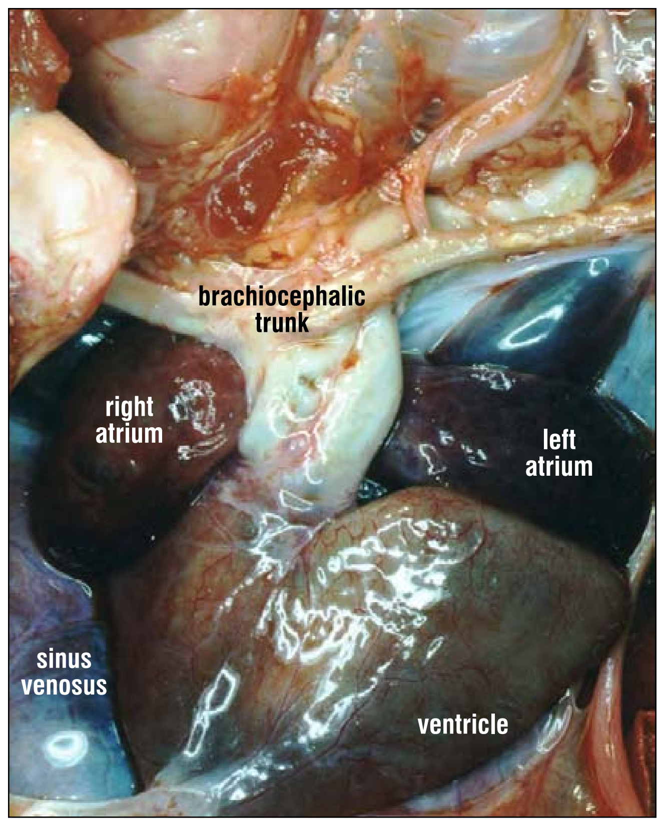
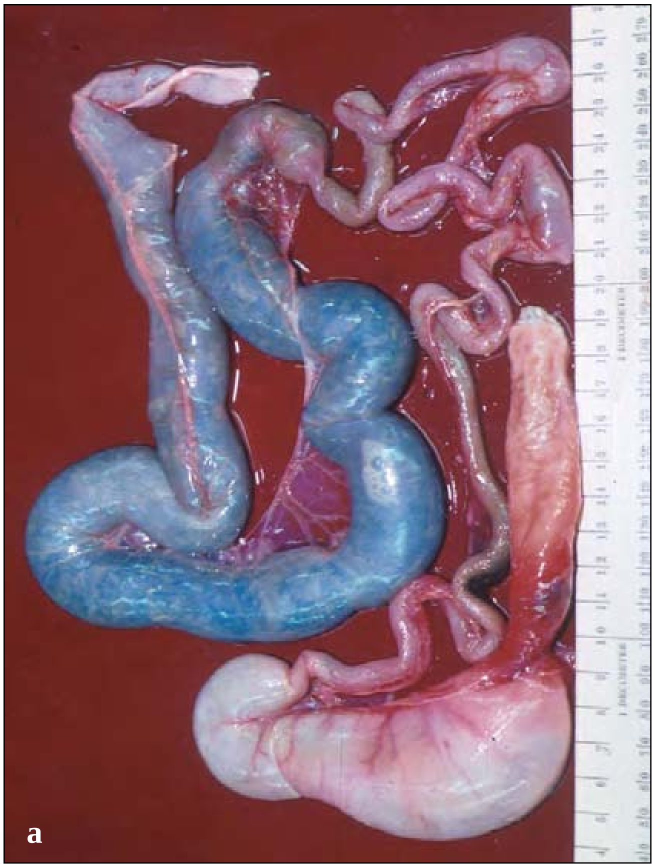
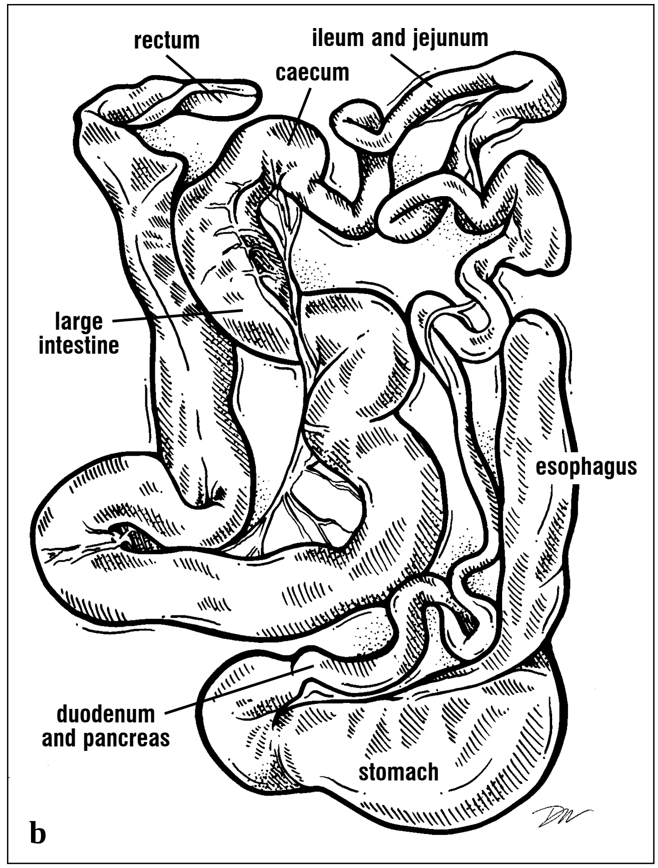


Fig. 76. *The heart has 4 chambers: the sinus venosus, right atrium, left atrium, and ventricle. The two aortas and pulmonary trunk emerge from the anterior aspect of the ventricle and are seen between the two atria. The brachiocephalic trunk is a landmark for locating the thyroid and thymus glands. The heart is pushed laterally to show the sinus venosus.*





Figs. 77a and 77b. *The gut of a hawksbill after it has been removed and cut free from the liver, spleen, mesenteries, and cloaca. The GI tract includes the esophagus, stomach, small intestine, and large intestine, which are easily distinguished from one another.*

Once you have located the esophagus, tie it off near the mouth with string or rubber bands that will not slip. You can then cut it away from the mouth and start removing the gut for examination. Separate the esophagus and stomach from the trachea and liver by blunt dissection. The stomach is attached to the liver's left lobe ventrally and to the left lung dorsally. These attachments must be cut or broken carefully in order to free the stomach and leave the liver and left lung intact.

Continue to remove the gut by tearing or breaking the **mesenteries** (flat tissues that suspend and support the organs) and blood vessels. Be careful not to cut the stomach or intestines. The stomach joins the small intestine at the **pyloric sphincter**, a thick muscular sphincter or valve. Just past the pyloric sphincter, the **pancreas** can be seen running distally along the **duodenum** (Fig. 77) past the **common bile duct** (a short attachment to the **gallbladder** which is found in the liver's right lobe). The pancreas is usually smooth, shiny (pink to peach colored), except in turtles that have decomposed. The common bile duct from the gallbladder can be identified by the green bile stain. The **spleen** can be found near the distal end of the pancreas. It is nearly round to oblong in shape, dark red, and highly vascular (see Circulatory Anatomy, Fig. 158 and Gastrointestinal Anatomy Fig. 164).

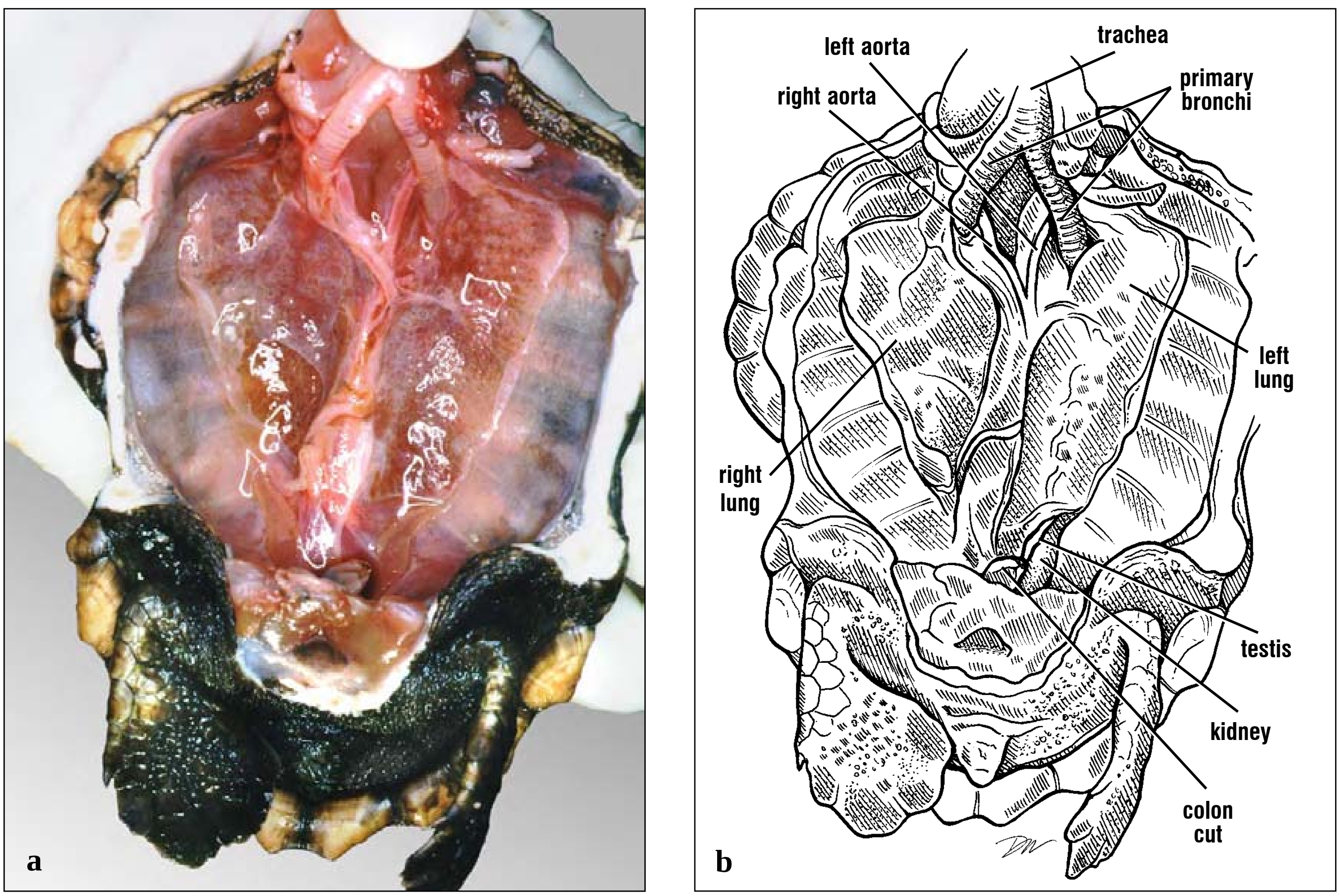
The intestine is long and must be cut away from its highly vascular, fan-shaped mesentery. The posterior part of the intestine is the **colon** (large intestine), which ends in a muscular **rectum** (Fig. 77). The rectum is often pigmented. It enters the **cloaca**, a chamber that receives urine, eggs or sperm. Before cutting through the rectum, tie it off with string or rubber bands.

The **urinary bladder** (discussed shortly) is anatomically ventral to the rectum and is suspended on the midline of the pelvis. It too, connects to the cloaca.

Before opening the gut to examine the contents and the lining, it helps to tie it off in 3 or more sections so that there are landmarks available when describing the parts. By using pairs of ties, the gut can be cut without spilling the contents. The gross appearance of the lining of the intestines does not always allow one to describe the location of a structure, tissue, or contents, so preset landmarks are useful. When opening the intestine, it helps to have trays or bowls ready to receive contents.

If you have not removed the **liver** with the gut, do so now by carefully freeing it from its attachments to the lungs and the peritoneum. The dense liver is composed of two lobes, with a connection of varying size between the two (Fig. 73). The right lobe is usually larger and, on its posterior surface, houses the round gallbladder. The gallbladder is usually dark green and may be full and convex or collapsed and concave (when empty).

Once the gut is removed, it is easy to see the lungs and the gonads (Fig. 77) at their posterior margin.



Figs. 78a and 78b. *The lungs are in contact with the carapace. By tracing the trachea posteriorly to the 2 bronchi, the lungs can be found. They extend for most of the length of the carapace. The gonads are found at the base of each lung. In this animal, the testes are shown.*

Gonads. The gonads are attached to the peritoneal wall, posterior to the lung and anatomically ventral to the kidneys. The **ovaries** of mature and maturing turtles have a number of round yellow follicles that appear as small (~2 mm - 2 cm) diameter spheres embedded throughout the length of the long narrow organ. Immature ovaries are more compact, flat, often elongate, and fusiform in outline. They are often pink and granular in appearance. Ovaries tend to be attached along their length by one edge. The **oviduct** transports the follicles, then eggs, to the cloaca when mature. The oviduct is located lateral to the ovary and is not attached to it. Each oviduct extends anteriorly from the cloaca for about 2/3 the length of the body. In mature turtles, it has an "accordion" appearance. In immature turtles, it is a simple flat tube that is very narrow in the youngest and increasingly wide in older turtles (see Urogenital Anatomy, Figs. 220-221).

The **testis** is often yellow or tan, and smooth. It is fusiform in outline and is attached to the body wall by its flat dorsal surface. The **vas deferens** is a coiled tube that is found lateral to the testis transports sperm to the cloaca. In breeding males, both the testis and the vas deferens become enlarged. When in doubt about the sex of the turtle, the coiled vas deferens, even in young turtles, is an important clue (see Urogenital Anatomy, Figs. 221-222).

Lungs. The lungs are located dorsally and are attached to the carapace and vertebral column (Fig. 78). In some species (e.g., *Lepidochelys kempii* and *Caretta caretta*) the lungs are more closely attached to the vertebral column than in other species. The lungs can either be examined in the body, or by removing them. To remove the lungs, free their lateral borders, being careful not to cut into the lung tissue. The medial border of the lung will be firmly attached to each side of the vertebral column. Sometimes it helps to free the trachea from the associated connective tissue prior to breaking the fibrous connections between the lung and the vertebrae.

The trachea bifurcates into two bronchi. A bronchus enters each lung and continues with multiple internal openings into the lung. Each bronchus extends almost to the posterior end. The lungs are spongy and highly elastic.

Urinary bladder and kidneys. The urinary bladder is suspended from the midline on the dorsal surface of the pelvis (Fig. 79). It is located between the rectum and the anterior pelvis (pubis). The bladder opens into the cloaca and is not connected to the kidneys. Urine flows from the kidneys, through the **ureters**, to the cloaca. Urine enters the bladder from the cloaca (see Urogenital Anatomy, Fig. 219).

The **kidneys** are located posterior to the lungs. They are "retroperitoneal" which means that they lie beneath the peritoneal lining next to the carapace.

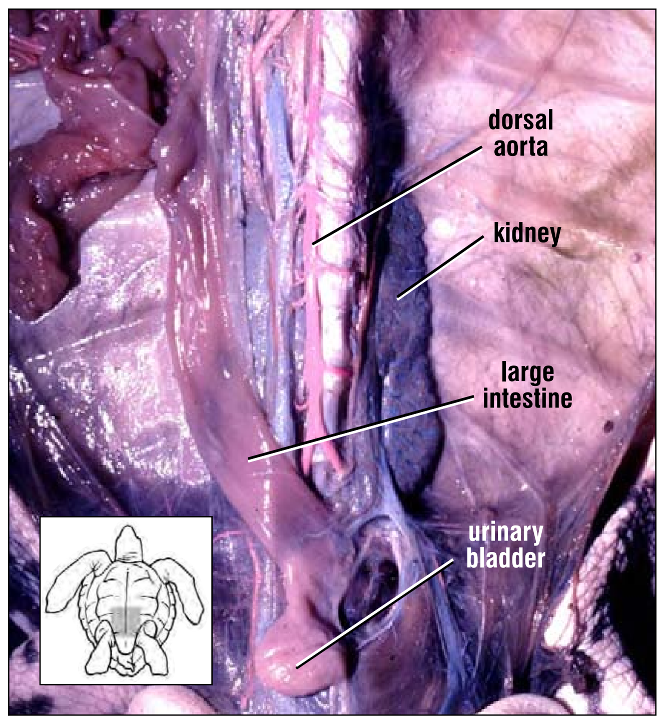


Fig. 79. *A kidney in this young leatherback, is exposed and its circulation injected to separate arteries from veins. The urinary bladder is seen on the midline, as is the collapsed large intestine to one side. The dorsal aorta is along the vertebral column and gives off many branches.*

They are deep relative to the gonads and slightly medial from the posterior-most border of the lungs. By making a cut in the peritoneum and teasing it away, the lobular red kidneys (Fig. 79) and their extensive systems of arteries and veins can be exposed. The ureters, often difficult to find, extend from each kidney to the cloaca.

At the anterior end of each kidney, and very near the vertebral column, there is a small elongate **adrenal gland**. The adrenal glands are often yellow or orange. They are frequently easier to locate by palpation than by sight (see Glands, Fig. 186).

Brain. To examine the brain, cut off the head near the base of the skull. Secure it with a vice or hold it carefully on a no-skid surface. In *Dermochelys coriacea* the brain and its tracts make a series of dorsoventral turns as it proceeds from anterior to posterior. A single cut will not expose this well protected structure. In the cheloniids, one of the easiest ways to expose the brain, in the absence of special saws, is to make a straight cut from the top of the snout, proceed along the inside of the top of the orbits, then continue to the posterior end of the head (Fig. 80). Once the skull cap is removed, the small brain can be seen (Fig. 81) with its (anterior to posterior) **olfactory tracts** to the nose, **optic lobes, cerebral hemispheres** and **cerebellum** (see Nervous System, Figs. 187 and 189). Sometimes the fibrous covering, the dura mater, remains covering the brain. This can be cut away.

Fig. 80. *The brain can be exposed by a cut parallel to the skull's long axis, running from the snout, through the tops of the orbits and posteriorly toward the middle of the supraoccipital crest.*

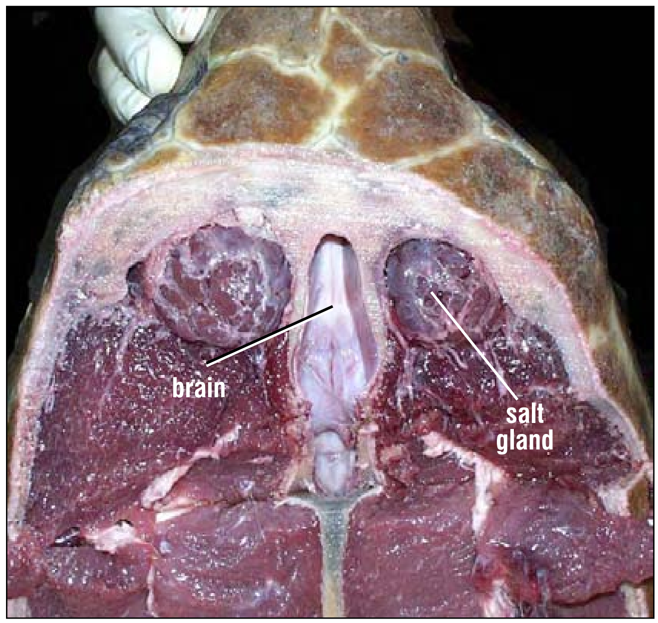


Fig. 81. *The brain, along the midline, is elongate and white. Grossly, one can see the olfactory tracts. The olfactory bulbs, cerebral hemispheres, and optic lobes are covered by the dura mater; the cerebellum is the single round structure at the end of the exposed brain. If the brain is removed, then lateral and ventral cranial nerves and the pituitary can be seen. The two round, lobed structures dorsal and posterior to the eyes are the salt glands. The remaining dark tissue is muscle.*

Skeletal Anatomy

The skeleton is composed of bones and cartilages. Typically, it is divided into 3 main parts: the skull, axial skeleton and appendicular skeleton (Figs. 82-84). In sea turtles, each of these bony groups is a composite of several structures. The **skull** includes the **braincase, jaws,** and **hyoid apparatus** (Figs. 85-86). The **axial skeleton** is composed of the carapace, vertebrae, and ribs and the derivatives of the ribs. The **plastron** (Fig. 83) is a composite including derivatives of the axial and appendicular skeleton (ventral ribs plus shoulder elements). The appendicular skeleton includes the **flippers, hind limbs**, and their supporting structures (the **pectoral** and **pelvic girdles**).

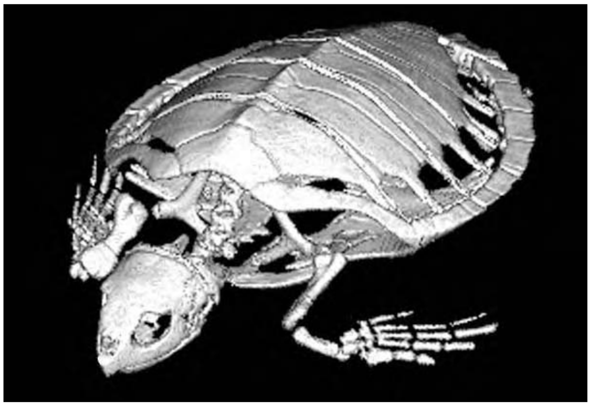


Fig. 82. *This CT (computed tomography) scan of an immature ridley turtle shows the three parts of the skeleton: the skull, axial, and appendicular skeletons and the spatial relationships of the bones. Cartilage (at the ends of many bones) is not detected by this imaging technique so bones appear loosely articulated. The arrangement of the forelimbs is such that the shoulder joint is inside the shell. The elbow flexes so the forearm moves from an anterolateral position to a medial position. Lines crossing the posterior skull and carapace are image processing artifacts.*

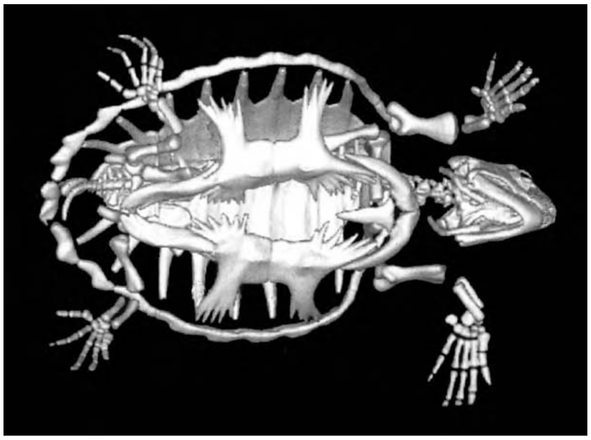


Fig. 83. *Individual plastron bones are not fused in immature turtles. The processes from the lateral plastron do not yet articulate with the peripheral bones. The hyoid apparatus (the body of the hyoid and both bony hyoid processes), which is usually lost in skeletal preparations, can be seen in the throat region. The distal phalanges of the flippers were outside of the field of view in this CT scan so the ends of the flippers are omitted.*

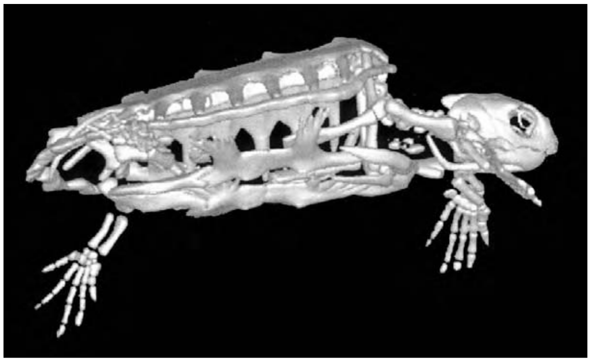
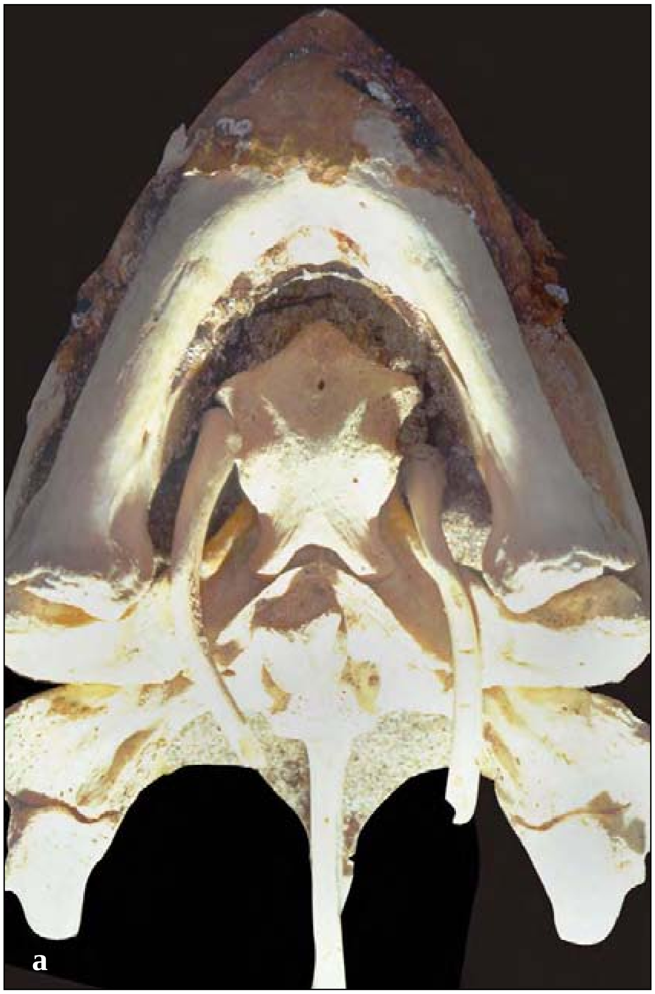
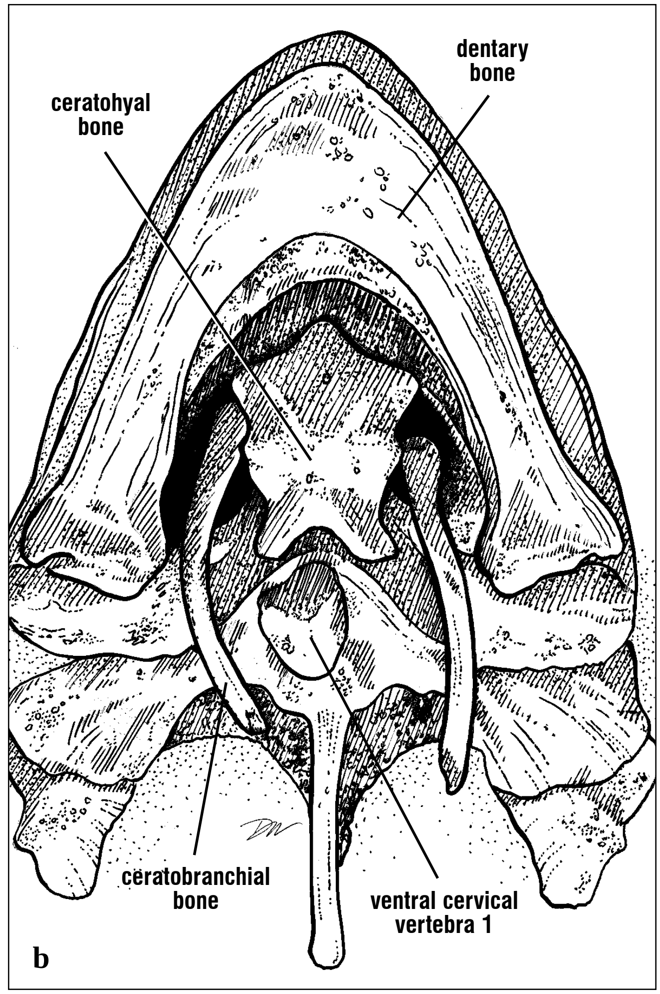


Fig. 84. *In this lateral view of an immature loggerhead, the hyoid process can be seen clearly as it passes posterior and ventral to the skull. Note that the orbits contain a ring of bones (scleral ossicles) that support the eyes. The right hind limb is directed laterally so it cannot be seen clearly.*

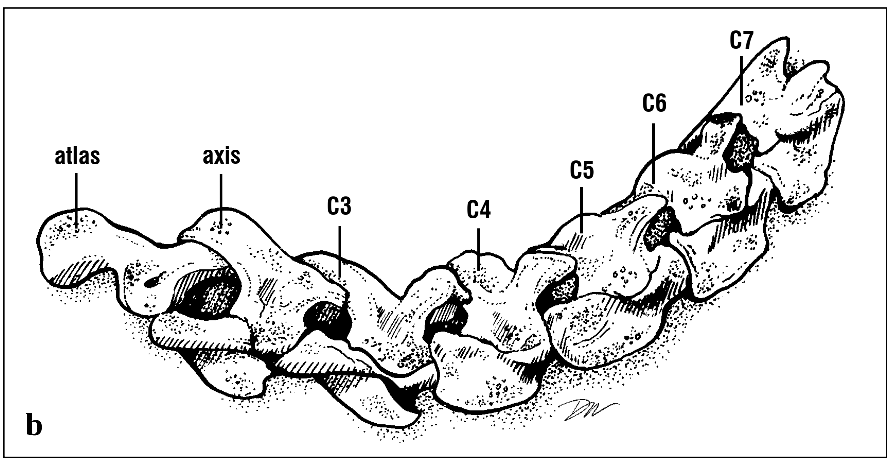




Figs. 85a and 85b. *Loggerhead skull (ventral) showing parts of the ceratohyal or the body of the hyoid, and paired hyoid processes of the hyoid apparatus. Two cartilaginous hyoid processes are lost in skull preparation. Hyoid bones are loose in the prepared skull but are suspended between and behind the lower jaws in life. The hyoid apparatus supports the tongue and glottis and serves as muscle attachment sites for some of the throat muscles. Part of the atlas (ventral cervical vertebra 1) is resting on the occipital part of the skull, posterior to the hyoid apparatus.*

Fig. 86. *Hyoid apparatus. The hyoid body supports the glottis in its concavity. Muscles attach to the hyoid processes (ceratobranchial bones) that move the throat. Cartilaginous processes are missing.*

Like all turtles, sea turtles have 7 mobile cervical vertebrae (an 8th is fused to the carapace; Figs. 87-88) and 10 thoracic vertebrae. There are 2-3 sacral vertebrae and 12 or more caudal vertebrae (Figs. 89-90). The caudal vertebrae of females are short and decrease in size distally; those of mature males are large with robust lateral and dorsal processes (Fig. 89). Each thoracic vertebra articulates with a pair of ribs, bilaterally arranged. Each rib head is aligned with the junction of two vertebral bodies (Fig. 91). Fusions of vertebrae and ribs with dermal bone result in unique carapacial bones. **Neural** bones are associated with the vertebral column, **pleurals** are formed by the ribs and their dermal expansions, and **peripheral** bones form the margin of the carapace (Figs. 92-93). The anterior-most bone is the **nuchal** and the posterior-most is the **pygal**. Between the last neural bone and the pygal is the **suprapygal**, which lacks any vertebral fusion (Figs. 92-93). The lateral processes of the sacral vertebrae are not fused to the carapace (Fig. 89).



Figs. 87a and 87b. *Lateral view of the cervical vertebrae from an adult green turtle. Each vertebra is composed of a ventral body and a dorsal arch. The ventral part of the atlas is missing from this series. The atlas articulates with the occipital condyle at the back of the skull. C7 articulates with the cervical vertebra fused to the carapace.*

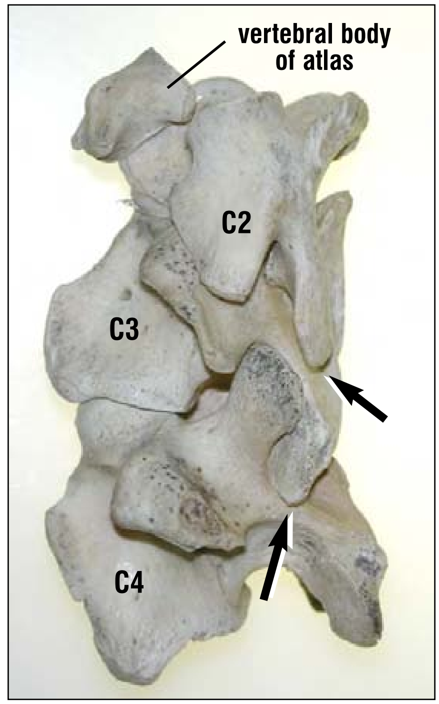
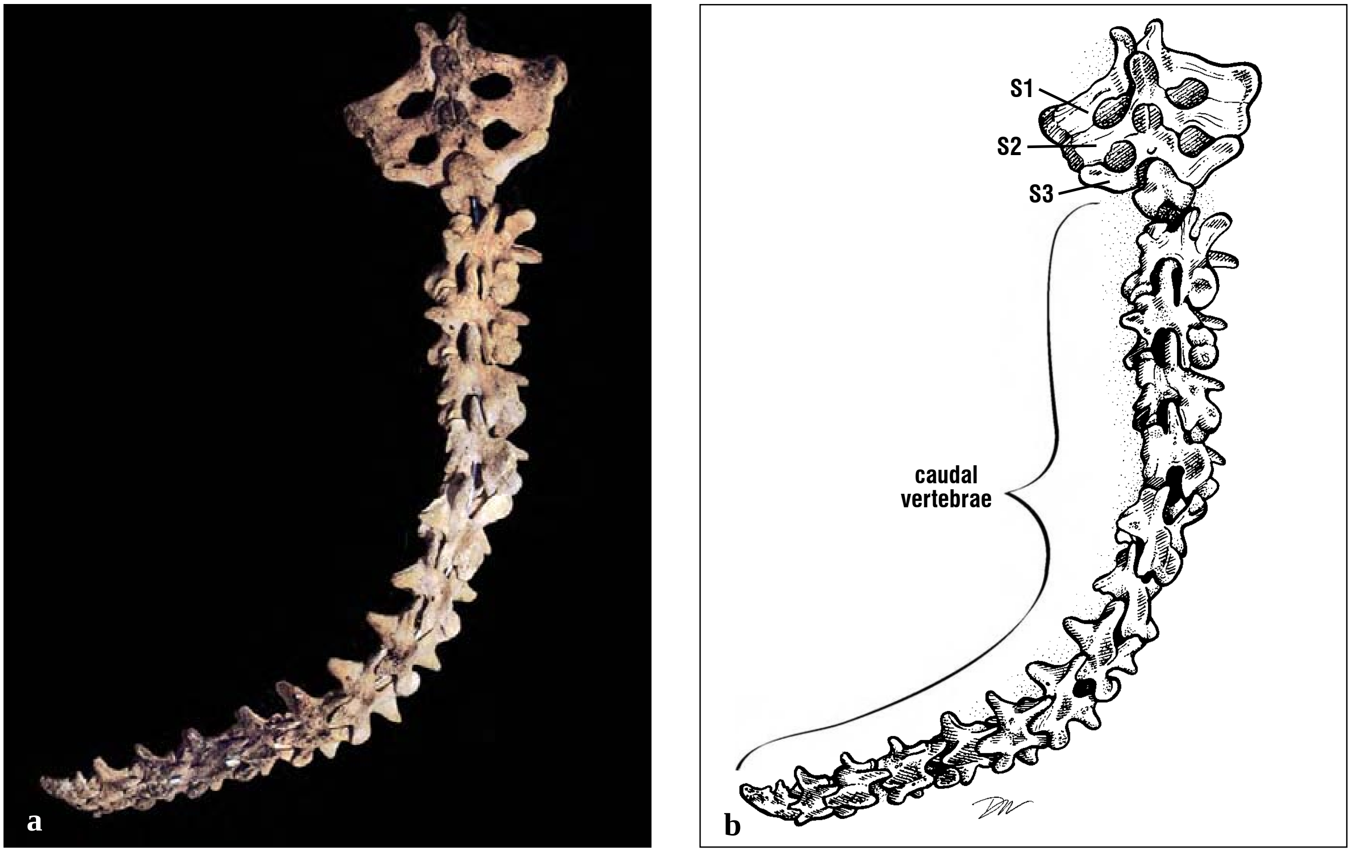


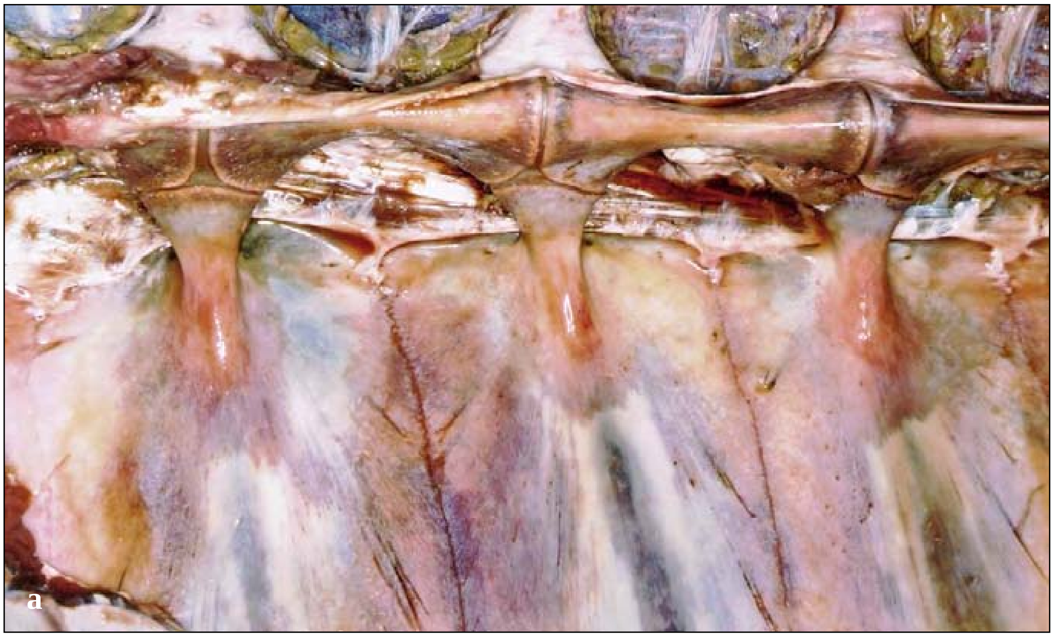
Fig. 88. *The atlas (C1) and axis (C2) complex and C3 - C4, in lateral view. Dorsal is to the right. The vertebral arches of the successive cervical vertebrae articulate via sliding joints (arrows) that allow some dorsal-ventral bending of the neck, but little twisting. Each vertebra is composed of separate dorsal and ventral elements.*

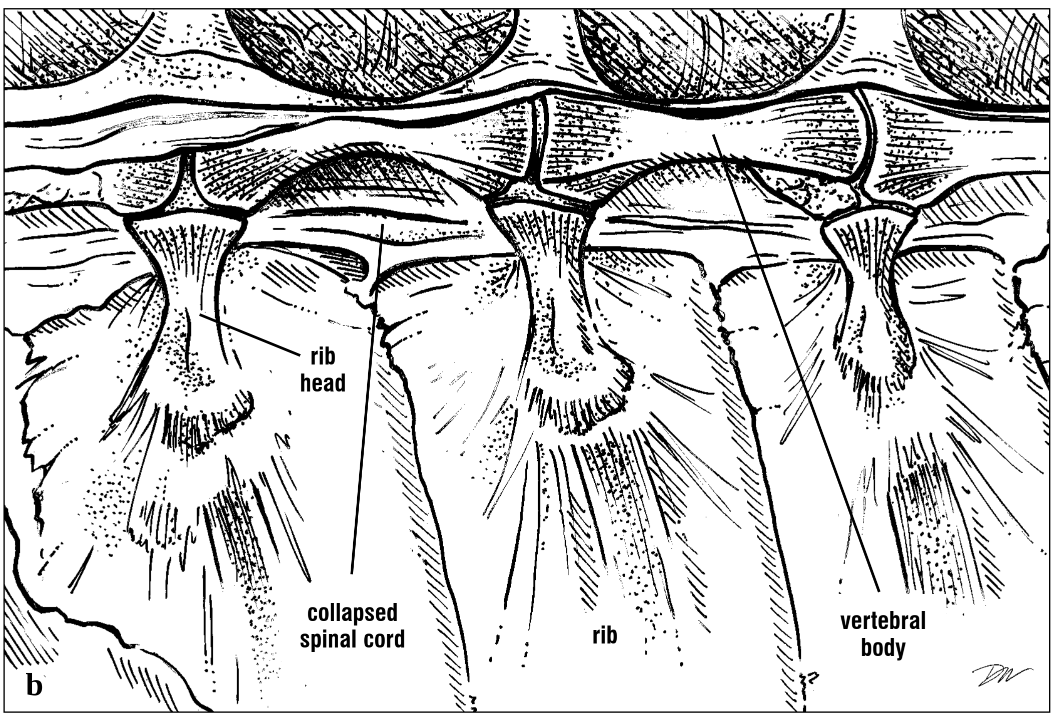


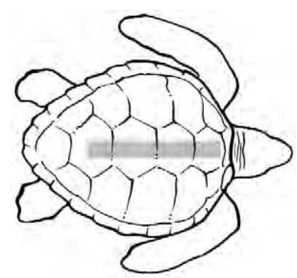
Figs. 89a and 89b. *The sacral and caudal vertebrae of an adult male green turtle. The large dorsal and lateral processes are the sites of attachments for the muscles that move the prehensile tail of mature males. S: sacral The lateral extensions of the sacral vertebrae are formed by rib-like processes that articulate with the ilium.*

In hatchlings and *Dermochelys*, the carapace is composed of ribs and vertebrae. In cheloniids, as they mature, the shell becomes increasingly ossified. Dermal bone hypertrophies between the ribs and grows outward to form the carapace (Figs. 90 and 92-93). The ribs grow laterally to meet the peripheral bones (lying beneath the marginal scutes) in *Caretta caretta*, *Eretmochelys imbricata* and *Chelonia mydas*. In *Lepidochelys kempii*, the peripheral bones also widen with age and increasing size. The spaces between the ribs and the carapace, **fontanelles**, are closed by a membrane underlying the scutes. The fontanelles are closed completely by bone in some adult ridleys and loggerheads, but are retained posterolaterally in green turtles and hawksbills (Fig. 93).

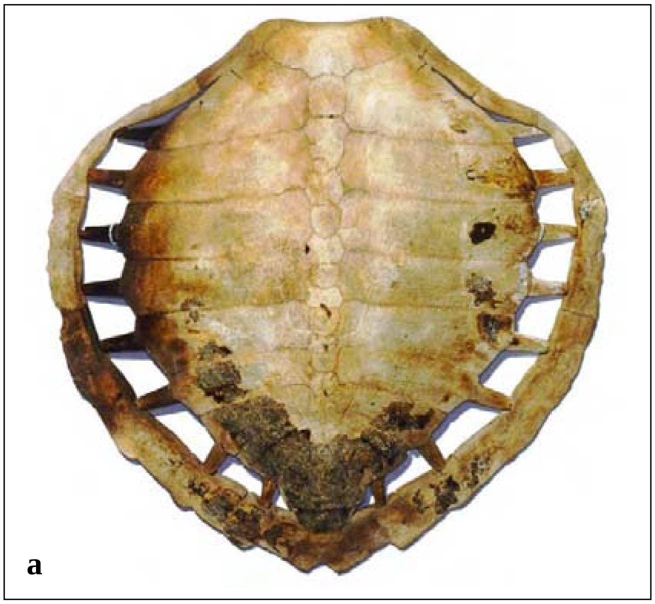
Fig. 90. *Cleared and stained hatchling loggerheads. (Left) Dorsal view with carapace removed showing vertebral regions and the level of ossification at the time of hatching. (Right) Dorsal view showing ribs, vertebrae and initial dermal bone hypertrophy along the ribs as the carapace develops. The plastron was removed in this specimen.*

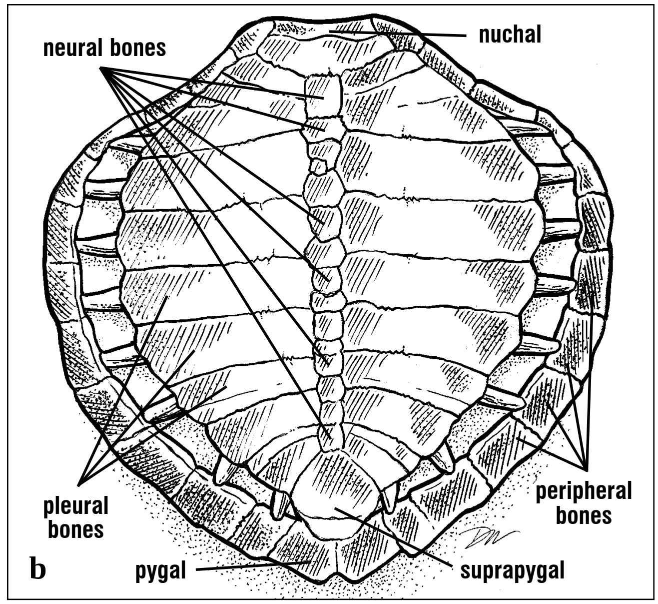




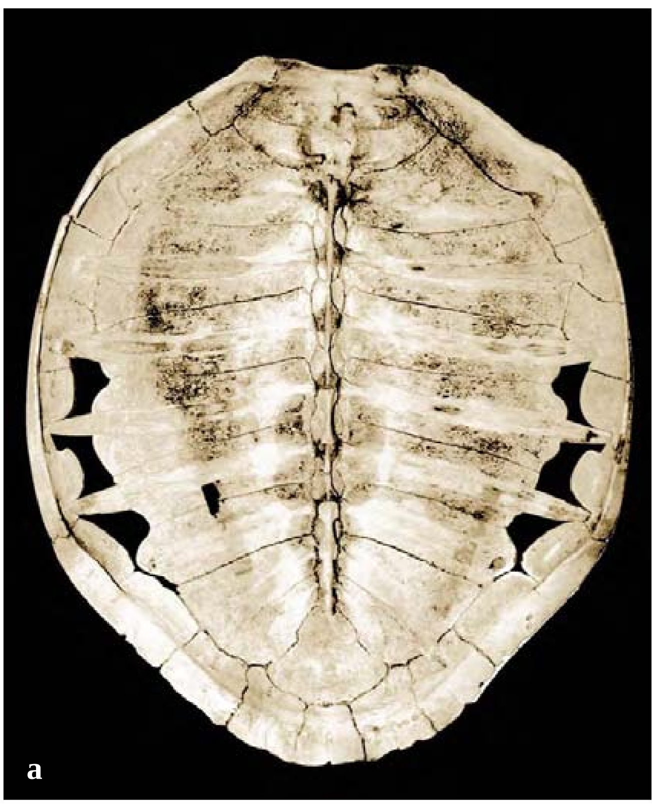


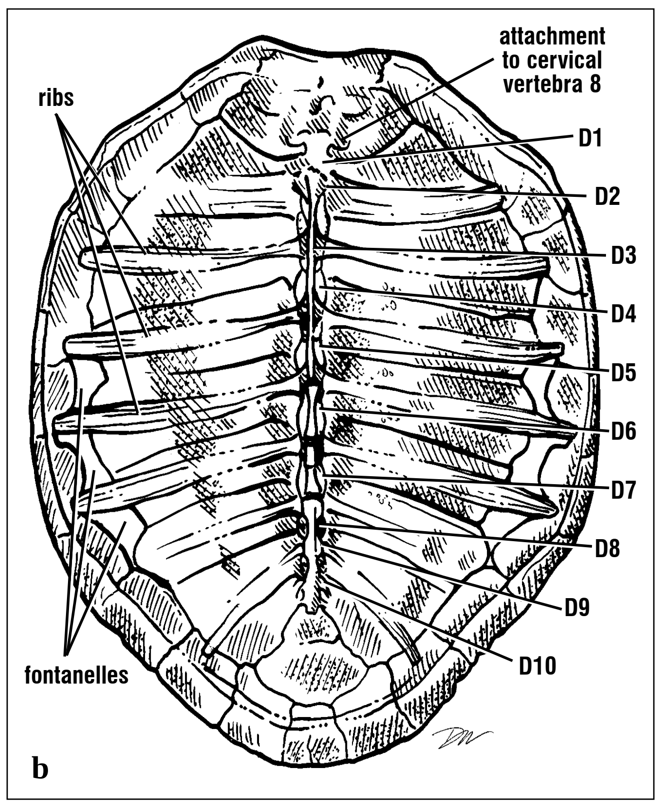
Figs. 91a and 91b. *Ventral view of the carapace showing the arrangement of the ribs and vertebral bodies. The vertebral arch is incorporated into the vertebral (neural) bones of the carapace and hence, is not seen in this view. The spinal cord travels in the space formed between the neural bones and the vertebral bodies.*





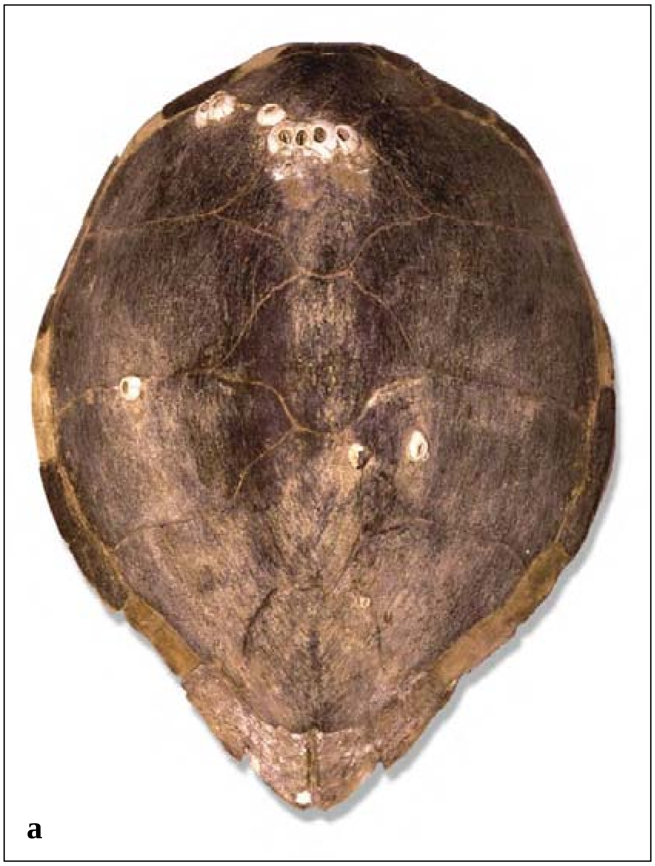
Figs. 92a and 92b. *The bones of the carapace dorsal view are identified in this Kemp's ridley. The bony arrangement of the shell is such that in some species supernumerary neural bones are common.*





Figs. 93a and 93b. *Ventral view of this hawksbill carapace shows the vertebral bodies (dorsal elements), ribs, and fontanelles. The ribs have fused with the peripheral bones anteriorly. D: dorsal elements.*

The carapace is composed of bone covered by keratinous scutes (cheloniids, Fig. 94) or blubber and skin in *Dermochelys* (Fig. 95). The margins of cheloniid scutes and the bones' sutures do not align with one another (Fig. 96). In the leatherback, the blubber overlies ribs and vertebrae and itself is covered dorsally with waxy skin and embedded dermal ossicles (Fig. 95).



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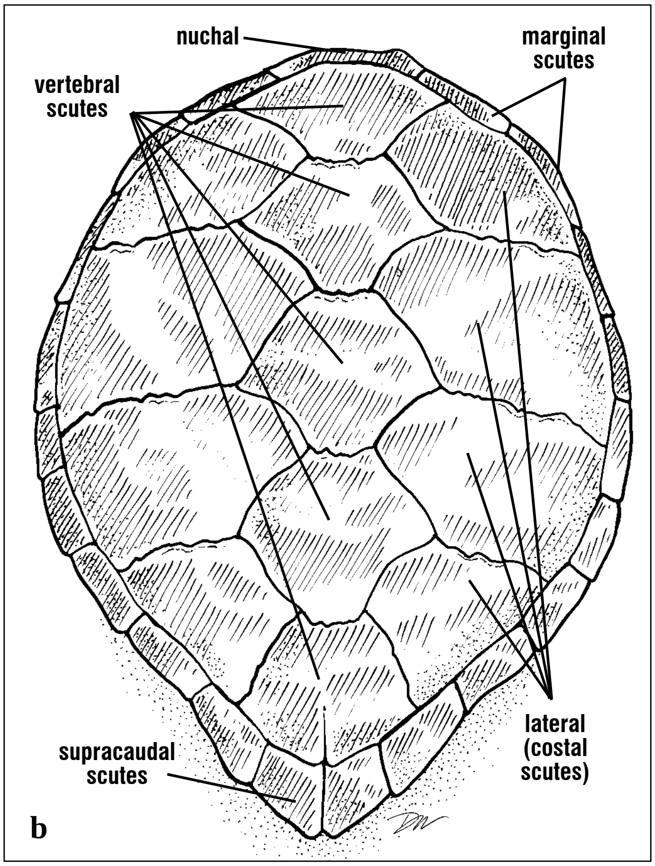


b

Figs. 94a and 94b. *The scutes are keratinous epidermal structures that grow above the carapace bones. Scutes grow two ways. They increase in size (area) at their margins. The entire scute can increase in thickness.*

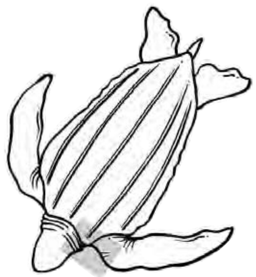


Fig 95. *Dermal ossicles are bony plates that reside deep to the skin in the leatherback carapace.*

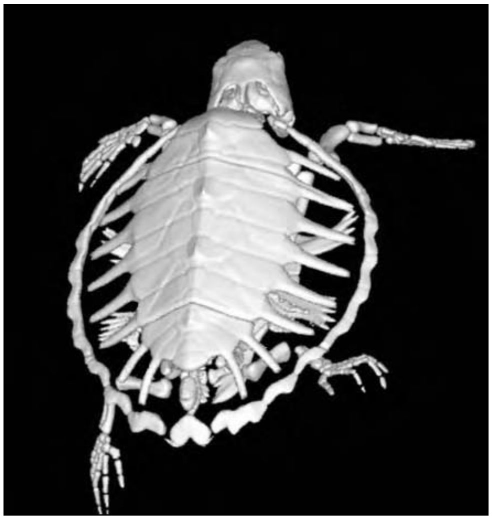
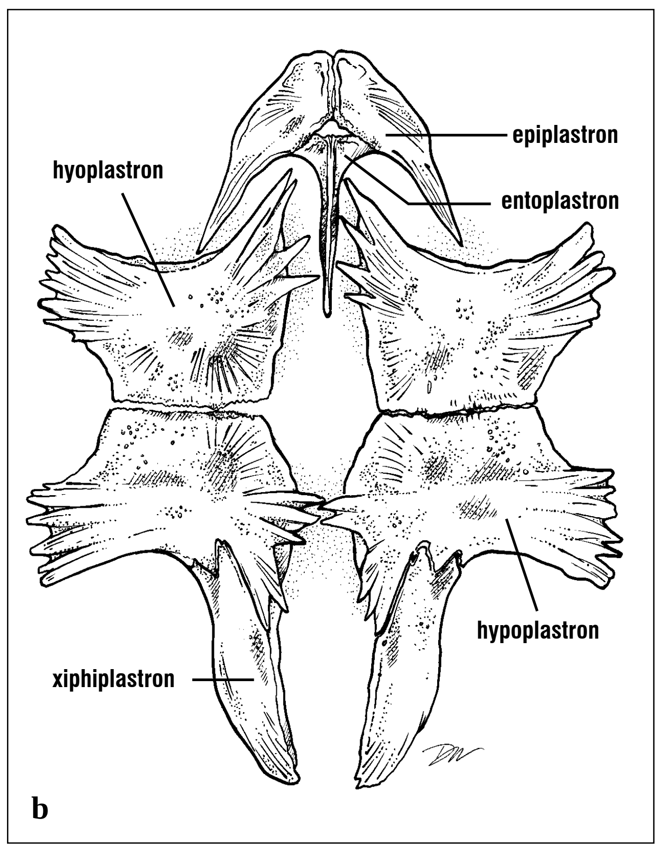


Fig. 96. *Immature loggerhead skeleton showing outgrowth of dermal bone to form the shell. The spaces between the ribs and the peripheral bones are the fontanelles. The pattern of the scutes is barely visible but hints at the lack of alignment with bony sutures. The distal parts of the flippers are cut off by the field of view in this CT image.*

The plastron is composed of 4 pairs of bones in sea turtles (from anterior to posterior: **epiplastron, hyoplastron, hypoplastron** and **xiphiplastron**) and 1 unpaired bone (**entoplastron**; Fig. 97). The shape of the entoplastron bone is sometimes used as a key characteristic (Fig. 98) for species identification.



Figs. 97a and 97b. *The plastron is composed of 9 bones that are separate in hatchlings but become fused in older turtles. Anterior is toward the top of the picture.*

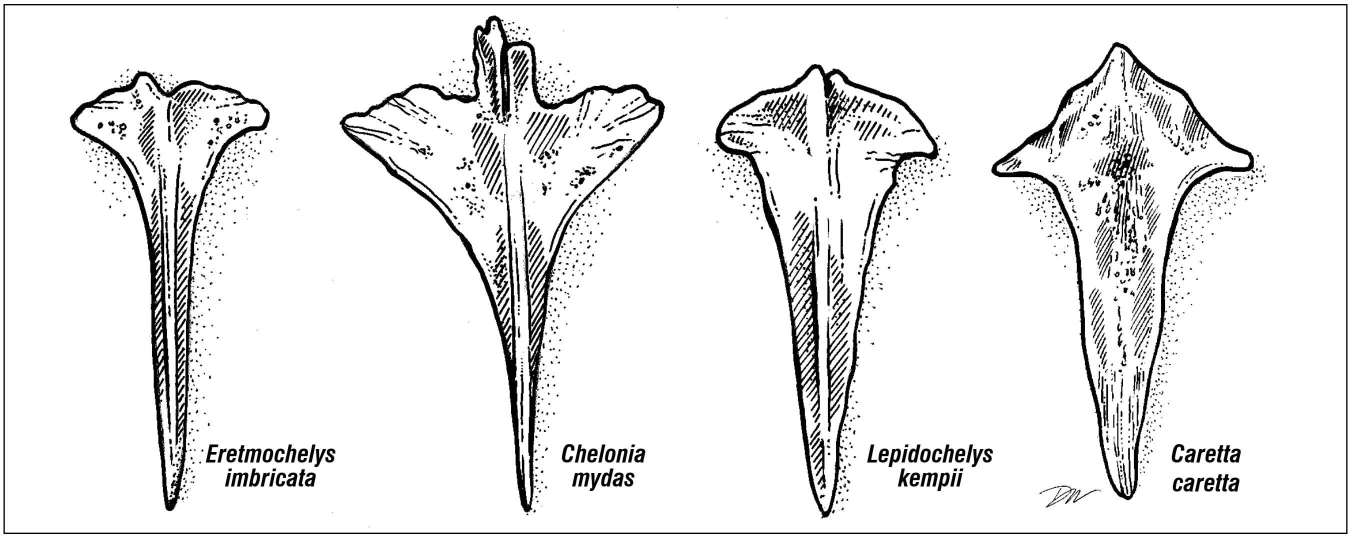


Fig. 98. *The distinct shape of the entoplastron bones may serve as a key characteristic to distinguish some cheloniid species. In E. imbricata and C. mydas the elongated shaft is narrow. The bone is roughly T-shaped in hawksbills and the shaft narrows abruptly. It is arrow-shaped in green turtles; wide anteriorly with a shaft that narrows gradually. In L. kempii and C. caretta, the shaft is wide. The overall shape is almost dagger-like in the Kemp's ridley as the shaft narrows gradually. The bone is cruciform in loggerheads; the lateral processes are distinct and the shaft tapers along its posterior half. The entoplastron has not been described diagnostically for the olive ridley. Entoplastron bones change shape during ontogeny, hence it is recommended that this characteristic be used only in adults.*

In *Dermochelys*, there is no hypertrophy of bone between the ribs of the carapace. The bony carapace remains composed solely of an expanded nuchal, ribs, and vertebrae. Ventrally, the plastron is composed of a ring of reduced plastron bones. No entoplastron is present.

The anterior appendicular skeleton includes the flippers and pectoral girdles. The pectoral girdles are composed of two bones, the **scapula**, with its **acromion process**, and the **coracoid** (= procoracoid); these form a triradiate structure (Fig. 99).

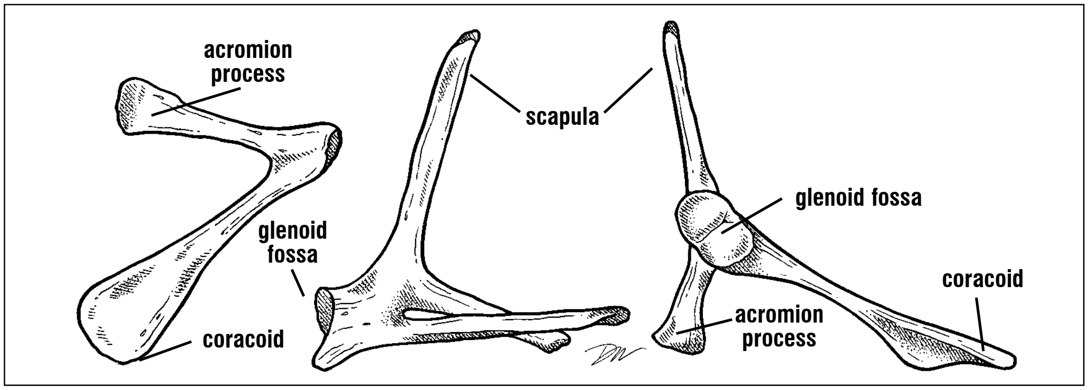


Fig. 99. *The pectoral girdle, (left to right) in ventral, posterior, and anterior views, is composed of two bones and 3 parts that serve as a major site for attachment of the swimming musculature. The acromion process extends medially from the ventral part of the scapula. The coracoid a ventral bone, is flat and wide distally. The shoulder joint (glenoid fossa), is formed by the coracoid and the scapula. (After Wyneken, 1988).*

The scapula is aligned dorsoventrally and attaches to the carapace near the first thoracic vertebra. Ventrolaterally it forms part of the shoulder joint, the **glenoid fossa** (Fig. 99). The acromion processes extend medially from each scapula to articulate with the entoplastron via ligaments. The coracoids form the remainder of the glenoid fossa and then extend posterior medially. Each terminates in a crescent-shaped coracoid cartilage. The **acromialcoracoid** ligament extends from the acromion to the coracoid. The majority of the flipper retractor and abductor muscles attach to the coracoid processes and the acromialcoracoid ligaments.

The forelimb is composed of the **humerus**, **radius** and **ulna, carpals, metacarpals,** and 5 **phalanges** (Figs. 100-103). The flipper blade is formed by widening and flattening of the wrist bones and elongation of the digits (Fig. 100). The humerus, which articulates with the shoulder at the glenoid fossa, is flattened with its head offset by ~20° from the bone's shaft (Fig. 101). There is a large bony **medial process** extending beyond the humeral head to which flipper abductor and extensor muscles attach (Fig. 101). Distal to the head and almost diagonally opposite is the **lateral process** or deltoid crest to which attach flipper protractor muscles (Figs. 101-103). In *Dermochelys*, the humerus is extremely flattened. It is composed primarily of **cancellous** bone, relatively little **cortical** lamellar bone, and with thick vascular cartilage on its articular surfaces (Figs. 104-105). In prepared skeletons, the cartilage is often lost. The extensive vascular channels in the cartilage are indicative of chondro-osseus bone formation (Fig. 104). This is unlike the cheloniid bone, which is formed by deposition of relatively thick layers (lamellae) of cortical bone around a cellular bony core (cancellous bone; Fig. 105).

The flipper (Fig. 100) is composed of wrist elements (**radiale, ulnare, centrale, pisiform, distal carpals**) and elongated **metacarpals** and **phalanges** (Figs. 100, 102-103). The **radius** and **ulna** are short in sea turtles and, in adults, functionally fused by fibrous connective tissue.

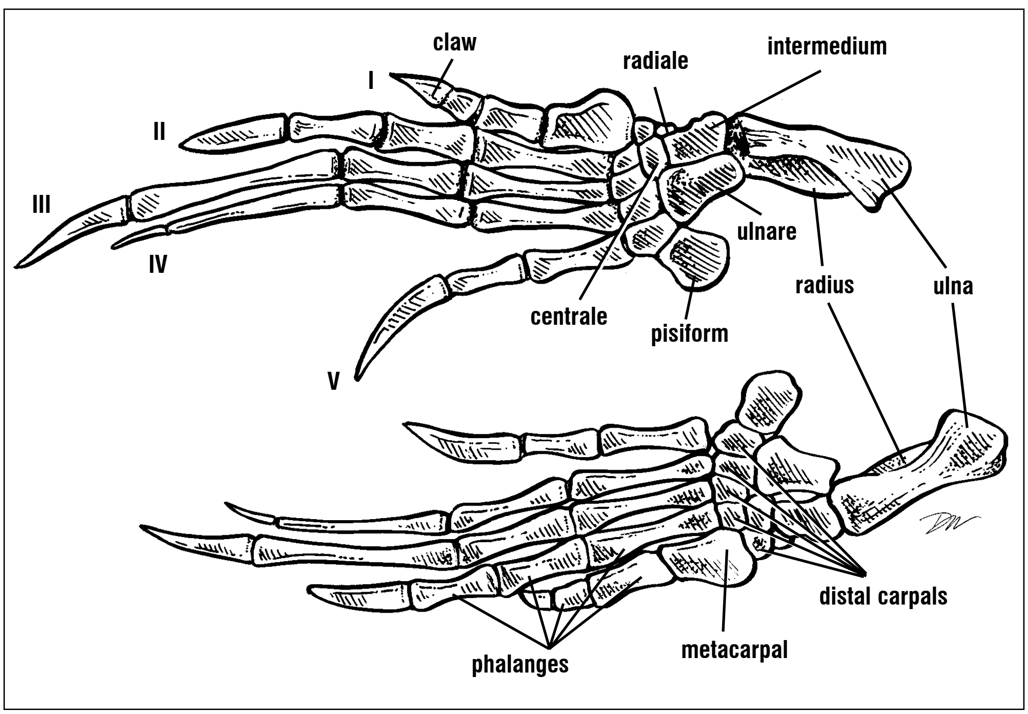


Fig. 100. *Skeletons of flippers (left and right) shown in dorsal view. Note the flat wide wrist and the elongated digits that form the flipper blade.*