A KEY TO THE COMMON GENERA OF NEOGENE SHARK TEETH

BY

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How to Use This Key

To use this key successfully, please familiarize yourself with the terminology illustrated on pages 12-14, and then, read the instructions below.

If you have many shark teeth sort them into groups of teeth with similar shapes and features; select the most complete specimens from each group to use with this key. These teeth should have complete roots and crowns. Worn and incomplete teeth cannot be correctly identified with this key.

The key consists of 50 couplets (pairs of descriptive statements), each couplet offers two alternatives (a, b) for you to choose from, but only one correctly applies to the tooth being identified. Starting with couplet number 1, select the alternative statement which best describes your specimen, and go on to the next couplet as indicated to the right of the chosen statement until your selections bring you to a generic name (such as Sphyrna). This should be the correct identity of your specimen. In this key, figure numbers refer to the drawings on P. 15-17. The number in parentheses following the couplet number allows you to retrace your steps.

Key Problems

If we all perceived objects in the same manner, keys would be much easier for us to use; however, because we do see things differently, terms, such as fine and coarse, will be perceived differently by each one of us. Therefore, to lessen the effects of our own biases, I offer the following definitions for the following terms:

Cutting edges:

Angular	Refers to the angularity of the shallow notch, which occurs about midway between the apex and base of the cutting edge; it may be subangular (slightly arched).
Arcuate	Forming an arc .
Notch, deep	Distal cutting edge of the crown is more or less vertical and forms a distinct notch with the shoulder.
Notch, shallow	Refers to the notch on the cutting edge about halfway between the apex and the base of the cutting edge forming a very obtuse angle.

Crown attitude:

Recurved	Apical portion of crown or denticle is curved.

Serrations:

weak	Can be seen clearly only with the aid of a magnifying glass or a microscope.
very fine	Not easy to see with the naked eye; can be felt by running finger nail along the cutting edge.
fine	Visible to the naked eye; the number of serrations is not easily countable with the naked eye.
coarse	The number of serrations is easily countable with the naked eye.

Terms indicating direction:

labial:	Lip side of tooth; it is usually flat or the flattest side.
lingual:	Tongue side of tooth; it is usually rounded, and on the root, this side has a central foramen (circular opening) or a transverse groove.
mesial:	The side of the tooth toward the midline of the jaws where left and right jaws meet.
distal:	The side of the tooth away from the midline of the jaws.

Since shark tooth form varies greatly within a species and more so within a genus, there are bound to be exceptions to the key; also the key may contain errors and ambiguities that have escaped my attention. If you encounter any problems with the key, please feel free to write me about them at the following address:

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Key Notes

The terminology used in Figures 3 - 5 (p. 15 - 17) and in this key is taken from Compagno, 1988; this change was made to comply with Compagno's request for a standardization of terminology. If you have used previous editions of this key, you will notice that nutritive foramen and nutritive groove are now the central foramen and the transverse groove; lateral denticles have been changed to lateral cusplets.

Tooth Types and Morphological Variation

Basic Tooth Types

Do you know which position in the jaw your shark tooth comes from? In identifying shark teeth, knowing the tooth's jaw position is important. By the attitudes of their crowns, by their root form, by their shape, and by their relative size, the jaw positions of shark teeth can be identified. In the key you will find references to different tooth types, such as upper and lower, anterior or lateral; therefore, if you know the tooth's jaw position, you will have one more indication as to whether or not you are using the key correctly. The following paragraphs describe how to identify these different tooth types.

Lowers and uppers - Unlike the upper teeth, the lower tooth crowns are not as compressed; their tips usually recurve into the jaw (lingually) or toward the more convex side of the tooth. In the anterior teeth of some lamnoid sharks, however, the very tips of the teeth recurve toward the lips (labially)(see figure 4D). In the lateral teeth, the angle formed by the root lobes is smaller, more acute, than those in the upper lateral teeth (compare figures 4B and 4C).

In the upper teeth, the crown, in profile or lateral view, is straight and its tip may recurve toward the lips (labial) -- the flatter side of the tooth is the lip side -- and the crowns are more compressed or blade-like than those of corresponding teeth of the lower jaw (see figures 4A and 4C). The upper anterior teeth of some lamnoid sharks, such as *Carcharias, Odontaspis,* and *Isurus*, are not blade-like. The roots of the upper teeth, except the first two anteriors, are thicker than those of the corresponding lower teeth.

Tooth positions - Several basic tooth types occur in lamniform sharks, which include Alopias, Carcharias, Carcharodon, Isurus, etc. Leriche (1905) and Applegate (1965) defined terms for these tooth types: median, symphyseal, alternate, anterior, intermediate, lateral, and posterior (see figure 1).

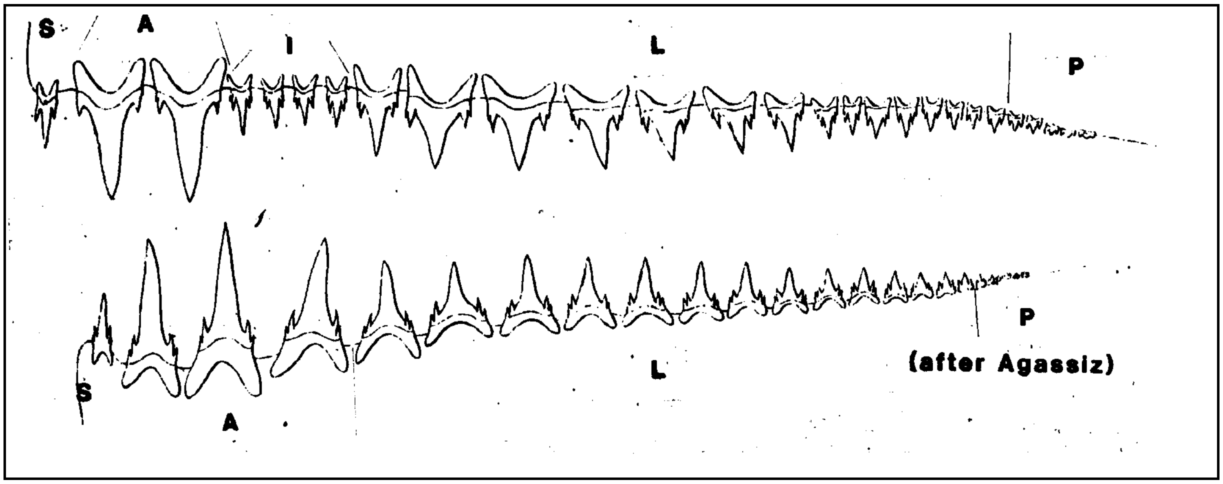

Figure 1 Outline drawing of *Odontaspis* tooth types. A = Anteriors. I = Intermediates. L = Laterals. P = Posteriors. S = Symphyseals.

Parasymphyseal teeth - In the symphyseal region of the jaws, where right and left jaws meet, small symmetrical and asymmetrical teeth can be found in many species of sharks; Applegate identified these as: median or medial, symphyseal, and alternate (definitions from Compagno, 1988). **Medial teeth** are small, often symmetrical but may be asymmetrical and occur at the juncture of the left and right jaws. These teeth are found in the Scyliorhinidae, Triakidae, Pseudotriakidae, Carcharhinidae, Sphyrnidae, Hexanchidae, Squalidae, Dalatiidae and Heterodontidae. **Alternate teeth** are small teeth with very asymmetrical roots. Compagno (1988) also noted that they "are small teeth with asymmetrical crowns that form two interdigitated rows on the symphysis, with the cusps of each row hooked mesially toward the opposite row." They occur in the Carcharhinidae and Hemigaleidae. **Symphyseal teeth** have asymmetrical roots and occur on either side of the symphysis usually in the lower jaw but may occur in the upper jaw; they usually look like miniatures of the first anterior teeth. Odontaspididae, Carcharhinidae, Sphyrnidae, Hemigaleidae, and the Mitsukurinidae have them.

Anterior teeth - These teeth usually have erect, awl-like crowns; their tips may curve distally. In *Odontaspis, Carcharias, Mitsukurina, Scapanorhynchus,* and small species of *Isurus,* the anterior teeth, in lateral view, have a sigmoidal appearance, but in the upper teeth this sigmoidal curvature is not as great, and the root is not as thick as in the lower anterior teeth. In the upper teeth of *Carcharodon carcharias* and *Isurus xiphodon,* only in the anteriors do the root lobes exhibit a noticeable angular relationship; in the lateral teeth of these sharks the root lobes form nearly a straight line. The width of the anterior teeth is less than 80%of the tooth's height.

In the **first upper anterior tooth** (Applegate's type A tooth), the most symmetrical tooth in the upper anteriors, the root lobes are nearly equal in size and form an acute angle. In the dentitions of lamniform sharks, this tooth is present in *Cretodus, Protolamna, Otodus, Cretoxyrhina, Carcharias* and *Mitsukurina* (Compagno, 1990) but it is absent in the dentitions of other lamniform sharks, whose dental formula is known; where it is missing, the "first" upper anterior tooth is actually the second (Applegate's type C tooth).

In the **second upper anterior tooth**[1] (Applegate's type C tooth) the root lobes, which form a wide acute to right angle, are not equal in size (the longest root lobe is usually on the mesial side of the tooth, in both uppers and lowers). The crown has a slight distal slant, and the distal cutting edge is nearly straight or convex. Toward the crown's apex, the mesial cutting edge is more conves than the distal one. The mesial root lobes are more pointed or tapered than the distal ones. In *Carcharodon* only, this is largest and most symmetrical tooth.

In the **third upper anterior tooth** (Applegate's type E tooth), which is the shortest in the upper anterior series, the mesial root lobe is noticeably longer, and the crown has a distal lean. The mesial cutting edge is slightly concave to straight while the distal one is slightly to strongly convex. This is usually the largest tooth in *Alopias.*

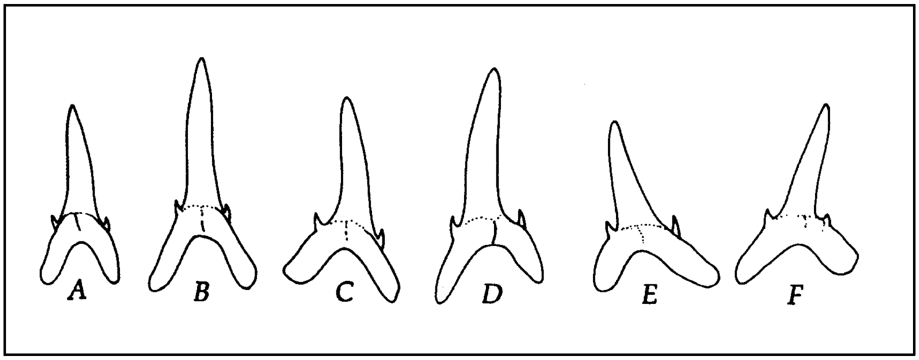

Figure 2 Applegate's six types of anterior teeth from *Carcharias taurus.* A = 1st upper anterior. B = 1st lower anterior. C = 2nd upper anterior. D = 2nd lower anterior. E = 3rd upper anterior. F = 3rd lower anterior. (After Applegate, 1965)

The lower anterior teeth are erect with their crowns curved slightly distally and their roots, in lateral view, are thicker when compared to the upper anterior teeth (except the upper A3 that is usually thicker than the lower A3). As in the uppers, the **first anterior tooth**'s (Applegate's type B tooth) root lobes, which are equal or nearly so in length, form an acute angle, usually U-shaped in appearance; one lobe may be somewhat flattened. The torus or swollen area surrounding the transverse groove and/or central foramen attains its greatest development in this tooth. The crown of this tooth, the most symmetrical of the lower anterior teeth, has the least amount of distal curvature. In *Lamna* this tooth is usually the largest in the dentition.

In the **second lower anterior tooth** (Applegate's type D tooth), the root lobes form an angle close to a right angle, and the mesial lobe is longer. The curvature of the crown is similar to that of the first. Except for *Carcharodon, Lamna*, and *Alopias,* this tooth is the largest in the dentition.

In the **third lower anterior tooth** (Applegate's type F tooth), which is the shortest in the lower anterior series, the root lobes form a right to an obtuse angle, and the mesial root lobe is longer and may be more pointed than the distal one. The torus is more prominent in this tooth than in its

[1]In the teeth of large species, such as *Carcharodon megalodon* and *Isurus xiphodon,* the root angles mentioned are broader. Leriche 1926 has excellent illustrations of these teeth identified to tooth position.

upper counterpart. The tooth's crown has a strong distal lean to it; its mesial edge is almost straight or concave.

Intermediate teeth - Intermediate teeth occur in the upper jaws of lamniform sharks between the anterior and lateral teeth. Although they are usually small, they may be almost as large the neighboring teeth. Two sharks of the same size and species may have intermediate teeth of markedly differing sizes. These teeth, except in *Carcharodon* and *Isurus xiphodon*, have U-shaped roots, and except in *Carcharodon,* the crowns that slant distally. The mesial edge of the crown is slightly concave to convex, and the distal edge is concave. In Carcharodon, the intermediate teeth have triangular crowns or crowns similar to those of lower lateral teeth and root lobes that form obtuse angles; their crowns often curve labially with their apices pointing mesially or straight up.

Lateral teeth - These teeth have root lobes that form obtuse angles, but the angles of the lower lateral teeth are smaller than the corresponding upper teeth. The crowns of these teeth are more blade-like than those of the lowers. The upper crowns curve or slant distally; whereas, in the lowers they tend to be more erect. In the upper lateral teeth, the second or third lateral tooth is the largest lateral, and the second and third laterals are larger than the first lateral tooth. In the lower jaw, the lateral teeth diminish in size distally. The roots of the upper laterals are thicker than those of the "occluding" lower teeth.

Posterior teeth - In the posterior teeth, the crowns are small and not well developed. These teeth are not identified in this key.

Teeth of no distinction - For dentitions where the above tooth types cannot be determined, Compagno (1988) provided the following definitions: "When anteriors are not differentiated (as often is the case in the lower jaw) but posteriors are, the more mesial teeth are termed **anterolaterals**; when posteriors are not differentiated but anteriors are, the more lateral teeth are **lateroposteriors**; and when neither anteriors nor posteriors are differentiated, the parasymphyseal teeth are **anteroposteriors**." In Carchrhiniform sharks, the anterior teeth are taller than they are wide, but they are not the tallest teeth in the dentition. For identifying these types of teeth to jaw position, you should compare them to actual dentitions or to those illustrated in papers by Bigelow and Schroeder, 1948, Bass et al., 1975, Compagno, 1988, and Herman et al.

Identifying tooth types may seem formidable, particularly if you do not have any dentitions of living sharks, but if you desire to develop a proficiency in identifying fossil shark teeth, it is important for you to learn how to identify the different tooth types.

Teeth vary not only by jaw position but also with age and by the sex of the shark. Pathologic or abnormal teeth often occur in shark dentitions; these are formed by tooth germs that were damaged by a foreign object, such as a sting ray spine, that was in the prey eaten by the shark (see Gudger, 1937, and Cadenat, 1962). The following sections present information about these variations in tooth form.

Tooth Variation Due to Ontogeny

Juvenile shark teeth often differ from those of adults, and juvenile dental characters may persist into adulthood. The following lists, which summarize these differences, are based on information from Bass et al. (1975), Compagno (1984, 1988), Gilbert (1967), Raschi et al. (1982), Sadowsky (1970), Smith (1951), Springer and Waller (1969), and Taniuchi (1970):

Juvenile Teeth Without Lateral Cusplets But Present in Adults:

Lamna
Odontaspis
Notorynchus
Echinorhinus

Juvenile Teeth With Lateral Cusplets But Absent in Adults:

Carcharodon
Alopias (distal cusplets present in adults of *A. pelagicus*)
Carcharhinus amboinensis

Juvenile Teeth Without Serrations But Present in Adults:

Hexanchus
Carcharodon (lower teeth and some of these may be partially serrated.)
Sphyrna

Juvenile and Small Adult First Upper Anterior Teeth With Incomplete Cutting Edges But Complete In Adults:

Isurus oxyrincus

Juvenile Teeth With Complete Cutting Edges But Incomplete In Adults:

Alopias

Loss of Distal Cusplets With Age:

Triakis
Negaprion
Prionace

Increase in Number of Distal Cusplets With Age:

Chaenogaleus
Galeorhinus
Gogolia
Hemigaleus
Hemipristis
Hemitriakis
Hexanchus
Paragaleus

Loss of Some or All Serrations With Age:

Negaprion
Prionace

Increase of Serrations With Age:
Hemipristis
Carcharhinus (some species)

Small teeth may be from juvenile sharks; in which case, you may not obtain correct identifications of them with this key, which was constructed for use with adult teeth. For example, juvenile *Lamna* teeth can key out as those of *Isurus, Alopias, Sphyrna,* or a juvenile *Carcharodon carcharias* tooth could lead you to a couplet where neither alternative would apply. If you suspect that you may have a juvenile tooth, please consult the above references for more information.

Sexual Dimorphism in Teeth

Sexual dimorphism is not very common in the larger-toothed, living sharks, but it is known to occur in a few species, which are listed below. Its absence in others may be an artifact of taxonomic research; shark specialists often do not consider tooth morphology to be important characters for identifying sharks. For them, shark soft body parts are more useful for taxonomic studies.

Alopias superciliosus and *A. vulpinus* - females have broader teeth (see Gruber & Compagno, 1981)
Carcharhinus brachyurus - "The upper teeth of large males are distinctly hooked near the tips as compared to those of females." (Bass et al., 1973, p. 24)
C. sealei - "The cusps of the lower teeth are very finely serrated, so minutely as to be visible only under high magnification. These serrations are more pronounced in young specimens of both sexes and in adult females than in males where the cusps of the lower are virtually smooth." (Bass et al., 1973, p.71)

Abnormal Teeth

These teeth are easily identified by their abnormally bent and/or wrinkled crowns, by their unusual asymmetry, or by the unusual holes or notches in them. Other teeth may not be recognized at first as abnormal teeth; these teeth arise from split tooth germs, and they look like symphyseal or posterior teeth (See Gudger, 1937; Cadetnat, 1962). Gudger and Cadenat have published illustrations of many different types of these teeth; please consult their papers for the form of these teeth. According to these researchers, these abnormalities occur when the tooth germs are impaled by a foreign object, such as a sting ray or marine catfish spine.

Using Artificial Tooth Sets to Identify Fossil Shark Teeth

Well-illustrated references will facilitate your task of reconstructing artificial tooth sets. For living shark dentitions, Bass et al., Bigelow and Schroeder, 1948; Compagno, 1984 and 1988, Garrick, 1982 and 1985, and Herman et al. have useful illustrations. In Herman et al. the teeth are not identified as to their position in the jaw, but they do provide excellent illustrations of teeth from most Recent species.

Now that you understand all of the above information and have all of the cited references that you need, you are ready to identify fossil shark teeth. First, use the key to identify your specimens to a genus; then, within a genus, sort the upper teeth from the lowers and left teeth from the right ones. Using your references, start with the anterior or anterior most teeth and reconstruct dentitions for each genus. If you have several hundred specimens for each genus, you should be able to reconstruct for each sets of upper teeth and lower teeth. If you cannot do so, reconstruct the tooth set as best as you can with the available specimens and leave spaces for the missing teeth. You may be able to find them on a future collecting trip. Please remember that this is a trial and error process (see Accuracy, p. 13), and experience is the best teacher.

Sharks are very conservative genetically; their species persist for longer periods of time than most other groups of vertebrates; therefore, compare your reconstructed shark dentitions to those of the living species first, as many as possible of one species or genus. This is important. You must examine as many dentitions as possible of both male and female individuals from juvenile to large adult. The dental variation in these teeth are great. It is best that you measure the teeth in these dentitions, photograph them, and draw the teeth or use published illustrations to map the variations that you observe in the teeth. Photographs will not show every tooth feature. Measure each tooth's height perpendicular to a line tangent with the basal lobes of the root, greatest width, and, if possible the thickness of the root at its midpoint. If you enter this data in a computer spread sheet, you can calculate the averages for each tooth position and graph the data.

Of the following groups, the tooth sets of the lamniform sharks will be the easiest to reconstruct while those of the other shark orders will be the more difficult.

Hexanchiform Sharks - These sharks, which include *Hexanchus, Heptranchias,* and *Notorynchus,* do not have distinct anterior teeth, and intermediate teeth are lacking. Their lower teeth are broader and possess more cuspletsthan the uppers. Herman, et al., (1987) illustrate the posterior teeth of these sharks. Tooth sets of these sharks are best assembled by comparing your specimens with published illustrations of dentitions (see Bigelow and Schroeder, 1948; Bass et al., 1975; and Compagno, 1984).

Squaliform Sharks - For illustrations of *Echinorhinus* dentitions see Bigelow and Schroeder, 1948, and Bass, et al., 1976; for other squaliform sharks see Garrick (1954, 1955, 1956, 1957, 1959, 1960).

Lamniform Sharks - The sharks of this group included in this key are *Alopias, Carcharias, Carcharodon, Isurus, Lamna, Odontaspis,* and *Parotodus.* Select the teeth of one genus, and sort them into upper and lower, symphyseal, anterior, intermediate, and lateral teeth (see above and fig. 1 and 2). Since the anteriors exhibit the least amount of variation within a species, they are the most useful for determining species. I find it helpful to label them as I determine their jaw position; I do it in pencil in case I change my mind later. The label will save you from identifying the same tooth twice.

After sorting them, examine the anterior teeth for differences in morphology; if differences do exist, are they between large and small teeth or teeth of similar size? Does ontogenetic variation occur in the morphology of the anterior teeth of the living species of the same genus? If there is more than one living species in the genus, how do the anterior in these species differ? By answering these questions and considering how your answers apply to your fossil specimens, you can lessen the chance of placing a juvenile and adult specimens in different species or even genera.

When you feel confident with your identifications of the anterior teeth, you are ready to consult the publications that pertain to the geologic age of your specimens for the characters that these authors use for distinguishing fossil species. Did they use characters that fall within the range of variation in the living species? Do they compare the range of variation in the teeth of the living and the fossil species? If not, their species identifications are not justified scientifically and may not be valid. Within a living shark species, considerable ontogenetic and intraspecific variations occur in tooth morphology; some of these variations differ significantly from those of published dentitions (see Hubbell, 1996). For example, in *Isurus oxyrinchus,* the short finned mako, the upper teeth widen and become thinner in larger individuals. Although their teeth are usually published in a fairly erect position, recently caught specimens show that the teeth (both uppers and lowers) of this species may be strongly arched distally. So make your identifications with morphologic variations in mind.

Carcharhiniform Sharks - These dentitions are best reconstructed with the aid of illustrations from Bass, et al., 1973 and 1975, Compagno 1988, and Garrick 1982 and 1985.

Possible Effects of Shark Distribution on the Occurrence of Fossil Teeth

Recent discoveries by ichthyologists about the behavior and distributions of extant sharks may have affected the distribution of fossil species. Springer (1967) and others report that the distribution of many sharks is determined by size, sex, or water temperature. How might these discoveries apply to the distribution of fossil sharks?

Some shark species, such as *Carcharias* and *Carcharhinus* enter shallow water to bear their young. While in these shallow waters, the adult females do not feed. As the young grow bigger, they move into deeper waters. Therefore, the teeth of these genera will be segregated by size. A series of sediments representing the deepening of a sea maycontain a series of *Carcharias* or *Carcharhinus* teeth that get progressively bigger from the shallow to the deep water sediments. In such a sequence of marine sediments, a progressive increase in the size of the teeth of these genera could result from environmental changes rather than evolutionary changes.

Along the California coast, female great white sharks also migrate to nursery areas (Klimley, 1985). In this instance the female great white shark swims south to an area where there are fewer predators (on juvenile great white sharks) to bear her young. As the young mature, they move northward toward the adult feeding area. Did this migration occur in *Carcharodon megalodon* also (Purdy, 1996)?

In areas where adult sharks feed, the arrival of a very large shark, such as *Carcharodon,* can affect species distribution. Pratt et. al. (1982) observed great white sharks, *Carcharodon carcharias,* feeding on a floating baleen whale carcass; they noted that when the largest great white shark came in to feed, the smaller great white sharks moved away from the carcasses without a contest, and they did not return until well after the large great white left. Even the normally present blue and mako sharks were gone. What effect would the presence of *Carcharodon megalodon* have on smaller competitor sharks in a feeding area?

How do all these ecological and anatomical facts about living sharks affect the identification of fossil shark species? As we learn more about the ecology and distribution of living sharks, this information will help us to understand better the speciation and distribution of fossil sharks. I believe it will allow us to synonymize more species and even some genera of fossil sharks that are only ecological, sexual, or only dental variations of previously described species. Therefore, it is important to know exactly which stratigraphic horizon your specimens come from. I encourage you, then, to maintain accurately the geographic and stratigraphic data you collect. This information will not only enhance the scientific value of your collection, but with this information, your specimens may provide another clue about the speciation and distribution of fossil sharks.

Accuracy

Don't worry about making mistakes. Many fossil shark species were defined in the last 150 years; many are based upon incomplete teeth or teeth from different jaw positions of already described species. Most of the types for these species were in European collections; some still exist, while many others were lost or were destroyed during wars. For these lost or destroyed specimens only their published illustrations exist, and some of these are not accurately drawn. Because paleontologists do not always examine the types of species or the original type illustrations, some erroneous identifications of fossil species are firmly established in the literature. Finally, dental variation in living sharks has not been adequately studied. Therefore, accuracy in identifying fossil shark teeth to species is difficult at best, and correcting species identifications is almost unavoidable; it happens even in museum collections. The best way to attain a level of proficiency with identifying fossil shark teeth is to examine as many dentitions of living sharks that you can lay your hands on. But always remember shark species identifiers beware! Variation in tooth form is the rule not the exception.

Figure 3 Illustration of shark tooth terminology. Drawing by Mary Parrish

Figure 4 Illustration of shark tooth terminology continued. Drawing by Mary Parrish.

Figure 5 Illustration of shark tooth terminology continued. Drawing by Mary Parrish.

Key to The Common Genera of Neogene Shark Teeth

1. **a)** teeth single cusped (includes teeth with lateral denticles) 2
b) teeth multicusped (see fig. 3B) 25

2. **(1a)** **a)** cutting edges of teeth notched (angular) on one or both edges, (see fig. 3C-F) 3
b) cutting edges of teeth not notched 8

3. **(2a)** **a)** cutting edges of teeth partially or completely serrated 4
b) cutting edges of teeth smooth 11

4. **(3a)** **a)** one cutting edge of tooth with angular notch 5
b) both cutting edges of tooth with angular notches 28

5. **(4a)** **a)** angular notch deep 6
b) angular notch shallow 34

6. **(5a)** **a)** shoulder (see fig. 3E and G) with fine to coarse serrations 7
b) shoulder with weak to very fine serrations . . . . *Sphyrna* (in part), *Carcharhinus* (in part), *Rhizoprionodon* (in part)

7. **(6a)** **a)** basal margin of root strongly arcuate (see fig. 3E), transverse groove not well developed or absent . . . .*Galeocerdo*
b) basal margin of root straight to subangular (see fig. 3C,D and F) with well developed transverse groove 14

8. **(2b)** **a)** cutting edges of teeth are serrated (see fig. 3A,D, and G) 9
b) cutting edges of teeth are smooth 15

9. **(8a)** **a)** root does not protrude lingually at midline of tooth; labial face of root without valley 10
b) root protrudes lingually (may be slight) at midline of tooth; labial face of root with valley 47

10. **(9a)** **a)** teeth greater than 1" (2.54 cm.) in height; basal margin of enamel of lingual face is gently arched to straight in small teeth and becoming strongly arched in larger specimens; coarse to fine serrations, thick to massive root . . . . *Carcharodon*
b) teeth 1" or less in height; basal margin of enamel of lingual face is strongly arched; moderately fine serrations, root not massive..*Carcharhinus longimanus* (upper teeth)

11. **(3b)** **a)** one cutting edge of tooth with angular notch 12
b) both cutting edges of tooth with angular notches. 19

12. **(11a)** **a)** crown contorted..*Galeocerdo* (in part)
b) crown not contorted 13

13. **(12b)** **a)** enamel shoulder with faint to coarse serrations . . . . *Galeorhinus, Paragaleus* (in part), *Rhizoprionodon* (in part), *Carcharhinus* (in part)
b) enamel shoulder smooth 20

14. **(7b)** **a)** teeth much higher than wide..................................... *Prionace* (in part)
b) teeth nearly equilateral 39

15. **(8b)** **a)** teeth have lateral cusplets (see fig. 4A, C, and D) 16
b) teeth do not have lateral cusplets 21

16. **(15a)** **a)** number of lateral cusplets on each side of crown equal 17
b) number of lateral cusplets on each side of crown unequal 23

17. **(16a)** **a)** lateral cusplets adjacent to basal edge of crown;
cutting edge of crown complete (see fig.4C and D) 18
b) lateral cusplets well above basal margin of crown;
cutting edge of crown incomplete . . . . *Hemipristis* (in part, lower anterior)

18. **(17a)** **a)** transverse groove absent; cutting edges usually straight and never
parallel toward apex . . . . *Lamna*
b) transverse groove present; cutting edges usually concave and in
more anterior teeth nearly parallel toward apex 32

19. **(11b)** **a)** root protrudes on lingual side; central foramen in shallow groove. . . . *Negaprion* (in part)
b) root does not protrude on lingual side; central foramen in deep
transverse groove . . . .*Carcharhinus* (in part)

20. **(13b)** **a)** cutting edge extends to base of crown . . . . *Scoliodon, Rhizoprionodon* (in part), *Loxodon, Sphyrna* (in part)
b) cutting edge does not extend to base of crown . . . . *Prionace* (lower teeth)

21. **(15b)** **a)** transverse groove present (see fig. 3C) 22
b) transverse groove absent or incipient 27

22. **(21a)** **a)** asymmetrical teeth; transverse groove does not extend to basal margin of root . . . . *Alopias* (in part)
b) nearly symmetrical teeth; transverse groove extends to basal margin of root to form a notch . . . . *Carcharhinus* (lower teeth)

23. **(16b)** **a)** main portion of crown recumbent . . . . *Echinorhinus*
b) main portion of crown not recumbent 24

24. **(23b)** **a)** root not lobate 50
b) root lobate 48

25. **(1b)** **a)** mesial edge of main cusp serrated, cusplets decline regularly in size distally 26
b) mesial edge of main cusp with one or more denticles, cusplet distal to main cusp shorter than more distal cusplets . . . . *Heptranchias*

26. **(25a)** **a)** 3 to 4 cusplets, serrations recurved . . . . *Notorynchus*
b) 7 to 10 cusplets, serrations not recurved . . . . *Hexanchus*

27. **(21b)** **a)** central foramen present; lingual face of root smooth 31
b) central foramen absent; lingual face of root striated . . . . . *Hexanchus* (upper anterior teeth)

28. **(4b)** **a)** cutting edges of crown smooth; enamel shoulders weakly to finely serrated 29
b) cutting edges of crown partially or completely serrated 30

29. **(28a)** **a)** transverse groove shallow or absent . . . . *Negaprion* (in part)
b) transverse groove deep (see Fig. 4-7) . . . . *Carcharhinus* (in part)

30. **(28b)** **a)** lingual face of root convex . . . . *Carcharhinus* (in part)
b) lingual face of root flattened . . . . *Sphyrna* (in part)

31. **(27a)** **a)** roots massive . . . . *Parotodus*
b) roots not massive 49

32. **(18b)** **a)** lateral cusplets prominent, not strongly curved 33
b) lateral cusplets not prominent, strongly curved . . . . *Carcharias*

33. **(32a)** **a)** two or more pairs of lateral cusplets, root lobes deeply arched and narrow . . . . *Odontaspis ferox*
b) one pair of lateral cusplets, root lobes moderately arched and broad . . . . *Odontaspis noronhai*

34. **(5b)** **a)** relatively narrow cusps 35

b) broad cusps 37

35. **(34a)** **a)** mesial cutting edge concave with slightly coarser serrations on both shoulders . . . . *Carcharhinus limbatus* & *C. amblyrhynchoides*
b) mesial cutting edge convex or straight to slightly concave with coarse to saw-toothed serrations on distal shoulder 36

36. **(35b)** **a)** mesial cutting edge straight to convex with coarse serrations at midpoint between apex and root . . . . *Carcharhinus cautus*
b) mesial cutting edge slightly concave without coarse serrations at midpoint between apex and root . . . .*Carcharhinus amblyrhynchus*

37. **(34b)** **a)** cusps with slightly coarser serrations distally 38
b) cusps with uniform serrations . . . . *Carcharhinus altimus*

38. **(37a)** **a)** mesial cutting edge marked by noticeable gap in serrations . . . . Carcharhinus *falciformis* (upper anteriors)
b) mesial cutting edge not marked by noticeable gap in serrations . . . . *Carcharhinus falciformis* (upper laterals)

39. **(14b)** **a)** cusps narrow 40
b) cusps moderately broad . . . . Carcharhinus brachyurus

40. **(39a)** **a)** cusps uniformly serrated with fine serrations . . . . *Sphyrna* (in part) & *Carcharhinus* (in part)
b) cusps not uniformly serrated 41

41. **(40b)** **a)** saw-toothed serrations on distal enamel shoulder 42
b) fine serrations on distal enamel shoulder . . . . *Carcharhinus acronotus*

42. **(41a)** **a)** mesial and distal cutting edges of cusp curved 43
b) mesial and distal cutting edges of cusps essentially straight 45

43. **(42a)** **a)** mesial cutting edge straight to convex; distal edge slightly concave . . . 44
b) mesial cutting edge concave near tip; distal edge convex . . . . . *Carcharhinus sealei*

44. **(43a)** **a)** serrations saw-toothed on shoulder . . . .*Carcharhinus melanopterus*
b) serrations coarse but not saw-toothed on shoulder . . . *Carcharhinus wheeleri*

45. **(42b)** **a)** mesial serrations fine 46
b) mesial serrations coarse basally . . . . *Carcharhinus fitzroyensis*

46. **(45a)** **a)** mesial cutting edge essentially straight . . . . *Carcharhinus porosus,*

C. sealei, C. dussumieri, C. sorrah
b) mesial cutting edge noticeably concave basally . . . . *Carcharhinus perezii*

47. **(9b)** **a)** transverse groove present in lingual root protrusion . . . . . *Hemipristis* (in part)
b) transverse groove absent in lingual root protrusion . . . . . Carcharodon (in part)

48. **(24b)** **a)** basal margin of root broadly arched . . . . *Alopias* (in part)
` **b)** basal margin of root not broadly arched . . . .*Hemipristis* (in part)

49. **(31b)** **a)** root lobes round and extend beyond basal limit of crown . . . . . *Alopias* (in part)
b) root lobes not round (in teeth under 1.5" in height) and do not extend noticeably beyond basal limit of crown . . . . *Isurus*

50. **(24a)** **a)** mesial cutting edge forms shoulder with one or more cusplets . . . . Notorynchus (in part)
b) mesial cutting edge without shoulder and cusplets . . . . *Hexanchus* (in part)

Scientific and Common Names of Sharks

Alopias	Thresher shark	L
Aprionodon	Smooth shark	C
Carcharias	Sand tiger shark	L
Carcharhinus	Bull, dusky, and others	C
Carcharodon	Great white shark	L
Echinorhinus	Bramble shark	S
Galeocerdo	Tiger shark	C
Galeorhinus	Soupfin shark	C
Hemipristis	Snaggletooth shark	C
Heptranchias	Seven-gilled shark	H
Hexanchus	Six-gilled shark	H
Isurus	Mako shark	L
Lamna	Mackerel shark	L
Loxodon	Sliteye shark	C
Negaprion	Lemon shark	C
Notorynchus	Broadnose sevengill shark	H
Odontaspis	Sand tiger shark	L
Paragaleus	Weasel shark	C
Prionace	Great blue shark	C
Rhizoprionodon	Sharpnose shark	C
Scoliodon	Spadenose shark	C
Sphyrna	Hammerhead shark	C

C	Carcharhiniform
H	Hexanchiform
L	Lamniform
S	Squaliform

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