# Notes on . . . .
# Dental Anatomy

WIDDOWSON

# NOTES ON
# DENTAL ANATOMY
## (A POCKET TOMES).

BY

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# PREFACE TO THE SECOND EDITION.

As was stated in the first edition, this work constitutes, to a great extent, an abridged "*Tomes*," to which has been added the most important theories, &c., of other authorities upon the subject. It is intended for use in conjunction with *Tomes'* "Dental Anatomy," *Hopewell-Smith's* "Histology and Patho-Histology of the Teeth," the same author's "Dental Microscopy," and *Howard Thompson's* "Comparative Dental Anatomy." Many readers have acknowledged its helpfulness and have expressed their desire and the desire of others, for a revised second edition, containing blank pages for the addition of their own notes and drawings. Numerous alterations and additions have been made, but the matter has been kept as concise, and arranged as simply, as possible.

The author trusts that the work will still remain useful, in simplifying the mass of matter dealing with the subject of "*Dental Anatomy*," and also help in furnishing a foundation upon which to build future knowledge. The writer wishes to acknowledge the great help he has received from the published works of *Mr. Charles Tomes*, *Mr. Hopewell-Smith*, and *Mr. Howard Thompson* in the compilation of these notes.

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## ERRATA.

Before perusal the following errata should be noticed and the alterations made.

Page 19, line 2, for "avoid" read "ovoid."
,, 42, ,, 14, ,, "(2)" ,, "(3)."
,, 57, ,, 33, ,, "ziphioid" read "ziphoid."
,, 88, ,, 28, ,, "Ziphioid" ,, "Ziphoid."

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# NOTES ON DENTAL ANATOMY.

(A POCKET TOMES.)

## CHAPTER I.

### ENAMEL.

Definition.—Enamel is an inorganic substance composed of lime salts, deposited in particular patterns, and formed under the influence of organic tissues which have disappeared during the process of formation (*Tomes*).

Properties.—It is hard, in its perfect form being the hardest tissue in the human body, smooth, brittle, bluish white, and semi-translucent. It contains *no* organic matter. The external surface is finely striated, the striæ being transverse to the long axis of the crown.

Composition.—

| | | |
|---|---|---|
| Salts—Calcium phosphate and calcium fluoride ... | 89·82 | per cent. |
| ,, carbonate ... ... ... ... | 4·37 | ,, |
| Magnesium phosphate ... ... ... ... | 1·34 | ,, |
| Other salts ... ... ... ... ... | ·47 | ,, |
| Water ... ... ... ... ... ... ... | 4·0 | ,, |
| Organic matter ... ... ... ... ... ... | None | |

TOMES' PROOFS OF NON-EXISTENCE OF ORGANIC MATTER.

(1) Enamel does not char on heating.

(2) On heating enamel in a flask and collecting what is given off in a tube containing calcium chloride, and then analyzing, the substance given off and absorbed by

the calcium chloride is found to be 4 per cent. of water, the 96 per cent. remaining being inorganic salts.

ENAMEL PRISMS.—Enamel is fibrous and can be split up into prisms, which in transverse section are hexagonal. Each prism is shaped like a solid cylinder in the first instance, the hexagonal shape having been produced through pressure. The prisms run from the dentine to the free surface, and are fixed into depressions in the *dentine* at one end and *Nasmyth's* membrane at the other.

In *human* enamel they have a decussating course.

In the *eel* no structure is visible, this being due to the tissue being so highly calcified.

In the *manatee* they are straight (simplest form of enamel).

In the *sciuridæ* they are divided into outer and inner portions, being thus more complex (see *Tomes*).

In the *beaver* they are still more complex (outer and inner layers).

In the *porcupine* they are more complex than in the beaver.

In the *leporidæ* (hares and rabbits) there is no lamelliform arrangement, the prisms being slightly flexuous.

In the *rat* the prisms are serrated.

## THEORIES UPON THE STRUCTURE OF ENAMEL.

*Bödecker's.*—Enamel is composed of calcified rods or prisms, between which is an active protoplasmic matrix (organic material) continuous with the contents of the dentinal tubes and thus with the pulp. This active protoplasm sends thorns into the prisms at right angles to their length. Between the enamel and the dentine are masses of active protoplasm.

*Klein's.*—In the first instance the enamel cells are separated by an organic substance, and the remains of the substance must be present between the completed enamel prisms.

*Von Ebner's.*—There is an organic substance between the prisms traceable into continuity with *Nasmyth's* membrane.

*Leon Williams.*—The enamel prisms are regularly beaded, the beaded portions being called varicosities. The varicosities lie side by side and do not interdigitate. The interprismatic substance is not organic, being of a somewhat similar structure to the prisms, but of lower order. (Probably correct.)

When enamel fractures, the fracture runs through the centre of the prisms and not through the interprismatic substance. This is due to calcification proceeding from without inwards in each prism producing fibril. The central portion is thus the last to calcify and probably the least calcified (see Calcification of Enamel).

### MARKINGS IN ENAMEL (MICROSCOPICALLY).

(1) Cross striations on the prisms.
(2) Brown striæ of *Retzius*.
(3) *Schreger's* lines.
(4) Pigmentation.
(5) Supplemental prisms.
(6) Tubular enamel.
(7) Enamel spaces or spindles.

### (1) Cross Striations on the Prisms.

Each prism presents faint transverse striations. These are very marked in the rat, due to the prisms being serrated. They are seen best marked in the outer portions of the enamel.

*Theories for this Striation.*

(*a*) Intermittent calcification (*Hertz*).

(*b*) Varicosities (*Leon Williams*). Probably correct.

(*c*) *Bödecker's* thorns.

(*d*) Irregularities on the surface of the rods (*Sudduth* and *Febiger*).

(*e*) Acids in mounting (*von Ebner*).

(2) Brown Striæ of Retzius.

These are brownish lines parallel neither to the surface of the enamel nor the dentine, seen in longitudinal section, running obliquely transverse to the long axis. They are well marked in the crocodile.

*Theories for Appearance.*

(*a*) Pigmentation (*Leon Williams*). Probably correct.

(*b*) Lamellated mode of formation of enamel (*Walkhoff*).

(*c*) Air spaces (*von Ebner*).

(*d*) Kinds of food upon which animals subsist.

(3) Schreger's Lines.

These are seen in longitudinal section only, and according to *Hopewell-Smith*, by either reflected or transmitted light, and are lines dependent upon the different directions of the contiguous groups of enamel prisms.

(4) Pigmentation.

*Hopewell-Smith's* investigations have led him to believe that nearly all enamel, whether normal, pathological, ground, mounted in balsam or glycerine, stained or unstained, or slightly decalcified, reveals a certain degree of pigmentation. He states that this is intensified if the enamel has undergone *Golgi's* rapid silver chromate method, and also that ovarian and deciduous teeth exhibit this phenomenon. Pigmented enamel is also seen in

some *rodents* (*beaver*) and some *insectivora*, and may be due to the kinds of food upon which these animals subsist.

### (5) Supplemental Prisms.

These exist between the other prisms, near to the external surface of the enamel. The circumference here is greater than at the dentine surface, so that as the prisms proceed outwards spaces are left which are occupied by these shorter supplemental rods.

### (6) Tubular Enamel.

In human teeth dentinal tubes will sometimes be seen piercing the enamel. According to *Walkhoff* the presence of the tubes in enamel is due to a resorption of the first-formed dentine, with the exception of some very resistant portions around the tubes, these eventually becoming enclosed by the forming enamel. According to *Paul* they are due to the separation of several ameloblasts by imperfectly-calcified dentine matrix, this eventually causing the presence of spaces or tubes in the fully-formed enamel. *Tomes* asserts that the tubes in enamel are probably due to arrested development in these positions. Two theories are advanced *re* the position of the tubes :—

(*a*) They are between the prisms (*Paul*, *Hopewell-Smith*).

(*b*) They are in the centre of the prisms (*Tomes*)—*e.g.*, *marsupials*. *Von Ebner* states that in *marsupial* enamel the tubes are not in the axes of the prisms.

In the lower animal world there are two forms of tubular enamel :—

(*a*) Tubes enter from without.

(*b*) Tubes enter from the dentine.

Examples of (1) *Sargus, Cestracion Phillipi, Lamna.*

Examples of (2) *Marsupials* except the *wombat,* some *fish* (*barbel* and *serrasalmo*), the *hyrax*, some *insectivora* (*soricidæ*), some *rodents* (*jerboa*), and a *fossil fish* (*spherodus*).

*Sargus.* — The tubes run at right angles from the external surface proceeding inwards. They then bend abruptly at an angle and form branches which sometimes pierce the dentine.

*Cestracion Phillipi.*—The tubes open upon the external surface by large mouths, and as they pass inwards they are gathered into bundles.

### (7) Enamel Spaces or Spindles.

These are club or spindle-shaped spaces situated in the enamel near to its junction with the dentine (*amelo-dentinal junction*), and are continuous with any dentinal tubes which pass into the enamel, appearing to be enlargements of them, like ears on the stems of the straw of corn bound up into sheaves (*Hopewell-Smith*). According to *Tomes* they are pathological.

*Theories regarding contents :—*

(*a*) Air (*von Ebner*).

(*b*) Calcareous masses (*Wedl*).

(*c*) Protoplasm (*Hopewell-Smith, Bödecker*). Probably correct.

### DISTRIBUTION OF ENAMEL.

In teeth of *limited* growth it usually stops at the neck. It is complex in *ruminants.*

In teeth of *persistent* growth it goes to the base.

It may be confined to the front and sides (incisor of a *rodent*).

It may be confined to the front only (incisor of the *wombat*).

It may be very thick (incisor of the *aye aye*).

It may be merely a tip (teeth of the *eel* and *hake*, *elephant's* incisor).

It is absent from the teeth of *edentates*, the molars of the *dugong*, the canines of the *sus babirusa*, the teeth of some *reptiles*, the *narwhal*, and some *fish*.

It covers the whole of the labial surface of the incisor of the *horse*, both root and crown, but only two-thirds of the posterior surface. It exists on the under surface only of the upper canine of the *pig* and the two anterior surfaces of the lower canine. It sometimes occurs in longitudinal bands, as in the lower incisors of the *pig* and the upper incisors of the *hippopotamus*.

According to *Choquet* the enamel in human teeth overlaps the cementum more often than the cementum overlaps the enamel. The two tissues are more often in contact with one another without overlapping. On rare occasions the two tissues do not meet, being separated slightly by the dentine.

# CHAPTER II.

## DENTINES.

CLASSIFICATION (*Tomes*).

(1) *Dentines developed on the surface of the pulp.*
(*a*) Hard unvascular dentine (ortho-dentine).
(*b*) Plici-dentine.
(*c*) Vaso-dentine.
(2) *Dentines developed within the pulp.*
(*d*) Osteo-dentine.
(*e*) Secondary dentine.

*Röse* classifies dentines as follows :—

(1) Normal tubular dentine.
(2) Vitro-dentine (has no protoplasmic processes).
(3) Vaso-dentine.
(4) Trabecular dentine (osteo-dentine).

### (*a*) HARD UNVASCULAR OR ORTHO-DENTINE.

DEFINITION.—An organic matrix impregnated with lime salts and permeated by tubes which radiate outwards from a simple pulp chamber (*Tomes*).

PROPERTIES.—Yellowish white, somewhat translucent, hard and elastic. Fractured dry dentine is lustrous, due to the presence of air in the tubes. When the lime salts have been removed by acids, the matrix yields a cartilaginous substance. If this be boiled for some time gelatine results with a small residue of elastin. The latter is derived from *Neumann's* sheaths.

COMPOSITION :—

| | | |
|---|---|---|
| Salts—Calc. carb. ... | ... | 66 per cent. |
| Mag. carb. ... | ... | |
| Calc. phos. ... | ... | |
| Mag. phos. ... | ... | |
| Calc. fluoride | ... | |
| Organic matter comprising cartilage and fat | ... | 26 „ |
| Water ... ... | ... | 8 „ |

In the dentine or ivory of the *elephant* there is about 45 per cent. of organic matter, the dentinal tubes are finer, and there is a greater number of secondary curvatures and interglobular spaces, all these conditions rendering the dentine of the elephant more elastic than man's.

STRUCTURE.—The matrix, which in many places is translucent, appears to be homogeneous and structureless, due to it being masked by the dentinal tubes and interglobular spaces. It has been proved by *Mummery*, however, to consist of fibrous connective tissue, which is more marked in carious and decalcified dentine. This is also the case in vaso-dentine, where there are neither tubes nor interglobular spaces to mask the structure. The fibres are uncalcified and are closely related to the connective tissue fibres of the pulp. They have been called *odontogenic* fibres.

DENTINAL TUBES.—Each tube starts upon the surface of the pulp, then runs out towards the periphery, becoming smaller and breaking up into two branches. These also become branched and the branches are more numerous in the root. At the pulp the diameter is greater, and they are very closely packed, so that there is not much room for matrix. Near to the surface they are more widely separated. The tubes describe larger and smaller *curvatures*. The larger are known as *primary* *curvatures.* They are *ʃ* shaped, less numerous and abrupt than the smaller, and are better seen in the crown than in the root. They are spirally twisted and so produce the smaller or *secondary curvatures*, which are more numerous and more marked in the root. The tubes contain the dentinal fibrils and a serous exudation from the pulp. *Magitot* says that the tubes contain a colourless transparent fluid. *Morgenstern* states that the tubes contain many nerve filaments. The tubes may *terminate* by—

(1) Anastomosing and forming loops.

(2) Ending in fine points in the dentine.

(3) Passing into the interglobular spaces.

(4) Ending in the lacunæ and canaliculi in the cementum.

(5) Passing into the enamel spindles.

(6) Passing into the enamel.

Dentinal Sheaths of Neumann.—These are the indestructible linings of the tubes, resistant to the action of acids, alkalies, and caries, are formed of elastin, and stain black with silver nitrate (*Golgi's* method). They cannot be fully demonstrated except by partial destruction of the dentine matrix. Much discussion has arisen with respect to the existence of these so-called sheaths. *Tomes* asserts that they do exist, and are distinct from either the fibrils or the matrix, whilst others assert that the outer portion of the fibril is the sheath. *Suddoth, Magitot*, and *Underwood* doubt the existence of a sheath. Whether, however, a sheath exists or not, the action of acids upon dentine renders it safe to assert that the portion of substance directly surrounding the fibril differs from the greater portion of the dentine matrix in the degree of its calcification.

Dentinal Fibrils.—Each tube is occupied by a fine

fibril, connected, according to *Magitot*, with the so-called *odontoblastic* layer of cells beneath. The fibrils do not stain readily, and although their function is both nutrient and sentient, they are not true nerves. They are difficult to stain, and are surrounded by a serous exudation which prevents injury. They are of some size, and when the tubes are fractured they stick out so straight as to appear stiff.

### *Theories re their Connection with the so-called Odontoblasts.*

*Magitot, Tomes,* and *Beale.*—The nerves of the pulp are continuous with a reticulate layer of cells beneath the so-called odontoblasts. These communicate freely with the latter, which themselves are connected with the dentinal fibrils, so that there is a direct line of communication between the fibrils and the pulp.

*Klein and others.*—The fibrils pass between the so-called odontoblasts to the deep cells of the pulp, and are not connected with them.

INTERGLOBULAR SPACES OF CZERMAK AND THE GRANULAR LAYER OF TOMES.—These spaces are found in the dentine and most marked just below the cementum and the enamel, where they are known as the *granular layer of Tomes.* Seen under a low power in these positions they present a granular appearance. Although common, they should not be regarded as truly normal, but as indications of arrested development in the positions in which they occur. They contain a soft plasm or a hard matrix. Sometimes the soft plasm calcifies, and the dentine is then known as *areolated dentine.* Sometimes the dentinal tubes end in these spaces. If they contain a soft plasm the tubes often run round them; if a hard matrix, through them. They may be stained with carmine or a deep black with silver nitrate. They are well marked in the dentines of the cetacea and the crocodile.

In a *transverse* section of dentine rings are seen concentric with the pulp. They have been observed and described by three authorities, viz:—

(1) *Schreger.*—The rings or the lines run parallel with the exterior of the dentine, and are due to the coincidence of the primary curvatures of the dentinal tubes.

(2) *Owen.*—The same appearance has been called the contour lines of *Owen*, and is due to the coincidence of the primary curvatures of the dentinal tubes, and sometimes to rows of interglobular spaces.

(3) *Salter.*—They have also been termed the incremental lines of *Salter*, and show how the tissue has been built up—in strata.

*Note.*—These lines of *Owen*, *Schreger*, and *Salter* are well marked in sections of the tusk of the walrus.

LAMELLÆ OR LAMINÆ.—These are described by *Hopewell-Smith* as lines seen occasionally near to the periphery of the dentine running at right angles to the tubes, and parallel to the external surface of the pulp, and have probably been caused by the manner in which the tissue has been built up—in strata.

### (*b*) PLICI-DENTINE.

DEFINITION.—An organic matrix impregnated with lime salts and permeated by tubes which radiate outwards from a pulp rendered complex by the folding in of its walls. The *structure, composition,* and *properties* are like those of hard unvascular dentine. Examples exist in the *varanus* or *monitor lizard,* in which the upper half of the tooth is ordinary tubular dentine, and the lower half plici-dentine, arranged like a paddle-wheel, in the

*Lepidosteus oxyurus*, which has simple inflexions, *L. spatula*, which has branched inflections, and a pulp chamber filled in with osteo-dentine, *labyrinthodon*, which has radiating plates of dentine, *rays*, *skates*, *myliobates*, *pristis*, *aardvark*, *selachi maxima* or *basking shark*, and the *wolf fish*.

In *myliobates*, *pristis*, and *aardvark*, instead of the tissue being described as plici-dentine, it may be said to consist of a series of small, parallel fused denticles. (See *Tomes*).

### (*c*) Vaso-dentine.

Here dentinal tubes are absent, but canaliculi exist with blood circulating through them. The pulp can be pulled out, being of simple form. The matrix is slightly laminated and its structure is fibrous. In the *hake* and other examples there exist faint thorn-like processes running out from the vascular canals. The latter radiate outwards from the periphery of the pulp. Examples exist in the *hake*, *cod*, *flounders*, *haddock*, *two-toed sloth*, *extinct megatherium*, *chætodonts*, and the principal cusp of the *ornithorhynchus*. Vascular canals rarely occur in human dentine. The remains of vascular canals occur in the dentines of the *sargus*, *manatee*, and *tapir*, which otherwise are of the ordinary hard tubular variety.

*Sargus.*—This fish has vaso-dentine with uniform vascular loops, the concavities of the loops being directed towards the pulp. The ends of the loops are continuous with one or several dentinal tubes.

### (*d*) Osteo-dentine.

This is formed within the pulp. Here calcified trabeculæ shoot through the pulp, dividing it into small portions, so that there is no clearly-defined pulp margin. There are small canals (canaliculi) but no long dentinal tubes. Large irregular spaces exist, containing pulp tissue and blood vessels. Examples occur in the *pike*, *sharks*, and other *fish*.

In the *pike* there is a surface layer of ordinary tubular dentine. Beneath this layer the structure is osteo-dentine. In the fine-tubed dentine the tubes as they pass inwards are gathered into fewer and larger tubes.

### (*e*) Secondary Dentine.

Secondary dentine is formed within the pulp, and may be found in connection with any of the before-mentioned varieties. It may be structureless or irregular. It occurs readily in elephants' tusks and whales' teeth (after injury) as a protection to the pulps, in senile human teeth, and physiologically in teeth growing from persistent pulps. In connection with the human pulp there are several pathological varieties, viz.—

*Areolar*, which contains a large number of inter-globular spaces. It is the commonest variety and is formed rapidly.

*Fibrillar*, which is like normal tubular dentine. There is a bend between the tubes of the normal dentine and the secondary, and the boundary zone between the two is well marked.

*Hyaline*, which is homogeneous and is formed slowly.

*Cellular*.

*Laminar*.

# CHAPTER III.

## CEMENTUM OR CRUSTA PETROSA.

In human teeth this tissue covers the roots and is absent from the crowns.

*Nasmyth's membrane,* which occurs external to the enamel, was once thought to be cementum. In such teeth as the molars of the *elephant,* the *capybara,* and the *wart-hog,* the denticles are fused together with cementum. It exists over the crowns of the teeth of *ruminants,* is often thickened by disease (*exostosis*), and sometimes joins the roots of one or several teeth together (*gemination*). In a single-rooted tooth it is thickest at the apex, but where there is more than one root it is thickest at the bifurcation. It is absent from *ovarian* and *anchylosed* teeth, and from the teeth of most *fish* and *reptilia.* It merges into, and is so closely connected with, the dentine, by means of the granular layer, that it is difficult to distinguish where one ends and the other begins.

Properties.—It is whitish yellow, dark, and smooth.

Structure.—According to *Hopewell-Smith* human cementum is nearly structureless, having neither lamellæ nor lacunæ. Should cementum, however, become diseased or exostosed, these structures may be seen. Under this condition vascular canals may also occur, but only on rare occasions. The matrix of cementum yields gelatine on boiling, and if decalcified becomes soft and pliable, but retains its shape, being thus chemically like bone. It is also developed like bone in either of two ways—in membrane or in cartilage. In marsupial cementum, which is thick, lamellæ, lacunæ, and canaliculi are a characteristic feature.

Perforating Fibres and Canals.—These fibres and canals are seen near to the dentine passing into the cementum at right or acute angles to it. The canals may extend half way through the cementum, and *Black* considers that the fibres are the calcified or semi-calcified remains of the principal fibres of the periodontal membrane.

Sharpey's Fibres.—These are seen in cementum penetrating the tissue from without. They are white connective tissue fibres contained in canals, and pass through the whole substance of the cementum. They are not fully calcified.

Incremental Lines of Salter.—These are lines or markings running at right angles to the long axis of the tooth, showing the manner in which cementum has been built up—in strata.

Lamellæ.—These are well marked in the cementum of *cetacea*, and are seen in transverse section as rings running concentric with the pulp. They are thinner towards the neck of a tooth than towards the apex, but there is the same number in all positions. They are more numerous in young than in completed cementum.

Lacunæ.—These are spaces, very numerous in the cementum of cetacea, elongated in the direction of the lamellæ, and containing cementoblasts, being also furnished with canaliculi.

Encapsuled Lacunæ.—Sometimes lacunæ furnished with short processes are contained within well-defined contours. They are individual cementoblasts, or nests

of cementoblasts, which during calcification have preserved to some extent their individuality. They frequently occur in the cementum of the horse.

Canaliculi.—These are the processes of the lacunæ, and are given off mostly at right angles, and chiefly from the external borders, thus differing from bone canaliculi, which are given off from all sides of the lacunæ, and in all directions. They also differ from bone canaliculi in being longer and more numerous. They communicate with one another, and also with the dentinal tubes. The cementoblasts of the lacunæ communicate with one another through these canaliculi, and those near to the external surface with the periodontal membrane; hence a pulpless tooth is not necessarily a dead tooth, as it may still receive nutrition from the periodontal membrane.

## THE PULP.

This occupies the central portion of a tooth. It was formerly the dentine papilla, and therefore the formative organ of dentine, eventually becoming its nervous and vascular supply. It varies in anatomical form according to age. In advanced age it diminishes in size, progressive calcification producing a deposit upon the walls of the cavity. Eventually the so-called odontoblasts may atrophy, and the fibrous tissue become well marked. It (the pulp) may become reddish-brown in colour, due to the degeneration of the red-blood corpuscles. Fat globules may appear along the lines of the vessels and nerves, and the walls of the former and the sheaths of the latter may degenerate. Pulp stones (calcareous degeneration) may result, or calcification of the whole tissue occur. The whole structure may break down into a greasy mass, containing fatty acid crystals. Such pathological conditions, according to *Hopewell-Smith*, do not seem at first to affect the shape of the so-called odontoblast cells of the pulp.

STRUCTURE.—As the dentine papilla it consisted of roundish cells, with the so-called odontoblasts soon making their appearance upon the surface. In young pulps the deeper cells are large, angular, rounded, or spindle-shaped. In adult pulps they are chiefly stellate or angular. The matrix of the pulp is of a mucoid protoplasmic character, and holds together the cells (including the so-called odontoblasts), fibrous connective tissue, arteries, veins, capillaries, and nerves.

THE SO-CALLED ODONTOBLASTS.—According to *Hopewell-Smith* the smaller central cells of the pulp should be called *odontoblasts*, as they produce the dentine, and the so-called odontoblasts *pulp corpuscles*. The term *odontoblasts* will, however, in this work be confined to the surface layer of cells. In young pulps they constitute one and in adult pulps several layers of large, elongated, granular cells, each having a large nucleus, usually situated at the end furthest away from the dentine. The nucleus, however, may be in the centre or at the distal end of the cell. There may be two nuclei, due to the fusion of two odontoblasts, and sometimes nucleoli. The odontoblasts probably have no limiting membrane, and, according to *Hopewell-Smith*, they are not closely packed together, but separated. When treated with hardening reagents, such as alcohol, or with water or chromic acid, they shrink and show up well-defined contours which are not seen in the fresh state. They vary in shape according to age. When very young they consist of a large oval nucleus devoid of visible protoplasm, with no dentinal process (*Paul*). When a little

older they are pyriform; when active, squarish; and when old, avoid and shrunken. They have been called the *membrana eboris*, or ivory membrane, because they are so readily pulled away from the pulp when the dentine is removed, on account of their being so closely adherent to the latter.

They possess—

*Dentinal processes*, which enter the dentinal tubes. There is usually one, which is bifurcated, in each tube, but more than one, sometimes six, may be contained in a dentinal tube;

*Pulp processes*, which communicate with the deep cells of the pulp, and, according to some authorities,

*Lateral processes*, which communicate with the lateral processes of other odontoblasts. These, if they do exist, about which there is much doubt, are exceedingly difficult to spot.

The cells of the pulp, as seen in transverse section, are arranged in a direction radiating outwards from the centre. The deeper ones, in the early stages of development are large, rounded, angular, or spindle-shaped. In the adult they are chiefly stellate or angular with long processes. The fibrous tissue present, which is continuous with that of the dentine, cannot be seen microscopically unless the pulp has degenerated. This connective tissue holds together the cells and slings the pulp up in its cavity. The granules of *Purkinje* are small cells scattered through the pulp.

Basal Layer of Weil.—This occurs between the inner end of the odontoblasts and the outer surface of the pulp, and is comparatively pale and translucent. According to *Weil*, it consists of fine connective tissue which communicates with processes of the odontoblasts. *Mummery* asserts that it is absent in the growing base of young teeth and it is in the crown that it is most pronounced. *Röse* and *von Ebner* doubt its existence and attribute the appearance to the shrinkage of the pulp, the odontoblasts being held up to the dentine by means of their dentinal processes.

Vessels of the Pulp.—Three or more branches from the superior and inferior dental and infra-orbital divisions of the internal maxillary artery enter at the apical foramen, break up into branches, which are at first parallel with the long axis of the pulp, and finally form a plexus beneath the odontoblasts. The arteries are accompanied by veins, capillaries, and nerves.

Nerves of the Pulp.—One large and three or four small trunks enter by the apical foramen from the periodontal membrane, pursue a parallel course and give off branches. They are accompanied by arteries, veins, and capillaries. They are smaller than other nerves, but otherwise are similar in structure. Their termination is obscure. They may end in a rich plexus, *the plexus of Razchkow*, beneath the odontoblasts (*Huber*); they may pass between the odontoblasts into the dentinal tubes (*Boll*); they may pass into the cells immediately beneath the odontoblasts. These being connected with the odontoblasts form a line of communication between the dentinal fibrils to the nerves (*Magitot*); they may pass between the odontoblasts to the under surface of the dentine (*Retzius*); they may pass directly into the odontoblasts and thus become, through the latter, continuous with the dentinal fibrils (*Aitchison Robertson*); they may pass between the odontoblasts, into the dentinal tubes, to the enamel (*Römer*); or they may terminate in a basket of varicose fibres embracing and often closely attached

to the cell walls of the individual odontoblasts (*Hopewell-Smith*).

The author recommends the student to read carefully the description of the nerves of the pulp, and to study minutely the diagrams of the possible methods of nerve terminations so ably given by *Hopewell-Smith* in his work "The Histology and Patho-Histology of the Teeth."

No *lymphatics* exist in the pulp.

## CHAPTER IV.

### ALVEOLAR DENTAL PERIOSTEUM OR ALVEOLO DENTAL LIGAMENT.

THIS is the membrane surrounding the root of a tooth and is thickest at the apex and the neck. In the latter position it imperceptibly merges into the gum and periosteum. It is thickest in the young, age producing a progressive calcification which extends from both the cementum and the bone. It is a fibrous connective tissue with no elastic fibres, and presents *Sharpey's fibres*, and bundles of less conspicuous fibrous tissue, the general direction of which is obliquely transverse. Near to the bone they are in conspicuous bundles, whilst towards the cementum they form a fine network of interlacing bands and pierce that tissue. The actual attachment is through the medium of the white connective tissue fibres which pass through the substance of the cementum where they are not fully calcified. They are known as *Sharpey's fibres.* The alveolar dental membrane is a single membrane, since vessels, nerves, and fibres can be traced throughout its whole thickness without any deviation in their course. It contains lymphatics. It also contains the following cells, &c. :—

*Fibroblasts,* which may be flattened or lamellar. They are supplied with nuclei and are joined together by processes.

*Cemento- or osteo-blasts* are found on the surfaces next to the cementum and the bone, and produce either cementum or bone.

*Osteo-clasts or myeloplaxes* are giant cells seen where absorption is proceeding.

*Epithelial cellular bodies or rests* are sometimes seen near to the cementum, and may originate from the remains of the epithelial sheath of *Hertwig* (this sheath is produced by prolongations of the internal enamel epithelium at the base of the dentine papilla), or from remains of the *Zahnleiste* or tooth band (*Hopewell-Smith*).

CALCOSPHERITE SPHERULES.—These are almost structureless masses of calco-globulin, occasionally seen near to the epithelial bodies, and more often when the membrane is inflamed (*Hopewell-Smith*).

GINGIVAL GLAND.—This so-called gland is a mass of cells at the gingival margin near to the attachment of the gum to the tooth. *Black* asserts that it has no glandular function. It encircles a portion only of the neck of the tooth and is sometimes absent.

BLOOD SUPPLY.—This is from the pulp, gums, and vessels of bone. The capillaries are few in number.

NERVE SUPPLY.—This is from the nerves in the bony canals, and the dental nerves.

ORIGIN.—It originates from the external layer of the dental follicle.

FUNCTIONS.—Nutrition, to sling up the tooth in its socket, to attach the tooth to the bone, and to form cementum.

DISTRIBUTION.—It is present in all gomphosed teeth, and absent in anchylosed teeth, hinged teeth, and teeth with fibrous attachment.

## GUM.

The gum is a smooth, pale pink, firm, and dense tissue, clothing the alveolar portions of the jaws. It is continuous with the mucous membranes of the mouth, but is denser. At the neck of a tooth the gum is continuous with the periosteum on the inner side of the alveoli, and there is no distinct line of demarcation between them.

ORIGIN.—The superficial epithelial portion originates from the stomodæal epiblast, the submucous from the stomodæal mesoblast.

The denseness of the gum is due to—

(1) Its dense tendinous fasciculi, which are fan shaped.

(2) Its being bound down to the bone by the blending of its fasciculi with those of the periosteum.

Single or compound broad-based papillæ beset the gum. Its epithelium is stratified in character, flattened cells occupying the surface, cubical ones a little deeper, whilst deepest of all they are columnar and constitute the *rete Malpighii.*

The gum may be divided into *stratum corneum, stratum lucidum,* and *stratum granulosum.* The epithelial mucous membrane is perforated in several places for the passage of the ducts of the mucous glands. In addition to the glands the gum contains fat lobules, and *Glands of Serres* or pavement epithelium in the submucous tissue. The function of the *Glands of Serres* is unknown. The gum is rich in vessels and lymphatics, but not in nerves.

FUNCTION.—Nutrition, and to act as padding for the bone.

## NASMYTH'S MEMBRANE OR ENAMEL CUTICLE.

Except in those teeth where enamel is covered by cementum, it is situated external to the enamel in all unworn teeth. It was at one time supposed to be cementum. It may be removed by dilute acids, is $\frac{1}{20000}$ part of an inch in thickness, is indestructible, resisting the action of acids and alkalies, is worn off speedily

except from the depressions and fissures between the cusps, and is not so hard as enamel. It consists of two layers, the outer having several layers of large hexagonal cells with nuclei, once thought to be the impressions of the ends of the enamel prisms (they are however ten times larger than the latter); the inner marked by small hexagonal impressions, probably the impressions of the ends of the enamel prisms.

Origin.—It is derived from the epiblast, the external from the external enamel epithelium, and the internal, according to *Hopewell-Smith*, from the spent cells of the internal enamel epithelium.

Function.—To protect enamel.

# CHAPTER V.

## DEVELOPMENT OF HUMAN TEETH.

In dealing with the development of the teeth, the notes will apply to the lower jaw for the sake of convenience. The process is similar in the upper.

Each tooth consists originally of an enamel organ and a dentine germ. These are universal. There is usually also a dental follicle or sac. This however may be absent (*e.g.*, tooth germs of newt and germs of anchylosed teeth of fish). Enamel is not always developed (see Distribution of Enamel).

The following changes take place before birth:—

*Fortieth to forty-fifth Day.*—An ingrowth of epithelium appears round the future tooth-bearing portion of the jaw. The groove thus formed, as seen in section, is filled in with cellular elements. The ingrowth of epithelium is known as the *primitive tooth band* and the heaping up of cellular elements as the *Zahnwall.*

*Forty-eighth Day.*—The primitive tooth band splits up into two portions—the outer vertical portion being called the *Lippenfurche, labio dental strand,* or *lip furrow* (the central cells atrophying and forming a groove), and the inner horizontal portion, the *true tooth band, dental lamina, common dental germ,* or *Zahnleiste.* Tomes mentions three theories concerning the development of the *lip furrow* and the *Zahnleiste.*

(1) *Röse.*—The Lippenfurche and the true tooth band arise from a common origin—the primitive tooth band.

(2) *Baume* and *Sudduth.*—The true tooth band originates in the Lippenfurche.

(3) *Leche.*—They have independent origins but arise simultaneously.

*Ninth Week.*—Near to the free end of the true tooth band, ten dippings-in occur. These constitute the enamel organs of the ten temporary teeth.

*Tenth Week.*—Eight thickenings then occur in the mesoblastic tissue (the first eight dentine papillæ), and about ten days later two other dentine papillæ appear for the second temporary molars. About this time the *labio-dental sulcus* is formed through the atrophy of the central cells of the *labio-dental strand.*

*Seventeenth Week.*—From prolongations backwards of the true tooth band on either side, special dippings-in occur. These are the enamel organs of the six-year-old molars. Their dentine germs arise almost simultaneously. During development the true tooth band broadens backwards, and from this broadened portion the enamel organs of the permanents develop, those of the incisors and canines at the *twenty-fourth week*, of the first pre-molars at the *twenty-ninth week*, and of the second pre-molars at the *thirty-third week* (*Röse*, *Hopewell-Smith*). The enamel organs of the permanent second and third molars develop after birth similarly to those of the other permanent teeth, those of the twelve year, *three months*, and those of the third molars *three years* after.

The dentine papillæ of the permanent teeth arise, almost simultaneously with the development of their enamel organs, from portions of the mesoblastic tissue beneath, their presence being demonstrated in the early stages by the opacity of the parts. The enamel organs, however, are much further advanced in structure.

An old theory, *re* the development of the enamel organs of the permanent tooth germs, was that those of the incisors, canines, and premolars arose from the necks of the enamel organs of the temporary teeth, that of the first molar directly from the true tooth band, that of the second molar from the neck of the enamel organ of the first, and that of the third molar from the neck of the enamel organ of the second.

Each dentine papilla rises up to meet its enamel organ which is being prolonged to meet the former. The enamel organ is at first club shaped. Eventually, through pressure from the dentine papilla, it becomes flattened and then Florence-flask shaped. Its connection now with the true tooth band is simply a thin cord consisting of two layers of cells. This becomes perforated and cribriform prior to its atrophy and consequent detachment of the enamel organ from its connection. In the tooth band, in the position where development has far advanced, degenerative changes also occur, perforation, and eventually atrophy taking place. Sometimes portions remain. These constitute the *Glands* of *Serres* or pavement epithelium.

*Conclusion.*—In origin the enamel organ is *ecderonic* or *epiblastic*, the dentine papilla and the dental follicle, *enderonic* or *mesoblastic*.

Structure of the Enamel Organ.—When the enamel organ is bud shaped, the peripheral cells are columnar, the central cells polygonal. Later the central cells become stellate in character. Between the *stellate reticulum* and the *internal enamel epithelium* occurs a narrow layer of cells, the *stratum intermedium*. When the papilla makes its appearance the peripheral enamel cells next to it become elongated and specialized, and form the layer of enamel cells or *ameloblasts*. The other

peripheral cells do not enlarge, but form the *external enamel epithelium.* At first the external surface of the enamel organ is smooth, but later it becomes indented by the surrounding tissues, and presents projections or *tufts.*

The enamel organ therefore consists of, from without inwards:—

*External enamel epithelium.*

*Stellate reticulum.*

*Stratum intermedium.*

*Internal enamel epithelium.*

External Enamel Epithelium.—This consists of cubical or rounded cells.

*Function.*—To form the external layer of Nasmyth's membrane.

Stellate Reticulum.—This constitutes the biggest portion of the enamel organ, and is composed of stellate or star-like cells from which spring long processes. The inter-spaces are filled with fluid portions rich in albumen known as enamel pulps or jellies.

*Function.*—Although enamel may be developed without this layer, it probably keeps the space for, and determines the shape of the future tooth. It is absent from the enamel organs of the tooth germs of lizards.

Stratum Intermedium.—The cells are intermediate in character between the cells of the stellate reticulum and the internal enamel epithelium, being small, polygonal, and branched.

*Function.*—To nourish the enamel cells.

Internal Enamel Epithelium.—This consists of elongated columnar cells, hexagonal in shape, several times longer than they are broad, and having large oval nuclei at their ends furthest from the forming enamel. They are granular. *Waldeyer* states that they have no limiting membrane at the ends, only at the sides. They are called *ameloblasts*. *Hopewell Smith* points out that the ameloblasts are surmounted by epithelial papillæ around and between which is a free distribution of capillary loops. The ameloblasts have an intimate relationship with the papillæ, each apparently having a root-like process. Each papilla supplies from twenty to twenty-five ameloblasts. They are supposed to originate in spindle-shaped cells. The ameloblasts, when spent, form the inner layer of Nasmyth's membrane.

THE EPITHELIAL SHEATH OF HERTWIG.—This is formed by the continuation downwards to the base of the dentine papilla of the internal enamel epithelium, and may determine the shape of the future roots.

THE INNER AND OUTER AMELOBLASTIC MEMBRANES OF LEON WILLIAMS.—These are lines, sometimes seen after staining, at either end of the ameloblasts, the inner between the ameloblasts and the formed enamel, and the outer between the ameloblasts and the cells of the stratum intermedium. The inner has been described as the *membrana preformativa*.

MEMBRANA PREFORMATIVA.—The existence of this as a membrane is doubted by *Tomes*.

*Henle* asserts that it exists between the dentine and the enamel.

*Huxley* describes it as being between the enamel and the enamel organ.

Others say that it exists between the dentine and the pulp.

*Paul*, *Wedl*, and *Magitot* say that the enamel organ is unvascular, whilst *Beale* asserts that there is a vascular network in the stratum intermedium.

STRUCTURE OF THE DENTINE PAPILLA.—This consists of myxomatous tissue, and is very rich in cells and vessels.

At first the cells are rounded; later, the deeper cells become branched, and those on the surface become differentiated into the odontoblasts or membrana eboris (for a description of these see under The Pulp). The papilla soon takes on the form of the future root or roots.

Dentogenetic Zone.—This is a band of formed but uncalcified dentine situated between the completed dentine and the layer of odontoblasts. It disappears when calcification is complete (*Hopewell-Smith*).

Structure of Dental Follicle or Sac.—In the first stage the follicle differs from the surrounding tissue in being denser, and richer in cells and vessels. It consists of bundles of white connective tissue fibres interlacing with one another. When fully developed it has two layers, an outer dense, which forms the alveolar dental membrane, and an inner loose, which forms cementum, osteo- or cemento-blasts being developed in its structure. The sac blends at the base with the dentine papilla. Where there is to be coronal cementum, as in ruminants, it is probable that a special cement organ of a cartilaginous character is developed between the follicle wall and the enamel organ.

Gubernaculum.—A bundle of fibrous tissue passing through the apex of each tooth crypt.

*Function.*—It was once thought to be to direct the passage of the tooth into its place.

## DEVELOPMENT OF TEETH IN VARIOUS CLASSES.

Fishes :—

*Teleostei* (bony fish).—There is neither Zahnleiste nor Zahnwall, the tooth germs arising *de novo.* The stellate reticulum of the enamel organ is rudimentary, having no cells but fibres. There is no dental follicle.

*Elasmobranchii* (cartilaginous).—Here there is an inflection of epithelium or Zahnleiste, which is continually growing and very thick. It is situated down the side of the jaw, and the enamel organs are developed in it. The dentine germs are developed from connective tissue beneath. There is no dental follicle. The spines on the external skin are similar in structure to the teeth. There is a continuous succession of teeth, and those not in use are usually covered and not fully calcified.

AMPHIBIA :—

*Newt.*—A tooth band exists, but the germs have no follicles.

*Frog.*—It is not known whether the enamel organs are derived from a tooth band or develop independently.

REPTILIA :—

*Crocodilia.*—Development is similar to the process in man. The succeeding teeth, however, erupt into the same sockets as the preceding ones (*Thecodont*).

*Lacertilia.*—The Zahnleiste is very long, so that the tooth germs are formed very deeply. There is neither stellate reticulum nor stratum intermedium in the enamel organ. The condensation of the cells and fibrous tissue of the submucous tissue produces an *adventitious capsule* (*Hopewell-Smith*).

*Ophidia.*—The tooth band is very short and grows continuously. The germs are at first vertical, but eventually, when near to the surface and about to erupt, they assume a horizontal position. The germs not in use are surrounded by a capsule, and this area is known as the *area of tooth development.*

# CHAPTER VI.

## CALCIFICATION.

If lime salts be added to water an amorphous powder results, but if, in addition, albumin be added, concentrically round bodies (calco spherites), and an insoluble albuminous substance (calco globulin) result.

Lime salts + an albuminoid substance = cornified substance.
Lime salts + a gelatigenous substance = calcified material.

In the actual calcification of the hard tissues, minute concentrically laminated granules embedded in calco-globulin combine with the calcium salts of the latter to form calco-spherites. These conglomerate and calcify *en masse* to form the hard material.

Dentine forms first, enamel next, and cementum last, the salts being derived from the vascular supply.

## CALCIFICATION OF ENAMEL.

The true manner of its calcification is not known. The following are the most important theories :—

(1) Actual calcification and conversion of the ameloblasts (*John Tomes*).

(2) Excretion from the ameloblasts (*Charles Tomes, Leon Williams, and others*).

(3) The ameloblasts grow near to the forming enamel, and this new growth becomes calcified into enamel (*Schwann*).

The following are the conclusions of *Charles Tomes* :—

(1) The ameloblasts themselves do not calcify.

(2) Enamel is excreted from the ameloblasts which during the process recede.

(3) Each ameloblast furnishes a fibrillar process, continuous with its own plasm, which serves for the entire length of one enamel prism.

(4) Each fibril undergoes calcification from without inwards, the process reaching the central axis, except in tubular enamels.

The following may be said to be *facts* in connection with the calcification of enamel :—

(1) Osteo-genetic fibres, calco-globulin, and lime salts occur in the corners of the ameloblasts next to the forming enamel toughening them.

(2) These changes spread upwards and inwards.

(3) The ameloblasts can be pulled away from the forming enamel, the hardened corners remaining behind. Each cell now presents a process (*Tomes' process*).

(4) During calcification Tomes' processes become everted and have trumpet-like mouths. The nuclei of the ameloblasts become large and oval, and are sometimes squarish, sometimes angular, and sometimes crescent-shaped. The ameloblasts contain granules of a highly-refractive nature which stain black with osmic acid.

## CALCIFICATION OF DENTINES.

Hard Unvascular Dentine.—Dentine is formed from without inwards, so that there is no increase externally.

Theories of Formation :—

(1) The odontoblasts become incorporated in the dentine, the outer parts of the cells becoming gelatinous, these being the seats of calcification. The intermediate

parts become partially formed (Neumann's sheaths), whilst the most central portions remain soft as the fibrils (*Waldeyer*, *Boll*, and *Beale*).

(2) Same as above, with the exception that the outer parts of the cells become fibrillar gelatinous (*von Ebner*).

(3) Dentine is excreted from the odontoblasts (*Carl Huber*).

(4) The odontoblasts take part in the formation of the fibrils, and perhaps Neumann's sheaths, receding during the formation of dentine, each leaving behind a fibril which keeps open the dentinal tube. They do not excrete the dentine, the formation of which is due to a calcification in fibrous connective tissue (derived from the pulp), through the medium of the round osteoblastic-like cells of the pulp (*Mummery, Hopewell-Smith, and others*).

Plici-dentine.—The formation is like that of hard unvascular dentine with the exception that the pattern of the tissue formed is more complex, due to the presence of a complex pulp.

Vaso-dentine.—Similar to the formation of hard unvascular dentine with the exception that the capillary plexus just behind the odontoblasts does not recede with them, but remains stationary, so that it becomes involved in the tissue formed, calcification going on around it.

Osteo-dentine.—With osteo-dentine there is usually a thin layer of hard tubular dentine. With the exception of this, the dentine is formed by an internal calcification. Soft trabeculæ shoot through the pulp. These become covered with osteoblasts, through the agency of which they become calcified, so that eventually the pulp cannot be pulled out.

## CALCIFICATION OF CEMENTUM.

Cementum may be formed in two ways :—

(i) In membrane (roots).

(ii) In cartilage (coronal).

(i) When the crown of the tooth appears through the gum, the roots have not formed, but the position which they are to occupy is surrounded by the vascular follicle wall. On the inner side of this, large cells (*osteoblasts of Gegenbaur*) or cementoblasts exist. Between these and the membrane, white connective tissue fibres occur. On the one side these become connected with the cementum, and on the other with the bone, and persist as Sharpey's fibres. The *osteoblasts of Gegenbaur* are the formative cells of cementum formed in membrane.

(ii) Between the follicle wall and the enamel organ, at about the period of dentine formation, a greyish vascular area may be seen which is firmer than the enamel organ. It becomes fibro-cartilaginous, containing *chondroplasts*, after the completion of the enamel and dentine. It is from these *chondroplasts* that coronal cementum is formed.

The following table from *Douglas Gabell's* "Dental Anatomy Note-book" is instructive :—

| Temporary dentition | Central | Lateral | Canine | 1st Molar | 2nd Molar |
|---|---|---|---|---|---|
| Enamel buds appear | 9th week | 9th week | 9th week | 9th week | 9th week |
| Calcification starts | 20th week | 20th week | 24th week | 24th week | 24th week |
| Condition at birth | 1 (crown) | $\frac{4}{5}$ | $\frac{1}{5}$ | $\frac{1}{2}$ | $\frac{1}{2}$ |
| Eruption occurs .. | 6th month | 9th month | 18th month | 14th month | 26th mont |
| Calcification ends.. | 3rd year | $3\frac{1}{2}$ year | $4\frac{1}{2}$ year | 5th year | 6th year |
| Absorption starts .. | 4th year | 5th year | 9th year | 7th year | 8th year |

| Permanent dentition | $I_1$. | $I_2$. | C. | $B_1$. | $B_2$. | $M_1$. | $M_2$. | $M_3$. |
|---|---|---|---|---|---|---|---|---|
| Enamel buds appear | 24th wk. | 24th wk. | 24th wk. | 29th wk. | 33rd wk. | 17th wk. | 4th mth. | 3rd y |
| Calcification starts | 1st mth. | 2nd mth. | 6th mth. | $1\frac{1}{2}$ yr. | 2nd yr. | At birth | 2nd yr. | 12th y |
| Condition at 6 years | 1 (crown) | $\frac{4}{5}$ | 1 | $\frac{2}{3}$ | $\frac{1}{3}$ | $\frac{1}{4}$ (root) | $\frac{1}{3}$ (crown) | — |
| Eruption occurs .. | 7th yr. | 8th yr. | 11th yr. | 10th yr. | 11th yr. | 7th yr. | 13th yr. | 24th y |
| Calcification ends .. | 10th yr. | 10th yr. | 11th yr. | 13th yr. | 13th yr. | 9th yr. | 16th yr. | ? |

## VASCULAR SUPPLY OF DENTAL TISSUES.

This is from two sets of vessels:—

(1) External or superficial.

(2) Internal or deep.

The external supplies the gum and certain parts of the enamel organ.

The internal supplies the dentine papilla, dental sac and surrounding bone.

The two sets have no connection except in the periodontal membrane where they anastomose freely. (For further details see *Hopewell-Smith's* "Histology and Patho-Histology of the Teeth.")

# CHAPTER VII.

## DEVELOPMENT OF THE JAWS.

UPPER JAW.—This appears at about the twentieth day of fœtal life as two buds growing inwards towards the median line; these are the maxillary processes. They originate from the base of the first visceral arch. The relations of the primitive buccal cavity are :—

*Above.*—Naso-frontal process.

*Below.*—Meckel's cartilage.

*Sides.*—Maxillary processes.

Whereas the two portions of *Meckel's* cartilage, around which the lower jaw is built up, meet one another and coalesce, the maxillary processes do not, and the space between them becomes occupied by a prolongation downwards of cartilage from the forehead (*naso-frontal process*). This consists of three portions—a median, which forms the intermaxillary bone, and two lateral (*processus globularis*), which fuse together and form the upper lip. Their outer edges fuse with the maxillary processes. The intermaxillary suture closes early.

LOWER JAW.—Inside the first visceral arch, a cartilage is developed running from the base of the cranium to meet its fellow of the opposite side. They fuse together in the median line. This bar of cartilage is known as *Meckel's* cartilage. With the exception of a small portion of the symphysis, the lower jaw is not developed in this. The malleus and the incus bones of the ear, however, are. The cartilage forms a foundation around which the lower

jaw is built up—in membrane. Ossification starts about the fortieth day, and whilst this progresses Meckel's cartilage atrophies, until at the seventh month it has disappeared. There are six centres of ossification –*viz.*, *dentary* (below the future mental foramen), *condyloid*, *coronoid*, *angle*, *mento-meckelian* or chin, and *splenial*. These are rapidly osseously connected.

*Splenial.*—This is like a shelf on the inner side of the jaw, situated above Meckel's cartilage and the inferior dental nerve. The tooth germs are situated upon it. As Meckel's atrophies the splenial portion joins the dentary, so cutting off the mylohyoid branch of the inferior dental nerve. The portion above the inferior dental canal is developed for the milk teeth. When these are lost it becomes absorbed and re-forms for the permanents. After the loss of the permanents it becomes absorbed and never re-forms. The portion below develops late and never disappears.

APPEARANCES OF JAWS AT DIFFERENT AGES—

*Before birth.*—The tooth germs are contained in a continuous gutter of bone. The sides of this groove rise as high as the tops of the tooth germs, but do not over-arch them.

*At birth.*—The ascending ramus is at a very obtuse angle with the horizontal, the condyle still being on a very low level. The two halves of the lower jaw are not osseously united but joined by fibro-cartilage. What was a continuous groove before birth is now seen to be separated into a number of crypts or alveoli, through the agency of bony septa, which are not fully formed at the back of the mouth. The crypts for the centrals are larger within than at their orifices and there are depressions upon the lingual walls for the germs of the permanents. The septa between the centrals and laterals pass backwards and inwards towards the median line, so that the crypts for the centrals are wider in front than behind. The lateral crypts are *vice versa* and situated a little posterior to the crypts for the centrals. The canine crypts are anterior to the lateral, giving a flattened appearance anteriorly. In the upper, the antrum of Highmore is a mere depression on the wall of the nasal cavity. The amount of calcification at this period is as follows: half the crowns of the centrals, a little less than half the crowns of the laterals, the tips of the canines, the masticating surfaces of the first temporary molars, and the cusps of the second temporary molars irregularly united by dentine.

*Six months after birth.*—The symphysis is well marked and the mental foramen noticeable. The crypts for the six-year-old molars appear but are incomplete, those in the upper jaw having no posterior walls. The cells for the permanent centrals are well marked, whilst those for the laterals are depressions on the lingual walls of the crypts for the temporary laterals.

*Eight months after birth.*—Anchylosis of the lower jaw occurs. The symphysis and the mental foramen are pronounced. The antrum in the upper jaw extends under two thirds of the orbit. Eruption of the teeth has set in.

*Adult.*—The alveolar portion is much deeper. The ascending ramus is nearly at right angles with the horizontal.

*Aged.*—The ascending ramus has almost the same relation to the horizontal as at birth, forming a very obtuse angle with it. There is also a loss of teeth and absorption of the alveolus.

*Changes preceding teething.*—A general increase in the size of the jaw bones takes place, ossification going on

rapidly in the sutures and from the periosteum. The angle of the jaw becomes less oblique. The crypts increase in depth and the edges bend in over the tooth sacs.

Fixed Points for Measurement.—For purposes of comparison certain fixed points are used. These are:—

(i) Genial tubercles.

(ii) Inferior dental canal and orifice.

(iii) Mental foramen.

In the fœtus, the genial tubercles are situated just below the central incisor crypts. Their relation to the permanents is the same. The upper are about on a level with the mental foramen. There is a slight alteration in and addition to the mental foramen, since the periosteum adds tissue to the surface, thus lengthening the canal, directing it outwards and upwards. This happens soon after birth. In the temporary dentition it is situated beneath the centre of the first temporary molar, whilst in the permanent dentition its situation is beneath the first premolar.

Measurements from these fixed points indicate that the twenty permanent teeth succeed almost vertically the temporaries into the same positions, the alveolar portion of the jaw containing these altering very slightly except by an addition to the external surface. The enlargement of the lower jaw is principally backwards by an absorption at the base of the coronoid process and a deposition at the angle, and also in thickness through a deposition from the periosteum. There is a gradual increase in depth during the formation of the alveolar portion, and enlargement also goes on at the sutures and in the sub-articular cartilage.

# CHAPTER VIII.

## ERUPTION OF THE TEETH.

Theories for Cause.—(1) Blood pressure is the active mechanical factor (*Constant*). This is the most plausible, as during eruption there exists an excessive quantity of blood in the part, and pressure from this probably forces a tooth in the direction of least resistance. However, if this is so why does eruption cease, and why do some teeth move sideways?

(2) Rotary movement of the mucous membrane, carrying the teeth with it, as in the sharks.

(3) Pressure from the addition of dentine and consequently elongation of the root.

(4) Pressure from deposition of bone in the tooth crypts.

With respect to (2) and (4), as the crown of a tooth often travels a further distance than would have been effected by either of these causes, they are probably incorrect. Again, teeth with stunted roots often erupt, and fully-formed teeth sometimes never erupt.

(5) Enamel is an epithelial structure and tends to return to the surface. Glands and nerves, however, which are epithelial structures, do not return. Again, teeth without enamel (*Edentates*) erupt.

Process.—The alveoli of the temporary incisors are absorbed. This goes on chiefly over the anterior wall, which is removed, the bone behind remaining to help in the formation of the crypts for the permanent teeth.

When the crown of a tooth appears through the gum, a deposition of bone commences and this embraces the neck, loosely at first but later on firmly. The roots and jaw deepen first in the incisor region.

Eruption is not continuous, and the periods of rest which occur allow of recuperation. The eruption of the first dentition is complete about the end of the second year. When the permanents are about due (sixth year), spacing of the temporary teeth occurs and they come to lie more anterior.

APPROXIMATE DATES OF ERUPTION.

*Primary Dentition.*

| | After Birth |
|---|---|
| Lower central incisors .. .. .. .. | 7 months |
| Upper ,, ,, .. .. .. .. | 9 ,, |
| All lateral incisors .. .. .. .. .. | 12 ,, |
| First molars .. .. .. .. .. .. | 14 ,, |
| Canines .. .. .. .. .. .. | 18 ,, |
| Second molars .. .. .. .. .. | 26 ,, |

The canines are the only temporary teeth to erupt between already erupted teeth.

*Permanent Dentition.*

| | After Birth |
|---|---|
| First molars .. .. .. .. .. .. | 6 years |
| Lower central incisors .. .. .. .. | 7 ,, |
| Upper ,, ,, .. .. .. .. | 8 ,, |
| All lateral incisors .. .. .. .. .. | 9 ,, |
| First premolars .. .. .. .. .. | 10 ,, |
| Second ,, .. .. .. .. .. | 11 ,, |
| Canines .. .. .. .. .. | 11—13 ,, |
| Second molars .. .. .. .. .. | 12 ,, |
| Third ,, .. .. .. .. | 17—26 ,, |

GENERAL RELATION OF UNERUPTED PERMANENTS WITH ERUPTED DECIDUOUS TEETH.—The canine is far above and out of the arch. There is a slight overlapping of the laterals and centrals. The premolars are beneath and sometimes enclosed by the roots of the deciduous molars.

After absorption of the alveolus the permanents erupt in a similar manner to the temporaries.

The permanents stand obliquely when erupted, the temporaries vertically.

The roots of the several teeth are completed about two and a half years after the eruption of the crowns commences.

Agents Determining Articulation—

*Pressure* from (1) The tongue.
(2) The lips.

*Opposition*, upon the upper and lower teeth meeting.

## ABSORPTION.

Some assert that absorption of the temporary teeth is due to pressure from the permanents, others that it is due to the action of an absorbent organ acting in one of three ways.

(1) Acid secretion.

(2) Phagocytosis.

(3) Amœbiform process.

Absorption is probably not dependent upon pressure. "In the frog and the crocodile the successional tooth sac passes bodily into the excavation made before it in the base of the preceding tooth, and therefore, if eruption had been due to pressure, the cells of the enamel organ, &c., would have been crushed and destroyed. Again, absorption not dependent upon pressure attacks the roots of the permanent teeth." (*Tomes.*)

Process.—Upon any part of the roots of the temporary teeth, undergoing absorption, cup-shaped depressions, *Howship's lacunæ*, occur. These coalesce, enlarge, and destroy the tissue. The cementum is attacked first and then the dentine, except a very resistant portion in close proximity to the pulp. Very closely applied to the roots undergoing the process, there exists a soft vascular tissue, the *absorbent organ*, consisting of a dense connective tissue

containing cells and blood vessels. Contained in the cup-shaped depressions and upon the surface of the absorbent organ are *osteoclasts, giant,* or *absorption cells.* The absorption of the temporaries is physiological, whilst of the permanents it is pathological, the process however being similar.

Origin.—The outer layer of the dental follicle of the permanent teeth. (*Hopewell-Smith and others.*)

# CHAPTER IX.

## ATTACHMENTS OF TEETH.

(1) Gomphosis.

(2) Fibrous.

(3) Anchylosis.

(4) Hinged.

(1) Gomphosis.—This attachment occurs in the teeth of *man*, *mammals*, some *reptiles*, and the *pristis*, or *saw-fish*. A membrane (*alveolar dental membrane*) exists between the tooth and the socket of bone in which the former is situated. Removal by disease of this membrane would cut off nourishment from the tooth. In some reptiles (*crocodile*, *&c.*), socketed teeth occur, but differ from those of man, &c., in that the succeeding rows of teeth come into the same sockets as the preceding ones occupied. In the pristis the gomphosed teeth grow from persistent pulps.

(2) Fibrous.—This attachment occurs in the teeth of *sharks*. The teeth are attached to the membrane of the jaws by means of slips of this membrane attaching themselves to the former. The rotation of the mucous membrane over the jaws brings the successional rows of teeth into place. In the *sargus* or *sheep's head* and many other fish each tooth is perched upon a pedestal of bone and is connected with it by means of an annular ligament.

(3) Anchylosis.—Here the tooth and the bone are

connected, and there is no intervention of soft tissue. Sometimes they are so intimately connected with one another that it is difficult to tell where one begins and the other ends. Usually, union of the tooth and bone takes place through the medium of osseous cylinders (*bone of attachment*), the pulp cavity of the tooth being continuous with the hollow of the cylinder. When the tooth is shed the hollow cylinder is absorbed to the level of the bone of the jaw and another is formed for a succeeding tooth.

*Examples* :—

*Eel.*—The teeth are situated upon hollow cylinders of bone which differ in lamination from the bone of the jaw. The attachment is *acrodont*—that is, the whole of the base of the tooth rests upon the bony cylinder.

*Haddock.*—As in the eel, except that the attachment is *pleurodont*—that is, a portion only of the base of the tooth, in this case the outer portion, rests upon the bony cylinder, the inner portion passing within the hollow.

*Mackerel.*—The teeth are slung up between the plates of the jaw by means of osseous trabeculæ which pass between the inner side of the alveolus and the outer sides of the teeth, the bases of the latter resting upon nothing hard.

Development of Osseous Cylinders.—Soft trabeculæ spring between the bone of the jaw and the teeth. These become lined with osteoblasts, through the agency of which they become calcified, and so produce the cylinders.

Hinged Teeth.—These occur in the *cod, hake, angler, pike, Odontostomus hyalinus, Bathysaurus ferox*, and many others.

*Angler.*—Here the hinged teeth are supplied posteriorly with fibrous elastic ligaments. On the teeth being bent inwards these become compressed, the teeth returning to their original positions upon the force being removed.

*Hake.*—The teeth have elastic hinges. The pulps are very vascular and the vessels pass through foramina, which are about the axes of motion, in the hinges, and this prevents their being injured. The free edges of the bases of the teeth are thickened and rounded and adapted for resisting shock. These edges are on a higher level than the edges to which the hinges are attached and fit upon buttresses of bone; therefore the teeth cannot be bent outwards without injury to the ligaments. This arrangement is for catching fish. The hake has other teeth which are anchylosed. The *bathysaurus* and *odontostomus* have teeth with elastic hinges.

*Pike.*—This fish has anchylosed and hinged teeth. In the hinged variety rods shoot down through the pulp but remain soft and elastic. They are attached to all parts of the teeth but only to the hinged side of the bone. The hinge itself is not elastic and the elasticity of the arrangement is due to these soft trabeculæ. This adaptation is for swallowing.

*General Note.*—Hinged teeth have arisen independently, in families widely removed from one another, from the former fixed teeth of those families.

# CHAPTER X.

## FORMS OF HUMAN TEETH.

$$\text{Formula—}\quad I\,\frac{2}{2}\;C\,\frac{1}{1}\;PM\,\frac{2}{2}\;M\,\frac{3}{3} = 32$$

Each tooth consists of a crown, a neck, and a root or roots. The crown is that portion above the gum and is covered with enamel. The neck is the constricted portion at which the enamel terminates, and the root or roots, the portion which is covered with cementum, and embedded in the bony socket. Each tooth has four surfaces, a mesial, nearest the median line, a distal, furthest away from the median line, a lingual, nearest the tongue, and a buccal or labial, nearest the cheek or lips.

### Incisors.

*Upper central.*—This is larger than the upper lateral. The neck is not very constricted. The crown is oblong. The median angle is lower than the distal and more acute. The labial surface is convex, and often presents two longitudinal grooves terminating in two notches at the biting edge. The lingual surface is slightly concave, and terminates towards the gum in the cingulum. The pulp cavity terminates towards the biting edge in two cornua, and the root is cylindrical.

*Upper lateral.*—It is smaller than the central. The neck is not very constricted and the labial surface is convex. The lingual surface is flatter than that of the central and the distal angle is more rounded than is the case with the central. The cingulum is often more pronounced. The pulp cavity ends in cornua as in the central, and the root is cylindrical.

*Lower central.*—It is narrower than the upper. The neck is more constricted and the root is flattened from side to side. The labial surface is convex and the lingual concave. There is no well-marked cingulum. The distal angle is only slightly rounded off. The pulp cavity ends in cornua towards the biting edge.

*Lower lateral.*—It is larger than the central, and the distal angle is considerably rounded. Otherwise it is like the central.

## Canines.

*Upper.*—The point at which the crown ends is in a line with the long axis of the tooth. From this point, on each side, is a slope, the distal being the longer. The lingual surface is convex, and presents a ridge running from the point to the cingulum, the latter being well marked. In transverse section, the neck is triangular with rounded corners. The labial surface is convex, and presents a feebly marked perpendicular ridge. The root is cylindrical.

*Lower.*—It is less pronounced than the upper, the lingual surface is concave, the point is blunter, and the root is shorter, and flattened from side to side. There is no perpendicular ridge on the labial aspect. Otherwise it is like the upper.

## Premolars.

*Upper.*—The crown is quadrilateral and presents two cusps, the outer being the larger. The labial surface is convex as is also the lingual, the latter not presenting a cingulum. There is a transverse depression between the cusps. The root is usually single in the second and

flattened from side to side, and double in the first. The second differs also from the first in having a larger inner cusp. The pulp cavity ends in cornua.

*Lower.*—It is smaller than the upper and has two cusps, labial and lingual, which are joined by a ridge. The outer cusp bends inwards, and the inner is not well developed. The root is rounded. The second differs from the first in that the inner cusp is much more pronounced, and the whole tooth is larger. The pulp cavity ends in cornua.

### Molars.

*Upper.*—The crown is squarish, with four cusps, of which the antero-internal is the largest. By means of an oblique ridge it is connected with the postero-external. The cusps are separated by grooves, which are continued on to the lingual and labial aspects of the tooth. Sometimes the postero-internal cusp is suppressed. There are three roots, one palatine, which is the largest, and two buccal, the posterior of which is the smallest of the three. The third upper molar is often small and the roots confluent. The pulp cavity ends in cornua.

*Lower.*—It has a squarish crown, and in 80 per cent. of man five cusps on the first, four on the second, and five on the third. The other 20 per cent. has five cusps on each of the three. One cusp is situated at each corner, and where there is a fifth, this lies between, and a little behind the postero-internal and the postero-external, where one of the fissures seen on the crown surface divides. The roots are two in number, and are flattened from before backwards and placed anteriorly and posteriorly. The third tooth is often large, and the roots are often confluent and curved backwards.

From the foregoing description, it will be seen that by gradations the molar passes to its shape and form from the incisor, through the canine and premolar, by a rounding-off of the distal angle in the lateral, the formation of a prominent point in the canine, the elevation of the cingulum in the premolar, and the addition of cusps in the molar.

Each tooth in the upper jaw except the third molar articulates with two in the lower.

The *temporary* teeth differ from the permanent in the following respects :—

(1) They are smaller.

(2) Their roots are more divergent.

(3) Their necks are more constricted.

(4) The enamel ends abruptly at the necks.

(5) The first upper molar has three cusps, and the second four.

(6) The first lower molar has four cusps, and the second five.

(7) They show marked signs of attrition.

(8) They are on a lower level in the jaw.

(9) They have a perpendicular implantation.

## Definitions of Teeth.

*Incisors.*—The upper are those situated in the inter-maxillary bone, and the lower are those which oppose the upper.

*Canines.*—The upper is the first tooth past the inter-maxillary suture, providing it is not too far behind. The lower is the tooth which bites directly in front of the upper.

*Premolars.*—Those teeth in front of the molars. They are usually more simple than the latter and have displaced deciduous teeth.

*Molars.*—The teeth behind the premolars which have no predecessors.

*Difficulties in Connection with Definitions.*

*Ruminants* have eight lower front teeth all similar, the last one being called a canine because it bites in front of the upper canine, because it is the last of the series to erupt, and because six is the typical number of incisors. *Tomes* points out that the first reason is weak, because in the *oreodon, lemurs* and *insectivora*, the caniniform tooth bites behind the upper canine, but is called a premolar, that the second reason is weak because although the fourth tooth is the last of the series to erupt, the periods of rest between the eruption of the other teeth are about the same as the period of rest between the eruption of the third and the fourth, and that the last reason is also weak because the *oreodon* had eight lower incisors and also lower canines.

## MILK TEETH.

*Homodonts* are usually *monophyodonts*. *Heterodonts* are usually *diphyodonts*. Sometimes the milk teeth are lost very early (*mole, bear*, &c.). Sometimes they are lost in utero (*seal*). In man they remain until about the seventh year.

In some mammals they remain until the adult stage (*ungulates*). Where only one set of teeth exists it is usually the milk set. In milk teeth sexual differences are not marked.

*Owen* asserts that having no predecessors and arising directly from the tooth band the permanent molars are milk teeth, *Woodward* and *Magitot*, that they belong to the second in replacing dentitions, *Schwalbe*, that they represent both milk and permanent dentitions through a fusion of the germs of both, and others that each tooth is the last of a separate series. *Baume* suggests that the permanent and temporary germs originally laid side by side, but due to want of room they have become crowded upon one another. The teeth lying near to the surface are developed, used, and lost first, being absorbed and ejected by those lying beneath.

*Cetacea.*—The milk teeth persist, except in the *balænoptera rostrata*, where the deciduous germs, partially calcified, are lost before birth.

*Rodentia.*—There is a poorly-marked milk dentition, except in *hares* and *rabbits,* which have $\frac{3}{3}$ incisors and $\frac{6}{4}$ molars, lost early. In *rats* there are no deciduous teeth.

*Carnivora.*—There is a well-marked milk dentition, except in *aquatics.* Formula $\frac{3.1.3}{3.1.3}$ except *Felidæ* $\frac{3.1.3}{3.1.2}$.

*Insectivora.*—There is a well-marked milk dentition, often remaining late, so that the permanent and milk dentitions are mixed. In *shrews*, the milk dentition is greatly reduced. In *bats*, the milk teeth are homodont, the permanent heterodont.

*Chiroptera.*—There is an ill-developed milk dentition.

*Primates.*—There is a well marked milk dentition. The formula in *apes* is $\frac{2.1.2}{2.1.2}$.

*Ungulates*—The milk teeth are well marked and remain late. Formula $\frac{3.1.4}{3.1.4}$. In the *elephant* there is no vertical succession in the cheek teeth, only in the incisors.

*Edentates.*—There is no milk dentition except in the *nine-banded armadillo* and the *aardvark.*

*Marsupials.*—*Leche* and others assert that the functional teeth are milk teeth and that the tooth which displaces two others is a permanent. Others assert that the functional teeth are permanents and that the tooth which displaces others is a post-permanent. *Tomes* regards the presence of pre-milk and post-permanent teeth as hypothetical.

*Sirenia.*—There is a fairly well-marked milk dentition in the *manatee*, but only two incisors in the *dugong.*

## RELATION OF THE TEETH TO OTHER DERMAL APPENDAGES.

Teeth are called dermal appendages on account of the relationship of their development with the development of hair, scales, &c. That the development is similar may be observed in the young dogfish, where the mucous membrane of the mouth is continuous with the external skin. There is no line of demarcation between the two, and the spines outside are continued into the mouth. Later, when the mucous membrane of the mouth becomes marked off from the external skin, the internal spines become specially developed and form the teeth. The teeth, the scales of the shark, and human hair, are similar in *development*. Teeth are therefore *homologous* to other dermal appendages. Things are, on the other hand, *analogous*, when they are alike in form and function only, *e.g.*, feathers of birds and clothing of man. The following are several examples of the relation of the growth of the teeth with other dermal appendages and other organs (*correlation of growth*).

(1) Where horns exist, canine teeth are absent and *vice versâ* (deer, &c.).

(2) Castration of the pig stops the growth of its canines.

(3) The skin of the edentates and the structure of their teeth are peculiar.

(4) Inherited baldness is usually associated with inherited deficiency of teeth.

(5) Almost hairless dogs in Turkey have few teeth.

(6) Abnormally hairy people have few or poor teeth.

(7) Hornless rhinoceroses have augmented incisor teeth. The two-horned adult rhinoceros has no incisor teeth.

# CHAPTER XI.

## COMPARATIVE DENTAL ANATOMY.

### INTRODUCTION.

It was once thought that the different types of teeth had been derived from a standard organization by modifications of and departures from that type. According to modern authorities, however, the present numerous forms of teeth have been derived from several simpler forms, by progressive modifications of and differentiations from those forms, and their transmission through *inheritance.*

### Nature's Agents Influencing Form.

(1) *Adaptive modification or natural selection.*

(2) *Correlation of growth or concomitant variation.*

(3) *Sexual selection or survival of the fittest.*

(1) Adaptive Modification. — The suppression of things not needed and the increased development of things most used.

*Examples of Suppression :—*

(i.) Milk teeth of the *rorqual.*

(ii.) The incisors of the female *narwhal.*

(iii.) The incisors of the *manatee.*

(iv.) The upper incisors of *ruminants.*

(v.) The lower incisors of the *dugong.*

(vi.) The teeth of the *ornithorhynchus.*

(vii.) The maxillary teeth of *poisonous snakes.* (The more poisonous the snake the fewer the maxillary teeth.)

(viii.) The upper incisors of the female *dugong*.

The foregoing examples of suppression prove that although natural selection affects the teeth, *inheritance* preserves, to some extent, organs which are of little or no use.

*Examples of Increased Development* :—

(i.) The left tusk in the male *narwhal*.

(ii.) The poison fang in *snakes*. (The more poisonous the snake the more specialized is the fang.)

(iii.) The hinged teeth of *fish*.

(iv.) Sexual canines in the *wild boar* and other animals.

(v.) The balæn plates of the *rorqual*.

(vi.) The incisors of *rodents*, the *wombat*, and the *aye aye*. These are three animals widely different in parentage, and living in different parts of the world, which have arrived at dentitions very alike through adaptive modification.

(2) Correlation of Growth or Concomitant Variation.—(See p. 55).

(3) Sexual or Natural Selection, or Survival of the Fittest.—More animals are born into the world than the world is capable of holding, so that a great number die off, namely, those which are placed at a disadvantage.

A competition amongst organisms and a tendency to vary, the variations being capable of being transmitted, are necessary for the efficient action of natural selection.

Animals having certain characteristics, giving them an advantage over others, are more certain to propagate their kind, *e.g.*, the sexual canines of *primates*, *wild boar*, *Sus babirusa*, *deer*, &c. ; the incisors of the *narwhal*, *dugong*, *wombat*, *aye aye*, *rodents*, and *ziphioid cetacean* ; the horns of *deer* ; feathers, and singing powers of *birds* ;

the prolongation of cartilage from the lower jaw of the *male salmon,* in the breeding season.

A continuance of natural selection is necessary in order to keep an organ efficient.

### Theories for the Existence of Multi-Cuspid Teeth.

(1) Fortuitous.

(2) Concrescence theory.

(3) Tritubercular theory.

(4) Cusps are added through elevations of the cingulum.

(5) Kinetogenetic theory.

(2) *Concrescence Theory* (*Röse and Kukenthal*).—Additional cusps are due to the coalescence of several simple cones through a shortening of the jaw and a crowding together of single teeth. According to *M. F. Woodward,* this view will not hold for all mammals, for if the lingual continuation of the dental lamina represents the *anlage* of the replacing teeth, that structure can be seen to remain quite distinct from the adult molar, and in the end to gradually disintegrate from it as the growth energy is abstracted from it by the larger and earlier developed teeth.

(3) *Tritubercular Theory.*—In arriving at multi-cuspid teeth there have been certain stages, as follows:—

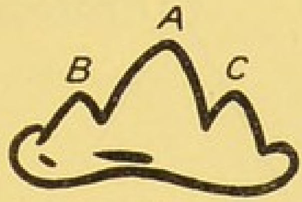
(*a*)

(*a*) Haplodont. A simple conical tooth, not known among primitive mammalia.

(*b*) Protodont (*Dromatherium*).—Addition of accessory cuspules.

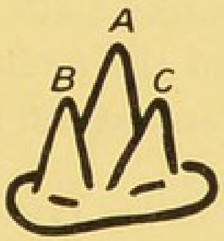
(*b*)

(*c*) Triconodont (*Phascolotherium*).—One main cusp with two lateral accessory cusps in a straight line, thus—




(*c*)

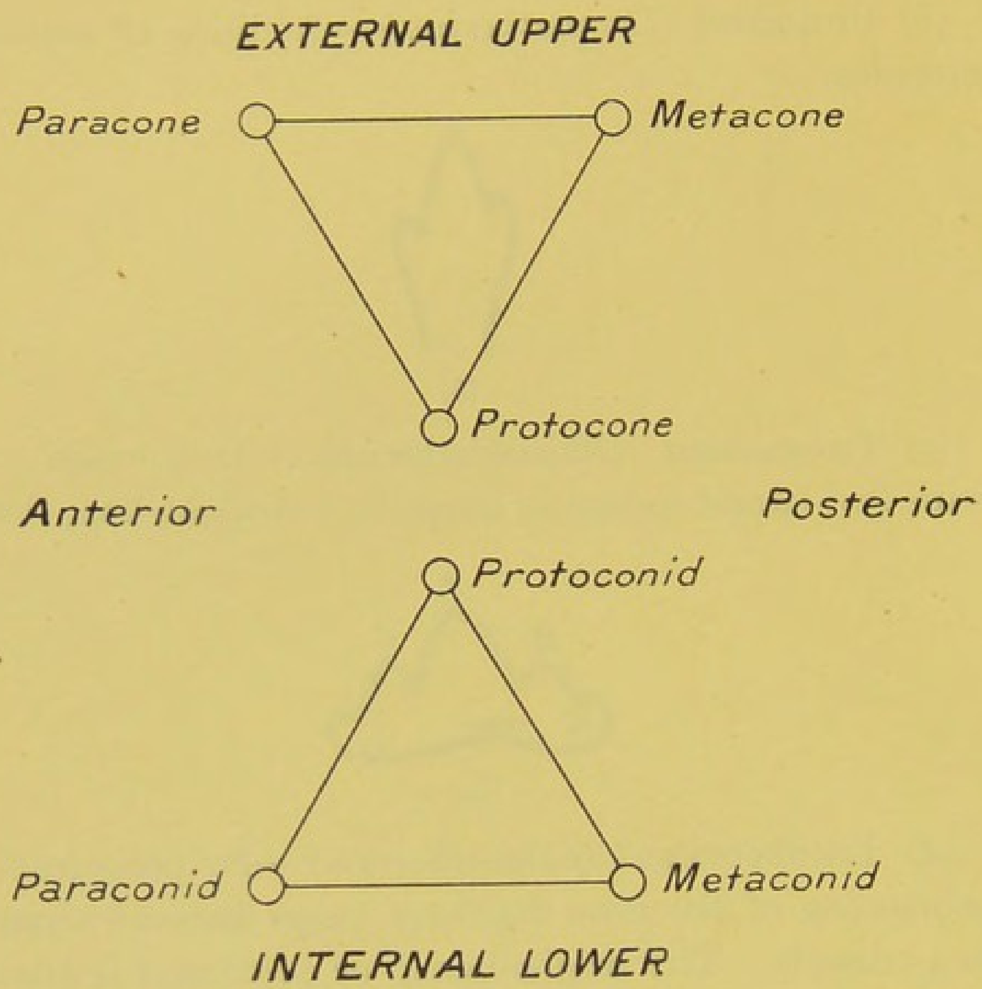
(*d*) Tritubercular (*Spalacotherium*).—By pressure from shortening of the jaws the three cusps become arranged in a triangle. The original cusp or protocone is internal in an upper tooth and external in a lower.




(*d*)

In an upper tooth the original or principal cone A is called protocone; in a lower, protoconid; the anterior cone B, paracone; in a lower, paraconid; the posterior cone C, metacone; in a lower, metaconid.

The following diagrams show an upper and a lower tooth of the same side. The upper should therefore lie over the lower, but for purposes of description they have been drawn side by side.




This primitive triangle forms the foundation for the building up of multi-cuspid teeth by the suppression of one or more cusps and the addition of others. Cusps may be added thus. See diagram p. 61.

*Facts in Support of the Tritubercular Theory.*

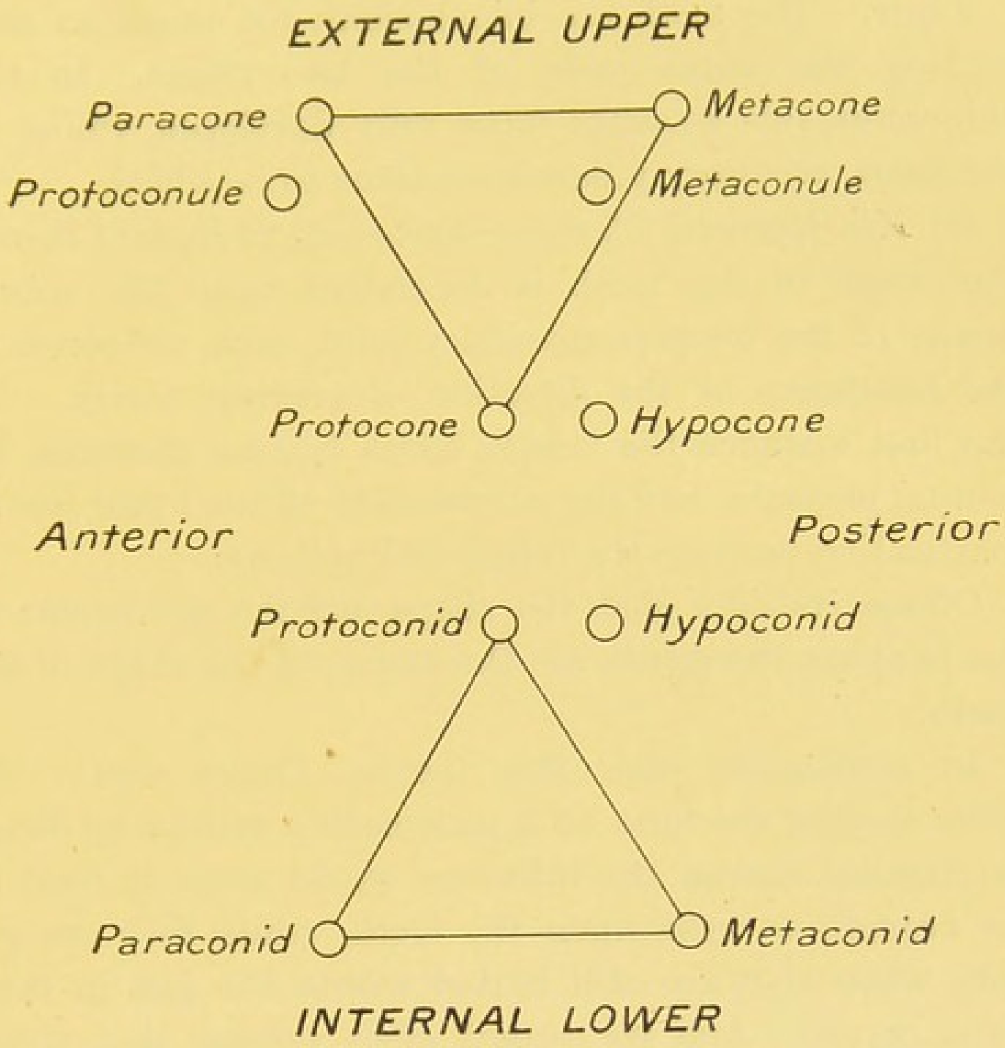
(i.) The almost universal occurrence of the tritubercalate molar amongst Mesozoic mammals.

(ii.) The presence of indications, in present forms of teeth (*Carnivora, &c.*), of three main cusps.

*Objections to the Theory.*

(i.) The very earliest mammals were multitubercular.

(ii.) Authorities differ in determining the homologies of the cusps.




(4) *Addition of Cusps through Elevations of the Cingulum.*—On the cingulum of a human tooth accessory cusps are sometimes present. In *insectivora* the well-marked cingulum is probably raised into accessory cusps. Other examples are *mastodon* and *elephant* (ungulata).

*Urotrichus.*—An insectivora which has the cingulum raised into three cusps on the outer, and one on the inner aspect.

*Mole.*—An insectivora which has three cusps on the outer cingulum.

*Pig.*—Here the cingulum on the molar increases in size from the first to the third, the latter having it divided into a number of accessory tubercles.

*Tapir.*—The teeth are bilophodont, the cingulum connecting the outer ends of the two ridges. In the *rhinoceros,* this becomes more fully developed, whilst in the *horse,* accessory pillars have come to be added.

(5) *Kinetogenetic Theory.*—According to *Ryder's* theory the shape of the tooth is dependent upon the movements of the temporo-maxillary joint, with reference to the resistance of the direction of greatest strain. In the first instance the simple cones become flattened by mutual pressure, and the movements of the lower jaw in mastication produce the ridges and hollows.

Others consider that the shape and the movement of the joint are the *result*, *not* the cause, of the shape of the tooth.

In connection with this theory, *Tomes* says: "In order to alter the form of a masticating surface by direct mechanical means, the influence would seem to need to be brought to bear upon the teeth, while they are yet soft, when they are still buried within the jaw in their bony crypts. And we cannot safely assume that structures like enamel-covered dentine can be altered by pressure, the essential character of dentine being its elasticity, and that of enamel its rigidity. It, therefore, follows that the tooth is of a nature very little likely either to be deformed by pressure, or, being deformed, to retain the deformity."

On the other hand it is interesting to note that there is probably some relation between the condyle, the movements of the lower jaw, and the forms of the teeth.

Thus *bunodonts* have a cylindrical condyle.

*Selenodonts,* a condyle expanded and plain.

*Lophodonts,* a globular condyle.

*Carnivora,* a hinge joint.

*Rodents,* a condyle permitting only of an antero-

posterior or a postero-anterior movement, except in *leporidæ*, where there exists also a slight lateral movement.

From the tritubercular form not only are teeth from their different requirements modified by the *addition of cusps* through elevations of the cingulum, but they may also be modified in the following ways :—

(1) Suppression of tissues, *e.g.*, Absence or partial absence of enamel.

(2) Invagination of tissues, *e.g.*, Incisor of horse.

(3) Addition of tissue, *e.g.*, Formation of osteo dentine in teeth of sperm whale, &c.

(4) Lengthening of cusps, *e.g.*, Rodent's teeth of persistent growth.

(5) Suppression of cusps, *e.g.*, Posterior basal cusp in the lower carnassial teeth of felidæ.

(6) Addition of cusps, *e.g.*, Upper carnassial teeth of carnivora, which have the antero-internal basal cusp.

&c., &c.

## Definitions of Terms Used.

| | | |
|---|---|---|
| Homodont | = | All teeth alike. |
| Heterodont | = | Teeth differ in form. |
| Monophyodont | = | One set of teeth. |
| Diphyodont | = | Two sets of teeth. |
| Polyphyodont | = | Endless succession. |
| Acrodont | = | All on bone of attachment. |
| Pleurodont | = | Partly on, partly off. |
| Bunodont | = | Simple cones. |
| Selenodont | = | Bicrescentic and elongated from before backwards. |
| Secodont | = | Sectorial or cutting teeth. |
| Lophodont | = | Ridged. |
| Bilophodont | = | Two ridges. |
| Polylophodont | = | Many ridges. |
| Brachyodont | = | Long roots, short crowns. |
| Hypsodont | = | Long crowns, short roots. |
| Haplodont | = | Simple conical. |
| Thecodont | = | Contained in the same socket. |

*Gnathic Index:* The comparison of the amount of brain with the amount of mouth, and is obtained by multiplying the basi-alveolar length by 100 and dividing by the basi-o-nasal. The basi-alveolar line is taken from the alveolar border between the two centrals of the upper jaw to the anterior border of the foramen magnum. The basi-o-nasal line is taken from the root of the nose to the same place. Then

Orthognathous = below 98
Mesognathous = between 98 and 103.
Prognathous = above 103.

An older method of comparison was *Camper's*, viz.:—

*Facial Angle.*—A line was drawn along the floor of the nose from the middle of the auditory meatus to the tips of the central incisors, and another from between the supra-orbital eminences to the same place. These produced the angle, and the smaller the angle the smaller the amount of brain in comparison to the size of the mouth. The objections to this method are:—

(1) Undue inclination of the teeth.

(2) Undue development of the supra-orbital ridges.

*Dental Index:* The comparison of the size of the teeth with the amount of the brain, and is got by taking a line from the front edge of the occipital foramen to the naso-frontal suture (*cranio-facial axis*), and a line from the front of the first premolar to the back of the third molar (*length of teeth*), then

$$\frac{\text{The length of the teeth} \times 100}{\text{Cranio-facial axis}} = \text{Dental index.}$$

Microdont = 42
Mesodont = 43
Megadont = 44 and upwards.

Functions of Teeth.—In *man*, teeth aid the speech and prepare the food. In connection with the preparation of food there are four stages:—

(1) Seizing or prehension.

(2) Division.

(3) Mastication.

(4) Insalivation, or the mixing of the saliva with the food.

Although the chief function of the teeth in the animal world is the preparation of food, they have many other uses, such as :—

| | |
|---|---|
| Porterage ... ... | in the *elephant*. |
| Progression ... ... | ,, *walrus*. |
| Sexual warfare ... | ,, *sus babirusa*, *wild boar*, &c. |
| Combing fur ... ... | ,, *lemurs*. |
| Holding on to mother | ,, *desmodus*. |
| Prehension ... ... | in *most fish*. |
| Chopping or cutting... | in the *carnivora* and *lepidosiren*. |
| Swallowing ... ... | ,, *pike*. |
| Poisoning ... ... | ,, *viper* and *cobra*. |
| | &c., &c. |

# CHAPTER XII.

The *Animal Kingdom* is divided into two *sub-kingdoms, phyla*, or *series*, viz. :—

(I.) *Invertebrates.*
(II.) *Vertebrates.*

They are sub-divided into :—

| | | | |
|---|---|---|---|
| *Classes* | *e.g.*, | *mammalia* | these again into |
| *orders* | ,, | *carnivora* | ,, ,, ,, |
| *sub-orders* | ,, | *æluroids* | ,, ,, ,, |
| *families* | ,, | *felidæ* | ,, ,, ,, |
| *genera* | ,, | *felis* (*lions, tigers, cats, &c.*) and | ,, ,, ,, |
| *species* | ,, | *felis tigris* (*tiger*). | |

The following are the general differences between Vertebrates and Invertebrates :—

| *Vertebrates* | *Invertebrates.* |
|---|---|
| Have an internal *vertebral column* holding the bony framework together and attaching the limbs. It contains the spinal cord, which has an enlarged upper extremity, the brain. In the *amphioxus* the vertebral column is cartilaginous. | There is no *vertebral column*, no spinal cord, and no brain. The nervous system consists of chains of ganglia connected by nervous substance. Through filaments from this arrangement the various parts are supplied. |
| The *digestive system* consists of the mouth and teeth for the preparation of the food, a digestive stomach, and | The *digestive system* is simple, consisting of a sac with one opening, or an alimentary canal with two open- |

the intestinal canal leading to the anal opening.

*Circulation.*—This is complete in all forms of vertebrates. The blood is corpusculated and generally red. The heart has from two to four chambers.

*Respiration.*—This is performed by gills in *fishes*, gills and lungs in *reptiles*, and lungs only in *birds* and *mammalia*.

*Locomotion.*—This is performed by limbs which never number more than four. There are only two in some forms, whilst *snakes* have none.

*Reproduction* takes place by the laying of eggs, which are gelatinous in *fishes* and *batrachian reptiles*, and have a hard shell in higher *reptiles* and *birds*. These animals are *oviparous*. In the higher *mammals* the young are born alive (*viviparous*).

ings, the oral and anal. In the higher orders specialized glands sometimes occur, but not in the lower.

*Circulation.*—In the lowest forms it is a water vascular system with no true corpusculated blood and no organs of circulation. In the higher forms true arteries, veins, and blood exist. The blood may be colourless or greenish. A heart with one ventricle exists in *insects*. In *mollusca* there is a heart with one valve which propels the blood both ways alternately. Some have a bilocular heart.

*Respiration* is performed by cilia or tentacles in the lowest forms, and by cilia or gills in the higher aquatics. In *insects*, the air circulates in the pulmonary tubes and aerates the blood. In *snails*, breathing is performed by means of an air sac with a ciliated lining.

*Locomotion* takes place through cilia and tentacles in the lower forms, legs and wings in *insects*, legs in *crustacea*, and a fleshy peduncle in *mollusca*.

*Reproduction* occurs through fission and budding in the lower forms, and through the laying of gelatinous eggs in the higher.

## TEETH OF INVERTEBRATES.

Not many possess teeth. When they do exist they are *analogous* to those of vertebrates, but not *homologous* to them. They have the same *function*, namely, the preparation of food, but not the same *origin* or *structure*. They are *ecderonic*. In insects and crustaceans the food apparatus is modified from the horny external covering. The former may consist of serrated jaws (*Nereis*), a beak (*cuttle-fish*), or true teeth, as in the *sea urchin*, which has five true teeth set in alveoli. *Prehension* is performed by cilia, a suctorial form of mouth, tentacles, horny jaws, or modified limbs, *cutting* by jaws, and *mastication* by gizzards. No invertebrate has true masticating teeth. The food apparatus is sometimes used for combat, sexual attraction, drilling through shells to get at the juices, or even for drilling into rocks.

## TEETH OF VERTEBRATES.

### FISHES.

General Notes.—(1) The *teeth* are usually numerous. The *pipe* and *hippocampus* are edentulous.

(2) *Use.*—Usually for prehension, crushing in *Cestracion philippi*, *rays*, *skates*, and *myliobates*, warfare in the *pristis*, swallowing in the *pike*, and cutting in the *lepidosiren*.

(3) *Attachment.*—Usually anchylosis, fibrous in *sharks*, gomphosis in *pristis*, *barracuda*, *pike*, *lepidosteus*, and *file fish*, and hinged in the *cod*, *hake*, *angler*, and *pike*, *&c.*

(4) *Growth.*—From non-persistent pulps. Persistent pulps occur in the rostral teeth of the *pristis*.

(5) Teeth which are very fine and very closely set are called "*dents en velours*," "*ciliiform*," or "*setiform*," when a little stouter "*dents en brosse*" or "*villiform*," and when still stronger and sharper "*dents en cardes*."

(6) *Succession*—Continuous; usually from the sides of preceding teeth. From behind in *sharks;* vertical in *gymnodonts.*

(7) *Form.*—They may be rod-shaped, conical, triangular, wedge-shaped, or lamelliform. They are usually homodont.

(8) *Sexual Differences.* — Slight. In the breeding season the *male salmon* has a cartilaginous hook proceeding from the lower jaw; it is then known as a *kelt.* The *Raia clavata* presents slight sexual differences.

(9) *Structure.*—They may be cornified as in the *lamprey,* or they may be calcified, consisting of any or all of the dental tissues. Cementum is rare, and enamel is usually a varnish.

CLASSIFICATION (*Paul*).

(1) *Cephalo-Chordata* or *Leptocardii.*—These are fish having no heart, no jaws, and no teeth, *e.g., Amphioxus* or *Branchiostoma.*

(2) *Cyclostomata.*—These are parasitic, and have round mouths supplied with conical teeth, which are calcified in the *myxine* and *bdellastoma,* and cornified in the *lamprey.* The two former bore their way into the bodies of other fish. They have a large, pointed, median tooth, and two small comb-like teeth on the tongue. In the *myxine* the horny cones are super-imposed upon tooth germs partially calcified. The free edges of each cone rest in a horn-forming groove of oral epithelium. According to *Dr. Beard,* the tooth germs consist of partially-formed dentine, capped with enamel, and a pulp with odontoblasts. The *lamprey* has a sucking mouth, by means of which it attaches itself to the bodies of other fish. There is a large specialized tooth in each jaw, the upper being called the maxillary and the lower the mandibular. The horny teeth clothing

the mouth consist of super-imposed horny cones, above dermal papillæ, with a horn-producing groove at the base of each papilla.

(3) *Elasmobranchii* (cartilaginous).

(4) *Teleostei* (bony).

(5) *Dipnoi* (mud fish).

(6) *Ganoidei* (sturgeon).

(3) ELASMOBRANCHII (*Sharks*). — The mouth is a transverse fissure on the under surface of the head. This arrangement forces the fish to turn upon its side in seizing its prey. The jaws are the representatives of the palato quadrate arch, and Meckel's cartilage, being cartilaginous in structure. They are supplied with concentric rows of teeth, which have a fibrous attachment. They are triangular in shape, endless in succession, and the teeth of the succeeding rows come into the spaces between the teeth of the preceding ones, when the latter have been shed. The row in use is vertical, and the others are procumbent and covered by mucous membrane. The usual structure is a varnish of enamel, hard tubular dentine, and osteo dentine. The scales (*shagreen*) on the backs of sharks are similar in structure to the teeth.

*Lamna.*—A shark in which the several rows of teeth are in different degrees of recumbency, and the succeeding rows come into the positions of the preceding ones.

*Carcharias* (*Bloodthirsty White Shark*).—The teeth have convex posterior surfaces and serrated edges.

*Selache maxima* (*Basking Shark*).—This shark has teeth upon the branchial arches, 5 in. long, for straining water. They have plici dentine.

*Cestracion philippi.*—In this shark the teeth differ from those of typical sharks in being lamelliform. In the front of the mouth they are small, whilst further behind they are large. They are blunt, but when they

first come into use they are supplied with small points which become worn off. They have tubular enamel. The food consists of shell-fish.

*Rays and Skates.*—The teeth are something similar to those of the Cestracion Philippi, being blunt. In the *myliobates* the jaw is straight from side to side, and convex antero-posteriorly. The teeth are arranged like a mosaic pavement, and, as in rays and skates, the structure is plici dentine. They live on shell-fish.

*Pristis* (*Saw Fish*).—This is a ray, in which the teeth in the mouth are like those of other rays. There exists also a rostral snout supplied with teeth, which are gomphosed, have plici dentine, and grow from persistent pulps.

(4) TELEOSTEI.—*Chætodonts.*—These fish have fine teeth supplied with vaso-dentine and hooks of enamel.

*Pike.* — It has numerous teeth, anchylosed on the margins of the jaw, the lingual bone, the three median bones, and the intermaxillary bone; hinged on the vomer and the palate bones. On the vomer they are directed backwards and outwards, and on the palate bones backwards and inwards. The structure is chiefly osteo dentine.

*Sword Fish.*—Has a long, protruding snout, on the under surface of which are rudimentary teeth.

*The Wolf Fish* (*Anarrhicas lupus*).—Has blunt conical teeth on the intermaxillary bone, opposed by similar ones in the lower. These are for the purpose of tearing shell-fish from the rocks. Similar but blunter teeth exist on the vomer and the two palate bones. They are anchylosed and have plici dentine.

*Hake and Angler.*—These have two rows of teeth, the outer anchylosed, and the inner hinged.

*Gymnodonts.*—These include the *diodon*, *tetrodon*, *scarus*, and *pseudo-scarus*.

*Diodon.*—The teeth in the front of the mouth are fused to the bone, form a beak, and are not covered by the lips. In the mouth behind the front teeth are a number of teeth fused together, which help in the treatment of food. The beaks have a vertical succession.

*Tetrodon.* — The beaks are similar to those of the diodon, but the upper and lower plates are divided into two, hence the name. They have a vertical succession, and there are no discs inside the mouth.

*Scarus* (*Parrot Fish*).—The beaks are divided more distinctly into several plates which have not become fused together. They have a vertical succession.

*Pseudo-Scarus* (*False Parrot Fish*).—The beaks have a vertical succession, and the successional teeth are cemented together by cement or *bone of attachment.* The upper and lower pharyngeal bones are supplied with teeth, like human incisors, the pulps of which are protected by secondary dentine upon the teeth wearing down.

*The Sargus.*—It has human-like incisors, and round-topped crushing teeth inside. They have enamel and the remains of vaso dentine.

The *Carp* and its allies have no teeth in the mouth proper, but have pharyngeal teeth.

(5) Dipnoi (*Lung Fishes*).

*Lepidosiren or Mud Fish.*—Has four plates, one on either side of each jaw, anchylosed to the bone. Each plate has five deep notches. They consist of enamel and dentine. In the front of the upper jaw are two sharp, conical teeth for prehension. This fish bridges over the fishes with *amphibia.* It has lungs and gills which persist through life.

(6) Ganoidei.

The *sturgeon* is edentulous except in the larval state.

The *lepidosteus* has plici dentine.

# CHAPTER XIII.

## AMPHIBIA OR BATRACHIA.

### CLASSIFICATION.

(1) *Gymnophiona* are tailless, worm-like, and subterranean.

(2) *Urodela.*—They have persistent tails, small, haplodont, bifid, enamel-tipped teeth. They have fins and breathe by gills—*e.g.*, *newt* and *salamander.*

(3) *Anura* are tailless in adult life, and are born with gills, some of which persist. They develop lungs, however, and have no fins, but digits. The heart has three chambers, and the teeth are polyphyodont.

*Examples :—*

The *toad*, which is edentulous.

The *tadpole*, which has horny plates like turtles' bills covering the jaws, and horny spines on the lips.

The *frog* is edentulous in the lower jaw and has small teeth in the upper. They are haplodont, anchylosed, pleurodont, and have a vertical succession. They consist of hard dentine and a varnish of enamel.

The *extinct labyrinthodon* had teeth in the upper jaw, whilst in the lower was a double row. It also had palatine teeth. The structure was plici dentine and the attachment anchylosis.

## REPTILIA.

In many, teeth are developed for the purpose of gaining an exit from the egg-shell, after which they are lost.

### Classification.

(1) *Chelonia.*—Tortoises and turtles.

(2) *Lacertilia or Saurians.*—Lizards.

(3) *Ophidia.*—Snakes.

(4) *Crocodilia.*—Crocodile, alligator, and garial.

(1) Chelonia.—They are edentulous, but, according to *Röse,* have an early tooth-band. They may be carnivorous or herbivorous, the margins of the jaws being sharp and thin edged in the former, and blunt and rugged in the latter.

(2) Lacertilia.—These differ from the other reptiles in having clavicles. The teeth are round cones or are pointed. They are polyphyodont, anchylosed, either acrodont or pleurodont, homodont, haplodont and may be serrated. They consist of hard unvascular dentine with enamel caps.

#### *Examples.*

*Mexican Lizard* (*Heloderma*).—The teeth are grooved back and front and are pleurodont. The bite of this lizard is poisonous, the secretion coming from the submaxillary gland.

*Rhyncocephalus, Hatteria, or Sphenodon.*—It has two rodent-like incisors on the inter-maxillary bone. The other teeth are small, acrodont, anchylosed, homodont, haplodont, and have tubular enamel. There is no replacement of teeth.

*Varanus or Monitor Lizard.*—It has about thirty small anchylosed teeth which are pleurodont, the structure being plici dentine.

*Chamæleons.*—Here there is no replacement of teeth, although teeth are being constantly added to the back of the series.

(3) Ophidia (*Snakes*).—These have no limbs, scapulæ,

or thoracic or pelvic arches, except the *Pythons* and *Tortricidæ*, which have hind limbs and a rudimentary pelvis.

### Classification by Poisonous Qualities.

(*a*) *Typhlophedal.*—These are small and subterranean, and have slightly distensible jaws. They are non-poisonous, *e.g.*, *Uropeltidæ*, *Typhlopidæ*.

(*b*) *Colubrines.*—They are non-poisonous and kill by crushing, *e.g.*, *Pythons*.

(*c*) *Colubrines venemosi.*—Are poisonous, *e.g.*, *cobra*, *sea snake* (*hydrophis*).

(*d*) *Viperines.*—They are the most poisonous, *e.g.*, *viper*, *puff-adder*, *rattlesnake*.

### Classification by Forms of Teeth (*Tomes and others*).

(*a*) *Aglypha.*—Here none of the maxillary teeth are grooved or canaliculated, *e.g.*, python, &c.

(*b*) *Opisthoglypha.*—One or more of the posterior maxillary teeth are grooved, *e.g.*, *whip-snake*, &c.

(*c*) *Proteroglypha.*—The front teeth on the maxilla are grooved or tubular, *e.g.*, *hydrophis*, *viper*, &c.

### *Examples.*

*Pythons and Boas.*—They have one row of recurved teeth in the lower, and two in the upper jaw. Their function is simply prehension, as snakes do not masticate their food. In the upper, the outer row is on the maxilla and the inner on the palatine and pterygoid bones. They are anchylosed. The lower jaw is very elastic at the symphysis. The germs which are to replace others lie parallel to the surface wrapped in a capsule. This is known as the *area of tooth development*. The teeth are polyphyodont and consist of hard dentine and enamel. The successional teeth erupt vertically until near to the surface, when they assume a horizontal position, eventually erupting vertically. This is to prevent injury to the mucous membrane from the unerupted teeth during the tremendous distension of the mouth whilst the reptile is swallowing its prey, when the mucous membrane is greatly stretched.

*Dazypeltis or Rachiodon.*—This reptile has rudimentary teeth in the mouth. It lives on eggs which are swallowed, the shells being broken on spines which exist on the anterior surfaces of the vertebræ.

*Elachistodon.*—An Indian snake which has remarkable distensible jaws and lives on eggs.

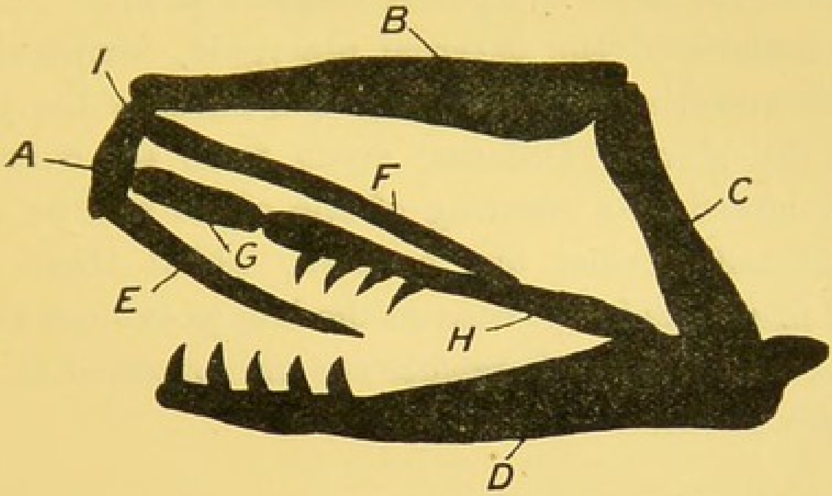
*Hydrophis* (*Sea-Snake*).—Has five teeth on the maxilla, the first of which is specialized and grooved anteriorly for poison.

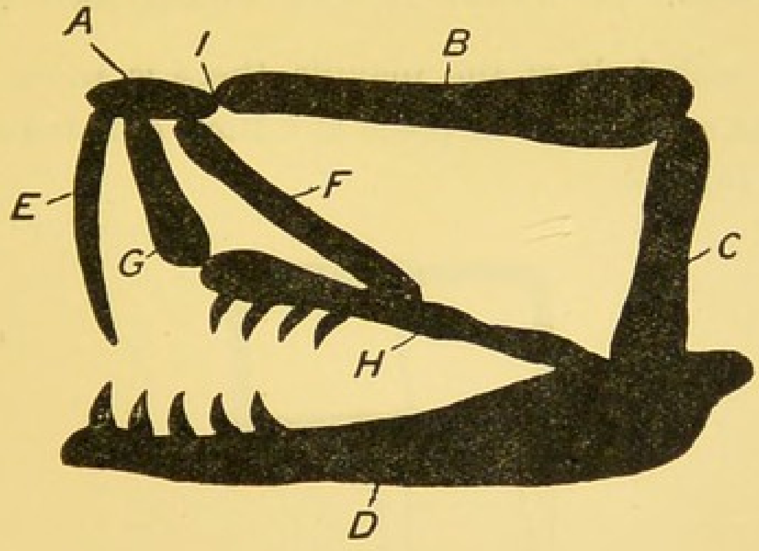
*Crait* (*Bungarus*).—An Indian snake, very poisonous, having several small solid teeth on the maxilla in addition to the poison fang.

*Australian Death-Adder and Cobra.*—The maxilla is shorter in comparison with the less poisonous snakes. The poison fang is specially developed with only one small tooth behind it. The groove on the front of the fang, which is about $\frac{1}{3}$ of an inch long, is closed by a meeting of the edges which are round. The maxilla is slightly movable and the fang fits into a depression in the lower lip. In the cobra and very poisonous snakes, the poison is derived from the parotid gland. The duct of the gland does not reach the fang, but is connected with it by a flap of mucous membrane, which to some extent prevents the escape of poison. In an angry cobra th escape, however, is somewhat excessive. *The successional fangs to replace one are in a single series.* The reptile bites like a dog.

*Viper, Puff-Adder, Rattlesnake.*—These have very short maxillæ. The poison fang is the only tooth on the maxilla and is only erect when in use. It is canali-

Mouth closed.




Mouth open.

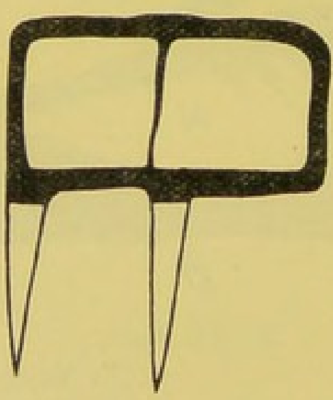
*A*. Maxilla.
*B*. Skull.
*C*. Quadrate bone.
*D*. Lower jaw.
*E*. Fang.
*F*. Transverse bone.
*G*. Palate bone.
*H*. Pterygoid bone.
*I*. Lachrymal hinge.

culated and the canal ends just above the point. This arrangement in poisonous snakes suggested the hypodermic needle. The fang is rendered more elastic by the dentine being continued almost to the point. The duct of the parotid gland, as in the cobra, does not reach the fang, but is joined to it by a flap of mucous membrane. The maxilla is much more movable than in the cobra, and the fang much longer. The latter is erected by a rotation of the maxilla, *e.g.*, see diagram p. 77.

The actions of the external pterygoid, temporal, and digastric muscles erect the fang and squeeze the poison out of the gland. Differing again from the cobra, the canal is closed by a meeting of the edges or lips, which are flattened against one another, whilst there is no enamel inside, as is the case in the less poisonous reptile. *The succeeding fangs to replace one are arranged in pairs.* The viper strikes.

### Succession of Fangs in the Cobra and Viper.

Upon each half of the maxilla there is room for two fangs, but only one is in place at a time, situated at either extreme thus:—



When the tooth in use falls out it is succeeded by another at the other extreme. The position of the fangs is usually as seen in the foregoing diagram. Sometimes they are, as regards position, symmetrical, but then one is usually loose. When one fang is lost, its bone of

attachment is absorbed, and a new bone of attachment forms for the new fang.

*Note.*—Gradations exist in the form of grooving of poison fangs, from open grooves to closed canals.

(4) CROCODILIA.—The teeth are polyphyodont, have a vertical succession, are gomphosed, vary in size, and are sharp and conical. The successional teeth erupt into the same sockets as the preceding ones occupied.

*Examples.*

*Crocodile.*—The teeth are often compressed from side to side, whilst certain ones are specialized and large, viz., the first and fourth lower, and the third and ninth upper. The specialized lower teeth bite into deep notches on the side of the muzzle. They consist of dentine, which presents numerous *interglobular spaces*, and enamel, in which the *brown striæ of Retzius* are well marked. The roots are covered with cementum.

*Alligator.*—The specialized large lower teeth bite into pits in the upper jaw.

*Garial.*—A slender-snouted crocodile with more teeth than the ordinary variety.

The *Dinosauria, Anomodont reptiles,* and *Pterosauria* are extinct.

## BIRDS.

At the present time no birds have teeth. Fossils prove that they once possessed them and that they had a continuous succession. Present birds perform mastication by means of gizzards.

The *Icthyornis* had gomphosed teeth. Succession was as in the crocodile.

The *Archæopteryx* possessed teeth.

The *Hesperornis* had teeth situated in a continuous groove, reptilian in character.

The beaks of present-day birds are adapted to their forms of food. Those of insect eaters are long, pointed and slender. Those birds which separate food from sand, &c., such as geese and swans, have long, flat beaks with sensitive edges, whilst hawks and vultures have beaks which are hooked, and very sharp and strong for tearing flesh.

# CHAPTER XIV.

## MAMMALIA.

*Mammalia* may be divided up into:—

(1) *Prototheria.*—These are the lowest in the mammalian class, *e.g.*, *Ornithorhynchus*, *Echidna*, and *Proechidna.*

(2) *Metatheria.*—These are low, but not so low as the Prototheria, *e.g.*, *Marsupials.*

(3) *Eutheria.*—These comprise mammals which suckle their young, *e.g.*, *Rodents*, *Carnivora*, *&c.*, *&c.*

## (1) PROTOTHERIA.

### MONOTREMES.

These include the *Ornithorhynchus*, *Echidna*, and *Proechidna.* In these animals the two oviducts enlarge each into a distinct uterine cavity or womb, which opens separately from its neighbour into a *cloaca*, or chamber, which also receives the terminal ducts of the urinary organs and the rectum.

*Ornithorhynchus* (*Duck-billed platypus*).—This animal is found in Australia. It has mammary glands, but lays eggs. The jaws are wide and flat, and each possesses four plates formed like a duck's bill, being grooved to strain food from water. The anterior ones are long and narrow, and the posterior, broad, and marked by depressions and elevations corresponding with those in the opposing plates, with which they articulate. They consist of cornified epithelium, and similar hardened

6

portions occur upon the tongue. The young animal has twelve teeth, three on each posterior plate, resting above the plates. They have broad crowns, narrow necks, and short roots, the roots piercing the plates. The upper have two long cusps on the inner aspect and a crenated border on the outer. This arrangement is reversed in the lower teeth. The under surfaces of the plates are penetrated by long papillæ, which send up processes of deeply staining cells. When the teeth are lost, which happens when the animal is about twelve inches long, the holes through which the roots passed become filled in with cornified epithelium.

*Structure of the teeth :—*

| | |
|---|---|
| Surface .. .. | Varnish of enamel. |
| Principal cusp .. | Vaso dentine. |
| Body of tooth .. | Hard tubular dentine. |
| Root .. .. | As the root is approached a large number of inter-globular spaces occur, and the structure is very poor. |

*Echidna* (*Old-world Ant-eater*).—Is edentulous but has horny spines on the tongue and the roof of the mouth, to crush the ants caught by the viscous tongue.

## (2) METATHERIA.

### MARSUPIALS.

These are implacent mammals and do not suckle their young. The latter are born in a very helpless condition and are carried about and protected in external pouches, which contain nipples. There are many different forms of marsupials adapted to different conditions of life ; thus some are carnivorous, some rodent like, some herbivorous, and some insectivorous. The functional teeth are probably the permanent teeth, the milk set having probably been suppressed. There is only one tooth which displaces vertically another and this is

sometimes absent. The *Wombat* has no such tooth. The *Thylacine* has the tooth calcified, but it is absorbed or shed before any other teeth erupt. The *Kangaroo* possesses it, but it is retained much longer. In the *Kangaroo rat* (*Hypsiprymnus*), it remains very late, being in position when the last permanent molar comes into place. This successional tooth in these animals is so large as to displace two others when it erupts. *Röse* and *Kukenthal* believe that the functional set is the milk set and that the permanent dentition is suppressed. *Woodward* believes that the successional tooth belongs to the same set as the functional teeth (these being the milk teeth), having been crowded out and erupting later.

Other characteristics of the marsupials are, that the angle of the lower jaw usually presents the well-marked pterygoid fossa, the lower jaw is in many cases movable at the symphysis, and the enamel, with the exception of the *Wombat's*, is tubular. The dental formula is

$$I\ \frac{3}{3}\quad C\ \frac{1}{1}\quad PM\ \frac{3}{3}\quad M\ \frac{4}{4}$$

The *incisors* are sometimes more numerous than the foregoing formula indicates, and the *premolars* are more simple than the *molars*. The former differ from the ordinary mammalian premolars in that, with the exception of one, the hindmost, they have not displaced other teeth.

*Division of marsupials* :—

| | *Diprotodonts* | *Polyprotodonts* |
|---|---|---|
| Incisors .. | Never more than $\frac{3}{3}$ .. .. | Numerous. |
| Canines .. | Ill marked; occurring only in the upper jaw, or absent | Well marked. |
| Cheek teeth | Bluntly crowned .. .. | Sharply and strongly crowned. |

## Diprotodonts.

*Wombat.*—

Formula— $I\frac{1}{1}\ C\frac{0}{0}\ PM\frac{1}{1}\ M\frac{4}{4}$

Its teeth are rodent-like in type, and have enamel on the fronts only of the *incisors.* This is non-tubular, and is covered with cementum. The *premolars* are simple and the *molars* double, the latter being deeply grooved on their sides. All the teeth grow from persistent pulps.

*Kangaroo.*—

Formula— $I\frac{3}{1}\ C\frac{0}{0}\ PM\frac{1}{1}\ M\frac{4}{4}$

The upper *incisors* are vertical, and grow from persistent pulps, the lower are procumbent and grow from persistent pulps. The *canines* are often absent altogether, but the upper are sometimes rudimentary. The *cheek teeth* are herbivorous in type, and the symphysis is movable.

*Hypsiprymnus (kangaroo rat).*—

Formula— $I\frac{3}{1}\ C\frac{1}{0}\ PM\frac{1}{1}\ M\frac{4}{4}$

This animal is about the size of a rabbit. Of the upper *incisors* the first pair grow from persistent pulps, the other from non-persistent. They are vertical. The lower are procumbent and grow from persistent pulps. The upper *canines* are small, and not rudimentary, and the *molars* are squarish and have four cusps.

*Tarsipes.*—Has a long protrusible tongue, rudimentary *molars* which are soon shed, and lives on insects and the nectar of flowers.

## Polyprotodonts.

*Thylacine (dog-headed opossum).*—

Formula— $I\frac{4}{3}\ C\frac{1}{1}\ PM\frac{3}{3}\ M\frac{4}{4}$

Has carnivorous and dog-like type of teeth. The *incisors* are small and sharp, the outermost being caniniform. The *canines* are strong and large, and the *premolars* sectorial in type. The *molars* are like those of the carnassial teeth of the carnivora.

*Dasyurus ursinus* (*Tasmanian devil*).—The teeth are like those of the thylacine, but not so sectorial in type. This animal is very destructive to sheep.

*Dasyurus viverrinus*.—Has insectivorous-like type of teeth.

*Myrmecobius*.—Its teeth are insectivorous-like.

Formula— $I\frac{4}{3}\ C\frac{1}{1}\ PM\frac{3}{3}\ M\frac{6}{6}$

*Opossums*.—The small have insectivorous-like teeth. The large live on small mammals, birds, &c.

# CHAPTER XV.

## (3) EUTHERIA.

Comprise *edentates, cetacea, sirenia, ungulata, rodentia, carnivora, insectivora, chiroptera, primates.*

### EDENTATES.

*General Characteristics.*—Many feed on insects, the tongue being long and whip-like, and covered with a viscous mucus, to which the insects become attached. The *sloths* live on a vegetable diet, and the *armadillos* and *ant-eaters* chiefly on insects, although some of the *armadillos* eat animal food and vegetables.

Most edentates have teeth, but probably few members have them on the intermaxillary bone. The *aardvark* may have rudimentary lateral incisors. True edentates, such as the *great ant-eater*, are edentulous. The animals are monophyodont with the exception of the *nine-banded armadillo* and the *aardvark*, which are diphyodont, and homodont, with the exception of the *two-toed sloth* and the *aardvark*, which are heterodont, the former because the anterior tooth is much larger than the others, and the latter because the last milk tooth differs from the other teeth in being molariform. The structure of the teeth is usually hard dentine and cementum and no enamel. The *two-toed sloth* has hard and vaso dentine, and the *aardvark* plici dentine. All the teeth grow from persistent pulps with the exception of the displaced milk teeth.

*Examples.*—

*Two-toed Sloth.*—Formula $\frac{5}{4}$.
Heterodont.
Vaso dentine.
Add general characteristics.

*Nine-banded Armadillo.*—Has seven or eight teeth on either side of each jaw, which are bilophodont before being worn down. Add general characteristics.

*Priodon.*—Has 100 teeth. Add general characteristics.

*Manis* (*Scaly Ant-eater*).—Is edentulous.
Tooth band ?

*Aardvark, Orycteropus* (*Cape Ant-eater*).—

Has 36 teeth not all in place together.

May have rudimentary lateral incisors.

Has plici dentine.

Is heterodont, the last milk tooth being molariform.

Is diphyodont, the milk teeth being rudimentary, functionless, and calcified. They probably never erupt.

Apply general characteristics.

*Extinct Glyptodon.*—The teeth are grooved longitudinally.

*Extinct Megatherium.*—The teeth are grooved. The structure is hard dentine, vaso dentine, and vascular cementum.

## CETACEA.

*General Characteristics.*—They are aquatic mammals, unfit for terrestrial life, and include the toothed and balæn *whales*. They are mostly homodont and monophyodont. They have probably been derived from heterodont and diphyodont ancestors, and the permanent teeth have probably been suppressed. The extinct *Zeuglodon* and *Squalodon* were heterodont.

*Structure of Teeth.*—The dentine presents a great number of interglobular spaces, and in the cementum are numerous lacunæ and well-marked lamellæ. The enamel is a slight investment, and the pulp becomes partially or wholly converted into secondary dentine.

Cetacea are divided up into :—

(i.) *Odontoceti* (*toothed whales*).

(ii.) *Mystacoceti* (*balæn whales*).

### (I.) Odontoceti.

*Dolphin.*—Has about 200 teeth which are gomphosed, conical, and sharply pointed.

*Porpoise.*—Has about 100 teeth, with blunt and flattened tips, which are gomphosed.

*Grampus.*—Has about 50 large, conical teeth, which are gomphosed.

*Narwhal* (*Monodon monoceros*).—Is edentulous in the lower jaw and has two *incisor* tusks in the upper. In the *female*, both are buried, are about eight inches long, and grow from non-persistent pulps. In the *male*, the right one is buried, and the left one is from ten to twelve feet long, extending from the jaw. It has no enamel, thus rendering the weapon elastic, consists of dentine, grows from a persistent pulp, and has a spiral which runs from right to left. Sometimes the male has two of these tusks, and then the spiral runs from right to left in both. In the *young* there are two milk teeth, each about ½ an inch long behind the permanents.

*Ziphioid cetacean.*—This animal is edentulous in the upper jaw. There are two thin, flat, strap-shaped *incisors* in the lower. These pass up outside the upper jaw, cross one another, and each ends in a denticle of triangular shape, about ⅓ of an inch long, consisting of enamel and

dentine. The teeth themselves may be 10 inches long. The denticles have the same direction as the shafts. Females have been found with their skins near to the pudenda marked by these tusks, which may be sexual weapons. The structure of the teeth is enamel, hard dentine, vaso dentine, and cementum. The enamel is worn off, and the pulp becomes obliterated by the formation of osteo or secondary dentine.

*Sperm whale* (*Physeter*).—Has many teeth in the lower jaw with fibrous attachment, There are a few buried teeth in the upper. They are thecodont. The bladder yields sperm oil.

*Bottle-nosed whale* (*Hyperoodon bidens*).—Has two, sometimes four, enamel-tipped, conical teeth, more or less embedded, in front of the lower jaw, and twelve or thirteen rudimentary loose teeth in both jaws.

## (II.) Mystacoceti.

*Balænoptera rostrata* (*Rorqual*).—Has forty-one tooth germs in the lower jaw. These become partially calcified, a small portion of dentine being formed. They are heterodont, the germs in the front being simple, in the middle, bifid, and at the back, trifid. They are lost *in utero*. In the upper jaw several hundred balæn plates are developed in place of teeth. They are triangular in shape, cross the roof of the mouth, but not the median line. Here smaller plates exist. The outer ones are calcified and the inner cornified, and they grow from persistent pulps. The edges of the plates fray out, and when the mouth is shut there is a triangular space in the middle, the floor being formed by the tongue. Water is taken into the mouth and by means of the frayed edges is sifted. It is then forced out sideways between the plates, and the tongue sweeps backwards all animalculæ which may have been caught in the fringes.

Whalebone matrix is produced by a metamorphosis of the epithelium covering the papillæ of the palate, being epithelial in structure and comparable to the marked ridges upon the palates of certain *Herbivora*.

## SIRENIA.

*General Characteristics.*—These animals live in shallow coast waters and the estuaries of rivers, and have a vegetable diet. They possess the power of sitting up in the water in a semi-erect position, and give birth to one young at a time. The intermaxillary bone is at an angle with the rest of the jaw. They include the *dugong* and the *manatee*. The *rhytina* is extinct; it had no teeth, but horny plates to cut the soft seaweed.

*Dugong* (*Halicore*).—The intermaxillary bone is at an angle with the rest of the skull and carries two *incisors*. In the *male* these protrude slightly from the bone, have enamel on the fronts and sides, and grow from persistent pulps. In the *female* they are completely buried, have enamel on the tips, and grow from non-persistent pulps. In the *young* there are two deciduous incisors in front of the permanents. The symphysis of the lower jaw presents about eight depressions. These, when the animal was young, carried teeth which were covered by plates of horn set with bristles. The *molars* are $\frac{5}{5}$. These are degenerating teeth of semi-persistent growth and are gradually lost until $\frac{2}{2}$ remain. They consist of dentine and cementum and have no enamel.

*Manatee.*—The intermaxillary bone is at an angle with the rest of the skull, as in the dugong. The *incisors* are functionless and covered, as are the lower incisors of the

dugong, with horny plates. The *molars* are forty-four in number, only six being in place on either side of each jaw at one time, and are shed from before backwards. Each successional tooth is bigger than the one preceding it. They are bilophodont, as in the tapir, and the upper have three roots and the lower two. The structure is enamel of the simplest form (straight prisms), and hard dentine showing the remains of vascular canals.

# CHAPTER XVI.

## UNGULATES.

### HOOFED MAMMALS.

THESE are hoofed mammals which develop large nails or hoofs for protection in walking. Not more than four fully developed toes exist on each foot. The teeth are diphyodont and heterodont. They are herbivorous. The typical permanent dental formula is

$$I \frac{3}{3} \; C \frac{1}{1} \; PM \frac{4}{4} \; M \frac{3}{3}$$

and the typical milk dentition

$$I \frac{3}{3} \; C \frac{1}{1} \; M \frac{4}{4}$$

### CLASSIFICATION.

- UNGULATES VERA
  - Perissodactyle (odd toed): Tapir, Rhinoceros, Horse
  - Artiodactyle (even toed):
    - (1) Suina (pigs, &c.)
    - (2) Tylopoda (camels, &c.)
    - (3) Tragulina (chevrotains).
    - (4) Pecora (sheep, deer, &c.)
- SUB-UNGULATES
  - Hyracoidea
  - Proboscidea
  - Extinct Sub-orders

*Note.—Tylopoda, Tragulina,* and *Pecora* are *ruminants,* ruminants being animals which regurgitate the bolus of food from the stomach to subject it to a second chewing.

# UNGULATES VERA.

## ARTIODACTYLES.

(1) Suina.—These include the *pig, hippopotamus, sus babirusa*, and *wart-hog*.

*Pig and Wild Boar*.—The formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{3}{3}$$

Of the *incisors*, the first pair of upper touch at the biting edges but not at the bases; the third pair is small and separated from the others. The lower incisors are procumbent, and ribbed on the upper surfaces with enamel.

There is a *diastema* or space between the last upper incisor and the upper canine.

Of the *canines* the upper pass forwards, outwards, and upwards, are ribbed with enamel on the under surfaces, and grow from persistent pulps. The lower are slender and sharp, and pass forwards, outwards, and upwards. They are triangular on section, have enamel on the two anterior surfaces, and grow from persistent pulps. Castration stops the growth of the canines, which are sexual weapons. In the wild boar these weapons are much more pronounced. Of the *premolars* the first is small with one cusp and two roots and may be a temporary tooth remaining late or a permanent tooth erupting early. The second and third pass gradually to the shape and size of the fourth, which has two cusps and four roots.

The *molars* have four cusps and four roots. The cingulum at the back gradually increases in size until in the third it has become greatly enlarged and divided into accessory cusps.

*Sus babirusa*.—The formula is

$$I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{3}{3}$$

The teeth are similar to those of the pig with the exception of the *canines*. In the upper jaw the canines pass abruptly upwards, pierce the upper lip, and then after passing a short distance, pass backwards and downwards, sometimes piercing the skull and killing the animal. The upper canines were once supposed to protect the eyes of the animal in passing through the brushwood in which it lives, but seeing that the female has only small upper canines and that it also lives in brushwood, they are probably not adapted for that purpose but are more likely sexual weapons. The lower canines are triangular on section and are directed backwards and outwards. All the canines grow from persistent pulps and have no enamel.

*Wart-hog* (*Phacochœrus*).—The teeth are gradually lost until only the canines and the last molar on either side of each jaw remain. The *canines* are very large in both sexes and the *molar* is as large as all the other cheek teeth put together, consisting of islands of enamel and dentine joined together by cementum.

*Hippopotamus*.—The formula is

$$I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{3}{3}$$

In the upper jaw the outer pair of *incisors* is the longer. They are vertical, grow from persistent pulps, and are ribbed with enamel. In the lower, they are procumbent, grow from persistent pulps, have tips of enamel, and the median pair is the longer. There is a *diastema* in front of the upper canine. The *canines* grow from persistent pulps, the lower being the larger. The function of the incisors and canines is to uproot aquatic plants. The roots of these plants are mixed with sand, which causes the cheek teeth to become much worn. The *premolars*

are simple, the first being either a milk tooth remaining late or a permanent tooth erupting early. The *molars* are bunodont, consisting of four tri-lobed cones separated on the crown surface by a crucial depression, the transverse groove being the deeper. At first when worn down the crown presents four three-lobed figures. Then the longitudinal depression goes and two four-lobed figures remain. Eventually the transverse groove passes away and dentine of a simple pattern surrounded by enamel results.

*Anoplotherium.* — This animal is extinct. The formula is

$$I\,\frac{3}{3}\quad C\,\frac{1}{1}\quad PM\,\frac{4}{4}\quad M\,\frac{3}{3}$$

The teeth are of nearly uniform height and set close together, there being no diastema. The *molars* are rhinoceros like.

*Oreodon.*—Is extinct. The formula is

$$I\,\frac{3}{3}\quad C\,\frac{1}{1}\quad PM\,\frac{4}{4}\quad M\,\frac{3}{3}$$

It has ruminant-like *molars.*

*Canines* are also present. The lower tooth biting directly in front of the upper canine is incisor like, the lower caniniform tooth biting behind the upper canine.

(2) TYLOPODA.—These include the *camel* and *llama.*

*Camel.*—The formula is

$$I\,\frac{1}{3}\quad C\,\frac{1}{1}\quad PM\,\frac{3}{2}\quad M\,\frac{3}{3}$$

The upper incisor remaining is the outermost, two having been lost. The *canines* are large in both sexes, and do not grow from persistent pulps. Of the *premolars* those usually remaining are the first and the last, the others being lost. The first is caniniform, erupts at the sixth year, and persists through life. The second has been lost, the third is lost early, and the last persists. The *molars* are selenodont with the concavities directed outwards in the upper and inwards in the lower.

(3) TRAGULINA.—These are known also as *chevrotains*. Their formula is

$$I\frac{0}{3}\ C\frac{1}{1}\ PM\frac{3}{3}\ M\frac{3}{3}$$

They are small animals like deer, and include the *Pigmy Musk Deer* (*Tragulus*), and the *Hornless Musk Deer* (*Moschus*). The males have large upper *canines* growing from persistent pulps, and the females small ones growing from non-persistent pulps. The lower canines are like those of the *Pecora*. The *cheek teeth* are selenodont.

(4) PECORA.—The formula is

$$I\frac{0}{3}\ C\frac{0}{1}\ PM\frac{3}{3}\ M\frac{3}{3}$$

They include *sheep*, *oxen*, and *deer*.

There are no *incisors* in the upper jaw, the lower biting against a pad of gum. There are eight teeth in the lower, all incisor like, but the last is called a canine because it bites in front of the upper canine. *Canines* are usually absent in the upper jaw. They exist, however, in both jaws and in both sexes in most *Cervidæ*. The *cheek teeth* are selenodont.

GENERAL NOTE.—Where horns are present upper canines are absent, and *vice versa*. An exception to this rule is the *Indian Muntjac Deer* (*Cervulus*), which has both horns and upper canines. The latter, however, do not grow from persistent pulps. In *Artiodactyles* the premolars are usually simpler than the molars, the last molar has an accessory lobe, and the anterior portion of

a posterior cheek tooth lies more external than the posterior portion of an anterior tooth, thus rendering the line of cheek teeth irregular.

## PERISSODACTYLES.

These include the *tapir*, the *rhinoceros*, and the *horse*.

*Tapir.*—

$$\text{Formula—}\quad I\,\frac{3}{3}\quad C\,\frac{1}{1}\quad PM\,\frac{4}{3}\quad M\,\frac{3}{3}$$

The third upper *incisor* is larger than the *canine*, and articulates with the lower canine, which ranges with the incisors. The first upper *premolar* is triangular, the rest are squarish. The *molars* are squarish. All the cheek teeth are bilophodont, there is very little outer wall, and the remains of vascular canals exist in the dentine.

*Rhinoceros.*—The formula is doubtful. Some give

$$I\,\frac{2}{2}\quad C\,\frac{0}{0}\quad PM\,\frac{4}{4}\quad M\,\frac{3}{3}$$

The *cheek teeth* are selenodont. The outer wall is more marked than is the case in the tapir, and the transverse laminæ are directed obliquely backwards. Spaces called *sinuses* exist, and these remain open and are not filled in with cementum. When horns are present the *incisors* are reduced or absent. If horns are absent, the incisors are augmented. In the two-horned species there are no incisors in the adult.

*Horse.*—The formula is

$$I\,\frac{3}{3}\quad C\,\frac{1}{1}\quad PM\,\frac{4}{4}\quad M\,\frac{3}{3}$$

*Ancestry of the Horse.*—The earliest member of the family was *Orohippus*, which had four digits or toes on the anterior limb. It was about the size of a fox. In *Miohippus*, from the miocene of Oregon, there were only three digits, and the animal was somewhat larger than a sheep. *Protohippus*, from the pliocene beds of Nebraska, was about 2½ feet high. *Eohippus*, found in the Nebraska pliocene sands, was about the size of an ass. The lateral digits were reduced to splint bones, as in the horse. In these ancestors the *teeth* pass by gradations from the brachyodont and bunodont to the hypsodont and selenodont types of teeth of the horse.

*Dentition of the Horse.*—The *incisors* have an edge-to-edge bite and extend in the jaw as they become worn down. They grow from non-persistent pulps. On the crown surface a dipping in of the tissues produces "*the mark*" by which the age of a horse may be told. After the tooth is worn some distance this passes away, presenting the whole of the worn surface, "*the table*," and another mark appears in front of what was "*the mark*." This is secondary dentine formed over the pulp to protect it from exposure. The enamel is situated on the whole of the anterior surfaces of the teeth, both roots and crowns, but only on two-thirds of the posterior surfaces. It is covered by cementum. There is a *diastema* in front of the upper canine. Formerly the horse had no diastema. The *canines* are rudimentary in mares, occurring only in the lower jaw. They exist in both jaws in the stallion. Castration has no effect upon their growth. Behind the canines is a large space into which the bit fits. The *cheek teeth* are selenodont and hypsodont, and extrude from the jaw as they become worn. They have a complex enamel structure and accessory pillars. The first premolar is rudimentary, is soon shed, and is popularly called the "*wolf tooth*." According to *Huxley* the cheek teeth of the horse have been derived from those of

the tapir, through those of the rhinoceros, by means of a development of the outer wall, the movement to a more oblique backward direction of the transverse laminæ, the filling up of the sinuses with cementum, and the addition of accessory pillars.

*Appearances of the Teeth of the Horse at various Ages.*

| | |
|---|---|
| Birth .. | .. Two incisors are present in each jaw. |
| 9 weeks .. | .. Four incisors are present in each jaw. |
| 2½ years .. | .. The temporary central incisors are shed. |
| 3½ years .. | .. The temporary lateral incisors are shed. |
| 4½ years .. | .. The outermost temporary incisors are shed. |
| 6 years .. | .. "*The mark*" begins to disappear from the central incisors. |
| 8 years .. | .. "*The mark*" has entirely gone from the cental incisors. |
| 8 to 10 years | .. A stain remains on the centrals. |
| 10 years .. | .. A longitudinal groove appears on the labial surface of the third incisor at the neck. |
| 12 years .. | .. "*The mark*" has wholly disappeared. |
| 12 to 13 years | .. Secondary dentine protecting the pulps from injury occurs in front of the position occupied by "*the mark*" |
| 21 years .. | .. The longitudinal groove on the third incisor has reached the biting edge. |

## SUB-UNGULATES.

HYRACOIDEA. *Hyrax* (Biblical Coney).—

$$\text{Formula—}\quad I\,\frac{2}{2}\quad C\,\frac{0}{0}\quad PM\,\frac{4}{4}\quad M\,\frac{3}{3}$$

It is about the size of a rabbit. The first pair of upper *incisors* are rodent-like, and grow from persistent pulps They have thick enamel on the fronts and sides. The lateral incisors are soon lost, and the lower are procumbent, the middle ones being the smaller. The *cheek teeth* are like those of the rhinoceros.

PROBOSCIDEA. *Elephant.*—The formula is

$$I\frac{1}{0}\ C\frac{0}{0}\ PM\frac{0}{0}\ M\frac{6}{6}$$

or

$$I\frac{1}{0}\ C\frac{0}{0}\ PM\frac{3}{3}\ M\frac{3}{3}$$

The permanent *incisors* are preceded by two deciduous ones which are lost about the second year. The permanent have tips of enamel covered by cementum, until the latter is worn off. In Indian elephants half the length of each tusk is implanted. The tusks of the Indian are not so large as those of the African variety, and in some of the former the males have tusks no bigger than the females, and are known as *Mucknas.* The incisor teeth grow from persistent pulps, and are composed chiefly of dentine or ivory, which is very elastic (see page 9). In females they are often eroded at or near to the gum margin, eventually breaking off. Hunters' spears and bullets have been discovered embedded in the teeth, the injuries having been repaired by the formation of a protective covering of secondary dentine. The best ivory comes from the wet Gaboon neighbourhood. The further from the Equator and the higher and drier the locality, the poorer is the ivory. Of the *cheek teeth* only one and a portion of one are in place at a time, on either side of each jaw. They erupt in a part of a circle, and the front portion of a tooth is often worn before the back part has fully developed. This arrangement diminishes weight and space. The teeth consist of several plates joined together by cementum, and there is one pulp chamber for all the plates. When worn they are lozenge-shaped in the African, and slot-shaped and crinkled in the Indian variety. They are broader in the former, but more numerous in the latter. They are not so elastic as the

incisors, the dentine containing about the same percentage of lime salts as the dentine of man. Successive teeth increase in size and in the number of plates.

| | Erupts at | Number of plates |
|---|---|---|
| 1st tooth .. | 3 months .. | 4 |
| 2nd ,, .. | 2 years .. | From 8—9 |
| 3rd ,, .. | 5 ,, .. | ,, 11—13 |
| 4th ,, .. | 9—10 ,, .. | ,, 15—16 |
| 5th ,, .. | 20 ,, .. | ,, 17—20 |
| 6th ,, .. | 30—40 ,, .. | ,, 20—27, and lasts throughout the rest of the animal's life. |

## EXTINCT SUB-UNGULATES.

*Mastodon*.—The formula is

$$I\,\frac{1}{1}\quad C\,\frac{0}{0}\quad PM\,\frac{0}{0}\quad M\,\frac{6}{6}$$

Both upper and lower *incisors* exist. The upper are sometimes twenty feet in length. The lower were often rudimentary and sometimes absent. The *molars* have transverse ridges with nipple-like processes, increase in size from before backwards, and have definite roots. Not more than three were in place at one time on either side of each jaw. They were gradually lost until only $\frac{1}{1}$ remained. The animal had $\frac{3}{3}$ deciduous molars.

*Dinotherium*.—Was probably of aquatic habits. *Tusks* exist in the lower but not in the upper jaw. The animal was about the size of an elephant, and the tusks are about two feet long. The dentine is of a poor structure. The *molars* are like those of the tapir. The deciduous molars were $\frac{3}{3}$, the permanent formula being

$$I\,\frac{0}{1}\quad C\,\frac{0}{0}\quad PM\,\frac{2}{2}\quad M\,\frac{3}{3}$$

*Dinoceras.*—One of the *Dinocerata* of the sub-order *Amblypoda*. The dental formula is

$$I \frac{0}{3} \ C \frac{1}{1} \ PM \frac{3}{3} \ M \frac{3}{3}.$$

The condyles have a posterior direction differing from other *Ungulata*. This arrangement was to allow the mouth to be fully opened, which otherwise would have been impossible, on account of the long upper *canines*. The symphysis of the lower jaw is fully ossified. The latter is slender with the exception of two pronounced posterior processes, which probably prevented the two large tusks from being broken off. The lower *incisors* are directed forwards. The lower *canines* are small and set close to the incisors. The crowns of the *molars* have transverse crests and the last is the largest.

*Phenacodus.*—A member of the sub-order *Condylarthra*. The dental formula is

$$I \frac{3}{3} \ C \frac{1}{1} \ PM \frac{4}{4} \ M \frac{3}{3}$$

The *incisors* are expanded transversely, the lowers being directed obliquely forwards. The *canines* are not large. The *premolars* are separated from one another, and the first has one root and one cusp and the others three cusps. The upper *molars* have four large and two small cusps, and the lower, four large and one small one. The small cusps are situated between the large ones, and in later forms they become developed into ridges, producing lophodont teeth.

*Toxodon.*—A member of the sub-order *Toxodontia*. It was about the size of the hippopotamus. The dental formula is

$$I \frac{2}{2} \ C \frac{?0}{1} \ PM \frac{4}{3} \ M \frac{3}{3}$$

Of the *incisors* the first upper pair is small, and the outer large. The latter grow from persistent pulps and extend in the jaw under the cheek teeth, as in rodents. The lower are sub-equal in size, grow from persistent pulps, and are only partially invested with enamel. Of the *canines* the upper are absent, although sockets exist. The lower are sharp edged and only partially invested with enamel. The *molars* grow from persistent pulps and are only partially invested with enamel. They have curved sockets and in the upper, the apices of the roots almost meet in the middle line of the palate.

*Tillotherium.*—A member of the sub-Order *Tillodontia.* The dental formula is

$$C\ \frac{2}{2}\quad I\ \frac{1}{1}\quad PM\ \frac{3}{2}\quad M\ \frac{3}{3}$$

The skull has the general form of that of the bear, but in structure resembles the *Ungulata.* Of the *incisors* the median pair is the larger. The outermost are small, and grow from non-persistent pulps. The median teeth are rodent-like, being scalpriform, and growing from persistent pulps. The *canines* are small, and the molars are like those of the ungulates.

# CHAPTER XVII.

## RODENTIA.

### *General Characteristics.*

It has been suggested that the different varieties of teeth found in this group prove that all rodents are not of the same origin. They are vegetable eaters, and the milk dentition is poorly marked. In *hares* and *rabbits* the milk formula is

$$I\,\frac{3}{3}\quad C\,\frac{0}{0}\quad M\,\frac{6}{4}$$

These are lost early. The *squirrel* and the *mouse* have milk incisors. In no other rodent are milk incisors known. The *guinea-pig* has one milk cheek tooth on either side of each jaw which never becomes functional. The *beaver* has milk molars. In the *atherina*, a porcupine, there is one well-developed functional milk cheek tooth on either side of each jaw. Milk cheek teeth also occur in *castor*, *dasyprocta*, *ctenodactylus*, *hystrix*, and *erethizon*.

All the permanent teeth grow from persistent pulps except the molars of rodents having a mixed diet, *e.g.*, *rats, mice,* and the *beaver*, where the molars are human-like and have roots.

The *condyles* are directed antero-posteriorly, and are adapted for the gnawing movements of the jaws. In *Leporidæ* (*hares* and *rabbits*) the condyles are so adapted as to allow of a slight lateral movement also.

The enamel of some rodents is pigmented, the pigment

being in the substance of the tissue. Tubular enamel occurs in the *jerboa*, where the tubes are continuous with those of the dentine. The structure of the enamel of rodents is peculiar, the prisms being divided into inner and outer portions (see under *sciuridæ*, *beaver*, *porcupine*, *leporidæ*, and *rat*, page 2).

The *incisors* of rodents are scalpriform and form parts of circles, the upper, large segments of small circles, and the lower, small segments of large ones. They are implanted very deeply, and the lower pass beneath all the cheek teeth, the purpose of this modification being to diffuse pressure. The nerves supplying the persistent pulps are often anterior to the ends of the roots, running forwards beneath the latter and then bending abruptly back to reach the tooth pulps. The teeth have enamel on the fronts and sides, hard dentine behind, softer dentine still further behind, and cementum at the backs. This disposition keeps them sharp, the softer tissues wearing away more rapidly than the hard enamel, which forms a sharp edge. The permanent formula varies. In *squirrels* it is

$$I\,\frac{1}{1}\quad C\,\frac{0}{0}\quad PM\,\frac{1}{1}\quad M\,\frac{3}{3}$$

in the *rat*

$$I\,\frac{1}{1}\quad C\,\frac{0}{0}\quad PM\,\frac{0}{0}\quad M\,\frac{3}{3}$$

and in *hares*

$$I\,\frac{2}{1}\quad C\,\frac{0}{0}\quad PM\,\frac{3}{2}\quad M\,\frac{3}{3}$$

One of the two former is common to many rodents.

There is a long gap between the incisors and the cheek teeth.

The *cheek teeth* are usually few in number and obliquely implanted. Some have long roots, some short, and some none, these conditions being due to differences in diet. Those growing from persistent pulps have curved roots. In the *beaver* they are strong, the tissues being arranged as in the ungulates, being thus kept constantly rough for the vegetable fibre upon which it subsists. In *hares* and *rabbits* they are very long, of continuous growth, and at first tuberculate. In *squirrels*, the premolars are triangular and have three roots, the molars having crests and valleys. In *rats*, the molars decrease in size from before backwards, and are simply tuberculate before the tubercles wear away. They have three roots. In *mice*, the molars may be without roots. In the *capybara*, which is aquatic, and the largest of the rodents, the molars consist of plates joined together by cementum, and the last has twelve. These teeth are therefore like the cheek teeth of the elephant. They differ, in that each plate has a separate pulp chamber. The brachyodont, bunodont type of tooth, is the older, and the laminated, hypsodont type is the later acquisition in rodents.

# CHAPTER XVIII.

## CARNIVORA.

*General Characteristics.*—The *cat* is a typical carnivora, the *dog* is more generalized, and the *bear* is herbivorous. Carnivora have well-developed muscular processes, especially the zygomatic. The milk dentition of the terrestrials is

$$I\,\frac{3}{3}\quad C\,\frac{1}{1}\quad M\,\frac{3}{3}$$

except *felidæ*, which have

$$I\,\frac{3}{3}\quad C\,\frac{1}{1}\quad M\,\frac{3}{2}$$

The temporo-maxillary *articulation* constitutes a hinge joint. The *incisors* number six in each jaw, and are ranged straight across the front of the jaw. In some species the lower are tri-lobed. The third is sometimes caniniform. There is a *diastema* in front of the upper canine into which the lower canine bites. The *canines* are strong, long, and sharp, flattened from side to side, and separated from the premolars. The *premolars* are sectorial in type, the last one in the upper jaw being the *carnassial* tooth. This is characterized by having an antero-internal basal cusp. Of the *molars*, the first in the lower jaw is the *carnassial* tooth, and is characterized by having a posterior basal cusp. The last in the upper jaw is sometimes within the arch. In typical carnivora the cheek teeth are reduced in number and blade-like. In those having a mixed diet they are more numerous, and have broad crowns.

## Classification.

(1) *Fissipedia* (terrestrials).

(2) *Pinnipedia* (aquatics).

*Fissipedia* may be divided up into

(*a*) *Æluroidea* (cats, civets, hyenas).

(*b*) *Arctoidea* (bears, weasels, racoons).

(*c*) *Cynoidea* (dogs, wolves, foxes).

*Pinnipedia* into

(*a*) *Otariidæ* (eared seals).

(*b*) *Phocidæ* (other seals).

(*c*) *Trichechidæ* (walrus).

(1) *Fissipedia.*—

*Cat, lion, tiger* (*Felidæ*).—

The permanent formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{3}{2}\ M\frac{1}{1}$$

They are typical carnivora. The *incisors* are short, and the *canines* large, pointed, and ridged longitudinally. The *premolars* nearest the canines are very short. The upper *molar* is within the arch, and the lower *carnassial* tooth has a poorly marked or no posterior basal cusp. Add general characteristics.

*Machairodus.*—An extinct feline animal. The permanent formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{1}{1}$$

The upper *canine* is enormous, and the lower is small and ranged with the incisors.

*Smilodon.*—An extinct feline animal. Its permanent formula is

$$I\frac{3}{2}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{0}{1}$$

*Professor Cope's* summary of the modified parts in extinct cats is.—

(i.) Reduced number of molars.
(ii.) Large upper canines.
(iii.) Small lower canines.
(iv.) Conical incisors.
(v.) Addition of a cutting lobe to the anterior base of the upper sectorial tooth.
(vi.) The obliteration of the inner tubercle of the lower sectorial tooth.
(vii.) The extinction of the heel of the lower sectorial tooth.
(viii.) The development of an inferior flange at the latero-anterior angle of the front of the ramus of the lower jaw.
(ix.) The development of cutting lobes upon the posterior border of the large premolar teeth.

*Civets* (*Viverridæ*).—The permanent formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{2}{2}$$

The lower carnassial tooth is pectinated and insectivorous like in type. Apply the general characteristics.

*Hyæna* (*Hyænidæ*).—The jaw is short, strong, and stout. The *cheek teeth* are reduced in number, and each has a well-developed cingulum. This affords protection to the gums from pressure, the animal subsisting upon bones. The upper molar is within the arch. Apply the general characteristics.

*Aardwolf.*—An animal like the hyæna. The *canines* are well marked and the *cheek teeth* rudimentary. It bites off sheep's tails, upon which, and putrid flesh, it lives.

*Dog, Wolf, Fox* (*Canidæ*).—The permanent formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{2}{3}$$

They are not so sectorial as felidæ. The *incisors* are trilobed. The *canines* have anterior and posterior ridges. The upper, and the last two lower *molars* are blunt. In long-muzzled dogs the cheek teeth are separated, whilst they are in contact in short-muzzled varieties. Apply the general characteristics.

*Weasel.*—The permanent formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{1}{2}$$

The *cheek teeth* are approaching the type of the bear's, becoming broad-topped.

*Racoons* and *Coatimundis* (*Procyonidæ*).—The permanent formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{2}{2}$$

The teeth more closely resemble those of the bear, the sectorial teeth becoming broad-topped and the *molars* broad with several cusps.

*Bear.*—The permanent formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{2}{3}$$

The *incisors* are trilobed. The *canines* are in comparison with the other teeth not so large as in other carnivora. The *cheek teeth* are close up to the canines, and are broad-topped and somewhat human like. The first and the fourth *premolars* are not lost but the second and the third are, and in the order named. The upper *carnassial* tooth retains slightly the characteristics of a typical one, but not the lower. Apply general characteristics.

(2) *Pinnipedia.*—*Otaria, eared seals* (sea lions).—The formula is

$$I\frac{3}{2}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{1}{1}$$

The number of *incisors* varies in different groups. The *canines* are large. The *cheek teeth* are homodont and tend to erosion. There is a poorly-marked milk dentition.

*Phoca* (common seals.)—The formula is

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{1}{1}$$

The *incisors* are simple, the outer being the larger. The *canines* are well marked. The *cheek teeth* are tricono-dont, having three cusps. They tend to erosion.

*Walrus* (*Trichechus rosmarus*). — The permanent formula is

$$I\frac{1}{0}\ C\frac{1}{1}\ PM\frac{3}{3}\ M\frac{0}{0}$$

In young specimens there are three *incisors* in each jaw, and five *molars* in the upper, and four in the lower. Sometimes all these teeth persist through life. The milk teeth are lost at birth. The upper *canines* are enormous teeth in both sexes, grow from persistent pulps, consist of dentine and cementum, and are used for progression over the ice, tearing up marine plants, and warfare.

# CHAPTER XIX.

## INSECTIVORA.

THESE include the *mole, hedgehog, galeopithecus, shrew*, &c.

### GENERAL CHARACTERISTICS.

They live on insects, crushing the chitinous covering with their peculiarly adapted teeth, which have sharp cusps. The teeth of extinct insectivora were differentiated into *incisors*, large *canines, premolars*, and *molars*. In recent insectivora, the canines are often incisor-like, and the first lower premolars, caniniform. In addition to these modifications, the often late presence of the milk teeth, ranging and working with the permanent, renders it difficult to determine the formulæ. The molars are of the V or W shape pattern, and bristle with numerous sharp cusps. The teeth are heterodont and diphyodont. The lower incisors are small and recumbent, and the canines are often two-rooted. Tubular enamel occurs in the *soricidæ*. Some have comb-like incisors (*galeopithecus*), and some, pigmented enamel (*shrews*).

*Galeopithecus.*—The dental formula is

$$I\frac{2}{3}\ C\frac{0}{0}\ PM\frac{3}{3}\ M\frac{3}{3}$$

It lives on fruits and leaves. The lower *incisors* are comb-like, and may be so modified to comb the fur, or the result of a peculiarity of diet. The caniniform tooth

lower central are large, horizontal, and have their points bent upwards. These fit into the notches on the upper. The *cheek teeth* are of the W shape pattern, are small, and have sharp cusps.

*Mole* (*Talpa*).—The formula is probably

$$I\frac{3}{3}\ C\frac{1}{1}\ PM\frac{4}{4}\ M\frac{3}{3}$$

The upper *incisors* are small, the first being the largest. The lower are small. The upper *canine* is half in the maxilla and half in the pre-maxilla, the suture passing across it. It has two roots. Of the upper *premolars*, the first three are small, and the fourth, molariform and much larger. The first lower is caniniform, and does the work of a canine. It is two-rooted, and bites behind the upper caniniform tooth. The three other are small and single-rooted. The upper *molars* bristle with cusps, the first two being large, and the third small and simple. The lower have large heels, are large, and have long and sharp cusps.

## CHIROPTERA.

These comprise the *bats*. They differ from other mammals in possessing wings. They are divided up into—

(1) Insectivorous.

(2) Frugivorous.

(1) INSECTIVOROUS.—They are the more numerous. The formula is

$$I\frac{2}{3}\ C\frac{1}{1}\ PM\frac{3}{3}\ M\frac{3}{3}$$

The *incisors* are small.

Their *canines* are large.

They have sharp cusps on the *cheek teeth*, usually of the W pattern.

The *desmodus* (vampire bat) has only one permanent upper *incisor* on each side. It is long, thin, and sharp. The lower incisors are small and notched. The *canines* are large, and the *cheek teeth* are stunted. The animal lives by sucking blood, the wounds being produced by the upper incisors. The dental formula is

$$I\ \frac{1}{2}\quad C\ \frac{1}{1}\quad PM\ \frac{2}{3}\quad M\ \frac{1}{1}$$

The milk teeth are hooked, probably to aid the young in holding on to the mother.

(2) FRUGIVOROUS.—The dental formula is

$$I\ \frac{2}{2}\quad C\ \frac{1}{1}\quad PM\ \frac{2}{3}\quad M\ \frac{3}{3}$$

The *incisors* are small.

The *canines* are large.

The *cheek teeth* are simple, compressed from side to side, and non-insectivorous in type. The molars are separated from one another, and are sometimes reduced in number.

# CHAPTER XX.

## PRIMATES.

### CLASSIFICATION.

(1) Lemuridæ.

(2) Simiadæ, including Anthropoid Apes.

(3) Anthropidæ (man).

(1) LEMURIDÆ.—These, in general structure, are like insectivora. They are found in Africa and Southern Asia, but the true Lemurs are almost exclusively confined to Madagascar. They are arboreal in their habits, and are chiefly vegetable eaters, although their food also consists of insects, reptiles, birds, and birds' eggs. The permanent formula is

$$I\frac{2}{2}\quad C\frac{1}{1}\quad PM\frac{3}{3}\quad M\frac{3}{3}$$

The upper *incisors* are small and spaced, and the lower, long, thin, narrow, and procumbent, biting into the inter-dental space between the upper. The upper *canines* are large, and the lower are ranged with the incisors and are similar in type. The *premolars* are compressed from side to side, are sharp, and have two roots, outer and inner. The first lower is caniniform and bites behind the upper canine. The *molars* have three, sometimes four cusps, and the upper have an oblique ridge, as in man.

*Indris brevicaudatus.*—This is the largest of the lemurs, is about 3 ft. high, and is trained by the people

of Madagascar for hunting purposes. Its permanent formula is

$$I\frac{2}{1}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{3}{3}$$

*Tarsius.*—The dentition of this animal resembles that of man in having no diastema.

*Aye Aye* (*Chiromys*).—This is a nocturnal animal with doubtful habits. Its permanent formula is

$$I\frac{1}{1}\ C\frac{0}{0}\ PM\frac{1}{0}\ M\frac{3}{3}$$

Its *incisors* are rodent-like, grow from persistent pulps, and have thick enamel, which forms a complete investment. There is an absence of laterals and *canines*, but a well-marked milk dentition exists, which is

$$I\frac{2}{2}\ C\frac{1}{0}\ M\frac{3}{2}$$

Behind the incisors is a big space, and then four upper and three lower cheek teeth. These grow from non-persistent pulps, have definite roots, and resemble the molars of omnivorous rodents.

(2) SIMIADÆ.—These are divided into—
(*a*) New World Monkeys.
(*b*) Old World Monkeys.

### (*a*) NEW WORLD MONKEYS.

The permanent formula is

$$I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{3}{3}\ M\frac{3}{3}$$

They are *platyrhine* (broad-nosed), and have prehensile tails. There are neither cheek pouches nor callosities on the seat.

*Marmoset.*—The formula is

$$I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{3}{3}\ M\frac{2}{2}$$

The upper molars have an oblique ridge, as in man.

*Cebidæ.* — These monkeys have insectivorous-like molars.

*Ateles (Spider Monkeys).*—The outer lower *incisors* are caniniform. The *canines* are long and sharp. The lower *premolars* are single-rooted, and the internal cusp, which is small on the first, gradually increases in size to the last. The upper are slightly bifurcated at the roots. The first two upper *molars* are three-rooted, the third showing slight signs of bifurcation.

## (*b*) Old World Monkeys.

Their formula is

$$I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{3}{3}$$

They are *catarrhine* (narrow-nosed), and have non-prehensile tails. There are cheek-pouches, and, in many cases, callosities on the seat.

*Macaque Monkey.*—The *incisors* are directed obliquely forwards, the lateral being much smaller than the central. There is a *diastema* in front of the upper canine. The upper *canine* is large, triangular on section, grooved anteriorly, and ridged posteriorly. The lower is large, but not so large as the upper. The upper *premolars* have three roots. The first lower has two roots, and one cusp, the latter being situated over the posterior root, and the second has two roots. The *molars* have four cusps. The third lower may have three to five. The upper have three roots, and the lower two. The molars increase in size from before backwards.

*Anthropoid Apes.*—These include the *Gibbons* (*Hylobates*), *Orang utan*, *Gorilla*, and *Chimpanzee*. They differ from the lower primates in having no tails, and no callosities on the seat. They assume a semi-erect attitude, and have a broader thorax, and an elongated forearm for support.

The *general characteristics* of the teeth and jaws may be given in comparing them with those of man.

| | Apes. | Man. |
| --- | --- | --- |
| *Formula* | $I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{3}{3}$ | $I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{3}{3}$ |
| *Milk formula* | $I\frac{2}{2}\ C\frac{1}{1}\ M\frac{2}{2}$ | $I\frac{2}{2}\ C\frac{1}{1}\ M\frac{2}{2}$ |
| *Incisors* | Like man's, but larger, coarser, and inclined more obliquely forwards. | Smaller than in apes, and not inclined so obliquely forwards. |
| *Canines* | Large and sexual. They erupt late, and are larger in the male than in the female. In the *gorilla* they erupt after the third molar. | Non-sexual. They erupt much earlier, and there is no difference in size in the male and the female. |
| *Premolars* | The upper have three roots, and the lower two. The upper have two cusps. In the lower, the first is a blunt copy of the canine with a poorly marked inner cusp, and the second is tricuspid. | All have one root except the first upper, which often has two. In the lower, however, there is often a tendency to bifurcation. They all have two cusps. |
| *Molars* | They increase in size from before backwards. The upper have four cusps, and the lower five. There is an oblique ridge on the | The third is often the smallest tooth. All the upper have four cusps. The lower have five on the first, four on the second, and five on the third, in 80 per cent., whilst in the remaining 20 per |

| Apes. | Man. |
|---|---|
| upper, passing from the postero - external to the antero-internal cusp. | cent. they all have five. As in the apes, there is an oblique ridge on the upper. |
| *Intermaxillary suture*...Remains open. | Closes early. |
| *Intermaxillary bone*...More developed and pronounced than in man. | Not so pronounced as in apes. |
| *Supernumerary teeth* ... Sometimes occur; *e.g.*, *Cebidæ*, *Ateles*. | Sometimes occur. |
| *Jaws*...Square, the lines of teeth being parallel or tending to diverge. | Horse-shoe shaped, the lines of teeth converging. |
| *Diastema*...A space existing in front of the upper canine. | Non-existent. |
| *Other characteristics*— | |
| Megadont. | More often Mesodont or Microdont. |
| Prognathous. | Not so prognathous. |
| Heterodont | Heterodont. |
| Diphyodont. | Diphyodont. |

These *general characteristics* may be applied to all apes, with the following modifications :—

The dentition of the *chimpanzee* is the most like that of man. The *canines* are non-sexual, the intermaxillary suture closes early, the roots of the lower *premolars* are fused, and the third *molar* is smaller than the others.

The *gibbons* are the lowest of the anthropoid apes. Their dentition is next like that of man, except that the *canines,* in comparison to their other teeth, are long.

In the *gorilla*, the first *premolar* is caniniform, showing the close relationship between the canines and premolars. The *canine* erupts after the third molar.

In the *orang utan*, the upper lateral *incisors* are much smaller than the centrals, and are caniniform. The first upper and lower *premolars* are caniniform, the lower having only a very slight inner cusp. The *molars* have

a fine crinkled pattern. The roots of all the teeth are remarkable for their length and strength. *Tomes* says, respecting the dentition of the orang, " I am not acquainted with any dentition which exemplifies the transition from incisors to canines, from canines to premolars, and from premolars to true molars, better than that of the orang."

(3) ANTHROPIDÆ (MAN).—The teeth of the lower races of man approach the *Simian* type. *Palæolithic* man, or man of the Stone Age, stood nearer to apes than modern races. They were, in comparison with modern races :—

More prognathous.

The arch was squarer.

The third molars were neither stunted nor crowded, and the roots were separate.

The glabella (the space between the eyebrows), and the superciliary ridges, were stronger and more prominent.

They had a receding chin.

The jaws were large and strong.

The canines were large.

Signs of attrition occur on the biting surfaces, due probably to the coarse diet. The teeth and jaws were often used as tools.

The teeth of man are not so specialized as, for instance, the teeth of carnivora and herbivora, and they are more degraded in form and structure. Some of the results of civilization, viz., pernicious habits, love of luxury, indolence, &c., &c., have led to the teeth and jaws of civilized races being more deficient in structure than is the case in savage races. The typical mammalian formula is :—

$$I\ \frac{3}{3}\quad C\ \frac{1}{1}\quad PM\ \frac{4}{4}\quad M\ \frac{3}{3}$$

In man, apes, &c., this formula is deficient, twelve teeth having been lost. In man, the lateral incisors and the third molars are gradually disappearing. In *man* and *mammalia* generally, when *incisors* are lost, the outermost are usually the first to disappear. Exceptions occur in the *seal*, where the first incisor is lost, and in the *camel*, where the first and the second have disappeared. When *premolars* are lost, they are usually lost from before backwards. Exceptions to this rule occur in the *bear* and the *bat*. *Molars* are lost from behind forwards. Exceptions occur in the *hog* and the *kangaroo*.

Man may be *brachycephalous* (having a round and short head), *dolichocephalous* (having a long and narrow head), or *mesocephalous* (medium). The measurement, or the *cephalic breadth index*, is obtained by multiplying the transverse diameter by 100, and dividing by the long (antero-posterior) diameter. The latter is a line measured from the glabella to the occiput. Then

below 75 = *Dolichocephalous.*
between 75 and 83 = *Mesocephalous.*
above 83 = *Brachycephalous.*

The jaws, head, and teeth differ in the different races of man as follows:

(1) Ethiopic Division (black or negro).

(*a*) *African* (*Western*) *section.*—They are dolichocephalous, prognathous, megadont, have large, conical canines, and the lines of teeth are parallel.

(*b*) *Australasian* (*Oceanic or Eastern*) *section.*—They are dolichocephalous *Negrillos*, are brachycephalous, their incisors are much broader at the biting edges than at their necks, and they are prognathous, as are also *Australians* and *Papuans*. In *Australians* the molars do not decrease in size from before backwards, and all the lower have five cusps. They are the lowest form of man, and are very treacherous, cruel and indolent. Their teeth are megadont.

(2) Mongolic (yellow).—They are brachycephalous. slightly prognathous, and megadont. The teeth of the *Japanese* and *Esquimaux* are smaller than those of the *Chinese*, and in *Esquimaux* the third molars show an appearance of being crowded out.

(3) American.—The head is variable. The jaw is massive and slightly prognathous. The teeth vary in size in divers races. In *Indians*, they are megadont.

(4) Caucasic (white).

(*a*) *Xanthochroid* (light type).—*Scandinavians, Germans, British*, &c. They are dolichocephalous, mesodont, and have square jaws. The canines are prominent, and the teeth light-coloured.

(*b*) *Melanochroid* (dark type).—*Mediterraneans, ancient Egyptians, Hindoos, Persians, Slavs*, &c. They are brachycephalous, microdont, and have a round arch. The teeth are stronger and better than is the case with the light type.

# INDEX.

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