ODONTOLOGY.

INTRODUCTION.

Introduction.

Definition.

ODONTOLOGY[1] is that branch of anatomical science which treats of the teeth. The term "tooth" has been applied in Zoology and Zootomy to various organs and parts; usually to such as are so solid, so shaped, and so situated in animal bodies, as to serve for seizing and operating on the food; but it has been also applied to parts, such as the prominences on the hinge of bivalve shells, which have no relation to the digestive function. The silicious spines of infusory animalcules, the calcareous jaws of sea-urchins, the chitinous hooks and hooklets of sea-worms, and many corresponding parts of invertebrate animals, are described as "teeth;" but the present essay exclusively relates to those bodies, hardened chiefly by the phosphate of lime, which are attached to parts of the mouth or beginning of the alimentary canal, and which are peculiar to the vertebrated classes of animals.

The term "tooth" is immediately derived from the Teutonic word *tunth*, which we may trace through the old English or Anglo-Saxon *tain*, the Danish *tand*, the German *zahn*, the Latin *dens*, the French *dent*, the Italian *dente*, the Greek *odous*, *odontes*, the Welsh *dant*, the Erse *dend*, and the Lithuanic *dantis*, to the Sanscrit mother-root *dantas:* these synonymes being strikingly illustrative of the coincidence, in one of the primary words, of a natural class of languages which prevails from Central Asia, westward, over Europe, and of the unity of stock of the great Indo-European family of mankind.

True calcified teeth are primarily, if not permanently, distinct parts from the bony skeleton, and are exposed, save where their development is prematurely arrested, as, *e.g.*, in the rudimental tusk of the narwhal. The exceptions to their calcified condition in the Vertebrata are very few; such, *e.g.*, as the horny teeth in the Myxinoid fishes and the Monotremes. But true calcified teeth vary in their tissue and composition, and still more in regard to number, size, form, structure, position, and mode of attachment in different animals. They are principally adapted for seizing, tearing, dividing, pounding, or grinding the food: in some they are modified, to serve as weapons of offence and defence; in others as aids to locomotion, means of anchorage, instruments for uprooting or cutting down trees, or for transport and working of building materials. They are characteristic of age and sex; and, in man, they have secondary relations subservient to beauty and to speech.

Teeth are always most intimately related to the food and habits of the animal, and are therefore highly interesting to the physiologist. They form, for the same reason, most important guides to the naturalist in the classification of animals; and their value as zoological characters is enhanced by the facility with which, from their position, they can be examined in living or recent animals; whilst the durability of their tissues renders them not less available to the palæontologist in the determination of the nature and affinities of extinct species, of whose organization they are often the sole remains discoverable in the deposits of former periods of the earth's history.

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Composition.

Teeth are composed of a cellular and tubular basis of animal matter containing earthy particles, a fluid, and a vascular pulp. In general, the earth is present in such quantity as to render the tooth harder than bone, in which case the animal basis is gelatinous, as in other hard parts where a great proportion of earth is combined with animal matter. In the very few instances among the vertebrate animals above cited, where the hardening material exists in a much smaller proportion, the animal basis is albuminous; the teeth here agree, in both chemical and physical qualities, with horn.

Teeth rarely consist, like bones, of a uniform or nearly uniform substance, but are composed to two or more tissues, characterized by the proportions of their earthy and animal constituents, and by the size, form, and direction of the cavities in the animal basis which contain the earth, the fluid, or the vascular pulp. The tissue which forms the body of the tooth is called "dentine" (Lat. *dentinum;* Germ. *zahnbein, zahnsubstanz;* Fr. *l'ivoire*); (fig. 1, *d*). The tissue which forms the outer crust of the tooth is called "cement" (Lat. *cæmentum, crusta petrosa*); (figs. 1 and 5, *c*). The third tissue, when present, is situated between the dentine and cement, and is called "enamel" (Lat. *encaustum, adamas*); (figs. 1 and 5, *e*).

Dentine consists of an organized animal basis, and of earthy particles: the basis is disposed in the form of compartments (fig. 3, *a*), of minute tubes (fig. 3, *d*), and cells (fig. 3, *g*); the particles have a twofold arrangement, being either blended with the animal matter of the interspaces (*c*) and parietes (*d*) of the tubes and cells, or being contained in a minutely granular state in their cavities. The density of the dentine arises principally from the proportion of earth in the former of these states of combination. The tubes and cells contain, besides the granular earth, a colourless fluid, probably "plasma," or "liquor sanguinis," in a delicate cellular tissue, and thus relate not only to the mechanical conditions of the tooth, but to the vitality and nutrition of the dentine.

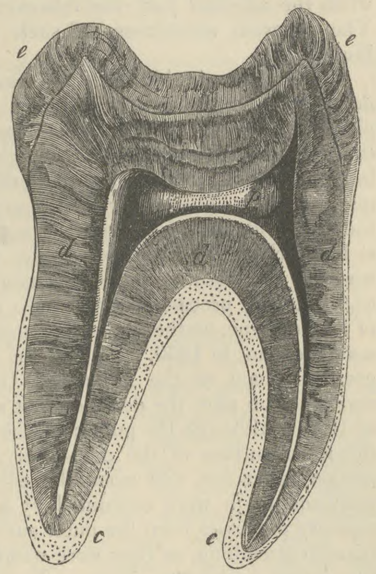

Fig. 1.
Section of Human Molar Tooth (magn.).

Approximative steps to the recognition of the true nature of teeth were made by Purkinjé[2] and Retzius;[3] but the first definite and unequivocal announcement of the observed organic connection between the vascular and vital soft parts of the frame and the hard substance of a tooth, was communicated to the Institute of France in 1839.[4] "If the

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[1] From οδους, a tooth, and λογος, a discourse.

[2] *De penitiori Dentium Humanorum structurâ Observationes* (Fraenkel), and *Meletemata circa Mammalium Dentium Evolutionem* (Rashkow), 4to, 1835.

[3] *Mikroskopiska Undersökningar öfver Jädernes särdeles Tandbenets struktur*, Stockholm, 1837.

[4] "Mais si un bulbe, dans ces conditions, est sousmis au microscope, et comparé à un bulbe encore dépourvu de matière calcaire, on voit qu'il n'est plus revêtu de la membrane lisse, dense, que l'on observe dans ce dernier; et le bord apical du bulbe dont on a détaché son étui émaillé parâit villeux et flocconeux." . . . . "A mesure que la formation de la dent est plus avancée, il devient plus difficile de séparer la portion calcifiée du bulbe de la portion non calcifiée, et en même temps plus facile de découvrir la continuation des pro-

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pulp of a growing tooth be submitted to microscopical examination, and compared with a pulp before it has begun to be calcified, it will be seen to be not covered by any outer membrane, like the so-called 'membrana propria,' or the smooth dense covering of the uncalcified pulp; but the surface of the pulp, from which the calcified sheath has been removed, will appear cottony and villous: in proportion as the tooth is more advanced in its formation, it becomes more difficult to separate the calcified from the non-calcified part of the pulp, and at the same time more easy to discover the continuation of the prolongations of the pulp in the interior of the numerous medullary canals which constitute so many distinct centres of radiation for the plexiform dentinal tubes." This discovery of the organic connection between the pulp and the canals of the dentine, made by observation of the development of the teeth of the shark, was affirmed to be applicable to the teeth of Mammalia: it was only the excessive smallness of the dentinal tubes in the latter which rendered invisible to the naked eye the irregularity of the uncalcified surface of the pulp, when the calcified part was detached in a growing tooth. The apparent smoothness of such exposed surface was illusory.

Dr Schwann, in his important essay on the correspondence in structure and development between animals and plants,[1] spoke of the "presumed" transition of the cells of the pulp into the dentinal tubes, which he calls "fibres," but leaves that capital fact as one still of uncertainty, and questionable. The author of the present article published the full evidence of his original propositions, above cited, in his work entitled *Odontography*, 4to, 1840–1845, and was able to give more direct testimony of the continuation of filamentary processes of the pulp into the minute tubes of hard dentine, on the occasion of anatomizing a full-grown male elephant in 1850. "I had the tusk and pulp of the great elephant at the Zoological Gardens longitudinally divided, soon after the death of that animal in the summer of 1847. Although the pulp could be easily detached from the inner surface of the pulp-cavity, it was not without a certain resistance, and when the edges of the co-adapted pulp and tooth were examined by a strong lens, the filamentary processes from the outer surface of the pulp could be seen stretching, as they were withdrawn from the dentinal tubes, before they broke. They are so minute that, to the naked eye, the detached surface of the pulp seems to be entire, and Cuvier was thus deceived in concluding that there was no organic connection between the pulp and the ivory."[2]

Confirmatory evidence of the continuation of filamentary processes of the pulp into the dentinal tubuli in the human teeth, has recently been communicated to the Royal Society of London by Mr Tomes.[3] It has appeared to the present writer that the filamentary processes of the pulp become resolved, at or near the first bifurcation of the tubuli, into mere delicate membranous linings of the dentinal tubes, which are chiefly occupied by the plasma contained in these continuations of the pulp, with occasional detached calcareous particles.

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Structure.

Until a comparatively recent period, the analogy of dentine to bone was supposed to be confined to their chemical constitution, and the nature of the hardening material; while the arrangement, as well as the mode of deposition of the tooth-tissue, were considered to be wholly different from that of bone; and the dentine to agree, in its general nature and mode of growth, with hair and other extravascular horny parts, with which most teeth closely correspond in their vital properties.[4]

The structure of a tooth, in fact, was regarded as simply laminated, and the ivory was described as being formed layer within layer, deposited by, and moulded upon, the formative superficies of the vascular pulp. The illustrations and supposed proof of this structure and mode of growth were derived from the apparently detached condition of the newly-formed particles of dentine on the pulp's surface, when exposed by the removal of the calcified part of the tooth; from the appearance observed in the teeth of animals fed alternately with madder and ordinary food, which undoubtedly illustrate the true progress of dental development; from the illusory traces of laminated structure observed in vertical sections of teeth when viewed with the naked eye, or with a low magnifying power; and lastly, and chiefly, from the successive hollow cones into which a large tooth, such as the elephant's tusk, is commonly resolved in the process of decomposition.

With regard, however, to the appearances presented by the teeth of animals under the influence of madder, and the separation of the dentine into superimposed lamellæ during decomposition, the same conclusions, as to intimate structure and mode of development, might be drawn respecting true bone, which also commonly resolves itself into the concentric lamellæ during decomposition, and presents the same appearance of alternate white and red layers in animals fed alternately with madder and ordinary food during the progress of its growth. The lines running parallel to each other, and to the contour of the crown, presented by the cut surfaces of vertical sections of teeth, especially of the elephant's tusk, or of the tooth of the cachalot, are due to a totally different structure from that to which they are ascribed. The lamellated arrangement, thus seemingly demonstrated, is, moreover, far from being a constant appearance; on the contrary, the superficies of vertically cut or fractured surfaces of the human and most other teeth offer a very different character, and one which has led to many approximations and allusions to the true structure of dentine, in the works of anatomists who have recorded their own original observations.

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longements du bulbe dans l'interieur de ces nombreux canaux médullaires qui constituent tant de centres de radiation distincte pour les tubes calcigères plexiformes. Le principe du dévelopment dentaire s'effectuant par *depôt dans la substance* et non par *exsudation en dehors de la substance* d'un bulbe pré-existant, tel qu'il ressort de la dentition des squales, est d'une application sans effort, naturelle et manifeste à la formation des dents des mammifères. Dans l'ivoire d'une dent simple de mammifère, il existe un canal médullaire unique, appelé cavité du bulbe, et un système unique de tubes rayonnés calcigères; mais le plan et la mode de formation sont les mêmes que dans les squales." "Les tubes calcigères d'une dent de mammifère cnt des parois distinctes tant dans les portions calcifiées que dans les portions non calcifiées du bulbe. Ces parois sont rendues fragiles par le dépôt qui s'y fait de particules terreuses dans la portion calcifiée du bulbe, et alors se separent facilement de leur portion non calcifiée, laquelle se continue dans le reste du bulbe, et c'est l'excessive petitesse des tubes rompus qui rend invisible à l'œil nu l'irregularité de la surface du bulbe: mais cette appearance d'une surface naturelle libre, exsudante, n'est qu'une illusion." (*Recherches sur la structure et la formation des dents des Squaloïdes, et application des faits observés à une nouvelle théorie du développement des dents*, par M. R. Owen; *Comptes Rendus des Séances de l'Academie des Sciences*, No. 25, 16 Décembre 1839, p. 786.

[1] *Mikroscopische Untersuchungen ueber die Uebereinstimmung in der Struktur und dem Wachsthum der Thiere und Pflanzen*, 8vo, 1839, p. 117.

[2] *Cyclopœdia of Anatomy and Physiology*, p. 929, part xxxviii., Feb. 1850. Compare with *Annales du Muséum*, tom. viii., p. 96, and the *Ossemens Fossiles* of Cuvier, tom. i., p. 517, ed. 1834–6.

[3] *Philosophical Transactions*, 1856, p. 515.

[4] See English translation of Müller's *Physiology*, 1837, pp. 391 and 392; De Blainville, *Ostéographie et Odontographie*, Primates, p. 15, without date, but communicated by the author to the Institute of France, December 1839; vide *Comptes Rendus de l'Academie* of that month, Dec. 16, p. 782.

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Whoever attentively observes a polished section or a fractured surface of a human tooth, may learn, even with the naked eye, that the silky and iridescent lustre reflected from it in certain directions is due to the presence of a fine fibrous structure.

Malpighi, in whose works may be detected the germs of many important anatomical truths that have subsequently been matured and established, says, that the teeth consists of two parts, of which the internal bony layers (dentine) seem to be composed of fibrous, and, as it were, tendinous capillaments reticularly interwoven.[1] Retzius cites many recent authors—*e.g.*, Sœmmering, Schreger,[2] and Weber[3]—who mention the silky, glistening lustre of the dentine; and Frederick Cuvier, in the preliminary discourse of his admirable work, the *Dents des Mammifères*, observes, "Les dents de l'homme, de singes, de carnassiers, ont un ivoire d'apparance soyeuse, qui semble formé de fibres" (p. 27). These intelligible hints of the true structure of the dentine, which the foregoing observers received from a superficial but unprejudiced inspection, failed, however, to incite them to a closer interrogation of nature in regard to the dental tissues. One of her most persevering investigators had, nevertheless, long before obtained a true and definite answer to his more direct inquiries. Leeuwenhoek having applied his microscopical observations to the structure of the teeth, discovered that the apparent fibres were really tubes, and he communicated a brief but succinct account of his discovery to the Royal Society of London, which was published, together with a figure of the tube, in the 140th number of their *Transactions*. This figure of the dentinal tubes, with additional observations, again appears in the Latin edition of Leeuwenhoek's Works, published at Leyden in 1730. The dental substance (dentine) of the human teeth, and of those taken from young hogs, is described as "being formed of tubuli spreading from the cavity in the centre to the circumference."[4] Fig. 2 is accurately copied from Leeuwenhoek's original figure, intended to represent the general arrangement of these tubuli in the human molar tooth. The Dutch microscopist computed that he saw 120 of the tubuli within the forty-fifth part of an inch.[5] Leeuwenhoek also shows that he was aware of the peculiar substance, distinct from the ivory and enamel, and now termed the cement, or *crusta petrosa*, which enters into the composition of the teeth of the horse and ox;[6] a component part of the tooth which Hunter speaks of as a second kind of bone, and which was first accurately and specifically described by Tenon[7] and Blake.[8]

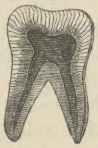

Fig. 2.
Section of Human Molar Tooth; after Leeuwenhoek.

The discovery of Leeuwenhoek that the dentine was made up of very minute tubes, which proceeded from the inner to the outer surface of the tooth, was confirmed by Purkinjé[9] so far as regarded their existence; but Purkinjé added an exact and particular account of the direction of these tubes in the human dentine, and showed that, in addition to them, the dentine contained an intermediate or intertubular tissue. This he describes as homogeneous and without structure, and as entering into the composition of the dentine in a greater proportion than the tubes themselves. The more extensive, varied, and minute observations of Professor Retzius[10] led to the discovery of the cells of the intertubular tissue of the ramuli (fig. 3, *f*), sent off from the main dentinal tubes (fig. 3, *d*), into that tissue, and of the anastomoses of the ramuli with each other (fig. 3, *b*), with the intertubular cells, and with the cells at the periphery of the dentine (fig. 3, *g*). According to the researches of Dr Schwann,[11] the animal basis of the intertubular tissues possesses a fibrous structure. Besides the primary and secondary branches of the dentinal tubes, Retzius first clearly described their curvatures and undulations, which may be defined as follows:—As a general rule, the dentinal tubes are directed, as affirmed by Leeuwenhoek and Purkinjé, from the inner to the outer surface of the tooth, and vertically to those surfaces, as shown in the section of the human incisive tooth (fig. 4), and of the molar tooth (fig. 1, at *d*, *d*). But in their course the tubes describe two, three, or more curvatures, appreciable by a low magnifying power. These are termed the "primary curvatures."[12] With a higher power, the tubes are seen to be bent throughout the whole of their flexuous course into minute and oblique undulations or gyrations (fig. 3, *d*), 200 of which were counted by Retzius in one-tenth part of an inch length of a human dentinal tube; these are termed the "secondary curvatures" or gyrations.[13] Both the primary and secondary curvatures of one dentinal tube are usually parallel with those of the contiguous tubes; and from the radiated course of these tubes, they occasion the appearance of lines running parallel with the ex-

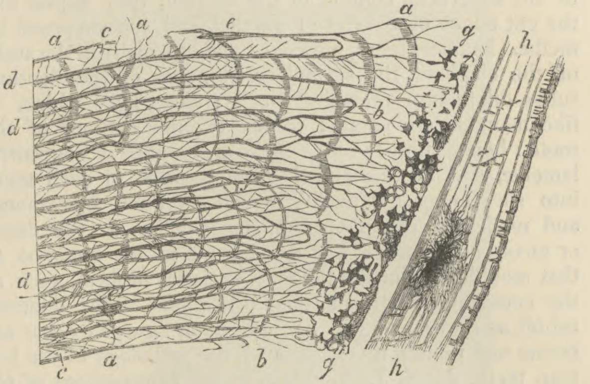

Fig. 3.
Highly-magnified section of Dentine and Cement, from the Fang of a Human Molar Tooth.

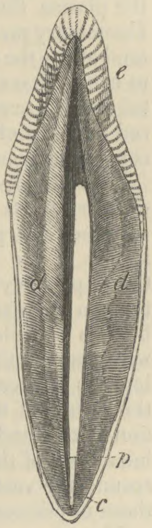

Fig. 4.
Section of Human Incisor.

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[1] "Duplici excitantur parte, quarum interior ossea lamella fibrosis et quasi tendinosis capillamentis in naturam implicetis constat." (*Anatome Plantarum*, Lugd. Batav. 1687, p. 37.)

[2] Isenflamm und Rosenmüller's *Beiträgen zur Zergliederungskunst*, band i., p. 3 (1800).

[3] See his edition of Hildebrand's *Handbuch der Anatomie*, band i., p. 206.

[4] "Microscopical Observations on the Structure of Teeth and other Bones (*Philosophical Transactions*, 1678, p. 1002).

[5] See Hoole's translation of the *Select Works* of Leeuwenhoek, 4to, 1798, p. 114.

[6] "Parvi molares, quos bos, dum adhuc admodum juvenis sive vitulus, habuerat, undiquaque *alio osse* circumducti erant." (*Continuatio Epistolarum*, 4to, Lugd. Bat. 1689, p. 7.)

[7] "Mémoire sur une Méthode particulière d'etudier l'Anatomie," in *Mémoires de l'Academie des Sciences*, Paris, an. vi.

[8] *An Essay on the Structure and Formation of Teeth*, Dublin, 1802.

[9] *De penitiori Dentium Humanorum structura Observationes*, 4to, 1835.

[10] *Mikroskopiska Undersökningar öfver Jädernes särdeles Tandbenets struktur*, 8vo, Stockholm, 1837.

[11] *Microskopische Untersuchungen über die Uebereinstimmung in der Strucktur der Thiere und Pflanzen*, 8vo, 1839.

[12] *Trans. Brit. Assoc.*, vol. vii., p. 148. See *Odontography*, plate 24, fig. 1; 64 A, fig. 2; 74, fig. 1; 94.

[13] *Odontography*, p. 141; see plates 16, fig. 3; 24, fig. 2; 64 A, fig. 3.

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ternal contour of the tooth; for, when the surface of a longitudinal section of a tooth is viewed with the naked eye, the light is differently reflected from the different parts of the oblique secondary curves of the tube on which it falls; but the curves being parallel to each other, and to the superficial contour of the section, they appear like the cut edges of a series of parallel and superimposed lamellæ. In many teeth, moreover, and especially in the tusks of the elephant, the secondary branches of the dentinal tubes dilate into intertubular cells; along lines which, in like manner, are parallel to the coronal contour of the tooth: hence another cause of the appearance of concentric lamellæ, and of the actual decomposition of such teeth into superimposed lamelliform cones. Such appearances and modes of decomposition are peculiar to the dense or unvascular dentine, but are by no means common to that modification of the tissue. Varieties of form, such as the occasional aneurismal-like dilatations of the dentinal tubuli, as shown at *e* (fig. 3), have been figured by that accurate and minute investigator of the pathology of the human teeth, Mr S. J. A. Salter, in the *Transactions of the Pathological Society of London* for 1855, pl. i., fig. 3. In fig. 3 the delicate filamentary prolongations of the pulp are represented at *d, d;* the dentinal compartments, or indications of the original cells of the dentinal pulp are shown at *a, a;* and the modified peripheral layer of the dentine at *g*, to the superior sensibility of which M. Duval first called attention, distinguishing it by the name of "dictyodonte."[1]

Such is the typical structure of dentine, which structure relates, in regard to the curvilinear compartments, *a, a* (fig. 3), to the steps in its formation; and in regard to its tubular columns, to the strength of the tooth and its vitality; the latter important property depending on the percolation of the plasma through the delicate cellular structure of the filamentary prolongations of the pulp, so far as they may extend along the tubuli. The sensibility of the dentine is due to concomitant productions of neurine; but the distinct tubules are not large enough to admit capillary vessels with red particles of blood, and the tissue above described has consequently been sometimes termed "unvascular dentine."

The simplest modification of dentine is that in which capillary tracts of the primitive vascular pulp remain uncalcified, and permanently carry red blood into the substance of the tooth. These so-called medullary canals (more properly "vascular canals"), present various dispositions in the dentine, which they modify, and which modification is called "vasodentine."[2] It is often combined with true dentine in the same tooth; *e.g.*, in the scalpriform incisors of certain rodents,[3] the tusks of the elephant,[4] the molars of the extinct iguanodon.[5] A third modification of the fundamental tissue of the tooth is where the cellular basis of the dentine is arranged in concentric layers around the vascular canals, and contains radiated cells like those of osseous tissues; it is called "osteodentine."

The tissue called "cement" closely corresponds with osteodentine and with the osseous tissue of the skeleton of the same animal in which it is found; and wherever it occurs of sufficient thickness, as upon the teeth of the horse (fig. 5, *c*), sloth (fig. 9, *c*), or ruminant, it is also traversed, like bone, by vascular canals. In reptiles and mammals, in which the animal basis of the bones of the skeleton is excavated by minute radiated cells, forming with their contents the "corpuscles of Purkinjé," these are likewise present, of similar size and form, in the "cement;" and are its chief characteristic as a constituent of the tooth. The hardening material of the cement is partly segregated and combined with the parietes of the radiated cells and canals; and is partly contained in disgregated granules in the cells, which are thus rendered white and opaque viewed by reflected light.

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Fig. 5.
Highly-magnified Section of part of a Horse's Tooth.

The relative density of the dentine and cement varies according to the proportion of the earthy matter, and chiefly of that part which is combined with the animal matter in the walls of the cavities, as compared with the size and number of the cavities themselves. In the complex grinders of the elephant (fig. 140), the wart-hog (fig. 121), the voles (fig. 88), and the capybara, the cement *c*, which forms nearly half the mass of the tooth, wears down sooner than the dentine.

The "enamel" is the hardest constituent of a tooth, and consequently the hardest of animal tissues; but it consists, like the other dental substances, of earthy matter arranged by organic forces in an animal matrix. Here, however, the earth is mainly contained in the canals of the animal membrane; and, in mammals and reptiles, completely fills those canals which are comparatively wide, whilst their parietes are of extreme tenuity. The hardening salts of the enamel are not only present in far greater proportion than in the other dental tissues; but in some animals are peculiarly distinguished by the presence of a small proportion of fluate of lime.

The examples are extremely few, and confined to cold-blooded animals, of calcified teeth which consist of a single tissue; and this is always a modification of dentine. The maxillary denticles of the parrot-fish (*Scarus*), and the large pharyngeal teeth of the wrasse (*Labrus*), consist of a very hard kind of unvascular dentine. Fig. 6 shows a vertical section of one of the latter teeth, supported upon the vascular osseous tissue of the pharyngeal bone; *p* is the pulp cavity.

The next stage of complexity is where a portion of the dentine is modified by vascular canals. Teeth thus composed of dentine and vaso-dentine are very common in fishes. The hard dentine is always external, and holds the place, and performs the office, of enamel in the teeth of

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[1] *Observations Anatomiques sur l'Ivoire*, 8vo, Paris, 1838, p. 14. "Souvent les molaires sont tellement usées que, au lieu d'etre tuberculeuse, leur face triturante est lisse par l'effet de la détrition. On y distingue parfaitment, comme après la coupe transversale d'une dent, les aspects sous lesquels se presentent ses substances dures; l'un appartient à l'émail qui est tres-blanc; le second à la substance osseuse, que je désigne sous le nom *d'osteodonte;* et le troisième à cette partie qui, sous forme de zone circulaire et de couleur de corne, se trouve entre ce dernier et l'émail, et que j'appelle *dictyodonte.* Si avec la pointe d'un curedent d'acier, ou d'une sonde, on touche une de ces parties, l'émail ne donne aucun signe de sensibilité, l'osteodonte quelquefois un peu, mais le dictyodonte beaucoup et plus souvent. (Duval, *Observations Pratiques sur la Sensibilité des Dents*, 8vo, 1833, p. 7.)

[2] This substance was first characterized as a component of tooth distinct from ivory, enamel, cement, and true bone, and as easily recognisable, in a paper by the author, communicated to the British Association in 1838, *loc. cit.* p. 137.

[3] *Odontography*, 4to, p. 405.

[4] Ibid., p. 643.

[5] Ibid., p. 251.

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higher animals.[1] Fig. 7 illustrates this structure in a longitudinal section of a tooth of a shark of the genus *Lamna*; in the outer layer of hard unvascular dentine, the earthy constituent so predominates that it takes a polish like enamel, for which it has commonly been mistaken in the teeth of fishes; it is called "vitrodentine."

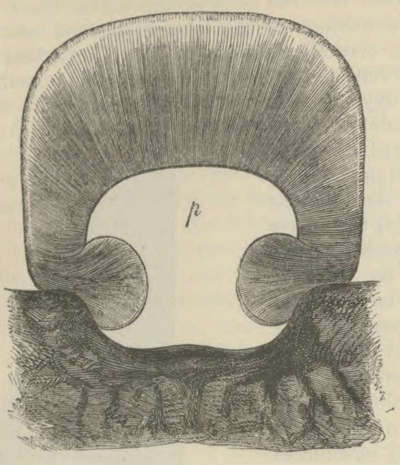

Fig. 6.
Magn. section of a Pharyngeal Tooth of *Labrus*.

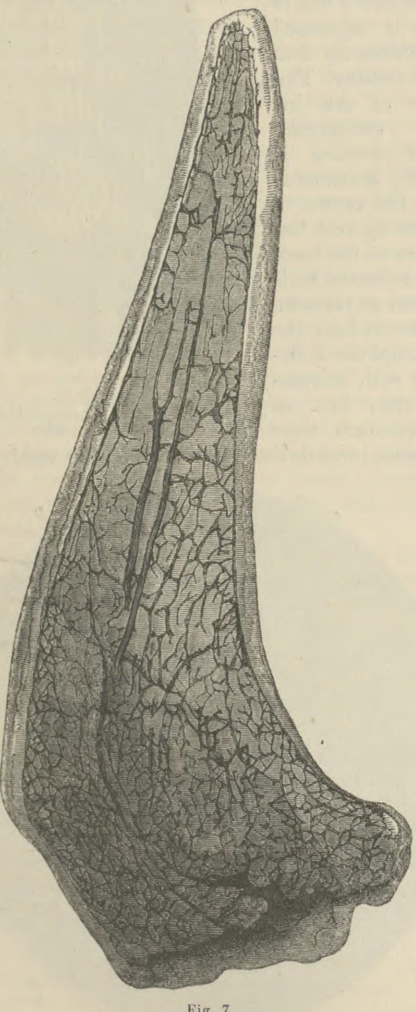

Fig. 7.
Magn. section of a Tooth of a Shark (*Lamna*).

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Fig. 8.
Magn. section of part of a Molar Tooth of the Dugong (*Halicore indicus*).

The molars of the dugong are examples of teeth composed of dentine and cement; the latter tissue forming a thick external layer. Fig. 8 shows a transverse section of the crown of the second molar, natural size, and above it a magnified view of a portion of the section; in which *d* is the dentine, remarkable for the number of minute calciferous cells at its periphery, and *c* is the cement. A small portion of osteodentine usually occupies the centre of the crown at *o*. In the large teeth of the lower jaw of the cachalot (*Physeter*) the pulp-cavity of the growing tooth becomes filled up by osteodentine, the result of a modified calcification of the dentinal pulp; and the full-grown tooth presents three tissues, as shown in fig. 62, in which *c* is the thick external cement, *d* the hard dentine, and *o* the osteodentine: the latter is sometimes developed into stalactitic-shaped nodules, loose in the pulp-cavity.

In the teeth of the sloth, and of its great extinct congener the megatherium, the hard dentine is reduced to a thin layer, and the chief bulk of the tooth is made up of a central body of vasodentine, and a thick external crust of cement. Fig. 9 represents a longitudinal section of a lower molar of the three-toed sloth (*Bradypus tridactylus*) magnified; *v* is the vasodentine, *d* is the hard dentine, and *c* is the cement; *p* is the apex of the wide persistent pulp-cavity. In the megatherium the hard dentine, which is the firmest tissue, forms the transverse ridge of the grinding surface (fig. 54, *d*), like the enamel-plates in the elephant's grinder: it has consequently been described to be enamel,[2] but its relation to that tissue is only one of analogy or function.

The human teeth, and those of the carnivorous mammals, appear at first sight to be composed of dentine and enamel only, as they were described to be by the Cuviers,[3] who called them therefore "simple teeth;" but their crowns are originally, and their fangs are always, covered by a thin coat of cement. There is also commonly a small central tract

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[1] *Odontography*, pp. 17, 37.

[2] Cuvier, *Ossemens Fossiles*, 4to, tom. v., p. 172.

[3] *Dents de Mammifères*, p. 1; *Leçons d'Anat. Comp.* iv. (1836), p. 199.

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of osteodentine in old teeth. In figs. 1 and 4, magnified

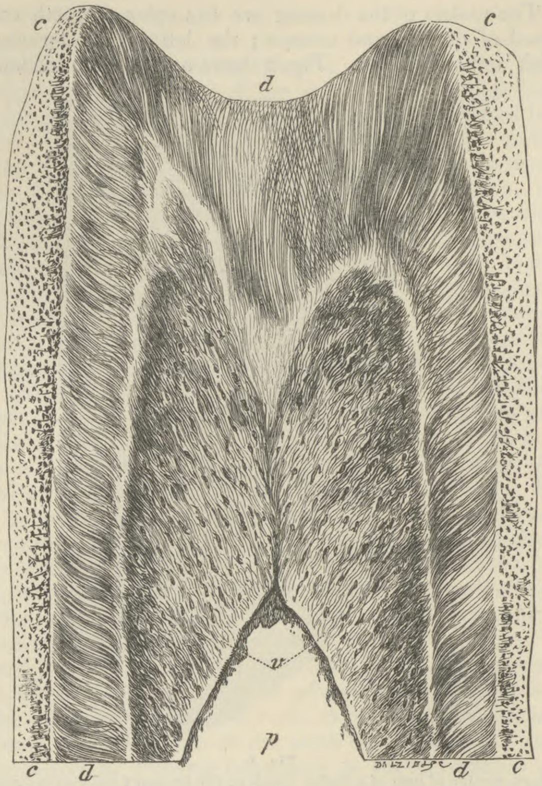

Fig. 9.
Magn. section of a Molar of the Sloth (*Bradypus tridactylus*).

views are given of longitudinal sections of a human incisor and molar tooth, in which *d* is the dentine, *e* the enamel, and *c* the cement.

The teeth called by Cuvier "compound" or "complex" in Mammalia, differ, as regards their composition, from the preceding only by the different proportion and disposition of the constituent tissues. Fig. 10 is a longitudinal section of the incisor of a horse; *d* is the dentine, *e* is the enamel, and *c* the cement; *c′* is the layer of cement reflected into the deep central depression of the crown, usually occupied by a coloured mass of tartar and particles of food, forming the "mark" of the horse-dealer. The characteristic structure of the three tissues—*d* dentine, *e* enamel, *c* cement—is shown in the magnified part of the section in fig. 5.

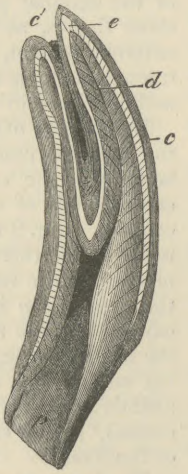

Fig. 10.
Magn. section of part of the Incisor of a Horse.

A very complex tooth may be formed out of two tissues by the way in which they are interblended as the result of an original complex disposition of the constituents of the dental matrix. The teeth of certain fishes, and of a singular extinct family of gigantic sauroid Batrachians, called "Labyrinthodonts,"[1] exhibit, as the name implies, a remarkable instance of this kind of complexity. Fig. 11 is a view of a canine tooth of the *Labyrinthodon salamandroïdes*, of the natural size; and fig. 12 is a slightly magnified view of a transverse section across the part of the crown marked *a*. At first view the tooth appears to be of the simple conical kind, with the exterior surface merely striated longitudinally, but every such streak

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is a fissure into which the very thin external layer of cement *c* is reflected into the body of the tooth, where it follows the sinous wavings of the lobes of dentine which diverge from the central pulp-cavity *pp*. The inflected fold of cement *c* runs straight for about half a line, and then becomes wavy, the waves rapidly increasing in breadth as they recede from the periphery of the tooth: the first two, three, or four undulations are simple; then their contour itself becomes broken by smaller or secondary waves; these become stronger as the fold approaches the centre of the tooth, when it increases in thickness, and finally terminates by a slight dilatation or loop close to the pulp-cavity, from which the free margin of the inflected fold of cement is separated by an extremely thin layer of dentine. The number of the inflected converging folds of dentine is about fifty at the middle of the crown of the tooth figured, but is greater at the base. All the inflected folds of cement at the base of the tooth have the same complicated disposition with increased extent; but as they approach their termination towards the upper part of the tooth, they gradually diminish in breadth, and consequently penetrate to a

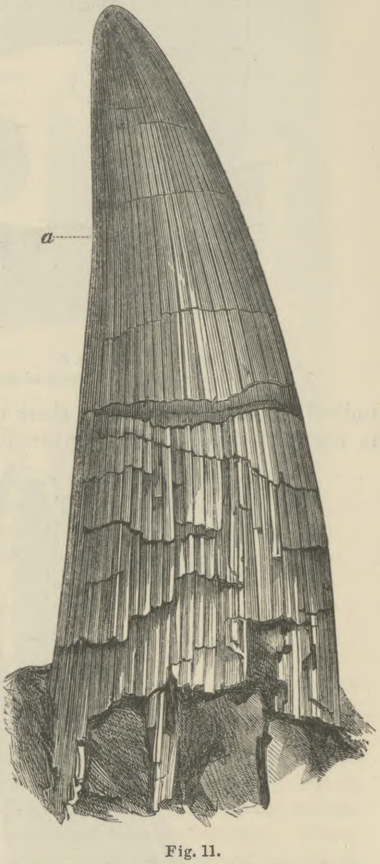

Fig. 11.
Canine Tooth of the *Labyrinthodon salamandroïdes* (nat. size).

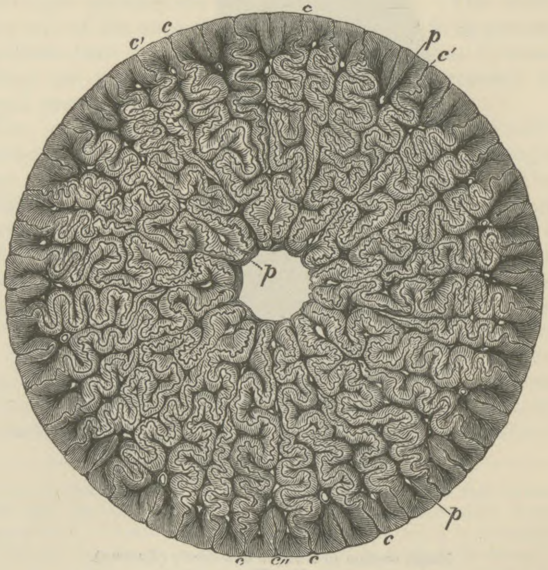

Fig. 12.
Transverse section of a Tooth of the *Labyrinthodon* (magn.)

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[1] *Proceedings of the Geological Society*, January 20, 1841, p. 257.

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less distance into the substance of the tooth. Hence, in such a section as is delineated, it will be observed that some of the convoluted folds, as those marked c, extend to near the centre of the tooth; others, as those marked c', reach only about half way to the centre; and those folds, c'', which, to use a geological expression, are "cropping out," penetrate to a very short distance into the dentine, and resemble in their extent and simplicity the converging folds of cement in the pulp of the tooth of the *Ichthyosaurus*. The disposition of the dentine is still more complicated than that of the cement. It consists of a slender central conical column, excavated by a conical pulp-cavity for a certain distance from the base of the tooth; and that column sends radiating outwards from the circumference a series of vertical plates, which divide into two once or twice before they terminate at the periphery of the tooth. Each of these diverging and dichotomizing plates gives off throughout its course smaller processes, which stand at right angles, or nearly so, to the main plate; they are generally opposite, but sometimes alternate; many of the secondary plates or processes which are given off near the centre of the tooth also divide into two before they terminate, and their contour is seen in the transverse section to partake of all the undulations of the folds of cement which invest and divide the dentinal plates and processes from each other. The dental pulp-cavity is reduced to a mere line about the upper third of the tooth, but throughout its whole extent fissures radiate from it corresponding in number with the radiating plates of dentine. Each fissure is continued along the middle of each bifurcation and process to within a short distance of the line of cement. The pulp-fissure commonly dilates into a canal at the origin of the lateral processes of the radiating plates, before it divides to accompany and penetrate those processes. The main fissures or radiations of the pulp-cavity extend to within a line or half a line of the periphery of the tooth, and suddenly dilate at their terminations into spaces, which in transverse section are subcircular, oval, or pyriform (p); the branches of the radiating lines, which are continued into the lateral secondary plates or processes of the dentinal lamellæ, likewise dilate into similar and generally smaller spaces. All these spaces or canals in the living tooth, must have been occupied by corresponding processes of the vascular pulp; they constitute so many centres of radiation of the fine calciferous tubes, which, with their uniting clear substance, constitute the dentine.[1]

An analogous complexity is produced by numerous fissures radiating from a central mass of vasodentine, which more or less fills up the pulp-cavity of the seemingly simple conical teeth of the extinct family of fishes called "Dendrodonts," characterizing the Old Red Sandstone, or Devonian system. Fig. 13 is one of these fossil teeth of the natural size—a, a transverse section; and fig. 14 a reduced view of a portion of the same section enlarged twenty diameters. Thus magnified, a central pulp-cavity of relatively small size, and of an irregular lobulated form, is discerned, a portion of which is shown at p; this is immediately surrounded by transverse sections of large cylindrical vascular or pulp canals of different sizes; and beyond these there are smaller and more numerous medullary canals, which are processes of the central pulp-cavity. In the transverse section these processes are seen to be connected together by a net-work of smaller vascular canals belonging to a coarse osseous texture, into which the pulp has been converted, and this structure occupies the middle half of the section. All the vascular canals were filled up by the opaque matrix. From the circumference of the central net-work straight pulp-fissures radiate at pretty regular intervals to the periphery of the tooth; most of these fissures divide once, rarely twice, in their course,—the division taking place sometimes at their origin, in others at different distances from their terminations,—and the branches diverge slightly as they proceed. Each of the above pulp-canals or fissures is continued from a short process of the central structure, which is connected by a concave line with the adjoining process, so that the whole periphery of the transverse section of the central coarse reticulo-vascular body of the tooth presents a crenate outline. From each ray and its primary dichotomous divisions short branches are sent off at brief intervals, generally at right angles with the trunk, or slightly inclined towards the periphery of the tooth. These subdivide into a few short ramifications like the branches of a shrub, and terminate in irregular and somewhat angular dilations simulating leaves, but which resolve themselves into radiating fasciculi of minute dentinal tubes. There are from fifteen to twenty-five or thirty-six of these short and small lateral branches on each side of the medullary rays.

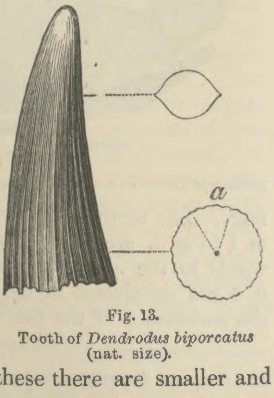

Fig. 13.
Tooth of *Dendrodus biporcatus* (nat. size).

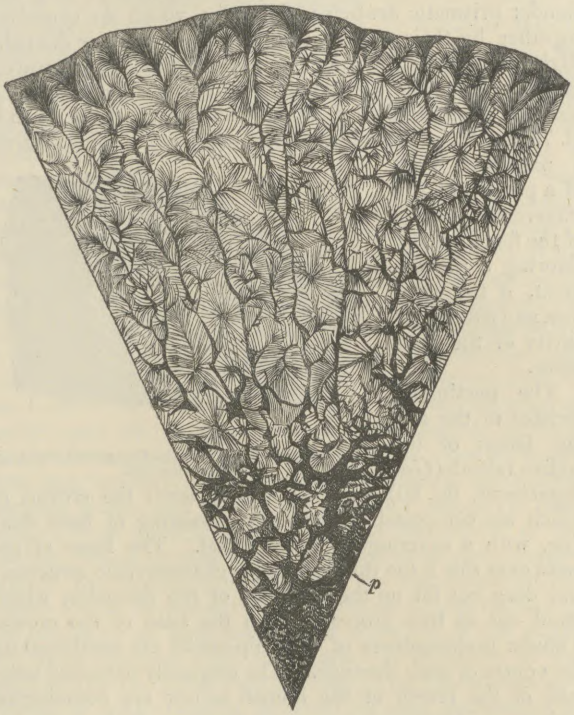

Fig. 14.
Magn. section of part of *Dendrodus biporcatus*.

A third kind of complication is produced by an aggregation of many simple teeth into a single mass.

The examples of these truly compound teeth[3] are most common in this class of fishes, but the illustration here selected is from the mammalian class. Each tooth of the Cape ant-eater (*Orycteropus*, fig. 15) presents a simple form; is deeply set in the jaws, but without dividing into

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[1] *Odontography*, pp. 195-217, pl. 64 A, 64 B.

[2] Ibid., p. 171.

[3] In the *Leçons d'Anatomie Comparée* of Cuvier, the teeth in which folds of enamel and cement penetrate the entire substance of the crown are called "compound." "Nous appellons dent composée celle dont les differentes substances forment des replis tellement pro-

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fangs; its broad and flat base is porous, like the section of a common cane. The canals to which these pores lead contain processes of a vascular pulp, and are the centres of radiation of as many independent series of dentinal tubules. Each tooth, in fact, consists of a congeries of long and slender prismatic denticles of dentine, which are cemented together by their ossified capsules, the columnar denticles slightly decreasing in diameter, and occasionally bifurcating as they approach the grinding surface of the tooth. A figure of a longitudinal section of the molar teeth is given in pl. 76, fig. 10, of the author's *Odontography*. Fig. 15 gives a magnified view of a portion of the transverse section of the fourth molar, showing *c* the cement, *d* the dentine, and *p* the pulp-cavity of the denticles.

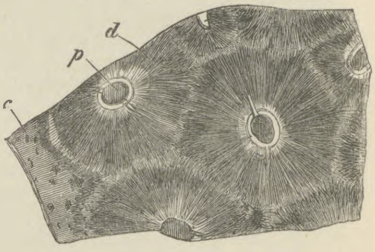

Fig. 15.
Magn. section of a part of the Compound Tooth of the *Orycteropus*.

The pectinated incisors of the flying lemur of the Indian Islands (*Galeopithecus*, fig. 86) are examples of teeth the crowns of which are composed of denticles consisting of hard dentine, with a covering of true enamel. The layer of cement over this is too thin to show its characteristic structure, and does not fill up the intervals of the denticles, which stand out as free processes from the base of the crown. Tubular prolongations of the pulp-cavity are continued up the centre of each denticle. The originally detached summits of the crown of the human incisor are homologous with these columnar processes or denticles of the incisor of the *Galeopithecus*. In the compound molars of the great African wart-hog (*Phacochœrus*), the columnar denticles are in three rows, and their interspaces are filled up by cement; each denticle consists of a slender column of hard dentine inclosed in a thick sheet of enamel, the whole being bound together by the cement; and the denticles, as in the *Galeopithecus*, blend together into a common base in the fully-developed tooth. A figure is given of the grinding surface of the third true molar of the *Phacochœrus Pallasii* in fig. 121.

In the elephant the denticles of the compound molars are in the form of plates, vertical to the grinding surface, and transverse to the long diameter of the tooth (figs. 140, 141). When the tooth is bisected vertically and lengthwise, the three substances—*d* dentine, *e* enamel, and *c* cement—are seen interblended.

A still more complex grinding apparatus is found in certain fishes. The lower pharyngeal bone of the parrot-fish (*Scarus*), for example, supports a dental plate with a triturating surface, like that of the compound molars of the *Phacochœrus;* the interlocked upper pharyngeals (fig. 35) support dental masses with a grinding surface, more like that of the compound molars of the elephant. When a vertical and longitudinal section is made of one of these upper pharyngeal compound teeth, each denticle is seen to be composed of a body of very hard and unvascular dentine, with a thick sheath of enamel, the denticles being united together by the cement, and supported and further united together, and to the pharyngeal bone, by a basal mass of vascular osteodentine. When worn down by the trituration of hard corals to this basis, four alternating kinds of dental tissue, of varying degrees of density, and of corresponding variations of level, are exposed in this fish.[1]

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Such are some of the prominent features of a field of observation which comparative anatomy opens to our view, —such the varied nature, and such the gradation of complexity of the dental tissues, which, up to December 1839, continued, notwithstanding successive approximations to the truth, to be described in systematic works as a "*Phaneros*, or a dead part or product exhaled from the surface of a formative bulb."[2]

Development.

In the development of a tooth, a matrix or formative organ, corresponding in complexity with the kind of tooth to be formed, is first developed. It consists either of a soft vascular papilla,—a free conical process,—as in certain fishes (fig. 24, *c*), which mold of the future simple tooth is called its "pulp," or the "dentinal pulp;" or it consists of the "pulp" inclosed in a "capsule;" or of a pulp with such a modification of a peripheral part, situated between the pulp proper and the capsule, as to merit a distinct definition as an "enamel organ." The first and most constant of these parts is termed the "dentinal pulp" (fig. 16, *p*); the second is the capsule, or "cemental pulp" (fig. 16, *c*); the third is the "enamel pulp" (fig. 16, *e*).

The linear cavity in the gums of the embryo, in which the pulps of the first series of teeth are formed, is termed the "primary dental groove:" where the first are succeeded by a second set of teeth, the pulps of these teeth are developed in a distinct recess, called the "secondary dental groove."

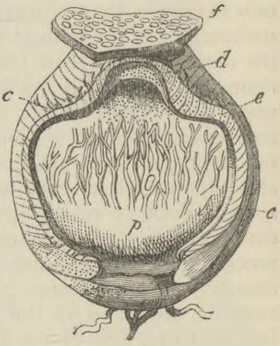

Fig. 16.
Matrix of a Human Tooth (magn.)

In man a certain proportion only of the teeth developed in the primary groove are displaced by teeth developed in a secondary groove; and the twenty teeth, so displaced, are called "milk-teeth," or deciduous teeth. The teeth of the molar series developed in the secondary groove are called "premolars," or bicuspids. The true molars are a continuation of the primary series, and are only "permanent," inasmuch as those of the secondary series are not co-extensive with them in number and position in the jaws. The differentiation of teeth, according to place and order of development, is illustrated (fig. 17) in the lower jaw of a young hog. The teeth of the grinding series marked *d* 1 to *d* 4, *m* 1 to *m* 3, are successively developed from before backwards in the primary groove; the teeth marked *p* 2 to *p* 4 are developed in the secondary groove, as are also the successors of the canines and incisors. Both grooves

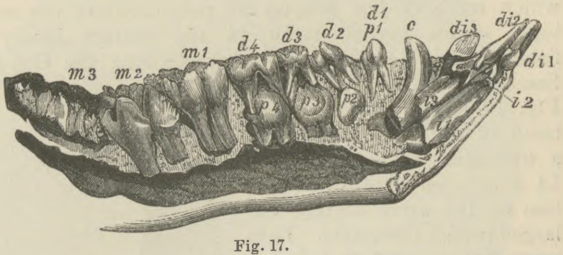

Fig. 17.
Section of Lower Jaw of a young Hog, showing the Teeth in course of formation.

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fonds, que dans quelque sens qu'on coupe la dent, on coupe plusieurs fois chacune des substances qui la composent; telles sont les dents molaires de *l'elephant*." The teeth ofthe 'Labyrinthodonts' would come under this definition more truly than those of the elephant, although they differ from them in having no enamel; for a molar of an elephant might be bisected vertically and transversely without cutting the tissues across more than once.

[1] Numerous other modifications of dental structure will be found described and figured in the author's *Odontography*, 4to, 1840–45.

[2] De Blainville, *Ostéographie*, passim.

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are converted into a closed chamber, and then subdivided into as many "formative cavities" as teeth, in the progress of dental development. The proper tissue of the dentinal pulp consists of nucleated cells (fig. 18, *p*), with capillary vessels and nerves invested by a structureless membrane, which disappears during the formation of the dentine. The superficial pulp-cells assume an elongated form as they approach the periphery; and after the formation of the tooth has commenced, their nuclei correspond in diameter and direction with the tubes of the contiguous cap of dentine. The cells are observed in a state of transition into dentine in the interspace between the pulp and the previously formed cap of dentine: they adhere to the latter when it is displaced from the pulp.

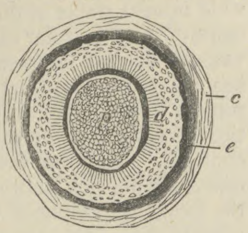

Fig. 18.
Section of the Matrix of the Pulp of a Human Tooth.

Observations on the pulp in its various stages of conversion into dentine, whilst in undisturbed connection with the calcified portion in the thin transparent lamelliform teeth of a fœtal shark (*Carcharias*), first yielded unequivocal demonstration of the organic continuity of the cap of dentine with the supporting vascular pulp; they also indicated some stages of the progress of the conversion of the pulp into dentine, and produced that clear idea of the nature and relations of dental development which is expressed (as previously quoted) in the *Theory of Dentification by Centripetal Calcification of the Pulp's Substance*, submitted to the French Academy in December 1839.[1] The following are the progressive steps of the calcifying processes, according to the writer's microscopic researches on the formation of the different substances which compose the more complex teeth of reptiles and mammals, as pursued in various species of both classes, but chiefly in the higher organized domestic animals :—

Three formative organs are developed, as already described, for the three principal or normal dental tissues. The dentinal pulp (figs. 16 and 18, *p* and *d*), or pulp proper, for the dentine; the "capsule" (figs. 16 and 18, *c*), for the cement; and the enamel-pulp (figs. 16 and 18, *e*), for the enamel. The essential fundamental structure of each formative organ is cellular; but the cells differ in each organ, and derive their specific character from the properties and metamorphoses of their nucleus, upon which the specific microscopical character of the resulting calcified substances depend. In the cells of the dentinal pulp the nucleus fills the parent cell with a progeny of nucleoli before the work of calcification begins; in the enamel-pulp the nucleus of the cell disappears, like the cytoblast of the embryo plant in the formation of most vegetable tissues; in the cells of the capsule the nucleus neither perishes nor propagates, but retains its individuality, and gives origin to the most characteristic feature of the cement,—viz., the radiated cell. The primordial material of each constituent of the tooth-matrix is derived from the blood, and special arrangements of the blood-vessels pre-exist to the development and growth of the constituent substances. A pencil of capillaries is directed to a particular spot in the primitive dentiparous groove, and terminates there by a looped net-work, from which spot a group of nucleated cells begin to arise in the form of a papilla. The cells of the papilla are, however, colourless, and the plexus of capillaries is confined to its base.

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In the Mammalia (embryo calf of 3 inches in length) membranous septa are formed, into which the vessels extend, which septa cross the groove and inclose the papilla in a follicle; the epithelial gum closing in the follicle is shown at *f*, fig. 16. From the free margin of this follicle the processes are developed which indicate the configuration of the future crown of the tooth, and in the molars of the calf subsequently develop the re-entering folds on which the complex structure of the crown of the molar tooth depends. The primary dentinal papilla and its capsule rapidly increase by successive additions of nucleated cells, apparently derived by material supplied by the capillary plexus at the base; the capillaries now begin to penetrate the substance of the pulp itself, where they present a sub-parallel or slightly diverging penicillate arrangment, but preserve their looped and reticulate termination near the apex of the pulp. Fine branches of nerves accompany the capillaries, and terminate also in loops. The primary cells and the capillary vessels and nerves are imbedded in, and supported by, a homogeneous, minutely sub-angular mucilaginous substance, the "blastema." The cells which are smallest at the base of the pulp, and have large, simple, sub-angular nuclei, soon fall into linear series directed towards the periphery of the pulp; where the cells are in close proximity with that periphery, they become more closely aggregated, increase in size, and present the following changes in their interior :—A pellucid point appears in the centre of the nucleus, which increases in size, and becomes more opaque around that central point, rendering the compressorium requisite for its demonstration. A division of the nucleus in the course of its long axis is next observed, in the larger and more elongated cells, still nearer the periphery of the pulp, and to the field of calcification. The sub-divided and elongated nuclei become attached by their extremities to the corresponding nuclei of the cells in advance, and the attached extremities become confluent. Whilst these changes are proceeding, the calcareous salts of the surrounding plasma begin to be accumulated in the interior of the cells, and to be aggregated in a semitransparent state around the central granular part of the elongated nuclei, which now present the character of secondary cells (fig. 19, *d*), and the salts occupy, in a still clearer and more compact state, the interspaces *c* of such cells; the elongated granular matter of the terminally confluent secondary cells establishes the area of the tubes *d*, by resisting, as it would seem, the encroachments of the calcareous salts, the nuclear tracts receiving a smaller proportion of the salts in the condition of minute disgregated particles, which are usually arranged in a linear series of nodules, and contribute to cause the white colour of the moniliform area of the tube when viewed by reflected light, and its opacity when viewed by transmitted light. Thus the primitive existence of the granular nuclei, their multiplication in the primary or parent cell, their elongated form, their serial arrangement end to end, and terminal confluence, are indicated in the calcified pulp by the areæ of the dentinal tubes (fig. 19, *d*); the interspaces of the metamorphosed nuclei being occupied by calcareous salts in a clearer and more compact state *c*, with evidence, however, of a distinctness of nucleolar membrane or secondary cell from the cavity of the common containing cell, which sustains the

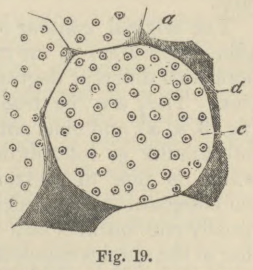

Fig. 19.
Highly-magnified portion of newly-calcified Dentinal Pulp (Calf).

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[1] The general results of this communication were given in the *Comptes Rendus*, 1839, p. 783. The commission appointed by the French Academy to report on a subsequent memoir on the same subject, advert to some of the phenomena previously communicated by the present writer. "Quant aux préparations qui montrent l'aréolite de la pulpe, non seulement nous les avons reproduites avec succes; mais de plus nous avons constaté, à l'état frais, la granulation des areoles signalée par M. Richard Owen," *loc. cit.* 1842, p. 1063.

interpretation of the "proper parietes" of the dentinal tube. The indications of the primitive boundary or proper parietes of the parent cell (fig. 19, *a*) are in like manner more or less distinctly retained, through a modification of the arrangement of the calcareous salts in the boundaries and in the interspaces of the cells. The salts are sometimes blended with the blastema in these interspaces in a disgregated condition, which renders them almost as opaque as the areæ of the tubes. When a layer of the calcified cells is carefully detached, the exposed uncalcified surface of the pulp presents the appearance of a net-work, the meshes being formed by the exposed cells and the intervening very thin layer of blastema. Each mesh, however, which gives a transparent or bright contour to the cell, when viewed by transmitted light, instead of presenting a single stellate nucleus, shows, by well-directed light under a higher power, several points, each of which have been torn from the cavities of the dentinal tubes in the displaced cap of dentine. A view of the thin transparent margin of the cap of a growing tooth, which may be cut off with a pair of fine scissors, easily affords the means of demonstrating the corresponding structure in that calcified part of the pulp. A slight change of focus is required to bring the ends of the tubuli in view, from that in which the clear outline of the dentinal cell is best seen. In proportion as the process of calcification approximates the cells, and as these have undergone the changes in their nucleolar contents preparatory to the proper arrangement of the hardening salts within, the proportion of the basal substance in the interspaces of the cells to the enlarged cells themselves decreases, and the cells become more readily detached, and seemingly independent, when torn out in the displacement of the cap of dentine. Although they are less adherent laterally to the basal substance of the pulp, they are more coherent with the cells of the same linear series, the tubes of the calcified cell accepting or effecting a union with the peripheral ends of the elongated granular nuclei, or nucleolar cavities of the contiguous cell in the next central layer. The angles at which the elongated nuclei, or successive portions of the dentinal tubuli, thus unite, constitute the secondary gyrations or curves of the cells. The primary curves depend upon the arrangement of the primary linear series of the parent cells or compartments of the pulp.

The original contour of these cells is most discernible after calcification of the teeth of the Mammalian class, and here with different degrees of distinctness in different species. They are the true dentinal cells or compartments (fig. 3, *a*, *a*), and must not be confounded with the so-called intertubular or interfibrous cells *f*, *g*, the first notice of which is due to Retzius. The diameter of the dentinal compartments or calcified primary cells of the pulp is usually one-fourth or one-half larger than that of the blood-disc of the species manifesting them. These cells are figured in the treatise on *Odontography* above referred to, in the *Mylodon* (pl. 79), in the incisive tusk of the *Dugong* (pl. 95), in the premolar (pl. 113), and in the canine (pl. 113, *a*) of the *Pteropus*, in the incisor of the chimpanzee (pl. 119, *a*), and of the human subject (pl. 123), and in the molar of a rhinoceros (pl. 139). They have been subsequently described and figured by Czermak.[1]

The altered mode of action, or change in the nuclei of the smaller central cells of the pulp, is the first and essential step in the modification of the dentinal tissue which produces the substances which are termed osteodentine and vasodentine. In the former, many of the cells retain their nucleus undivided, and the hardened salts are impacted around it in the interior of the cell, but enter only partially into the granular substance of the nucleus, in the minutely disgregated form, which produces the opacity and whiteness of the resulting corpuscle. In the formation of vasodentine many of the cells lose their nucleus, which seems to have become dissolved. In both the latter modifications of dental tissue the blood-vessels remain, and establish the wide tubular tracts in the calcified substance to which the name of the "vascular canals" is given. In true, hard, or unvascular dentine no trace of the blood-vessels remains; all has been converted into a much more minute calcified tubular tissue by the assimilative or intersusceptive properties of cells, and by the modification of their nucleolar contents. But the vascularity of the dentinal pulp, and especially the rich network of looped capillaries that adorns the formative peripheral layer at the period of its functional activity, have attracted general notice, and have been described by Hunter and subsequent authors on dental development. By most this phenomenon has been regarded as evidence of the secreting function of the surface of the pulp, and the dentine as an out-pouring from that vascular surface which was supposed to shrink or withdraw from the matter excreted. For it has been asked, "If the unvascular dentine be the effect of the conversion of the vascular pulp, by what process is all trace of the vascular ramifications obliterated, since none can be detected in such dentine?" The same question is equally applicable to the nerves of the pulp. In the explanation of this process attention must first be paid to the almost straight and sub-parallel course of the vessel in the pulp's substance, and to the remarkable regularity of form and size of the meshes of the terminal reticulation on the surface of the pulp.

At the part where calcification has commenced the extremities of the capillaries are commonly found in a state of congestion, and crowded with blood-discs, which are pressed together into polyhedrons, and apparently stagnated and left out of the current of circulation. These aggregated blood-discs exhibited, in various and often in striking degrees, those changes of the contained matter to which their own multiplication may be due. In this present situation and condition it is obvious that such changes must be preparatory either to their disappearance and removal, or to some important share which they are destined to take in the development of the dental tissue. The stagnant corpuscles nearest the vascular and unchanged pulp exhibit the irregularity of contour which has given rise to the terms "mulberry" or "granulated," applied to such altered blood-discs when seen in other circumstances. These corpuscles in other respects, as colour, size, and general form, retained their usual character. The blood-discs nearer the cap of dentine exhibited more plainly the contained granules, to the commencing development of which the irregular contour above mentioned is due; this appearance was associated with an increase of size, a change from the circular to the elliptical form, and a gradual loss of the characteristic colour, which was longest retained by the central granular matter.

The enamel-pulp differs from the dentinal pulp at its first formation by the more fluid state of its blastema, and by the fewer and more minute cells which it contains. The part of the blastema next the dental pulp acquires more consistence by an increased number of its granules, and it contains more numerous and larger cells. Many of these show a nuclear spot, others a nucleus and nucleolus; the spherical nucleolar cells in the part of the blastema farther from the capsule are so numerous as to form an aggregate mass, with a small quantity of the condensed blastema in the minute interspaces left between the cells, which are pressed together into hexagonal or polygonal forms. In this state they constitute a great part of the enamel-pulp, which is of considerable extent in the complex molar teeth of the ruminants. The appearance produced by these

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[1] *Beiträge zur Mikroskopischen Anatomie der Menschlichen Zähne*, 8vo, 1850, taf. i. und ii.

Introduction.

aggregate cells, in a section of the tooth-matrix of a calf's molar, is compared by Raschkow[1] and Purkinjé to the actinenchyma of certain vegetable tissues, and the connecting condensed blastema to threads of cellular tissue. The field of the final metamorphosis of the cells into the moulds for the reception of the solidifying salts is confined to close contiguity with the surface of the dentinal pulp. Here the cells increase in length, lose all trace of their nucleus, and become converted into long and slender cylinders, usually pointed at both ends, and pressed by mutual contact into a prismatic form. These cylinders have the property of imbibing the calcareous salts of the enamel from the plasmatic fluid, and of compacting them in a clear and almost crystalline state in their interior—the disappearance of the nucleus being evidently the condition of the absence of any permanent cavity, cell, canal, or other modification of the mineral matter, at least in the enamel-fibres of the calf. In the human subject it is probable that the cavity of the cylinder may be subdivided, by a multiplication of delicate nucleoli, into compartments; or that the remains of such multiplied nucleoli may cause a modification of the walls of the cylinder, and so produce the characteristic transverse striæ of the enamel-fibre. This appearance is not presented in the enamel of the frog's tooth, nor in that of the teeth of the hog or calf, in which animals the writer's observations of the development of this tissue have been chiefly made. As the development proceeds, the cells in immediate contiguity with the calcified prisms undergo the same changes as their predecessors, and become united to them by their peripheral pointed extremities; whilst the fluid plasmatic contents of the cells are exchanged for the dense salts of which the enamel is chiefly composed. The selective surface formed by the organic membrane of the cell would seem to be destroyed by the very pressure resulting from its own action, and exerted by the contents of the closely-packed contiguous prisms when the cavities of the cells are completely filled. The membrane ceases, at least, to be distinguishable under the microscope from the solid contents of the cell, except at that surface of the enamel next the capsule, and which is still in progress of growth. What is remarkable here is, that not the whole of the actinenchymatous part of the enamel-pulp is converted into the long and slender prismatic cellular basis of the enamel; at least in the valleys of the complex crown of the molars of the ruminant and pachyderm (calf and colt). This part of the enamel-pulp originally occupies more space than the subsequent layer of enamel does; and this superfluous peripheral part seems to be absorbed, and its place to be occupied by a growth or thickening of the vascular capsule. No capillaries pass from the capsule into the actinenchymatous pulp of the enamel; nor has the writer been able to trace a blood-vessel into that part of the capsule which was actually the seat of the calcifying processes. Here, as in the dentinal and enamel pulps, the calcareous salts are selected and arranged by the assimilative, selective, and intus-susceptive properties of the cell walls, and by the repellent power of their nuclei. The enamel pulp bears a relation to the dentinal pulp analogous to that which the peripheral part of the matrix producing the vitrodentine of the shark's tooth bears to the body of the matrix forming the osteodentine. Evidence of the close connection between the enamel and dentine in the marsupial Mammals is given in plate 102 of the author's *Odontography.* The differentiation of the two tissues, and the distinction of their formative pulps, become greater in the higher Mammalia.

The blastema or fundamental tissue of the capsule is at first semitransparent, and of a pearly or opaline colour, but richly ornamented with blood-vessels. As the period of its calcification approaches, which is later than that of the dentinal pulp, it becomes denser, and exhibits numerous nucleated cells. The blastema itself presents more evidently a fine cellular or granular structure, in which the calcareous salts are impacted in a comparatively clear state, constituting the framework of the cemental tissue. The characteristic features of this tissue are due to the action of the proper nucleated cells upon the salts of the plasma diffused through the blastema, in which those cells are imbedded—the cells being characterized by a single large granular nucleus, which almost fills the clear area of the cell itself. If, when the formation of the cement has begun in the incisor or molar of a colt, one of the detached specks of that substance, with the surrounding and adhering part of the inner surface of the capsule in which it is imbedded, be examined, these nucleated cells are seen closely aggregated around the calcified part in concentric rows, the cells of which are farther apart as the rows recede from the field of calcification. Those next the cement rest in cup-shaped cavities in the periphery of the calcified part; just as the first calcified cells of the thick cement which covers the crown of a complex molar are lodged in the exterior of the enamel. These exterior cavities of the cement are formed by centrifugal extension of the calcifying process in the blastema in which the cells are imbedded. The calcareous salts penetrate, in a clearer and more compact state, the cavity of the cell; but their progress is arrested apparently by the nucleus, which maintains an irregular area, partly occupied by the salts in a subgranular, opaque condition, but chiefly concerned in the reception and transit of the plasmatic fluid, which enters and escapes by the minute tubes which are subsequently developed from the nucleolar cavity as calcification proceeds. The radiated cells or cavities thus formed are the most common characteristic of the cement, but not the constant one. The layer of the capsule which surrounds the crown of the human teeth, and of the simple teeth of *Quadrumana* and *Carnivora*, consists of the granular blastema, without or with very few nucleated cells; and the radiated corpuscles are consequently not developed, or are sparingly developed, in the cement which results from its calcification. In the thicker parts of the inflected folds of the capsule of the complex teeth of the *Herbivora*, traces of the vascularity of that part of the matrix are persistent, the blastema calcifying around certain of the capillaries, and forming the medullary canals. The parietes of these canals are traversed by minute tubes, continued from, or communicating with, the radiated cells.

In the deep sockets of the teeth of persistent growth the matrix is maintained by the constant additions of new blastema and cell material to the bases of the dentinal, enamel, and cemental pulps. The author has demonstrated the partial growth of the enamel-pulp along the side of the capsule corresponding to the convexity of the long incisor of the under-jaw of the porcupine, in the preparation now in the physiological series of the Hunterian collection (No. 375 A.)

Composition of teeth.

Chemical analyses[2] of the composite substances, as built up by the organizing processes in the fundamental tissues of the matrix above described, have yielded the following results:—

Incisors of Adult Man.

	Dentine.	Enamel.	Cement.	
			I.	II.
Organic substance...	28·70	3·59	29·42	29 12
Inorganic substance.	71·30	96·41	70·58	70·88
	100·00	100·00	100·00	100·00

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[1] *Meletemata circa dentium evolutionem*, 4to, 1835.

[2] These results are cited chiefly from Bibra's *Chemische Untersuchungen über die Knochen und Zähne*, 8vo, 1844.

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Molars of Adult Man.

	Dentine.	Enamel.
Phosphate of lime, with a trace of fluate of lime	66·72	89·82
Carbonate of lime	3·36	4·37
Phosphate of magnesia	1·08	1·34
Salts	0·83	0·88
Chondrine	27·61	3·39
Fat	0·40	0·20
	100·00	100·00

Berzelius' analysis gives—

	Dentine.	Enamel.
Phosphate of lime, with a trace of fluate of lime	64·3	88·5
Carbonate of lime	5·3	8·0
Phosphate of magnesia	1·0	1·5
Soda and muriate of soda	1·4	...
Cartilage and other animal matter	28·0	2·0
	100·0	100·0

Canine of a Lion.

	Dentine.	Enamel.
Phosphate of lime, with a trace of fluate of lime	60·03	83·33
Carbonate of lime	3·00	2·94
Phosphate of magnesia	4·21	3·70
Salts	0·77	0·64
Chondrine	31·57	9·39
Fat	0·42	a trace.
	100·00	100·00

Teeth of a Dolphin (Delphinus delphis).

	Dentine.	Cement.
Phosphate of lime, with a trace of fluate of lime	66·37	69·42
Carbonate of lime	1·84	1·79
Phosphate of magnesia	1·36	1·47
Salts	0·99	0·93
Chondrine	28·62	25·73
Fat	0·82	0·66
	100·00	100·00

Tusk of Elephant.

	Ivory.
Phosphate of lime, with a trace of fluate of lime	38·48
Carbonate of lime	5·63
Phosphate of magnesia	12·01
Salts	0·70
Chondrine	42·94
Fat	0·24
	100·00

Tusk of Wild Boar.

	Dentine.
Phosphate of lime, with a trace of fluate of lime	60·00
Carbonate of lime	2·51
Phosphate of magnesia	6·43
Salts	0·43
Chondrine	30·50
Fat	0·13
	100·00

Incisors of Ox.

	Dentine.	Enamel.	Cement.
Phosphate of lime, with a trace of fluate of lime	59·57	81·86	58·73
Carbonate of lime	7·00	9·33	7·22
Phosphate of magnesia	0·99	1·20	0·99
Salts	0·91	0·93	0·82
Chondrine	30·71	6·66	31·31
Fat	0·82	0·02	0·93
	100·00	100·00	100·00

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Crocodile.

	Dentine.	Cement.
Phosphate of lime, with a trace of fluate of lime	53·69	53·39
Carbonate of lime	6·30	6·29
Phosphate of magnesia	10·22	9·99
Salts	1·34	1·42
Chondrine	27·66	28·15
Fat	0·79	0·76
	100·00	100·00

Pike (Esox lucius), *Large Teeth of Lower Jaw.*

	Dentine.
Phosphate of lime, with a trace of fluate of lime	63·98
Carbonate of lime	2·54
Phosphate of magnesia	0·73
Salts	0·97
Chondrine	30·60
Fat	1·18
	100·00

The proportion of mineral or inorganic substance would seem to vary, within certain limits, in different individuals of the same species. Thus, in the molar teeth of one man Bibra found 79·00 of inorganic matter, and in another, 71·99; whilst Berzelius found 72·0. The proportion of inorganic matter in hard dentine will depend in some degree upon the number of dentinal tubes, from the area of which the salts are in part excluded: thus, in the modified dentine (ivory) of the elephant's tusk, in which the tubuli are more numerous, close-set, and extensively undulated in a given space than in ordinary dentine, the organic bears a greater proportion to the inorganic matter than in the dentine of the teeth of most other Mammals. The cement of the composite molar teeth of the ruminants and of the elephant contains a little more organic matter than the dentine does; but in the cetaceous dolphin it contains a rather less proportion, and is consequently harder.

Nerves of the teeth.

The nerves of the teeth are derived from the trigeminal or fifth pair, of which the second division supplies those of the upper jaw, the third division those of the lower jaw (fig. 20). In the human subject, the three dental branches of the infra-orbital nerve intercommunicate by their primary branches, from which, and from a rich plexus formed by secondary branches upon the membrane lining the antrum, two sets of nerves are sent off to the alveolar processes of the upper jaw: one set (*rami dentales)* supplies the teeth, the other (*rami gingivales*) the osseous tissue of the jaw and the gums. The latter agree in number with the intervals of the teeth, as the proper dental nerves do with the teeth themselves. These two sets are not, however, so distinct but that some intercommunications are established between the fine branches sent off in their progress to the parts they are specially destined to supply. The *rami dentales* take the more direct course through the middle part of the osseous tissue to the teeth, penetrate the orifices of the fangs, and form a rich plexus with rhomboidal meshes

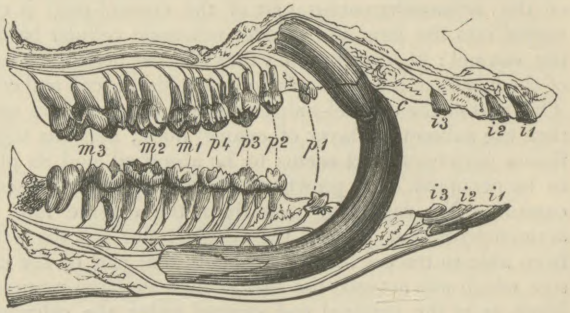

Fig. 20.
Upper and Lower Jaws of a Hog, dissected to show the Nerves of the Teeth.

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upon the coronal surface of the pulp, the peripheral elementary filaments returning into the plexus by loops.

In the lower jaw, the dental nerve, besides supplying the proper nerves to the teeth, also forms a rich plexus, in which it is joined by some branches from the division of the nerve that afterwards escapes by the *foramen mentale*, and from this plexus the cancellous tissue of the bone, as well as the gums, are supplied.

In the dog and other Carnivora the nerve of the laniary tooth is conspicuous from its size: that which supplies the still more developed analogous tooth or tusk of the boar (fig. 20, *c*) is still more developed, having relation also to the continual reproduction of the matrix at the base of the tusk. In the lower jaw of the porcupine (fig. 21) the nerve of the great incisor is given off from the dental nerve (*n*), near the middle of its course through the osseous canal, and returns at an acute angle to penetrate the cavity at the base of the scalpriform tooth, and supply its persistent pulp *i*. This recurrent course indicates the progressive change in the relative position of the pulp to the origin of its nerve.

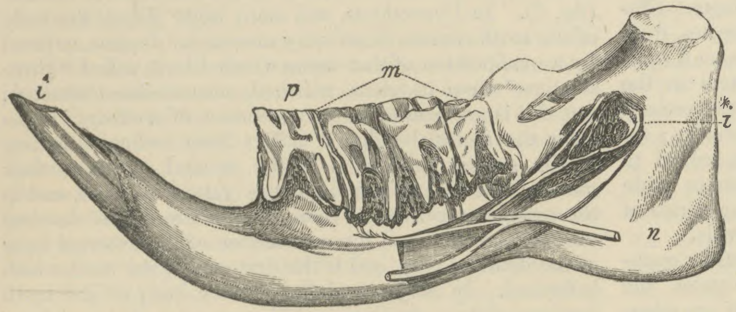

Fig. 21.

Lower Jaw of a Porcupine, dissected to show the Nerves of the Great Incisor, natural size.

Besides the branches for the molar teeth, many smaller filaments penetrate the spongy texture of the bone, and form a rich plexus, from which the gum derives its filaments. The maxillary plexus is most richly developed, in the horse, above and between the alveoli of the three premolar teeth; it is less complex where it supplies the molar teeth, their alveoli, and the gums. In the lower jaw of the horse a very rich plexus begins to be formed in the cancellous substance of the bone by branches of the dental nerve soon after its entry into the canal. The intercommunications between the dental and gingival nerves, and those supplied to the osseous tissue from the supra-maxillary and infra-maxillary plexuses, explain the sympathies manifested in neuralgy and rheumatic pains between the teeth and the osseous cavities in which they are implanted.

Histology of teeth.

The class of tissues in which teeth should rank has frequently been a subject of controversy in systems of histology; the fact being overlooked, that they have not the same unity of composition as bones or epidermal appendages. One constituent of teeth, viz., the cement, ought clearly to rank with the osseous tissue; and the dentine or ivory, which was described for the last time, probably, in July 1838, as being, "like the hair, arranged in concentric layers,"[1] bears, on the contrary, a close analogy to bone in structure, and is almost identical with it in chemical composition. Its modifications, called "vasodentine" and "osteodentine," form intermediate gradations between the hard dentine and true bone. True enamel is a tissue *per se;* but in the teeth of fishes there are several intermediate stages of gradation, which link enamel to dentine, as the dentine itself in most fishes passes gradually into bone. Heusinger[2] admits that the relation of the teeth to the corneous tissue (*horngewebes*) is not clearly elucidated in human anatomy, but he affirms that it is most conclusively established in that of the lower classes of animals.

No doubt, in tracing the modifications of the dental system through the animal kingdom, we find true horny productions substituted for teeth in certain vertebrate species, as the Ornithorhynchus, whale, tortoise, &c. So likewise the office of teeth is performed by parts (modified as to form) of the crustaceous and chitinous integuments of the articulate classes; but there are no transitional or intermediate structures, such as Heusinger alludes to, between teeth and nails, horns or hair. The lamellar disposition traceable in the texture of the hardest dentine is much more closely similar to that of bone, especially the concentric plates surrounding the Haversian canals, than to the texture of nails. The structure of the tooth of Orycteropus is essentially like that of all true teeth: the apparent resemblance which it presents to the horn of the rhinoceros, or to baleen, arises from its being compounded of many minute parallel and elongated denticles. And the close resemblance in intimate structure and chemical composition between true teeth and bones being established, it may be observed that the osseous tissue is not confined to the endo-skeleton: it is developed largely to form the exo-skeleton in fishes, in the loricate reptiles, and even in the Mammalian class,—as, for example, in the armadillos, where bone is substituted, to strengthen the integument, for horn, which forms the scaled armour of the allied pangolins. Now, the relation of the tooth of the armadillo to that of the Ornithorhynchus is precisely analogous to that which subsists between the osseous plates of the armadillo, and the corneous scales of the Manis; but this relation no more establishes identity of tissue or system of tissues in the one case than in the other.

The general form of the matrix or formative organ of teeth, and the relative position of the dentinal pulp to its product, bear a close analogy with those of the formative organ of hairs, bristles, shells, and other productions of the epidermal system. In these, however, the papilla or pulp is developed from the external skin; in the teeth from the mucous membrane or internal skin. Teeth further agree with the extra-vascular appendages of the skin in being shed and reproduced,—sometimes once,—sometimes frequently during the lifetime of the individual; the latter condition may be termed "interrupted reproduction." In some cases, again, as with certain epidermal productions, the reproduction of the tooth is "uninterrupted," and goes on continuously during the lifetime of the individuals, new matter being added to the base as the old is worn away from the apex or working surface of the tooth.

A tooth, when fully formed, is subject to decay, but has no inherent power of reparation. A tooth of limited growth can only increase in size after its formation is completed by abnormal growth of its most highly organized constituent, the cement. Thus the analogy of the dental organs to those of the corneous system holds only in their mode of development,[3] in their shedding and reproduction, and in their exposure to external influences, and to the contact of extraneous bodies: but the antlers of deer are similarly exposed, and are likewise shed and reproduced annually, and also contemporaneously with the fall and reproduction of the hair; yet antlers are not therefore classed with the horny tissues, any more than the bony cone of the horns of the cavicorn ruminants.

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[1] *Medico-Chirurgical Review*, p. 43.

[2] *System der Histologie*, 4to, 1823, p. 160.

[3] The cells and fibres of the horny tissues are formed in, and not excreted from, the surface of their formative pulps.

SECT. I.—TEETH OF FISHES.

The fishes of Great Britain, and those which are known to us by vernacular names, form a comparatively small part of the class; but wherever the dentition of such is described, the species will be indicated in the present article by their common names. As, however, many interesting modifications of the dental organs occur in exotic fishes, known by no other names than those by which they are recorded in the systems and catalogues of naturalists, the information respecting their dentition which is here endeavoured to be given must be unavoidably confined to those who combine some knowledge of Zoology with that of Comparative Anatomy.

Excellent illustrations of the dental system in fishes are given in the article ICHTHYOLOGY, as, *e.g.*, from the predaceous *Alepisaurus* (p. 213, fig. 19), the phytiphagous *Plotosus* (p. 220, fig. 50), and in various other species, from figs. 52 to 62 inclusive, accompanied with so exact a summary of the general modifications of the system in the piscine class, as leaves little to be added in the present article on that head. Yet this little appears necessary; for the teeth of fishes, whether we study them in regard to their number, form, substance, structure, situation, or mode of attachment, offer a greater and more striking series of varieties than do those of any other class of animals.

Number. As to *number*, they range from zero to countless quantities. The lancelet, the ammocete, the sturgeon, the paddle-fish, and the whole order of *Lophobranchii*, are edentulous. The Myxinoids have a single pointed tooth on the roof of the mouth, and two serrated dental plates on the tongue. The tench has a single grinding tooth on the occiput, opposed to two dentiferous pharyngeal jaws below. In the lepidosiren (fig. 36), a single maxillary dental plate is opposed to a single mandibular one, and there are two small denticles on the nasal bone. In the extinct sharks with crushing teeth, called *Ceratodus* and *Ctenodus*, the jaws were armed with four teeth, two above and two below. In the *Chimeræ* two mandibular teeth are opposed to four maxillary teeth. From this low point the number in different fishes is progressively multiplied, until in the pike and many other fishes the mouth becomes crowded with countless teeth.

Substance. With reference to the main and fundamental tissue of tooth, we find not fewer than six leading modifications in fishes:—Hard or true dentine,—*Sparoids, Labroids* (fig. 6), *Lophius, Balistes, Pycnodonts, Prionodon, Sphyræna, Megalichthys, Rhizodus, Diodon, Scarus:* Osteo-dentine,—*Cestracion, Acrodus, Lepidosiren, Ctenodus, Hybodus, Percoids, Sciænoids, Cottoids, Gobioids*, and many others: Vaso-dentine,—*Lamna* (fig. 7), *Psammodus, Chimæroids, Pristis, Myliobates:* Plici-dentine,—*Lophius, Holoptychius, Lepidosteus oxyurus*, at the base of the teeth: Labyrinthodentine,—*Lepidosteus platyrhinus, Bothriolepis:* and Dendro-dentine,—*Dendrodus* (fig. 14); besides the compound teeth of the *Scarus* and *Diodon*.

Structure. One structural modification may prevail in some teeth, another in other teeth of the same fish; and two or more modifications may be present in the same tooth, arising from changes in the process of calcification and a persistency of portions or processes of the primitive vascular pulp or matrix of the dentine. The modifications of dentine, called vasodentine and osteodentine,[1] predominate much more than in the higher Vertebrata; and they thus more closely resemble the bones which support them. There is, however, great diversity in respect of substance. The teeth of most of the Chætodonts are flexible, elastic, and composed of a yellowish subtransparent albuminous tissue; such, likewise, are the labial teeth of the Helostome, the premaxillary and mandibular teeth of the Goniodonts, and of that percoid genus thence called *Trichodon*. In the Cyclostomes (lampreys) the teeth consist of a denser albuminous substance. The upper pharyngeal molar of the carp consists of a peculiar brown and semitransparent tissue, hardened by salts of lime and magnesia. The teeth of the flying-fish (*Exocœtus*) and sucking-fish (*Remora*) consist of osteodentine. In many fishes, *e.g.*, the *Acanthurus, Sphyræna*, and certain sharks (*Lamna*, fig. 7), a base, or body of vasodentine, is coated by a layer of true dentine, but of unusual hardness, like enamel; in *Prionodon* this hard tissue predominates. In the *Labrus* the pharyngeal crushing teeth consist wholly of hard or unvascular dentine (fig. 6). In Pycnodonts, and many other fishes, the body of the tooth consists of ordinary unvascular dentine, covered by a modification of that tissue which I have called "vitrodentine," from its clear, polished, enamel-like character; but this is not enamel, nor the product of a distinct organ from the dentinal pulp: it differs from ordinary dentine in the greater proportion of the mineral particles, their more minute diffusion through the gelatinous basis, and in the straighter course and more minute size of the dentinal tubes; it results from the calcification of the external layer of the dentinal pulp, and is the first part of the tooth which is formed. In *Sargus* and *Balistes* the body of the tooth consists of true dentine, and the crown is covered by a thick layer of a denser tissue, developed by a distinct organ, and differing from the "enamel" of higher animals only in the more complicated and organized mode of deposition of the earthy salts. The ossification of the capsule of the complex matrix of these teeth covers the enamel with a thin coating of "cement." In the pharyngeal teeth of the *Scarus* a fourth substance is added by the ossification of the base of the pulp after its summit and periphery have been converted into hard dentine; and the teeth thus composed of cement, enamel, dentine, and osteodentine, are the most complex, in regard to their substance, that have yet been discovered in the animal kingdom.

The tubes which convey the capillary vessels through the substance of the osteodentine and vasodentine of the teeth of fishes[2] were early recognised on account of their comparatively large size,—as by André, *e.g.*, in the teeth of *Acanthurus*, and by Cuvier and Von Born in the teeth of the wolf-fish and other species. Leeuwenhoek had also detected the much finer tubes of the peripheral dentine of the teeth of the haddock. These dentinal tubuli are given off from the parietes of the vascular canals, and bend, divide, and subdivide rapidly in the hard basis-tissue of the interspaces of those canals in osteodentine; the dentinal tubuli alone are found in true dentine, and they have a straighter and more parallel course, usually at right angles to the outer surface of the dentine. Those conical teeth of fishes which, when fully-formed, consist wholly or in great part of osteodentine or vasodentine, always first appear with an apex of hard or true dentine. In some fishes the simple central basal pulp-cavity of such teeth, instead of breaking up into irregular or parallel canals, sends out a series of vertical plates from its periphery, which, when calcified, give a fluted character to the base of the tooth, *e.g.*, in *Lepidosteus oxyurus*. Sometimes such radiating vertical basal plates of dentine are wavy in their course, and send off narrow processes from their sides; and as a thin layer of the outer capsule inter-

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[1] *Odontography*, Introduction, p. lxxii.

[2] The vasodentine of *Pristis* and *Myliobates* is like that of the teeth of the Cape ant-eater (*Orycteropus*); the vasodentine of the Psammodonts resembles that which forms the base of the tooth of the sloth and megatherium; the vasodentine of Mammals differs from the osteodentine, in the absence of the radiated "Purkingian" cells.

digitates with the outstanding plates of the dentinal pulp, and becomes co-calcified with them, a transverse section of such a tooth presents a series of interblended wavy or labyrinthic tracts of thick dentine radiating from the centre, and of thin cement converging towards the centre of the tooth.

An analogous but more complicated structure obtains, when the radiating wavy vertical plates of dentine dichotomize, and give off from their sides, throughout their course, numerous branch plates and processes, which are traversed by medullary sinuses and canals, with their peripheral terminations dilated, and becoming the centres of lobes or columns of hard dentine. The transverse section of such teeth gives the appearance of branches of a tree, with leaf-stalks and leaves radiating from the central pulp-cavity to the circumference of the tooth; whence the fossil fish in which this structure was first detected has been called *Dendrodus* (fig. 14).

Situation.

With respect to *situation* the teeth in sharks and rays are limited to the bones (maxillary and mandibular) which form the anterior aperture of the mouth. In the carp and other Cyprinoids the teeth are confined to the bones (pharyngeal and basi-occipital) which circumscribe the posterior aperture of the mouth. The wrasses (*Labrus*) and the parrot-fishes (*Scarus*) have teeth on the premaxillary and premandibular bones, as well as on the upper and lower pharyngeals; both the anterior and posterior apertures of the mouth being thus provided with instruments for seizing, dividing, or comminuting the food, the grinders being situated at the pharynx. In most fishes teeth are developed also in the intermediate parts of the oral cavity; as on the palatines, the vomer, the hyoid bones, the branchial arches; and, though less commonly, on the pterygoids, entopterygoids, the sphenoids, and even on the nasal bone (fig. 36, *c*). It is very rare to find teeth developed on the true superior maxillary bones; but the herring and salmon tribes, some of the ganoid fishes, and the great *Sudis*, are examples of this approach to the higher Vertebrates. Among the anomalous positions of teeth may be cited, besides the occipital alveolus of the carp,[1] the marginal alveoli of the prolonged, depressed, well-ossified rostrum of the saw-fish (*Pristis*). In the lampreys, and in *Helostomus* (an osseous fish), most of the teeth are attached to the lips. Lastly, it is peculiar to the class *Pisces*, amongst Vertebrata, to offer examples of teeth developed in the median line of the mouth, as in the palate of the Myxines; or crossing the symphysis of the jaw, as in *Notidanus*, *Scymnus*, and *Myliobates*.

Attachment.

Nor is the mode less varied than the place of *attachment.* The teeth of *Lophius*, *Pœcilia*, and *Anableps* are always moveable; in most fishes they are anchylosed to the jaw by continuous ossification from the base of the dental pulp, the histological transition being more or less gradual from the structure of the tooth to that of the bone. Sometimes we find, not the base, but one side of the tooth anchylosed to the alveolar border of the jaw, and the teeth oppose each other by their sides instead of their summits (*Scarus*); in *Pimelodus*, however, where the teeth are thus attached, the crown is bent down in the upper teeth, and is bent up in the lower ones, at right angles to the fang, so that they oppose each other in the normal way. Certain teeth of recent or fossil cartilaginous fishes have their base divided into processes like fangs; but these serve for the attachment of ligaments, and are not set in bony sockets like the true fangs or roots of the teeth of Mammals. Some sharks have two divaricating fangs. Some fossil teeth, referred to the genus *Petalodus* by Agassiz, with the specific name "radicans," have the base divided into several fangs or processes, indicating a generic distinction. The base of anchylosed teeth is at first attached to the jaw-bone by ligament; and in the cod-fish, wolf-fish, and some other species, as calcification of the tooth progresses towards its base, the subjacent portion of the jaw-bone receives a stimulus, and develops a process corresponding in size and form with the base of the tooth. For some time a thin layer of ligamentous substance intervenes, but anchylosis usually takes place to a greater or less extent before the tooth is shed. Most of the teeth of the Lophius retain the primitive ligamentous connection. The ligaments of the large internal or posterior teeth of the upper and lower jaws radiate on the corresponding sides of the bones, the base of the tooth resting on a conformable alveolar process.

Some implanted teeth in the present class have their hollow base further supported, like the claws of the feline tribe, upon a bony process arising from the base of the socket; the incisors of the file-fish (*Balistes*, fig. 22), *e.g.*, afford an example of this double or reciprocal gomphosis. In fig. 22 the teeth in place, and the outer wall of the premaxillary, have been removed to show, as at *a*, the socket and the basal peg of the fully developed incisor; at *b* the apex of a successional incisor, which has worn away the peg, and caused the fall of the incisor it was about to succeed; and at *c* the less advanced germ of the tooth destined to succeed that which was supported by the peg *a*.

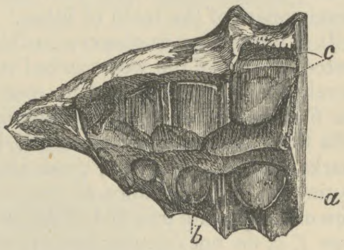

Fig. 22.
File-Fish (*Balistes forcipatus*).

The vertical section of a pharyngeal jaw and teeth of the wrasse (*Labrus*, figs. 23 and 6), would afford the architect a model of a dome of unusual strength, and so supported as to relieve from pressure the floor of a vaulted chamber (fig. 23, *c*, *c*) beneath. The base of the dome-shaped tooth *a* is slightly contracted, and is implanted in a shallow circular cavity, the rounded margin of which is adapted to a circular groove in the contracted part of the base; the margin of the tooth, which immediately transmits the pressure of the bone, is strengthened by an inwardly projecting convex ridge. The masonry of this inner buttress, and of the dome itself, is composed of hollow columns, every one of which is placed so as best to resist or transmit in the due direction the external pressure (fig. 23). The floor of the alveolus is thus relieved from the office of sustaining the tooth: it forms, in fact, the roof of a lower vault, in which the germ of a successional tooth (fig. 23, *b*, *b*) is in course of development. Had the crushing tooth in use rested, as in the wolf-fish, by the whole of its base upon the alveolus, the supporting plate, gradually undermined by the growth of the new tooth, must have given way, and been forced upon the subjacent delicate and highly vascular and sensitive matrix of the half-formed tooth. But the superincumbent pressure is exclusively sustained by the border of the alveolus, whence it is transferred to the walls dividing the vaulted cavities containing the germs of the new teeth.

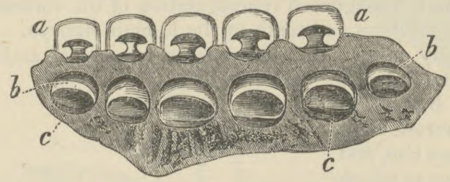

Fig. 23.
Section of Pharyngeal Bone and Teeth of a Wrasse (*Labrus*.)

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[1] *Odontography*, pl. 8, vol. iii., p. 980, fig. 518.

The roofs of these cavities yield to the absorbent process consequent on the growth of the new teeth, without materially weakening the attachment of the old teeth, and without the new teeth being subjected to any pressure until their growth is sufficiently advanced to enable them to bear it with safety. By this time the sustaining borders of the old alveolus are undermined, and the worn-down tooth is shed.

Many analogous structures could be adduced did space permit: in fact, the whole of this part of the organization of fishes is replete with beautiful instances of design, and instructive illustrations of animal mechanics.

Development.

As might have been anticipated from the discovery of the varied and predominating vascular organization in the teeth of fishes, and the passage from non-vascular dentine to vascular dentine in the same tooth, the true law of the development of dentine "by centripetal metamorphosis and calcification of the cells of the pulp," was first definitely enunciated and illustrated from observations made on the development of the teeth of fishes.[1]

It is interesting to observe in this class the process arrested at each of the well-marked stages through which the development of a mammalian tooth passes. In all fishes the first step is the simple production of a soft vascular papilla from the free surface of the buccal membrane. In sharks (fig. 24) and rays, these papillæ *c* do not proceed to sink into the substance of the gum, but are covered by caps of an opposite free fold of the buccal membrane. These caps *f*, *g*, do not contract any organic connection with the papilliform matrix; but, as this is converted into dental tissue, the tooth is gradually withdrawn from the extraneous protecting cap to take its place and assume the erect position on the margin of the jaw, as at *a*, *b*. Here, therefore, is represented the first and transitory "papillary" stage of dental development in Mammals; and the simple crescentic cartilaginous maxillary plate, with the open groove behind containing the germinal papillæ of the teeth, offers in the shark a magnified representation of the earliest condition of the jaws and teeth in the human embryo.

In many fishes, *e.g.*, the angler (*Lophius*) and pike, the dental papillæ become buried in the membrane from which they rise, and the surface to which their basis is attached becomes the bottom of a closed sac; but this sac does not become inclosed in the substance of the jaw; so that teeth at different stages of growth are brought away with the thick and soft gum, when it is stripped from the jaw-bone. The final fixation of teeth so formed is effected by the development of ligamentous fibres in the sub-mucous tissue between the jaw and the base of the tooth; which fibres become the medium of connection between those parts, either as elastic ligaments, or by continuous ossification. Here, therefore, is represented the "follicular" stage of the development of a mammalian tooth; but the "eruptive" stage takes place without previous inclosure of the follicle and matrix in the substance of the jaw-bone.

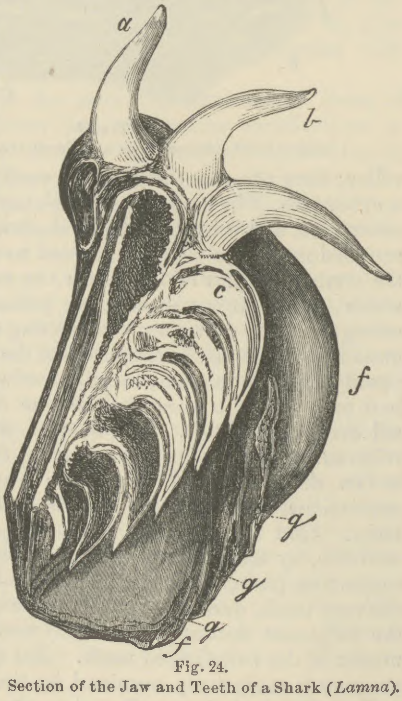

Fig. 24.
Section of the Jaw and Teeth of a Shark (*Lamna*).

In *Balistes* (fig. 22), *Scarus* (fig. 34), *Sphyræna*, the Sparoids, and many other fishes, the formation of the teeth presents all the usual stages which have been observed to succeed each other in the dentition of the higher Vertebrata: the papilla sinks into a follicle, becomes surrounded by a capsule, and is then included within a closed alveolus of the growing jaw (fig. 22, *c*), where the development of the tooth takes place, and is followed by the usual eruptive stages. A distinct enamel-pulp is developed in *Balistes*, *Scarus*, *Sargus*, and *Chrysophrys*.

Squalidæ, or sharks.

No cartilaginous fish has teeth implanted in maxillary alveolar cavities, or confluent with the substance of the jaw; they are attached to the fibrous and mucous membrane which cover the maxillary cartilages; thence it occurs, in certain genera, as *Myliobates* and *Scymnus*, that a single tooth in the median plane may lie directly across the symphysis, and be supported by the two rami of the jaw. The Plagiostomes, like many other natural families of fishes, present such modifications of their common and characteristic type of structure as fit them for very different habits of life, and the acquisition of different kinds of food. The active and predatory sharks are associated in this order with the sluggish omnivorous rays, and the dental system presents every grade of modification from the laniary to the molary type. The *Lamna* (fig. 24), with its teeth exclusively adapted for holding, piercing, and lacerating, and the *Myliobates* (fig. 26), with its maxillary mosaic pavement of flattened molars, form the two extremes of the series.

The sharks, or *squaloid* Plagiostomes, with few exceptions, have teeth of a conical, sharp-pointed, more or less compressed form, sometimes with trenchant or serrate edges and accessary basal denticles; they are arranged along the margin and posterior surface of the jaws in close-set vertical rows of from three to thirteen teeth in each row, according to the species. The teeth of the contiguous rows in certain genera, as *Selache* and *Lamna*, are parallel to each other; but in *Galeus* and *Carcharias* they are placed alternately, so that the base of one tooth advances laterally into the interspace of two teeth of the contiguous row, and reciprocally; but the laterally contiguous teeth are never articulated with each other, as in certain rays.

In general the anterior or external tooth only of each row is erect, the rest being recumbent. In *Lamna*, however, the second and third teeth are commonly seen in positions intermediate between those of the erect anterior (fig. 24, *a*) and the recumbent posterior teeth (*c*). It is scarcely necessary to repeat, that although the teeth of the sharks possess greater individual mobility than those of the rays, the recumbent ones (fig. 24, *c*) cannot, as has been supposed, be voluntarily erected. These teeth are still in progress of development, and several of them are covered by a reflection of the mucous membrane of the mouth (fig. 24, *g*), which would be lacerated by such a movement; it is by a gradual change of position in the fibrous membrane, to which their base is attached, that the altered direction of the consolidated teeth is effected.

The formation of the teeth of the sharks, as of many other fishes, exemplifies, on a large scale, the earliest or papillary stage of dental development in the higher classes of animals. It is not succeeded here by either a follicular or an eruptive stage; the formative papillæ are never inclosed, and consequently never break forth. The pulp, when consolidated by the deposition of the calcareous salts in the pre-existing cells and tubes, is gradually withdrawn from the protective sheath (fig. 24, *g*), which the thecal fold of mucous membrane *f*, *f* afforded during the early stages of its formation. In the uterine fœtus, one foot long, of the great white shark (*Charcharodon*), the jaws seem at first sight to be edentulous; a fissure presents itself on the inner side of the margin of each jaw, running parallel with it, between the thin smooth membrane covering the convex edge of the cartilage, and the free margin of a fold of mucous membrane which lies parallel to and upon the inner side of the jaw. When this fold is drawn away from the jaw, the minute teeth are exposed, arranged in the usual vertical rows; these points are all directed backwards and towards the base of the jaw, and are seen to slip out of fossæ or sheaths in the membranous folds, as this is gradually reflected backwards and

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[1] In the author's *Hunterian Lectures*, delivered at the Royal College of Surgeons, May 1839. See also *Compte Rendu de l'Académie des Sciences*, Dec. 1839, p. 784; and *Odontography*, Introduction, and part i., *passim*.

eeth of
ishes.

towards the base of the jaw. Here the anterior lamina of the fold, which, from its office, may be termed "thecal," is continuous with the mucous membrane at the base of the rows of teeth; the posterior layer is reflected backwards to the front line of attachment of the tongue. Close to the anterior line of reflection there is a row of simple conical papillæ; in the succeeding row the papillæ are larger, the cone broader and flatter, and its apex is covered with a small cap of dense and glistening dental substance, which is readily removed, though not without displacement of part of the dental pulp, the granules of which, adherent to the cavity of the displaced dental cap, are always readily recognisable under the microscope. The third series of papillæ, counting from below in the lower jaw, have acquired the size and shape of the future tooth, with the crenate edges well marked; half the tooth is completed, and its removal from the fleshy base of the pulp cannot be effected without evident laceration of the pulp. When this is done under the microscope, the torn processes of the pulp continued into the medullary canals of the new-formed tooth are plainly visible. The fourth tooth is completely formed, as also the fifth and sixth in the ascending series: these progressively diminish in size. The last or highest, which is first exposed on reflecting the thecal fold, and the first which was completed in the order of development, consists of a simple cone, similar in form and size to the apical third of the ordinary-sized teeth below it; yet its growth is quite completed, and its base firmly attached to the maxillary membrane.

In a fœtus of a white shark (*Carcharias ferox*) 3 inches long, which had not lost its external branchiæ, the membranous groove between the jaw and thecal fold was much shallower, and only two rows of papillæ were present on the maxillary membrane. The minute anterior teeth in the more advanced fœtus were developed from these primitive papillæ, which must be succeeded by others of progressively larger size, till the normal form and dimensions of the adult teeth are attained. The fœtal shark is peculiarly favourable for such comparisons, as it presents numerous pulps and teeth in every stage of formation, easily detached, and without violence, from their exposed situation, and of a flattened form, well adapted for microscopical observation.

The unossified pulps, examined with a high power, consist of semi-opaque polyhedral granules or cells suspended in a clear *matrix*, and the whole is inclosed in a tough transparent membrane, which forms the outer surface of the pulp. Beneath this membrane, at the crenate margins, the nucleated cells are arranged in lines precisely corresponding with those of the subsequent dentinal tubes. The formation of the tooth commences by the deposition of earthy particles in the tough external membrane of the pulp. The present writer has been unable to recognise the distinct arrangement of the hardening salts in this layer. It is transparent, extremely dense, and forms the enamel-like polished coating of the tooth; in sections of fully-formed teeth, the finest terminal branches of the parallel peripheral dentinal tubes are lost in the above clear enamel-like substance. When this outer layer of the apex of the tooth is completed, it is so easily detached from the subjacent pulp, that it might be readily supposed that there was no organic connection between them. If, however, the so exposed pulp be now examined with the microscope, and compared with an uncalcified pulp, it is seen to be no longer covered with the smooth, dense membrane observable in the latter; but the apical edges, from which the enamel-like cap has been detached, appear villous or floccular. It is obvious that the first shell of the tooth has been neither transuded from the superficies of the external membrane of the pulp, nor has been deposited between that membrane and the granular part of the pulp, but is due to the conversion of the external membrane into a dense enamel-like bone. The formation of the body of the tooth by deposition of earthy particles in pre-existing and pre-arranged cavities is still more satisfactorily demonstrable. In proportion as the formation of the tooth has advanced, the difficulty of separating the calcified from the uncalcified portion of the pulp is increased; and at the same time it becomes easier to detect the continuation of the processes of the pulp into those medullary canals which form so many separate centres of radiation of the plexiform dentinal tubes.

As a consequence of a formation of a tooth by conversion of, instead of transudation from, a pre-existing pulp, the successive formation of these pulps necessarily follows where a succession of teeth is required. These reproductive pulps are developed, in the shark, from the vascular mucous membrane at the angle of reflection of the thecal fold upon the groove of the basal line of the jaws. They gradually advance from this situation towards the margin of the jaw, the centripetal calcification extends as they advance, and consolidation is completed (as in fig. 24, *c*) by the time the teeth are ready to change their recumbent for the erect position *ba*, and take the place of the tooth previously shed.

Teeth of
Fishes.

Raiidæ, or
Rays.

The teeth of the rays are in general more numerous than those of the sharks; they have less mobility, are more closely impacted, and in some cases are laterally united together by fine sutures, so as to form a kind of mosaic pavement on both the upper and lower jaws. The *Myliobates*, or eagle-rays, which present the last-mentioned condition, unique in the vertebrate sub-kingdom, have large and massive teeth (fig. 26); but in the rest of the present family of cartilaginous fishes, the teeth (fig. 25) are remarkable for their small size as compared with those of the sharks. The teeth in some species of rays are adapted for crushing, but in others they have the middle or one of the angles of the crown produced into a sharp point. In all genera of the ray tribe, whatever the diversity of size and shape of the teeth, they are placed in several rows, and succeed each other uninterruptedly from behind.

In the genus *Rhina*, each tooth is supported on a short fang or pivot, which tapers as it recedes from the crown; there is a groove along the posterior part of the pivot, and a perforation on each side; the crown is lozenge-shaped, convex above, and sculptured with a series of transverse and slightly undulating and punctate ridges, presenting a pattern which somewhat resembles that of the grinding surface of the comparatively gigantic tooth of the extinct cartilaginous fish of the chalk formation called *Ptychodus*. The modification of the dentigerous surface of the jaws, and the beautiful quincuncial arrangement of these teeth, are exhibited in fig. 25.

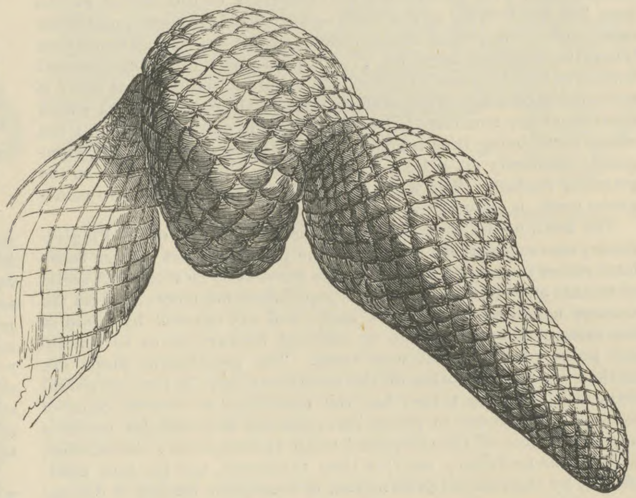

Fig. 25.
Dental Pavement of the Upper Jaw (*Rhina*).

The middle part of the upper jaw forms a bold prominent convexity, separated by a depression on each side from a lateral and less produced rising. The contour of the dentigerous surface of the lower jaw presents depressions corresponding to the eminences above, and *vice versa*.

The modification of the plagiostomous type of teeth, for the purpose of crushing alimentary substances, is most complete in the genus *Myliobates*. A view of this armature of the mouth, as seen from behind in the *Myliobates aquila*, is given in fig. 26. Both jaws are covered with a pavement of broad teeth, having a flat grinding surface, vertical and finely-undulated sides, by which

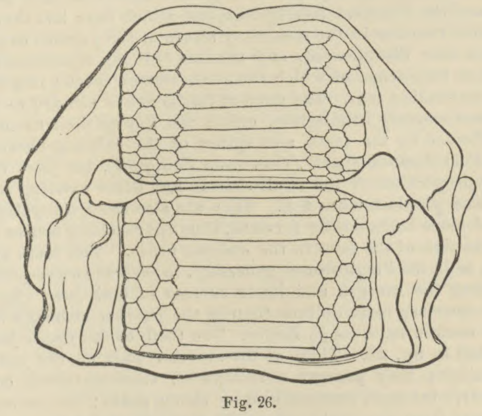

Fig. 26.
Jaws and Teeth of an Eagle-Ray (*Myliobates aquila*)

contiguous teeth are joined together, as by a suture (fig. 27, *c*), and a base divided into a number of small parallel longitudinal ridges.

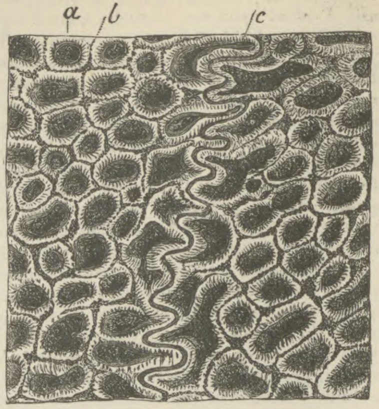

Fig. 27.
Magnified Section of parts of two contiguous Denticles of *Myliobates aquila.*

The entire phalanx of dental plates of the upper jaw describes the segment of a circle. A longitudinal and vertical section of a single dental plate, viewed by a compound lens of an inch focus, exhibits at its base a coarse network of large irregular canals, filled with a vascular medullary pulp. From this network smaller medullary canals proceed towards the flat grinding surface, in a straight and slightly diverging course, subdividing dichotomously, with interspaces equal to their own diameter at the base, but much wider at the working surface of the tooth; under the same power, the area of the medullary canals presents generally an irregular elliptical form (fig. 27, *a*), from which radiating dentinal tubes are faintly perceptible. Each canal and its series of tubes is surrounded by a line of generally a hexagonal form (fig. 27, *b*), which constitutes the boundary between contiguous canals and tubes; the whole tooth being thus composed of an aggregate of slender, elongated, commonly six-sided prismatic teeth, placed vertically to the grinding surface. The wavy line of the suture, uniting two contiguous teeth, is shown at *c*.

The teeth of the Myliobates, like those of the rest of the Plagiostomes, are successively formed at the posterior part of the tesselated series in proportion as they are worn away in front. A series of minute and closely-aggregated papilliform matrices rise from the mucous membrane behind the teeth, and are covered by a fold of the same membrane, which is reflected forward so as to conceal the pulps of the last-formed teeth. The papilliform pulps are ossified by the deposition of the calcareous salts in the peripheral cells and radiating tubes; but the medullary or central canal of each pulp continues to retain its organized and vascular contents until the whole of the compound tooth is completed; the calcified wall of the medullary canal is then thickened, and the area diminished, by the successive formation of concentric laminæ of osseous matter.

As the teeth of the *Myliobates* are gradually carried forwards into action by the direction of growth of their basis of support, the areæ of the medullary canals become progressively diminished, as in bone, by osseous deposition in concentric layers, and they thus become finally consolidated in the anterior teeth.

Cestracionts.

The dental characters of this family of cartilaginous fishes are chiefly manifested in a form of tooth better adapted for crushing or comminuting alimentary substances which offer only passive resistance, than for piercing, cutting, and lacerating a living prey; and in most of the species the teeth vary in form and size in the same individual to a greater degree than in the sharks. Of the numerous singular forms of this tribe of cartilaginous fishes that once peopled the seas of the Northern Hemisphere, and which have left their less perishable remains in the secondary strata of the present dry land, all have now disappeared, and the sole existing representative is the genus *Cestracion*, of which the most common species is met with in the Australian seas. The ancient fossils above alluded to would have been scarcely intelligible, unless the key to their nature had been afforded by the teeth and spines of the existing Cestracion. In the Port Jackson shark (*Cestracion Phillippii*), the jaws form a greater proportion of the skull than in any other existing cartilaginous and plagiostomous fish. They are also more elongated, and directed more horizontally forward, thus approaching nearer to the usual position of the jaws in the osseous fishes. The teeth are arranged, as in the Plagiostomes generally, in several antero-posterior rows along the margin and inner surface of both jaws (fig. 28); but the rows are more oblique than in the sharks, although less so than in certain rays,—*e.g.*, *Rhina*. The teeth of the upper jaw are delineated in fig. 28. Those at the anterior part of the jaws are the smallest; they present a transverse, subcompressed, conical figure, with the apex produced into a sharp point; the points are worn away from the used teeth at the anterior and outer parts of the jaw, but are strongly marked in those which still lie below the margin. There are six subvertical rows of these small cuspidate teeth on each side of the jaw, together with a median row close to the symphysial line, and there are from twelve to fourteen teeth in a row. Behind the cuspidate teeth the five consecutive rows of teeth progressively increase in all their dimensions, but principally in their antero-posterior extent. The sharp point is converted into a longitudinal ridge traversing a convex crushing surface, and the ridge itself disappears in the largest teeth. As the teeth increase in size, they diminish in number in each row. The series of the largest teeth includes from six to seven in the upper, and from seven to eight in the lower jaw. Behind this row the teeth, although preserving their form as crushing instruments, progressively diminish in size, while at the same time the number composing each row decreases. From the oblique and apparently spiral disposition of the rows of teeth, their symmetrical arrangement on the opposite sides of the jaw, and their graduated diversity of form, they constitute the most elegant tesselated covering to the jaws which is to be met with in the whole class of fishes.

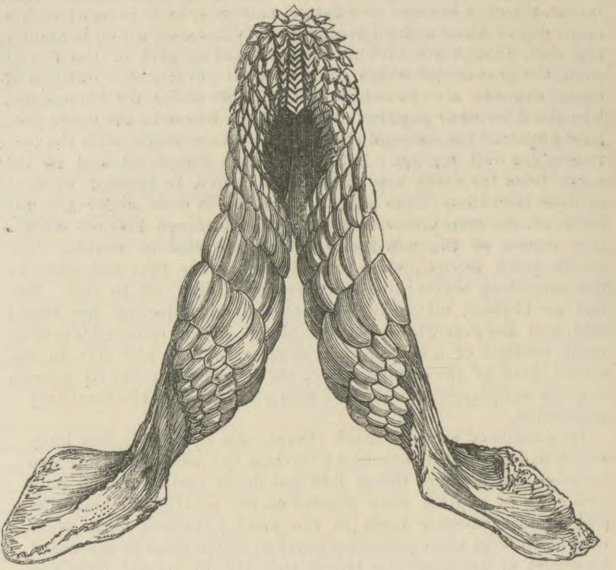

Fig. 28.
Upper Jaw and Teeth of Port Jackson Shark (*Cestracion*), half nat. size.

The modifications of the form of the teeth above described, by which the anterior ones are adapted for seizing and retaining, and the posterior for cracking and crushing alimentary substances, are frequently repeated, with various modifications and under different conditions, in the osseous fishes. They indicate, in the present cartilaginous species, a diet of a lower organized character than in the true sharks; and a corresponding difference of habit and disposition is associated therewith. The testaceous and crustaceous invertebrate animals constitute most probably the principal food of the Cestracion, as they appear, by their abundant remains in secondary rocks, to have done in regard to the extinct Cestracionts, with whose fossil teeth they are associated.

From the extensive series of osseous fishes, the limits of the present article compel a selection of a few of the more remarkable modifications of the dental system.

Anarhicas.

Genus ANARHICAS.—The cat-fish or wolf-fish (*Anarhicas lupus*) has two kinds of teeth with well-marked distinction of form, according to which they might be termed laniaries or canines, and molars. The anterior teeth (fig. 29, *a*) form strong cones, and diverge so as to act as grappling hooks, well fitted for a firm grasp of the mailed body of a struggling lobster, or for extracting the shell-fish from his rocky recess or sandy burrow. The back teeth *c* are like paving-stones, and are powerful crushers. The premaxillary teeth (fig. 29, *a*) are all conical, and arranged in two rows; there are two, three, or four in the exterior row, at the mesial half of the bone, which are the largest; and from six to eight smaller teeth are irregularly arranged behind. There are three large, strong, diverging laniaries at the anterior end of each premandibular bone (fig. 29), and immediately behind these an irregular number of shorter and smaller conical teeth, which gradually exchange this form for that of large obtuse tubercles; these extend backwards, in a double alternate series, along a great part of the alveolar border of the bone, and are terminated by two or three smaller teeth in a single row, the last of which again presents the conical form. Each palatine bone supports a double row of teeth, the outer ones being conical and straight, and from four to six in number; the inner ones two, three, or four in number, and tuberculate. The lower surface of the vomer (fig. 29, *c*) is covered by a double irregularly alternate series of the same kind of large tuberculate crushing teeth as those at the middle of the premandibular bone.

Fig. 29.
Upper and Lower Jaws and Teeth of the Wolf-fish (*Anarhicas lupus*), half nat. size.

All the teeth are anchylosed to more or less developed alveolar eminences, but a narrow line of demarcation is long discernible (as at 2, fig. 30). From the enormous development of the muscles of the jaws, and the strength of the shells which are cracked and crushed by the teeth, their fracture and displacement must obviously be no unfrequent occurrence: and most specimens of the jaws of the wolf-fish exhibit some of the teeth either separated at this line of imperfect anchylosis, or, more rarely, broken off above the base, or, still more rarely, detached by fracture of the supporting osseous alveolar process.

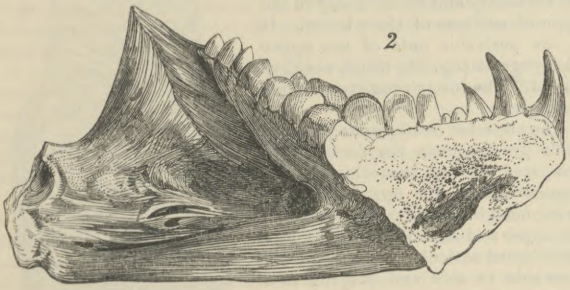

Fig. 30.
Section of Lower Jaw and Teeth of *Anarhicas lupus*, half nat. size.

Lophius.

The angler (*Lophius piscatorius*) has teeth on the premaxillary, premandibular, palatine, vomerine, and pharyngeal bones. They are of an elongated, conical, sharp-pointed, and slightly incurved form, presenting merely difference of size, degree of curvature, and mode of fixation, but all bespeaking the predatory and carnivorous habits of the species. In the upper jaw, the teeth are congregated in three or four irregular rows at the median or upper third part of each premaxillary bone, and form a single and regular series along the lower two-thirds of the same bone. These latter, which may be termed the *serial teeth*, are from fifteen to eighteen in number; they are short, strong, pointed, and incurved, of nearly equal size, and placed at regular distances from each other. The two outer irregular rows of the median intermaxillary teeth are somewhat larger, and are directed forwards. The inner rows at this part contain the longest teeth, and their points are turned back; but they are movably connected with the bone by a mechanism which will be described when treating of those of the lower jaw. The superior pharyngeal teeth are arranged in three groups upon as many separate bones on each side; each group describes a curve, with the convexity turned forwards. The teeth of the posterior bone are the smallest. The inferior pharyngeal bones are two in number, and have the teeth arranged in a double alternate row along each margin.

The pharyngeal, palatine, and vomerine teeth are fixed by anchylosis to their respective bones; this is also the case with most of the premaxillary teeth, and with the exterior teeth of the lower jaw (fig. 31, *a*, *a*), but the remainder, and especially the large posterior teeth of the lower jaw (fig. 31, *b*, *b*), are attached by means of elastic ligaments to the margins of slightly elevated alveolar processes. These ligaments (fig. 31, *c*, *c*) are principally inserted into the inner straight margin of the base of the tooth, from which their glistening fasciculi radiate to be implanted into the jaw. The rest of the base of the tooth is connected at its circumference with more lax and yielding fibrous bands, and with the mucous membrane of the mouth, which covers the alveolar tract in the interspaces of the teeth. To any attempt to bend these teeth outwards resistance is offered by the internal ligaments above described, and by the pressure of the anterior angle at the base of the tooth against the alveolar processes or raised tubercle on which it rests; but the tooth readily yields to a force acting in the opposite direction, and the largest and most prominent teeth can be bent inwards and backwards (as at *c*, fig. 31), so as to point to the gullet when the hand is pressed over them in the direction a body would take when drawn into the mouth to be swallowed. The moment, however, this force ceases to act, the teeth recoil to their erect position, as shown by the dotted outline in fig. 31) as if operated on by a spring. If everything attached to the base of the tooth, excepting the internal pyramidal band of ligamentous fibres, be removed, the tooth, after being bent down, returns with the same force to the erect position; it is therefore to this band that its resilience is due.

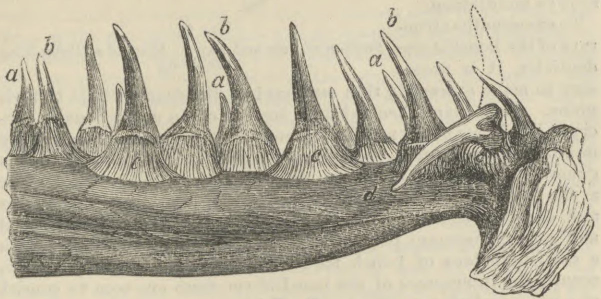

Fig. 31.
Section of Mandible and Teeth of the Angler (*Lophius piscatorius*).

Cyprinidæ.

The cyprinoid fishes, properly so called, which are typified by the carp and loach, respectively representing the genera *Cyprinus* and *Cobitis*, have the jaws completely deprived of teeth. The inferior pharyngeals, or throat-bones, are armed with one or more rows of teeth, which are flattened, conical, or curved, according to the species. These are succeeded by teeth at the external, as the old are shed from the internal, surface of those bones. They work against each other, and upon the very hard callous or calcified plate which is fixed in a depression on the inferior surface of the basi-occipital bone. The omnivorous barbels (*Barbus* and *Labeobarbus*) have three rows of pharyngeal teeth, which are weaker in the latter genus. In *Acanthopsis* the pharyngeal teeth are sharp-pointed, and are placed in a single row. In the loaches (*Cobitis*), which feed on worms and aquatic insects, the pharyngeals are attenuated, with chisel-shaped extremities. In the gudgeons (*Gobio*), which feed on worms, aquatic larvæ, and small molluscous animals, with their ova or fry, the pharyngeal teeth are conical, slightly curved at the extremity, and arranged in two rows. In the carp (*Cyprinus Carpio*), which feeds on the soft part of aquatic plants, larvæ of insects and worms, the pharyngeal teeth have broad, flat-ridged crowns, like the molars of herbivorous quadrupeds.

Diodon.

In the globe-fishes (*Diodon*), the lamellated structure of the tooth, and its reproduction by successive transudation of layers from a persistent pulp, were supposed to be clearly demonstrated in the broad rounded triturating tubercule which is situated behind the alveolar border of the upper and lower jaw. The exposed surface of this tooth presents, in fact, a series of transverse and parallel striæ, which in a vertical section (fig. 32) are seen to be the margins of thin, superimposed, horizontal, and slightly flexuous plates *a*, *b*, which have been partially abraded by trituration in an oblique plane. The superior layers are the most worn; in proportion as they descend, in the lower jaw, they increase in breadth, and finally, instead of being soldered together, they become detached, thinner, and of a more friable texture; the lowest and incompletely developed plates lying loosely in the cavity of the jaw, beneath the superincumbent mass (as at *a*, fig. 32). If a vertical section of the dental tubercle be made on one side of the median plane, the laminæ are seen to be developed in two distinct lateral moieties, which become anchylosed together by means of a thin median vertical osseous partition at their median margins; their lateral margins are similarly anchylosed to the outer walls of the dentigerous cavity. The laminæ are developed successively; and in proportion as the anterior ones are worn away, the posterior ones appear in readiness to replace them; so that the due number of ridges on the triturating surface is always maintained.

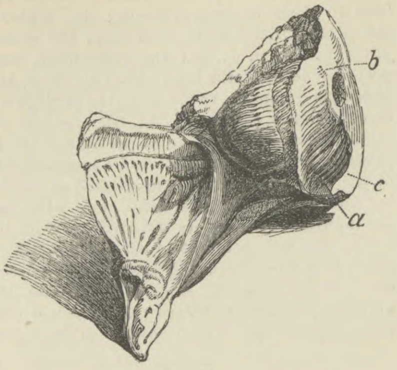

Fig. 32.
Section of Jaw and Dental Mass of a Globe-fish (*Diodon*).

To examine the structure of the lamelliform denticles, it is necessary to make extremely thin sections in a direction vertical to their plane. Each plane then exhibits, instead of an amorphous or subcrystalline mass of excreted calcareous matter, a series of extremely minute dentinal tubes, occupying its whole extent, and having a general direction vertical to its plane. The tubes are obviously wider at the lower side of the plate, and gradually disappear in the clear and dense substance at the opposite surface. When the thinnest and most transparent parts of the same section are examined with a compound lens of $\frac{1}{8}$-inch focus, the horizontal partitions which occupy the interspaces of the lamelliform teeth are seen to consist of a coarse cellular osseous texture, without any radiating cells, but similar to the texture of the rest of the endo-skeleton of the *Diodon*. The main tubes of the dental plate are continued immediately from the cells of the osseous septum; they proceed for a short distance vertically, or with a slight curvature, in the substance of the dental plate, and then quickly divide and subdivide, the branches generally coming off at an angle of 45°, being slightly bent, crossing each other in an inextricable manner, and terminating ultimately in the clear matrix of the upper surface of the dental plate. By the time that calcification has begun in one pulp, a second has been developed beneath it, and it is the portion of the pulp solidified which gives rise, in the macerated and dried jaws, to the loose and thin lamellæ in the dental cavity. These lamellæ become fixed by means of the coarser calcification or ossification which subsequently takes place in the remains of the pulp; and their margins are thus anchylosed to the surrounding bones in a manner analogous to the fixation of the base of the ordinary shaped teeth in other fishes.[1]

Scarus. *Genus* Scarus.—The dense tesselated covering of the beak-like jaws (fig. 33) of the parrot-fishes (*Scarus*) consists of a stratum of prismatic denticles (fig. 34, *a*), standing almost vertically to the external surface of the jaw-bone, the square tuberculate ends of which appear externally wedged close together, like the blocks in wood-pavement. This peculiar armature of the jaws is well adapted to the habits and exigences of a tribe of fishes which browse upon the lithophytes that clothe, as with a richly-tinted carpet, the bottom of the sea, just as the ruminant quadrupeds crop the herbage of the dry land.

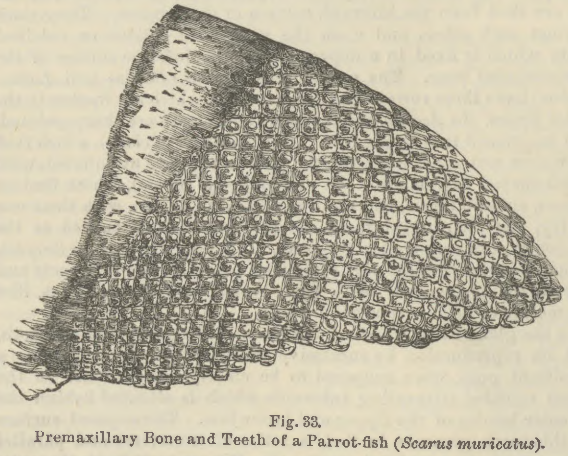

Fig. 33.
Premaxillary Bone and Teeth of a Parrot-fish (*Scarus muricatus*).

The irritable bodies of the gelatinous polypes, which constitute the food of these fishes, retract, when touched, into their star-shaped stony shells; and the *Scari* consequently require a dental apparatus strong enough to break off or scoop out these calcareous recesses. The jaws are therefore prominent, short, and stout; and the exposed portions of the premaxillaries and premandibulars are encased by the complicated dental covering represented in figs. 33 and 34. The polypes and their cells are reduced to a pulp by the action of the pharyngeal jaws and teeth (fig. 35) that close the posterior aperture of the mouth.

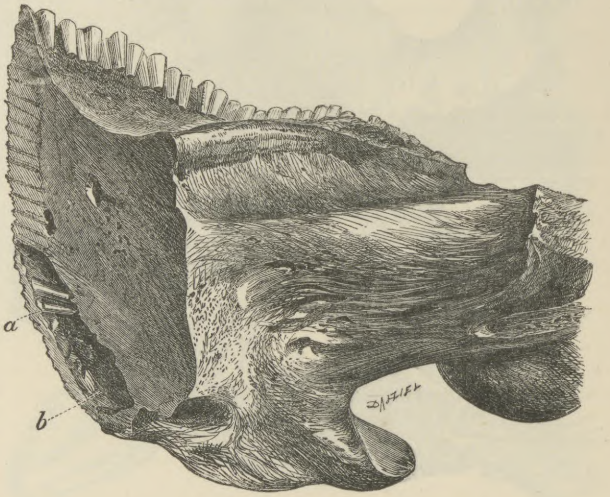

Fig. 34.
Section of Premandibular Bone and Teeth of Parrot-fish (*Scarus muricatus*).

The typical *Scari* have both upper and lower pharyngeal bones paved with strong, thick lamelliform teeth, set vertically and transversely in the opposed surfaces of these bones. It is the posterior pair of the upper pharyngeals (fig. 35) which are thus armed. The lower pharyngeal bone is single.

The superior dentigerous pharyngeals present each the form of an elongated vertical inequilateral triangular plate; the upper and posterior margin is sharp and concave; the upper and anterior margin forms a thickened articular surface, convex from side to side, and playing in a corresponding groove or concavity upon the base of the skull; the inferior boundary of the triangle is the longest, and also the broadest; it is convex in the antero-posterior direction, and flat from side to side. It is on this surface that the teeth are implanted; and in most species they form two rows, the outer one consisting of very small teeth (fig. 35, *a*), the inner one of large teeth *b*. These present the form of compressed conical plates or wedges, with the basis excavated and the opposite margin moderately sharp, and slightly convex to near the inner angle, which is produced into a point. These plates are set nearly transversely across the lower surface of the pharyngeal bone, and are produced beyond the margin of the bone, and interlock with those of the adjoining bone when the pharyngeals are in their natural position. The smaller denticles of the outer row are set in the external interspaces of those of the inner row.

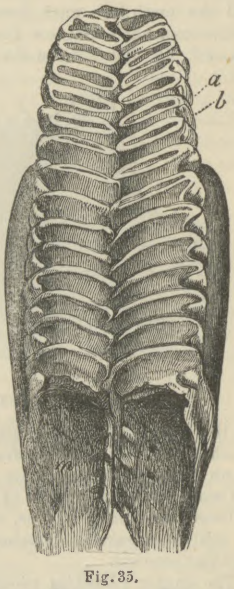

Fig. 35.
Upper Pharyngeal Bones and Teeth of a Parrot-fish (*Scarus muricatus*).

The dentine of the pharyngeal teeth of the *Scarus* consists of dentinal tubes and a clear intermediate substance. The tubes average a diameter of $\frac{1}{20000}$th of an inch, and are separated by interspaces equal to twice their own diameter; and these tubes, on leaving the pulp-cavity, form a curve with the convexity turned towards the base of the tooth, and then bend slightly in the opposite direction; the sigmoid curve being most marked in the tubes at the base of the denticles, whilst those towards the apex become longer and

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[1] For other details of the gymnodont dentition, see *Annales des Sciences Naturelles*, 2de série, tom. xii., p. 347.

straighter. Besides the primary curvatures exemplified in the figure, each dentinal tube is minutely undulated; it dichotomizes three or four times near its termination, sends off many fine lateral branches into the clear uniting substance, and finally terminates in a series of minute cells and inosculating loops, at the line of junction with the enamel.

This substance is as thick as the dentine, and consists of a similar combination of minute tubes and a clear connecting substance. The tubes may be described as commencing from the peripheral surface of the tooth, to which they stand at right angles; and having proceeded parallel to each other half-way towards the dentine, they then begin to divide and subdivide, the branches crossing each other obliquely, and finally terminating in the cellular boundary between the enamel and dentine.

The teeth which present this complex structure are successively developed at one extremity of the bone in proportion as they are worn away at the other—not, however, as Cuvier describes, from behind forwards in both upper and lower pharyngeal bones, but in opposite directions in the opposite bones, the course of succession being from before backwards in the upper, and from behind forwards in the lower pharyngeal bones. In the progress of the attrition to which they are subjected, the thin coat of cement resulting from the ossification of the capsule is first removed from the apex of the tooth, then the enamel constituting that apex, next the dentine, and finally the coarse central cellular bone supporting the hollow wedge-shaped tooth; and thus is produced a triturating surface of four different substances of different degrees of density. The enamel, being the densest element, appears in the form of elliptical transverse ridges inclosing the dentine and central bone; and external to the enamel is the cement which binds together the different denticles.

The single inferior pharyngeal bone consists principally of an oblong dentigerous plate. Its breadth somewhat exceeds that of the conjoined dentigerous surfaces of the pharyngeals above; and it is gently hollowed, to correspond with their convexity. This dentigerous plate is principally supported by a strong, slightly curved, transverse, osseous bar, the extremities of which expand into thick obtuse processes for the implantation of the triturating muscles. A longitudinal crest is continued downwards and forwards from the middle line of the inferior pharyngeal plate, anterior to the transverse bar, to which the protractor muscles are attached.

A longitudinal row of small oval teeth, alternating with the large lamelliform teeth, like those of the superior pharyngeals, bounds the dentigerous plate on each side. The intermediate space is occupied exclusively by the larger lamelliform or wedge-shaped teeth, set vertically in the bone, and arranged transversely in alternate and pretty close-set rows.

There is a close analogy between the dental mass of the *Scarus* and the complicated grinders of the elephant, both in form, structure, and in the reproduction of the component denticles in horizontal succession. But in the fish the complexity of the triturating surface is greater than in the mammal, since, from the mode in which the wedge-shaped denticles of the *Scarus* are implanted upon, and anchylosed to, the processes of the supporting bone, this likewise enters into the formation of the masticatory surface when the tooth is worn down to a certain point.

The proof of the efficacy of the complex masticatory apparatus above described is afforded by the contents of the alimentary canal of the *Scari*. Mr Charles Darwin, the accomplished naturalist and geologist, who accompanied Captain Fitzroy, R.N., in the circumnavigatory voyage of the Beagle, dissected several parrot-fishes soon after they were caught, and found the intestines laden with nearly pure chalk, such being the nature of their excrements; whence he ranks these fishes among the geological agents to which is assigned the office of converting the skeletons of the lithophytes into chalk.

Sphyræna.

Genus SPHYRÆNA.—The most formidable dentition in the order of osseous fishes is that which characterizes the Barracuda sea-pikes (*Sphyræna*), and some extinct fishes allied to this predatory genus. In the great Barracuda of the southern shores of the United States (*Sphyræna barracuda*, Cuv.), the lower jaw contains a single row of large, compressed, conical, sharp-pointed, and sharp-edged teeth, resembling the blades of lancets, but stronger at the base. The two anterior of these teeth are twice as long as the rest; but the posterior and serial teeth gradually increase in size towards the back part of the jaw. There are about twenty-four of these piercing and cutting teeth in each premandibular bone. They are opposed to a double row of similar teeth in the upper jaw, and fit into the interspace of these two rows when the mouth is closed. The outermost row is situated on the premaxillary, the innermost on the palatine bones. There are no teeth on the vomer or superior maxillary bones. The two anterior teeth in each premaxillary bone equal the opposite pair in the lower jaw in size; the posterior premaxillary teeth are serial, numerous, and of small size; the second of the two anterior large premaxilliary teeth is placed on the inner side of the commencement of the row of small teeth, and is a little inclined backwards. The retaining power of all the large anterior teeth is increased by a slight posterior projection, similar to the barb of a fish-hook, but smaller. The palatine bones contain each nine or ten lancet-shaped teeth, somewhat larger than the posterior ones of the lower jaw. All these teeth afford good examples of the mode of attachment by implantation in sockets, which is a rare one in the class of fishes.

The base or fang of the fully-developed tooth of the *Sphyræna* is anchylosed to the parietes of the socket in which it is inserted. The pressure of the crown of the new tooth excites absorption of the inner side of the base of the old, which thus finally loses the requisite strength of attachment, and its loss is followed by the absorption of the old socket, as in the higher animals.

It is interesting to observe that the external teeth are in general contemporaneously shed, so that the maxillary armour is always preserved in an effective state. The relative position of the new teeth to their predecessors, and their influence upon them, resembles some of the phenomena which will be described in the dentition of the crocodilian reptiles. To the crocodiles the present voracious fish also approximates in the alveolar lodgment of the teeth; but it manifests its ichthyic character in the anchylosis of the fully-developed teeth to their sockets, and still more strikingly in the intimate structure of the teeth. The loss or injury to which these destructive weapons are liable in the conflict which the *Sphyræna* wages with its living and struggling prey is repaired by an uninterrupted succession of new pulps and teeth. The existence of these is indicated by the foramina, which are situated immediately posterior to, or on the inner margins of, the sockets of the teeth in place. These foramina lead to alveoli of reserve, in which the crowns of the new teeth, in different stages of development, are loosely imbedded. It is in this position of the germs of the teeth that the sphyrænoid fishes, both recent and fossil, mainly differ as to their dental characters from the rest of the scomberoid family, and proportionally approach the sauroid type.

In all fishes the teeth are shed and renewed, not once only, as in mammals, but frequently during the whole course of their lives. The maxillary dental plates of *Lepidosiren*, the cylindrical dental masses of the chimæroid and edaphodont fishes, and the rostral teeth of the *Pristis* (if these modified dermal spines may be so called), are perhaps the sole examples of permanent teeth to be met with in the whole class. In the great majority of fishes the germs of the new teeth are developed, like those of the old, from the free surface of the buccal membrane throughout the entire period of succession; a circumstance peculiar to the present class. The angler, the pike, and most of our common fishes, illustrate this mode of dental reproduction; it is very conspicuous in the cartilaginous fishes, in which the whole phalanx of their numerous teeth is ever marching slowly forwards in rotatory progress over the alveolar border of the jaw; the teeth being successively cast off as they reach the outer margin, whilst the new teeth rise from the mucous membrane behind the rear rank of the phalanx. This endless succession and decadence of the teeth, together with the vast numbers in which they often co-exist in the same fish, illustrate the law of "vegetative" or "irrelative repetition," as it manifests itself on the first introduction of new organs in the animal kingdom; under which light we must view the above-described organized and calcified preparatory instruments of digestion in the lowest class of the vertebrate series.

Lepidosiren.

At the extreme limit of the class of fishes, and connecting that class with the reptiles, stands the very remarkable genus, the dental system of which is shown in fig. 36. This consists of two small, slender, conical, sharp-pointed, and slightly recurved teeth, which project downward from the nasal bone *a*, and of strong trenchant dental plates, anchylosed with the alveolar border of the upper (*b*) and lower (*c*) jaw, in each of which the plate is divided at the middle or symphysial line, so as to form two distinct lateral teeth.

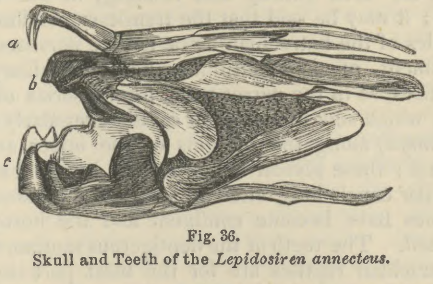

Fig. 36.
Skull and Teeth of the *Lepidosiren annecteus.*

The office of the two laniariform teeth is to pierce and retain the nutritive substance or prey, which is afterwards divided and comminuted by the strong maxillary dental plates. The upper pair of these plates is supported by the anterior part of a strong arch of bone, which combines the character of the superior maxillary, palatine, and pterygoid bones. The superior maxillary is represented by the median and anterior bar, passing in front of the dental plate of the lower jaw when the mouth is shut, and terminating on each side in a process which projects outwards and backwards on each side of the anterior part of the arch; the palatine portion constitutes the median part of the roof of the mouth behind the foregoing. The pterygoid portion is indicated by its fulfilling the usual function of an abutment extended between the palatine portion of the upper jaw and the articular pedicle of the lower jaw. The upper dental plates are confined to the first two parts of the arch (maxillary and palatine), and do not extend upon the pterygoid portion; the lower dental plates are anchylosed to the premandibular bone. Viewing the upper pair of plates as a single tooth, it may be described as indented at its outer surface by five vertical angular notches, penetrating inwards through half the breadth of the supporting bone, and dividing the plate into six angular processes, which, from the direction and varying form and breadth of the entering notches, radiate from the posterior part of the median line or division of the tooth. The inferior dental plate is similarly notched on its outer side, but the proportions of the angular indentations are such that they receive all the processes of the upper dental plate when the mouth is shut, whilst only the four anterior processes are reciprocally received into the notches of the upper dental plate. The dental plate consists, as in the cod and *Sphyræna*, of a central mass of coarse osseous substance traversed by large and nearly parallel medullary canals, and an external sheath of very hard "vitrodentine."

Dendrodonts.

The labyrinthic structure of the teeth of the bony gar-fish of the North American lakes and rivers (*Lepidosteus*) has been already alluded to in the introductory generalization on dental tissues. The still more complex structure of the fossil teeth of the extinct Dendrodonts (fig. 14) is there more fully described. As compared with the vasodentine (fig. 7) of the sharks and of many existing osseous fishes, the dental tissue of the Dendrodonts differs in both the extent and regularity of the radiating medullary canals, and more especially in the straight course of the fine dentinal tubes.

Both the foregoing genera of fishes have been termed "sauroid," but are more truly "salamandroid," and approach, like the Lepidosiren, most closely to the lower confines of the reptilian class; and as this existing annectant genus is allied to the perennibranchiate Batrachians, so the *Dendrodus* may have linked some extinct group of the class of fishes with the equally extinct family of sauroid Batrachians which have been termed "Labyrinthodonts."

SECT. II.—TEETH OF REPTILES.

In the class Reptilia, the whole order of *Chelonia* is edentulous, as well as the family of toads (*Bufonidæ*), in the order *Batrachia;* certain extinct genera of Saurians were edentulous, *e.g.*, the remarkable *Rhynchosaurus* of the New Red Sandstone of Shropshire, and some of the extinct Saurians of South Africa.

In the tortoises and turtles, the jaws are covered by a sheath of horn, which in some species is of considerable thickness, and very dense; its working surface is trenchant in the carnivorous species, but variously sculptured, and adapted for both cutting and bruising, in the vegetable feeders; it may be said that the transitory condition of the mandibles of the batrachian larvæ is here persistent. The development of the continuous horny maxillary sheath commences, as in the parrot tribe, from a series of distinct papillæ, which sink into alveolar cavities, regularly arranged (in *Trionyx*) along the margins of the upper and lower jaw-bones; these alveoli are indicated by the persistence of vascular canals long after the originally separate tooth-like cones have become confluent and the horny sheath completed. The teeth of the dentigerous saurian, ophidian, and batrachian reptiles are for the most part simple, and adapted for seizing and holding, but not for dividing or masticating their food. The siren alone combines true teeth with a horny maxillary trenchant sheath, like that of the chelonian reptiles.

Number.

With respect to *number*, in no existing reptiles are the teeth reduced so low as in certain mammals and fishes; nor, on the other hand, are they ever so multiplied as in many of the latter class. The extinct dicynodont reptiles of South Africa had but two teeth, which were long tusks implanted in the upper jaw (fig. 44).[1] Some species of *Amphisbæna* (*A. alba*), with fifteen teeth in the upper jaw and fourteen in the lower, afford examples of the smallest number of teeth amongst existing reptiles; and certain Batrachians, with teeth "en cardes" at the roof of the mouth, or which have upwards of eighty teeth in each lateral maxillary series, present the largest number. It is rarely that the number of the teeth is fixed and determinate in any reptile, so as to be characteristic of the species; and still more rarely have the individual teeth such characters as to be determined homologically from one species to another.

Form.

The teeth of reptiles, with few exceptions, present a simple conical *form*, with the crown more or less curved, and the apex more or less acute. The cone varies in length and thickness; its transverse section is sometimes circular, but more commonly elliptical or oval, and this modification of the cone may be traced through every gradation, from the thick, round, canine-like tooth of the crocodile, to the sabre-shaped fang of the Varanus, the Megalosaur, and Cladeiodon.[2] Sometimes, as in the fully-formed teeth of the Megalosaur, one of the margins of the compressed crown of the tooth is trenchant, sometimes both are so; and these may be simply sharp-edged, as in the Varanus of Fimor, or finely serrated, as in the great Varanus, the Cladeiodon, and the Megalosaur.[3]

The outer surface of the crown of the tooth is usually smooth: it may be polished, as in the Leiodon; or impressed with fine lines, as in the Labyrinthodon (fig. 11); or raised into many narrow ridges, as in the Pleiosaur and Polyptychodon; or broken by a few broad ridges, as in the Iguanodon (fig. 42); or grooved by a single longitudinal furrow, as in some lizards and serpents (fig. 38).[4]

The cone is longest, and its summit sharpest, in the serpent; from these may be traced, chiefly in the lizard tribe, a progressive shortening, expansion of the base, and blunting of the apex of the tooth, until the cone is reduced to a hemispherical tubercle or plate, as in the Thorictes and Cyclodus. The extinct *Placodus* was remarkable for the great size of its flat crushing teeth; in one species (*Pl. laticeps*) the diameter of the crown of the last palatal tooth is one inch four lines, the length of the skull being eight inches: this is the largest proportional grinding-tooth in the animal kingdom. In the Pleiosaur, the dental cone is three-sided, with one of the angles rounded off. The posterior subcompressed teeth of the alligator (fig. 46) present a new modification of form; here they terminate in a mammillate summit, supported by a slightly constricted neck. In the tooth of the Hylœosaur the expanded summit is flattened, bent, and spear-shaped, with the edges blunted. But the breadth of the compressed crown is greatest in the subcompressed teeth of the extinct Cardiodon and the existing Iguanas, the teeth of which latter reptiles are further complicated by having the margins notched. The great Iguanodon had the crown of the tooth expanded both in length and breadth, and combined marginal dentations with longitudinal ridges; this tooth (fig. 42) presents the most complicated external form as yet discovered in the class of reptiles. In no reptiles does the base of the tooth ever branch into fangs.

Situation.

With respect to *situation*, the teeth may be present on

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[1] *Transactions of the Geological Society*, 2d series, vol. vii., p. 59.

[2] *Odontography*, pl. lxii. A, fig. 4.

[3] Ibid., fig. 60.

[4] Ibid., pl. lxv.

the jaws only,—viz., the maxillary, premaxillary, and mandibular bones, as in the crocodiles, and many lizards; or upon the jaws and roof of the mouth; and here, either upon the pterygoid bones, as in the Iguana and Mosasaur; or upon both palatine and pterygoid bones, as in most serpents; or upon the vomer, as in most Batrachians; or upon both vomerine and pterygoid bones, as in the Axolotl; or upon the vomerine and phenoid bones, as in the *Salamandra glutinosa*, Maclure. With respect to the marginal or jaw teeth, these may be absent in the premaxillary bones, as in many serpents; or they may be present in the upper and not in the lower jaw, as in most frogs; or in both upper and lower jaws, as in the tailed Batrachians; and among these they may be supported, upon the lower jaw, by the premandibular or dentary piece, as in the Salamander, Menopome, Amphiume, Proteus; or upon the splenial piece,[1] as in the Siren; or upon both the splenial and premandibular bones, as in the Axolotl. The palatine and pterygoid teeth may, in the Batrachians, be arranged in several rows, like the "dents en cardes" of fishes. The sphenoid and splenial teeth are always so arranged in the few species that possess them. The premaxillary, maxillary, and premandibular teeth are uniserial, or in one row, with the exception of the *Cæcilia*, and the extinct Labyrinthodonts, which have a double row of teeth at the anterior part of the lower jaw.

Attachment. As a general rule, the teeth of reptiles are anchylosed to the bone which supports them; when they continue distinct, they may be lodged either in a continuous groove, as in the Ichthyosaurs,[2] or in separate sockets, as in the Plesiosaurs and crocodiles (fig. 46).

The base of the tooth is anchylosed to the walls of a moderately deep socket in the extinct Megalosaur and Theocodon. In the Labyrinthodonts and Cæciliæ, among the Batrachians, in most Ophidians,—and in the Geckos, Agamians, and Varanians, among the Saurians,—the base of the tooth is imbedded in a shallow socket, and is confluent therewith. In the Scincoidians, the safeguards (*Tejus*) in most Iguanians, in the Chameleons, and most other lacertian reptiles, the tooth is anchylosed by an oblique surface, extending from the base, more or less, upon the outer side of the crown, to an external alveolar plate of bone,[3] the inner alveolar plate not being developed. In the frogs, the teeth are similarly but less firmly attached to an external parapet of bone. The lizards, which have their teeth thus attached to the side of the jaw, are termed "Pleurodont." In a few Iguanians, as the Istiures, the teeth appear to be soldered to the margins of the jaws; these have been termed "Acrodonts." In some large extinct Lacertians,—*e.g.*, the Mosasaur and Leiodon,—the tooth is fixed upon a raised conical process of bone, as shown in the author's "Odontography," plate 68, fig. 1; and plate 72, fig. 2.

These modifications of the attachment of the teeth of reptiles are closely adapted to the destined application of those instruments, and relate to the habits and food of the species: we may likewise perceive that they offer a close analogy to some of the transitory conditions of the human teeth. There is a period, for example,[4] when the primitive dental papillæ are not defended by either an outer or an inner alveolar process, any more than their calcified homologues, which are confluent with the margin of the jaw in the Rhynchocephalus.[5] There is another stage,[6] in which the groove containing the dental germs is defended by a single external cartilaginous alveolar ridge; this condition is permanently typified in the *Cyclodus*, and most existing lizards (fig. 41). Next, there is developed in the human embryo an internal alveolar plate, and the sacs and pulps of the teeth sink into a deep but continuous groove, in which traces of transverse partitions soon make their appearance: in the ancient Ichthyosaur the relation of the jaws to the teeth never advance beyond this stage. Finally, the dental groove is divided by complete partitions,[7] and a separate socket is formed for each tooth; and this stage of development is attained in the highest organized reptiles—*e.g.*, the crocodiles.

Substance. The tissues entering into the composition of reptilian teeth may be four-fold, and a single tooth may be composed of dentine, cement, enamel, and bone; but the dentine and cement are present in the teeth of all reptiles. In the Batrachians and Ophidians a thin layer of cement invests the central body of dentine, and, as usual, follows any inflections or sinuosities that may characterize the dentine. Besides the outer coat of cement, which is thickest at the base of the teeth, a generally thin coat of enamel defends the crown of the tooth in most Saurians, and the last remains of the pulp are not unfrequently converted into a coarse bone, both in the teeth which are anchylosed to the jaw, and in some teeth, as those of the Ichthyosaur, which remain free. The only modification of the dentine, which could at all entitle it to be regarded in the light of a new or distinct substance, is that which is peculiar in the present class to the teeth of the Iguanodon, and which will be presently described.

Structure. The varieties of dental structure are few in the reptiles, as compared with either fishes or mammals, and its most complicated condition arises from interblending of the dentinal and other substances, rather than from modifications of the tissues themselves. In the teeth of most reptiles, the intimate structure of the dentine corresponds with that which has been described as the type of the tissue,—*e.g.*, the hard or unvascular dentine,—and which is the prevailing modification in mammals, viz.,—the radiation of a system of minute plasmatic tubes from a single pulp-cavity, at right angles to the external surface of the tooth. The most essential modification of this structure is the intermingling of cylindrical processes of the pulp-cavity in the form of medullary canals, with the finer tubular structure.[8] Another modification is that in which the dentine maintains its normal structure, but is folded inwardly upon itself, so as to produce a deep longitudinal indentation on one side of the tooth. It is the expansion of the bottom of such a longitudinal deep fold that forms the central canal of the venom-fang of the serpent; but a glance at fig. 39 will show that, notwithstanding the singularly modified disposition of the dentine (*b*), its structure remains unaltered; and although the pulp-cavity (*p*) is reduced to the form of a crescentic fissure, the dentinal tubes continue to radiate from it according to the usual law. By a similar inflection of many vertical longitudinal folds of the external cement and external surface of the tooth, at regular intervals around the entire circumference of the tooth, and by a corresponding extension of radiated processes of the pulp-cavity and dentine into the interspaces of such inflected and converging folds, a modification of dental structure is established in certain extinct reptiles, which, by the various sinuosities of the interblended folds of cement, and processes of dentine, with the partial dilations of the radiated pulp-cavity, produces the complicated structure, which has been described at page 412, and figured in cut 12. But this complication is, nevertheless, referable to a modification of form or arrangement of the dental tissues, rather than of their number in the same tooth: the dentinal tubes in each

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[1] "Opercular bone" of Cuvier (in reptiles).

[2] *Odontography*, pl. xiii., fig. 9.

[3] Ibid., pl. lxvii.

[4] At the sixth week of gestation. See Prof. Goodsir "On the Development of the Human Teeth," *Edinburgh Medical and Surgical Journal*, No. 138.

[5] *Geological Transactions*, 2d Series, vol. vii., pt. ii., pl. vi., figs. 5 and 6, p. 83.

[6] At the seventh or eighth week. (Ibid.)

[7] At the sixth month. (Ibid.)

[8] *Odontography*, pl. lxxi., "Iguanodon."

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sinuous lobe of dentine in the most complex tooth of the *Labyrinthodon* exhibit the same general disposition and course as in the fang of the serpent, and in the still more simple tooth of the Saurian.

Development.

The teeth of reptiles are never completed, as in certain fishes, at the first or papillary stage; the pulp in all sinks into a follicle, and becomes inclosed by a capsule: in certain reptiles this becomes more or less surrounded by bone; but in the existing species the process of development never offers the "eruptive stage," in the sense in which this is usually understood, as signifying the extrication of the young tooth from a closed alveolus. The completion of a tooth, with the exception of the extinct dicynodont reptiles, is soon followed by preparation for its removal and succession: the faculty of developing new tooth-germs seems to be unlimited in the present class, and the phenomena of dental decadence and replacement are manifested at every period of life. The number of teeth is generally the same in each successive series, and the difference of size presented by the teeth of different and distinct series is considerable. The new germ is always developed, in the first instance, at the side of the base of the old tooth, never in the cavity of the base: the crocodiles form no exception to this rule. The poison-fangs of serpents succeed each other from behind forwards: in almost every other instance the germ of the successional tooth is developed from the bottom and towards the outer side of a small fissure in the mucous membrane or gum that fills up the shallow groove at the inside of the alveolar parapet and its adherent teeth; the papilla is soon enveloped by a capsular process of the surrounding membrane; a small enamel-pulp is developed in the matrix opposite the apex of the tooth; the deposition of the earthy salts in this mould is accompanied by ossification of the capsule, which afterwards proceeds *pari passu* with the calcification of the dentinal papilla or pulp; so that, with the exception of its base, the surface of the uncalcified part of the pulp alone remains normally unadherent to the capsule. As the tooth acquires hardness and size, it presses against the base of the contiguous attached tooth, causes a progressive absorption of that part (fig. 46, *a*), and finally undermines, displaces, and replaces its predecessor. The number of nascent matrices of the successional teeth is so great in the frog, and they are crowded so close together, that it is not unusual to find the capsules of contiguous tooth-germs becoming adherent together as their calcification proceeds. After a brief maceration, the soft gum may be stripped from the shallow alveolar depression, and the younger tooth-germs in different stages of growth are brought away with it.

The mode of development of the teeth of serpents does not differ essentially from that of the teeth of the Batrachians above described, except in the relation of the papillæ of the successional poison-fangs to the branch of the poison-duct that traverses the cavity of the loose mucous gum in which they are developed.

Batrachia.

The variations which the dental system presents in the Batrachian order of reptiles are more conspicuous in the number, situation, and structure of the teeth, than in their form or mode of attachment.

Certain Batrachians are edentulous, as the genus *Hylaplesia*, among the tree frogs, and the *Bufonidæ*, or family of toads—some of the species of *Bombinator* excepted.

The teeth, when present, are generally numerous, simple, of small and equal size, and close-set, either in a single row, or aggregated like the teeth of a rasp.

It is not without interest to observe, that a characteristic condition of the dental system in fishes—viz., the absence of teeth on the superior maxillary bone,—is continued in those genera of perennibranchiate Batrachians which stand at the lowest steps of the reptilian class.

In the Siren (*Siren lacertina*, Linn.), the lower margin of the intermaxillary bones, and the sloping anterior and upper margin of the lower jaw, are trenchant, and are each incased in a sheath of firm, albuminous, minutely fibrous tissue, harder than horn. The bones thus armed slide upon each other like the blades of a pair of curved scissors, when the mouth is closed, and are well adapted for dividing the bodies of small fish, aquatic larvæ, worms, &c. The splenial or opercular element in the jaw is beset with numerous minute pointed teeth, arranged in short oblique rows, and directed obliquely backwards. The palatal surface of the mouth presents on each side two flat, thin, and moderately broad bones, forming an apparently single oblique oval plate, which converges to meet its fellow at the anterior part of the palate, so as conjointly to constitute a broad rasp-like surface in the form of a chevron. The anterior long plate on each side of the divided vomer, supports six or seven oblique rows of small pointed retroverted teeth; the smallest posterior plate, probably the homologue of the pterygoid, is beset with four rows of similar teeth; there being thus ten or eleven rows on each side of the palatal chevron. The number of denticles in the middle rows is eleven or twelve; these become fewer in the anterior and posterior rows; they are all of similar size and form, corresponding with those of the lower jaw, to which they are opposed.

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The condition of the dental system in this, the lowest of the Batrachia is not without interest, independently of the absence of the superior maxillary teeth, and of the presence of the palatal and inferior maxillary rasp-teeth (*dents en cardes*). The maxillary sheaths of the Siren being composed of horn, and being, moreover, easily detached from the subjacent bones, closely resemble the deciduous mandibles of the tadpoles of the higher Batrachians.

The *Proteus anguinus*, though retaining its external gills, offers a further advance to the dental characters of the higher Batrachians. The alveolar border of each intermaxillary bone is armed with a row of eight or ten minute and fine sharp-pointed teeth; each premandibular bone supports a greater number of similar but larger teeth, likewise arranged in a single row. The vomerine bones support a row of denticles, similar, and parallel to, the intermaxillary crescentic series: but the horns of the palatine dental crescent are continued much farther back, and terminate, as in the *Menobranchus*, on the anterior part of the pterygoid bones; each half of the crescentic or chevron-shaped series contains twenty-four teeth. The superior maxillary bones are represented in the Proteus by mere cartilaginous rudiments.

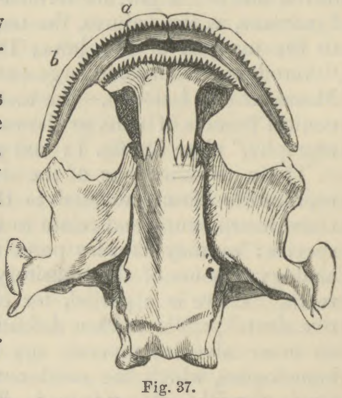

Fig. 37.
Cranium and Upper Jaw and Teeth of the Menopome. (*Menopoma alleghanniense*).

The Menopome makes a nearer approach to the caducibranchiate group, and allies itself most closely with the gigantic newt of Japan (*Sieboldtia*, Bonap.), and with that equally gigantic extinct species of newt so noted in Palæontology, as the "*Homo diluvii testis*" of Scheuchzer. The single close-set series of small, equal, conical, and slightly recurved teeth describes a semicircle on both the upper and the lower jaws; in the former the majority are supported by true maxillary bones *b*, about eight or ten on the premaxillaries *a*. The row of similar but smaller teeth on the anterior expanded border of the divided vomer *c* runs parallel with, and at a short distance behind, the median part of the maxillary series. The premandibular teeth are received into the narrow interspace

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between the two rows in the upper jaw when the mouth is closed. The teeth of the Menopome, as of the Amphiume are anchylosed by their base and part of the outer side to a slightly elevated external alveolar ridge.

Genus LABYRINTHODON.—The dental system in this extinct genus is more formidable than in any existing Batrachian, the teeth being implanted in distinct sockets, and a few of the anterior ones developed into large tusks (fig. 11).

A close-set series of subsequent teeth extends along the alveolar border of both upper and lower jaws, and along the anterior part of the outer margin of each broad vomerine bone. Both the division and dentigerous character of this bone exemplify the batrachian affinities of the reptiles in question. Two or three canine-shaped teeth, at least three times the size of the serial teeth, are placed in the premaxillary bones, also at the anterior and external angle of each vomer, at the fore-part of the maxillaries, and behind the anterior extremity of the serial teeth of the lower jaw. This allocation of teeth in a double row is peculiar, among reptiles, to the Cecilia and the present equally aberrant form of Batrachian: it is a common dental character in the class of fishes.

But the remarkable characteristic of the teeth of the Labyrinthodonts is the complex structure described in the general introduction, and illustrated in fig. 12. By this character the author, in 1841,[1] determined the nature of certain fossil teeth which had been found in a member of the New Red Sandstone series in Warwickshire, but which were of extreme rarity in that formation in England. The geological evidence at that period had left it uncertain whether this light-coloured sandstone was the equivalent of the "Keuper" or "Bunter" division of the German Trias.[2]

So far as the geological question depended upon the determination of the generic identity of the reptilian fossils in the English and German formations, it supported the view entertained by certain geologists as to the correspondence of the Warwick sandstones with the Keuper sandstones of Germany. And if, on the one hand, geology has in this instance derived any benefit from microscopical investigations of animal tissues, on the other hand it must be admitted, that in no instance has comparative anatomy been more directly indebted to geology than for the fossils, and the stimulus to their microscopic investigation, by means of which a knowledge has been obtained of the most beautiful and complicated modification of dental structure hitherto known, and of which no adequate conception could have been gained from investigations, however close and extensive, of the teeth of existing species of animals.

Ophidia.

The order *Ophidia*, as it is characterized in the system of Cuvier, requires to be divided into two sections, according to the nature of the food, and the consequent modification of the jaws and teeth. Certain species, which subsist on worms, insects, and other small invertebrate animals, have the tympanic pedicle of the lower jaw immediately and immovably articulated to the walls of the cranium. The lateral branches of the lower jaw are fixed together at the symphysis, and are opposed by the usual vertical movement to a similarly complete maxillary arch above; these belong to the genera *Amphisbæna* and *Anguis* of Linnæus, the latter represented by our common slow-worm. The rest of the Ophidians, including the ordinary serpents and constrictors, which form the typical members, and by far the greatest proportion of the order, prey upon living animals of frequently much greater diameter than their own; and the maxillary apparatus is conformably and peculiarly modified to permit of the requisite distension of the soft parts surrounding the mouth, and the transmission of their prey to the digestive cavity.

In the present article the description will be restricted to the dental peculiarities of the true serpents. All these subsist on animal matter, and swallow their food whole, whether they prey on living animals, as is the case in almost every species, or feed on the eggs of birds, as in the *Deirodon scaber*, O. (*Coluber scaber*, Linn.)

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With the exception of this and some congeneric species, in which the teeth of the ordinary bones of the mouth are so minute as to have been deemed wanting, the maxillary and premandibular bones in all true Ophidians are formidably armed with sharp-pointed teeth; there is on each side of the palate a row of similar teeth supported by the palatine and pterygoid bones. In the great Pythons, and some species of boa, the premaxillary bone also supports teeth. All the teeth, whatever be their position, present a simple conical form, the cone being long, slender, and terminated by an acute apex, and the tooth is either straight, or, more commonly, bent a little beyond the base, or simply recurved, or with a slight sigmoid flexure. The teeth are thus adapted for piercing, tearing, and holding, and not for dividing or bruising. In some species certain teeth are traversed by a longitudinal groove for conveying an acrid saliva into the wounds which they inflict; in others, two or more teeth are longitudinally perforated for transmitting venom; such teeth are called "poison-fangs" (fig. 38, *b*), and are always confined to the superior maxillaries, and are generally placed near the anterior extremity of those bones.

In the genus *Deirodon*, the teeth of the ordinary bones of the mouth are so small as to be scarcely perceptible, and they appear to be soon lost; so that it has been described as an edentulous serpent. An acquaintance with the habits and food of this species has shown how admirably this apparent defect is adapted to its wellbeing. Its business is to restrain the undue increase of the smaller birds by devouring their eggs. Now, if the teeth had existed of the ordinary form and proportions in the maxillary and palatal regions, the egg would have been broken as soon as it was seized, and much of its nutritions contents would have escaped from the lipless mouth of the snake in the act of deglutition; but, owing to the almost edentulous state of the jaws, the egg glides along the expanded opening unbroken, and it is not until it has reached the gullet, and the closed mouth prevents any escape of the nutritious matter, that the shell is exposed to instruments adapted for its perforation. These instruments consist of the inferior spinous processes of the seven or eight posterior cervical vertebræ, the extremities of which are capped by a layer of hard cement, and penetrate the dorsal parietes of the œsophagus. They may be readily seen, even in very young subjects, in the interior of that tube in which their points are directed backwards. The shell being sawed open longitudinally by these vertebral teeth, the egg is crushed by the contractions of the gullet, and is carried to the stomach, where the shell is no doubt soon dissolved by the acid gastric juice.

In the boa-constrictor, the teeth are slender, conical, suddenly bent backwards and inwards above their base of attachment, with the crown straight or very slightly curved, as in the posterior teeth. The premaxillary bone supports four small teeth; each superior maxillary bone has eight much larger ones, which gradually decrease in size as they are placed farther back. There are eight or nine teeth of similar size and proportions in each premandibular bone. These teeth are separated by wide intervals, from which other teeth similar to those in place have been detached. The base of each of the above teeth is extended transversely, compressed antero-posteriorly, and anchylosed to a shallow alveolus extending obliquely across the shallower alveolar groove. An affinity to the lizard tribes is manifested by the greater development of the outer as compared with the inner wall of the alveolar furrow.

The palatine teeth, of which there are three or four in each palatal bone, are as large as the superior maxillary ones, and are similarly attached. The pterygoid teeth, five or six in number, which complete the internal dental series on the roof of the mouth, are of smaller size, and gradually diminish as they recede backwards. In the interspaces of the fixed teeth in both these bones, the places of attachment of the shed teeth are always visible, so that the dental formula, if it included the vacated with the occupied sockets, would express a greater number of teeth than are ever in place and use at the same time. In the smaller species of boa, the premaxillary bone is edentulous. All the teeth have a lethal perfection of form for piercing. Their direction prevents the escape of the prey in which they are once fixed; while the separate and independent movement of each half of both upper and lower jaw, and of the dentigerous bones of the palate, allows of the different series of teeth being successively withdrawn and implanted in a more advanced position in the victim, which is thus gradually drawn into the gullet without the retaining force being unduly relaxed during any part of the engulphing process.

The Colubers, like other true serpents, have two longitudinal

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[1] *Proceedings of the Geological Society*, Jan. 20, 1841, No. xx., p. 257.

[2] *Geological Transactions*, 2d series, vol. v., p. 345.

rows of teeth on the roof of the mouth, extending along the palatines and pterygoids. The genus *Oligodon* appears to form the sole exception to this rule. In the *Dryinus nasutus*, M. Duvernoy has noticed a few small teeth on the transverse bone or external pterygoid, as well as on the internal pterygoid.

In certain genera of non-venomous serpents, as *Dryophis, Dipsas,* and *Bucephalus,* in which the superior maxillary teeth increase in size towards the posterior part of the bone, the large terminal teeth of the series are traversed along their anterior and convex side by a longitudinal groove. In the *Bucephalus capensis,* the two or three posterior maxillary teeth present this structure, and are much larger than the anterior teeth, or those of the palatine or premandibular series; they add materially, therefore, to the power of retaining the prey, and may conduct into the wounds which they inflict an acrid saliva, but they are not in connection with the duct of an express poison-gland. The long grooved fangs are either firmly fixed to the maxillary bones, or are slightly moveable, according to their period of growth; they are concealed by a sheath of thick and soft gum, and their points are directed backwards. The sheath always contains loose recumbent grooved teeth, ready to succeed those in place.

In most of the *Colubri* each maxillary and premandibular bone includes from twenty to twenty-five teeth; they are less numerous in the genera *Tortrix* and *Homalopsis,* and are reduced to a still smaller number in the poisonous serpents in the typical genera, of which the short maxillary bone supports only a single perforated fang.

The transition to these serpents, which was begun in the *Bucephali* and allied genera with grooved maxillary teeth, is completed by the poisonous serpents of the genera *Pelamis, Hydrophis, Elaps, Bungarus,* and *Hamadryas;* which latter genus, as its cervical integument can be expanded into a hood, constitutes an intermediate link between *Bungarus* and *Naja.*

Fig. 38.
Skull and Teeth of the Rattlesnake (*Crotalus durissus*).

The superior maxillary bone (fig. 38, *b*) diminishes in length with the decreasing number of teeth which it supports; the ectoe pterygoid bone elongates in ths same ratio, so as to retain itt position as an abutment againsd the shortened maxillary, and the muscles implanted into this ectopterygoid style communicate, through it, to the maxillary bone, the hinge-like movements backwards and forwards upon the ginglynoid articulations connecting that bone with the anterior frontal and palatal bones. As the fully-developed poison-fangs are attached by the same firm basal anchylosis to shallow maxillary sockets, which forms the characteristic mode of attachment of the simple or solid teeth, they necessarily follow all the movements of the superior maxillary bone. When the external pterygoid is retracted, the superior maxillary rotates backwards, and the poison-fang is concealed in the lax mucous gum with its point turned backwards; when the muscles draw forward the external pterygoid, the superior maxillary bone is pushed forwards, and the recumbent fang withdrawn from its concealment and erected.

In this power of changing the direction of a large tooth, so that it may not impede the passage of food through the mouth, we may perceive an analogy between the viper and the Lophius; but in the fish the movement is confined to the tooth alone, and is dependent on the mere physical property of the elastic medium of attachment; in the serpent, the tooth has no independent motion, but rotates with the jaw, whose movements are governed by muscular actions. In the fish, the great teeth are erect, except when pressed down by some extraneous force; in the serpent, the habitual position of the fang is the recumbent one, and its erection takes place only when the envenomed blow is to be struck.

A true idea of the structure of a poison-fang will be formed by supposing the crown of a simple tooth, as that of a boa, to be pressed flat, and its edges to be then bent towards each other, and soldered together so as to form a hollow cylinder open at both ends. The flattening of the fang, and its inflection around the poison-duct, commences immediately above the base, and the suture of the inflected margins runs along the anterior and convex side of the recurved fang: the poison canal is thus in front of the pulp-cavity. The basal aperture of the poison-canal is oblique, and its opposite outlet is more so, presenting the form of a narrow elliptical longitudinal fissure, terminating at a short distance from the apex of the fang.

The character most commonly adduced from the dental system, as distinguishing the venomous from the non-venomous serpents, is, that the former have two, the latter four, rows of teeth in the upper jaw, the two outer or maxillary rows being supplied by the single poison-fang. The exceptions to this rule are, however, too numerous for its value as a distinguishing character in a question of such practical moment as the venomous or non-venomous properties of a serpent. In all the family of marine serpents the poison-fang is only the foremost of a row of fixed maxillary teeth. In the *Hydrophis striatus, e.g.,* there are four teeth, and in the *Hydrophis schistosa* there are five teeth behind the venom-fang, of rather smaller size than it; the two-coloured sea-snake (*Pelamys bicolor*) has also five maxillary teeth in addition to the perforated one. The poison-fang in this genus is relatively smaller than in the venomous serpents of the land, but presents the same peculiar structure, and death has followed the wound it has inflicted. The poison-glands occupy the sides of the posterior half of the head: each consists of a number of elongated narrow lobes, extending from the main duct, which runs along the lower border of the gland, upwards and slightly backwards; each lobe gives off lobules throughout its extent, thus presenting a pinnatifid structure; and each lobule is subdivided into smaller secerning cæca, which constitute the ultimate structure of the gland.

The whole gland is surrounded by a double aponeurotic capsule, of which the outermost and strongest layer is in connection with the muscles by whose contraction the several cæca and lobes of the gland are compressed and emptied of their secretion. This is then conveyed by the duct to the basal aperture of the poison-canal of the fang. We may suppose that, as the analogous lacrymal and salivary glands in other animals are most active during particular emotions, so the rage which stimulates the venom-snake to use its deadly weapon must be accompanied with an increased secretion and great distension of the poison-glands; and, as the action of the compressing muscles is contemporaneous with the blow by which the serpent inflicts its wound, the poison is at the same moment injected with force into the wound from the apical outlet of the perforated fang.

The duct which conveys the poison, although it runs through the centre of a great part of the tooth, is really on the outside of the tooth—the canal in which it is lodged and protected being formed by a longitudinal inflection of the parietes of the pulp-cavity, or true internal canal of the tooth. This inflection commences a little beyond the base of the tooth, where its nature is readily appreciated, as the poison-duct there rests in a slight groove or longitudinal indentation on the convex side of the fang; as it proceeds, it sinks deeper into the substance of the tooth, and the sides of the groove meet and seem to coalesce, so that the trace of the inflected fold ceases in some species to be perceptible to the naked eye, and the fang appears, as it is commonly described, to be perforated by the duct in the poison-fang.

From the real nature of the poison-canal it follows, that the transverse section of the tooth varies in form in different parts of the tooth. At the base it is oblong, with a large pulp-cavity of a corresponding form, with an entering notch at the anterior surface; farther on, the transverse section presents the form of a horse-shoe, and the pulp-cavity that of a crescent, the horns of which extend into the sides of the deep cavity of the poison-fang; a little beyond this part the section of the tooth is crescentic, with the horns obtuse and in contact, so as to circumscribe the poison-canal; and along the whole of the middle four-sixths of the tooth, the section shows the dentine of the fang inclosing the poison-cavity, and having its own centre or pulp-cavity *p*, in the form of a crescentic fissure, situated close to the concave border of the inflected surface of the tooth. It is such a section of which a magnified view is given in fig. 39. The pulp-cavity disappears, and the poison-canal again assumes the form of a groove near the apex of the fang, and terminates on the anterior surface in an elongated fissure.

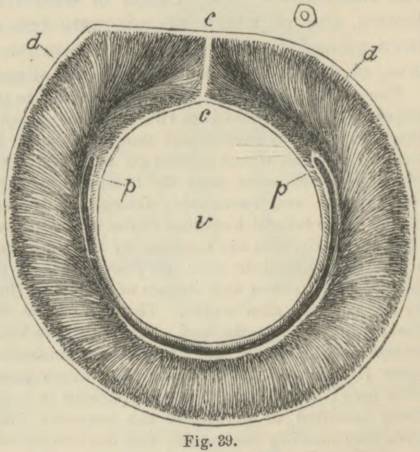

Fig. 39.
Transverse Section of the Poison-Fang of a Rattlesnake.

The venom-fangs of the viper, rattlesnake, and fer-de-lance are coated only with a thin layer of a subtransparent and minutely-cellular cement; the disposition of the calcigerous tubes is obedient to the general law of verticality to the external surface of the tooth: it is represented, as seen in a transverse section from the middle of the fang, in fig. 39. Since the inflected surface of the tooth can be exposed to no other pressure than that of the turgescent duct with which it is in contact, the tubes which proceed to that surface, *v*, while maintaining their usual relation of the right angle to it, are extremely short, and the layer of dentine separating the poison-tube from the pulp-cavity *p* is proportionably thin. The dentinal tubes that radiate from the opposite side of the pulp-cavity to the exposed surface of the tooth *d* are disproportionately long.

The teeth of all Ophidians are developed and completed in that which is the original seat of the tooth-germs in all animals—viz., the mucous membrane or gum covering the alveolar border of the dentigerous bones. This gum presents the same lax tissue, and is as abundantly developed, as in the pike, Lophius, and many other fishes, in which it likewise serves as the nidus and locality for the complete development of the teeth.

The primitive dental papilla in the common harmless snake very soon sinks into the substance of the gum, and becomes inclosed by a capsule. As soon as the deposition of the calcareous salts commences in the apex of the papilla, the capsule covering that part becomes ossified and adherent to the dentine, and the tooth begins to pierce and emerge from the gums before its mould, the pulp, is half completed. Fresh layers of cells are successively added to the base of the pulp, and converted by their confluence and calcification into the tubular dentine, until the full size of the tooth is attained, when its situation in the gum is gradually changed, and its base becomes anchylosed to the shallow cavity of the alveolar surface of the bone.

In the posterior part of the large mucous sheath of the poison-fang, the successors of this tooth are always to be found in different stages of development: the pulp is at first a simple papilla, and when it has sunk into the gum, the succeeding portion presents a depression along its inferior surface, as it lies horizontally with the apex directed backwards. The capsule adheres to this inflected surface of the pulp; and the introduction of the duct of the poison-gland is completed by the extension of the borders of the inflected pulp around that tube.

Lacertia.

Among the inferior or squamate Saurians (lizards, monitors, iguanas) there are two leading modifications in the mode of attachment of the teeth, the base of which may be either anchylosed to the summit of an alveolar ridge, or to the bottom of an alveolar groove, and supported by its lateral wall; these modifications are indicated by the terms "acrodont" and "pleurodont." A third mode of fixation is presented by some extinct Saurians, which in other parts of their organization adhere to the squamate or lacertine division of the order,—the teeth being implanted in sockets, either loosely or confluent with the bony walls of the cavity: these may be termed the "thecodont"[1] Lacertians. Most of the ancient triassic and permian Saurians belong to this group.

Varanidæ.

In the crocodilian monitor-lizard (*Varanus crocodilinus*), the large fixed compressed teeth, of which there may be about seven in each upper maxillary bone, and six in each premandibular, are anchylosed by the whole of their base, and by an oblique surface leading upwards on the outer side of the tooth to a slight depression on the oblique alveolar surface, as in the variety called *striatus*. In this monitor the base of the tooth is finely striated, the lines being produced by inflected folds of the external cement, as in the Ichthyosaur and Labyrinthodon, but being short and straight, as in those of the former genus.

The alveolar channel or groove has scarcely any depth; but the anchylosed base of the tooth is applied to an oblique surface, terminating in a sharp edge, from which the outer side of the free crown of the tooth is directly continued. The great *Varanus*, like the variegated species, manifests its affinity to the Crocodilians in the number of successive teeth which are in progress of growth to replace each other; but from the position in which the germs of the successional teeth are developed, the more advanced teeth in this species, as in the variety *variegatus*, do not exhibit the excavation that characterizes the same parts of the teeth of the Enaliosaurs and crocodile.

Dinosauria.

The compressed piercing and trenchant form of tooth which characterizes the varanian lizards was anciently manifested by a gigantic extinct Saurian, of which the remains were discovered by the late Dr Buckland in the oolitic slate of Stonesfield, near Oxford. These remains have been examined by the writer in the geological museum of that university. The specimen which is most illustrative of the dental peculiarities is a portion of the lower jaw with a few teeth. The first character which attracts the attention of the anatomist in this fossil is the inequality in the height of the outer and inner alveolar walls. This assures him of the saurian affinities of the gigantic reptile, a similar inequality characterizing the jaws of almost all the existing lizards. But in these the oblique groove, so bounded, to which the bases of the developed teeth are anchylosed, is much more shallow, and is relatively wider; and the teeth in all the stages of growth are completely exposed when the gum has been removed.

Megalosaurus.

In the great oolitic carnivorous lizard, which its discoverer has called *Megalosaurus*, the greater relative development of the inner alveolar wall, as compared with the dentigerous part of the jaw in existing Saurians, narrows the dental groove, and covers a greater proportion of the bases of the teeth, besides concealing more or less completely the germs of their successors. Moreover, instead of the mere shallow impressions upon the inner side of the outer alveolar plate to which the teeth are attached in modern lizards, there are distinct sockets formed by bony partitions connecting the outer with the inner alveolar wall in the jaw of the Megalosaurus. These partitions rise from the outer side of the inner alveolar wall in the form of triangular vertical plates of bone, and from the middle of the outer side of each plate a bony partition crosses to the outer parapet, completing the alveoli of the fully-formed or more advanced teeth; the series of triangular plates forming a kind of zig-zag buttress along the inner side of those alveoli. The outer parapet rises an inch higher than the inner one.

Of the fully-developed teeth, only one has been preserved *in situ* in the specimen under description; the others appear rather to have slipped out than to have been broken off, the anchyloses of the basal capsule of the tooth to the alveolar periosteum being but slight, and apparently taking place tardily, in the Megalosaurus.

Fig. 40 exhibits a portion of another jaw of the *Megalosaurus*, also from Stonesfield oolite, from which the inner wall has been removed

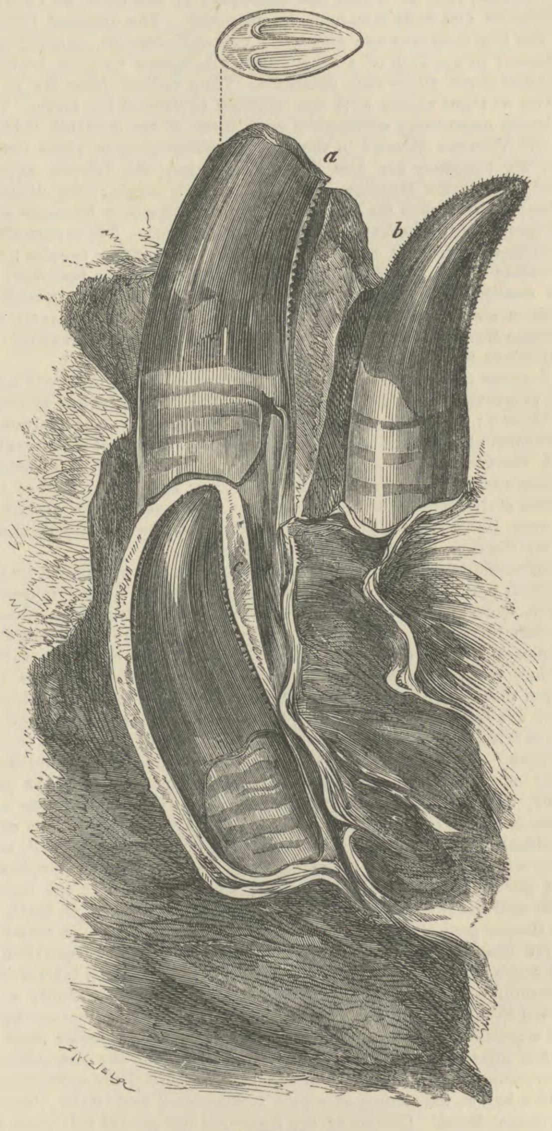

Fig. 40.
Section of Jaw with Teeth of the *Megalosaurus Bucklandi*, nat. size.

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[1] Θηκη, *a sheath*; οδȣς, *a tooth*.

to show the germ of a successional tooth *c*, about to succeed an old tooth *a*, which has been broken, and near to which is a newly-formed tooth coming into place *b*. These teeth well exemplify the shape of the crown of the tooth, which is subcompressed, slightly recurved, sharp-edged, and sharp-pointed, the edges being minutely serrated; the edge upon the convex or front border *b* becomes blunted as it descends about two-thirds of the way towards the base of the tooth; that upon the concave hinder border *a* is continued to the base. The lower half of the crown is thicker towards the fore margin than towards the hind one; so that a transverse section, like that above (*a*, in fig. 40), gives a narrow oval form pointed behind. At the upper half of the crown the sides slope more equally from the middle thickest part to both margins, and the section is a narrow pointed ellipse. The crown is covered by a smooth and polished enamel, which wholly forms the marginal serrations. The base of the tooth is coated with a smooth, lighter-coloured cement, forming a thin layer, and becoming a little thicker towards the implanted end of the tooth. The remains of the pulp are converted into osteodentine in the basal part of the completely formed tooth. Moderately magnified, the surface of the enamel presents a finely-wrinkled appearance. The marginal serrations show, under a somewhat higher power, that the points are directed towards the apex of the tooth—a structure well adapted for dividing the tough tissues of the saurian integument.

The main body of the tooth consists of dentine, of that hard unvascular kind of which the same part of the teeth of existing crocodiles and most mammals is composed. The dentinal tubules in the Megalosaurus are extremely fine and close-set, presenting a diameter of $\frac{1}{28000}$th of an inch, with interspaces varying between two and three times that diameter. They radiate from the pulp-cavity at right angles with the external surface of the tooth. The primary curvatures correspond with those of the dentinal tubules in the Varanus (figured in the author's *Odontography*, plate lxvii., fig. 2), but they are less marked; so that the tubules appear straighter in the Megalosaurus. After their origin, they dichotomize sparingly, but the number of minute secondary branches sent off into the intermediate substance is very great. These secondary branches proceed at acute angles from the primary tubules; the divisions of the latter become very frequent near the periphery of the dentine, and the terminal branches dilate into, or inosculate with, a stratum of minute calcigerous cells, which separates the dentine from the enamel.[1] No part of the dentine is pervaded by medullary canals, as in the Iguanodon.

A series of teeth from individual Megalosauri, of different ages, are preserved in the British Museum and in the geological museum at Oxford; although differing in size, they preserve the characteristic form above described. In one specimen the point of the crown and the trenchant margins have been rubbed down to a smooth obtuse surface; it seems to have come from the hinder part of the dental series, where the teeth may have been smaller and less sharp, or more liable to be blunted by a greater share in the imperfect act of mastication, than the teeth in advance.

Successional teeth in different stages of growth are shown in the original portion of jaw of the Megalosaurus in the Oxford museum. Some, more advanced, show their crowns projecting from alveoli already formed by the plates extending across from the triangular processes before described. Vacant sockets, from which fully-formed teeth have escaped, occur, generally in the intervals between these more advanced teeth. The summits of less developed teeth are seen protruding at the inner side of the basal interspaces of the triangular plate, between them and the true internal alveolar parapet. There can be no doubt that, in the course of the development of these teeth, corresponding changes take place in the jaw itself, by which new triangular plates and alveolar partitions are formed, as the old ones become absorbed, analogous to those concomitant changes in the growth and form of the teeth, alveoli, and jaws which take place in so striking a degree in the elephant. The peculiarity of the Megalosaurus, as compared with the crocodiles and lizards, which have a like endless succession of teeth, is the deeper position of the successional tooth (fig. 40, *c*), in relation to the one (*a*) it is destined to replace, and the great proportion of the tooth which is formed before it is protruded. This interesting character is well exhibited in the portion of the jaw kindly submitted to the author's examination by the late Duke of Marlborough, and a portion of which is shown in fig. 40. The anterior tooth *a* in this specimen shows at the inner side of its base the commencing absorption stimulated by the encroaching capsule of the successional tooth *c* below, the crown of which is completed externally, though not consolidated. On one of the fractured margins of this piece of jaw, a part of the basal shell of an absorbed and shed tooth remains, with part of the root of the successional tooth, which has risen into place, but which shows its base full of matrix, the pulp not having been calcified at that period of the tooth's growth.

In the proportion of the successional teeth which is formed in the formative cavity in the substance of the jaw, the Megalosaurus offers a closer resemblance to the mammalian class than do any of the recent or extinct crocodilian or lacertian reptiles. But the evidence of uninterrupted and frequent succession of the teeth in the Megalosaurus is unequivocal; and this part of the dental economy of the great carnivorous reptile is strictly analogous to that which governs the same system in the existing members of the class. The different forms of the teeth at different stages of protrusion did not fail to attract the attention of the gifted discoverer of the Megalosaurus, in whose words this notice of its dentition may be fitly concluded:—

"In the structure of these teeth we find a combination of mechanical contrivances analogous to those which are adopted in the construction of the knife, the sabre, and the saw. When first protruded above the gum, the apex of each tooth presented a double cutting edge of serrated enamel. In this stage its position and line of action were nearly vertical; and its form, like that of the two-edged point of a sabre, cutting equally on each side. As the tooth advanced in growth, it became curved backwards in the form of a pruning-knife, and the edge of serrated enamel was continued downwards to the base of the inner and cutting side of the tooth, whilst on the outer side a similar edge descended, but a short distance from the point; and the convex portion of the tooth became blunt and thick, as the back of a knife is made thick for the purpose of producing strength. The strength of the tooth was further increased by the expansion of its side. Had the serrature continued along the whole of the blunt and convex portion of the tooth, it would in this position have possessed no useful cutting power; it ceased precisely at the point beyond which it could no longer be effective. In a tooth thus formed for cutting along its concave edge, each movement of the jaw combined the power of the knife and saw; whilst the apex, in making the first incision, acted like the two-edged point of a sabre. The backward curvature of the full-grown teeth enabled them to retain, like barbs, the prey which they had penetrated, In these adaptations we see contrivances which human ingenuity has also adopted in the preparation of various instruments of art."[2]

Iguanidæ.

The lizards of the Iguanian family are characterized by a short contractile tongue, slightly notched at its extremity, but are distinguished for the most part by having teeth on the pterygoid bone, and also by the complicated form of the crown of the maxillary teeth in the typical genera, the species of which subsist chiefly on vegetable substances. In most of the Iguanians the teeth are lodged in a common shallow, oblique, alveolar groove, and are soldered to excavations on the inner surface of the outer wall of the groove.

In the pleurodont Iguanians, the teeth never present the true laniary form; and if simply conical, as at the extremes of the maxillary series, the cone is more or less obtuse; but in general it is expanded, more or less trilobate, or dentated along the margins of the crown.

The dentition of the Basilisks differs little from that of the Iguanæ. The posterior teeth are rather trilobate than tricuspid; the anterior ones are small, circular, pointed, and slightly curved. There are generally from five to six conical teeth on each pterygoid bone; but in the mitred Basilisk there are twelve teeth in each of these rows.

The *Amblyrhynchus*, a genus which is somewhat remarkable for the marine habits of at least one of the species (*Amblyrhynchus ater*), whose diet is sea-weed, has the tricuspid structure well developed in the posterior teeth.

The typical genus of the present family of Saurians is characterized by the crenate or dental margin of the crown of the maxillary and premandibular teeth, a few of the anterior small ones excepted. The pterygoid teeth are arranged in two or three irregular rows, resembling somewhat the *dents en cardes* of fishes.

In the full-grown horned Iguana (*Metopoceros cornutus*, Dum.), there are about fifty-six teeth in both the upper and lower jaws, of which the four first are conical and slightly recurved; the twelve succeeding teeth are somewhat larger in size, with more compressed and expanded crowns; the rest are triangular, compressed, with dentated margins. The inner surface of the crown of the tooth is simply convex and smooth, the outer surface traversed by a median longitudinal, broad, obtuse ridge. Fig. 41 gives a view of these teeth on the inner side of the lower jaw: *a*, the teeth in place, anchylosed to the outer parapet of the alveolar groove; *b*, the germ

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[1] The microscopic characters of the tooth of the Megalosaurus are represented in the *Odontography*, pl. lxx. A, in part of a transverse section of the middle of the crown, including the pulp-cavity and its osteo-dentine.

[2] Buckland, *Bridgewater Treatise*, vol. i., p. 237.

of a successional tooth; *c*, a tooth more advanced, and rising into place. The base of the older teeth soon begins to be sapped by the absorbent process excited by the pressure of the capsules of their successors. In the common as in the horned iguana there is a single row of small teeth implanted in each pterygoid bone; but no iguanian lizard has teeth on the palatine bones.

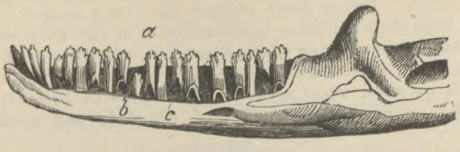

Fig. 41.
Lower Jaw and Teeth of an Iguana (*Metopoceros cornutus*).

The pulp-cavity in old teeth becomes occupied by a coarse bone, characterized by large irregularly-shaped calciferous cells; and the interspaces are filled with irregular moss-like reticulations of tubes. Branches of the pulp-cavity are never continued in the form of medullary canals into the substance of the dentine in the existing Iguanæ.

The germs of the successional teeth (*b*, fig. 41), are developed from the mucous membrane covering the inner side of the base of those in place. The apex of the dentated crown is first formed; by its pressure it excites absorption of the base of the fixed tooth, and soon undermines it, and then occupies the recess in the alveolar plate in the interspace of the two adjoining fixed teeth. After the crown is completed, the rest of the tooth forms a contracted and elongated fang, which at first is hollow, then becomes consolidated by ossification of the remaining pulp *c*, and is afterwards a second time excavated by the pressure of a new tooth.

Dinosauria.

Iguanodon.

The value of a knowledge of the comparative anatomy of the teeth, and especially of their external characters, in the cold-blooded classes of animals, has never, perhaps, been placed in so striking a point of view as in the leading steps to the discovery of the present most extraordinary and gigantic reptile. The detached teeth and bones of the *Iguanodon*, successively discovered in the Wealden strata of Sussex, and afterwards found associated together to the extent of nearly half the skeleton of one and the same individual, in the greensand of Kent, offer not the least marvellous or significant evidences of the inhabitants of the now temperate latitudes during the later secondary periods of the formation of the earth's crust.

With vertebræ, subconcave at both articular extremeties, having, in the dorsal region, lofty and expanded neural arches, and doubly articulated ribs, and characterized in the sacral region by their unusual number and complication of structure; with a Lacertian pectoral arch, and unusually large bones of the hind limbs, excavated by large medullary cavities, and adapted for terrestrial progression;—the *Iguanodon* was distinguished by teeth, resembling in shape those of the Iguana, but in structure differing from the teeth of that and every other known reptile, and unequivocally indicating the former existence in the Dinosaurian order of a gigantic representative of the small group of living lizards which subsist on vegetable substances.

The important difference which the fossil teeth presented in the form of their grinding surface was pointed out by Cuvier,[1] of whose description Dr Mantell adopted a condensed view in his *Illustrations of the Geology of Sussex*, 4to, 1827, p. 72. The combination of this dental distinction with the vertebral and costal characters, which prove the *Iguanodon* not to have belonged to the same group of Saurians as that which includes the Iguana and other modern lizards, rendered it highly desirable to ascertain by the improved modes of investigating dental structure, the actual amount of correspondence between the *Iguanodon* and Iguana in this respect. This has been done in the author's general description of the *teeth of reptiles*,[2] from which the following notice is abridged :—

The teeth of the *Iguanodon* (fig. 42), though resembling most closely those of the Iguana, do not present an exact magnified image of them, but differ in the greater relative thickness of the crown, its more complicated external surface, and, still more essentially, in a modification of the internal structure, by which the *Iguanodon* equally deviates from every other known reptile.

As in the Iguana, the base of the tooth is elongated and contracted; the crown expanded and smoothly convex on the inner side; when first formed it is acuminated, compressed, its sloping sides serrated, and its external surface traversed by a median longitudinal ridge, and coated by a layer of enamel; but beyond this point the description of the tooth of the *Iguanodon* indicates characters peculiar to that genus. In most of the teeth that have hitherto been found, three longitudinal ridges traverse the outer surface of the crown, one on each side of the median primitive ridge; these are separated from each other and from the serrated margins of the crown by four wide and smooth longitudinal grooves. The relative width of these grooves varies in different teeth; sometimes a fourth small longitudinal ridge is developed on the outer side of the crown. The marginal serrations which, at first sight, appear to be simple notches, as in the Iguana, present under a low magnifying power (fig. 43), the form of transverse ridges, themselves notched, so as to resemble the mammilated margins of the unworn plates of the elephant's grinder; slight grooves lead from the interspaces of these notches upon the sides of the marginal ridges. These ridges or dentations do not extend beyond the expanded part of the crown; the longitudinal ridges are continued farther down, especially the median ones, which do not subside till the fang of the tooth begins to assume its subcylindrical form. The tooth at first increases both in breadth and thickness; then it diminishes in breadth, but its thickness goes on increasing; in the larger and fully formed teeth, the fang decreases in every diameter, and sometimes tapers almost to a point. The smooth unbroken surface of such fangs indicates that they did not adhere to the inner side of the maxillæ, as in the Iguana, but were placed in separate alveoli, as in the Crocodile and Megalosaur; such support would appear, indeed, to be indispensable to teeth so worn by mastication as those of the *Iguanodon*.

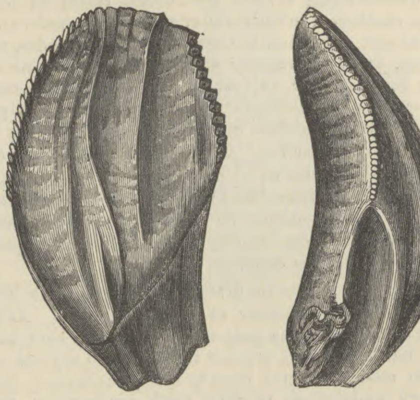

Fig. 42.
Front and side views of a Tooth of the Iguanodon, nat. size.

Fig. 43
Marginal ridges on the Tooth of the Iguanodon, magn.

The apex of the tooth soon begins to be worn away, and it would appear, by many specimens, that the teeth were retained until nearly the whole of the crown had yielded to the daily abrasion. In these teeth, however, the deep excavation of the remaining fang plainly bespeaks the progress of the successional tooth prepared to supply the place of the worn-out grinder. At the earlier stages of abrasion a sharp edge is maintained at the external part of the tooth by means of the enamel which covers that surface of the crown; the prominent ridges upon that surface give a sinuous contour to the middle of the cutting edge, whilst its sides are jagged by the lateral serrations. The adaptation of this admirable dental instrument to the cropping and comminution of such tough vegetable food as the *Clathrariœ* and similar plants, which are found buried with the *Iguanodon*, is pointed out by Dr Buckland, with his usual felicity of illustration, in his *Bridgewater Treatise*, vol. i., p. 246.

When the crown is worn away beyond the enamel, it presents a broad and nearly horizontal grinding surface (fig. 44). and now another dental substance is brought into use, to give an inequality to that surface; this is the ossified remnant of the pulp, which, being firmer than the surrounding dentine, forms a slight transverse ridge in the middle of the grinding surface: the tooth in this stage has exchanged the functions of an incisor for that of a molar, and is prepared to give the final compression, or comminution, to the coarsely divided vegetable matters.

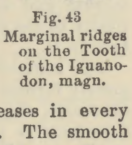

Fig. 44.
A worn Tooth of the Iguanodon.

The marginal edge of the incisive condition of the tooth and the median ridge of the molar stage are more effectually established by the introduc-

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[1] *Ossemens Fossiles*, 1824, vol. v., pt. ii., p. 351.

[2] *Odontography*, pt. ii., p. 249; *Transactions of the British Association*, 1838.

tion of a modification into the texture of the dentine, by which it is rendered softer than in the existing Iguanæ and other reptiles, and more easily worn away. This is effected by an arrest of the calcifying process along certain cylindrical tracts of the pulp, which is thus continued, in the form of medullary canals, analogous to those in the soft dentine of the Megatherium's grinder, from the central cavity, at pretty regular intervals, parallel with the dentinal tubes, nearly to the surface of the tooth. The medullary canals radiate from the internal and lateral sides of the pulp-cavity, and are confined to the dentine forming the corresponding walls of the tooth. Their diameter is $\frac{1}{1\cdot250}$th of an inch. They are separated by pretty regular intervals equal to from six to eight of their own diameters. They sometimes divide once in their course. Each medullary canal is surrounded by a clear space. Its cavity was occupied in the section described by a substance of a deeper yellow colour than the rest of the dentine.

The dentinal tubes present a diameter of $\frac{1}{25,000}$th of an inch, with interspaces equal to about four of their diameters. At the first part of their course, near the pulp-cavity, they are bent in strong undulations, but afterwards proceed in slight and regular primary curves, or in nearly straight lines to the periphery of the tooth. The secondary undulations of each tooth are regular, and very minute. The branches, both primary and secondary, of the dentinal tubes are sent off from the concave side of the main inflections; the minute secondary branches are remarkable at certain parts of the tooth for their flexuous ramifications, anastomoses, and dilatations into minute calcigerous cells, which take place along nearly parallel lines for a limited extent of the course of the main tubes. The appearance of interruption in the course of the dentinal tubes, occasioned by this modification of their secondary branches, is represented by the irregularly dotted tracts in the figure. This modification must contribute, with the medullary canals, though in a minor degree, in producing that inequality of texture and of density in the dentine, which renders the broad and thick tooth of the *Iguanodon* more efficient as a triturating instrument.

The enamel which invests the harder dentine, forming the outer side of the tooth, presents the same peculiar dirty brown colour, when viewed by transmitted light, as in most other teeth. Very minute and scarcely perceptible undulating fibres, running vertically to the surface of the tooth, form the only discernible structure in it.

The remains of the pulp in the contracted cavity of the completely formed tooth are converted into a dense but true osseous substance, characterized by minute elliptical radiated cells, whose long axis is parallel with the plane of the concentric lamellæ, which surround the few and contracted medullary canals in this substance.

The microscopical examination of the structure of the *Iguanodon's* teeth thus contributes additional evidence of the perfection of their adaptation to the offices to which their more obvious characters had indicated them to have been destined.

To preserve a trenchant edge, a partial coating of enamel is applied; and, that the thick body of the tooth might be worn away in a more regularly oblique plane, the dentine is rendered softer as it recedes from the enamelled edge, by the simple contrivance of arresting the calcifying process along certain tracts of the inner wall of the tooth. When attrition has at length exhausted the enamel, and the tooth is limited to its function as a grinder, a third substance has been prepared in the ossified remnant of the pulp to add to the efficiency of the dental instrument in its final capacity. And if the following reflections were natural and just, after a review of the external characters of the dental organs of the *Iguanodon*, their truth and beauty become still more manifest as our knowledge of their subject becomes more particular and exact:—

"In this curious piece of animal mechanism we find a varied adjustment of all parts and proportions of the tooth, to the exercise of peculiar functions, attended by compensations adapted to shifting conditions of the instrument during different stages of its consumption. And we must estimate the works of nature by a different standard from that which we apply to the productions of human art, if we can view such examples of mechanical contrivance, united with so much economy of expenditure, and with such anticipated adaptations to varying conditions in their application, without feeling a profound conviction that all this adjustment has resulted from design and high intelligence."[1]

Dicynodon. The existing species of lizard differ from those of the crocodile in the anchylosed condition of the teeth, which present few modifications of importance; those that yield most fruit to physiology, and which have most expanded our ideas of the extent of the resources and exceptional deviations from what was deemed the rule of structure in the Saurian dentition, have been discovered by the study of the fossil teeth of extinct forms of the order. Amongst these the most extraordinary, in respect of their dental system, have been recently discovered in a probably "Permian" formation in South Africa. These fossil reptiles have been termed "Dicynodonts," from their dentition being reduced to one long and large canine tooth on each side of the upper jaw, and these teeth impart, at first sight, a character to the jaws like that which the long poison-fangs give, when erected, to the jaws of the rattlesnake. Fig. 45 is a reduced side view of the skull and teeth of the *Dicynodon lacerticeps*. The maxillary bone is excavated by a wide and deep alveolus, with a circular area of half an inch, and lodges a long and strong, slightly curved, and sharp-pointed canine tooth or tusk *c*, which projects about two-thirds of its length from the open extremity of the socket. The direction of the tusks is forwards, downwards, and very slightly inwards; the two converging in the descent along the outer side of the compressed symphysis of the lower jaw. The tusk is principally composed of a body of compact unvascular dentine. The base is excavated by a wide conical pulp-cavity, with the apex extending to about one-half of the implanted part of the tusk, and a linear continuation extending along the centre of the solid part of the tusk. From this central line the dentinal tubes radiate, with a gentle curve at the beginning, convex towards the point of the tusk, and then proceeding straight to the periphery of the tooth, but inclining towards the apex. They present parallel secondary curves, divide dichotomously twice or thrice near their beginning, and send off numerous small lateral branches, chiefly from the side next the apex. At their primary curve the dentinal tubes are $\frac{1}{12000}$th of an inch in diameter, and their intervals are $\frac{1}{6000}$th of an inch across. The dentinal cells are most conspicuous near the periphery of the tooth, and vary in diameter from $\frac{1}{800}$th to $\frac{1}{1000}$th of an inch.

Fig. 45.
Skull and Tusks of *Dicynodon lacerticeps*.

The enamel, at least at the middle of the tusk, is thinner than in the teeth of the crocodile. It presents only a finely lamellated texture, the layers being parallel with the surface of the dentine on which it rests. There is only a fine linear trace of cement on the exterior of the sections of the implanted base of the tusks; and here it is too thin to allow of the development of the radiated cells in its substance. There is no trace of teeth or their sockets in the lower jaw,[2] so much of the alveolar border as is exposed presents a smooth and even edge, which seems to have played like a scissor-blade upon the inner side of the corresponding edentulous border of the upper jaw; and it is most probable, from the analogies of similarly-shaped jaws of existing reptilia, that the fore-part of both the upper and under jaws were sheathed with horn.

Until the discovery of the Rhynchosaurus, this edentulous and horn-sheathed condition of the jaws was supposed to be peculiar to the chelonian order among reptiles; and it is not one of the least interesting features of the Dicynodonts of the African sandstones, that they should repeat a chelonian character hitherto peculiar amongst Lacertians, to the above-cited remarkable extinct edentulous genus of the new red sandstone of Shropshire; but our interest rises almost to astonishment, when, in a saurian skull, we find, superadded to the horn-clad mandibles of the tortoise, a pair of tusks, borrowed, as it were, from the mammalian class, or rather foreshadowing a structure which, in the existing creation, is peculiar to certain members of the highest organized warm-blooded animals.

Crocodilia. *Crocodilia.*—The ancient writers on natural history appear to have been much struck with the great number of teeth in the crocodile; and their descriptions were exaggerated to the tone of the impressions thus produced. Thus, according to Achilles Tatius, the crocodile had as many teeth as there were days in the year.

How many teeth a crocodile may develop through the whole course of its life in uninterrupted succession, will never, perhaps, be determined; they then would doubtless far exceed in number the liberal allowance of Tatius; but with regard to those teeth which are in use in the jaws at any given time, the number is now

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[1] Buckland's *Bridgewater Treatise*, vol. i., p. 249.

[2] δις, two, *κυνόδους*, canine tooth.

Teeth of Reptiles.

well established—*e.g.*, the crocodile of the Nile has $\frac{17—17}{16—16}=66$; that of the West Indies (*Crocodilus acutus*) has $\frac{17—17}{16—16}=66$; the common aligator (*Aligator lucius*), has $\frac{20—20}{18—18}=76$. The great gavial or garrhial (*Gavalis Gangeticus*) has $\frac{30—30}{20—20}=778$. Thus the different species and genera of crocodiles differ from each other in the number of teeth, and also the individuals differ within small limits.

The best and most readily recognisable characters by which the existing Crocodilians are grouped in appropriate genera are derived from modifications of the dental system.

In the caimans (genus *Alligator*) the teeth vary in number from $\frac{18—18}{18—18}$ to $\frac{22—22}{22—22}$; the fourth tooth of the lower jaw or canine, is *received into a cavity* of the palatal surface of the upper jaw, where it is concealed when the mouth is shut; in old individuals the upper jaw is perforated by these large inferior canines, and the fossæ are converted into foramina.

In the true crocodiles (genus *Crocodilus*) the first tooth in the lower jaw perforates the palatal process of the intermaxillary bone when the mouth is closed; the fourth tooth in the lower jaw is *received into a notch* excavated in the side of the alveolar border of the upper jaw, and is visible externally when the mouth is closed.

In the two preceding genera the alveolar borders of the jaws have an uneven or wavy contour, and the teeth are of unequal size.

In the gavials (genus *Gavialis*) the teeth are nearly equal in size and similar in form in both jaws, and the first as well as the fourth tooth in the lower jaw passes into a groove in the margin of the upper jaw, when the mouth is closed.

The number of teeth is always greater in the gavials than in the crocodiles or alligators. The first five pairs of teeth above are supported by the premaxillary bones; the first, second, and fourth of the lower jaw are the longest.

The eight or nine posterior teeth are nearly conical, the rest are sub-compressed antero-posteriorly, and present a trenchant edge on the right and left side, between which a few faint longitudinal ridges traverse the basal part of the enamelled crown (fig. 46).

The position of the opposite sharp ridges, and the direction of the flat sides of the crown, are reversed in the extinct crocodile (*Croc. cultridens*), which in other respects most nearly resembles the gavial in the form of the teeth.

In most of the extinct species of Crocodilians the teeth are characterized by more numerous and strongly developed longitudinal ridges upon the enamelled crown, than in the recent species; and they are commonly longer, more slender, and sharp-pointed. But in one of the crocodiles with sub-biconcave vertebræ (*Goniopholis crassidens*), from the Wealden formation and Purbeck limestone, the teeth have crowns which are as round and as thick in proportion to their length as in the recent crocodiles or alligators.

Fig. 46.
Teeth of the Gavial.

The more ancient crocodiles, from the Oolite and Lias, called *Steneosauri* and *Teleosauri*, had jaws like those of the modern gavials, but sometimes longer and more attenuated, and armed with more numerous, equal, and slender teeth, adapted for the capture of fishes, which appear to have been the only other vertebrate animals existing at those periods in numbers sufficient to yield subsistence to carnivorous marine Saurians.

In all the *Teleosauri* the teeth are more slender, less compressed, and sharper pointed than in the gavial; they are slightly recurved, and the enamelled crown is traversed by more numerous and better defined ridges—two of which, on opposite sides of the crown, are larger and more elevated than the rest. The fang is smooth, cylindrical, and always excavated at the base. The teeth of the *Steneosauri*, or extinct crocodiles with long and slender jaws, and with vertebræ sub-concave at both extremities, but with subterminal nostrils, differ from those of the *Teleosauri* in being somewhat thicker in proportion to their length, and larger in proportion to the jaws.

The teeth of both the existing and extinct crocodilian reptiles consist of a body of compact dentine, forming a crown covered by a coat of enamel, and a root invested by a moderately thick layer of cement. The root slightly enlarges or maintains the same breadth to its base (fig. 46, *a*), which is deeply excavated by a conical pulp-cavity extending into the crown, and is commonly either perforated or notched at its concave or inner side.

In the black alligator of Guiana, the first fourteen teeth in the lower jaw are implanted in distinct sockets. The remaining posterior teeth are lodged close together in a continuous groove, in which the divisions for sockets are faintly indicated by vertical ridges, as in the jaws of the Ichthyosaurus.

Teeth of Reptiles.

A thin compact floor of bone separates this groove and the sockets anterior to it (fig. 47) from the large cavity of the ramus of the jaw. It is pierced by blood-vessels for the supply of the pulps of the growing teeth and the vascular dentigerous membrane which lines the alveolar cavities.

The tooth-germ *c* (fig. 47) is developed from the membrane covering the angle between the floor and the inner wall of the socket. It becomes, in this situation, completely enveloped by its capsule, and partially calcified, before the young tooth penetrates the interior of the pulp-cavity of its predecessor.

Fig. 47.
Section of Jaw with Teeth of the Alligator.

The matrix of the young growing tooth affects, by its pressure, the inner wall of the socket, as shown in fig. 47, and forms for itself a shallow recess, at the same time it attacks the side of the base of the contained tooth; then, gaining a more extensive attachment by its basis and increased size, it penetrates the large pulp-cavity of the previously formed tooth either by a circular or semicircular perforation. The size of the perforation in the tooth, and of the depression in the jaw, proves them to have been in great part caused by the soft matrix, which must have produced its effect by exciting absorbent action, and not by mere mechanical force. The resistance of the wall of the pulp-cavity having been thus overcome, the growing tooth and its matrix recede from the temporary alveolar depression, and sink into the substance of the pulp contained in the cavity of the fully-formed tooth.

As the new tooth grows, the pulp of the old one is removed; the old tooth itself is next attached, and the crown, being undermined by the absorption of the inner surface of its base, may be broken off by a slight external force, when the point of the new tooth is exposed, as in figs. 46 and 47, *b*.

The new tooth disembarrasses itself of the cylindrical base of its predecessor (fig. 47, *a*) with which it is sheathed, by maintaining the excitement of the absorbent process so long as the cement of the old fang retains any vital connection with the periosteum of the socket; but the frail remains of the old cylinder, thus reduced, are sometimes lifted out of the socket upon the crown of the new tooth (as in fig. 46, *a*), when they are speedily removed by the action of the jaws. This is, however, the only part of the process which is immediately produced by violence; an attentive observation of the more important previous stages of growth, teaches that the pressure of the growing tooth operates upon the one to be displaced only through the medium of the vital absorbent action which it has excited.

Most of the stages in the development and succession of the teeth of the crocodiles are described by Cuvier with his wonted clearness and accuracy; but the mechanical explanation of the expulsion of the old teeth, which Cuvier adopts from M. Tenon, is opposed by the disproportion of the hard part of the new tooth to the vacuity in the walls of the old one, and by the fact that the matter impressing, viz., the uncalcified part of the tooth matrix, is less dense than the part impressed.

No sooner has the young tooth (fig. 46, *b*) penetrated the interior of the old one (fig. 46, *a*) than another germ *c*, begins to be developed from the angle between the base of the young tooth and the inner alveolar process; or in the same relative position as that in which its predecessor began to rise, and the processes of succession and displacement are carried on uninterruptedly throughout the long life of these cold-blooded carnivorous reptiles.

From the period of exclusion from the egg, the teeth of the crocodile succeed each other in the vertical direction; none are added from behind forwards like the true molars in Mammalia. It follows, therefore, that the number of the teeth of the crocodile is as great when it first sees the light as when it has acquired its full size; and, owing to the rapidity of their succession, the cavity at the base of the fully-formed tooth is never consolidated.

The fossil jaws of the extinct Crocodilians demonstrate that the same law regulated the succession of the teeth at the ancient epochs when those highly-organised reptiles prevailed in greatest numbers, and under the most varied generic and specific modifications, as at the present period, when they are reduced to a single family composed of so few and slightly varied species as to have constituted in the system of Linnæus a small fraction of the genus *Lacerta*.

Teeth of Mammals.

Sect. III.—TEETH OF MAMMALS.

Number.

The class *Mammalia*, like that of *Reptilia* and *Pisces*, includes a few genera and species that are devoid of teeth; the true ant-eaters (*Myrmecophaga*), the scaly ant-eaters, or Pangolins (*Manis*), and the spiny monotrematous ant-eater (*Echidna*), are examples of strictly edentulous Mammals. The *Ornithorhynchus* has horny teeth, and the whales (*Balæna* and *Balænoptera*) have transitory embryonic calcified teeth (fig. 59), succeeded by whalebone substitutes (fig. 58), in the upper jaw. Horny processes analogous to, perhaps homologous with, the lingual and palatal teeth in fishes, are present in the *Echidna.* The female Narwhal seems to be edentulous, but has the germs of two tusks in the substance of the upper jaw-bones (fig. 62); one of these becomes developed into a large and conspicuous weapon in the male Narwhal (fig. 62, A), and accordingly suggested to Linnæus the name, for its genus, of *Monodon*, meaning single tooth. But the tusk is never median, like the truly single tooth on the palate of the Myxine; and occasionally both tusks are developed in the Narwhal. In another Cetacean—the great Bottle-nose or *Hyperoodon*—the teeth are reduced in the adult to two in number (fig. 61), whence the specific name, *H. bidens;* but they are confined to the lower jaw. The sharp-nosed dolphin (*Ziphius*) has also but two teeth, one in each ramus of the lower jaw; and this is perhaps a sexual character.

The *Delphinus griseus* has five teeth on each side of the lower jaw; but they soon become reduced to two. Amongst the Marsupial animals, the genus *Tarsipes* is remarkable for the paucity as well as minuteness of its teeth. The Elephant has never more than one entire molar, or parts of two, in use on each side of the upper and lower jaws, to which are added two tusks, more or less developed, in the upper jaw.

Some Rodents, as the Australian water-rats (*Hydromys*), have two grinders on each side of both jaws, which, added to the four cutting teeth in front, make twelve in all; the common number of teeth in this order is twenty; but the hares and rabbits have twenty-eight teeth. The Sloth has eighteen teeth. The number of teeth, thirty-two, which characterizes man, the apes of the old world, and the true Ruminants, is the average one of the class Mammalia; but the typical number is forty-four.

The examples of excessive number of teeth are presented, in the order *Bruta*, by the Priodont Armadillo, which has ninety-eight teeth; and in the Cetaceous order by the Cachalot, which has upwards of sixty teeth, though most of them are confined to the lower jaw; by the common porpoise, which has between eighty and ninety teeth; by the Gangetic dolphin, which has one hundred and twenty teeth; and by the true dolphins (*Delphinus*), which have from one hundred to one hundred and ninety teeth, yielding the maximum number in the class *Mammalia.*

Where the teeth are in excessive number, as in the species above cited, they are small, equal, or sub-equal, and of a simple conical form; pointed, and slightly recurved in the common dolphin; with a broad and flattened base in the Gangetic dolphin; with the crown compressed, and broadest in the porpoise; compressed, but truncate, and equal with the fang, in the Priodon. The compressed triangular teeth become coarsely notched or dentated at the hinder part of the series in the great extinct cetaceous *Zeuglodon.* The simple dentition of the smaller Armadillos, of the Orycterope, and of the three-toed Sloth, presents a difference in the size, but little variety in the shape of the teeth, which are subcylindrical, with broad triturating surfaces; in the two-toed Sloth, the two anterior teeth of the upper jaw are longer and larger than the rest, and adapted for piercing and tearing.

Teeth are fixed, as a general rule, in all *Vertebrata*, and the only known exceptions are those presented by certain species of fishes; *e. g.*, the Sharks, Lophioids, Goniodonts. In the higher Vertebrata the movements of the teeth depend on those of the jaw-bones to which they are affixed, but appear to be independent in the ratio of the size of the tooth to the bone to which it is attached. Thus the extent of rotatory movement to which the large perforated poison-fangs of the rattle-snake are subject, depends upon the rotation of the small maxillary bone; so, likewise, the seemingly individual movements of divarication and approximation observable in the large lower incisors of the *Bathyergus* and *Macropus*,[1] are due entirely to the yielding nature of the symphysis uniting the two rami of the lower jaw, in which those incisors are deeply and firmly implanted.

In man, where the premaxillaries early coalesce with the maxillary bones, where the jaws are very short, and the crowns of the teeth are of equal length, there is no interspace or "diastema" in the dental series of either jaw, and the teeth derive some additional fixity by their close apposition and mutual pressure. No inferior Mammal now presents this character; but its importance, as associated with the peculiar attributes of the human organization, has been somewhat diminished by the discovery of a like contiguous arrangement of the teeth in the jaws of a few extinct quadrupeds; *e. g.*, *Anoplotherium*, *Nesodon*, and *Dichodon*.

Development

The teeth in the Mammalia, as in the foregoing classes, are formed by superaddition of the hardening salts to pre-existing moulds of animal pulp or membrane, organized so as to insure the arrangement of the earthy particles according to that pattern which characterizes each constituent texture of the tooth.

The complexity of the primordial basis, or matrix, corresponds, therefore, with that of the fully-formed tooth, and is least remarkable in those conical teeth which consist only of dentine and cement. The primary pulp, which first appears as a papilla rising from the free surface of the alveolar gum, is the part of the matrix which, by its calcification, constitutes the dentine. In the simple teeth, the secondary, or enamel pulp, covers the dentinal pulp like a cap; in the complex teeth it sends processes into depressions of the coronal part of the dentinal pulp, which vary in depth, breadth, direction, and number, in the different groups of the herbivorous and omnivorous quadrupeds. The dentinal pulp, thus penetrated, offers corresponding complications of form; and, as the capsule follows the enamel pulp in all its folds and processes, the external cavities or interspaces of the dentine become occupied by enamel and cement—the cement, like the capsule which formed it, being the outermost substance, and the enamel being interposed between it and the dentine. The dental matrix presents the most extensive interdigitation of the dentinal and enamel pulps in the Capybara and Elephant. The matrix of the mammalian tooth sinks into a furrow, and soon becomes inclosed in a cell in the substance of the jaw-bone, from which the crown of the growing tooth extricates itself by exciting the absorbent process, whilst the cell is deepened by the same process, and by the growth of the jaw, into an alveolus for the root of the tooth. Where the formative parts of the tooth are reproduced indefinitely, to repair, by their progressive calcification, the waste to which the working surface of the crown of the tooth has been sub-

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[1] See Mason Good's *Book of Nature*, vol. i. p. 285. 1826.

ject, the alveolus is of unusual depth, and of the same form and diameter throughout, except in the immature animal, when it widens to its bottom or base. In teeth of limited growth, the dentinal pulp is reproduced in progressively decreasing quantity after the completion of the exterior wall of the crown, and forms, by its calcification, one or more roots or fangs, which taper, more or less rapidly, to their free extremity. The alveolus is closely moulded upon the implanted part of the tooth; and it is worthy of special remark, that the complicated form of socket which results from the development of two or more fangs, is peculiar to animals of the class *Mammalia.*

In the formation of a single fang, the activity of the reproductive process becomes enfeebled at the circumference, and is progressively contracted within narrower limits in relation to a single centre, until it ceases at the completion of the apex of the fang, which, though for a long time perforated for the admission of the vessels and nerves to the interior of the tooth, is, in many cases, finally closed by the ossification of the remaining part of the capsule.

When a tooth is destined to be implanted by two or more fangs, the reproduction of the pulp is restricted to two or more parts of the base of the coronal portion of the pulp, around the centre of which parts the sphere of its reproductive activity is progressively contracted. The intervening parts of the base of the coronal pulp adhere to the capsule, which is simultaneously calcified with them, covering those parts of the base of the crown of the tooth with a layer of cement. The ossification of the surrounding jaw, being governed by the changes in the soft but highly organized dental matrix, fills up the spaces unoccupied by the contracted and divided pulp, and affords, by its periosteum, a surface for the adhesion of the cement or ossified capsule covering the completed part of the tooth.

The matrix of certain teeth does not give rise, during any period of their formation, to the germ of a second tooth, destined to succeed the first. This, therefore, when completed and worn down, is not replaced; all the true *Cetacea* are limited to this simple provision of teeth. In the Armadillos, Megatherioids, and Sloths, the want of germinative power, as it may be called, in the matrix, is compensated by the persistence of the matrix, and by the uninterrupted growth of the teeth. In most other Mammalia, the matrix of the first developed tooth gives origin to the germ of a second tooth, which sometimes displaces, sometimes takes its place by the side of, its predecessor and parent. All those teeth which are displaced by their progeny are called temporary, deciduous, or milk teeth (fig. 17, *d i-d*, 4). The mode and direction in which they are displaced and succeeded, viz., from below upwards in the lower jaw, in both jaws vertically, are the same as in the crocodile; but the process is never repeated more than once in any mammiferous animal. A considerable proportion of the dental series is thus changed; the second, or permanent teeth (fig. 17, *i* 1-*p*, 4), having a size and form as suitable to the jaws of the adult as the displaced temporary teeth were adapted to those of the young animal.

The permanent teeth (fig. 17, *m* 1-*m*, 3), which assume places not previously occupied by deciduous ones, are always the most posterior in their position, and generally the most complex in their form. The successors of the deciduous incisors and canines differ from them chiefly in size. The successors of the deciduous molars may differ likewise in shape, in which case they have always less complex crowns than their predecessors. The "bicuspids" in human anatomy, and the corresponding teeth called "premolars" in the lower mammals, illustrate this law.

The Mammalian class might be divided, in regard to the succession of the teeth, into two groups—the *Monophyodonts*,[1] or those that generate but one set of teeth, and the *Diphyodonts*,[2] or those that generate two sets of teeth. The Monophyodonts include the *Cetacea* and the *Bruta* (*Edentata* of Cuvier); all the other orders are Diphyodonts.

Form. The teeth of the Mammalia, especially of the Diphyodonts, have usually so much more definite and complex a form than those of fishes and reptiles, that three parts are recognised in them, viz. the "fang," the "neck," and the "crown." The fang or root (*radix*) is the inserted part; the crown (*corona*) is the exposed part; and the constriction which divides these is called the neck (*cervix*). The term "fang" is properly given only to the implanted part of a tooth of restricted growth, which fang gradually tapers to its extremity; those teeth which grow uninterruptedly have not their exposed part separated by a neck from their implanted part, and this generally maintains to its extremity the same shape and size as the exposed crown.

Fixation. It is peculiar to the class Mammalia to have teeth implanted in sockets by two or more fangs; but this can only happen to teeth of limited growth, and generally characterizes the molars and premolars; perpetually growing teeth require the base to be kept simple and widely excavated for the persistent pulp (figs. 54 and 55). In no mammiferous animal does anchylosis of the tooth with the jaw constitute a normal mode of attachment. Each tooth has its particular socket, to which it firmly adheres by the close co-adaptation of their opposed surfaces, and by the firm adhesion of the alveolar periosteum to the organized cement which invests the fang or fangs of the tooth.

Situation. True teeth implanted in sockets are confined, in the Mammalian class, to the maxillary, premaxillary, and mandibular or lower maxillary bones, and form a single row in each. They may project only from the premaxillary bones, as in the Narwhal, or only from the lower maxillary bone, as in Ziphius; or be apparent only in the lower maxillary bone, as in the Cachalot; or be limited to the superior and inferior maxillaries, and not present in the premaxillaries, as in the true Ruminants and most *Bruta.*

Substance. The teeth of the Mammalia usually consist of hard unvascular dentine, defended at the crown by an investment of enamel, and everywhere surrounded by a coat of cement. The coronal cement is of extreme tenuity in Man, Quadrumana, and terrestrial Carnivora; it is thicker in the Herbivora, especially in the complex grinders of the Elephant, and is thickest in the teeth of the Sloth, Megatherium, Dugong, Walrus, and Cachalot. Vertical folds of enamel and cement penetrate the crown of the tooth in the Ruminants, and in most Rodents and Pachyderms, characterizing by their various forms the genera of the last two orders; but these folds never converge from equidistant points of the circumference of the crown towards its centre. The teeth of the quadrupeds of the order *Bruta* (*Edentata*, Cuv.) have no true enamel; this is absent likewise in the molars of the Dugong and the Cachalot. The tusks of the Narwhal, Walrus, Dinotherium, Mastodon, and Elephant, consist of modified dentine, which, in the last two great proboscidian animals, is properly called "ivory," and is covered by cement.

Kinds. The Dolphins and Armadillos present little variety in the shape of the teeth in the same animal, and this

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[1] μόνος, once; φύω, I generate; οδους, tooth.

[2] δις, twice; φύω, and οδους.

Teeth of Mammals.

sameness of form is characteristic of most of the Monophyodonts, in which, therefore, the teeth are not divisible into distinct kinds.

In almost all the other Mammalia, particular teeth have special forms for special uses: thus, the front teeth, from being commonly adapted to effect the first coarse division of the food, have been called cutters or *incisors;* and the back teeth, which complete its comminution, grinders or *molars;* large conical teeth, situated behind the incisors, and adapted by being nearer the insertion of the biting muscles, to act with greater force, are called holders, tearers, laniaries, or more commonly *canine* teeth, from being well developed in the dog and other Carnivora, although they are given, likewise, to many vegetable feeders for defence or combat; *e. g.*, Musk-deer. Molar teeth, which are adapted for mastication, have either tuberculate, or transversely rigid, or flat summits, and usually are either surrounded by a ridge of enamel, or are traversed by similar ridges arranged in various patterns. Certain molars in the Dugong, the Mylodon, and the Zeuglodon, are so deeply indented laterally by opposite longitudinal grooves, as to appear, when abraded, to be composed of two cylindrical teeth cemented together, and the transverse section of the crown is bilobed. The teeth of the *Glyptodon* were fluted by two analogous grooves on each side. The large molars of the Capybara and Elephant have the crown cleft into a numerous series of compressed transverse plates, cemented together side by side. The modifications of the crown of the molar teeth are those that are most intimately related to the kind of food of the animal possessing them. Thus, in the purely carnivorous mammals, the molars are simple, trenchant, and play upon each other like scissor-blades. In the mixed feeding species, the working surface of the molars becomes broader and tuberculated; in the insectivorous species it is bristled with sharp points; and in the purely herbivorous kinds, the flat grinding surface of the teeth is complicated by folds and ridges of the enamel entering the substance of the tooth, the most complex forms being presented by the Elephants.

Ornithorhynchus.

The substances serving for teeth in the anomalous Duck-mole or Platypus of Australia, are of a horny texture, consisting of close-set, vertical hollow tubes, resembling the outer compact tissue of baleen or "whalebone." They are eight in number, four in the upper, and as many in the under jaw. The anterior tooth of the upper jaw (fig. 48, *a*) is extended from behind forwards, but is low, very narrow, and four-sided; the broadest side forms the base of attachment, and is slightly concave; the outer and inner facets converge to a serrated edge in the young *Ornithorhynchus*, but becomes worn in the old animal, and forms the fourth side of the tooth. The corresponding tooth in the lower jaw is rather narrower, and retains longer its trenchant edge.

Fig. 48.
Jaws and Teeth of the Platypus, (*Ornithorhynchus paradoxus*).

At a distance from the anterior tooth, equal to its own length, is situated the horny molar (*b*), which consists of a flattened plate of an oblong subquadrate figure. A slightly raised margin includes two large concave surfaces, a little elevated above the intervening part of the grinding surface. The corresponding tooth in the lower jaw is somewhat narrower, but of similar form. Each division or tubercle of the molar is separately developed, and they become confluent in the course of growth. According to the analysis of Lassaigne, 99·5 parts of the dental tissue of the Ornithorhynchus have the composition of horn; this is hardened by 0·3 parts of phosphate of lime.

Teeth of Mammals.

The notice of the dental apparatus of the Monotremes ought to include mention of the two short and thick conical processes which project from the forepart of the raised intermolar portion of the tongue, in the *Ornithorhynchus;* which, like the more numerous spines on the corresponding part of the tongue of the Echidna, represent, in these low-organized mammals, the lingual teeth of fishes.

Order Bruta.

The teeth of the Orycterope, or Cape Ant-eater, are of a simple form, but peculiar structure; their common number in the mature animal is $\frac{7}{6}\cdot\frac{7}{6}=26$ (fig. 49, *A*), and they all belong to the molar series.

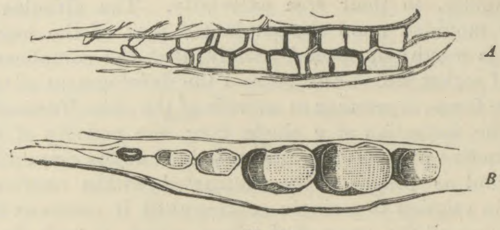

Fig. 49.
Teeth of the Cape Ant-eater, (*Orycteropus.*)

The anterior teeth are very small, and are not unfrequently wanting, or are concealed by the gum, especially the first in the upper jaw; the second tooth of the upper jaw is small, compressed, and obtuse; it opposes a similar one in the lower jaw; the third and fourth molars increase in size, have an elliptical transverse section, and a triturating surface of two facets (fig. 49, *B*); the fourth and fifth molars are the largest in the upper jaw, are of equal size, and have a longitudinal depression in their internal and external sides, giving their transverse section a bilobed or hour-glass figure; the seventh molar is smaller and has the same simple figure as the fourth, (fig. 49, *B*). The proportions of these teeth, the depth of their sockets, and their structure, as viewed in longitudinal section with the naked eye, are shown in fig. 50. The teeth are continued solid, and of the same dimensions, to the bottom of the socket, and terminate by a truncate and undivided base. If each be viewed as an aggregate of teeth, as partially shown in fig. 15, it will be found that the component denticle has its base excavated by a conical pulp-cavity, as in other animals, and which is persistent, as in the rest of the order *Bruta*. The wide inferior apertures of these pulp-cavities constitute the pores observable on the base of the compound tooth of the Orycterope, and give to that part a close resemblance to the section of a cane. The canals to which these pores lead are the centres of radiation of the calciferous tubes of the denticle, (fig. 15); such denticles are cemented together laterally, slightly decreasing in diameter, and occasionally bifurcating as they approach the grinding surface of the tooth. The substance of the entire tooth thus resembles the teeth of the *Myliobates* and *Chimæroids* among fishes, rather than any true teeth in the Mammalian class, in which it offers a transitional step from the horny substitutes of teeth above described to the true teeth.

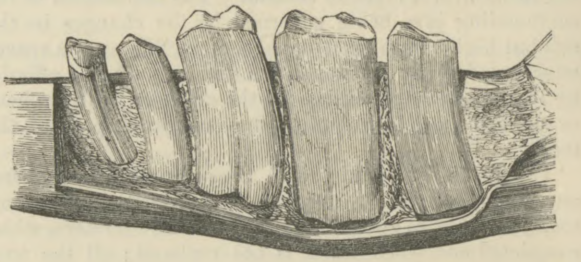

Fig. 50
Section of Lower Jaw and Teeth of the *Orycteropus*. Nat. size.

The teeth of the *Orycteropus*, when rightly understood, offer, however, no anomaly or exceptional condition in their mode of development. Each denticle is developed according to the same laws, and by as simple a matrix as those larger teeth in other mammals, which consist only of dentine and cement. The dentine is formed by ossification of the capsule; both pulp and capsule continue to be reproduced at the bottom of the alveolus, *pari passu* with the attrition of the exposed crown; and the mode and time of growth being alike in each denticle, the whole compound tooth is maintained throughout the life of the animal. The augmentation in the size of the whole tooth, during the growth of the jaw, is effected by the development of new denticles, and a slight increase of size in the old ones, at the base of the growing tooth, which, in the progress of attrition and growth, becomes its grinding surface.

Genus Dasypus.

The teeth of the Armadillo-tribe are harder than those of any other species of the order *Bruta;* but, as in all that order provided with teeth, they are wholly devoid of enamel. They consist, in

Teeth of Mammals.

both existing and extinct Armadillos, of three distinct substances, of which the unvascular dentine is present in greatest proportion, and forms the main body of the tooth; but it includes a small central axis of vascular dentine, and is surrounded by an extremely thin coating of cement. The teeth are more numerous in the Priodon—the largest of the existing Armadillos—than in any other land mammal; but they are of very small size and simple form, and are all referable to the molar series (fig. 51). They vary in number from twenty-four to twenty-six in each upper jaw, and from twenty-two to twenty-four on each side of the lower jaw, amounting to from ninety-four to one hundred in total number. They are compressed laterally, increasing in size, and especially in breadth, as they recede backwards, with oblique or horizontal flat grinding surfaces, and are continued of the same size and form to their implanted extremity, which is excavated by a large conical pulp-cavity. This absence of roots, and the undivided hollow base indicative of the constant growth of the tooth, are common not only to the teeth of the Armadillos, but to those of all the known species of the order *Bruta*.

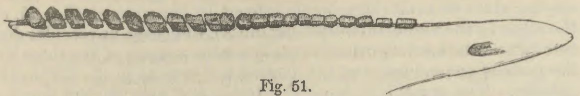

Fig. 51.

Teeth of the Lower Jaw of the Great Armadillo, (*Priodon gigas*).

In the Priodont the teeth, though so unusually numerous, are many of them separated by slight intervals; those of the lower jaw oppose their outer sides to the inner sides of the upper teeth when the mouth is shut.

The Armadillos of the sub-genus *Euphractus*, Wagler, to which the term *Dasypus* is restricted by F. Cuvier, are distinguished by having the anterior tooth (fig. 52, *i*), which is shaped like the succeeding molar, implanted in the premaxillary bone. The two anterior teeth of the lower jaw being in advance of the premaxillary tooth, are, with it, arbitrarily held to be incisors; they are compressed, but are terminated by obtuse crowns. The rest of the series, from which the incisors are not separated by any remarkable interval, gradually increase in size to the penultimate molar; they have the same alternate position and obliquely-worn grinding surfaces as in the *Tatusiæ*.

Fig. 52.

Jaw teeth of the weasel-headed Armadillo, (*Dasypus 6-cinctus*).

Some species of the extinct loricate genus, *Glyptodon*, surpassed the Rhinoceros in size, and the dentition of the genus was more complicated, and more adapted to a vegetable diet, than that of the small existing Armadillos. The total number of teeth in the Glyptodon has not yet been determined. A fragment of the anterior part of the lower jaw shows that the teeth extend close to the symphysis, and therefore indicates their presence in the premaxillary bones above.

The single tooth (fig. 53), on which the generic character of the Glyptodon was founded,[1] is long, rootless as in the existing Armadillos, but compressed laterally, and divided by two deep angular, longitudinal, and opposite grooves on each side, into three plates, which give the grinding surface the form of as many rhomboidal lobes. In the Glyptodon the osteo-dentine (fig. 53, *o*) occupies a larger proportion of the centre of the tooth than in the small Armadillos; it is harder than the dentine (*d*) or cement (*c*), and rises upon the grinding surface, in the form of a ridge extending along the middle of the long axis of that surface, and in three shorter ridges at right angles to the preceding, at the middle of each of the three rhomboidal divisions of the tooth.

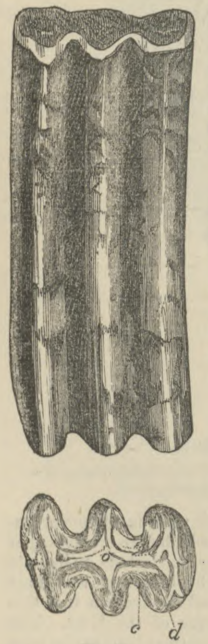

Fig. 53.

Tooth of great extinct Armadillo, (*Glyptodon clavipes*).

Sloths.

Of the leaf-eating species of the order *Bruta*, very few, and these the most diminutive of the tribe, now exist. They are called Sloths, or Tardigrades, from their inability to move otherwise than slowly and with difficulty on the ground; but they are excellent climbers, for which their organization especially befits them.

Teeth of Mammals.

The following are the common and constant characters of the dentition of the phyllophagous *Bruta*, both recent and extinct:—Teeth implanted in the maxillary and mandibular bones, few in number, not exceeding $\frac{5}{4}:\frac{5}{4}$; composed of a large central axis of vaso-dentine, with a thin investment of hard dentine, and a thick outer coating of cement. To these, of course, may be added the dental characters common to the order *Bruta*, viz., uninterrupted growth of the teeth, and their concomitant implantation by a simple, deeply-excavated base, not separated by a cervix from the exposed summit or crown.

The dental formula of the genus Bradypus is—$i\ \frac{0}{0}$; $c\ \frac{0}{0}$; $m\ \frac{5}{4}:\frac{5}{4}=18$. Dr Brandt[2] has described and figured the skull of a young Ai, in which a very small tooth preceded the compressed one on each side of the lower jaw, rendering the number of teeth equal to that in the upper jaw. In the two-toed sloth (*Cholœpus didactylus*, Illig.) the teeth (fig. 54) offer a greater inequality of size than has yet been observed in any other genus of *Bruta*; the first of each series, *a*, in both jaws, which in the rest of the order is the smallest, here so much exceeds the others as, with its peculiar form, to have received the name of a canine. This tooth is separated by a marked interval from the other teeth, especially in the upper jaw, so that those above play upon the anterior part of those below, contrary to the relative position and mutual action of the true canine teeth in the *Quadrumana* and *Carnivora*. They are of a triedral form, with the margins of the oblique abraded surface leading to the point, trenchant. The second tooth of the upper jaw (*b*) is the smallest of the series. The third (*c*) and fourth (*d*) molars are a little larger, and have two abraded surfaces which converge to the median ridge. The fifth molar (*e*) is the smallest, and has an oblique grinding surface. In each tooth the ridge is formed by the hard dentine, and is interrupted in the middle by an excavation of the soft dentine. The second, third, and fourth teeth of the lower jaw correspond in size and shape with the third and fourth above; and like the small upper molars, are separated by short intervals; the last is the smallest and most curved.

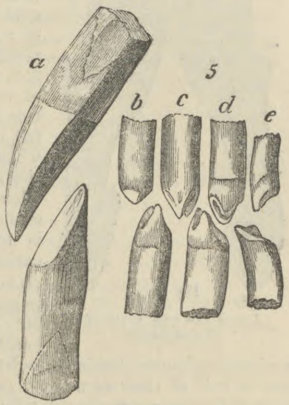

Fig. 54.

Teeth of the two-toed Sloth (*Cholœpus, didactylus*).

The teeth of the Sloths consist of a central axis of vaso-dentine (fig. 9, *v*), occupying rather more than half the thickness of the tooth, which is inclosed by a wall of unvascular dentine (*d*), and this by one of cement (*c*) of less thickness than the layer of hard dentine.

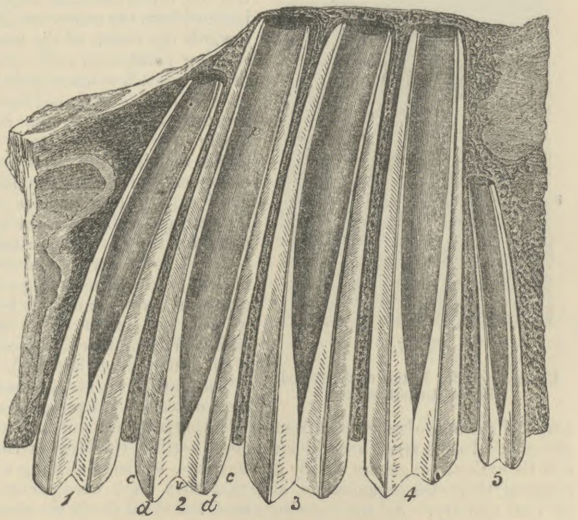

Fig. 55.

Section of Upper Jaw and Teeth of the Megatherium. One-third nat. size.

The teeth of the *Megatherium*, the most gigantic of the extinct

Megatherium.

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[1] *Geological Transactions*, 2d Series, vol. vi. p. 81-85.

[2] *Dissertatio Zoologica inauguralis de Tardigradis*, 4to, 1828, p. 31, pl. 2, figs. 5 and 6.

Teeth of Mammals.

quadrupeds of the Sloth tribe, are five in number on each side of the upper jaw (fig. 55), and four on each side of the lower jaw (fig. 56). They are more closely arranged, and longer, and more deeply implanted, than in the smaller Megatherioids, *e. g.*, *Mylodon*, *Megalonyx*, etc. They present a more or less tetragonal figure, and have the grinding surface traversed by two transverse angular ridges. Fig. 55 exhibits a longitudinal section of the five molars of the upper jaw, *in situ*, and demonstrates the great extent of the implanted part of the tooth; the natural length of the series of five grinders is ten inches.

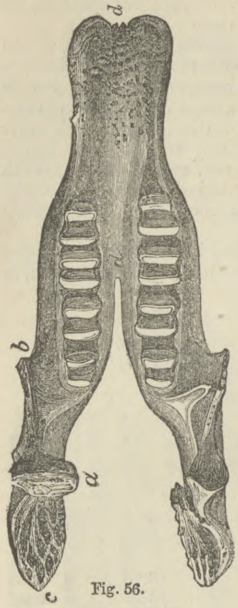

Fig. 56.

Lower Jaw and Teeth of Megatherium.

Each molar tooth of the Megatherium is excavated by an unusually extensive conical pulp-cavity (*p*), from the apex of which a fissure is continued to the middle depression of the grinding surface of the tooth (*v*). The central axis of vaso-dentine (*v*) is surrounded by a thin layer of hard or unvascular dentine (*d*), and this is coated by the cement (*c c*), which is of great thickness on the anterior and posterior surfaces, but is thin where it covers the outer and inner sides of the tooth. The vaso-dentine (fig. 57, *v*) is traversed throughout by medullary canals, measuring $\frac{1}{1500}$ of an inch in diameter, which are continued from the pulp-cavity, and proceed, at an angle of 50°, to the plane of the hard dentine, parallel to each other, with a slightly undulating course, having regular interspaces equal to one diameter and a half of their own area, generally anastomosing in pairs by a loop (*l l*), the convexity of which is turned towards the origin of the tubes of the hard dentine, forming a continuous reflected canal. The loops are situated near, and for the most part close to, the hard dentine (*d*). In a few places one of the medullary canals may be observed to extend across that tissue.

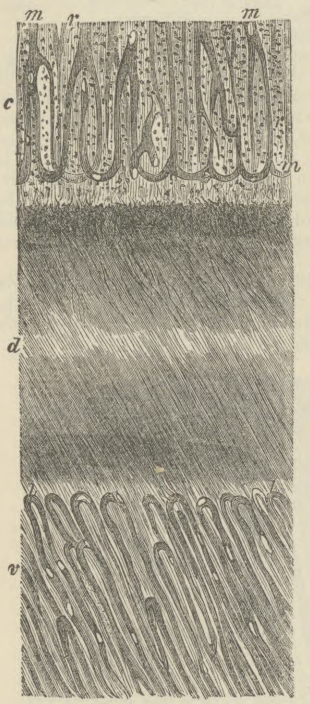

Fig. 57.

Highly magnified Section of the Dental Tissues, Megatherium.

The cement (fig. 57, *c*) is characterized by the size, number, and regularity of the vascular or medullary canals (*m*) which traverse it. They present the diameter of $\frac{1}{1200}$ of an inch, are separated by intervals equal to from four to six of their own diameters. Commencing at the outer surface of the cement, they traverse it in a direction slightly inclined from the transverse axis towards the crown of the tooth, running parallel to each other; they divide a few times dichotomously in their course; and finally anastomose in loops, the convexity of which is directed towards, and in most cases is in close contiguity with, the hard dentine (*d*). Fine tubules are sent off, generally at right angles from the medullary canals, which quickly divide and subdivide, form anastomosing reticulations, and communicate freely with the similar tubes that radiate from the calciferous cells of the intervening tissue (*r*).

The tooth of the Megatherium thus offers an unequivocal example of a course of nutriment from the dentine to the cement, and reciprocally. In the structure which the fossil teeth of the Megatherium and its extinct congeners clearly demonstrate, we have striking evidence of their rich organization, and that they were once pervaded by vital activity. All the constituents of the blood freely circulated through the vascular dentine and the cement, and the vessels of each substance, intercommunicated by a few canals, continued across the hard or unvascular dentine.

With respect to those minuter tubes, the more important as being more immediately engaged in nutrition, which pervade every part of the tooth, characterizing by their difference of length and course the three constituent substances, they form one continuous and freely intercommunicating system of strengthening and reparative vessels, by which the plasma of the blood was distributed throughout the entire tooth, for its nutrition and maintenance in a healthy state.

The grinding surface of the close-set molars of the Megatherium differs, on account of the greater thickness of the cement on their anterior and posterior surfaces, from those of all the smaller Megatherioids, in presenting two transverse ridges (fig. 56, *d*), one of the sloping sides of each ridge being formed by the cement (fig. 55, *c*), the other by the vascular dentine (fig. 55, *v*), whilst the unvascular dentine (*d*), as the hardest constituent, forms the summit of the ridge like the plate of enamel between the dentine and cement in the Elephant's grinder. The great length of the teeth, and concomitant depth of the jaws, the close-set series of the teeth, and the narrow palate, are also strong features of resemblance between the Megatherium and Elephant in their dental and maxillary organization. In both these gigantic phyllophagous quadrupeds, provision has likewise been made for the maintenance of the grinding machinery in an effective state throughout their prolonged existence; but the fertility of the creative resources is well displayed by the different modes in which this provision has been effected; in the Elephant, it is by the formation of new teeth to supply the place of the old when worn out; in the Megatherium, by the constant repair of the teeth in use, to the base of which new matter is added in proportion as the old is worn away from the crown. Thus, the extinct Megatherioids had both the same structure and mode of growth and renovation of their teeth as are manifested in the present day by the diminutive Sloths.

Whales.

Those cetaceous Mammals which are properly called "Whales" have no teeth, but horny substitutes in the form of plates, terminating or fringed by bristles. Of these plates, called "Baleen" and "Whalebone," the largest, which are of an equilateral triangular form, are arranged in a single longitudinal series on each side of the upper jaw, situated pretty close to each other, depending vertically from the maxillary bones, with their flat surfaces looking backwards and forwards, and their unattached margins outwards and inwards, the direction of their interspaces being nearly transverse to the axis of the skull. The smaller subsidiary plates are arranged in oblique series internal to the marginal ones. Thus, if the upper jaw of one side of the skull of a Whale were bisected transversely, the flat surface of a series of the baleen-plates would be exposed, as in fig. 58, in which *a* is the superior maxillary bone, *b* the ligamentous gum giving attachment to *c*, the horny base and body of the chief baleen-plate, which terminates in *d*, the fringe of bristles; *e* marks the smaller baleen-plates.

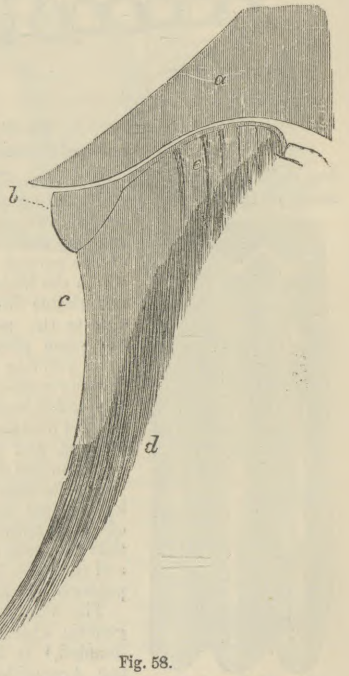

Fig. 58.

Section of Upper Jaw, with Baleen-plates, of a Whale (*Balænoptera*).

The base of each plate is hollow, and is fixed upon a pulp developed from a vascular gum, which is attached to a broad and shallow depression occupying the whole of the palatal surface of the maxillary and of the anterior part of the palatine bones, the Whale being thus, like Echidna, an example of a mammalian animal, which may be said to have palatal teeth. The base of each plate is unequally imbedded in a compact sub-elastic substance (*b*), which is so much deeper on the outer than on the inner side, as, in the new-born whale, to include more than one half of the outer margin of the baleen-plate. This margin is shown at *c* (fig. 58), and is continued downwards in a line dropped nearly vertically from the outer border of the jaws. The inner margin of each plate (*d*) slopes obliquely outwards from the base to the extremity of the preceding margin; the smaller plates decrease in length to the middle line of the palate, so that the form of the baleen-clad roof of the mouth is that of a transverse arch or vault, against which the convex dorsum of the thick and large tongue is applied when the mouth is closed. Each plate sends off from its inner and oblique margin the fringe of moderately stiff but flexible hairs, which project into the mouth.

The direction of the plates is not quite transverse at every part of

Teeth of Mammals.

the series; the inner border is turned rather forwards in the anterior, and obliquely backwards in the posterior plates; and the inner margin at the basal part of the posterior plates is slightly curved towards the back part of the mouth, to which the bristly terminations of these parts of such plates are directed, thus presenting an additional obstacle to the escape of the small marine animals,[1] for the prehension and detention of which this singular modification of the dental system is especially adapted. The baleen-pulp is situated in a cavity at the base of the plate, like the pulp of a true tooth; whilst the external cementing material maintains, both with respect to this pulp and to the portion of the baleen-plate which it developes, the same relations as the dental capsule bears to the tooth. According to these analogies, it must follow, that only the central fibrous or tubular portion of the baleen-plate is formed, like the dentine, by the basal pulp, and that the base of the plate is not only fixed in its place by the cementing substance or capsule, but must also receive an accession of horny material from it, as Hunter first indicated; this material answers to the cement of true teeth.

Mr Scoresby, who in his account of the *Balæna mysticetus*, notices only the large marginal plates, states that they are about two hundred in number on each side; the largest are from ten to fourteen feet, very rarely fifteen feet, in length, and about a foot in breadth at their base; these plates are overlapped and concealed by the under lip when the mouth is shut.

In the *Balænopteræ* or fin-backed whales (fig. 58), the baleen-processes (*e*), internal to the marginal plates, are fewer and smaller than in the *Balænæ*, the marginal plates (*c*) are more numerous, exceeding three hundred on each side; they are broader in proportion to their length, and much smaller in proportion to the entire animal; they are also more bent in the direction transverse to their long axis. As in the true whales, each plate of baleen consists of a central, coarse, fibrous substance, and an exterior, compact, fibrous layer, beyond which the central part projects in the form of the fringe of bristles.

A thin transverse section of baleen, viewed with a low magnifying power, demonstrates that the coarse fibres, as they seem to the naked eye, which form the central substance, are hollow tubes with concentric laminated walls. When a high magnifying power is applied to such a section, the concentric lines are shown not to be uniform, but interrupted here and there by minute elliptical dilatations, which are commonly more opaque than the surrounding substance, and which, like the radiated cells of true bone, are probably remains of the primitive cells of the formative substance; similar long elliptical opaque bodies or cells are dispersed irregularly through the straight parallel fibres of the dense outer laminæ of the baleen-plate.

The chemical basis of baleen, according to Brandt, is albumen hardened by a small proportion of phosphate of lime.

Rytina.

The singular armature of the palate and lower jaw, in the *Rytina*, or Arctic Dugong, likewise falls within the present category. According to Steller,[2] this marine animal has no true teeth, but only two large whitish dental masses, one adhering to the palate, the other to the opposed part of the lower jaw. They are not implanted by gomphosis, but adhere by numerous pores to corresponding papillæ of the membrane covering the palate and lower jaw; besides which, the palatal tooth is fixed at the sides of its anterior part to furrows in the lining membrane of the thick lip. The free surface of the dental mass is sculptured by undulating grooves and risings, adapted to corresponding inequalities in the opposite mass.

Dr Brandt has shown by later and more minute examination of the problematical teeth of the *Rytina*, deposited by Steller in the Petersburg collection, that their texture is horny, consisting of minute hollow fibres, placed vertically to the plane of the grinding surface of the tooth, but of unusual density. Thus the dentition of the Rytina closely resembles that of the *Ornithorhynchus* in both the texture and implantation of the teeth, which will probably be found to contain a similar or greater proportion of osseous matter. M. F. Cuvier has suggested that the above-described plates may be analogous in position, as in texture, to the horny covering of the opposed surfaces of the deflected portions of the upper and lower jaws in the Dugong.

Fœtal Whales.

The true Whales (*Balænidæ*), before they acquire their peculiar array of baleen-plates, manifest in their fœtal age a transitory condition of a true dental system, which, though abortive and functionless, beautifully typifies that which is normal and persistent in the majority of the order.

In an open groove (fig. 59, *a*) which extends along the alveolar border of both the upper and the lower jaws, there is a series of minute, conical, acute, or obtuse denticles, (fig. 59, 1-7), with hollow bases inclosing the uncalcified remains of a vascular pulp. In the fœtus of a *Balænoptera*, the jaws of which were about four inches in length, the unclosed alveolar groove of the upper jaw contained twenty-eight such denticles, that of the lower jaw forty-two. The anterior denticles in both jaws were the smallest; but they increase in size more gradually, and maintain a greater regularity of form in the lower jaw, where they are also most numerous, and in which the typical dentition of the carnivorous cetaceans manifests its plenary development in the great Cachalot.

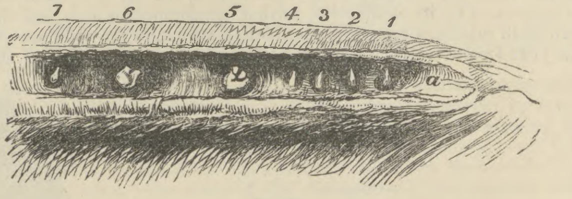

Fig. 59.
Extremity of Lower Jaw of a Fœtal Whale, with the Denticles. Nat. size.

Fig. 60 exhibits three of the transitory teeth of a fœtal Whale: one is simple, with the fang contracted to a point by the diminution and cessation of growth; the next tooth shows two fangs; and the third, more plainly, the origin of its double character to two contiguous and partly confluent tooth-germs.

Fig. 60.
Transitory Denticles of Fœtal Whale.

These small teeth and their matrices disappear before birth; yet the fœtal Whale comparatively long retains and palpably exemplifies the earliest stage of dental development in the higher Mammals, viz., the open fissure which in these is so rapidly closed, especially in the human subject. But beyond this stage, the true dentition of the *Balænidæ* is not destined to proceed, and they thus manifest, agreeably with the general laws of unity of organization, their closest relations to the typical characters of their order at the early periods of development—divesting themselves of part of the more general type, in order to assume their special and distinctive characters, as they advance towards maturity.

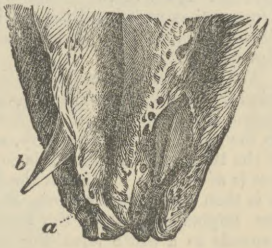

Fig. 61.
End of Lower Jaw, with the Teeth, of *Hyperoodon bidens*.

Hyperoodon.

The great Bottle-nose or bident Whale offers a transitional grade between the true Whales and the typical *Delphinidæ*. The palate is said to be beset with small, unequal, pointed, callous protuberances, which Cuvier conjectures to be rudimental baleen-plates. The fœtal denticles do not all perish, but two or three of the anterior pairs acquire a large size as compared with their transitory representatives in the *Balænidæ*—and one of these pairs is long retained in the lower jaw, though functionless, and hidden by the gum.

These teeth are figured, as seen, when the gum has been removed, at the extremity of the lower jaw of the *Hyperoodon*, in cut 61, *b*. They are conical, slightly curved, with an unusually sharp and slender apex, tipped by enamel. Though loose in their sockets, they project so little from them, and have such wide bases, that they are retained *in situ*, and do not fall out in the dried jaw; two smaller cavities (fig. 61, *a*) in front, and the remains of a larger socket in the alveolar groove, behind the retained teeth, attest the former presence of other teeth. Mr. Thompson of Belfast[3] has figured the lower jaw of a *Hyperoodon* with two small teeth on each side, near the symphysis; they were concealed by the gum, and so hidden in the sockets, as not to be visible in a side view of the jaw. The animal was a male, and twenty-three feet long; the first tooth was seven and a half lines from the end of the jaw; the second tooth was one and a half inch distant from the first.

Monodon.

In the Narwhal (*Monodon monoceros*), two of the primitive dental germs at the forepart of the upper jaw proceed in their development to a greater extent than do those in the lower jaw of the *Hyperoodon*; but every other trace of teeth is soon lost. The two persistent matrices rapidly elongate, but in the retrograde direction, forming a long fang rather than a crown; each tooth sinks into a horizontal alveolus of the premaxillary bone, or, rather, at the junction of the

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[1] *Clio borealis*, *Limacina arctica*, and small pelagic Crustacea. Before the naturalists of the Arctic expeditions had determined the nature of the food of the true balænæ, John Hunter had stated, "I do suppose the fish they catch are small when compared with the size of the mouth."—"On the Structure and Economy of Whales."—*Phil. Trans.* 1787, p. 397.

[2] "Masticationem absolvant præter normam omnium animalium, non dentibus, quibus in universum carent, sed *duobus ossibus validis, candidis*, seu dentium integris massis, quarum una palato, altera maxillæ inferiori, infixa et huic opposita est. Insertio ipsa, seu connexio prorsus insolita, nec ulla prorsus nomine exprimi potest, gomphosin vocare non licet ob id, quod ossa non infiguntur maxillis, sed multis papillis et poris, poris et papillis reciprocis, palati et mandibulæ inferioris recipitur. Ossa hæc molaria subtus multis foraminulis pertusæ, velut netricum digitale vel spongia, quibus arteriæ et nervuli eodem modo ut dentibus animalium inseruntur, superna parte glabra sunt."—*Nov. Commentar. Petropolit.*, vol. ii. p. 302.

[3] *Annals of Natural History*, March 1846, pl. *a*.

premaxillary with the maxillary, and soon, by the forward growth of these bones, becomes wholly inclosed, like the germs of the teeth of the higher Mammalia at their second stage of development. In the female Narwhal, the pulp is here exhausted, the cavity of the tooth is obliterated by its ossification, further development ceases, and the two teeth remained concealed, as abortive germs, in the substance of the jaws for the rest of life, so that in the skeleton a section of the skull must be made in order to display them, as in fig. 61, B. In the male Narwhal, (fig. 61, A) the matrix of the tooth in the left premaxillary bone continues to enlarge; fresh pulp material is progressively added, which by its calcification elongates the base, protrudes the apex from the socket, and the tusk continues to grow until it acquires the length of nine or ten feet, with a basal diameter of four inches. This is that famous "horn" which figures on the forehead of the heraldic unicorn, and so long excited the curiosity and conjectures of the older naturalists, until Olaus Wormius made an end of the speculative and fabulous "monocerologies," by the discovery of the true nature of their subject; whilst Anderson[1] in the year 1736, took advantage of the accident of the stranding of a Narwhal at the mouth of the Elbe, to communicate to the zoological world an accurate figure of the animal which bore the supposed single horn. Linnæus has embalmed the old idea of this weapon in the binomial *Monodon monoceros*, under which the Narwhal is entered in the *Systema Naturæ*.

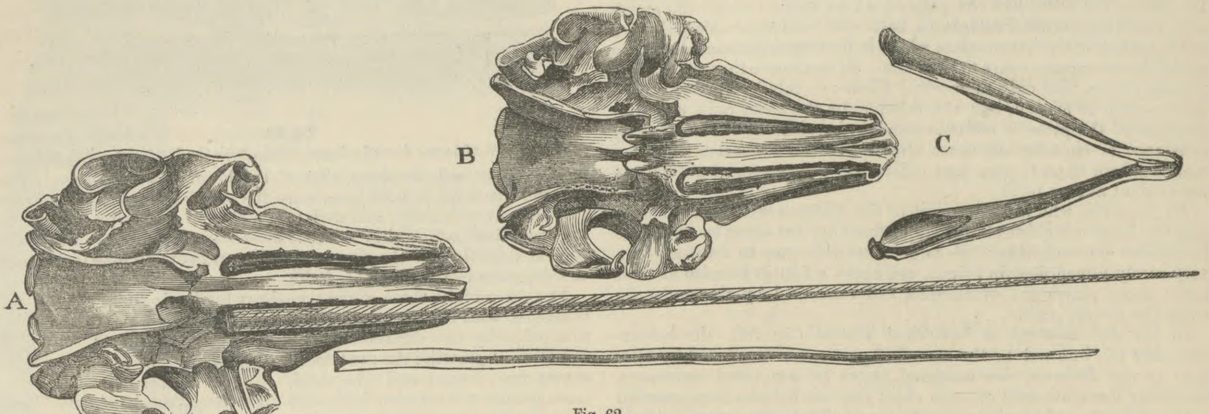

Fig. 62.
Base of Skulls of Male and Female Narwhal, with the Tusks and Lower Jaw.

The exterior of the long tusk is marked by spiral ridges, which wind from within forwards, upwards, and to the left. About fourteen inches is implanted in the socket; it tapers gradually from the base to the apex. The pulp-cavity, as shown in the longitudinal section of the tusk, given in fig. 62, is continued nearly to the extreme point, but is of variable width; at the base it forms a short and wide cone; it is then continued forwards, as a narrow canal, along the centre of the implanted part of the tooth, beyond which the cavity again expands to a width equalling half the diameter of the tooth; and finally, but gradually, contracts to a linear fissure near the apex.

Thus, the most solid and weighty part of the tooth is that which is implanted in the jaw, and nearest the centre of support, whilst the long projecting part is kept as light as might be compatible with the uses of the tusk as a weapon of attack and defence. The portion of pulp, in which the process of the calcification has been arrested, receives its vessels and nerves by the fissure continued from the basal expansion of the pulp-cavity.

In a few instances, both tusks have been seen to project from the jaw. In the cranium of such a Narwhal, figured by Albers, the right tusk projects only six inches from the socket, is proportionally slender, and is smooth.

With regard to the conjectured ulterior use of the concealed tusk (fig. 62, A), in the male, as a potential substitute, in the event of the loss of the large tusk, a conjecture more than once repeated by writers since first proposed by Reisel, the solidity of the concealed tusk, and its distorted and generally-closed base, evince that the term of its growth has expired.

In the *Delphinus griseus*, the dentition of the upper jaw is transitory, as in *Hyperoodon*, but at least six pairs of teeth rise above the gum, and acquire a full development at the forepart of the lower jaw. The crowns of these teeth soon become obtuse, and even their duration is limited, for the specimen described by M. F. Cuvier[2] had but two teeth on each side of the lower jaw. A Dolphin, perhaps an aged individual of this species, has been lately described with the dentition reduced to two teeth in the lower jaw.

Physeter. The outward and visible dentition of the great Sperm-whale or Cachalot (*Physeter macrocephalus*) is confined to the lower jaw. The series consists in each ramus of about twenty-seven subincurved, conical, or ovoid teeth, according to their state of development and usage; the smallest teeth are at the two extremes of the series. In the young Cachalot they are conical and pointed; usage soon renders them obtuse, whilst progressive growth expands and elongates the base into a fang, which then contracts, and is finally solidified and terminated obtusely. The teeth are separated by intervals as broad as themselves. In respect of their mode of implantation in the jaw, they offer in the Cachalot a condition intermediate between that of the teeth of the extinct cetaceous-like *Ichthyosaurus*, and of those of the piscivorous *Delphinus*. They are lodged in a wide and moderately deep groove, imperfectly divided into sockets, the septa of which reach only about half-way from the bottom of the groove. These sockets are both too wide and too shallow to retain the teeth independently of the soft parts, so that it commonly happens, when the dense semi-ligamentous gum dries upon the bone, and is stripped off in that state, that it brings away with it the whole series of the teeth like a row of wedges half driven through a strip of board. A firmer implantation would seem unnecessary for teeth which have no opponents to strike against, but which enter depressions in the opposite gum when the mouth is closed. That gum, however, conceals a few persistent specimens of the primitive fœtal series of teeth; these (of which one is shown at the upper part of fig. 63) are always much smaller and more curved than the functional teeth of the lower jaw, of which a section is given in the same cut.

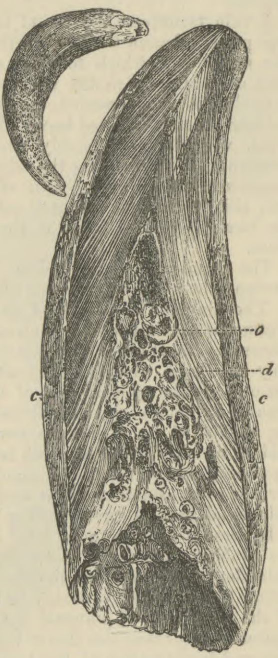

Fig. 63.
Rudimental Upper Tooth, and Section of a Functional Lower Tooth of the Cachalot, (*Physeter macrocephalus*).

There is a well-marked sexual distinction in the size of the jaws of the *Physeter macrocephalus*, those of the mature female being relatively shorter by full one-third than in the male. There are usually twenty-three teeth in each ramus of the lower jaw of a full-sized female Cachalot.

The first-formed extremity of the tooth in the young Cachalot is tipped with enamel; when the summit of the crown has been abraded, the tooth consists of a hollow cone of dentine (fig. 63, *d*), coated by cement (*c*), and more or less filled up by the ossified pulp (*o*). Irregular masses of this fourth substance have been found loose in the pulp-cavity of large teeth. The external cement is thickest at the junction of the crown and base, which are not divided by a neck.

Delphinus. The permanent or mature dentition of the Beluga (*Delphinus leucas*, Pall.), though scanty, is more normal than in the Physeter, nine functional teeth being retained on each side of the upper jaw, and eight in each ramus of the lower jaw. They present the form of straight subcompressed obtuse cones. The *Delphinus globiceps*,

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[1] Cited by Cuvier in his *Ossemens Fossiles*, tom. v. pt. i. p. 319.

[2] *Dents de Mammifere*, p. 243. It was eleven feet in length, and captured at Brest.

Teeth of Mammals.

which has $\frac{14}{12}\cdot\frac{14}{12}=52$, strong, conical, and pointed teeth in the vigour of its age, begins soon after to lose them, and in old individuals none remain in the upper jaw, and not more than eight or ten are preserved in the lower jaw; those at the anterior part of the jaws last longest, and their summits are received in cavities in the upper jaw, or the gum covering it, when the mouth is shut.

The most formidable dentition is that of the predaceous Grampus (*Phocœna orca*), whose laniariform teeth are as large in proportion to the length of the jaws as in the crocodile; they are in number $\frac{13}{12}\cdot\frac{13}{12}=50$; all fixed in deep and distinct sockets, separated by interspaces which admit of the close interlocking of the upper and lower teeth when the mouth is closed; the longest and largest teeth are at the middle of the series, and they gradually decrease in size as they approach the ends, especially the posterior one; the shortness of the anterior teeth is in great part due to the wearing down of the sharp summits, which are best preserved in the small posterior teeth; the position of the bruising and piercing teeth being the reverse of what commonly obtains.

The tooth continues to expand below the enamelled crown to the middle of the fang, which is three times the length, or more, of the crown; it then gradually diminishes to a truncated base, more or less excavated, according to the age of the tooth. The expanded ventricose fang is subcompressed and flattened at the sides. A worn tooth of an old Grampus much resembles the canine of the *Ursus spelæus;* but the long ventricose fang of that is flattened only on one side, is convex at the other, and the pulp cavity is obliterated long ere the crown is worn down; the base of the enamel is more evenly circular, less oblique from the convex to the concave side of the crown; the fang in the Grampus is marked by many wavy transverse lines of growth.

In the common Dolphin the number of teeth amount to 190, arranged in equal numbers above and below, and there is a pair of teeth in the premaxillaries which are toothless in the other *Cetacea.* They have slender, sharp, conical, slightly incurved crowns, and diminish in size to the two extremes of the dental series; the acute apices are longer preserved than in the foregoing species.

The teeth of the common Porpoise (*Phocœna vulgaris*) are arranged in equal number on each side of both upper and lower jaws, and are from 80 to 92 in number; the crown is slightly expanded and compressed, and the fully-formed fang is recurved and enlarged at its extremity.

The Gangetic Dolphin (*Platanista gangetica*) differs from the rest of the *Delphinidæ* scarcely less in the form of its teeth than in that of the jaws. Both the upper and lower maxillary bones are much elongated and compressed; the symphysis of the lower jaw is coextensive with the long dental series, and the teeth rise so close to it, that those of one side touch the others by their bases, except at the posterior part of the jaw. The lateral series of teeth are similarly approximated in the upper jaw at the median line of union, which line is compelled, by the alternate position of the teeth, to take a wavy course.

There are thirty teeth on each side of the upper jaw, and thirty-two on each side of the lower jaw. In the young animal they are all slender, compressed, straight, and sharp pointed, the anterior being longer than the posterior ones, and recurved. Contrary to the rule in ordinary Dolphins, the anterior teeth retain their prehensile structure, while the posterior ones soon have their summits worn down to their broad bases.

The most remarkable change that occurs in the progress of growth is the antero-posterior expansion, as well as elongation of the implanted base of the tooth, which likewise has its outer surface augmented by longitudinal folds or indentations, analogous to, but weaker than, those in the base of the teeth of the Sauroid fishes. Sometimes the posterior tooth of the Platanista has the base divided into two short fangs—the sole example of such a structure which I have met with in the existing carnivorous Cetacea.

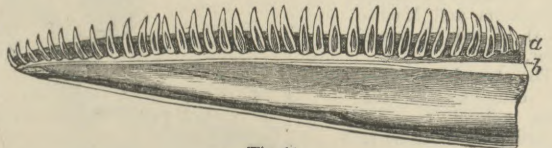

Fig. 64.

Section of Jaw and Teeth of a Dolphin (*Delphinus delphis*).

Development.

The primitive seat of the development of the tooth-matrix in the vascular membrane or gum (fig. 64, *a*) lining an open groove on the alveolar border of the maxillary bones (*b*), is maintained much longer in the *Cetacea* than in the highest organized *Mammalia;* a greater proportion of the tooth is also developed before the matrix sinks into, or is surrounded by a bony alveolus; and, with the exception of the rudimental tusks in the Narwhal, is at no period entirely enclosed in a bony cell; in which respect the *Cetacea* offer an interesting analogy to true fishes.

Teeth of Mammals.

The Cetacea permanently represent that early embryonic stage when no cervical constriction divides the large head from the trunk, and when the rudimental limbs offer no outward marks of joints or digits; they likewise retain a preponderating proportion of brain, and manifest for a long period, and on a magnified scale, the first stages in the development of teeth.

When, by the increasing depth of the jaw, and the reciprocal elongation of the tooth, its base or fang becomes supported by bone (fig. 64, *b*), a longer time than usual elapses before the alveolus is completed by the development of transverse partitions between the outer and inner walls of the open groove; and in the meanwhile the teeth are lodged, like those of the *Ichthyosauri,* in a common and continuous bony channel. In the *Delphinidæ* the teeth are successively developed from before backwards, and pass through all their stages of growth in that order of position—the anterior ones having their fangs and alveoli completed, whilst the posterior teeth are lodged in a common groove, or may be supported at the back part of the series by the gum only, as at *a*. When the formation of the entire series of teeth approaches its completion, the Dolphin resembles the Alligator in having the anterior teeth lodged in sockets, and the posterior teeth in an alveolar groove. In the Cachalot the large middle teeth of the series are the last to have the fang solidified. The conversion of the last remnant of the pulp produces the irregular bone-like deposit in the centre of the tooth, and closes up the lower aperture—one or two minute canals for the nutrient vessels being usually left. The mass of this fourth central substance is greatest in the Cachalot (fig. 63, *o*), in which the process sometimes commences at an independent centre, and proceeds centrifugally, as in ordinary ossification, giving rise to the detached stalactitic masses occasionally found loose in the unclosed pulp-cavity of large teeth.

Zeuglodon.

The remains of a gigantic animal discovered in a tertiary formation in the State of Louisiana, and originally interpreted to belong to the class of reptiles with the name of *Basilosaurus,*[1] having presented, in both portions of upper and lower jaws, teeth implanted by a double fang in deep sockets, the writer demonstrated from this character, and the microscopic structure of the teeth, both the mammalian nature and cetaceous affinities of the species, and proposed for it the name of *Zeuglodon,* or yoke-tooth.[2] The crowns of the large posterior teeth are sub-compressed and conical, with an obtuse apex. The upper part of the crown has its anterior and posterior margins strongly serrated (fig. 65). The crown is contracted from side to side in the middle of its base, so as to give its transverse section an hour-glass form (fig. 66); and the opposite wide longitudinal grooves which produce this form, become deeper as the crown approaches the socket, and at length meet and divide the root of the tooth into two separate fangs. The anterior teeth have a single root, and are somewhat smaller than the posterior ones; the crown is sharp-pointed, conical, slightly recurved and laterally compressed, the transverse section of the base forming an ellipse.

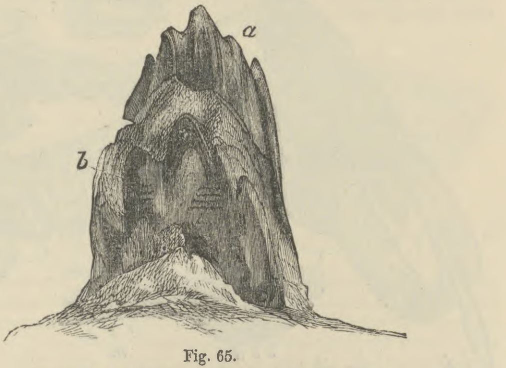

Fig. 65.

Deciduous and Permanent Teeth of the *Zeuglodon*.

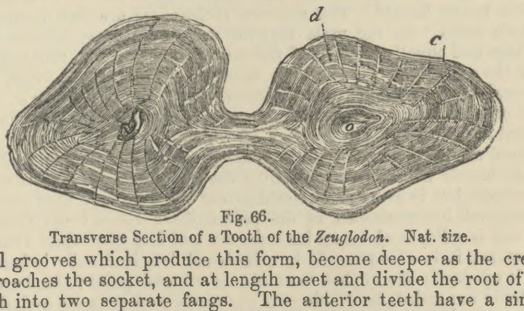

Fig. 66.

Transverse Section of a Tooth of the *Zeuglodon*. Nat. size.

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[1] Harlan, *Medical and Physical Researches,* 8vo, 1835. Prof. R. Grant, in Thomson's *British Annual* for 1839.

[2] *Transactions of the Geological Society of London,* 2d Series, vol. vi.

The teeth of a species of this genus were figured by Scilla in his work *De Corporibus Marinis*, 4°, 1747, tab. xii. fig. 1. They have been ascribed, since the above-cited memoir on *Zeuglodon* appeared, by Mr. Grateloup, to a genus called *Squalodon*, and by Dr. Gibbs to a genus called *Dorudon*. The mode of completion of the teeth in this extinct Cetacean is different from, and conforms to, a higher type than that of any of the existing carnivorous genera of the order. It is evident that the pulp which, from the form and structure of the crown, was originally simple, becomes afterwards divided into two parts, and that its calcification then proceeds towards two distinct centres, which are each separately surrounded by concentric striæ of growth. The *cavitas pulpi*, which is very small in the crown of the tooth, becomes contracted as the fangs descend, and is almost obliterated near their extremities.

The summits of the crown of the teeth of the *Zeuglodon* were sheathed with enamel. Their base exhibits an investment of a thin layer of cement, which augments in thickness where it surrounds the fangs.

Dr Carus[1] figures a fragment of the under jaw of the *Zeuglodon* (see fig. 65), in which a worn-out deciduous molar appears to be displaced and succeeded vertically by a premolar; this would imply an affinity to the *Sirenia*. In the *Sirenia*, whose dentition will next be described, the two-fanged structure is fully established in the Manatee, whilst the Dugong presents a near resemblance to the Zeuglodon in the composition and the intimate structure of the molar teeth. The vertebræ of the *Zeuglodon* resemble those of the carnivorous Cetacea. The size of the extinct animal is estimated at near seventy feet; it accordingly affords a very interesting addition to the history of the dental system in the Cetaceous order, and makes the typical group approach by another step nearer to the Dugongs and Manatees, which are more essentially related to the Pachyderms.

Order Sirenia.

Two marks of inferiority in the dental system of the carnivorous Cetacea, which they have in common with many of the order *Bruta*, viz.—uniformity of shape in the whole series of teeth, and no succession and displacement by a second or permanent set,—disappear when we commence the examination of the dentition of those apodal Pachyderms, which have been called by Cuvier the Herbivorous Cetacea.

Halicore.

In the Dugong (*Halicore*), for example, we find incisors distinguished by their configuration as well as position from the molars, and the incisive tusk is deciduous, displaced vertically, and succeeded by a permanent tusk; both these characters are shown in fig. 67. Of the incisors of the Dugong, only the superior ones project from the gum in the male sex, and neither upper nor lower ones are visible in the female. The superior incisors (*i*) are two in number in both sexes. In the male they are moderately long, substriedral, slightly and equally curved, of the same diameter from the base to near the apex, which is obliquely bevelled off to a sharp edge, like the scalpriform teeth of the *Rodentia*. Only the extremity of this tusk projects from the jaw, at least seven-eighths of its extent being lodged in the socket, the parietes of which are entire, and the exterior of the great intermaxillary bones presents an unbroken surface. In the female Dugong the growth of the permanent incisive tusks of the upper jaw is arrested before they cut the gum, and they remain throughout life concealed in the premaxillary bones; the tusk in this sex is solid, is about an inch shorter and less bent than that of the male; it is also irregularly cylindrical, longitudinally indented, and it gradually diminishes to an obtuse rugged point; the base is suddenly expanded, bent obliquely outwards, and presents a shallow excavation. The deciduous incisors of the upper jaw (fig. 67, *i d*) are much smaller than the permanent tusks of the female,[2] and are loosely inserted by one extremity in conical sockets immediately anterior to those of the permanent tusks (fig. 67), adhering by their opposite ends to their tegumentary gum, which presents no outward indication of their presence. Not more than twenty-four molar teeth are developed in the Australian Dugong (*Halicore Australis*), or more than twenty molar teeth in the Malayan Dugong, viz.—in the latter, five on each side of both upper and lower jaws (fig. 67, 1-5), but these are never simultaneously in use, the first being shed before the last has cut the gum.

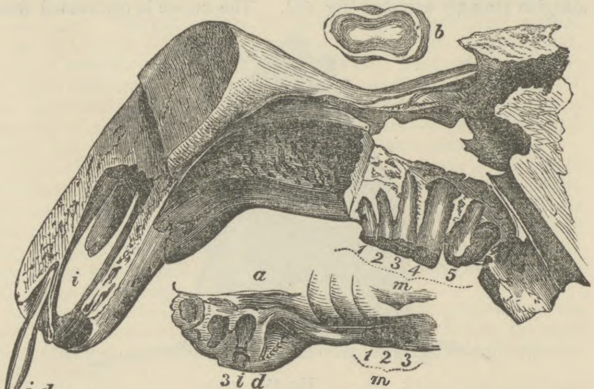

Fig. 67.
Section of Jaws and Teeth of a Dugong (*Halicore indicus.*)

The period when the molar series can be viewed in its most complete state in the Dugong is that represented in fig. 67. The molar teeth increase very regularly in size; the fang of the first (1) and of the second (2) is soon completed and solidified; that of the third (3) is more elongated, and retains its basal cavity longer, but it becomes at length contracted to a point, solidified, partially absorbed, and the tooth is then shed; the crown presents a regular oval shape in transverse section. The fourth molar, when fully formed, resembles a slightly bent cylinder with a nearly smooth outer surface; the crown is flat, or slightly depressed at the centre. The opposite extremity of the tooth is excavated by a regular conical cavity, lodging the remains of the pulp. With age, however, the fang contracts, takes on an irregularly fluted and tuberculate surface, and is at last closed at its extremity. The matrix of the last molar tooth (5) expands as the crown is forming, and manifests a tendency to divide into two fangs; but having acquired the size and form exhibited in fig. 67, *b*, in transverse section, the pulp is maintained in a wide basal pulp-cavity, to supply the waste of the crown according to that pattern.

The molar teeth of the Dugong consist of a large body of dentine (fig. 8, *d*), a small central part of osteo-dentine, and a thick external investment of cement (*c*). The communications between the tubes of the cement and those of the dentine are clearly discernible in several parts of the circumference of the latter substance, and the whole system of tubes adapted to circulate the plasma of the blood through the solid tissues of the tooth is, perhaps, in no existing mammal better seen than in the molar of the Dugong. The small portion of osteo-dentine in the centre of the tooth is permeated by a few vascular canals, which are derived from the remains of the pulp. In the female Dugong the whole of the smaller extremity of the tusk is surrounded by a thin coat of true enamel, which is covered by a thinner stratum of cement. In the male's tusk the enamel, though it may originally have capped the extremity, as in the female's, yet, in the body of the tusk, it is laid only upon the anterior convex, and on the lateral surfaces, but not upon the posterior concave side of the tusk; which is thickly coated with cement.

This side, accordingly, is worn away obliquely when the tusk comes into use, whilst the enamel maintains a sharp chisel-like edge upon the anterior part of the protruded end of the tusk.

The presence of abortive teeth concealed in the sockets of the deflected part of the lower jaw of the Dugong (fig. 67, *a*, *i d*) offers an interesting analogy with the rudimental dentition of the upper jaw in the Cachalot, and of both jaws in the fœtal Whales. The arrested growth and concealment of the upper tusks in the female Dugong, and the persistent pulp-cavity and projection of the corresponding tusks in the male, are equally interesting repetitions of the phenomena manifested on a larger scale in the singular dental system of the Narwhal; but the habitual abrasion to which the tusks of the male Dugong are subject prevents their closer resemblance to the male Narwhal's tusk in regard to length. The simple implantation of the molar teeth and their composition are paralleled in the teeth of the Cachalot; their difference of form, and the more complex shape of the hindmost tooth, are repetitions of characters which were present in the dentition of the extinct *Zeuglodon*.

The co-existence of incisive tusks with molar teeth, and the successive displacement of the smaller and more simple anterior ones by the advance of larger and more complex grinders into the field of attrition, already seem to sketch out peculiarities of dentition, which become established and attain their maximum in the Proboscidian family (Elephants and Mastodons) of the Ungulate order.

Manatus.

The transition from the cetaceous to the more normal type of pachydermal dentition is effected by the Manatee (*Manatus*), especially by the modification of the molar series.

The deflected anterior extremities of the intermaxillary bones each support a single deciduous tusk in the young Manatee (fig. 69, *i*); but this is not succeeded by a permanent one in either sex. Six depressions for rudimental teeth

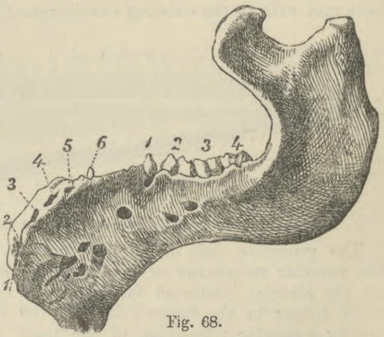

Fig. 68.
Lower Jaw and Teeth of a Young Manatee.

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[1] See Nova acta Cæs. Leop. Carol, vol. xxii. tab xxxix. B. fig. 2, p. 390.

[2] *Proceedings of the Zoolog. Society*, 1838, p. 41.

Teeth of Mammals.

occur in the gum, covering the deflected forepart of each ramus of the lower jaw in the young new-born American Manatee (fig. 68, 1-6), and in the sixth (6) Stannius[1] found a tooth, which he calls a sixth incisor.

The molars of the American Manatee are thirty-eight in number, ten on each side of the upper jaw, and nine, at least, on each side of the lower jaw; but they are never simultaneously in place and use. The number of teeth ordinarily in use at the same time is that represented in Fig. 69, 3-8, where the first and second molars (1, 2) have been shed, and the two last (9 and 10) have not come into place; in the lower jaw seven molars are usually in use in the adult. The first (figs. 68 and 69, 1) in both jaws is small and simple. Beyond the second, the crowns in the upper jaw are square, and support two transverse ridges with tri-tuberculate summits, having also an anterior and posterior basal ridge; each tooth is implanted by three diverging roots, one on the inner and two on the outer side; they increase in size very gradually, from the foremost to the last.

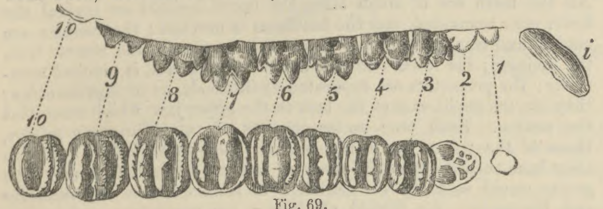

Fig. 69.
Teeth of the Upper Jaw of a Manatee.

The crowns of the four or five anterior molars of the lower jaw resemble those above, but the rest have a large posterior tubercle; they are all implanted by two fangs, which enlarge as they descend, and bifurcate at the extremity; the crowns are of moderate height, and project only a few lines above the sockets.

The molars consist of a body of dentine, a coronal covering of enamel, and a general investment of cement, very thin upon the crown, and a little thicker upon the fangs.

All the grinding teeth of the Manatee belong to the true molar series, in so far as that none are displaced by vertical successors; but the first molar (fig. 68, 1) is small, conical, and simple, and is separated by a brief interval from the first of the two-ridged molars (2 *e*). In this respect the Manatee manifests, like the Dugong, a cetaceous character, and the more strongly, inasmuch as the number of molars successively developed from before backwards is greater. The anterior teeth are, however, displaced before the posterior ones are developed, although they have no vertical successors; which circumstance is also characteristic of the Elephant, and the shape, the structure, and the mode of implantation of the molars of the Manatee, accord with the pachydermal type, and herein more especially with the teeth of the *Dinotherium* and *Tapir*.

Order Marsupialia.

In the Marsupial order, the typical number of the teeth in the molar series is seven on each side of both jaws, the first three of which displace as many milk teeth, and are "premolars" (fig. 76, *p* 1, 2, 3), the other four are true "molars," (fig. 76, *m* 1, 4). Incisors (fig. 71, *i*) are present in all the species, but are variable in number, in some genera exceeding that of the Mammalian type. Canines (fig. 71, *c*) are large in the Dasyures, are feebly represented in the Phalangers and Petaurists, are absent in the lower jaw of the Potoroos and Koala, and in both jaws of the Kangaroos and Wombats.

Thylacinus.

The Dasyures and Thylacine offer the carnivorous type of the dental system, but differ from the corresponding group of the placental Mammalia, in having the molars of a more uniform and simple structure, and the incisors in greater number; the dental formula of the Dog-headed Opposum, *Thalycinus*, is—

$$i\,\frac{4.4}{3.3};\ c\,\frac{1.1}{1.1};\ pm\,\frac{3.3}{3.3};\ m\,\frac{44}{44}=46.$$

The canine teeth are long, strong, curved, and pointed, like those of the dog tribe; the points of the lower canines are received in hollows of the premaxillary palatal plate when the mouth is closed, and do not project, as in the carnivorous placentals, beyond the margins of the maxillary bones. The premolars (*p*) present a simple compressed conical crown, with a posterior tubercle, which is most developed on the hindmost. The true molars (*m*) in the upper jaw are unequally triangular, the last being much smaller than the rest; the exterior part of the crown (fig. 70, *a*, *b*) is raised into one large pointed middle cusp and two smaller cusps; a small strong obtuse lobe (*c*) projects from the inner side of the crown. The molars of the lower jaw are compressed and tricuspidate; the middle cusp being the longest, especially in the two last molars, which resemble closely the carnassial teeth (dents carnassières) of the dog and cat.

Fig. 70.
Penultimate Upper Molar of the Thylacine.

Teeth of Mammals.

Dasyurus.

The dental formula of the genus *Dasyurus* is—

$$i\,\frac{4.4}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{2.2}{2.2};\ m\,\frac{4.4}{4.4}=42.$$

The eight incisors of the upper jaw (fig. 70, *i*) are of the same length and simple structure, and are arranged in a regular semicircle. The six incisors of the lower jaw (fig. 71, *i*) are similarly arranged, but have thicker crowns than the upper ones. The canines (fig. 71, *c*) present the same, or even a greater relative development, than in the Thylacine; in an extinct species of *Dasyurus*, they had the same form and relative proportions as in the Leopard. The premolars (*p* 2 and 3) answer to the two last in the Opossum, and have simple crowns. The upper true molars (*m*) have triangular crowns; the first presents four sharp cusps; the second and third each five; the fourth, which is the smallest, only three. In the lower jaw, the last molar is nearly of equal size with the penultimate one, and is bristled with four cusps, the external one being the longest. The second and third molars have five cusps, three on the inner and two on the outer side; the first molar has four cusps. The carnivorous character of the above dentition is most strongly marked in the Ursine Dasyure, or *Devil* of the Tasmanian colonists, the largest existing species of the genus.

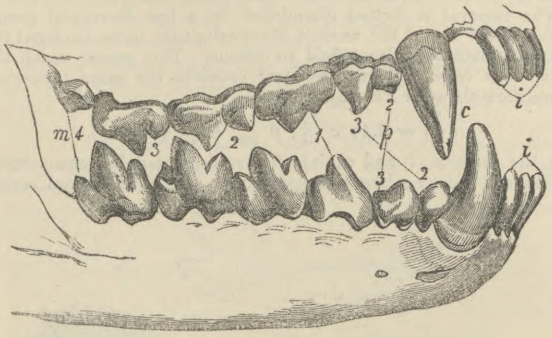

Fig. 71.
Dentition of the Ursine Dasyure. Nat. size.

Thylacoleo

A carnivorous Australian marsupial, of the size of a Lion, now extinct, which the writer determined under the name of *Thylacoleo carnifex*, in 1848, has a true carnassial tooth, upwards of an inch and a half in fore and aft extent, and one inch in height; consisting wholly of the "blade" in the lower jaw (fig. 72), and with the addition of a very feeble depressed tubercle in the upper jaw. On the occasion of a visit to London by M. Paul Gervais, at the period when the supposed marsupial character of the *Pterodon* or *Hynodon* (fig. 111) of the miocene deposits of Auvergne, Gard, and Vaucluse were under discussion, the writer took the opportunity to point out to that able comparative anatomist and palæontologist, certain characters deducible from the foramen caroticum and foramen lacrymale, bearing on this question, and illustrated those conclusions by reference to the then unique carnivorous fossil which had a short time before been transmitted from Australia. M. Gervais accordingly enters the genus *Thylacoleo* in the geographical table of fossil mammalia, of the "Zoologie and Paléontologie Française," and in his remarks on those of Australia (Nouvelle Hollande), he writes, "Les depôts pliocenes ou pleistocenes ont fourni des Grand Kangaroos, un grand Wombat,[2] divers autres espèces congenérès de celles d'à present, les genres de *Diprotodon* et *Nototherium*, qui ètaient aussi des Marsupiaux, mais dont les allues et la taille approchaient de celles de nos grands pachydermes Diluviens, et le Dasyurien, plus grand que le Lion, que M. Owen nomme *Thylacoleo*" (p. 192).

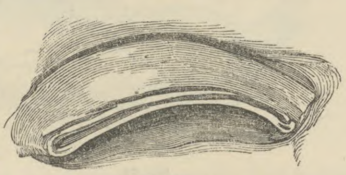

Fig. 72.
Lower Carnassial Tooth, viewed from above, of the Thylacoleo.

Phascogale

In some of the smaller species of the carnivorous group, as the Phascogale, the canines lose their great relative size, and the molar teeth present a surface more cuspidated than sectorial; there is also an increased number of teeth, and as a consequence of their equable development, they have fewer and shorter interspaces. The genus *Phascogale* is characterized by—

$$i\,\frac{4.4}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{4.4}{4.4}=46.$$

In this dental formula may be discerned a step in the transition from the Dasyures to the Opposums, not only in the increased number of spurious molars, but also in the shape and proportions of the incisors.

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[1] Beitrage zur Kenntniss der Amerikanischen Manati's, 4to, Rostock, 1845.

[2] That, viz., which is alluded to as being "at least four times as large as either of the known existing species," in the writer's memoir on the extinct species of *Phascolomys*.—(July 1845), *Trans. Zool. Soc.* tom. iii. p. 306.

Teeth of Mammals.

The general character of the dentition of these small predatory Marsupials approximates to the insectivorus type, as will be exemplified in the Shrew, Hedgehog, etc., among the placental Mammalia, and corresponds with the food and habits of the species, which thus lead from the predaceous, or flesh-feeding, to the Entomophegous tribes.

Phascolotherium.

The interval is further diminished by a lost Marsupial genus, which forms one of the ancient Mammalia that have rendered the oolitic formations at Stonesfield so famous. This genus, which the writer has called *Phascolotherium*,[1] presents the same numerical dental formula as in *Phascogale*, viz.—

$$i\,\frac{?.?}{3.3} \text{ or } 4.4;\ c\,\frac{?.?}{1.1};\ p\,\frac{?.?}{3.3};\ m\,\frac{?.?}{4.4} \text{ (Fig. 73).}$$

But the incisors (*i*) and canines (*c*) are separated by vacant interspaces, and occupy a larger proportional space in the dental series.

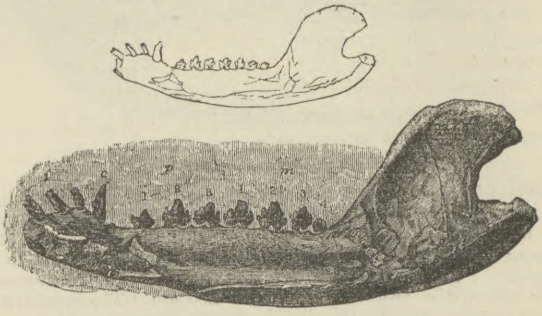

Fig. 73.

Lower Jaw and Teeth of the Phascolothere. Nat. size, in outline.

The transition from the false (*p* 1, 2, 3) to the true (*m* 1, 2, 3, 4) molars, is more gradual; the latter are more compressed than in the Opossum; the five larger teeth present each a large middle cusp, with a smaller one in front and behind it, and with a basal ridge, which, projecting a little beyond both the anterior and posterior smaller cusps, gives a quinque-cuspid character to the crown of the tooth.

Myrmecobius.

The *Myrmecobius* (fig. 74) is characterised by the following remarkable dental formula:—

$$i\,\frac{4.4}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{6.6}{6.6} = 54.$$

From this formula it will be seen that the number of true and false molars, eighteen in both jaws, exceeds that of any other known existing Marsupial. The molars (*m* 1, 6) present a distinct multicuspid structure, and both the true and false ones possess two separate fangs, as in other Marsupials. The inferior molars are directed obliquely inwards, and the whole dental series describes a slight sigmoid curve. The premolars (*p* 1, 2, 3) present the usual compressed triangular form, with the apex slightly recurved, and the base more or less obscurely notched before and behind. The canines (*c*) are very little longer than the false molars. The incisors (*i*) are minute, slightly compressed, and pointed; they are separated from each other and the canines by wide intervals.

Fig. 74.

Dentition of the Myrmecobius.

Amphitherium.

The genus Amphitherium is founded on fossil remains of lower jaws and teeth discovered, like those of the Phascolothere, in the oolitic slate at Stonesfield, in Oxfordshire, and it receives elucidation from the dental characters of the previous genus, but is remarkable for having a still greater number of molar teeth. The dental formula is as follows:—

$$i\,\frac{?.?}{3.3};\ c\,\frac{?.?}{1.1};\ p\,\frac{?.?}{6.6};\ m\,\frac{?.?}{6.6}.$$

There being thus thirty-two teeth in the lower jaw, and probably as many in the upper jaw. The incisors (fig. 75, *i*) are small, simple,

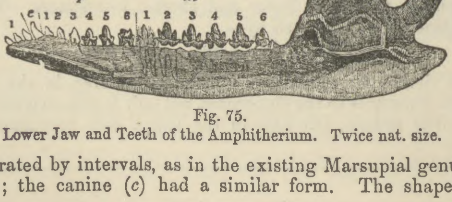

Fig. 75.

Lower Jaw and Teeth of the Amphitherium. Twice nat. size.

and separated by intervals, as in the existing Marsupial genus *Myrmecobius*; the canine (*c*) had a similar form. The shape of the crowns of the premolars (*p*) and molars (*m*) is shewn in the specimens of the larger species (*Amphitherium Broderipii*), in the museum at York, their implantation of the jaw, each by two long slender roots, as indicated in *m* 1 and 2, is demonstrated by one of the specimens of the smaller species (*Amphitherium Prevostii*) in the museum at Oxford.

Teeth of Mammals.

Chœropus.

The singular animal on which this genus was founded, has but two toes on each fore foot; its dental formula is—

$$i\,\frac{4.4}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{4.4}{4.4} = 46.$$

All the teeth are of small size; the upper incisors are conical, the lower ones truncated, and the hindmost is notched; the canines are conical and compressed; the upper one is simple and remote from the incisors; the lower one is near the incisors, and is notched anteriorly; the premolars are separated by intervals, as in *Myrmecobius;* they are tricuspid, except the first in the upper jaw, which resembles the canine. Each true molar consists of two triangular prisms, those of the upper jaw being broader than those below, and with their base turned outwards, contrary to those in the lower jaw. The genus would seem by its dentition to rank between *Myrmecobius* and *Perameles*. Its digital characters are anomalous and unique among the Marsupialia, but are evidently a degeneration from the Saltatorial or Bandicoot type.

Didelphys.

The dental formula of the genus *Didelphys* is—

$$i\,\frac{5.5}{4.4};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{4.4}{4.4}:\ 50 \text{ (Fig. 76).}$$

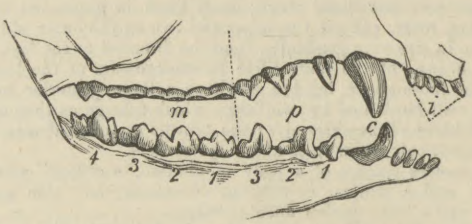

Fig. 76.

Dentition of the Virginian Opossum.

The Opossums resemble in their dentition the Bandicoots more than the Dasyures; but they closely resemble the latter in the tuberculous structure of the molars, the two middle incisors of the upper jaw are more produced than the others, from which they are also separated by a short interspace.

The canines still exhibit a superior development in both jaws adapted for the destruction of living prey, but the molars have a conformation different from that which characterizes the true flesh-feeders, and the Opossums consequently subsist on a mixed diet, or prey upon the lower organized animals.

The smaller species of *Didelphys*, which are the most numerous, fulfil in South America the office of the insectivorous Shrews of the old continent. The larger Opossums resemble in their habits, as in their dentition, the carnivorous Dasyures, and prey upon the smaller quadrupeds and birds; but they have a more omnivorous diet, feeding on reptiles and insects, and even fruits. One large species (*Did. Cancrivora*) prowls about the sea-shore, and lives, as its name implies, on crabs and other crustaceous animals. Another species, the Yapock, frequents the fresh water, and preys almost exclusively on fish. It has all the habits of the Otter; and, in consequence of the modifications of its feet, forms the type of the sub-genus *Chironectes*, Ill. Its dentition, however, does not differ from that of the ordinary Opossums.

Tarsipes.

The dental formula of the genus *Tarsipes* has not been accurately determined; the molars soon begin to fall; the small canines are also deciduous; the two procumbent incisors of the lower jaw remain the longest. The inferior incisors are opposed to six minute incisors above, which are succeeded by a small canine and some small molars; but these are reduced in some, perhaps old individuals, to a single tooth on each side.

Phalangista.

The Phalangers, being provided with hinder hands and prehensile tails, are strictly arboreal animals, and have a close external resemblance to the Opossums, by which name they are generally known in Australia and the islands of the Indian Archipelago, where alone they have hitherto been found. They differ from the Opossums chiefly in their dentition, and in accordance with this difference, their diet is more decidedly of a vegetable kind.

Phascolarctos.

The absence of anomalous or functionless premolars, and of inferior canines, appears to be constant in this genus, the dental formula of which, in other respects resembles that of *Phalangista;* it is—

$$i\,\frac{3.3}{1.1};\ c\,\frac{1.1}{0.0};\ p\,\frac{1.1}{1.1};\ m\,\frac{4.4}{4.4} = 30 \text{ (Fig. 77).}$$

The true molars (fig. 77) are larger in proportion than in the Phalangers; each is beset with four three-sided pyramids (*a*, *b*, *c*, *d*), the cusps of which wear down in age, the outer series in the upper

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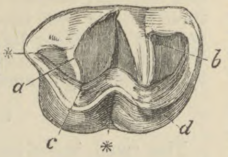
[1] *Transactions of the Geological Society of London*, vol. vi. 2d series, 1838, p. 58, pl. 6.

teeth being the first to give way; those in the lower jaw are narrower than in the upper; there is also the rudiment of a "cingulum," as at * *. The premolars (p 3) are compressed, and terminate in a cutting edge; in those of the upper jaw there is a small parallel ridge along the inner side of the base. The canine (c) slightly exceeds in size the posterior incisor, and terminates in an oblique cutting edge rather than in a point; the fang is closed at the extremity; it is situated, as in the Phalangers, close to the premaxillary suture. The lateral incisors of the upper jaw are small and obtuse; the two anterior or middle incisors are more than twice as large as the rest; they are conical, slightly curved, sub-compressed, bevelled off obliquely to the anterior cutting edge, but differing essentially from the *dentes scalprarii* of the Rodentia in being closed at the extremity of the fang. The two incisors of the lower jaw resemble those of the upper, but are longer and more compressed.

Fig. 77.

Dentition of the Koala (*Phascolarctos fuscus.*)



Molar Tooth of the Koala magnified.

Hypsiprymnus. The dental formula of *Hypsiprymnus*, the generic name of the Potoroos, or Kangaroo-rats, is—

$$i\frac{3.3}{1.1};\ c\frac{1.1}{0.0};\ p\frac{1.1}{1.1};\ m\frac{4.4}{4.4}=30$$

The anterior of the upper incisors, (fig. 78, i) are longer and more curved than the lateral ones, and their pulps are persistent. The canine (c) is larger than in the Koala; it is situated on the line of the premaxillary suture; and while the fang is lodged in the maxillary, the crown projects almost wholly from the premaxillary bone. In the large *Hypsiprymnus ursinus*, the canines are relatively smaller than in the other Potoroos, a structure which indicates the transition from the Potoroo to the Kangaroo genus. The single premolar (fig. 78, p) has a peculiar trenchant form; its maximum of development is attained in the arboreal Potoroos of New Guinea (*Hypsiprymnus ursinus* and *Hyps. dorcocepephalus*), in the latter of which its antero-posterior extent nearly equals that of the three succeeding molar teeth. In all the Potoroos, the trenchant spurious molar (p) is indented, especially on the outer side, and in young teeth, by many small vertical grooves. The true molars (m 1, 2, 3, 4) each present four three-sided pyramidal cusps; but the internal angles of the two opposite cusps are continued into each other across the tooth, forming two angular or concave transverse ridges. In the old animal these cusps and ridges disappear, and the grinding surface is worn quite flat.

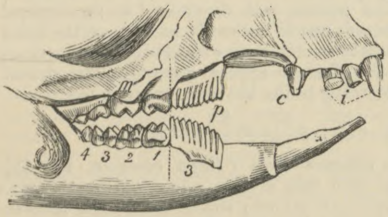


Fig. 78.

Dentition of the Potoroo, (*Hypsiprymnus.*)

In the genus Macropus (fig. 143), the normal condition of the permanent teeth may be expressed as follows:—

$$i\frac{3.3}{1.1};\ c\frac{0.0}{0.0};\ p\frac{1.1}{1.1};\ m\frac{4.4}{4.4}=28.$$

The main difference, as compared with *Hypsiprymnus*, lies in the absence of the upper canines as functional teeth; but the germs of these teeth are always to be found in the young mammary fœtus of the *Macropus major*, and the writer has detected them, but of very small size, and concealed by the gum, in the adults of some small species of Kangaroos, as, *e.g.*, *Macropus rufiventer*, Ogilby, and *Macr. psilopus*, Gould. This, however, is a rare exception; while the constant presence and conspicuous size of the canines will always serve to distinguish the Potoroo from the Kangaroo. The crown of the true molars supports two principal transverse ridges, with a broad anterior talon and a narrow hinder one. In most species a spur is continued from the hinder to the fore ridge, and another from the fore ridge to the front talon.

Dr Mason Good has remarked, "The *Mus maritimus*, or African rat, has the singular property of separating at pleasure, to a considerable distance, the two front teeth of the lower jaw, which are not less than an inch and a quarter long; that elegant and extraordinary creature, the Kangaroo, which, from the increase that has lately taken place in his Majesty's garden at Kew, we may soon hope to see naturalized in our own country, is possessed of a similar faculty."[1]

This faculty of divaricating the lower incisors is due to the laxity of the symphysial union of the two rami of the lower jaw; the teeth merely move with the bones in which they are implanted. Remains of gigantic Kangaroos have been discovered in the same caves in Australia which contained the teeth and jaws of the large extinct *Dasyurus laniarius*, and they probably formed the prey of that species and of its contemporary the Thylacine, which has equally become extinct in the continent of Australia.

Diprotodon. A gigantic extinct herbivorous Australian Marsupial, the bulk of which may be surmised from the length of the skull, which equals three feet, manifests a dentition which makes the nearest approach to the type of the Kangaroos; but the anterior or median pair of upper incisors of the upper jaw present the condition of large, curved, scalpriform, over-growing tusks, which work against a similar but straight procumbent pair of incisive tusks below; thus presenting a transitional feature between the Kangaroos and the Rodent form of Marsupial called Wombat (*Phascolomys*).

By reason of this modification, the writer separated the above large fossil Marsupial generically from Macropus, and proposed for it the name of Diprotodon, or two-incisored, in his Description of the Australian fossil Mammalia, in the appendix to "Mitchell's Expedition into the Interior of Eastern Australia," 8vo, 1838.

He has since ascertained that the second and third incisors are present, though of diminutive size, in the upper jaw of the Diprotodon; but as these teeth are actually reduced to two in the lower jaw, and functionally so in the upper one, the generic name is still applicable. There is no trace of canines in either jaw. The molars present the double transversely-ridged type of the Macropus, an anterior and posterior low basal ridge being added to the two principal eminences.

Five such molars were developed on each side of both jaws, progressively increasing in size from the first to the fourth. The first is generally shed before the last is in place.

A second genus of huge Marsupial Herbivora has been indicated under the name of *Nototherium*.[2] The *Thylacoleo* seems to have been designed to keep these giants of the order in check.

Phascolomys. The dental system presents, in fig. 79, the extreme degree of that degradation of the teeth, intermediate between the front incisors and true molars, which has been traced from the Opossum to the Kangaroos; not only have the functionless premolars and canines now totally disappeared, but also the posterior incisors of the upper jaw, which we have seen in the Koala and Potoroo to exhibit a feeble degree of development as compared with the anterior pair; these, in fact, are alone retained in the dentition of the genus *Phascolomys*.

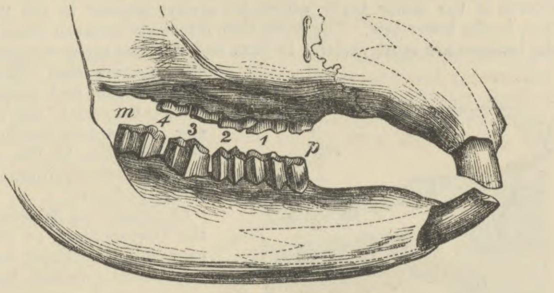


Fig. 79.

Dentition of the Wombat (*Phascolomys*).

The dental formula of the Wombat is thus reduced, both in number and kind, to that of the true Rodentia, viz.—

$$i\frac{2}{2};\ c\frac{0}{0};\ p\frac{1.1}{1.1};\ m\frac{4.4}{4.4}=24\ \text{(Fig. 79).}$$

The incisors (i), moreover, are *dentes scalprarii*, with persistent pulps; but are inferior, especially in the lower jaw, in their relative length and curvature to those of the placental *Glires;* they present a subtriedral figure, and are traversed by a shallow groove on their mesial surface. The premolars (p) present no trace of that compressed structure which characterises them in the Koala and Kangaroos, but have a wide oval transverse section; those of the upper jaw being traversed, on the minor side, by a longitudinal groove. The true molars (m 1-4) are double the size of the premolars; the superior ones are also traversed by an internal longitudinal groove; but this is so deep and wide that it divides the whole tooth into two prismatic portions, with one of the angles directed inwards. The inferior molars are in like manner divided into two triedral portions, but the intervening groove is here external, and one of the facets of each prism is turned inwards. All the grinders are curved, and describe about a quarter of a circle. In the upper jaw the concavity of the curve is directed outwards; in the lower jaw, inwards. The false and true molars, like the incisors, have persistent pulps, and

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[1] *Book of Nature*, vol. i. p. 285. 1826.

[2] Owen, *Report on the Extinct Mammals of Australia, &c.* 8vo, 1844, p. 12.

are, consequently, devoid of true fangs, in which respect the Wombat differs from all other Marsupials, and resembles the extinct *Toxodon*, the dentigerous *Bruta*, and herbivorous *Rodentia*.

The cuts, figs. 72, 70, 77, and 80, showing the working surface of the molar teeth, exemplify stages in the progressive transition from the carnivorous to the herbivorous modification of those teeth in the Marsupial series.

Figure 72, nat. size, is the lower carnassial tooth of the great extinct *Thylacoleo*. Fig. 70 is an upper molar of the largest existing Marsupial carnivore, the Thylacine of Tasmania; the addition of the inner lobe (*c*) gives it a triangular form. In the *Dasyurus* the inner lobe is augmented, and the outer division is thickened by the development of a pointed tubercle or cusp from the cingulum. In the Bandicoot (*Perameles Myosuros*), a second lobe answering to *d* in fig. 77 is added to the inner division of the crown, and two tubercles are developed from the outer part of the cingulum; in the *Phalangista* and Koala (fig. 77), the outer tubercles are obsolete, and the principal lobes (*a*, *b*, *c*, *d*) are almost equal, with a posterior basal ridge and the rudiment of an anterior one. In the *Hypsiprymnus* the lobes answering to *a* and *c* begin to coalesce and form a transverse ridge, as do those behind answering to *b* and *d*. In the Macropus (fig.143) the coalescence is more complete; and in the *Diprotodon* the double cross-ridged structure is complete. The parts of the cingulum forming the anterior and posterior basal ridges are present in all the three last examples. Finally, the Wombat (fig. 80) shows the most aberrant modification of the grinding surface. The cut is taken from a molar tooth of the lower jaw of the great extinct *Phascolomys gigas*.

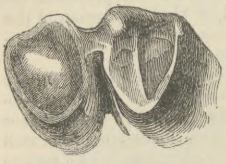

Fig. 80.

Grinding Surface of a Lower Molar (nat. size) of the Great extinct Wombat.

Order Insectivora.

The dental system in this order is remarkable for the many varieties and even anomalies which it presents—almost the only characteristic predicable of it in the numerous small quadrupeds which constitute it being the presence of several sharp points or cusps upon the crowns of the molar teeth, which are always broader in the upper than in the lower jaw. The teeth that intervene between these and the incisors are most variable in form and size, but are never absent; the incisors also differ in number, size, and shape, in different species, the anterior ones approximating in some species to the character of the scalpriform teeth of the Rodents.

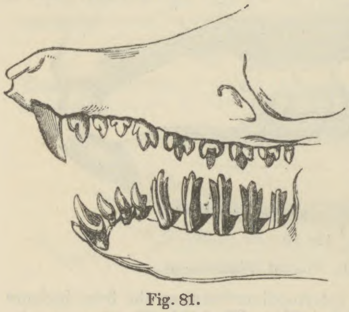

Fig. 81.

Dentition of the Cape-Mole (*Chrysochloris capensis*) magnified.

Chrysochloris.

Of all existing *Insectivora*, the Chrysochlore, or iridescent mole of the Cape, makes the nearest approach, by the number of its molar teeth (fig. 81), to that remarkable condition which was manifested in the most ancient period of Mammalian existence by the extinct *Amphitherium* and *Spalacotherium* of the Oolitic period in geology. At least $\frac{6}{5}\cdot\frac{6}{5}$ true molars may be assigned to the Chrysochlore according to their form—the only character, in the absence of the known order of vertical displacement and succession by which the true and false molars can at present be defined in this species. The anterior large laniariform tooth, and the two succeeding small teeth, are incisors, by virtue of their position in the premaxillary bones; the next small tooth, with a simple compressed tricuspid crown, may be regarded either as a canine or a premolar. The crowns of the true molars are thin plates, flattened from before backwards, with two notches on the working edge, and a longitudinal groove along the outer and thicker margin. Another anomaly, more remarkable than that of the shape of the true molars, is their separation from each other by vacant intervals, as in many Reptiles.

The crowns of the five lower true molars are compressed antero-posteriorly, but are of unusual length, and have the thicker margin turned inwards; the summit of the outer border is pointed and most prominent; the inner division is subdivided into two points. The anterior incisor is small and procumbent; the second has a larger laniariform crown; the third is small, and resembles the two premolars which intervene between this and the first large tricuspid molar. The lower molars are separated by wider intervals than those above; the crowns of the opposing series enter reciprocally the interspaces, and interlock; in mastication, the anterior margin of the lower tooth works upon the posterior margin of the opposite upper tooth.

According to M. Cuvier,[1] each series in the upper jaw of the Chrysochlore includes one incisor and nine molars; and in the lower jaw two incisors and eight molars. M. de Blainville, guided by the intermaxillary sutures in the young Chrysochlore, regards the first three teeth in each lateral series as incisors, the fourth as a canine, and the remaining six as molars in both upper and lower jaws. The writer's views, as given in the foregoing description, are expressed by the following formula:—

$$i\,\frac{3.3}{3.3};\ p\,\frac{1.1}{2.2};\ m\,\frac{6.6}{5.5}=40.$$

Spalacotherium.

The small insectivorous mammal, called *Spalacotherium*,[2] which has left its fossil remains in the upper Oolite of Purbeck, had ten molar teeth on each side of the lower jaw, of which six at least presented a tricuspid crown (fig. 82), with proportions very similar to those of the Chrysochlore.

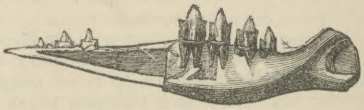

Fig. 82.

Part of Lower Jaw and Teeth of the *Spalacotherium tricuspidens*.

Scalops.

In the Shrew-moles of America (*Scalops*) the dentition makes an important step towards the normal mammalian condition, by the restriction of the characters of the true molar teeth to the three posterior ones in each lateral series; between these and the large scalpriform incisor, in the upper jaw, there are six teeth; the first two of which must also be regarded, by the analogy of the Chrysochlore, as incisors; the next tooth might pass for a canine; and the remaining three for premolars; of these the last is the largest, and has a triedral pointed crown. The true molars have large crowns, each with six cusps, four on the outer, and two on the inner part of the grinding surface. In the lower jaw the first incisor is small and procumbent, and the second large and laniariform, as in the Chrysochlore; the third is absent, and a vacant space separates the incisors from the three premolars, and the crown of each true molar consists of two parallel three-sided prisms, each terminated by three cusps, and having one of the angles turned outwards, and one of the faces inwards; the interspaces between the angles makes the outer surface of the long molars of the *Scalops* appear grooved. The dental formula of this genus, according to the above description, is—

$$i\,\frac{3\ 3}{2.2};\ c\,\frac{1.1}{0.0};\ p\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3.3}=36.$$

Talpa.

The dentition of the common mole (*Talpa europœa*, fig. 83) includes eleven teeth on each side of both upper and lower jaws. The first three in the upper jaw are very small, with simple incisive crowns, and are each implanted by a long and slender fang. These teeth are incisors. The next tooth (*c*), by the size and shape of the crown, represents a canine, but it is implanted by two fangs like the succeeding premolar teeth. Three of these teeth (*p* 1, 2, 3) are of small size, with compressed conical crowns; the fourth premolar (*p* 4) has a larger three-sided conical crown, supported by three fangs, the crowns of the true molars (*m* 1, 2, 3) are multicuspid; the middle one the largest, with five points, and usually supported by four fangs, the hindmost the smallest, with a tricuspid crown and three fangs. In the lower jaw the first four teeth on each side are small, simple, and single-fanged, like the three incisors above; the fifth tooth has a large laniariform crown, supported by two fangs, being very similar to, but shorter than, the two-fanged canine above. As it passes behind that tooth when the mouth is shut, we must regard the fourth tooth below, notwithstanding its small size and similarity to the incisors, as the true inferior canine, as it is in the Ruminants. The fifth tooth (*p* 1) is then the first and largest of the series of four premolars, each of which has a small posterior talon at the base of the compressed conical crown. The three true molars (*m* 1, 2, 3) are each implanted by two fangs, and have quinque-cuspid crowns, the middle molar being the largest.

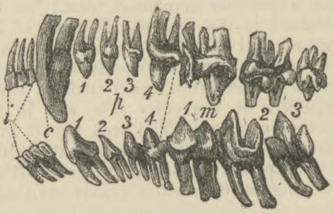

Fig. 83.

Dentition of the Mole (*Talpa europœa*).

The teeth of the mole have been differently classified by different authors; but the difference turns mainly upon the determination of the canine teeth. F. Cuvier[3] and T. Bell[4] both regard the fourth large tooth of the upper jaw (*c*) as a canine, notwithstanding it has two fangs. M. de Blainville[5] describes it as an incisor, in which case the double implantation would be still more anomalous. The position of the incisive foramen, however, indicates that the double socket of this tooth is posterior to the premaxillary suture, and that the number of incisors has been rightly determined by F. Cuvier.

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[1] *Dents de Mammiferes*, p. 63.

[2] *Proceedings of the Geological Society*, June 1854, p. 426.

[3] *Dents de Mammiferes*, p. 62.

[4] *History of British Quadrupeds*, 8vo, 1837, p. 85.

[5] *Osteographie, Insectivores*, 4to, p. 49.

By this justly-esteemed authority, the canines are held to be wanting in the lower jaw of the mole. Mr Bell regards as lower canines the large fifth tooth on each side, although posterior to the canine above; and M. de Blainville, having assigned eight incisors to the upper jaw, adopts the same view in regard to the lower jaw, and calls the first premolar (*p* 1) a canine. With regard to the fourth tooth above, if it be not developed in the premaxillary bone, it claims to be regarded as a canine by the size and shape of the crown, and to be a premolar by virtue of its two fangs; but, since the fang of a tooth is subject to more variety than the crown, the present writer has been guided by the more fixed character, and has called the tooth in question a canine.[1] The fourth tooth below (*c*), although so small, is the only one which has the true relative position of a canine, in advance of the one above when the mouth is shut, and we shall find in the genus *Lemur* a similar conformity of size and shape between the lower canine and incisors as exists in the common mole.[2] There is no difficulty about the other teeth, the canines being determined, and thus the dental formula of the genus *Talpa* is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{3.3}{3.3} = 44.$$

According to this homology, the teeth are equal in number, and alike in kind in both jaws; the true molars are reduced to the normal quantity in the placental series, and the entire dentition is the least anomalous of any which is manifested in the family *Talpidæ*.

In the *Talpa moogura*, *Temm.*, the inferior canine is absent, as in the genus *Scalops*. In the *Condylure*, or Rayed-mole, it is present, with the form and proportions of a canine.

In *Talpa leucura*, Blyth (*p* 1), is wanting.

Soricidæ.
Solenodon.

The transition from the Moles to the Shrews seems to be made by the water-moles (*Mygale*), and the *Solenodon*. The latter insectivore combines the form of a gigantic Shrew, with a dentition resembling that of the Chrysochlore. Each premaxillary bone contains three incisors, the first large, canine-shaped, grooved anteriorly, with the point inclined backwards; the other two incisors small, with simple conical crowns; these are succeeded by seven teeth, the two anterior having three-sided conical crowns, the other five bearing, in addition, an external tuberculate basal ridge In the lower jaw, the anterior incisor is very small, and the second large and laniariform, as in the Scalops and Chrysochlore; but it is remarkable for a deep longitudinal excavation upon its inner side,[3] apparently produced by the friction of the large upper incisors which are received into the interspace of the lower pair; the third lower incisor is small and simple; of the seven succeeding teeth, the four last have multicuspid crowns like true molars.

Mygale.

The Pyrenean Water-mole (*Mygale pyrenaica*) has eleven teeth on each side of both jaws; the first incisor above is relatively larger than in *Scalops*, trihedral, and sharp-pointed; the second and third incisors are very small; none of the succeeding teeth present the form and size of a canine; the last three teeth are multicuspid, and are true molars. In the lower jaw, all the teeth anterior to the true molars are small and simple.

The teeth in the lower jaw of a species of Water-mole (*Palæospalax*), as large as a Hedgehog, which has become extinct in England, present a close resemblance with those of the *Mygale*; the true molars have square, quinque-cuspid crowns, but are distinguished from the teeth of all known recent *Insectivora* by the presence of a minute tubercle at the bottom of the outer vertical fissure of the crown.[4]

The typical Shrews always manifest their rodent analogy by the great preponderance of the anterior pair of incisors in both upper and lower jaws. In the lower jaw the great incisor is uniformly succeeded by two small and three large multicuspid molars; but in the upper jaw the number of small premolars varies. The last true molar is commonly of small size. The subgenera of Shrews are chiefly based upon the form of the large incisors and the numerical variations of the dentition of the upper jaw. In the common Shrew (*Sorex araneus* of Linnæus) there are four true molars and three small teeth between these and the anterior incisor; this tooth has a pointed tubercle at the back of the base of the crown. The long procumbent incisor of the lower jaw has the trenchant superior margin entire. In the *Sorex* (*Amphisorex*) *tetragonurus*, the upper edge of the lower incisor is notched; the large upper incisor appears bifurcate from the great development of the posterior talon; five small teeth, progressively decreasing in size, intervene between the upper large incisor and the true molars. In the *Sorex* (*Hydrosorex*) *Hermanni*, the trenchant edge of the lower procumbent incisor is entire; there are four small teeth between the large anterior incisor and the true molars in the upper jaw, as in the great *Sorex indicus*; but the three first are subequal, and the fourth very minute; there is a fourth small true molar above. The enamelled tips of the teeth of the species of *Amphisorex* and *Hydrosorex* are stained of a bright brown colour; the teeth of *Sorex* proper, as the common Shrew (*S. araneus*), are not so stained.

In the progress of the formation of the large notched incisors, the summits of the tubercles are first formed as detached points, supported upon the common pulp, and do not become united until the centripetal calcification has converted this into a common dentinal base. Some anatomists have regarded the large incisor so formed as an aggregate of two or three teeth; but in *Sorex* proper and *Hydrosorex*, the calcification of the lower incisor spreads from a single point, and the interpretation of the notched incisor of the *Amphisorex*,[5] as the representative of these incisors, might, by parity of reasoning, be applied to the human incisor teeth, the dentated margins of which are likewise originally three or four separate tubercles.

The determination of the small teeth between the large anterior incisors and the multicuspid molars depends upon the extent of the early anchylosed premaxillaries; the incisors being defined by their implantation in those bones, the succeeding small and simple-crowned molars must be regarded as premolars; not any of them having the development or office of a canine tooth; their homotypes in the lower jaw are implanted by two roots.

The thickness of the enamel, in proportion to the body of dentine, is unusually great in these small insectivores, and the sharp points of the teeth long retain their fitness for the office of cracking and crushing the hard or tough teguments of insects.[6] The enamel-pulp of the large lower incisors is so large as to overlap, in the young Shrew, the growing margin of the socket, so as to encase with enamel not only the crown of the tooth, but also the contiguous part of the jaw-bone. Daubenton first drew attention to this structure, and M. Duvernoy has likewise made the interesting observation, that the roots of the teeth of Shrews become anchylosed to the jaw-bone, a reptilian character offered by the *Sorricidæ* alone in the mammalian class.

Erinaceidæ.
Glisorex.

In the dentition of the Tupaias (*Glisorex*) we begin to trace characters intermediate between those of the dentition of Shrews and of Hedgehogs. The dental formula of the *Glisorex tana* is—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3.3} = 36.$$

Gymnura.

The upper incisors are small, simple, and wide apart in the upper jaw; the anterior incisor in the lower jaw is long and procumbent, but relatively smaller than in the Shrews; the canines are small in both jaws; the premolars increase in size and complexity as they approach the true molars; the first two of these are subequal, with six cusps in the upper and five cusps in the lower jaw; the last true molar is smaller, and is tricuspid.

In *Macroscelis* (Elephant-mice of the Cape) and *Gymnura*, each intermaxillary bone contains three teeth, which, in the former genus, are succeeded by four premolars and three true molars, with the same number of teeth in the lower jaw. In *Gymnura* (fig. 84) the first tooth which succeeds the incisors has the form and size of a canine (*c*) in both upper and lower jaws, but has two roots in the upper jaw; this is followed by four premolars (*p* 1-4), the last of which, in the upper jaw, is large and quadricuspid, the first (*m* 1) and second (*m* 2) of the true molars have square multicuspid crowns; the last true molar (*m* 3) is smaller and triangular. In the lower jaw of the *Gymnura* the fourth premolar (*p* 4) has a compressed tricuspid crown. The dental formula of *Gymnura* is typical, viz.—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{4.4}{4.4} = 42.$$

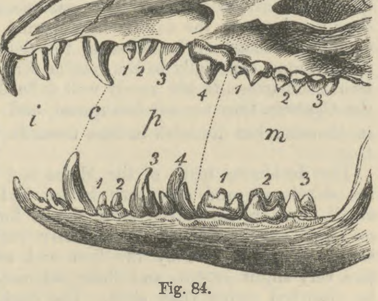

Fig. 84.

Dentition of the *Gymnuria Rafflesii*.

Erinaceus.

The dentition of our common Hedgehog (*Erinaceus europæus*) shows greater inequality in the upper and lower jaws, the formul being—

$$i\,\frac{3.3}{3.3};\ p\,\frac{4.4}{2.2};\ m\,\frac{3.3}{3.3} = 36.$$

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[1] *Odontography*, 1842, p. 416. Mr Blyth has arrived, as it seems independently, at the same conclusion. He writes: "In the moles, as in most other Insectivora, and also in the *Lemuridæ*, the lower canine is minute, and takes the form of an incisor, for which it has been very commonly mistaken, and the first premolar is developed to assume the form of a canine."—*Journal of the Asiatic Society*, No. 3, 1850.

[2] See *Brandt*, *Acta Petropol*, ii. 1834.

[3] The name of the genus (σολην, a pipe, οδους, a tooth, relates to this structure.)

History of British Fossil Mammals, p. 25.

See the beautiful monograph *Sur les musaraignes*, by Professor Duvernoy, in the *Memoires de la Societé d' Histoire Naturelle de Strasbourg*, 1834.

[6] See De Blainville, *Osteographie des Insectivores*, p. 55

The first incisor in both upper and lower jaws is larger and longer than the rest, and is very deeply implanted in the jaw; the tooth which follows the incisors is small in both jaws, but especially so in the lower; it has two roots in the upper jaw. The last premolar is the largest in both jaws; above it has a quadricuspid crown with three fangs; below, a subcompressed tricuspid crown with two fangs. The true molars decrease in size from the first to the third in both jaws, the first and second have subquadrate four-pointed crowns above; below, they are narrower, and the anterior and inner angle is produced into a fifth cusp.

The true molars of the tropical Hedgehogs, forming the sub-genera *Echinops* and *Ericulus*, are more simple, and approach the form of those in the Chrysochlore, being compressed from before backwards, with two outer cusps and one inner cusp in the upper jaw, and with one outer and two inner cusps in the lower jaw. The number of incisors is $\frac{2}{2}:\frac{2}{2}$ in both sub-genera, which are followed by $\frac{2}{2}:\frac{2}{2}$ small and simple premolars; but *Ericulus* has $\frac{5}{5}:\frac{5}{5}$ compressed tricuspid molars, and *Echinops* only $\frac{4}{4}:\frac{4}{4}$.[1]

Centetes.

The large Tenrecs or tailless Hedgehogs of Madagascar, combine the simple molars of the *Ericulus* with the most formidably developed canines which are to be met with in the whole order *Insectivora.* The incisors are two in number in the upper jaw, but three in the lower jaw; very small and sub-equal in both; the canines are long and large, compressed, trenchant, sharp-pointed, recurved, and single-fanged, thus presenting all the typical characters of those teeth in the *Carnivora*. They are separated in both jaws by a wide space from the premolars; the first above is compressed, unicuspid with a hinder talon, and two-fanged; the second has a larger prismatic tricuspid crown and three fangs; of the four posterior teeth, which by their antero-posterior compression may be regarded as true molars, the first three have tricuspid crowns as in the *Echinops*, and have three fangs; the fourth is smaller, is tricuspid, and has two fangs; all the lower molars have two fangs.

Structure.

The teeth of the insectivora consist of a basis of hard dentine, with a thick coronal investment of enamel, and an outer covering of cement, very recognizable in the interspaces of the coronal cusps, in microscropic sections of the molars of the larger species, as the Tenrecs and Macroscelles, and always thick where it closes the extremity of the fangs. Here the cement is commonly more highly organized, is traversed by medullary canals, generally presenting concentric walls, thus assumes the character of true bone, and, in the *Soricidæ*, is frequently continued into the substance of the jaw itself.

The small proportion of dentine, in comparison with the thick layer of enamel, has been already alluded to in the Shrews, yet the dentinal tubuli are at their commencement very little inferior in diameter to those of the human incisors; the trunks are very short, and are resolved into radiated penicilli of undulating branches, which quickly subdivide, interlace and anastomose together near the boundary line between the dentine and enamel. In most of the *Insectivora*, the secondary branches of the dentinal tubes are unusually conspicuous, especially in the dentine forming the fangs. The dentinal compartments are rarely well defined; in the large canines of the *Centetes*, they are sub-hexagonal, and about $\frac{1}{6000}$th of an inch in diameter, but diminish in size towards the periphery of the dentine.

Development.

The deciduous teeth of the Moles and Shrews are uterine, *i. e.*, are developed, and disappear before birth. They are extremely small, and are all of the most simple form. In the fœtal *Sorex araneus*, calcification of the papillary exposed pulps of the teeth, which are succeeded by the first and second premolars, proceed to a very slight extent, and these microscopic rudiments appear to be absorbed rather than shed. The deciduous incisors are further advanced before their displacement, and present the form of equal-sized dentinal spicula, tipped with enamel, attached by the opposite end to the gum, and not exceeding $\frac{1}{40}$th of an inch in length; the number of the uterine series of teeth is $\frac{4.4}{3.3}$.

Order Cheiroptera.

In the volant *Insectivora*, or Bats, the canines are always present in both jaws, of the normal form, and with slightly variable proportions. The molar series never exceeds $\frac{6.6}{6.6}$, and is divisible into premolars and true molars; the latter are bristled, with sharp points, and this type characterises the great bulk of the *Cheiroptera* of Cuvier. The molars of the large frugivorous Bats (*Pteropus*) have flat crowns.

The incisors are the most variable teeth in the *Cheiroptera;* they may be entirely wanting, or be present in the numbers of 1.1 to 2.2 in the upper, and from 1.1 to 3.3 in the lower jaw; they are always very small, and, in the upper jaw, commonly unequal, and separated by a wide median vacancy. In the genus *Chilonycteris*, the mid-incisors above, and the outer ones below, have the crown notched; the mid-incisors below have two notches, producing three lobes on the cutting border. Taking the common simple-nosed Bat (*Vespertilio murinus*) as a type of this Insectivorous group, we find its dental formula to be—

$$i\,\frac{2.2}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3} = 38.$$

Desmodus.

The dentition of the suctorial or Vampire Bats deviates, as might be anticipated, in a remarkable degree from that of the Insectivorous Bats. The crushing instruments required for the food of those species are not needed; and the true molars, with their bristled crowns, are entirely absent in the Vampires (*Desmodus*), (fig. 85). The teeth, at the fore-part of the mouth, are especially developed, and fashioned for the infliction of a deep and clean triangular puncture, like that made by a leech. The incisors are two in number above, closely approximated, one in each premaxillary bone, with a very large, compressed, curved, and sharp-pointed crown, implanted by a strong fang which extends into the maxillary bone. The upper canines have similar large lancet-shaped crowns, and their bases touch those of the incisors. In the lower jaw the incisors are two in number on each side, much smaller than the upper pair, and with bilobed crowns. The lower canines are nearly equal in size to those above, and have similar piercing trenchant crowns. The molar series is reduced above to two very small teeth, each with a simple compressed conical crown, implanted by a single fang. The first two molars below resemble those above; but they are followed by a third, which has a larger compressed and bilobed crown, implanted by two fangs. This tooth corresponds with the last premolar in the more normal genera of Insectivorous Bats. The dental formula of the true Vampire Bat (*Desmodus*), is thus reduced to—

Fig. 85.

Skull and Teeth of the Vampire-Bat (*Desmodus Vampirus*).

$$i\,\frac{1.1}{2.2};\ c\,\frac{1.1}{1.1};\ p\,\frac{2.2}{3.3} = 20.$$

Pteropus.

The opposite extreme which the aberrant varieties of the Cheiropterous dentition attain, is manifested in the great frugivorous Bats—sometimes, but erroneously, called Vampires—but which have never been met with in South America, the peculiar country of the true blood-sucking Bats.

The complex stomach of a *Pteropus* is described as that of a Vampyre Bat in the "Lectures of Comparative Anatomy," by Sir Everard Home, who thereupon infers that "the Vampyre Bat lives on the sweetest of vegetables," and that "all the stories related with so much confidence of its living on blood, and coming in the night to destroy people while asleep, are entirely fabulous," p. 160. But the blood-thirsty habits of the true Vampyres have been observed or experienced by more than one scientific traveller in South America. Dr Spix calls one of these Bats, which he discovered in Brazil, "*Sanguisuga crudelissima;*" and Mr Darwin has recorded the attack of another species which fastened upon the withers of his horse during a nocturnal bivouac in Chili.[2]

In some African *Pteropi* (*Pt. macrocephalus* and *Pt. Whitei*), the last small molar would seem to be wanting in both upper and lower jaws, according to Messrs Ogilby and Bennett.[3]

The frugivorous species, sometimes called "flying foxes," and by the French "Rousettes," include the largest animals of the order *Cheroptera*, and constitute the genus *Pteropus;* their dental formula is—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ p\,\frac{2.2}{3.3};\ m\,\frac{3.3}{3.3} = 34.$$

The deciduous teeth make their appearance above the gum in Bats, as in Shrews, before birth; but they attain a more completely developed state, and are retained until a short time after birth, when they are shed.

Galeopithecus.

The Colugos (*Galeopithecus*) resemble the Bats in the great expanse of their parachute, formed by the fold of integument extending on each side from the fore to the hind extremity; but they appertain, by the essential characters of their organization, to the *Lemuridæ;* the dental formula of the genus is—

$$i\,\frac{2.2}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{2.2}{2.2};\ m\,\frac{3.3}{3.3} = 34.$$

The two anterior incisors of the upper jaw are separated by a wide interspace; in the Philippine Colugo they are very small, with simple bilobed crowns; but in the common Colugo (*Lemur volans*, Linn; *Galeopithecus Temminckii*, Wat.) their crown is an expanded plate, with three or four tubercles; the second upper incisor, which is unquestionably supported by the intermaxillary bone, presents the peculiarity of an insertion by two fangs in both species of *Galeopithecus*.

In the lower jaw the crowns of the first two incisors present the

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[1] See Mr Martin's Memoir in the *Zoological Transactions*, vol. ii.

[2] See *Voyages of the Adventure and Beagle*, vol. iii. p. 25.

[3] *Trans. Zool. Soc.* ii. p. 34.

Teeth of Mammals.

form of a comb, and are in this respect unique in the class *Mammalia;* one is figured magnified three diameters in cut 86. This singular form of tooth is produced by the deeper extension of the marginal notches on the crown, analogous to those on the edge of the new-formed human incisor; the notches being also more numerous as well as deeper; each of these teeth is implanted by a single conical fang.

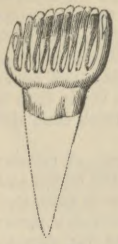

Fig. 86.

Lower Incisor of *Galeopithecus.* Magn.

Structure.

In the broad pectinated incisors of the *Galeopithecus* the pulp-cavity divides at the base of the crown into as many canals as there are divisions of the crown, one being continued up the centre of each to within a short distance of its apical extremity. The dentinal tubes which radiate from these canals have a diameter at their origin of $\frac{1}{15,000}$th of an inch; they quickly divide and subdivide dichotomously, with rather large and irregular secondary undulations, sending off many fine branches, and resolving themselves into numerous smaller ramifications which interlace irregularly near the enamel.

Order Rodentia.

In different orders of the class *Mammalia*, there are instances in which the ordinary number of incisors is diminished, and their growing power transferred to a single pair of tusks projecting from the forepart of the upper or the lower jaw, or of both. The Dinotheres, Toxodons, Mastodons, and Elephants, among the *Ungulata*, the Dugong in the *Sirenia*, the Aye-aye in the *Quadrumana*, the Diprotodon and Wombat in the *Marsupialia*, and the Narwhal amongst the *Cetacea*, are instances of this modification; which reaches its extreme in the latter mammal in which the dentiparous force seems concentrated in a single tooth of the upper jaw, which acquires the shape of a long spiral horn.

But there is an extensive series of small *Mammalia* in which a single pair of large, curved, ever-growing incisors in each jaw is associated with so many other peculiarities of structure, as to have caused them to be regarded as a distinct order of the class, which Linnæus defined as the *Glires*, and which Cuvier called, from the habit associated with that dental modification, "Rongeurs," *Rodentia* or Gnawers. These incisors (fig. 87, *i*), separated by a wide interval from a short series of molars, characterize the whole order of Rodents; the single exceptional family, *Leporidæ*, including Hares, Rabbits, and Picas or tailless Hares of Siberia (fig. 90) retaining a second minute incisor (*i*, 2) behind each of the large ones in the upper jaw.

The incisors are regularly curved, the upper ones (fig. 88, *i*) describing a larger segment of a smaller circle, the lower ones (fig. 21) a smaller segment of a larger circle; these are the longest incisors, and usually have their alveoli extended below, or on the inner side of those of the molars to the back part of the lower jaw (fig. 21, *i*). As in all teeth of unlimited growth, the implanted part of the incisors retains the form and size of the exposed part or crown, to the widely open base, which contains a long conical persistent dentinal pulp (fig. 21, *a*), and is surrounded by the capsule in a progressive state of ossification, as it approaches the crown, an enamel-pulp being attached to the inner side of that part of the capsule which covers the convex surface of the curved incisor. The matrix is here noticed in connection with the tooth, because it is always found in full development and activity to the time of the Rodent's death.

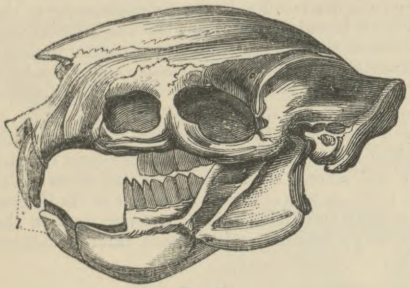

Fig. 88.

Skull and Teeth of a Porcupine.

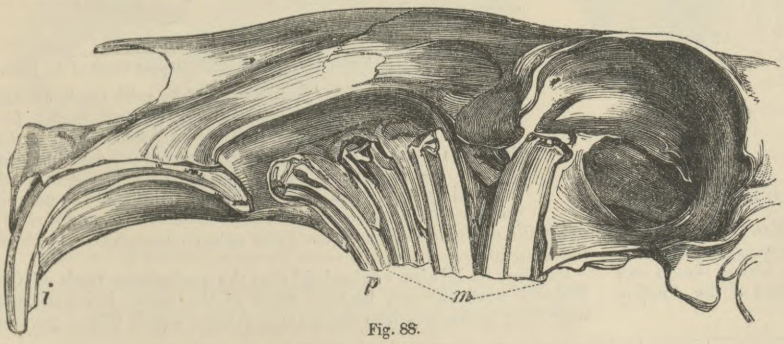

Fig. 88.

Cranium and Upper Teeth of the Patagonian Cavy (*Dolichitis*).

Teeth of Mammals.

The calcification of the dentinal pulp, the deposition of the earthy salts in the cells of the enamel-pulp, and the ossification of the capsule, proceed contemporaneously; fresh materials being added to the base of the vascular matrix as its several constituents are progressively converted into the dental tissues in the more advanced part of the socket. The tooth, thence projecting, consists of a body of compact dentine, sometimes with a few short medullary canals continued into it from the persistent pulp-cavity, with a plate of enamel laid upon its anterior surface, and a general investment of cement, which is very thin upon the enamel, but less thin, in some Rodents, upon the posterior and lateral parts of the incisor. The substances of the incisor diminish in hardness from the front to the back part of the tooth, not only in so far as the enamel is harder than the dentine, but the enamel consists of two layers, of which the anterior and external is denser than the posterior layer, and the posterior half of the dentine is rendered by a modified number and arrangement of the dentinal tubes less dense than the anterior half.

The abrasion resulting from the reciprocal action of the upper and lower incisors produces, accordingly, an oblique surface, sloping from a sharp anterior margin formed by the dense enamel, like that which slopes from the sharp edge formed by the plate of hard steel laid on the back of a chisel; whence the name "dentes scalprarii," given to the incisors of the Rodentia.

The varieties to which these incisors are subject in the different Rodents are limited to their proportional size, and to the colour and sculpturing of the anterior surface. Thus in the Guinea-pig, Jerboa, and Squirrel, the breadth of the incisors is not half so great as that of the molars; whilst in the Coypu they are as broad, and in the Cape Mole-rats (*Bathyergus* and *Orycteromys*), broader than the molars. In the Coypu, Beaver, Agouti, and some other Rodents, the enamelled surface of the incisors is of a bright orange or reddish-brown colour. In some genera of Rodents, as *Orycteromys*, *Otomys*, *Meriones*, *Girvilla*, *Hydrochœrus*, *Lepus*, and *Lagomys*, the anterior surface is indented by a deep longitudinal groove. This character seems not to influence the food or habits of the species; it is present in one genus and absent in another of the same natural family. In most Rodents the anterior enamelled surface of the scalpriform teeth is smooth and uniform.

The molar teeth are always few in number, obliquely implanted and obliquely abraded; the series in each side converging anteriorly in both jaws, but they present a striking contrast to the incisors in the range of their varieties, which are so numerous that they typify almost all the modifications of form and structure which are met with in the molar teeth of the omnivorous and herbivorous genera of other orders of mammalia.

In some Rodents—*e. g.*, Cavies (fig. 88), the molar teeth are rootless; others—*e. g.*, the Agouti, have short roots, tardily developed like the molars of the Horse and Elephant; others, again—*e.g.*, the Rat and the Porcupine, soon acquire roots of the ordinary proportional length.

The differences in the mode of implantation of the molar teeth relate to the differences of diet. The Rodents, which subsist on mixed food, and which betray a tendency to carnivorous habits, as, *e.g.*, the true Rats, or which subsist on the softer and more nutritious vegetable substances, such as the oily kernels of nuts, suffer less rapid abrasion of the molar teeth; a minor depth of the crown is therefore needed to perform the office of mastication during the brief period of existence allotted to these active little Mammals; and as the economy of nature is manifested in the smallest particulars as well as in her grandest operations, no more dental substance is developed after the crown is formed, than is requisite for the firm fixation of the tooth in the jaw.

Rodents that exclusively subsist on vegetable substances, especially the coarser and less nutritious kinds, as herbage, foliage, the bark and wood of trees, wear away more rapidly the grinding surface of the molar teeth; the crowns are therefore larger, and their growth continues by reproduction of the formative matrix at their base in proportion as its calcified constituents, forming the exposed working part of the tooth are worn away. So long as this reproductive force is active, the molar tooth is implanted, like the incisor, by a long undivided continuation of the crown. When the force begins to be exhausted the matrix is simplified by the suppression of the enamel-organ, and the dentinal pulp continues to be reproduced only at certain points of the base of the crown, which by their elongation constitute the fangs. The Beaver and other Rodents, in the second category of the order, according to the implantation of the molar teeth, exemplify the above condition. But in the Capybara, *Dolichotis* (fig. 88), and other Rodents with rootless molars, the reproduction of the grinders, like that of the incisors, appears to continue throughout the animal's existence. The rootless and perpetually growing molars are always more or less curved (fig. 88, *p*, *m*); they

Teeth of Mammals.

derive from this form the same advantage as the incisors, in the relief of the delicate tissues of the active vascular matrix from the effects of the pressure which would otherwise have been transmitted more directly from the grinding surface to the growing base.

The complexity of the structure of the crown of the molar teeth, and the quantity of enamel and cement interblended with the dentine, are greatest in the rootless molars of the strictly herbivorous Rodents. The crowns of the rooted molars of the omnivorous Rats and Mice are almost as simple as the tuberculate molars of the Bear or of the human subject, which they appear to typify. They are at first tuberculate. When the summits of the tubercles are worn off, the inequality of the grinding surface is for a time maintained by the deeper transverse folds of enamel, the margins of which are separated by alternate valleys of dentine and cement; but these folds, sinking only to a slight depth, are in time obliterated, and the grinding surface is reduced to a smooth field of dentine, with a simple border of enamel. Examples of various forms assumed by the inflected folds of enamel in the molars of the *Rodentia* are given in the works of the Cuviers and other naturalists.[1] These folds have a general tendency to a transverse direction across the crown of the tooth. Baron Cuvier has pointed out the concomitant modification of the shape of the joint of the lower jaw, which almost restricts it to horizontal movements to and fro, in the direction of the axis of the head, during the act of mastication. When the folds of enamel dip in vertically from the summit to a greater or less depth into the substance of the crown of the tooth, as in those molars which have roots, the configuration of the grinding surface varies with the degree of abrasion; but in the rootless molars, where the folds of enamel extend inwards from the entire length of the sides of the tooth, the characteristic configuration of the grinding surface is maintained without variation, as in the Guinea-pig, the Capybara, and the Patagonian Cavy.

The whole exterior of the molar teeth of the *Rodentia* is covered by cement, and the external interspaces of the enamel-folds are filled with the same substance. In the *Chinchillidæ* and the Capybara, where the folds of enamel extend quite across the body of the tooth, and insulate as many plates of dentine, these detached portions are held together by the cement. Such folds of enamel are usually parallel, as in the large posterior lower molar of the Capybara, which, in shape and structure, offers a very close and interesting resemblance to the molars of the Asiatic Elephant.

The modification observed in the Voles (*Arvicola*) calls to mind the molars of the African Elephant and some mastodons. The partial folds and islands of enamel in the molars of the Porcupine and Agouti typify the structure of the teeth of the Rhinoceros. The opposite lateral inflections of enamel in the molars of the Gerbille and Cape Mole-rat, represent the structure of the molars of the Hippopotamus. The double crescentic folds in the Jerboa sketch out, as it were, the characteristic structure of the molars of the Anoplothere and Ruminants, &c.

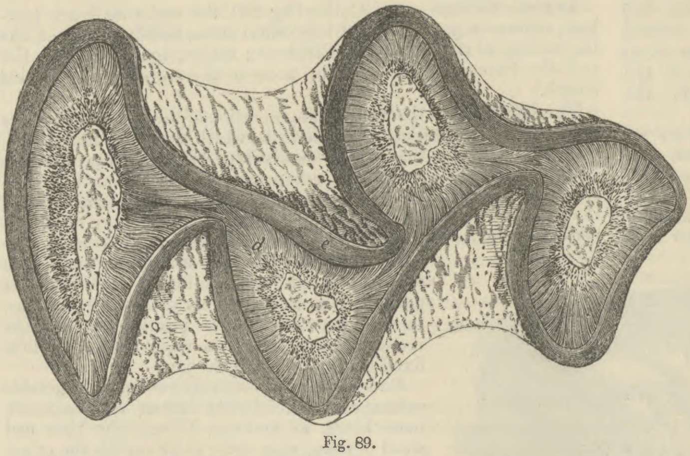

Fig. 89.
Structure of the Molar of the Water-Vole (*Arvicola amphibia*), magnified.

Teeth of Mammals.

The transverse section of the molar of the Water-vole (fig. 89) shows that modification of the grinding surface in which the folds of enamel (*e*) extend like promontories, some outwards, the others inwards, into the substance of the crown; a like section of the Beaver's molar exhibits islands with a promontory of enamel. The transverse section of the crown of the molar of *Lagostomus* displays not fewer than five islands of enamel, which hard substance is so thick that it enters more abundantly into the composition of the tooth than the dentine itself.

The pulp, after the formation of a certain thickness of tubular dentine, becomes converted into osteo-dentine in both the rooted and rootless molars of the Rodents. This fourth substance is exhibited at *o* in the magnified transverse section of the Water-vole's molar (fig. 89), which shows the four different dental tissues, viz. cement (*c*), enamel (*e*), dentine (*d*), and osteo-dentine (*o*), entering in more equal proportions into the formation of the crown than has hitherto been demonstrated in any other mammalian tooth. When the crown is worn by mastication down to the place of the section figured, the four substances appear in the same proportions on the grinding surface, contributing to its efficiency as a triturating organ by the inequalities consequent on their various degrees of density and resistance to the abrading forces.

The molars are not numerous in any Rodent; the Hare and Rabbit (*Lepus*), have $\frac{6}{5}\text{-}\frac{6}{5}$, *i. e.*, six molars on each side of the upper jaw (fig. 90), and five on each side of the lower jaw (fig. 91). The Pika (*Lagomys*), has $\frac{5}{5}\text{-}\frac{5}{5}$. The Squirrels have $\frac{5}{4}\text{-}\frac{5}{4}$. The families of the Dormice, the Porcupines, the Spring-rats (*Echimyidæ*), the Octodonts, the Chinchillas, and the Cavies (fig. 88), have $\frac{4}{4}\text{:}\frac{4}{4}$ molars. In the great family of Rats (*Muridæ*), the normal number of molars is $\frac{3}{3}\text{-}\frac{3}{3}$; but the Australian Water-rat (*Hydromys*), has but $\frac{2}{2}\text{:}\frac{2}{2}$ molars, making, with the incisors, twelve teeth, which is the smallest number in the Rodent order. The greatest number of teeth in the present order is twenty-eight, which is exemplified in the Hare and Rabbit; but forty teeth are developed in these species, ten molars and two incisors being deciduous.

In all the Rodents in which the number of molars exceeds three in a series, the additional ones are anterior to them, and are premolars, *i. e.*, they have each displaced a deciduous predecessor in the vertical direction. This it is which constitutes the essential distinction between the dentition of the marsupial and the placental Rodent; the latter, like the placental *Carnivora*, *Quadrumana*, and *Ungulata*, having never more than three true molars. Thus the Rodents which have the molar formula of $\frac{4}{4}\text{:}\frac{4}{4}$, shed the first tooth in each series, and this is succeeded by a permanent premolar which comes into place later than the true molars—later at least than the first and second, even when the deciduous molar is shed before birth, as was observed by Cuvier in the Guinea Pig. In the Hare and Rabbit, three anterior teeth in the upper jaw (fig. 90 *p*) succeed and displace three deciduous predecessors (fig. 90, *d*), coming into place after the first and second true molars (fig. 90, *m*) are in use, and contemporaneously with the last molar. It does not appear that the scalpriform incisors (fig. 90, *i*) are preceded by milk teeth, or, like the premolars of the Guinea Pig, by uterine teeth; but the second incisor (fig. 90, *i* 2) is so preceded—*e. g.*, by the tooth marked *d*, *i*, 2, at which period of dentition six incisors are present in the upper jaw.[2] This condition is interesting both as a transitory manifestation of the normal number of incisive teeth in the mammalian series, and it elucidates the disputed nature of the great anterior scalpriform teeth of the Rodentia.

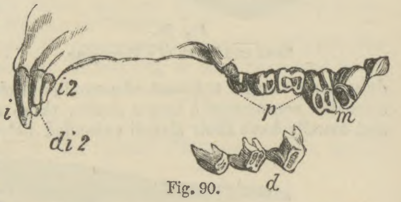

Fig. 90.
Upper Deciduous and Permanent Teeth of the Hare.

Geoffroy St Hilaire contended[3] that the scalpriform teeth of the Rodents were canines, because those of the upper jaw extended their fang backwards into the maxillary bone, which lodged part of

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[1] See *Natural History of the Mammalia*, by G. R. Waterhouse; order Rodentia. 8vo, 1849. *Ossemens Fossiles*, G. Cuvier. *Les Dents de Mammifères*, F. Cuvier.

[2] Pl. 104, fig. 5.

[2] Geoffroy St Hilaire, in his *Systeme Dentaire d'Oiseaux*, 8vo, 1824, Appendix, p. 73, claims the discovery for himself by prevision, and for his assistant Delalande by demonstration, of this interesting fact. "Je vis là un mode d'arrangement, comme on l'avait observé chez les Kanguroos; *et dans la chaleur d'improvisation*, je m'avisai d'ajouter que peut-être un cas d'atrophie avait causé l'absence de les trèisieme paire de dents, laquelle, ne manquant chez les lapins que pour ce motif, n'empêcherait pas qu'ils ne fussent, tout aussi bien à l'égard des incisives que sous d'autres rapports, comparables aux Kanguroos. J'etais comme de cotume accompagné de M. Delalande, qui préparait mes leçons; il prit confiance dans mon apperçu; il fit. dans un intervalle de deux jours, et sans m'en parler, des recherches a cet égard; et, à la leçon suivant, il me surprit en me présentant devant les élèves plusieurs pièces fraîches: 'Voici me dit il, en existence positive, voici en fait, ce que vous avez presenti pouvoir être; voici les têtes des lapins avec six dents incisives.' M. Lemaire de Lisancourt, aujourdhui membre de l'Acad. R. de Médecine, l'un de mes auditeurs à cette epoque, peut se rappeler la vive sensation que cela fit sur les élèves," p. 72.

[3] Isidore Geoffroy St Hilaire cites the opinion in Art. Rongeurs, Dict. Classique d'Histoire Naturelle

Teeth of Iammals.

their hollow base and matrix. But the scalpriform teeth are confined exclusively to the premaxillary bones at the beginning of their formation, and the smaller incisors which are developed behind them, in our anomalous native Rodents, the Hare and Rabbit, retain their usual relations with the premaxillaries, thus proving, *a fortiori*, that the tooth which projects anterior to them must also be an incisor.

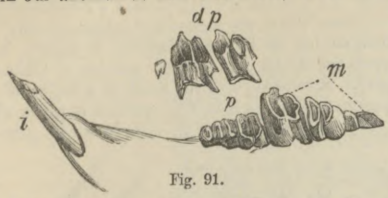

Fig. 91.

Lower Deciduous and Permanent Teeth of the Hare.

Fig. 91 shows the single incisor (*i*) of the lower jaw, the two deciduous molars (*d p*), the two premolars (*p*), and the three molars (*m*), of the young Hare (*Lepus timidus*).

The law of the unlimited growth of the scalpriform incisors is unconditional; and constant exercise and abrasion are required to maintain the normal and serviceable form and proportions of these teeth. When, by accident, an opposing incisor is lost, or when, by the distorted union of a broken jaw, the lower incisors no longer meet the upper ones, as sometimes happens to a wounded hare,[1] the incisors continue to grow until they project like the tusks of the Elephant, and their extremities in the poor animal's painful attempts to acquire food, also become pointed like tusks. Following the curve prescribed to their growth by the form of their socket, their points often return against some part of the head, are pressed through the skin, then cause absorption of the jaw-bone, and again enter the mouth, rendering mastication impracticable, and causing death by starvation.

In the Museum of the College of Surgeons, No. 2203, Osteological Series, there is a lower jaw of a Beaver, in which the scalpriform incisor has, by unchecked growth, described a complete circle. The point has pierced the masseter muscle, and entered the back of the mouth, passing between the condyloid and coronoid processes of the lower jaw, descending to the back part of the molar teeth, in the advance of the part of its own alveolus, which contains its hollow root.

Fig. 92.

Forepart of Upper Jaw of a Rabbit, with Incisors of Abnormal Growth.

The upper jaw of a Rabbit, with an analogous abnormal growth of the scalpriform and accessory incisors, is figured in cut 92.[2]

Order Quadru- ana Cheiromys.

Cheiromys.—In this genus of the Lemurine animals, represented by the Aye-aye (fig. 93), as in *Phascolomys* amongst the Marsupials, *Desmodus* amongst the Bats, and *Sorex* amongst the Insectivores, the dentition is modified in analogical conformity with the Rodent type, to which, in the present instant, it makes a very close approximation, the canines being absent, and a wide vacancy separating the single pair of large-curved scalpriform incisors in each jaw from the short series of molars.

Fig. 93.

Skull and Dentition of the Aye-aye (*Cheiromys Madagascariensis*).

The upper incisors are compressed, presenting a narrow oval transverse section, with the long diameter from before backwards. They are curved in the segment of a circle, and deeply implanted. The short exserted crowns touch one another; their simple widely excavated fangs diverging as they penetrate the substance of the jaw. These crowns also project obliquely forwards, and do not extend vertically downwards, as in the true *Rodentia*.

Teeth of Mammals.

The lower incisors are more depressed, and of greater breadth from before backwards, than the upper ones. They are more curved than in the *Rodentia*, describing a semicircle, three-fourths of which are lodged in the socket, which extends backwards beyond the last molar tooth to the base of the coronoid process. The most important character by which the incisors of this anomalous Lemur differ from those of the *Rodentia* is the entire investment of enamel, which is, however, thicker upon the front than upon the back part of the tooth. The molar teeth are four on each side of the upper jaw, and three on each side of the lower jaw; implanted vertically and in parallel lines. The molars are of simple structure, with a continuous outer coat of enamel, and a flat subelliptic grinding surface. The upper ones are of unequal size, the first being the smallest and the second the largest. In the lower jaw the inequality is less, and the last molar is the least. The first and last molars above have but one root; the second and third have each three roots. The first lower molar has two roots; the second and third have each a single root. The dental formula, in the Slow Lemurs (*Stenops*), is—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3\,3} = 36.$$

In the *Stenops Tardigradus*, the first upper incisor is larger than the second, as in the genus *Tarsius*.

Lemur.

The true Lemurs or Makis (*Lemur*, *Geoff.*) have the same number and kind of teeth as the Slow Lemurs. The inferior canines are compressed and procumbent like the incisors, but are a little larger. In the upper jaw the incisors are small and vertical, with short expanded crowns; the two on the right side are separated by a wide space from the two on the left. The canine (*c*) is long, curved, compressed, sharp-edged, and pointed. The three premolars have the outer part of the crown prolonged into a compressed pointed lobe, whilst the inner part forms a tubercle, which is largest in the second and third. In the true molars the inner division of the crown is so increased as to give it a quadrate form, the outer division being divided into two pointed lobes. The first of the true molars is the largest in both jaws.

Platyrhynæ.

All the Quadrumana of America are distinguished from the Apes and Monkeys of the Old World by certain well-marked characters; of these, the position of the nostrils at the sides of the broad nose, whence their collective name, is the most conspicuous; but they have a more important dental distinction in the superior number of the premolars, which are $\frac{3}{3}:\frac{3}{3}$ instead of $\frac{2}{2}:\frac{2}{2}$, whereby the American Monkeys manifest their closer affinity to the Lemurs, and their inferior position in the zoological scale. The small "Marmosets," however, forming the genera *Hapale* and *Midas*, have but two true molar teeth on each side of both jaws—their dental formula being—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{2.2}{2.2} = 32.$$

The lemurine character of the long, narrow, inferior incisors continues to be manifested by the Sakis (*Pithecia Ill.*), which, like the larger species of Platyrhines called Howlers, Capuchins, and Spider-Monkeys, have the normal number of true molar teeth in the Quadrumanous order—their dental formula being—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3.3} = 36.$$

The Capuchin Monkeys (*Cebus*) (fig. 94) have the four lower incisors (*i*) with broad, thick wedge-shaped trenchant crowns; a form

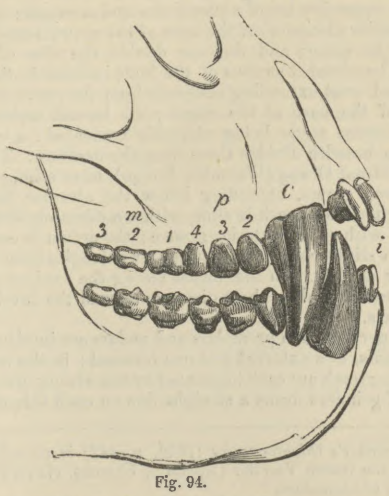

Fig. 94.

Dentition of a Capuchin Monkey (*Cebus secniulus*).

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[1] Professor Budge has described and figured the upper and lower jaws of a hare with preternaturally directed and elongated tusks, in the *Verhandlingen des Naturhistor, Vereines der Treuss.* Rheinlande, 6tes Jahrgang. 8vo, 1849, p. 506.

[2] See the specimens, Nos. 1966-1971, *Mus. Coll. Chir.* Lond.

which these teeth retain, with slight modifications, throughout the rest of the Quadrumanous order. The canines (*c*) are sufficiently developed to inflict severe wounds. The first three of the molar series (*p*, 2, 3, 4) are bicuspid premolars; the rest (*m*, 1, 2, 3) are quadricuspid true molars.

All the Platyrhine Monkeys have four more teeth in their first dentition than the Catarhine or Old World Quadrumanes possess—the deciduous formula being—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ m\,\frac{3.3}{3.3}=24.$$

Fig. 95 shows the deciduous series in place, together with the first of the permanent true molars (*m*, 1); the germs of the rest of the permanent teeth are exposed in the upper jaw.

Catarhina.

In the Catarhine division of the order, the first or deciduous dentition consists, as in man, of—

$$i\,\frac{2,2}{2.2};\ p\,\frac{1.1}{1.1};\ m\,\frac{2.2}{2.2}=20.$$

The two milk molars are displaced and succeeded vertically by the two bicuspid premolars, and are followed horizontally by three true molars on each side of both upper and lower jaws. The permanent formula in all the Old World *Quadrumana* is—

$$i\,\frac{2.2}{2\,2};\ c\,\frac{1\,1}{1.1};\ p\,\frac{2\,2}{2.2};\ m\,\frac{3.3}{3.3}=32.$$

The incisors have always a shape conformable to their name, but are very thick and strong; in the upper jaw the middle are larger than the lateral ones, and both are larger than those below. The canines are conical, pointed, with trenchant posterior margins, always longer than the adjoining teeth, and acquiring, in the males of the great Baboons and Orangs, the proportions of those teeth in the true *Carnivora*. The Mandrills (*Cynocephalus maimon*) have these dental weapons most formidable for their size and shape; especially the upper pair, which descend behind the crowns of the lower incisors, and along the outside of the first lower premolars, the crowns of which seem as if bent back by the action of the upper canines; the anterior longitudinal groove of these canines is very deep, their posterior margin very sharp. A long diastema divides the upper canine from the incisors, a short one separates it from the premolars; these and the three true molars, are arranged in a straight line.

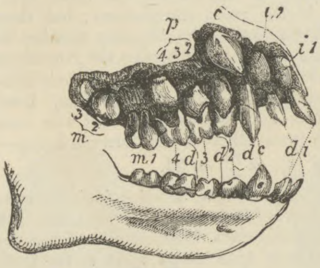

Fig. 95.

Deciduous and Permanent Teeth of a Young *Cebus Apella*.

In the great Orang-utan (*Pithecus Wurmbi*) the median incisors of the upper jaw are of unusual size and strength; the thickness (antero-posterior diameter) of the base of the crown almost equals the breadth of the same; and they are double the size of the lateral incisors. The abraded surface of the front incisors in the old Orang forms a broad tract extending obliquely from the cutting edge to the back part of the base of the crown; the lateral incisors are more pointed, the outer angle being obliquely truncated; a vacant space of their own breadth divides them from the canines. These, in the male of the Great Orang (Wurmb's Pongo), have a long and strong slightly-curved crown, extending below the alveolar border of the under jaw when the mouth is shut, with a moderately sharp posterior margin, but without an anterior groove; the crown is convex externally, with a slight convexity between two longitudinal depressions on the inner surface. In the female Orang the canines are smaller; the crowns extend only a short distance beyond the level of the adjoining molars.[1]

In the upper jaw both premolars and molars are implanted by three diverging roots, two external and one internal; in the lower jaw the corresponding teeth are each implanted by two strong diverging roots; the series of grinders forms a straight line on each side of both jaws.

Chimpanzee Troglodytes.

As the precise characteristics of the human dentition are best demonstrated by comparison with that brute species which is most nearly allied to man, and makes the first step in the descending scale, the details of such a comparison may perhaps be not unacceptable, as one of its subjects is a species of Chimpanzee (*Troglodytes Gorilla*), unknown to science when the writer's "Odontography" was published, and which, so far as its organization is known, is more anthropoid than even the docile and smaller species of Chimpanzee (*Troglodytes niger*). A side view of the teeth of a male full-grown, but not aged, specimen of the great Chimpanzee is given of the natural size in (fig. 96). This dentition, though in all its principal characters strictly quadrumanous, yet, in the minor particulars in which it differs from the dentition of the Orang, approaches nearer the human type. In the upper jaw the middle incisors (*i*) are smaller, the lateral ones (fig. 96, *i*, 2) larger than those of the Orang; they are thus more nearly equal to each other; nevertheless the proportional superiority of the middle pair is much greater than in Man, and the proportional size of the four incisors both to the entire skull and to the other teeth is greater. Each incisor has a prominent posterior basal ridge, and the outer angle of the lateral incisors (*i*, 2) is rounded off as in the Orang. The incisors incline forwards from the vertical line as much as in the great Orang. Thus the characteristics of the human incisors are, in addition to their true incisive wedge-like form, their near equality of size, their vertical or nearly vertical position, and small relative size to the other teeth and to the entire skull. The diastema between the incisors and the canine on each side is as well marked in the male Gorilla as in the male Orang. The crown of the canine (fig. 96, *c*), passing outside the interspace between the lower canine and premolar, extends in the male *Troglodytes Gorilla* a little below the alveolar border of the under jaw when the mouth is shut; the upper canine of the male *Troglodytes niger* likewise projects a little below that border. In the male of the smaller Chimpanzee (*Troglodytes niger*), the upper canine is conical, pointed, but more compressed than in the Orang, and with a sharper posterior edge; convex anteriorly, becoming flatter at the posterior half of the outer surface, and concave on the corresponding part of the inner surface, which is traversed by a shallow longitudinal impression; a feeble longitudinal rising, and a second linear impression divide this from the convex anterior surface, which also bears a longitudinal groove at the base of the crown. The canine is rather more than twice the size of that in the female. In the male *Gorilla* (fig. 96, *c*), the crown of the canine is more inclined outwards; the anterior groove on the inner surface of the crown is deeper; the posterior groove is continued lower down upon the fang, and the ridge between the two grooves is more prominent than in the *Troglodytes niger*. Both premolars (fig. 96, *p* 3 and *p* 4) are bicuspid; the outer cusp of the first, and the inner cusp of the second being the largest, and the first premolar (*p* 3) consequently appearing the largest on an external view. The difference is well marked in the

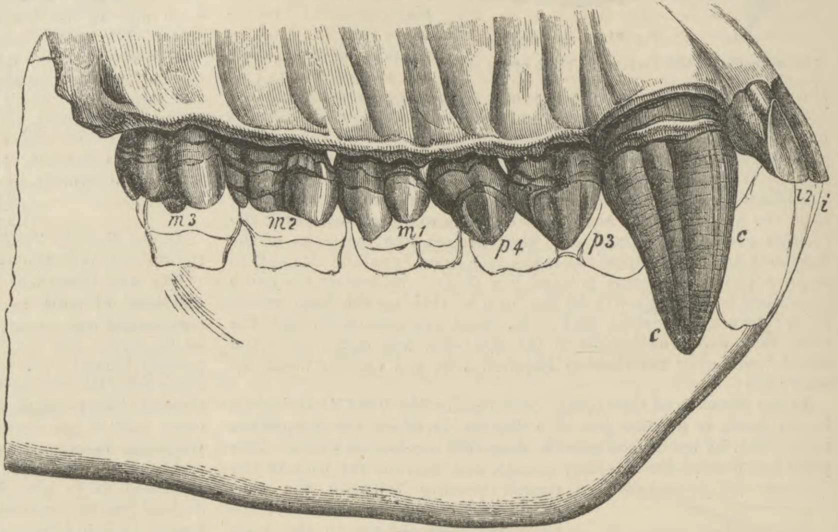

Fig. 96.

Dentition of an Adult Male (*Troglodytes Gorilla*), nat. size.

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[1] In the writer's *Odontography* (1842, p. 442) is recorded a variety which he observed in the dentition of a full-grown Orang-utan, in the collection of the Baron Van der Capella at Utrecht, viz., a supernumerary molar on each side of both jaws, making six molars, of which two only had the form of premolars.

In the Calcutta museum Mr Blyth has noticed in an adult female Bornean Orang, a fourth true molar on the left side of both upper and lower jaw, the supernumerary tooth above being of a round shape, and very small.

In a collection of skulls of the smaller species of Orang recently sent from Borneo (*Pithecus Morio*), the writer observed the skull of an adult male with the same supernumerary molar on each side of the upper jaw, but not in the lower jaw.—*Trans. Zool. Soc.*

These instances illustrate the tendency to variety in the remarkable Anthropoid Apes of Borneo, a tendency which seems to be also manifested in an occasional arrest of development of the characteristic long upper extremities.

female (fig. 97). The anterior external angle of the first premolar is not produced as in the Orang, which in this respect makes a marked approach to the lower *Quadrumana*. In Man, where the outer curve of the premolar part of the dental series is greater than the inner one, the outer cusps of both premolars are the largest; the alternating superiority of size in the Chimpanzee accords with the straight line which the canine and premolars form with the true molars.

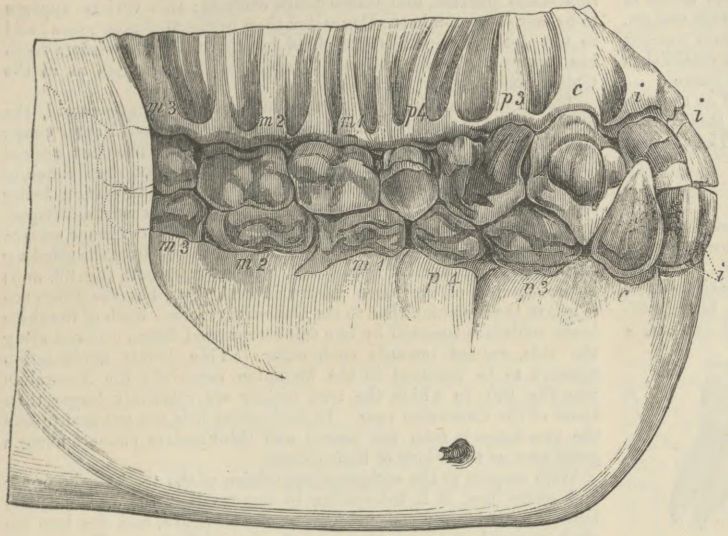

Fig. 97.

Dentition of an Adult Female Gorilla.

The true molars (fig. 96, *m* 1, *m* 2, *m* 3) are quadricuspid, relatively larger in comparison with the bicuspids than in the Orang. In the first and second molars of both species of Chimpanzee, a low ridge connects the antero-internal with the postero-external cusp, crossing the crown obliquely, as in Man. There is a feeble indication of the same ridge in the unworn molars of the Orang; but the four principal cusps are much less distinct, and the whole grinding surface is flatter and more wrinkled than in the Chimpanzee. In the *Troglodytes niger* the last molar is the smallest, owing to the inferior development of the two hinder cusps, and the oblique connecting ridge is feebly marked. In the *Troglodytes Gorilla* this ridge is as well developed as in the other molars, but is more transverse in position; and the crown of *m* 3 is equal in size to that of *m* 1 or *m* 2, having the posterior outer cusp, and particularly the posterior inner cusp, more distinctly developed than in the *Troglodytes niger*. The repetition of the strong sigmoid curves which the unworn prominences of the first and second true molars present in Man, is a very significant indication of the near affinity of the Chimpanzee as compared with the approach made by the Orangs or any of the inferior *Quadrumana*, in which the four cusps of the true molars rise distinct and independently of each other. A low ridge girts the base of the antero-internal cusp of each of the upper true molars in the male Chimpanzee; it is less marked in the female. The premolars as well as molars are severally implanted by one internal and two external fangs, diverging but curving towards each other at their ends, as if grasping the substance of the jaw. I have found the two outer fangs of the second premolar connate in one female specimen of the *Troglodytes niger*. In no variety of the human species are the premolars normally implanted by three fangs; at most the root is bifid, and the outer and inner divisions of the root are commonly connate. It is only in the black varieties, and more particularly that race inhabiting Australia, that I have found the wisdom tooth (*m* 3) with three fangs as a general rule; and the two outer ones are more or less confluent.

In the lower jaw of the Gorilla the lateral incisors are broader than the middle ones, although they are smaller relatively than in the *Troglodytes niger;* they are larger and less vertically implanted than in Man. The lower canines are two inches and a half in length, including the root; the enamelled crown is an inch and a quarter in length, and nearly an inch across the base; it is conical and trihedral; the outer and anterior surface is convex, the other two surfaces are flattened or subconcave, and converging to an almost trenchant edge directed inwards and backwards; a ridge separates the convex from the antero-internal flat surface; both this and the posterior surface show slight traces of a longitudinal rising at their middle part. The lower canine of the male shows the same relative superiority of size as the upper one compared with that in the female in both species of Chimpanzee. The canine almost touches the incisor, but is separated by a diastema one line and a half broad from the first premolar. This tooth (*p* 3) is larger externally than the second premolar, and is three times the size of the human first premolar (*p* 3); it has a subtrihedral crown, with the anterior and outer angle produced forwards, slightly indicating the peculiar feature of the same tooth in the Baboons, but in a less degree than in the Orang. The summit of the crown of *p* 3 terminates in two sharp trihedral cusps—the outer one rising highest, and the second cusp being feebly indicated on the ridge extending from the inner side of the first; the crown has also a thick ridge at the inner and posterior part of its base. The second premolar (*p* 4) has a subquadrate crown, with the two cusps developed from its anterior half, and a third smaller one from the inner angle of the posterior ridge. Each lower premolar is implanted by two antero-posteriorly compressed divergent fangs, one in front of the other, the anterior fang being the largest.

The three true molars are equal in size in the *Troglodytes Gorilla;* in the *Troglodytes niger* (fig. 98), the first (*m* 1) is a little larger than the last (*m* 3), which is the only molar in the smaller Chimpanzee as large as the corresponding tooth in the black varieties of the human subject, in most of which, especially the Australians (fig. 99), the true molars attain larger dimensions than in the yellow or white races. The four principal cusps, especially the two inner ones of the first molar of both species of Chimpanzee, are more pointed and prolonged than in Man; a fifth small cusp is developed behind the outer pair, as in the Orangs and the Gibbons, but is less than that in Man. The same additional cusp is present in the second molar, which is seldom seen in Man. The crucial groove on the grinding surface is much less distinct than in Man, not being continued across the ridge connecting the anterior pair of cusps in the Chimpanzee. The crown of the third molar is longer antero-posteriorly from the greater development of the fifth posterior cusp, which, however, is rudimental in comparison with that in the Semnopitheques and Macaques. All the three true molars are supported by two distinct and well-developed antero-posteriorly compressed divergent fangs, longitudinally excavated on the sides turned towards each other; in the white and yellow races of the human subject these fangs are usually connate in *m* 3, and sometimes also in *m* 2. The molar series in both species of Chimpanzee forms a straight line, with a slight tendency, in the upper jaw, to bend in the opposite direction to the well-marked curve which the same series describes in the human subject.

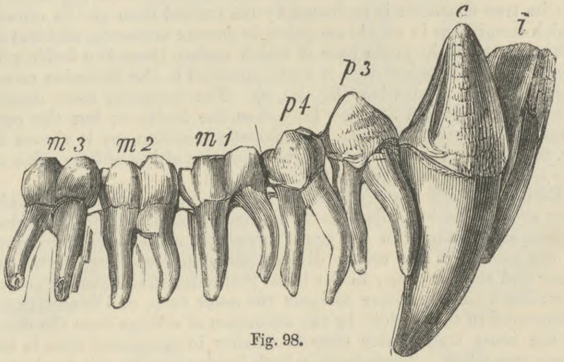

Fig. 98.

Teeth of Right Side, Lower Jaw, of adult male Chimpanzee, (*Troglodytes niger*). Nat. size.

This difference of arrangement, with the more complex implantation of the premolars, the proportionally larger size of the incisors as compared with the molars; the still greater relative magnitude of the canines; and, above all, the sexual distinction in that respect illustrated by figs. 96 and 97, stamp the Gorillas and Chimpanzees most decisively with not merely specific but generic distinctive characters as compared with Man. For the teeth are fashioned in their shape and proportions in the dark recesses of their closed formative alveoli, and do not come into the sphere of operation of external modifying causes until the full size of the crowns has been acquired. The formidable natural weapons with which the Creator has armed the powerful males of both species of Chimpanzee, form the compensation for the want of that psychical capacity to forge destructive instruments which has been reserved, as his exclusive prerogative, for Man. Both Chimpanzees and Orangs differ from the human subject in the order of the development of the permanent series of teeth; the second molar (*m* 2) comes into place before either of the premolars has cut the gum, and the last molar (*m* 3) is acquired before the canine. We may well suppose that the larger grinders are earlier required by the frugivorous Chimpanzees and Orangs than by the higher organized omnivorous species with more numerous and varied resources, and probably one main condition of the earlier development of the canines and premolars in Man may be their smaller relative size.

Homo.

Having reached, in the Gorilla, the highest step in the series of the brute creation, our succeeding survey of the human dental system, cleared and expanded by retrospective comparison, becomes fraught with peculiar interest, since every difference so detected establishes the true and essential characteristics of that part of man's frame.

The human teeth are the same in number and in kind as those of the Chimpanzee and Orang-utan, nor does man differ in this respect from any of the inferior catarhine Quadrumanes. The human dental formula is therefore—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ p\,\frac{2.2}{2.2};\ m\,\frac{3.3}{3.3}=32;$$

that is to say, there are on each side of the jaw, both above and below, two incisors, one canine, two premolars, and three true molars.

They are more equal in size than in the *Quadrumana*. No tooth surpasses another in the depth of its crown; and the entire series, which describes in both jaws a regular parabolic curve, is uninterrupted by any vacant space (fig. 99). The most marked distinction between the dentition of Man and that of the highest Quadrumanes, is the absence of the interval between the upper lateral incisor and the canine, and the comparatively small size of the latter tooth (fig. 100, *c*); but its true character is indicated by the conical form of the crown, which terminates in an obtuse point, is convex outwards, and flat or sub-concave within, at the base of which surface there is a feeble prominence. The conical form is best expressed in the Melanian races, especially the Australian (fig. 99, *c*). The canine is more deeply implanted, and by a stronger fang than the incisors; but the contrast with the Chimpanzee is sufficiently manifest, as is shown in fig. 98. There is no sexual superiority of size either of the canine or any other single tooth in the human subject.

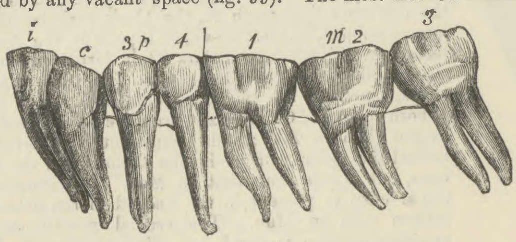

Fig. 99.

Teeth of Left Side, Lower Jaw, of Adult Male Australian. Nat. size.

Both upper and lower premolars (fig. 99, *p* 3 and 4) are bicuspid; they are smaller in proportion to the true molars than in the Chimpanzee and Orang. In the upper premolars a deep straight fissure at the middle of the crown divides the outer and larger from the inner and smaller cusp; in the lower premolars the boundary groove describes a curve concave towards the outer cusp, and is sometimes obliterated in the middle by the extension of a ridge from the outer to the inner cusp, which cusp is smaller in proportion than in the upper premolars. These teeth in both jaws are apparently implanted each by a single, long, subcompressed, conical fang; but that of the upper premolars is shown by the bifurcated pulp-cavity to be essentially two fangs, connate, and which, in some instances, are separated at their extremities.

The crowns of the true molars fig. 99, *m* 1, 2, 3) are larger in proportion to the jaws, are a little larger in proportion to the bicuspids, and still more so in proportion to the canine and incisor teeth, than in the Chimpanzees and Orangs. The contour of the grinding surface is more rounded, and we have seen that the higher *Quadrumana* already approximate to this character by the angles of the crown being less marked than in the lower *Quadrumana*. The first and second true molars of the upper jaw support four trihedral cusps; the internal and anterior one is the largest, and is connected with the external and posterior cusp by a low ridge extending obliquely across the grinding surface, with a deep depression on each side of it; the anterior groove extending to the middle of the outer surface, the posterior one to the inner surface. The enamel is first worn away by mastication from the anterior and internal or largest tubercle, a line of enamel extending from the outside to the middle of the crown is the last to be removed before the grinding surface is reduced to a field of dentine with a simple ring of enamel. It is worthy of remark, that by the time when the permanent teeth have come into place the first true molar in both jaws is much more worn, as compared with the second and third molars, than it is in the Chimpanzee or Orang, owing to the slow attainment of maturity characteristic of the human species, and the longer interval which elapses between the acquisition of the first and the last true molars, than in the highest *Quadrumana*. In the last true molar, called from its late appearance the "dens sapientiæ," or wisdom-tooth, the two inner tubercles are blended together, and a fissure extends in many instances, especially in the Melanian varieties, from the middle of the grinding surface, at right angles to that dividing the two outer cusps, to the posterior border of the tooth.

The first upper molar is always implanted by three diverging fangs, two external and one internal. The second molar is usually similarly implanted, but the two outer fangs are less divergent, are sometimes parallel, and occasionally connate; this variety appears to be more common in the Caucasian than in the Melanian races; and in the Australian skulls examined by the writer, the wisdom-tooth has always presented the same three-fanged implantation as in the Chimpanzee and Orang.

The crowns of the inferior true molars are quinque-cuspid, the fifth cusp being posterior and connected with the second outer cusp; it is occasionally obsolete in the second molar. The four normal cusps are defined by a crucial impression, the posterior branch of which bifurcates to include the fifth cusp; this bifurcation being most marked in the last molar where the fifth cusp is most developed. In the first molar a fold of enamel, extending from the inner surface to the middle of the crown, is the last to disappear from the grinding surface in the course of abrasion. The wisdom-tooth (fig. 99, *m* 3) is the smallest of the three molars in both jaws, but the difference is less in the Melanian than in the Caucasian races. Each of the three lower molars is inserted by two sub-compressed fangs, grooved along the side, turned towards each other. This double implantation appears to be constant in the Melanian, especially the Australian race (fig. 99), in which the true molars are relatively larger than those of the Caucasian race. In Europeans it is not unusual to find the two fangs in both the second and third molars connate along a great part or the whole of their extent.

With respect to the reciprocal apposition of the teeth of the upper and under jaw, it is interesting to observe that the crown of the lower canine is, as usual, in advance of that above, and fits into the shallow notch between that and the lateral incisor. The inferior incisors are so small that their anterior surface rests against the posterior surface of the upper ones when the mouth is closed; the other teeth are opposed crown to crown, the upper teeth extending a little more outwardly than the lower ones.

Hunter remarks that the supernumerary teeth happen oftener in the upper than in the under jaw, and he believed them to be always incisors or canines. In the Osteological series of the Museum of the London College of Surgeons there is a skull of a male Hindoo (No. 5541), in which there were two well-formed canine teeth placed side by side in the left upper jaw, the series being very regular and even. The wisdom-tooth is sometimes not developed.

The deciduous series of teeth in the human subject (fig. 100) consists of—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ m\,\frac{2.2}{2.2}=20.$$

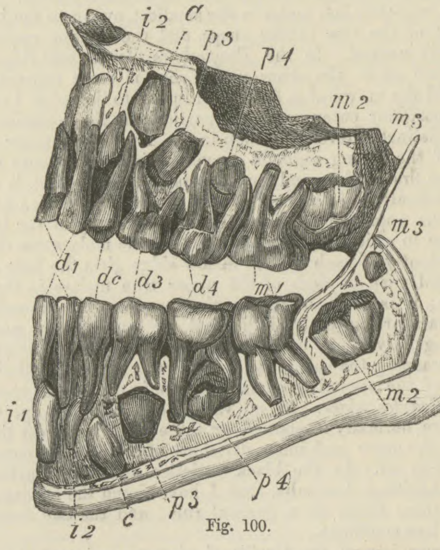

Fig. 100.

Deciduous and Permanent Teeth, Human Child: æt. 6½.

Comparison of the deciduous teeth in Man, the Chimpanzee, and Orang.

The upper milk incisors of the Chimpanzee are relatively larger than in Man, especially the middle pair; but the disproportionate size of these is still more manifest and characteristic of the Orang. The crown of the canine is longer and more pointed in the Chimpanzee than in Man; still more so, and further apart from the incisor in the Orang. The first upper milk-molar (fig. 100, *d* 3) is as large in the human subject as in the Chimpanzee, and its crown is divided into two principal cusps, but the outer and larger one has a small subdivision notched off posteriorly, and the inner cusp is relatively larger than in the Chimpanzee. The first upper milk-molar of the Orang is simply bicuspid, but is larger than in the Chimpanzee. The second milk-molar of the human child (fig. 100, *d* 4) could scarcely be distinguished from that of the young Chimpanzee; both are quadricuspid, and the same oblique ridge crosses the grinding surface from the antero-internal to the postero-externa tubercle; but the pointed summits of the two outer cusps are a little more produced in the Chimpanzee. The second molar of the Orang, besides its larger size, has the four tubercles better defined, and the oblique ridge less developed. The lower deciduous incisors of the anthropoid Apes differ from those of the human subject in their superior size, greater relative thickness, and, in the lateral incisor more particularly, by the rounding off of the outer angle. The lower canine of the Chimpanzee has a longer, larger, and more pointed crown, with a sharp posterior edge; it is less marked in the canine of the Orang, which is larger and thicker than in the Chimpanzee. The crowns of the upper and lower canines are more obliquely opposed, the lower one being more advanced in those apes than in the human subject. The first lower deciduous molar of the human subject has four tubercles and a small anterior ridge, and is larger than that of the Chimpanzee, which supports a single large-pointed cusp, and a posterior ridge. The corresponding molar of the Orang has a similar simple crown, but is as large as that of the human child. The second lower milk molar (fig. 100, *d* 4) is of equal or superior size in the human subject to that in the Chimpanzee, but it supports three outer and two inner cusps, while in the Chimpanzee it has but four cusps. In the Orang the fifth external and posterior tubercle is feebly indicated. The deciduous molars of the human subject, as in the Chimpanzee and Orang, have each three fangs in the upper, and two in the lower jaw.

The differences brought out by the foregoing comparisons, though less striking than those exhibited by the permanent teeth, will be appreciated by the philosophical anatomist as yielding more certain evidence of the essential distinction of the Bimanous species. He will perceive that they are not due to mere adaptive developments, but are manifested at a period when the subjects of comparison are far from having attained the pre-ordained term of deviation from the common type; that they are antecedent to those changes in the dental system itself, which more broadly characterize the species, and, in the Orang and Chimpanzee, proceed further to differentiate the male and female sexes.

Homo. Development.

Calcification of the permanent series of teeth commences first in the pulp of the first true molar (fig. 100, *m* 1), and, very soon after, if not simultaneously, in that of the anterior incisor (*i* 1), about five or six months after birth. The first true molar (*m* 1) comes into place and use between the sixth and seventh year; the first permanent incisor (*i* 1) between six years and a half and eight years; the calcification of the pulps of the lateral incisor (*i* 2) and canine (*c*) commences about eight or nine months after birth, and they cut the gum, the canine quickly following the incisor, between the seventh and ninth years. Calcification of the first premolar (*bicuspis*, *p* 3) begins at, or soon after, the second year; that of the second about a year later; and both premolars (*p* 3 and 4) have displaced the deciduous molars (*d* 3 and 4), and come into use between the eighth and tenth years. The pulp of the second molar (*m* 2) begins to be calcified about the fifth or sixth year, and it cuts the gum from about the twelfth year to the fourteenth year, but always later than the permanent canines and premolars. The third molar (*m* 3) begins to be calcified about the twelfth year, and usually comes into place at or after the twentieth year.

Both earlier and later periods of the development of the permanent teeth have been observed and recorded; but such varieties rarely affect the general order of succession. This order is here described as it occurs in the lower jaw, the teeth of which usually appear earlier than the corresponding ones above. It will be seen, therefore, that the human subject differs from the Chimpanzee and Orang in the order of progression of the permanent teeth.

John Hunter, after indicating the first incisor and the first molar as the earliest of the adult teeth that are formed, rightly observes, "The teeth between these two points make a quicker progress than those behind."[1] In the *Quadrumana* the progress is slower, the second molar preceding in the order of development the bicuspid, and the last molar the canines.

Order Carnivora. Felis.

Fig. 101.

Dentition of the Lion.

The Lion (*Felis Leo*) may be taken as the type of the flesh-feeders. The largest and most conspicuous teeth in this and the other feline quadrupeds are the canines (fig. 101, *c*); they are of great strength, deeply implanted in the jaw, with the fangs thicker and longer than the enamelled crown; this part is conical, slightly recurved, sharp-pointed, convex in front, with one or two longitudinal grooves on the outer side, almost flat on the inner side, and with a sharp edge behind. The lower canines pass in front of the upper ones when the mouth is closed.

The incisors, six in number on both jaws, form a transverse row; the outermost above (fig. 101, *i*) is the longest, resembling a small canine; the intermediate ones have broad and thick crowns indented by a transverse cleft. The first upper premolar (*p* 2) is rudimental; there is no answerable tooth in the lower jaw. The second (*p* 3), in both jaws, has a strong conical crown supported on two fangs. The third upper tooth (*p* 4) has a cutting or trenchant crown divided into three lobes, the last being the largest, and with a flat inner side, against which the cutting tooth (*m*) in the lower jaw works obliquely. Behind, and on the inner side of the upper tooth (*p* 4), there is a small tubercular tooth. The feline dental formula is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{2.2};\ m\,\frac{1.1}{1.1}=30.$$

A glance at the long sub-compressed, trenchant, and sharp-pointed canines, suffices to appreciate their peculiar adaptation to seize, to hold, to pierce, and lacerate a struggling prey. The jaws are strong, but shorter than in other carnivora, and with a concomitant reduction in the number of teeth; thus the canines are brought nearer to the insertion of the very powerful biting muscles, called "temporal" and "masseter," which work them with proportionally greater force. The use of the small pincer-shaped incisor teeth is to gnaw the soft, grisly ends of the bones, and to tear and scrape off the tendinous attachments of the muscles and periosteum. The compressed trenchant blades of the sectorial teeth play vertically upon each other's sides like the blades of scissors, serving to cut and coarsely divide the flesh; and the form of the joint of the lower jaw almost restricts its movement to the vertical direction, up and down. The wide and deep zygomatic arches, and the high crests of bone upon the skull concur in completing the carnivorous physiognomy of this most formidable existing species of the feline tribe.

The penultimate tooth in the upper jaw (fig. 101, *p* 4), and the last tooth in the lower jaw (fig. 101, *m*), were denominated by Cuvier "dents carnassières," which has been rendered "dens sectorius," the "sectorial," or scissor-tooth.[2] It is a very characteristic tooth in the carnivorous order, but undergoes many modifications, and preserves its typical form, as represented in figures 102 and 103, only in the most strictly flesh-feeding species. In it may be distinguished the part called the "blade" (fig. 102, *b*, *b*), and the part called the "tubercule" (fig. 102, *t*). The lower sectorial in the genus *Felis* consists exclusively of the blade (fig. 103), which is pretty equally divided into two lobes. The blade of the upper sectorial always plays upon the outside, and a little in advance of the lower sectorial.

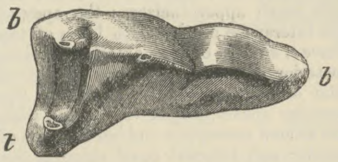

Fig. 102.

Working Surface of the Upper Sectorial Tooth, Hyæna. Nat. size.

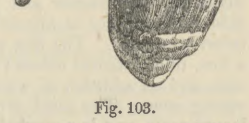

Fig. 103.

Side view of Lower Sectorial Tooth Lion. Nat. size.

Development.

The upper permanent sectorial (fig. 104, *p* 4) succeeds and displaces a deciduous tubercular molar (fig. 104, *d* 4) in all carnivora, and is, therefore, essentially a premolar tooth; the lower sectorial (fig. 104, *m* 1) comes up behind the deciduous series (*d* 3, *d* 4) and has no immediate predecessor; it is, therefore, a true molar, and the first of that class. By these criteria the sectorial teeth may always be distinguished under every transitional variety of form which they present in the carnivorous series, from *Machairodus* (fig. 145, VI.), in which the crown consists exclusively of the "blade" in both jaws, to *Ursus* (fig. 109), in which it is totally tubercular; the development of the tubercle bearing an inverse relation to the carnivorous propensities of the species.

Hyæna.

The dentition of this genus presents a nearer approach to the strictly carnivorous type, than in other *Carnivora*, by the reduction of the tubercular molars to a single minute tooth on each side of the upper jaw, the inferior molars being all conical or sectorial teeth; the molar teeth in both jaws are larger and stronger, and the canines smaller in proportion than in the Feline species, from the formula of which the dentition of the hyæna differs numerically only in the retention of an additional premolar tooth, *p* 1 above and *p* 2 below, on each side of both jaws. The dental formula of the genus *Hyæna* is:—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{3.3};\ m\,\frac{1.1}{1.1}=34.$$

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[1] *Natural History of the Human Teeth*, 4°, p. 82.

[2] *Odontography*, p. 475.

Teeth of Mammals

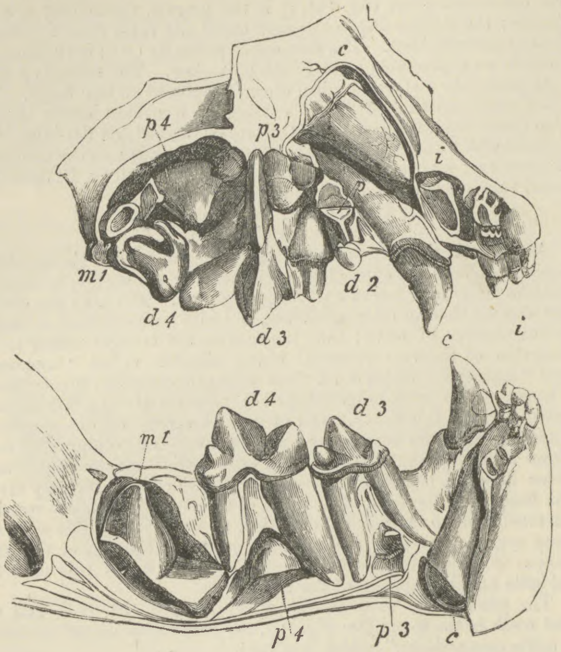

Fig. 104.
Deciduous Teeth; young Lion.

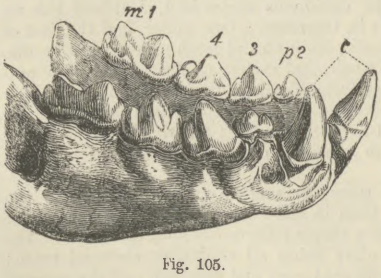

Fig. 105.
Dentition, Lower Jaw, of the Hyæna.

The crowns of the incisors form almost a straight transverse line in both jaws, the exterior ones, above, being much larger than the four middle ones, and extending their long and thick inserted base further back; the crown of the upper and outer incisor is strong, conical, recurved, like that of a small canine. The four intermediate small incisors have their crown divided by a transverse cleft into a strong anterior, conical lobe, and a posterior ridge, which is notched vertically; giving the crown the figure of a trefoil. The lower incisors gradually increase in size from the first to the third; this and the second have the crown indented externally; but they have not the posterior notched ridge like the small upper incisors; the apex of their conical crown fits into the interspace of the three lobes of the incisor above. The canines have a smooth convex exterior surface, divided by an anterior and posterior edge from a less convex inner side; this surface is almost flat and of less relative extent in the inferior canines. The first premolar above (p 1) is very small, with a low, thick, conical crown; the second presents a sudden increase of size, and an addition of a posterior and internal basal ridge to the strong cone. The third premolar exhibits the same form on a still larger scale, and is remarkable for its great strength. The posterior part of the cone of each of these premolars is traversed by a longitudinal ridge. The fourth premolar above is the carnassial tooth (fig. 102), and has its long blade (b, b) divided by two notches into three lobes, the first a small thick cone, the second a long and compressed cone, the third a horizontal sinuous trenchant plate; a strong triedral tubercle (t) is developed from the inner side of the base of the anterior part of the crown. The single true molar of the upper jaw is a tubercular tooth of small size. The first premolar of the lower jaw, (fig. 105, p 2) fits into the interspace between the first and second premolars above, and answers, therefore, to the second lower premolar in the *Viverridæ*; it is accordingly much larger than the first (p 1) above; it has a ridge in the forepart of its cone, and a broad basal talon behind. The second (fig. 105, p 3) is the largest of the lower premolars, has an anterior and a posterior basal ridge, with a vertical ridge ascending upon the fore as well as the back part of the strong rounded cone; the third premolar (p 4) is portionably less in the *Hyæna crocuta* than in the *H. vulgaris;* its posterior ridge is developed into a small cone; the last tooth (m 1) is the sectorial, and consists almost entirely of a blade divided by a vertical fissure into two sub-equal compressed pointed lobes; the points are less produced than in the Felines, but the lower sectorial of the hyæna is better distinguished by the small posterior basal talon, from which a ridge is continued along the inner side of the base, and is slightly thickened at the forepart of the crown.

The deciduous teeth consist of—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ m\,\frac{3.3}{3.3}=22.$$

The first normal deciduous molar is two-fanged, and has a more compressed and consequently more carnassial crown than that of the second permanent premolar, by which it is succeeded. The second deciduous molar is the sectorial tooth; the inner tubercle is continued from the base of the middle lobe, and thus resembles the permanent sectorial of the Glutton (*Gulo*) and many other *Mustelidæ;* the deciduous tubercular molar is relatively larger than in the adult *Hyæna,* and offers another feature of resemblance to the permanent dentition of the Glutton. It is also worthy of remark that the exterior incisor of the upper jaw is not only absolutely, but relatively smaller in the immature than in the adult dentition of the hyæna, and again illustrates the resemblance to the more common type of dentition in the Carnivora.

The permanent dentition of the *Hyæna,* as of other genera or families of the Carnivora, assumes those characteristics which adapt it for the peculiar food and habits of the adult, and mark the deviation from the common type, which always accompanies the progress to maturity. The most characteristic modification of this dentition is the great size and strength of the molars as compared with the canines, and more especially the thick and strong conical crowns of the second and third premolars in both jaws, the base of the cone being belted by a strong ridge which defends the subjacent gum.[1] This form of tooth is especially adapted for gnawing and breaking bones, and the whole cranium has its shape modified by the enormous development of the muscles which work the jaws and teeth in this operation.[2] Adapted to obtain its food from the coarser parts of animals which are left by the nobler beasts of prey, the hyæna chiefly seeks the dead carcass, and bears the same relation to the lion which the vulture does to the eagle. In consequence of the quantity of bones which enter into its food, the excrements consist of solid balls of a yellowish white colour, and of a compact earthy fracture. Such specimens of the substance, known in the old *Materia Medica* by the name of "album græcum," were discovered by Dr Buckland in the celebrated ossiferous cavern at Kirkdale. They were recognised at first sight by the keeper of a menagerie, to whom they were shown, as resembling both in form and appearance the fœces of the spotted Hyæna; and, being analysed by Dr Wollaston, were found to be composed of the ingredients that might be expected in fœcal matter derived from bones, viz. phosphate of lime, carbonate of lime, and a very small proportion of the triple phosphate of ammonia and magnesia. This discovery of the coprolites of the hyæna formed, perhaps, the strongest of the links in that chain of evidence by which Dr Buckland proved that the cave at Kirkdale, in Yorkshire, had been, during a long succession of years, inhabited as a den by hyænas, and that they dragged into its recesses the other animal bodies, whose remains, splintered and bearing marks of the teeth of the hyæna, were found mixed indiscriminately with their own.

Viverridæ.

This family of *Carnivora,* which comprehends the Civets, Genets, Ichneumons, Musangs, Surikates, and Mangues, is characterized with few exceptions, by the following formula:—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{2.2}{2.2}=40,$$

(fig. 106). It differs from that of the genus *Canis* by the absence of a tubercular tooth (m 3) on each side of the lower jaw; but, in thus making a nearer step to the feline dentition, the *Viverridæ,* on the other hand, recede from it by the less trenchant and more tubercular character of the sectorial teeth.

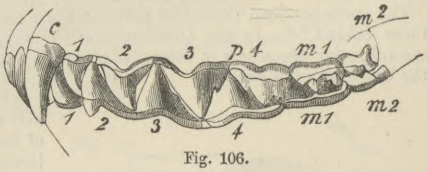

Fig. 106.
Dentition of Cynogale.

The canines are more feeble, and their crowns are almost smooth; the premolars, however, assume a formidable size and shape in some aquatic species, as those of the sub-genus *Cynogale* (fig. 106), in which their crowns (p 1-4) are large, compressed, triangular, sharp-pointed, with trenchant and serrated edges, like the teeth of certain sharks, (whence the name *Squalodon,* proposed for one of the species), and well adapted to the exigencies of quadrupeds subsisting principally on fish; the opposite or obtuse, thick form of the premolars is manifested by some of the Musangs, as *Paradoxurus auratus.*

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[1] An eminent civil engineer, to whom the writer showed the jaw of a hyæna, observed that the strong conical tooth, with its basal ridge, was a perfect model of a hammer for breaking stones for roads.

[2] "The strength of the hyæna's jaw is such, that in attacking a dog, he begins by biting off his leg at a single snap." Buckland, *Reliquiæ Diluvianæ,* p. 23.

In the lower jaw the sectorial tooth (*m* 1) manifests its true molar character by the presence of an additional pointed lobe on the inner side of the two lobes forming the blade at the forepart of the crown; the posterior, low, and large lobe of the tooth being also trituberculate, as in the dog. The last molar (*m* 2) has an oval crown with four small tubercles, resembling the penultimate lower molar in the dog, with which it corresponds.

The deciduous dentition consists, in the Viverrine family, of—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ m\,\frac{3\,3}{3.3}=28.$$

If the first permanent premolar has any predecessor, it must be rudimental, and disappear early in both jaws; the second premolar displaces the first normally developed deciduous molar; the third upper premolar displaces and succeeds the deciduous sectorial, which has a sharper and more compressed blade, and a relatively smaller internal tubercle, than the permanent sectorial. This tooth displaces the last deciduous molar, which is a tubercular tooth, resembling in form the first of the two upper permanent tuberculars; these coming into place without pushing out any predecessors, enter into the category of true molar teeth. In the lower jaw the third premolar displaces the deciduous sectorial, which has three trenchant lobes and a relatively smaller posterior talon than the permanent sectorial. The fourth premolar displaces the third or tubercular milk-molar. The permanent sectorial and tubercular molars displace no predecessors, and are therefore *m* 1 and *m* 2.

The alternate interlocking of the crowns of the teeth of the upper and lower jaws, which is their general relative position in the Carnivora, is well-marked in regard to the premolars of the *Viverridæ* (fig. 106); as the lower canine is in front of the upper, so the first lower premolar (*p* 1) rises into the space between the upper canine and first upper premolar; the fourth lower premolar in like manner fills the space between the third upper premolar (*p* 3) and the sectorial tooth (*p* 4), playing upon the anterior lobe of the blade of that tooth which indicates by its position, as by its mode of succession, that it is the fourth premolar of the upper jaw. The first true molar below, modified as usual in the *Carnivora* to form the lower sectorial, sends the three tubercles of its anterior part to fill the space between the sectorial (*p* 4) and the first true molar (*m* 1) above. In the Musangs, the lower sectorial is in more direct opposition to its true homotype, the first tubercular molar in the upper jaw; and these Indian *Viverridæ* (*Paradoxuri*) are the least carnivorous of their family, their chief food consisting of the fruit of palm-trees, whence they have been called "Palm-cats."

Canis.

The normal dental formula of the genus *Canis* is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{2.2}{3.3}=22\ \text{(fig. 107, \textit{Canis})}.$$

The incisors form a continuous series, describing the segment of a circle in both jaws, and progressively increase in size from the first to the third; the trenchant margin of the crown is divided by two notches into a large middle and two small lateral lobes. The canines (*c*) are curved, sub-compressed; the enamelled pointed crown forms nearly half the length of the tooth, and is smooth, without any groove. The premolars (*p*) have strong sub-compressed conical crowns gradually enlarging from the first to the third (*p* 3) in the upper jaw, and to the fourth (*p* 4) in the lower jaw, and acquiring one or two accessory posterior tubercles as they increase in size. The fourth upper premolar (*p* 4) presents a sudden increase of size, with its sectorial form; its blade is divided into two cones by a wide notch, the anterior cone being the strongest and most produced; the tubercle is developed from the inner side of the base of this lobe. The first and second upper molars (*m* 1 and 2) are tuberculate; but the second is very small, less than half the size of the first molar. The first true molar below (*m* 1) is modified to form the opposing blade to the sectorial tooth above; retaining the tuberculate character at its posterior half. The blade is divided by a vertical lineal fissure into two cones, the posterior being the largest; behind this the base of the crown extends into a broad, quadrate, trituberculate talon. The second molar has two anterior cusps on the same transverse line, and a posterior broad flat talon; the last lower molar (*m*, 3) is the smallest of all the teeth.

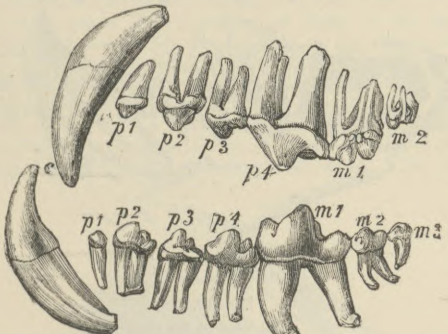

Fig. 107.
Teeth of the Dog.

The absence of a tuberculate molar in the lower jaw of the immature Dog, brings the character of the deciduous dentition of the genus *Canis* much closer to that of the typical members of the Carnivorous order, and affords an interesting illustration of the law that "unity of organization is manifested directly as the proximity of the animal to the commencement of its development."[1] The succession of two tubercular molar teeth behind the permanent sectorial tooth in the adult, or permanent dentition of the lower jaw, carries the genus *Canis* farther from the type of its order, and stamps it with its own proper omnivorous character, and this contributes to adapt the Dog for a greater variety of climates and food, and of other circumstances, all of which tend, in an important degree, to fit that animal for the performance of its valuable services to man. In no other genus of quadruped are the jaws so well or so variously armed with dental organs; notwithstanding the extent of the series, the vacancies are only sufficient to allow the interlocking of the strong canines. These are efficient and formidable weapons for seizing, slaying, and lacerating a living prey; the incisors are well adapted, by their shape and advanced position, for biting and gnawing; the premolars, and especially the sectorials, are made for cutting and coarsely dividing the fibres of animal tissues, and the tuberculate molars are as admirably adapted for cracking, crushing, and completing the comminution of the food, whether of an animal or vegetable nature.

Mustelidæ.

The dentition of the Weasel tribe (*Mustelidæ*) is illustrated in fig. 145, IV., *Mustela*, and by that of the Otter, fig. 108, which is a great aquatic Weasel or Polecat; its dental formula is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{3.3};\ m\,\frac{1.1}{2.2}=36.$$

The canines (*c*) are shorter than those of the Fox, narrower than those of the Badger, larger and relatively thicker than those of the Martin-cat. The first premolar (*p* 1) in the upper jaw, which is absent in the Polecat and Weasel, is retained in the Otter (fig. 108 and is placed on the inner side of the canine; the sectorial premolar (*p* 4) has its inner lobe much more developed in *Lutra* than in *Putorius*, and the tubercular molar (*m* 1) is relatively larger. Similar modifications of these teeth distinguish the dentition of the lower jaw of the Otter, which agrees in the number and kind of teeth with that of the Polecat. The increased grinding surface relates to the inferior and coarser nature of the animal diet of the Otter, the back teeth being thus adapted for crushing the bones of fishes before they are swallowed.

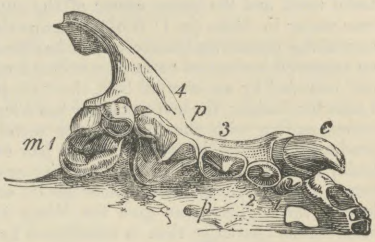

Fig. 108.
Teeth of Upper Jaw of the Otter.

In the Martin cats *(Mustela)*, the little homotype of *p* 1 above is present in the lower jaw; in the bloodthirsty Stoats and Weasels, *p* 1 is absent in both jaws; as it is likewise in the great Sea-otter *(Enhydra)*, in which also the two middle incisors are wanting in the lower jaw. In this animal the second premolar (*p* 3) has a strong obtuse conical crown, double the size of that of *p* 2; the third premolar (*p* 4) is more than twice the size of *p* 3, and represents the upper carnassial or sectorial strangely modified; the two lobes of the blade being hemispheric tubercles. The last tooth (*m* 1) has a larger crown than the sectorial, and is of a similar broad crushing form.

The *Mustelidæ* present great constancy in regard to the number of their true molar teeth; with one exception, the Ratel (*Mellivora*), in which *p* 2 is absent below, they have one true molar on each side of the upper jaw, and two on each side of the lower jaw; the second of these has always a broad tubercular crown, like the one above. The upper true molar is supported by one inner, and sometimes by one *(Putorius, Gulo)*, sometimes two *(Mustela, Lutra, Melphitis)* outer fangs. The second true molar below is also tubercular, but has a single fang. The crown of the first true molar below offers many gradations from the sectorial type, as manifested in *Putorius* and *Gulo*, to the tubercular type, as in the Taira, Ratel, and Sea-otter. The principal varieties occur, as usual, in the comparatively less important premolars; in the Martins and Gluttons, they are as numerous as in the Dog; the first, in both jaws, being implanted by a single fang; the rest by two, with the exception of the last above, which has three roots. In the Otter, we find the first premolar removed from the lower jaw; and the second (now the first) shows its true homology by its double implantation, as well as by the position of its crown behind the first in the upper jaw.

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[1] This law is defined and exemplified in the writer's *Lectures on the Invertebrate Animals*, pp. 368, 800, ed. 1843; p. 645, ed. 1855.

In the Stoats, Skunks, and Ratels, the premolar series is further reduced by the loss of the anterior tooth (*p* 1) in both jaws, and by the diminution of the size of *p* 2, which thus becomes the first in both jaws, and is also now implanted by a single fang. In a South American Skunk, the second premolar disappears in the upper jaw, leaving there only the homologues of the third and fourth of the typical formula, *p* 4 being always the sectorial in the *Mustelidæ*, as in other terrestrial Carnivora. This tooth, under all its modifications, retains the blade with the lobe, corresponding to the middle one in the feline sectorial, generally well-developed and sharp-pointed; the differences are principally manifested by the proportions of the inner tubercle, and the relative size of the third root supporting it. But the upper sectorial, being a premolar, and therefore requiring less modification of the crown to adapt it for its special functions, manifests a more limited extent of variety than the lower sectorial, which, being a true molar, requires greater modification of the typical form of its crown to fit it for playing upon the sectorial blade of *p* 4 above.

Melidæ. In this sub-family is comprised the European Badger (*Meles*), the Indian Badger (*Arctonyx*), and the American Badger (*Taxidea*); which, with respect to their dentition, stand at the opposite extreme of the *Mustelidæ* to that occupied by the predaceous Weasel, and manifest the most tuberculate and omnivorous character of the teeth. The formula is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{4.4};\ m\,\frac{1.1}{2.2}=30.$$

The canines are strongly developed, well pointed, with a posterior trenchant edge; they are more compressed in *Arctonyx* than in *Meles*. The first lower premolar (*p* 1) is very small, single-fanged, and, generally, soon lost. The first above, corresponding with the second in the dog, is also small, and implanted by two connate fangs. The second upper premolar (*p* 3) has a larger, but simple, sub-compressed conical crown, and is implanted by two fangs. The third (*p* 4) repeats the form of the second on a larger scale, with a better developed posterior talon, and with the addition of a trituberculate low flat lobe, which is supported by a third fang; the outer pointed and more produced part of this tooth represents the blade of the sectorial tooth and the entire crown of the antecedent premolars. The true molar in *Meles* (*m* 1) is of enormous size compared with that of any of the preceding Carnivora; it has three external tubercles, and an extensive horizontal surface traversed longitudinally by a low ridge. and bounded by an internal belt, the "cingulum" of Illiger. In the Labrador Badger, the last premolar has a larger relative size, the part corresponding with the blade of the sectorial is sharper and more produced, and the internal tubercle has two lobes; the succeeding molar tooth is reduced in size, and its crown presents a triangular form. The first true molar below has its sectorial lobes better developed; these differences give the North American badgers a more carnivorous character than is manifested by the Indian or European species.

Procyonidæ. In other allied genera, which, like the badgers, have been grouped, on account of the plantigrade structure of their feet, with the bears, a progressive approximation is made to the type of the dentition of the Ursine species. The first true molar below soon loses all its sectorial modification, and acquires its true tubercular character; and the last premolar above becomes more directly and completely opposed to its homotype in the lower jaw. The Racoon (*Procyon*), and the Coati (*Nasua*), present good examples of these transitional modifications; they have the complete number of premolar teeth, the dental formula being,

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{2.2}{2.2}=40.$$

The development of the inner part of the crown of the last upper premolar, which constitutes the tubercle of the sectorial tooth, now produces two tubercles on a level with the outer ones which represent the blade; and the opposite premolar below (*p* 4), which is the true homotype of the modified sectorial above, begins to acquire a marked increase of breadth and accessory basal tubercles. All the lower premolars, as well as the true molars, have two fangs; the three first premolars above have two fangs, the fourth has three, like the two true molars above.

The dental formula of the Indian Benturong (*Arctictis*) and Kinkajou (*Cercoleptes*) is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{2.2}{2.2}=36.$$

Ursidæ. The essential characteristic of the dentition of the Bears (figs. 109 and 145, II.), *Ursus*, is the development, in the lower jaw, of the truo molar teeth to their typical number in the placental *Mammalia*, and their general manifestation, in both jaws, of a tuberculate grinding surface; the premolar teeth are much reduced both in size and number. In the frugivorous Bears of India and the Indian Archipelago, the four premolars (*p* 1-4) are commonly retained longer than in the fiercer species of the northern latitudes. In the *Ursus labiatus*, the third small premolar above, and the second and third below, have each two connate fangs; the fourth premolar above presents three sub-equal obtuse tubercles supported by two distinct fangs. It is the only one of the four lower premolars retained in the dentition of the great extinct *Ursus spelæus;* the first premolar co-exists with it in the *Ursus priscus*, as also commonly in the *U. maritimus* and *U. arctos*. The second lower premolar is soon lost in the Bears of temperate and northern latitudes, but is longer retained in the tropical species called "Snn Bears" (*Helarctos*, Horsefield). The first true molar (*m* 1) has a longer and narrower crown than the one above. The second true molar (*m* 2) has a narrow, oblong, subquadrate, tubercular crown, which, like that of the first true molar, is supported by two fangs. The crown of the third lower molar (*m* 3) is contracted posteriorly, and supported by two connate fangs; it is relatively smallest in the Sun-bears, and largest in the great *Ursus spelæus*. The dental formula of the genus Ursus is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{2.2}{3.3}=42.$$

It is essentially the same both in number and kind of teeth as in genus *Canis*, but the individual or specific varieties, which in the Dog affect the true molar teeth, are confined in the Bears to the premolars. It would seem in the genus *Ursus* as if the preponderating size of the large tubercular true molars had tended to blight the development of the premolars.

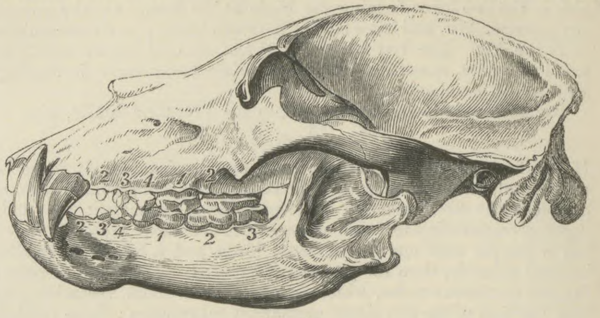

Fig. 109.
Dentition of the Bear (*Ursus*).

In fig. 110 the deciduous teeth and their successors are figured, as displayed by the removal of the outer wall of their sockets. The milk-molars, four in number on each side of both jaws, progressively increase from the first to the fourth. The characteristic relative position to them of the premolars is shown at *p* 2, 3, and 4. Behind these is shown the large formative cell of the first (*m* 1) of the true molar series.

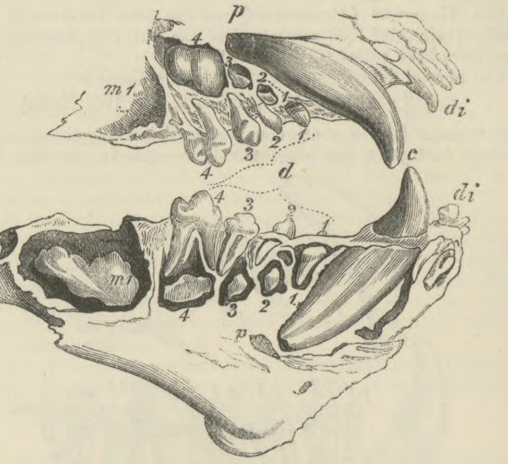

Fig. 110.
Milk-Teeth of the Bear.

Phocidæ. A tendency to deviate from the ferine number of the incisors is seen in the most aquatic and piscivorous of the Musteline quadrupeds, viz., the Sea-otter (*Enhydra*), in which species the two middle incisors of the lower jaw are not developed in the permanent dentition. In the family of true seals the incisive formula is further reduced, in some species even to zero in the lower jaw, and it never exceeds $\frac{3}{2}\cdot\frac{3}{2}$. All the *Phocidæ* possess powerful canines; only in the aberrant walrus (fig. 112), are they absent in the lower jaw, but this is compensated by the singular excess of development which they manifest in the upper jaw,

In the pinnigrade, as in the plantigrade, family of Carnivores, we find the teeth which correspond to true molars more numerous than in the digitigrade species, and even occasionally rising to the typical number, three on each side; but this, in the seals, is manifested in the upper, and not, as in the bears, in the lower jaw. The entire molar series usually includes five, rarely six, teeth on each side of the upper jaw, and five on each side of the lower jaw; with crowns which vary little in size or form in the same individual. They are supported in some genera, as the Eared Seals (*Otariæ*) and Elephant Seals (*Cystophora*), by a single fang; in other genera by two fangs, which are usually connate in the first or second teeth; the fang or fangs of both incisors, canines, and molars, are always remarkable for their thickness, which commonly surpasses the longest diameter of the crown. The crowns are most commonly compressed, conical, more or less pointed, with the "cingulum" and the anterior and posterior basal tubercles more or less developed; in a few of the largest species they are simple and obtuse, and particularly so in the walrus, in which the molar teeth are reduced to a smaller number than in the true seals.[1] In these the line of demarcation between the true and false molars is very indefinitely indicated by characters of form or position; but, according to the instances in which a deciduous dentition has been observed, the first three permanent molars in both jaws succeed and displace the same number of milk molars, and are consequently *premolars;* occasionally, in the seals with two-rooted molars, the more simple character of the premolar teeth is manifested by their fangs being connate, and in the *Stenorhynchus serridens* (fig. 111) the more complex character of the true molars (*m* 1 and 2) is manifested in the crown. There is no special modification of the crown of any tooth by which it can merit the name of a "sectorial" or "carnassial;" but we may point with certainty to the third molar above and the fourth below, as answering to those teeth which manifest the sectorial character in the terrestrial Carnivora.

The coadaptation of the crowns of the upper and lower teeth is more completely alternate than in any of the terrestrial Carnivora, the lower tooth always passing into the interspace anterior to its fellow in the upper jaw.

In the genus *Phoca* proper (*Calocephalus*, Cuv.) typified by the common seal (*Ph. vitulina*), the dental formula is—

$$i\,\frac{3.3}{2.2};\; c\,\frac{1.1}{1.1};\; p\,\frac{3.3}{3.3};\; m\,\frac{2.2}{2.2} = 34.$$

In the *Phoca Caspica* the upper molars have commonly one accessory cusp before, and one behind, the principal lobe; the lower molars have one accessory cusp before, and two behind, the lower molars.

In the *Phoca Grœnlandica* the upper molars have no anterior basal cusp, and only one behind; the lower molars have two behind and one in front, except the first, which resembles that above, and like it has connate fangs.

The condition of the molar teeth is nearly the same in the *Phoca barbata*, but the crowns are rather thicker and stronger, and the three middle ones above have two posterior basal cusps feebly indicated, the same being more strongly marked in the four last molars below.

The following genera of Seals with double-rooted molars(*Pelagius, Stenorhynchus*) have four incisors above as well as below, *i. e.* $\frac{2}{2}{:}\frac{2}{2}$.

The allied sub-genus (*Ommatophoca*) of Seals of the southern hemisphere has six molar teeth on each side of the upper, and five on each side of the lower jaw, with the principal lobe of the crown more incurved. The two first molars above are closely approximated, but this may prove to be a variety.

In the *Stenorhynchus* the jaws are more slender and produced, and the molar teeth are remarkable for the long and slender shape of the principal lobe, and of the accessory basal cusps. The incisors (fig. 111) have sharp conical recurved crowns, like the canines, and the external ones in the upper jaw are intermediate in size between the canines and the middle incisors.

Fig. 111.

Dentition of the Saw-toothed Seal. (*Stenorhynchus*).

In the *Stenorhynchus leptonyx* each molar tooth in both jaws is trilobed, the anterior and posterior accessory lobe curving towards the principal one, which is bent slightly backwards; all the divisions are sharp-pointed, and the crown of each molar thus resembles the trident or fishing-spear; the two fangs of the first molar in both jaws are connate. In *Stenorhynchus serridens* (fig. 111), the three anterior molars on each side of both jaws are four-lobed, there being one anterior and two posterior accessory lobes; the remaining posterior molars (true molars) are five-lobed, the principal cusp having one small lobe in front, and three developed from its posterior margin; the summits of the lobes are obtuse, and the posterior ones are recurved like the principal lobe. Sometimes the third molar below has three instead of two posterior accessory lobes. Occasionally, also, the second, as well as the first molar above, has its fangs connate; but the essentially duplex nature of the seemingly single fang, which is unfailingly manifested within by the double pulp-cavity, is always outwardly indicated by the median longitudinal opposite indentations of the implanted base. These slight and unessential varieties, presented by the specimens of the Saw-toothed Sterrink (*Stenorhynchus serridens*) brought home by the enterprizing naturalist of Sir J. Ross' Antarctic expedition, accord with the analogous varieties noticed in other species of Seals, and show the inadequacy of such characters as marks of subgeneric distinction.

In the genus *Otaria* the dental formula is—

$$i\,\frac{3.3}{2.2};\; c\,\frac{1.1}{1.1};\; p\,\frac{3.3}{3.3};\; m\,\frac{3.3}{2.2} = 36.$$

The two middle incisors are small, sub-compressed, with the crown transversely notched; the simple crowns of the four incisors below fit into these notches; the outer incisors above are much larger, with a long-pointed conical crown, like a small canine. The true canine is twice as large as the adjoining incisor, and is rather less recurved. The molars have each a single fang.

In the great proboscidian and hooded Seals (*Cystophora*), the incisors and canines still more predominate in size over the molars; but the incisors are reduced in number, the formula here is—

$$i\,\frac{2.2}{1.1};\; c\,\frac{1.1}{1.1};\; p\,\frac{3.3}{3.3};\; m\,\frac{2.2}{2.2} = 30.$$

All the molars are single-rooted, and all the incisors are laniariform. The two middle incisors above and the two below are nearly equal; the outer incisors above are larger. The canines are still more formidable, especially in the males; the curved root is thick and subquadrate. The crowns of the molar teeth are short, sub-compressed, obtuse; sometimes terminated by a knob and defined by a constriction or neck from the fang; the last is the smallest.

In the Walrus (*Trichechus rosmarus*, fig. 112), the normal incisive formula is transitorily represented in the very young animal, which has three teeth in each intermaxillary bone and two on each side of the forepart of the lower jaw; they soon disappear, except the outer pair above, which remain close to the intermaxillary suture, on the inner side of the sockets of the enormous canines, and seem to commence the series of small and simple molars which they resemble in size and form. In the adult there are usually three molars or premolars on each side, behind the permanent incisor, and four similar teeth on each side of the lower jaw; the anterior one passing into the interspace between the upper incisor and the first molar, and therefore being the homotype of the molar. In a young walrus' skull with canine tusks eight inches long, the writer has seen a fourth upper molar (fifth including the incisor) of very small size, about a line in breadth, lodged in a shallow fossa of the jaw, behind the three persistent molars. The crowns of these teeth must be almost on a level with the gums in the recent head; they are very obtuse, and worn obliquely from above down to the inner border of their base. The molars of the lower jaw are rather narrower from side to side than those above, and are convex or worn upon their outer side. Each molar has a short, thick, simple and solid root.

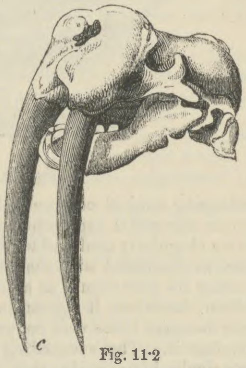

Fig. 11·2

Skull and Teeth of the Walrus

The canines (*c*) are developed only in the upper jaw, but are of enormous size, descending and projecting from the mouth, like tusks, slightly inclined outwards and bent backwards; they present an oval transverse section, with a shallow longitudinal groove along the inner side, and one or two narrower longitudinal impressions upon the outer side; the base of the canine is widely open, its growth being uninterrupted.

The food of the walrus consists of sea-weed and bivalves; the

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[1] The relation of *Trichechus* to the *Phocidæ* is analogous to that of *Machairodus* to the *Felidæ*, and also, in the simplification of the molars, to that of *Proteles* to the *Canidæ*.

molars are well adapted to break and crush shells; and fragments of a species of *Mya* have been found, with pounded sea-weed, in the stomach. The canine tusks serve as weapons of offence and defence, and to aid the animal in mounting and clambering over blocks of ice.

Machairodus.

A large extinct carnivorous animal (*Machairodus*, fig. 145, VI.), had the upper canine teeth (*c*) developed to almost the same disproportionate length as in the walrus, by which they were also compelled to pass outside the lower jaw when the mouth was shut. But these teeth were shaped after the type of the feline canines, only with more compressed and trenchant crowns; and they were associated with other teeth in number and kind demonstrating the due affinity of the *Machairodus* to the genus *Felis*.

The molar series of the upper jaw includes three teeth on each side, answering to the last two premolars (*p* 3 and *p* 4) and to the small tubercular tooth (*m* 1) in the lion. The inner tubercle of the carnassial tooth (*p* 4) is much less developed than in *Felis*. The molar series of the lower jaw accords with that of the lion, but *p* 3 is relatively very small in the South American *Machairodus* (*M. neogœus*).

The symphysis of the lower jaw presents a rapid increase in vertical diameter, whilst a depression on the outer side, between the canine and the first molar, indicates the part which received the long upper canine. The lower canine is much reduced in size, and appears to form the exterior tooth of the series of incisors; these are, however, six in number in the lower as in the upper jaw.

Both the anterior and posterior margins of the long upper falciform canines are finely serrated in *Machairodus*. The fossil teeth of this kind from Kent's Hole, Torquay, indicate a species of *Machairodus*, as big as the lion, and distinct from that of the Italian pliocene deposits, on which Cuvier founded his "*Ursus cultridens*."[1]

Hyænodon.

In more ancient tertiary formations, remains of carnivorous mammals have been found with the three true molar teeth as expressly modified for the division of flesh, and as worthy the express term of "sectorials" or "carnassials," as the teeth so called in the lion and other felines. And these teeth were associated with conical premolars, long canines, and short incisors, so as to exemplify the typical formula, *e. g.*—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{3.3}{3.3} = 44.$$

The extinct *Hyænodon* and *Pterodon* of the upper eocene formations of Hampshire, and of parts of France, manifest this interesting and instructive character of dentition.

A reduced view of the lower jaw of the *Hyænodon Requieni* is given in fig. 113. After the canines (*c*) come four successively enlarging conical compressed premolars (*p* 1-4); then, instead of a single carnassial representing the first true molar, there are three of these singularly modified teeth—the first (*m* 1) being of suddenly small size, as compared with the antecedent premolar, and obviously illustrating its true nature as a continuation of the deciduous series, with which, doubtless, it agreed in size. It became a permanent tooth only because there was no premolar developed beneath it, so as to displace it. The succeeding carnassial true molars (*m* 2 and 3) progressively increase in size. The symbols in fig. 111 denote the homologies of the teeth. The marks of abrasion on the lower teeth in the *Hyænodon* prove the upper series to have been the same in number.

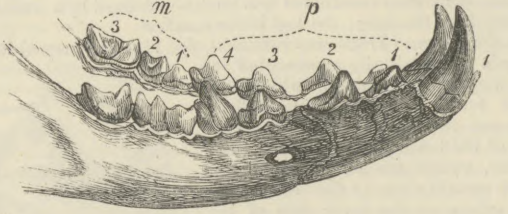

Fig. 113.

Dentition, Lower Jaw, of *Hyænodon*.

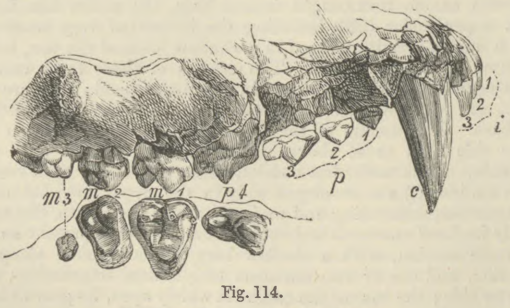

Fig. 114.

Dentition, Upper Jaw, of *Amphicyon*.

The obvious number of premolars in the *Hyænodon* negatives the notion entertained by De Blainville, that it was a marsupial carnivore.

Amphicyon.

A second form of equally ancient Carnivore was a mixed-feeding animal, allied to the Viverridæ and to the Dog tribe, the true molars presenting the tuberculate modification, and the typical number and kinds of teeth being functionally developed, as in the *Hyænodon*. The series in the upper jaw are shown in fig. 112. The term "tubercular" is as applicable to the three true molars of the *Amphycyon* (*m* 1, 2, 3) as the term "carnassial" is to those of the *Hyænodon*.

Structure Carnivora.

The teeth of the *Carnivora*, with the exception of the aberrant amphibious forms, so closely correspond in their intimate structure, both with each other and with those of the human subject, as to require here only a brief and general notice. They all enter into the category of "simple teeth," that is, the dentine or main body is not penetrated by folds of the other component tissues, but has an even exterior, covered, at the part forming the crown, with enamel, and having a general outer investment of cement, the coronal layer forming too thin a film to manifest any of the radiated cells. The dentine is of the kind called "hard or unvascular;" the tubuli are rather finer than in the human teeth; they have the same general direction from the pulp-cavity, but present stronger primary curvatures, more frequent dichotomous divisions, and more numerous minute lateral branches, which latter usually curve from the trunks at right angles. The dentinal compartments are subhexagonal, about $\frac{1}{5000}$th of an inch in diameter, with the peripheral contour forming almost a regular curve. In the Seals the dentine forms usually a smaller proportion of the tooth than in the terrestrial *Carnivora;* the characteristic thickness of the roots in this family is principally due to the thick covering of cement, and the pulp-cavity is usually closed by a more than usual quantity of the osteo-dentine. The tubes in the Seal's molar describe very strong and irregular curves on leaving the pulp-cavity; but when within a third of the distance to outer surface, they fall into more parallel and regular undulations; they are $\frac{1}{12000}$th of an inch in diameter, and the interspace between two tubes is about $\frac{1}{10000}$th of an inch in width.

The tubes dichotomise less frequently and less regularly than in the teeth of the Dog or Hyæna, but send off from both sides extremely numerous short branches, which bend almost transversely across the interspaces, and the side branches are occasionally sent off in greater abundance along lines parallel with the outer contour of the teeth, giving the appearance of opaque striæ, or concentric layers, to polished sections of the dentine. The dentinal tubes resolve themselves at their extremities into rich tufts of curved branches, which terminate in a layer of minute cells at the crown, and in the root communicate with the radiated cells of the cement.

In the molar teeth of the *Otaria jubata*, the tubes, proceeding in the long axis of the crown, are, on the peripheral half of the dentine, nearly parallel; towards the side of the crown they proceed in more zigzag, almost angular curves, and appear to cross each other, conspicuous branches being continued from the angles; the interspaces of the tubes were about $\frac{1}{8000}$th of an inch in width. The dentinal compartments are more numerous and less regular than in the teeth of the ordinary *Carnivora;* and their contour is more obscured by the deeper curves and more numerous branches of the dentinal tubes.

The enamel of the teeth of the *Carnivora* is extremely dense and brittle; it consists of fibres similar to those in the Human teeth, but relatively smaller, as, for example, in the large canines of the Tiger, and the molars of the Hyæna; the transverse striæ are also less distinct. In the molar of the *Otaria*, the enamel-fibres are very distinct, placed at right angles to the plane of the crown, and less curved than in Man or the Quadrumana; instead of the transverse striæ, they present a minute granular structure.[2]

The cap of enamel with which the teeth of the Walrus are at first tipped, is soon worn off; and, except at the abraded surface, the rest of the tooth—both tusks and molars—is thickly coated with cement. The dentine closely corresponds with that in the ordinary Seals; in the molar teeth the tubes present the same diameter, the same interspaces, and undulating curvatures; but their dichotomous divisions are more marked. In the canines the lateral branches terminate in minute opaque cells, dispersed throughout almost the whole dentine, but most numerous and conspicuous near its periphery, where the dentine is defined by a distinct layer of these cells; only a third part of the periphery of the canine is composed of true dentine, the central third part of the tooth is filled up by osteo-dentine, which, as in the teeth of the Cachalot, often projects in irregular rounded masses into the short and wide basal pulp-cavity. The whole mass, indeed, of the osteo-dentine consists of numerous independent calcifications of the pulp, having as many distinct centres, usually hollow, and producing, when the substance is examined by the naked eye, the appearance which Cuvier has compared to "pudding-stone." The central cavities are for the most part associated together and with the pulp-cavity by medullary canals. The tubes radiate from these central cavities in all directions, with sub-parallel, diverging curva-

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[1] *Ossemens Fossiles*, 4to, 1824, vol. v. pt. ii. p. 517.

[2] Retzius failed to detect any true enamel in the teeth of the *Phoca anellata*.

Teeth of Mammals.

tures, dividing, subdividing, and sending off numerous branches, which anastomose with those of the adjoining masses, and, where these are situated next the dentine, with the tubes of that tissue. In each lobe of the osteo-dentine the concentric rings parallel with the contour of the central medullary cavity are well marked. Myriads of minute calcigerous cells are dispersed throughout the osteo-dentine. The pulp-cavity of the incisor and molar teeth is filled up by a smaller quantity of the osteo-dentine.[1] Minute vascular canals convey the capillary blood-vessels to this structure, from the vascular membrane attached to the solid base of the molars, and in the tusks, from the persistent pulp, which fills the basal cavity.

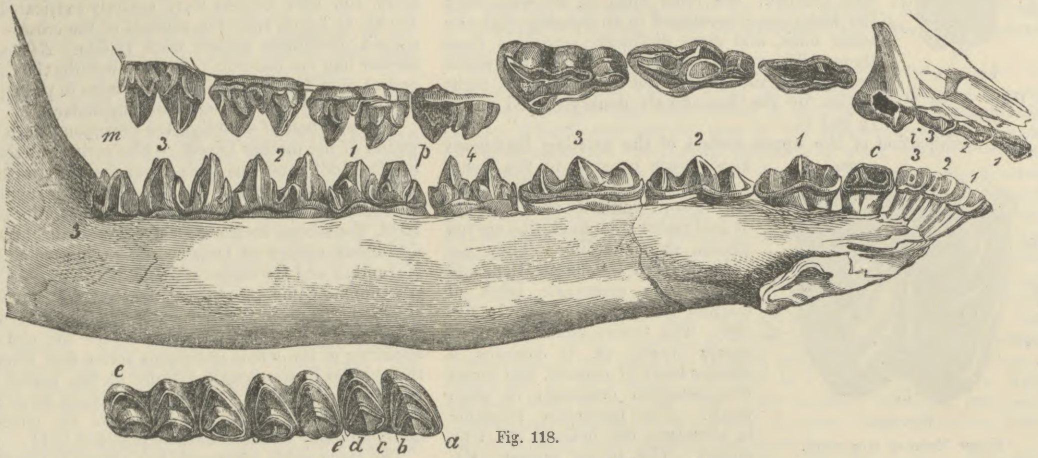

Fig. 118.

Dentition of the *Dichodon cuspidatus.*

The cement of the Morse's teeth is distinguished from the osteo-dentine by its continuous uniform structure, by the absence of the detached centres, and their concentric lines; but the radiated cells are disposed in regular layers, concentric and parallel with the contour of the body of dentine; the radiating tubes, from the cells forming the layer next the dentine, communicate freely with the peripheral ramifications of the dentinal tubes, and also with the proper cemental tubes, which are disposed vertically to the plane of the cement. Indeed, the evidence of an intercommunicating system of canals, too minute for the gross fluid of the circulating system, is most striking and universal throughout the substance of both the tusks and small teeth of the Walrus. Vascular canals are, however, present in the cement as in the osteo-dentine, from the capillaries in which it may be presumed that the colourless plasma is elaborated, which meanders through the minuter systems of cells and tubes.

Ungulata, or Herbivora.

The first forms of vegetable-eating mammals of which we have cognizance, those, viz., that have been restored from fossil remains discovered in the eocene or oldest tertiary deposits, have presented a dentition conformable, in number and kind of teeth, to the typical condition in the Placental Diphyodont series.

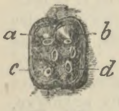

Fig. 115.

Upper Molar of *Hyracotherium.*

Transitional modifications of the molar teeth

The chief modifications are presented by the grinding surface of the molar teeth. In the *Hyracotherium* (e. *g.*, fig. 115) the grinding surface supports four principal cusps, each transverse pair (*a c*, *b d*) being connected by a ridge which is raised midway into a smaller conical tubercle, and the crown is girt by a cingulum.

In the Anoplotherium (fig. 116) the crown is divided into a front (*f*, *c*) and a back (*f*, *d*) lobe by a valley (*e*), extending from the inner side, two-thirds across, contracting as it penetrates. A second valley (*g*, *i*) crosses its termination at right angles, and forms a curved depression in each lobe, concave towards the outer side of the crown,—this side being impressed by two parallel excavations (*f f*). There is a large conical tubercle (*m*) at the wide entry of the valley (e).

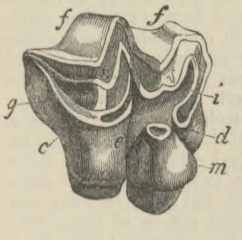

Fig. 116.

Upper Molar of *Anoplotherium.*

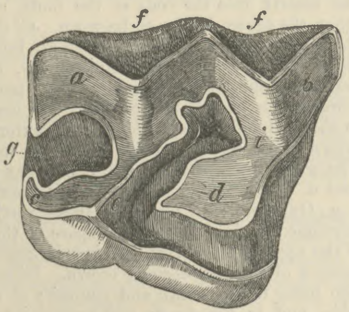

Fig. 117.

Upper Molar of *Palæotherium.*

The two points of the outer continuous border formed by the two outer lobes (*o*, *v*) are first abraded; those of the inner lobes (*c*, *d*) are next abraded; and thus a double crescentic field of dentine is exposed, with a detached island on the summit of the internal cone (*m*). This, afterwards, from the minor depth of the valley in front of its base, becomes blended with the lobe (*d*). In the *Palæotherium* (fig. 117) the crown of the molar is divided into an anterior (*b*, *d*) and posterior (*a*, *c*) part by an oblique fissure (*e*), continued from near the middle of the inner surface of the crown obliquely outwards and forwards, two-thirds across the tooth. Each division is subdivided partially into two outer (*a* and *b*) and two inner (*c* and *d*) lobes; the anterior division by the terminal expansion (*i*) of the fissure (*e*), the posterior one by the valley or fissure (*g*). The lobes (*c* and *d*) are bordered near their base by a ridge.

The first of the above types (fig. 115) of the upper grinders of the eocene *Herbivora* is continued into, or governs, with minor modifications, the corresponding teeth of the *Chæropotamus*, *Anthracotherium*, and the existing Hog-tribe and Hippopotamus. The second or Anoplotherian type (fig. 116) is continued into the *Dichodon*, *Dichobunes*, and the existing Ruminant dentition. The third (fig. 117) is the fundamental pattern of the upper molars of the tribes of the Horse and Rhinoceros.

A fourth form of eocene grinder, that of the genus *Lophiodon*, is very nearly allied to the *Palæotherium*, but the more complete union of the lobes *a*, *c*, and that of the lobes *b*, *d*, gives a more decided transversely-ridged character to the crown, and this type was carried on in the Dinotherium (fig. 136) and the existing Tapirs.

The space allotted to this article limits the selection of examples of the ungulate dentition to a few of the best-marked modifications, and the first of these forms a transitional step between the *Anoplotherium* and the *Ruminantia.*

The dentition in question is that of an extinct genus, the remains of which occur in the upper eocene of Hampshire, and which the writer has described under the name of *Dichodon cuspidatus*[2] (fig. 118). The dental formula is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{4.4};\ m\,\frac{3.3}{3.3} = 44.$$

The crowns of these different kinds of teeth are of nearly equal height, and there is no break in the series.

The incisors (*i* 1, 2, 3) have low and broad trenchant crowns. The canine (*c*) closely resembles them, but is a little larger, and with a low point: it is, however, more trenchant than piercing. The first (*p* 1), second (*p* 2), and third (*p* 3) premolars, have their crown much extended from before backwards, with three progressively more developed and pointed compressed cusps on the same line; to which is added, in the upper jaw, an inner ridge, developed in the third premolar (*p* 3) into an inner posterior cusp. The fourth premolar (*p* 4) has a thicker and shorter crown with two pairs of cusps. The upper true molars (*m* 1, 2, 3) have the two pairs of cusps sharp and pointed, with a series of five low accessory points developed from the outer part of the cingulum. The lower molars (*m* 1, 2, 3) have as complex crowns as the upper ones, but with the accessory basal points (*a*, *b*, *c*, *e*) developed from the inner, instead of the outer side of the crown, and with the convex sides of the chief cusps turned in the opposite direction to those above. In fig. 116 the outer side of the true molars, of the last premolar, of the canine, and of the incisors, is shown, together with the grinding surface of the three anterior premolars in the upper jaw. The inner surface of the

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[1] "L'ivoire des défenses du Morse est compact, susceptible d'un poli presque ausi beau que celui de l'hippopotame mais sans stries; la partie moyenne de la dent est formée de petits grains ronds placés pêle mêle, comme le Cailloux dans la pierre appelée *Poudingue;* c'est ce qui le caractérise. Les dents molaires de cet animal ont leur axe composé des mêmes petits grains que celui des défenses. Elles n'ont aucun cavité dans leur interieur."—*Cuvier, Leçons d'Anat. Comparée*, tom. iii. (1805), p. 106.

[2] *Quarterly Journal of the Geological Society*, June 1847.

Order Ruminantia.

entire series of the lower teeth is shown, together with the grinding surface of the three true molars of the last (m 3) here supports a third pair of lobes (e). As compared with the anoplotherian molar (fig. 116), the outer lobes (a, b) of that of the *Dichodon* (fig. 119) are thicker and sharper; the inner ones (c, d)—especially the latter—are developed to an equality with the outer ones, and more distinctly separated from them. The valley (m) extends across the whole breadth of the tooth, and is crossed at right angles by the fore-and-aft doubly-curved valley (g and i).

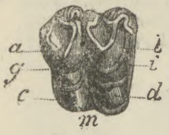

Fig. 119.

Upper Molar ot *Dichodon*.

The modification of the upper molars of the existing Ruminant quadrupeds consists in the lower and less pointed lobes of the crown, the unworn summits of which are at first rather trenchant, like curved blades, than piercing. They are soon abraded by mastication, and present the crescentic lobes of dentine (a, b, c, d) shown in fig. 120. The transverse double-crescentic valley (g, i) contains a thicker layer of cement, and forms two detached crescents in worn teeth. The premolars resemble in structure one half of the true molars. The upper incisors, the upper canine, and the first premolar of both jaws, are not developed in the typical Ruminants, the dental formula of which is—

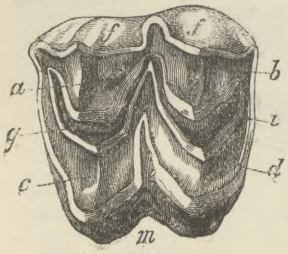

Fig. 120.

Upper Molar of Megaceros.

$$i\,\frac{0.0}{3.3};\ c\,\frac{0.0}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3.3} = 32.$$

The gazelle, the sheep, the ox—respectively representing the families *Antilopidæ*, *Ovidæ*, and *Bovidæ*, which are collectively designated the "hollow-horned ruminants"—all present this formula. It likewise characterises many of the solid-horned ruminants, or the deer tribe (*Cervidæ*), the exceptions having canine teeth in the upper jaw of the male sex, and sometimes also in the females, though they are always smaller in these.

The upper canines attain their greatest length in the small ruminants called Musk-deer, and especially in the typical species (*Moschus moschiferus*, fig. 145, VII.) These teeth, indeed, in the male Musk present proportions intermediate between those of the upper canines of the Machairodus and of the Morse. The inverse relationship in the development of teeth and horns, exemplified by the total absence of canines in the Ruminants with persistent and typical horns, by their first appearance in the periodically hornless deer, and their larger size in the absolutely hornless Musks, is further illustrated by the presence not only of canines, but of a pair of laniariform incisors in the upper jaw of the Camelidæ.

Camelidæ

In the Camel and Dromedary the upper canines are formidable for their size and shape, but do not project beyond the lips like the tusk of the Musk-deer; they are more feeble in the Llamas and Vicugnas, and are always of smaller size in the females than in the males. The inferior canines, moreover, retain their laniariform shape in the *Camelidæ*, and are more erect in position than in the ordinary Ruminants. They are separated by a short diastema from the incisors in the *Aucheniæ*.

The true nature of the corresponding canines in the ordinary Ruminants, in which they are procumbent, and form part of the same series with the incisors, is always indicated by the lateness of their development, and often by some peculiarity of form. Thus in the *Moschus* (fig. 145, VII. c) they are smaller and more pointed than the incisors, and in the Giraffe they have a much larger crown, which is bilobed. The laniariform tooth in the premaxillary bone of the *Camelidæ*, which represents the upper and outer incisor, is smaller than the true canine which is placed behind it in the Camel and Dromedary; but in the Vicugna it is as large as, or larger than, the true canine.

Development.

Most of the deciduous molars of the Ruminants resemble in form the true molars; the last milk-molar, for example (fig. 121, d 4), in the lower jaw, has three lobes like the last lower true molar (m 3). The deciduous molars in existing true Ruminants are three in number on each side, and, being succeeded by as many premolars, the ordinary permanent molar formula is—

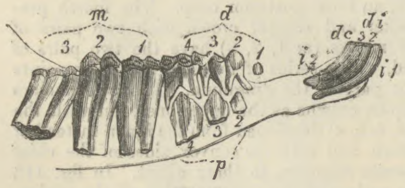

Fig. 121.

Deciduous and Permanent Teeth of a Sheep.

$$p\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3.3};$$

but there is a rudiment of d 1 in the embryo fallow-deer, and in one of the most ancient of the extinct Ruminants (*Dorcatherium*, Kaup) the normal number of premolars was fully developed.

The birth and growth of a young Giraffe at the Zoological Gardens of London, enabled the writer to make the following observations on the course of development and succession of the teeth in this Ruminant, which is the largest existing species of its order. The four middle deciduous incisors began to cut the gum one week after birth, and their crowns were entirely extricated at the end of four weeks, at which time the summit of the crowns of both the first and second deciduous molars were visible. At two months the third incisor had cut the gum; at three months the third deciduous molar, and at four months a fourth molar were in place; the latter being the first of the permanent series of true molars.

The progress of shedding the deciduous teeth was traced by observation of the mother Giraffe. She arrived at the Zoological Gardens in May 1836, and was then about eighteen months old, and had all the deciduous series, with the first permanent true molars. The two middle deciduous incisors were shed in the month of March 1838, the second incisor on each side in the following July, the first deciduous molars in October, and the second deciduous molars in November and December of the same year. At this time the second true molars came into place, the last true molars began to appear above the gum in August 1839, and the last deciduous molar was replaced by the third premolar before the end of that year. The shedding of the whole deciduous series was completed by the fall of the canines in the female Giraffe at the period of the birth of her second fawn in May 1841, when she must have been six years and a half old; the large bilobed crowns of the permanent canines were not completely in place until September 1841.

The same noble menagerie has afforded the opportunity of recording the following state of the first dentition of the *Dromedary*:—

In the new-born animal the six deciduous upper incisors present a larger size than any rudiments of these that have been discerned in the fœtus of ordinary Ruminants, and, as was discovered by subsequent dissection, these transitory incisors leave conspicuous alveoli in the premaxillary bones. The canine and first functional deciduous molar are small; the second and third deciduous molars are large, bilobed, and each lobe is bicrescentic. In the lower jaw the functional milk-teeth consist of the six incisors and two canines, one on each side, all with the overlapping leaf-shaped crowns. The functional molars are but two in number, in each ramus of the jaw. The first small, simple, conical, compressed, notched behind; the second very large, and three-lobed, each lobe bicrescentic, and the last lobe the largest. The middle incisors are relatively larger in the deciduous than in the permanent series, as compared with the outer ones and the canine in the ordinary Ruminants. The Giraffe deviates furthest from the typical proportions of these teeth in the superior expanse of the bilobed crown of the permanent canine, but it is interesting to find that the deciduous canine, though its crown is also bilobed, is relatively smaller in proportion to the incisors, and thus shows a less amount of deviation from the common type. The third molar is the last inferior true molar. This tooth in the great extinct Sivatherium retained more of the shape of its deciduous analogue, the last milk-molar, than is usually seen in existing species of *Ruminantia*.

The characteristic complexity of the molar teeth of a Ruminant is seen in most of the deciduous series, but in the permanent series only in the three posterior teeth of both upper and lower jaws, which are the true molars; the three first, or premolars, having more simple crowns than those which they displace. The complexity in question is the result of peculiar plications of the formative capsule, some of which are longitudinal, or project inwards from the sides of the capsule, and form peninsular folds of enamel upon the grinding surface of the tooth, whilst others depend vertically from the summit of the matrix into the body of the tooth, and form islands of enamel when the crown begins to be worn. Of the longitudinal folds, two in the upper true molars are external, broad, but shallow, and often sinuous, and one is internal, narrow, and deep, extending quite across the summit of the crown of the tooth, and decreasing in depth towards the base of the crown. The corresponding fold of enamel in the completed tooth, accordingly, extends more or less across the crown, from within outwards, as the tooth is less or more worn. The whole circumference of this complex molar is also invested by a coat of enamel and a thinner layer of cement. In some Ruminants, *e. g.*, Ox, Deer, and Giraffe, a small vertical column (fig. 120, m) is developed at the internal interspace of the two lobes of one or more of the upper true molars, varying in height, and rarely reaching the summit of the new-formed crown. Different genera of Ruminants also differ in the depth and sinuosity of the two outer longitudinal folds, and in the depth and complexity of the two vertical folds, which likewise are united in some species by a longer common base than in others, producing thereby a continuity of the enamel, and complete antero-posterior bisection of the grinding surface during a longer period of attrition. The upper molars also differ in their breadth, or antero-posterior diameter, as compared with their thickness or transverse diameter; but as the summit of the crown is always relatively broader in proportion to its thickness, care must be taken to compare teeth of the different species that have been worn to the same extent, or to allow for the difference.

In the Ox the outer contour of each lobe of the upper molars is more sinuous than in the Antelope or Sheep, the middle convexity being more prominent and the lateral depressions deeper. The crescentic islands are not so wide as in the larger Antelopes, and the secondary terminal indentations are less marked at the forepart of the island. The small internal accessory column (e) forms part of the periphery of the grinding surface at the inner interspace of the lobes, when the crown has been worn down about half an inch, from which part it decreases in size to the beginning of the fangs.

In the Deer (*Cervus*), the inner crescentic subdivision of each lobe is thicker transversely than in the *Bovidæ*. In the great extinct Irish Deer (*Megaceros*, fig. 120), which has molar teeth as large as those of the Aurochs, the crescentic islands are simple, narrow, and more curved or bowed than in the Ox, and in consequence of the later division of the vertical fold of the capsule, the cemental cavity of each is continued into the other until a later period of the attrition of the crown, as shewn in the upper molar (fig. 120). In the Elk (subgenus *Alces*), the central crescents are continuous for a still longer period, and the median longitudinal fold, which divides the crown transversely, retaining its full breadth for a greater extent. The crown of the molar is divided, during a longer period of attrition, by a crucial incision. The molars of the Camel present the most simple condition of the Ruminant type of these teeth; the transverse fold dividing the crown being short, the dentine of the two lobes soon forms a continuous tract. The common base of the crescentic vertical folds of the capsule being likewise short, the enamel islands are soon separated from each other. They include a shallow or narrow crescentic cavity, with a simple but slightly sinuous contour. The two outer shallow longitudinal depressions of the crown have no middle rising; and there is no columnar process at the interspace of the two inner convexities. Bojanus has well illustrated these characteristics of the upper molars of the Camel in his memoir on the *Merycotherium*,[1] a large extinct Cameloid genus of *Ruminantia*, founded on remains discovered in the drift of Siberia; and he has extended the comparison to the Sheep, the Elk, and the Ox.

Cuvier compares the lower molars of the Ruminants to the upper ones reversed. In the lower true molars the single median longitudinal fold is external, and divides the convex outer sides of the two lobes. The base of the fold extends, in some species, across the molar for some distance before it contracts in breadth, retreating towards the outer side, and the two lobes of the crown accordingly continue to be completely divided for a longer period, as in the Elk and Giraffe. The inner surface of the molar is gently sinuous, the concavities being rarely so deep as those of the outer surface of the upper molars. The lower molars are always thinner, in proportion to their breadth, than those above, and the crescentic islands are narrower and less bowed. The differences which the lower molars present in different genera of Ruminants are analogous to those in the upper molars, but are less marked. The accessory small column, when present, as in *Bos*, *Urus*, *Megaceros*, and *Alces*, is situated at the outer interspace of the convex lobes, and nearer the base in the *Cervidæ* than in the *Bovidæ*. It is not developed in the Antelopes, Sheep, or Camel, and is wanting in most of the smaller species of Deer. The last true molar of the lower jaw is characterized in all Ruminants by the addition of a third posterior lobe. This is very small and simple in the Camel and the Gnu, is relatively larger in the *Bovidæ* and *Cervidæ*, and presents, in the *Megaceros* and *Sivatherium*, a deeper central enamel island or fold, which also characterizes the smaller third lobe in the Giraffe. The lower molars of the genus *Auchenia* are peculiarly distinguished by the vertical ridge at the forepart of the anterior lobe, which does not exist in the Camels of the Old World.

In all Ruminants, the outer contour of the entire molar series is slightly zigzag, the anterior and outer angle of one tooth projecting beyond the posterior and outer angle of the next in advance. The premolars are smaller and more simple than the molars, with which they form a continuous series in the true Ruminants. In the upper jaw they are not divided into two lobes by an internal cleft, but resemble a single lobe of the true molars, of greater breadth than thickness, with a single central crescentic island, and usually with an internal nasal ridge.

The central crescents have a more complex contour in *Megaceros* than in *Bos*, and the first premolar, which is always the smallest, is relatively larger in the Deer than in the hollow-horned Ruminants. In the small Musk-deer, the crescentic enamel-island is reduced to a small internal notch or fold, and the outer border of the crown is trenchant and pointed. In the lower jaw the premolars decrease in size from the third to the first, which has usually a compressed conical crown, with a sinuous inner surface. The second and third premolars have two deeper notches on the inner side, and a small second hinder lobe seems to be slightly marked off by a vertical depression on the outer side of the crown. All the three lower premolars have compressed, sub-trenchant, and pointed crowns in the small Musk-deer (*Tragulus*). The true Musk (*Moschus*) more resembles the ordinary Deer in its premolars. The aberrant *Camelidæ* deviate most from ruminant type in the position, shape, and number of the premolars.

The extinct *Chœropotamus*, *Anthracotherium*, *Hyopotamus*, and *Hippohyus*, had the typical dental formula, and this is preserved in the existing representative of the same section of non-ruminant Artiodactyles, the Hog. The permanent dental formula of the genus *Sus* is illustrated in fig. 20.

Suidæ, Hog-tribe.

The upper incisors (fig. 20, i) decrease in size from the first to the third; the first has a short, strong, obtusely-pointed crown, obliquely levelled from the outside of the base to its apex, which inclines towards and touches that in the other premaxillary by its produced inner part; the crown, before it is worn, presents a semilunar depression on its inner side, the concavity of which, directed towards the base, receives a tubercular prominence, it is implanted by a short, thick, curved fang; this incisor is relatively larger in the *Sus larvatus* than in the *Sus scrofa;* the basal line of the enamel is extremely irregular; that substance extends more than an inch upon the outer side of the tooth, but only two or three lines on the inner side, where an angular piece seems to be cut out. The second incisor in the common Hog has a crown as broad as the first, but shorter and thinner; its edge is trenchant and dentated, but is soon worn down; in this state the abraded surface of both incisors shows a dark mark in the centre. The third is a very small tooth, a little removed from the second. The lower incisors are long, sub-compressed, nearly straight; the second is rather larger than the first; the third is the smallest, as in the upper jaw.

The upper canines, in the Wild Boar (fig. 20, c) curve forwards, outwards, and upwards; their sockets inclining in the same direction, and being strengthened above by a ridge of bone, which is extraordinarily developed in the Masked Boar of Africa. The enamel covering the convex inferior side of this tusk is longitudinally ribbed, but is not limited to that part; a narrow strip of the same hard substance is laid upon the anterior part, and another upon the posterior concave angle forming the point of the tusk, which is worn obliquely upwards from before, and backwards from that point. In the Sow the canines are much smaller than in the Boar. Castration arrests the development of the tusks in the male.

The teeth of the molar series progressively increase in size from the first to the last. The first premolar (fig. 20, p 1) has a simple, compressed, conical crown, thickest behind, and has two fangs; it is further removed from the second in the *Sus larvatus* than in the *Sus scrofa*. The second premolar (fig. 20, p 2) has a broader crown with a hind-lobe, having a depression on its inner surface, and each fang begins to be subdivided. The third premolar (fig. 20, p 13) has a similar but broader crown implanted by four fangs. The fourth premolar (fig. 20, p 4) has two principal tubercles and some irregular vertical pits on the inner half of the crown. The first true molar (m 1), when the permanent dentition is completed, exhibits the effects of its early development in a more marked degree than in most other Mammalia, and in the Wild Boar has its tubercles worn down, and a smooth field of dentine exposed by the time the last molar has come into place; it originally bears four primary cones, with smaller subdivisions formed by the wrinkled enamel, and an anterior and posterior ridge. The four cones produced by the crucial impression, of which the transverse part is the deepest, are repeated on the second true molar (fig. 20, m 2) with more complex shallow divisions, and a larger tuberculate posterior ridge. The greater extent of the last molar (fig. 20, m 3) is chiefly produced by the development of the back ridge into a cluster of tubercles; the four primary cones being distinguishable on the anterior main body of the tooth. The crowns of the lower molars are very similar to those above but are rather narrower, and the outer and inner basal tubercles are much smaller, or are wanting; the grinding surface of the last is shown in fig. 122.

The first or deciduous dentition of the Hog consists of—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ m\,\frac{3.3}{3.3} = 28, \text{(fig. 17).}$$

The first milk-incisor above is large, oblique, trenchant, and with a depression on the inner surface of the crown; the second and third are pointed, the latter being as long as the milk-canine. The first and second incisors, below, are trenchant and oblique, and have the indentations and ridge slightly marked on the upper or inner side of the long and narrow crown; the third is pointed, and like a canine. The outer third milk-incisor in both jaws is more advanced in growth than the rest at birth. The canines are feeble, and have their normal direction in both jaws, the upper ones ascending according to the general type, which is not departed from until at a later period of life.

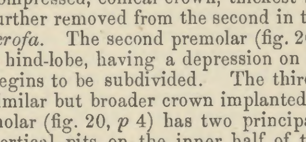

Fig. 122.

Last Lower Molar, Hog. Nat. size.

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[1] *Nova Acta Nat. Curios.* 4to, 1824, tom. xii. pt. i. p. 265, tab. xxi.

The first deciduous molar is not succeeded by a premolar, but holds the place of such some time after the other deciduous molars are shed and succeeded by the premolars (*p* 2, 3, and 4). The last true molar (fig. 122) is remarkable for its large proportional size and complexity of grinding surface. By the time it is acquired and in use, the first true molar (*m* 1) is worn flat.

The Hog is the only existing hoofed genus that manifests, as regards number, the typical dentition displayed by the *Dichodon* in common with many other Eocene ungulate and unguiculate Mammalia. The deviation in the Hog from this type is slight, being confined to the non-development of *p* 1, and the early reduction of the numerical formula by the loss of the small tooth (*d* 1, fig. 17 at the beginning of the molar series.

That the *Dichodon* belongs to the Artiodactyle series is inferred, notwithstanding the want of any direct evidence of the structure of its limbs, from the more simple form and structure of *p* 1, *p* 2, and *p* 3, as compared with the true molars, and from the symmetrical ruminating pattern of the grinding surface of the crown of the true molars.

From the true Ruminants the *Dichodon* differs in the development of the upper incisors and of *p* 1 in both jaws, which teeth are wanting in all the known existing species.

Such feeble traces of embryotic rudiments of these teeth as have been observed by Professor Goodsir and others, in the Cow and Sheep, and the more conspicuous germs of upper incisors, of which one pair is functionally developed, in the *Camelidæ*, are phenomena that derive increased significance and interest from the fact of the functional development of the same teeth in Artiodactyle Ungulates of the Eocene period.

In the configuration of the true molars the *Dichodon* would seem to be more nearly allied to the Ruminant section of the *Artiodactyla;* in the number and kinds of its teeth it more resembles the Hog-tribe amongst the non-Ruminant section. The known facts of the deciduous dentition of the *Dichodon* supply an additional test of its affinities, owing to the marked differences, in the times and order of succession of the permanent teeth, between the Hog-tribe and the Ruminants, at least in the Ox and Sheep.

In these the last true molar cuts the gum before any of the premolars appear, and the canine teeth ("corner-nippers" of the veterinarians) are the last of the permanent teeth to come into place, their appearance marking the completion of the third year in the Sheep, and a somewhat later period in the Ox. In the Hog the canines appear before the premolars, and these are in place and use before the last molar is on a level with the rest of the grinders.

In the *Dichodon cuspidatus* the second true molar, in the upper jaw, is in place before any of the deciduous series of teeth have been shed; and it is coming into place, with the crown complete, before the pulps of the premolars have even begun to be calcified. The lower jaw of the sheep at from nine to twelve months would afford the nearest parallel amongst existing Artiodactyles to that of the immature *Dichodon* figured in pl. 4. fig. 2, vol. iv. of the *Quarterly Journal of the Geological Society*. But by the time the second true molar in the Sheep is as far advanced in development as in the *Dichodon* (fig. 2, *loc. cit.*, *p.* 2, upper jaw) the first permanent incisor is in place, and the germs of the premolars in the cavities of reserve have calcified crowns.

The subjoined table indicates the several teeth by the symbols explained in the Section on the Homologies of the Teeth.[1]

The necessity of exactness in the records of the age of the valuable breeds of domesticated cattle, exhibited in competition at agricultural meetings, has led to a greater accuracy in the statements of the periods of development of the different teeth in the Ox, Sheep, and Hog; and the results of the writer's observations, with those recorded by Bojanus, the learned veterinary professor at Wilna, and by Mr Simonds, the professor of cattle pathology in the Royal Veterinary College of London,[2] are averaged in the following

Table of the Times of Appearance of the Permanent Teeth in the Ox, Sheep, and Hog.

Symbols.	Ox. Early. Year.	Ox. Early. Month.	Ox. Late. Year.	Ox. Late. Month.	Sheep. Early. Year.	Sheep. Early. Month.	Sheep. Late. Year.	Sheep. Late. Month.	Hog. Year.	Hog. Month.
i 1	1	9	2	3	1	0	1	4 to 8	1	0
i 2	2	3	2	9	1	6	2	0 to 4	1	6
i 3	2	9	3	3	2	3	2	9 to 12	0	9
c	3	3	3	9	3	0	3	6	0	9
m 1	0	4	0	6	0	3	0	6	0	6
m 2	1	3	1	8	0	9	1	0	0	10
m 3	2	0	2	3	1	6	2	0	1	6
d or *p* 1	0	0	0	0	0	0	0	0	0	6
p 2	2	6	2	8	2	0	2	6	1	0
p 3	2	6	2	8	2	0	2	6	1	0
p 4	2	8	3	0	2	3	2	6	1	3

Phacochœrus.

The dentition of the Wart-hogs is reduced by the suppression of certain incisors, and of the first two premolars—the tooth-forming energy being, as it were, transferred to the last true molar, which is even more remarkable than in the common hog for its size and complexity in both jaws. Fig. 123 shows the condition of the upper molar series in a *Phacochœrus Æliani*, soon after the acquisition of *m* 3. The first true molar (*m* 1), in consequence of its being in place much earlier than the rest of the permanent series, as shown in fig. 124, is now almost worn out. The premolars (*p* 4 and *p* 3) continue in use after *m* 1 is shed; and by the modifying growth of the jaw and the pressure on the grinders, they are brought into contact with *m* 2. The writer has seen instances in which *p* 4 has remained after *m* 2 has been shed, and when the molar series has been reduced to the teeth marked *p* 4 and *m* 3. This tooth (fig. 123, *m* 3)—the last true molar—is the most characteristic tooth of the *Phacochœrus*, and perhaps the most peculiar and complex tooth in the whole class of *Mammalia*. The surface of the crown presents three series of enamel islands, in the direction of the long axis of the grinding surface; the middle row, of eight or nine islands, is elliptic and simple; those of the other rows are in equal number, but are sometimes subdivided into smaller islands. These islands or lobes are the abraded ends of long and slender columns of dentine, encased by thick enamel, and the whole blended into a thick coherent crown by abundant cement,

Fig. 123.

Molar Series of adult Wart-hog (*Phacochœrus*). Nat. size.

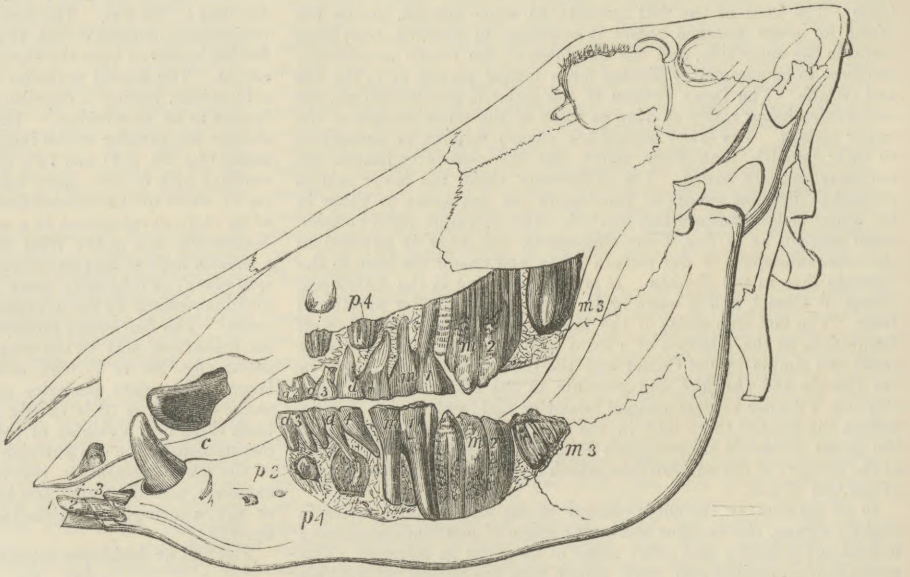

Fig. 124.

Dentition of a Young Wart-hog, *Phacochœrus*.

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[1] See also *Philosophical Transactions*, 1850, p. 481.

[2] *The Age of the Ox, Sheep, and Pig*, 8vo, 1854.

which fills up all the interspaces, and forms a thick exterior investment of the entire complex tooth.

The milk-molars are $\frac{3}{2}:\frac{3}{2}$ in number; but only the two last are succeeded by premolars (fig. 124, *p* 3 and *p* 4), although sometimes a small anterior milk-molar (*d* 2) is developed in the lower, as in the upper jaw. This interesting modification, as to order and number, in the change of the dentition, has thrown important light on the more anomalous dentition of the Elephant.

Hippopotamus.

The tendency to excessive and, as it may be termed, monstrous development which characterises the canine teeth in the typical *Suidæ*, affects both these and the incisors in the present remarkable genus, of which the *Hippopotamus* of the great rivers of Africa is now the sole existing representative.

The two median inferior incisive tusks are cylindrical, of great size and length, obliquely abraded at the upper and outer part of their extremity; the basal portion which is lodged in the deep alveolus is longitudinally grooved; the two outer incisors are likewise cylindrical and straight, are much smaller, and are worn towards the inner side of their point. The upper canines curve downwards and outwards, their exposed part is very short, and is worn obliquely at the forepart from above downwards and backwards; they are three-sided, with a wide and deep longitudinal groove behind. The lower canines (fig. 126) are extremely massive and large, curved in the arc of a circle, subtrihedral, the angle rounded off between the two anterior sides, which are convex and thickly enamelled, the posterior side of the crown being almost wholly occupied by the oblique abraded surface opposed to that on the upper canine. The implanted base of each of these incisive and canine teeth is simple, and excavated for a large persistent matrix, contributing to their perennial growth by constantly reproducing the dental matter to replace the abraded extremities. The direction of the abraded surface is in part provided for by the partial disposition of the enamel. The molar series consists of—

$$p\,\frac{4.4}{4.4};\ m\,\frac{3.3}{3.3} = 28.$$

The first premolar has a simple subcompressed conical crown, and a single root; it rises early, and at some distance in advance of the second premolar, and is soon shed; the other premolars form a continuous series with the true molars in the existing species, but in the extinct *Hippopotamus major*, whose remains are found in the superficial deposits of this island and on the Continent, the second premolar is in advance of the third by an interval equal to its own breadth. This and the fourth premolar retain the simple conical form, but with increased size, and are impressed by one or two longitudinal grooves on the outer surface, which, when the crown is much worn, give a lobate character to the grinding surface. The true molars are primarily divided into two lobes or cones by a wide transverse valley, and each lobe is subdivided by a narrow antero-posterior cleft into two half cones, with their flat sides next each other; the convex side of each half cone is indented by two angular vertical notches, bounding a strong intermediate prominence. When their summits begin to be abraded, each lobe or pair of demicones presents a double trefoil of enamel on the grinding surface, as shown in fig. 125; when attrition has proceeded to the base of the half cones, then the grinding surfaces of each lobe presents a quadrilobate figure. The crown of the last molar tooth of the lower jaw is lengthened out by a fifth cone, developed behind the two normal pairs of half cones, and smaller in all its dimensions.

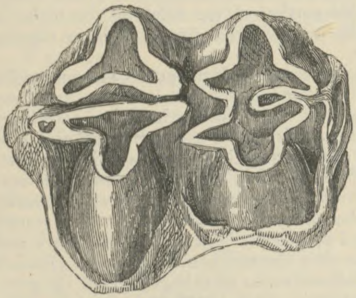

Fig. 125.

Molar Tooth, Hippopotamus.

The large tusks of the Hippopotamus exhibit the maximum of density in the chief component tissues. The enamel "strikes fire" with steel like flint. The compact dentine has a high commercia value, especially for the fabrication of artificial teeth. It differs from true ivory by showing, in transverse section, the simple concentric instead of the "engine-turned" or curvilinear decussating lines.

In the ordinary-sized tusks the fine-tubed dentine, which forms the concentric-lined ivory, continues with little or no alteration of texture from the periphery to the pulp-cavity; but in very large and old tusks the apex of that cavity contains osteo-dentine, and that tissue is abundantly developed when the normal function of the dentinal pulp is disturbed by injury or disease. A very remarkable example of the inferior tusk of the Hippopotamus is figured in cut 126, exemplifying the subserviency of the osteo-dentine in the reparation of a complete fracture of a tooth. The injury is indicated externally by a sudden transverse constriction of the tusk (fig. 126), with an interruption in the enamel at that part, and irregular deposits of dentine both there and at the adjoining concavity of the tusk. A longitudinal section of the tusk showed the pulp-cavity obliterated at the fractured part, and for some distance below it, towards the base of the tusk, by a mass of osteo-dentine, deposited principally in the form of nodules closely impacted together, their convex sides projecting into the re-established pulp-cavity next the base, the general disposition of the osteo-dentine being very like that in the centre of the tooth of the Cachalot. The remains of the pulp-cavity in the protruded part, or crown of the tusk, were unusually conspicuous, in the form of a narrow canal near the concave side of the tusk, and opening like a fistula upon that surface just beyond the fracture. Another irregular slender canal extended transversely through part of the uniting substance, and opened upon the concave side of the tusk just below the preceding. From these appearances it may be concluded that the tusk, either by the action of a shot, or other violence, had been snapped across its implanted and hollow base, with probably also fracture and injury to the prominent socket; but that the broken portions being held together by their adhesion to the surrounding parts, inflammation of the pulp and capsule had ensued, ending in an altered mode of action in the calcifying processes, which produced the more vascular substance, which has exemplified its resemblance to true bone by effecting the union of the fracture.

Fig. 126.

Lower Tusk, united after fracture, of the Hippopotamus.

Succession.

The true natural affinities of the Hippopotamus are clearly manifested by the character of its deciduous dentition; and if this be compared with the dentition at a like immature period in other *Ungulata, e. g.*, with that of the Horse tribe, it will be seen, by its closer correspondence with that of Artiodactyles, and more especially the Phacochere, that the Hippopotamus is essentially a gigantic Hog.

The formula of the teeth, which are shed and replaced, is—

$$i\,\frac{2.2}{2.2};\ c\,\frac{1.1}{1.1};\ m\,\frac{3.3}{3.3} = 24.$$

If the small and simple tooth, which is developed anterior to the deciduous molars, and which has no successor, be regarded, from its early loss in the existing Hippopotamus, as the first of the deciduous series, we must then reckon with Cuvier four milk-molars on each side of both jaws.

The incisors in both jaws are simply conical and subequal, with an entire cap of enamel on the crown. The deciduous canines scarcely surpass them in size in the upper jaw, and not at all in the lower. Projecting forwards, here, from the angles of the broad and straight symphysis, they appear like an additional pair of incisors; and we have seen that the character of equality of development was retained by the ancient form of Hippopotamus with the more typical number of incisors, $\frac{3}{3}.\frac{3}{3}$, which formerly inhabited India.

The first true deciduous molar has a conical crown and two fangs in both jaws. That above has also a conical crown with one strong posterior and two anterior ridges. The second deciduous molar has a large trilobate crown, the first lobe small, with an anterior basal ridge; the second large, conical, with three longitudinal indentations; the third lobe still larger, and cleft into two half-cones by an antero-posterior fissure assuming the normal pattern of the true molars. The third deciduous molar above more closely resembles the ordinary upper true molar; but its second pair of demi-cones are relatively larger. In the lower jaw the last deciduous molar has a more complex crown than that of any other teeth of the permanent or deciduous dentition.[1] It has three pairs of demi-cones, progressively increasing in size, from before backwards, with an anterior and posterior basal ridge and tubercles. Like the last trilobate deciduous lower molar of the Hog, it increases in thickness posteriorly, instead of diminishing here, like the last true molar of the lower jaw of the adult Hippopotamus.

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[1] This tooth is described as the first of four true molars by M. F. Cuvier, *Dents de Mammifères*, p. 207; but its true nature was recognised by Baron Cuvier. See *Ossemens Fossiles*, 4to, i. p. 289.

Teeth of Mammals.

Equidæ.

Perisso-dactyla.

The Horse yields the first example of the dentition of the hoofed Quadrupeds with toes in uneven number, because it offers in this part of its organization some transitional features between those of the dental characters of the typical members of the artiodactyle and of those of the Perisso-dactyle *Ungulata*.

All the kinds of teeth are retained, in nearly normal numbers, in both jaws, and with almost as little unequal or excessive development as in the Anoplothere; but the prolongation of the slender jaws carries the canines (figs. 127, 128, *c*) and incisors (ib. *i*) to some distance from the molars, and creates a long diastema, as in the Ruminants and Tapirs. The first deciduous molar (fig. 129, *d* 1) is very minute, and is not succeeded, as in the Anoplothere, by a permanent premolar; yet, remaining longer in place than the larger deciduous molars behind, it represents the first premolar, and completes the typical number of that division of the grinding series. If the dental formula of the genus *Equus* be restricted to the functionally developed permanent teeth, it will be—

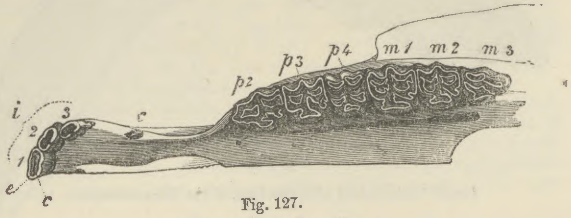

Fig. 127.

Dentition of Upper Jaw, Horse.

Fig. 128.

Dentition of Lower Jaw, Horse.

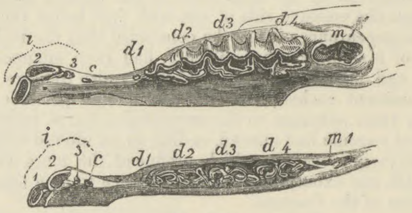

Fig. 129.

Deciduous Dentition, Horse.

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3.3};\ = 40.$$

The outer side of the upper molar of the Horse (*Equus Caballus*, fig. 130) is impressed, as in the Palæothere (fig. 117), by two wide longitudinal channels (fig. 130, *f*, *f*). The depression (*i*) is separated from the oblique valley (*e*); the depression (*g*) forms a crescentic island like *i*, when the crown begins to be worn away. There is a smaller depression (*h*) which indents the hinder side of the crown. An accessory lobe, apparently answering to that marked *m* in *Anoplotherium* (fig. 116), but more probably answering to the inner end of the lobe (*d*) in the Rhinoceros (fig. 132), is marked off by the anterior indentation (*k*), and adds to the complexity of the crown, which, in the general aspect of the grinding surface, approaches in character to that of the Ruminants (fig. 120). In the lower jaw, the correspondence of type with that of the Rhinoceros is more obvious. The teeth here, as is usual in other quadrupeds, are narrower transversely than in the upper jaw; they are divided externally into two convex lobes (pl. 128, *m* 1 and 2) by a median longitudinal fissure, and on the inner side they present three principal unequal convex ridges, and an anterior and posterior narrower ridge; but the crown of the molar is penetrated from the inner side by deeper and more complex folds than in the Rhinoceros or Palæothere. The anterior one, between the narrow ridge and the first principal internal column, expands into a sub-crescentic fold; the second is a short, simple fold, and terminates opposite that which penetrates the tooth from the outer side; the third inner fold expands in the posterior lobe of the tooth, like the first. Two short folds partially detach a small accessory lobe at the posterior part of the crown.

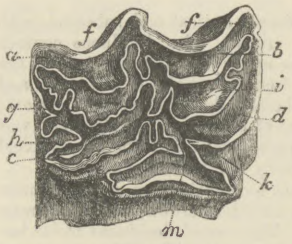

Fig. 130.

Upper Molar, Horse. Nat. size.

Teeth of Mammals.

The incisors (figs. 127, 128, *i*) are arranged close together in the arc of a circle at the extremity of both jaws. They are slightly curved, with long simple subtrihedral fangs tapering to their extremity (fig. 131). The crowns are broad, thick, and short. The contour of the biting surface, before it is much worn, approaches an ellipse. These teeth, if found detached, recent or fossil, are distinguishable from those of the Ruminants by their greater curvature, and from those of all other animals by the fold of enamel (fig. 131, *c*') which penetrates the body of the crown from its broad flat summit, like the inverted finger of a glove. When the tooth begins to be worn, the fold forms an island of enamel inclosed in a cavity, partly filled by cement and partly by the discoloured substances of the food; this is called by horse-dealers the "mark." In aged horses the incisors are worn down below the extent of the fold, and the mark disappears. The cavity is usually obliterated in the first, or mid-incisors at the sixth year, in the second incisors at the seventh year, and in the third or outer incisors, at the eighth year, in the lower jaw. It remains longer in those of the upper jaw, and in both the place of the mark continues for some years to be indicated by the dark-coloured cement.

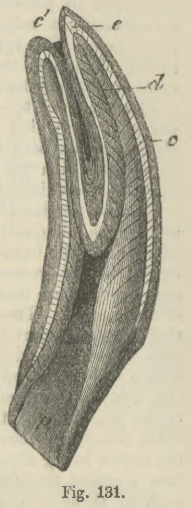

Fig. 131.

Section of Incisor. Horse.

The canines (figs. 127 and 128, *c*) are small in the stallion, less in the gelding, and rudimental in the mare. The unworn crown is remarkable for the folding in of the anterior and posterior margins of enamel, which here includes an extremely thin layer of dentine. The upper canine (fig. 127, *c*) is situated in the middle of the long interspace between the incisors and molars. The lower canine (fig. 128, *c*) is close to the outer incisor, as in the Ruminants, but is better distinguished by its cuspidate form. The antetype, or representative of the first premolar (fig. 129, *d* 1), is a very small and simple rudiment, and is soon shed. The three normal premolars (figs. 127, 128, *p* 2, 3, and 4) are as large and complex as the true molars (figs. 127, 128, *m* 1, 2, 3). The anterior one (*p* 2) is usually the largest of the series in the upper jaw, the anterior lobe extending forwards into an obtuse angle.

The most obvious character by which the horse's molars may be distinguished from the complex teeth of other *Herbivora* corresponding with them in size, is the great length of the tooth before it divides into fangs. This division, indeed, does not begin to take place until much of the crown has been worn away; and thus, except in old horses, a considerable portion of the whole of the molar is implanted in the socket by an undivided base. This is slightly curved in the upper molars.

The following is the average course of development and succession of the teeth in the *Equus Caballus*:—The summits of the first functional deciduous molar (fig. 129, *d* 2, "first grinder" of veterinary authors) are usually apparent at birth; the succeeding grinder (*d* 3) sometimes rises a day or two later, sometimes together with the first. Their appearance is speedily followed by that of the first deciduous incisor (fig. 129, *i* 1, "centre nipper" of veterinarians) which usually cuts the gum between the third and sixth days. The second deciduous incisor (fig. 129, *i* 2) appears between the twentieth and fortieth days, and about this time the rudimental grinder (*d* 1) comes into place, and the last deciduous molar (*d* 4) begins to cut the gum. About the sixth month the inferior lateral or third incisors (fig. 129, *i* 3), with the deciduous canine (*c*), make their appearance. The minute canine is shed about the time that the contiguous incisor is in place, and is not retained beyond the first year. The upper deciduous canine is shed in the course of the second year. The appearance of the third deciduous incisors or "corner nipper" completes the stage of dentition called the "colt's mouth" by veterinary authors. The first true molar (*m* 1) appears between the eleventh and thirteenth months. The second molar (*m* 1) follows before the twentieth month. The first functional premolar (*p* 2) displaces the deciduous molar (*d* 2) at from two years to two years and a half old. The first permanent incisor (figs. 127 and 128, *i* 1) protrudes from the gum at between two years and a half and three years. At the same period the second, or penultimate premolar (ib. *p* 3), pushes out the penultimate milk-molar (fig. 129, *d* 3), and the penultimate true molar (*m* 2) comes into place. The last premolar (*p* 4) displaces the last deciduous molar at between three years and a half and four years; the appearance above the gum of the last true molar (*m* 3) is usually somewhat earlier. The second incisor (*i* 2) pushes out its deciduous predecessor about the same period. The permanent canine or "tusk" (*c*) next follows; its appearance indicates the age of four years, but it sometimes comes earlier. The third, or outer incisor (fig. 128, *i* 3). pushes out the deciduous incisor (ib. 3 *d*) about the fifth year, but is

Teeth of Mammals.

seldom in full place before the horse is five years and a half old; the last premolar is then usually on a level with the other grinders. Upon the rising of the third permanent incisor, or "corner nipper" of the veterinarians, the "colt" becomes a "horse," and the "filly" a "mare," in the language of the horse-dealers; after the disappearance of the "mark" in the incisors, at the eighth or ninth year, the horse becomes "aged."

hinoceros.

The modifications which the upper molars of the rhinoceros present, as compared with those of its antetype, the Palæotherium, will be readily understood by comparing fig. 117 with fig. 132, and are as follows:—The concavities (*ff*) on the outer side of the crown, in fig. 117, are almost levelled, and from one of them a slight convexity projects, in some species of Rhinoceros, giving a gently undulated surface on that side of the crown. The valley (*e*) is more expanded at its termination (*i*), and in some species bifurcates and deepens, so that one branch may form an insulated circle of enamel when the crown is worn. The posterior valley (*g*) is usually deeper and more extended. The ordinary lobes (*a*, *b*, *c*, *d*) are very similar, and produce, by the confluence of *a* with *c*, and of *b* with *d*, the two oblique tracts of dentine which are more decidedly established as transverse ridges in the Lophiodont or Tapiroid group. A basal ridge (*r*) girts more or less completely the inner and the fore and hind parts of the base of the crown.

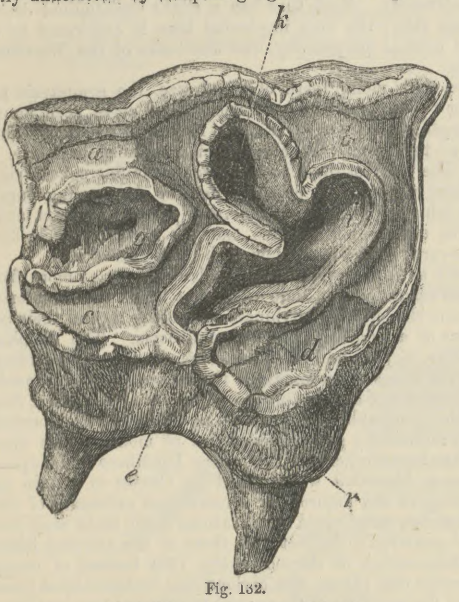

Fig. 132.

Upper Molar, Rhinoceros. Nat. size.

The formula of the functional molar series is—

$$p\,\frac{4.4}{4.4};\ m\,\frac{3.3}{3.3} = 28.$$

There are no canines. As to the incisors, the species vary, not only in regard to their form and proportions, but also their existence; and in the varieties of these teeth we may discern the same inverse relation to the development of the horns which is manifested by the canines of the Ruminants. Thus, the two-horned Rhinoceroses of Africa, which are remarkable for the great length of one (*Rh. bicornis*, *Rh. simus*) or both (*Rh. Keitloa*) of the nasal weapons, have no incisors in their adult dentition, neither had that great extinct two-horned species (*Rh. tichorinus*), the prodigious development of whose horns is indicated by the singular modifications of the vomerine, nasal, and pre-maxillary bones, in relation to the firm support of those weapons. The Sumatran bicorn Rhinoceros combines, with comparatively small horns, moderately-developed incisors in both jaws; and the same teeth are present in the nearly allied extinct two-horned Rhinoceros, called, after its discoverer, *Schleiermacheri*. The incisors are developed in both the existing Unicorn Rhinoceroses, (*Rh. Indicus* and *Rh. Sondaicus*), but they attain their largest dimensions in the singular extinct hornless species, the *Rhinoceros incisivus* of Cuvier, which makes the transition to the extinct genus *Palæotherium*, and forms the type of the aberrant subgenus *Acerotherium* of Dr Kaup.

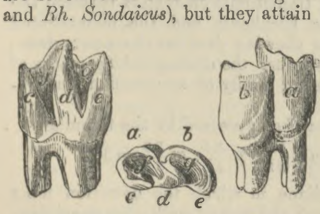

Fig. 133.

Lower Molar, Rhinoceros.

The molar teeth in the lower jaw consist of two subequal oblique crescentic or semicylindrical lobes, which, when slightly worn, present the appearance shewn in the middle of the three figures in cut 133, from a molar of the right ramus of the lower jaw. The figure opposite the right hand shews the outer side, that opposite the left hand the inner side. In each figure, *a d* is the anterior lobe, *b e* the posterior lobe; *c* is the antero-internal border, and *d* the postero-internal border of the anterior lobe; *e* is the postero-internal border of the posterior lobe; *f* is the concavity of the anterior, *g* that of the posterior lobe. The above structure characterises the last two premolars and all the true molars of the lower jaw of the Rhinoceros, the ultimate one not being characterised, as in the *Palæotherium*, by an accessory lobe.

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Fig. 134.

Deciduous and Permanent Teeth, Hyrax. Nat. size.

The deciduous molars of the Rhinoceros are, in number as well as in shape, closely similar to those in the diminutive, hornless, hairy, rhinoceros-like quadruped, called *Hyrax*, which bears the same relation to the great Rhinoceros as the small existing Sloth does to the extinct Megatherium. The change of dentition of the *Rhinocerotidæ* is, therefore, here illustrated by the young *Hyrax capensis* (fig. 134).

The law of development, so instructive and constant in the placental *Diphyodonts*, is well illustrated in this species. The four premolars (*p* 1, 2, 3, 4) are exposed above the four deciduous molars (*d* 1, 2, 3, 4), which they push out; the first true molar (*m* 1) is in place; the second (*m* 2) and third (*m* 3) molars are in different states of forwardness. The first premolar differs from the rest only by a graduated inferiority of size, which, in the last premolar (*p* 4), ceases to be a distinction between it and the true molars.

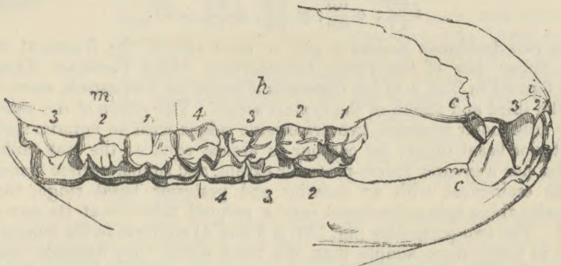

Fig. 135

Dentition of the Tapir.

Tapirus.

The dental formula of the Tapir is—

$$i\,\frac{3.3}{3.3};\ c\,\frac{1.1}{1.1};\ p\,\frac{4.4}{};\ m\,\frac{3.3}{3.3} = 42 \text{ (fig. 135).}$$

The median incisors above (*i* 1, 2, 3) have a broad trenchant crown, separated by a transverse channel from a large basal ridge; the wedge-shaped crowns of the opposite pair below fit into the channel, and have no basal ridge; the outer incisors above (*i* 3) are very large and like canines; those below are unusually small. The canines (fig. 135, *c*) have crowns much shorter than their roots, and not projecting, like tusks, beyond the lips; they are pointed, with an outer convex, separated by sharp edges from an inner, less convex, surface. The lower canines form part of the same semicircular series with the incisors; the upper ones project close to the intermaxillary suture, separated from the incisors by a short space for the reception of the crown of the lower canine. The first three premolars above (*p* 1, 2, 3) have the outer part of the crown composed of two half cones, the posterior one having a basal ridge; the anterior basal ridge rises into a small cusp in the second premolar, which increases in size in the third and fourth; in this tooth (*p* 4) the transverse depression divides at the base of the anterior and outer demicone, and the posterior division is continued into the interspace of the two demicones; these, therefore, now become in *m* 1 and 2 the outer ends of the two transverse wedge-shaped eminences, giving their summits a curve whose concavity is turned backwards; the last molar (*m* 3) may be known by the shorter and more curved posterior eminence. In the dentition of the lower jaw (fig. 136) the double transverse ridged type of tooth, which has been before described in the Kangaroo,

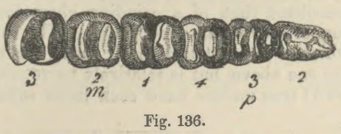

Fig. 136.

Molar Series, Lower Jaw, Tapir.

Teeth of Mammals.

Diprotodon, and Manatee, prevails throughout the molar series, the anterior talon being most produced and compressed in the first tooth (*p* 2).

The most extraordinary of extinct Pachyderms is that which Cuvier regarded as a gigantic Tapir, on account of the character of the molar teeth (see the lower fig. in cut 137); but which subsequent discovery of the cranium, and the enormous tusks of the lower jaw (fig. 137), has proved to be a genus connecting the tapiroid with the proboscidian families of Perissodactyla.

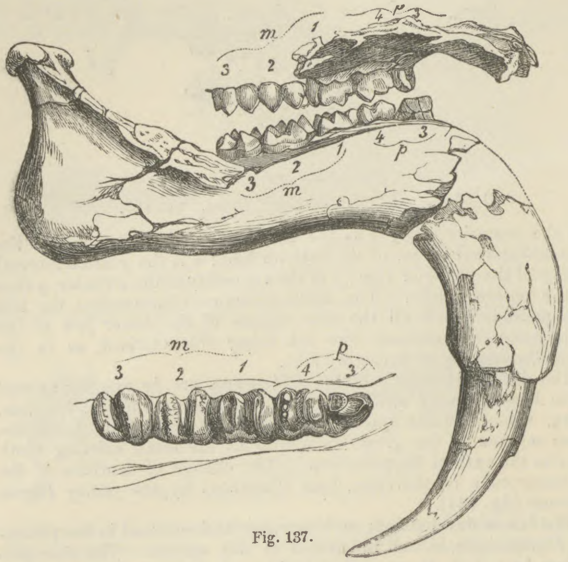

Fig. 137.

Dentition of Dinotherium

The permanent dentition of the genus *Dinotherium* is—

$$i\,\frac{0.0}{1.1};\ c\,\frac{0.0}{0.0};\ p\,\frac{2.2}{2.2};\ m\,\frac{3.3}{2.2}=22.$$

The two deciduous molars *in situ* on each side of the fragment of the upper jaw of the young *Dinotherium*, which Professor Kaup has figured in Tab. 1 of his *Ossemens Fossiles de Darmstadt*, answer to the third and fourth of the typical series. The crown of the anterior milk-molar supports two transverse ridges with an anterior and posterior basal ridge; its contour is almost square; the last milk-molar has a greater antero-posterior extent, and supports three transverse eminences with an anterior and posterior basal ridge, the anterior ridge being developed into a pointed tubercle at its outer end. The two premolars (fig. 137, *p* 3 and 4) conform to the general rule in being more simple than the teeth which they displace and succeed. The first upper premolar (*p* 3) supports a longitudinal ridge on the outer side of the crown, and two mamilloid tubercles, with confluent bases along the inner side of the crown, which is surrounded, except at its outer part, by a basal ridge. The unworn summits of both the ridge and tubercles are divided into smaller tubercles by a series of notches. The crown of the second premolar (*p* 4) supports four tubercles, the outer ridge being deeply cleft, and the two anterior tubercles are united by a continuous ridge, which converts them into a transverse eminence, like those which characterise the true molar teeth. The transverse diameter of the second premolar exceeds the antero-posterior one, the proportions being the reverse of those of the deciduous molar, which it displaces. The first true molar (*m* 1) repeats the structure of the hindmost deciduous molar, its crown having a disproportionate antero-posterior extent, and supporting three transverse eminences, with an anterior, posterior, and internal basal ridge. The Dinothere resumes the Tapiroid character, and differs essentially from the Mastodon, inasmuch as the posterior molars (*m* 2 and 3), instead of having an increased antero-posterior extent and more complex crowns, increase only in thickness, and support two instead of three transverse eminences; they have also an anterior and a posterior basal ridge. In the lower jaw the first premolar (*p* 3) is implanted, like that above, by two fangs; but it has a smaller and simpler crown, which is narrower in proportion to its antero-posterior extent, and is almost entirely occupied by the antero-posterior ridge, only the posterior of the two inner tubercles being developed; thus the crown presents more of a trenchant than of a grinding character; the second premolar (*p* 4) supports two transverse ridges. The third of the permanent series, which is the first true molar (*m* 1), has three transverse ridges, like the one above, but is relatively narrower, the second (*m* 2) and third (*m* 3) true molars have each large square crowns, with two transverse ridges, and an anterior and posterior talon, the latter being more developed than in the corresponding molars of the upper jaw.

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As the three-ridged or first true molar tooth is the first of the permanent series which comes into place, its crown, conformably with the general law, exhibits most abrasion.

The generic peculiarity of the *Dinotherium* is most strongly manifested in its tusks. These tusks (fig. 137) are two in number, implanted in the prolonged and deflected symphysis of the lower jaw, in close contiguity with each other, and having their exserted crown directed downwards and bent backwards, gradually decreasing to the pointed extremity. Each tusk has a slight longitudinal depression on its outer side; the long implanted base is excavated by a wide and deep conical pulp-cavity, like the tusks of the Mastodon and Elephant.

In jaws with molar teeth of equal size, the symphysis and its tusks offer two sizes; the larger ones, which have been found four feet in length, with tusks of two feet, may be attributed to the male Dinothere; the smaller specimens, with tusks of half size, to the female. The ivory of these tusks presents the fine concentric structure of those of the Hippopotamus, not the decussating curvilinear character which characterises the ivory of the Elephant and Mastodon. No corresponding tusks, nor the germs of such, have yet been discovered in the upper jaw of the *Dinotherium*.

Proboscidians.

No family of Mammalian quadrupeds has suffered more from the destructive operations of time than that which is characterised by the gigantic size of the individuals composing it, and their peculiar endowment of a long and prehensile proboscis. The Elephants of Africa, India, Ceylon, and Sumatra, represent the proboscidian type of the hoofed series of mammals at the present day; but much more numerous species of as huge proboscidians formerly existed, dispersed over a wider geographical range, and in which the Elephantine dentition was reduced by gradational series of modifications almost to the comparative simplicity of that of the Dinothere and Tapir.

Mastodon.

The name *Mastodon* was applied by Cuvier to certain species, which, being at the Tapiroid or Dinotherian extremity of the proboscidian series, manifested modifications of the teeth most meriting to be held generically distinct from those of the existing Elephants. The grinding surface of the molars (fig. 138), instead of being cleft into numerous thin plates, was divided into wedge-shaped transverse ridges, and the summits of these were subdivided into smaller cones, more or less resembling the teats of a cow, whence the generic name.[1] A more important modification appeared to distinguish the extinct genus, in respect of the structure of the molar teeth; the dentine, or principal substance of the crown of the tooth (fig. 138, *d*) is covered by a thick coat of dense and brittle enamel (*e*); a thin coat of cement is continued from the fangs upon the crown of the tooth, but this substance does not fill up the interspaces of the divisions of the crown, as in the Elephants (fig. 144, *c*). Such at least is the character of the molar teeth of the typical and first-discovered species of Mastodon, which Cuvier has termed *Mastodon giganteus* and *Mastodon angustidens* (fig. 138). Fossil remains of proboscidians have subsequently been found principally in the tertiary deposits of tropical Asia, in which the number and depth of the clefts of the crown of the molar teeth, and the thickness of the intervening cement, are so much increased as to establish transitional characters between the lamello-tuberculate teeth of the Elephants and the mammilated molars of the typical Mastodons, showing that the characters deducible from the molar teeth are rather the distinguishing marks of species than of genera in the present family of mammalian quadrupeds.

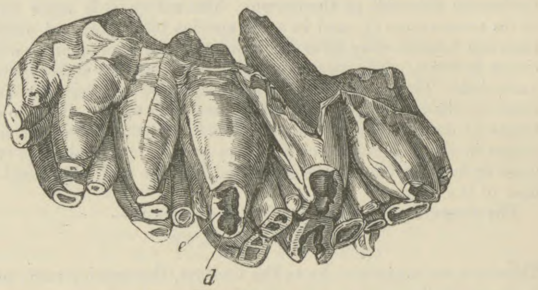

Fig 138.

Upper Molar of Mastodon.

The dentition of this family may be expressed by the formula—

$$d\,i\,\frac{1.1}{};\ i\,\frac{1.1}{1.1};\ c\,\frac{0.0}{0.0};\ m\,d\,\frac{3.3}{3.3};\ p\,\frac{1.1}{1.1};\ m\,\frac{3.3}{3.3}=34;$$

that is to say, in the proboscidians in which the dentition most nearly approached to the typical one, thirty-four teeth were developed,

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[1] μαστος, a nipple; οδους, a tooth.

Teeth of Mammals.

as follows:—In the upper jaw two deciduous incisors, followed by two, permanent incisors developed as tusks; six deciduous molars, (three on each side, *d* 2, 3, 4, fig 3 9 ; two premolars (one on each side, *p* 3, fig. 139), and six true molars (three on each side, *m* 1, 2, 3, figs. 139 and 140):—in the lower jaw, two incisors as tusks (uncertain whether preceded by deciduous tusks), deciduous molars, premolars, and molars, as in the upper jaw. The Elephantoid animal (*Mastodon longirostris*, Kaup; *Mastodon angustidens*, in part, Cuvier) which exhibited the above instructive dentition of the Proboscidian family, once roamed over the part of the earth now forming England, France, Italy, and Germany. The first steps in our knowledge of its dentition were made by Cuvier, who called it the narrow-toothed Mastodon "Mastodon à dents étroites," or *Mastodon angustidens.* This name was suggested by the less breadth of the grinding surface of the teeth as compared with those of a previously described species of Mastodon from North America, called the *Mast. giganteus* or *M. Ohioticus*. Cuvier describes and figures a last molar, upper jaw, from Trévoux, consisting, as in the specimen from Norfolk Crag (fig. 138), and as in that from Eppelsheim (fig. 140, *m* 3), of five transverse ridges, with a front and back talon or subsidiary ridge. The latter is the largest, and subdivided into teat-shaped tubercles, so as almost to merit the name of a sixth division of the tooth. The principal ridges are divided into two chief or primary tubercles, with secondary tubercles in the interspace; the chief tubercles are more or less deeply grooved lengthwise, or cleft at top, so that mastication wore them down to small circles of dentine surrounded by a thick border of enamel, and further attrition reduced these to a trilobed or trefoil form.

Fig. 139.

Deciduous dentition, young *Mastodon longirostris*.

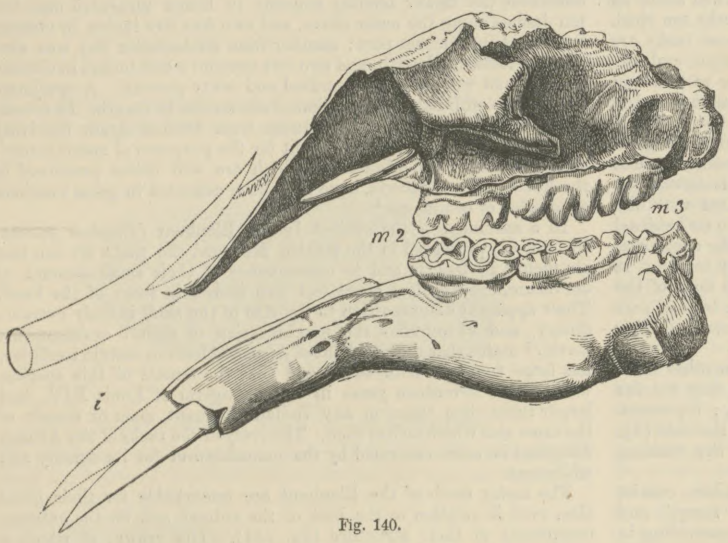

Fig. 140.

Dentition of old *Mastodon longirostris*.

The last lower molar of the *Mast. angustidens* from La Rochetta di Tanaro,[1] exhibits the same five principal transverse ridges and the hinder one, as in the corresponding tooth in the Eppelsheim Mastodon (fig. 140, *m* 3), and being the first of the series of narrow mastodontoid teeth to which Cuvier applied the name *angustidens*, it may be regarded as the type of that species. The characteristic premolar of the *Mast. angustidens*, with a quadrate crown of two ridges, each cleft into two tubercles (fig 139, *p* 3), is figured by Cuvier, in Op. cit. pl. i., fig. 3, and again, *in situ*, with the last deciduous molar (*d* 4) in a portion of the upper jaw of the *Mastodon angustidens* from Dax (ib. pl. iii., fig. 2). The nature of this quadrituberculate tooth as a premolar, *i. e.*, as a tooth which displaced and succeeded an earlier or deciduous tooth in the vertical direction, was recognised by Cuvier. "Je crois encore qu'on peut en conclure que la dent antérieure était susceptible de remplacement de haut ou bas, comme dans l'hippopotame: ma raison est, que cette petite dent de Dax n'est pas encore usée et qu'il faut qu'elle soit venue après la grande qui l'est."[2] Dr Kaup has described and figured the same premolar in the upper jaw of a younger individual of the *Mastodon angustidens* (his *longirostris*), in which it is still concealed in its formative cavity above the three-lobed deciduous tooth which it has replaced in Cuvier's specimen. The tooth next behind, which is the homologue of the last milk-molar (*d* 4, fig. 139) of the typical series, consists, in both the Dax and Eppelsheim specimens, of three principal ridges and a posterior bituberculate talon; this accessory portion being more developed in the Eppelsheim specimen. Whether such difference be valid for a specific distinction may be doubted; but that Cuvier assigned the name *angustidens* to a *Mastodon* with narrower molars than the *M. giganteus*, which had a quadri-tuberculate premolar, a penultimate molar of four principal divisions and a talon, and a last molar with five principal divisions and a talon, is certain. To that Mastodon, therefore, which has the same shaped and sized ultimate and penultimate true molars and premolar, the same name is here assigned.

The antepenultimate molar (fig. 139, *m* 1) consists of four ridges and a talon.

Three molars are developed anterior to this tooth; the first (fig. 3, *d* 2) is the smallest, with a subquadrate crown of two transverse ridges. The second molar (fig. 3, *d* 3), of twice the size of the first, has three ridges. The third molar (*d* 4), with an increase of one third the bulk of the former, has three ridges and a bituberculate talon, which in some specimens might almost be reckoned as a fourth ridge. The two-ridged premolar (*p* 3) above described, takes the place of the second of the above molars, after the first and second are shed. The above definition of the molar series applies to both upper and lower jaws, the cut (fig. 136), and the symbolic letters and numbers, preclude the necessity of verbal description.

From the analogy of the existing elephants, it may be inferred that the long tusks (fig. 137, *i*) supported by the premaxillaries, were preceded by a pair of small deciduous incisors. There is not such ground for concluding their existence in the mandible; but this jaw, at least in the male *Mastodon*, supported two incisive tusks, shorter and straighter than those above.

In the Proboscidian quadrupeds the molar teeth, progressively increasing in size, and most of them in complexity, follow each other from before backwards, at longer intervals than in other quadrupeds, and are never simultaneously in place. Not more than three are in use at any period on one side of either jaw; all the molars, save the penultimate (fig. 140, *m* 2) are shed by the time the crown of the last molar has cut the gum, and the dentition is finally reduced to *m* 3 on each side of both jaws, with commonly the loss of the inferior tusks, as in the old *Mastodon angustidens*, from the tertiary deposits of the Po, described and figured by Sismonda.[3]

The readiest and most intelligible key to the homologies of the above-described dentition, aberrant as regards the Mammalian type, but typical amongst the Proboscidian modifications, is that afforded by the Wart-hog (*Phacochœrus*). In fig. 122 the symbols are attached to the several teeth indicative of their homologies, as undoubtedly determined by comparison with the Hogs that retain the typical dentition.

The Wart-hog, moreover, is the hoofed animal that makes the nearest approach to the Elephant in the complex structure of the molars, in their progressive increase of size and complexity, in the early loss of the anterior molars, and the ultimate reduction of the series to the last large and complex one (*m* 3).

In Phacochœrus (fig. 122) only the last two premolars (*p* 3 and 4) are developed; in *Mastodon* (fig. 136) only the penultimate one (*p* 3); in *Elephas* proper, even this tooth becomes obsolete, and the guide to the deciduous molars is restricted to the homology of the true molars (*m* 1, *m* 2, and *m* 3), with the answerable teeth in *Mastodon* and *Phacochœrus*.[4]

As to the teeth anterior to the molar series, some might be tempted to regard the tusks of the Proboscidian as the homologue of the tusk-like canines of the boar tribe, advanced to the position of the incisors, which are in that view wholly wanting. But the numerous instances in which in *Herbivora*, the canines are obsolete whilst the incisors are retained, and the true incisive nature of the premaxillary tusk-like teeth in the Rodents, show the determination of the premaxillary and symphysial tusks of the Proboscidians, as incisors, to be the sounder conclusion.

Elephas.

The dentition of the genus *Elephas*, the sole existing modification of the once numerous and various Proboscidian family, includes two long tusks, one in each of the premaxillary bones, and large and complex molars in both jaws. Of the latter there is never more than one wholly, or two partially, in place and use on each side at any given time, the series continually being in progress of formation

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[1] Cuvier, *Op. cit. Divers Mastodontes*, pl. iv., fig. 1, top view, fig. 2, side view.

[2] *Ossemens Fossiles*, 4to, 1821, tom. i. p. 256.

[3] *Osteografia di un Mastodonte Angustidente*, 4to, Turin, 1851.

[4] *Odontography*, p. 621.

and destruction, of shedding and replacement; and, in the Elephants, all the grinders succeed one another, like true molars, horizontally, from behind forwards. The total number of teeth developed in the Elephant appears to be—

$$d\,i\,\frac{1.1}{0.0};\ i\,\frac{1.1}{0.0};\ d\,m\,\frac{3.3}{3.3};\ m\,\frac{3.3}{3.3} = 28.$$

The two large permanent tusks are preceded by two small deciduous ones, and the number of molar teeth which follow one another on each side of both jaws is certainly not less than six, of which the last three answer to the last three in the Mastodon, and to the true molars, *m* 1, 2 and 3, of other diphyodont placental Mammals. The writer has shewn in his *Odontography,* that "the deciduous tusk makes its appearance beyond the gum between the fifth and seventh months. It rarely exceeds two inches in length, and is about a third of an inch in diameter at its thickest, where it protrudes from the socket. The fang is solidified, and contracts to its termination, which is commonly a little bent, and is considerably absorbed by the time the tooth is shed, which takes place between the first and second year." "The socket of the permanent tusk in a new-born Elephant is a round cell about three inches in diameter, situated on the inner and posterior side of the aperture of the temporary socket." The permanent tusks cut the gum when about an inch in length, a month or two usually after the milk-tusks are shed. At this period, according to Mr Corse,[1] the permanent tusks are "black and ragged at the ends; when they become longer, and project beyond the lip, they soon are worn smooth by the motion and friction of the trunk." Their widely-open base is fixed upon a conical pulp, which, with the capsule surrounding the base of the tusk and the socket, continues to increase in size and depth, obliterating all vestiges of that of the deciduous tusk, and finally extending its base close to the nasal aperture. The ivory of the tusk is formed by successive calcification of layers of the pulp, in contact with the inner surface of the pulp-cavity; and, being subject to no habitual attrition from an opposed tooth, but being worn only by the occasional uses to which it is applied, it arrives at an extraordinary length. It follows the curve originally impressed upon it by the form of the socket, and gradually widens from the projecting apex to that part which was formed when the matrix and the socket had reached their full size.

These incisive teeth of the Elephant not only surpass other teeth in size as belonging to a quadruped so enormous, but they are the largest of all teeth in proportion to the size of the body; representing, in a natural state, those monstrous incisors of the Rodents (fig. 92), which are the result of accidental suppression of the wearing force of the opposite teeth.

The tusks of the Elephant, like those of the Mastodon, consist chiefly of that modification of dentine which is called "ivory," and which shows, on transverse fractures or sections, striæ proceeding in the arc of a circle from the centre to the circumference in opposite directions, and forming, by their decussations, curvilinear lozenges. This character is peculiar to the tusks of the Proboscidian Pachyderms, and is characteristic of true ivory. In the Indian Elephant there is a well-marked sexual difference in the growth of the tusks. They are always short and straight in the female, and less deeply implanted than in the male; she thus retaining, as usual, more of the characters of the immature state. In the male they have been known to acquire a length of nine feet, with a basal diameter of eight inches, and to weigh one hundred and fifty pounds; but these dimensions are rare in the Asiatic species.

Mr Corse, speaking of the variety of Indian Elephant, called "Dauntelah" from its large tusks, which project almost horizontally with a slight curve upwards and outwards, says: "The largest I have known in Bengal did not exceed seventy-two pounds avoirdupois; at Tiperah they seldom exceed fifty pounds." There are varieties of the Dauntelah, in which the large tusks of the male are nearly or quite straight; and in a more marked breed called "Mooknah" the tusks are much smaller, are straight, and point directly downwards. These ascertained varieties in an existing species ought to weigh with the observers of analogous varieties in the teeth of fossil Proboscidians, before they pronounce definitely on their value as characters of distinct species. More anomalous varieties occasionally present themselves in the African Elephant, as when one tusk is horizontal, the other vertical, or when, from some distortion of the alveolus, a spiral direction is impressed upon the growth of the tusk, as in that specimen figured by Grew in the "Rarities of Gresham College," tab. 4, and which is now in the Museum of the Royal College of Surgeons, London.[2] The tusk of the Elephant is slightly movable in its socket, and readily receives a new direction of growth from habitual pressure; this often causes distorted tusks in captive Elephants; and Cuvier relates the mode in which advantage was taken of the same impressibility in order to rectify the growth of such tusks in an Elephant kept at the Garden of Plants in Paris.

The tusks of the extinct *Elephas primigenius*, or mammoth, have a bolder and more extensive curvature than those of the *Elephas indicus;* some have been found which describe a circle, but the curve being oblique, they thus clear the head, and point outwards, downwards, and backwards. The numerous fossil tusks of the Mammoth which have been discovered and recorded, may be ranged under two averages of size—the larger ones at nine feet and a half, the smaller at five feet and a half in length. The writer has elsewhere[3] assigned reasons for the probability of the latter belonging to the female Mammoth, which must accordingly have differed from the existing Elephant of India, and have more resembled that of Africa in the development of her tusks, yet manifesting an intermediate character by their smaller size. Of the tusks which are referable to the male Mammoth, one from the newer tertiary deposits in Essex measured nine feet ten inches along the outer curve, and two feet five inches in circumference at its thickest part; another from Eschscholtz Bay was nine feet two inches in length, and two feet one and a half inches in circumference, and weighed one hundred and sixty pounds. A specimen, dredged up off Dungeness, measured eleven feet in length. In several of the instances of Mammoth's tusks from British strata, the ivory has been so little altered as to be fit for the purposes of manufacture; and the tusks of the Mammoth, which are still better preserved in the frozen drift of Siberia, have long been collected in great numbers as articles of commerce.[4]

In a specimen of the extinct Indian Elephant (*Elephas ganesa*, Fr. and C.) preserved in the British Museum, the tusks are ten feet six inches in length, and in consequence of their small amount of curvature, they project eight feet five inches in front of the head. Their apparent disproportion to the size of the skull is truly extraordinary, and exemplifies the maximization of dental development. Cuvier[5] states that the Elephant of Africa, at least in certain localities, has large tusks in both sexes, and that the female of this species, which lived seventeen years in the menagerie of Louis XIV., had larger tusks than those in any Indian Elephant, male or female, of the same size which he had seen. The ivory of the tusks of the African Elephant is most esteemed by the manufacturer for its density and whiteness.

The molar teeth of the Elephant are remarkable for their great size, even in relation to the bulk of the animal, and for the extreme complexity of their structure (fig. 141). The crown, of which a great proportion is buried in the socket, and very little more than the grinding surface appears above the gum, is deeply divided into a number of transverse perpendicular plates, consisting each of a body of dentine (*d*), coated by a layer of enamel (*e*), and this again by the less dense bone-like substance (*c*) which fills the interspaces of the enamelled plates, and here more especially merits the name of "cement," since it binds together the several divisions of the crown, as at *c*, before they are fully formed and united by the confluence of their bases into a common body of dentine. As the growth of each plate begins at the summit, they remain detached, and like so many separate teeth or denticles, as at the back part of fig. 141, until their base is completed, when it becomes blended with the bases of contiguous plates to form the common body of the crown of the complex tooth, from which the roots are next developed. The plates of the molar teeth of the Siberian Mammoth (*Elephas primigenius*, fig. 142) are thinner in proportion to their breadth, and more numerous in proportion to the size of the crown, than in the existing species of Asiatic Elephant (fig. 143).

In the African Elephant (fig. 144), on the other hand, the lamellar divisions of the crown are fewer and thicker, and they expand from the margins to the centre of the tooth, yielding a lozenge form when cut or worn transversely, as in mastication.

Development.

The horizontal as well as vertical course of development of the Elephant's grinder is well illustrated by the molar, the last of the lower jaw (fig. 141). The separate digital processes of the posterior plates are still distinct, and adhere only by the remaining cement. A little in advance we see them united to form the transverse plate

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[1] See Mr Corse's Memoir on the Teeth of the Elephant, in the *Philosophical Transactions*, 1799, p. 211. A good figure of the deciduous tusk is given in plate 5.

[2] Osteol. Series, No. 2757. The writer is indebted to the distinguished traveller, Dr Livingstone, for a similar tusk of an African Elephant, from the Zambesi district.

[3] *History of British Fossil Mammals*, 8vo, p. 247.

[4] In the account of the Mammoth's bones and teeth of Siberia, published in the *Philosophical Transactions* for 1737 (No. 446), tusks are cited which weighed two hundred pounds each, and "are used as ivory to make combs, boxes, and such other things; being little more brittle and easily turning yellow by weather and heat." From that time to the present there has been no intermission in the supply of ivory furnished by the tusks of the extinct Elephants of a former world.

[5] *Loc. cit.* p. 55.

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(*g*, *g*), and at the opposite extremity of the tooth the common base of dentine (*d*) is exposed, by which the plates are finally blended into one individual complex grinder.[1] This never takes place simultaneously along the whole extent of the tooth in the Indian Elephant.

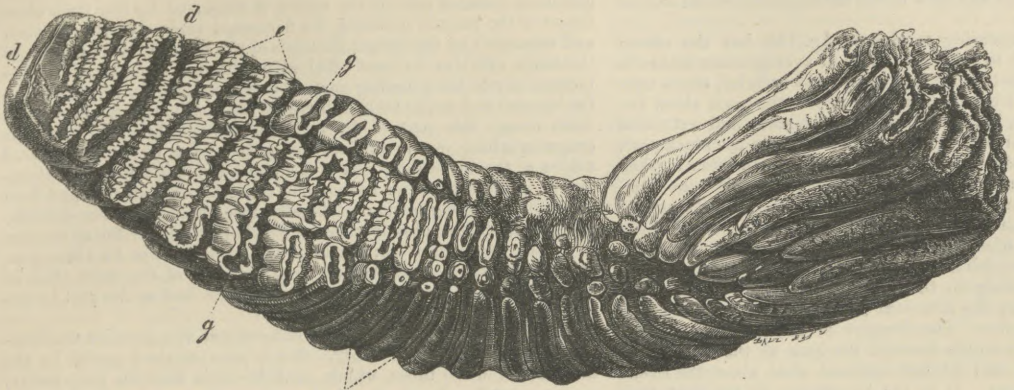

Fig 141.

Last Lower Grinder, Elephant.

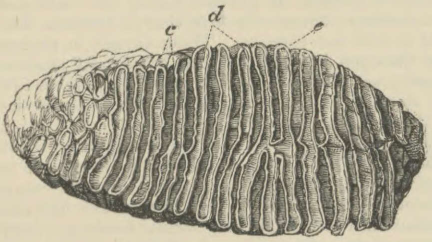

Fig. 142.

Upper Grinder of the Mammoth, (*Elephas primigenius*).

The African species manifests a closer affinity to the Mastodon by the basal confluence of the plates before the anterior ones are worn out.

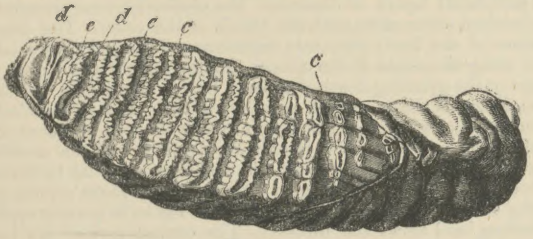

Fig. 143.

Upper Molar, Asiatic Elephant.

The formation of each grinder begins with the summits of the anterior plate, and the rest are completed in succession; the tooth is gradually advanced in position as its growth proceeds, and in the existing Indian Elephant, the anterior plates are brought into use before the posterior ones are formed. When the complex molar cuts the gum the cement is first rubbed off the digital summits, then their enamel cap is worn away, and the central dentine comes into play with a prominent enamel ring; the digital processes are next ground down to their common uniting base, and a transverse tract of dentine, with its wavy border of enamel, is exposed; finally, the transverse plates themselves are abraded to their common base of dentine, and a smooth and polished tract of that substance is produced. From this basis the roots of the molar are developed, and increase in length to keep the worn crown on the grinding level until the reproductive force is exhausted.

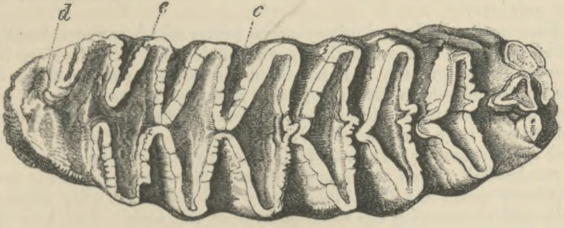

Fig 144.

Upper Molar, African Elephant.

When the whole extent of a grinder has successively come into play, its last part is reduced to a long fang supporting a smooth and polished field of dentine, with perhaps a few remnants of the bottom of the enamel folds at its hinder part.

When the complete molar has been thus worn down to a uniform surface, it becomes useless as an instrument for grinding the coarse vegetable substances on which the Elephant subsists; it is attacked by the absorbent action, and the wasted portion of the molar is finally shed. The grinding teeth of the Elephant progressively increase in size and in the number of lamellar divisions from the first to the last, and as the rate of increase in both respects is nearly identical in both jaws, they are here described as they appear in the lower one (fig. 141).

Succession.

The *first molar*, which cuts the gum in the course of the second week after birth, has a subcompressed crown nine-lines in antero-posterior diameter, divided by three transverse clefts into four plates, the third being the broadest, and the tooth here measuring six lines across. The first and second plates have two mamilloid summits, the third and fourth have three or four such; there is a single and sometimes a double mamilloid summit at the fore and back part of the crown, and the base slightly contracts, and forms a neck as long as the enamelled crown, but of less breadth, and this divides into anterior and posterior long, subcylindrical, diverging, but mutually incurved fangs; the total length of this tooth is one inch and a half. The corresponding upper molar, which Mr Corse describes as cutting the gum a little earlier than the lower one, has the anterior process or mammilla, and the posterior talon, developed into a fifth plate, smaller than the fourth, with which its middle part is confluent; the neck of this tooth is shorter, and the two fangs are shorter, larger, and more compressed, than those of the lower first molar. This tooth is the homologue of the deciduous molar (fig. 139, *d* 2) in the Mastodon and other Ungulates; it is not a mere miniature of the great molars of the mature animal, but retains, agreeably with the period of life at which it is developed, a character much more nearly approaching that of the ordinary pachydermal molar, manifesting the adherence to the more general type by the minor complexity of the crown, and by the form and relative size of the fangs. In the transverse divisions of the crown we perceive the affinity to the Tapiroid type, the different links connecting which with the typical Elephants are supplied by the extinct Lophiodons, Dinotheriums, and Mastodons. The subdivision of the summits of the primary plates recals also the character of the molars, especially the smaller ones, of the Phacochere in the Hog tribe. As the Elephant advances in age, the molars rapidly acquire their more special and complex character. The first molars are completely in place and in full use at three months, and are shed when the Elephant is about two years old.

The sudden increase and rapid development of the *second molar* answering to *d* 3 in fig. 139, may account for the non-existence of any vertical successor to the former tooth, or "premolar," in the Elephant. The eight or nine plates of the crown of this tooth are formed in the closed alveolus, behind the first molar, by the time this cuts the gum, and they are united with the body of the tooth, and most of them in use, when the first molar is shed. The average length of the second molar is two inches and a half, ranging from two inches to two inches and nine lines; the greatest breadth, which is behind the middle of the tooth, is from one inch to one inch three

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[1] Some anatomists have described the divisions of the crown of the Elephant's grinder as so many "distinct teeth," and Mr Corse (loc. cit. p. 213), who first propounded this view, calls each complex grinder "a case of teeth," and states, "that these teeth are merely joined to each other by an intermediate softer substance acting like cement." But this statement applies only to the incompletely formed tooth; and the detached eminences of each individual plate, or of the crown of any complex tooth, at that stage of growth when they are held together only by the still uncalcified supporting matrix, might reasonably be regarded as so many distinct teeth.

Teeth of Mammals.

lines. There are two roots; the cavity of the small anterior one expands in the crown, and is continued into that of the three anterior plates. The thicker root supports the rest of the tooth; the second molar is worn out and shed before the beginning of the second year.

The *third molar*, answering to *d* 4 in fig. 139, has the crown divided into from eleven to thirteen plates; it averages four inches in length and two inches in breadth, and has a small anterior, and a very large posterior root. It begins to appear above the gum about the end of the second year, is in its most complete state and extensive use during the fifth year, and is worn out and shed in the ninth year.

The *fourth molar*, answering to *m* 1 in fig. 139, presents a marked superiority of size over the third, and a somewhat different form. The anterior angle is more obliquely abraded, giving a pentagonal figure to the tooth in the upper jaw. The number of plates in the crown of this tooth is fifteen or sixteen; its length between seven and eight inches, its breadth three inches. It has an anterior simple and slender root supporting the three first plates; a second of larger size and bifid, supporting the four next plates; and a large contracting base for the remainder. The forepart of the grinding surface of this tooth begins to protrude through the gum at the sixth year; the tooth is worn away, and its last remnant shed, about the twentieth or twenty-fifth year. It is the homologue of the first true molar of ordinary Pachyderms.

The *fifth molar*, answering to *m* 2 in fig. 140, with a crown of from seventeen to twenty plates, measures between nine and ten inches in length, and about three inches and a half in breadth. The second root is more distinctly separated from the first simple root than from the large mass behind. It begins to appear above the gum about the twentieth year; its duration has not been ascertained by observation, but it probably is not shed before the sixtieth year.

The *sixth molar*, answering to *m* 3 in fig. 140, is the last, and has from twenty-two to twenty-seven plates; its length, or antero-posterior extent, following the curvature, is from twelve to fifteen inches; the breadth of the grinding surface rarely exceeds three inches and a half.

The reproductive power of the matrix in some cases surpasses that of the formative development of the cavity for lodging the tooth, and the last lamellæ are obliged to be folded from behind forwards upon the side of the tooth. Fig. 141 shows this condition in the last lower molar.

One may reasonably conjecture that the sixth molar of the Indian Elephant, if it make its appearance about the fiftieth year, would, from its superior depth and length, continue to do the work of mastication until the ponderous Pachyderm had passed the century of its existence.

The molars succeed each other from behind forwards, moving, not in a right line, but in the arc of a circle. The position of the growing tooth in the closed alveolus is almost at right angles with that in use. The grinding surface being at first directed backwards in the upper jaw, and forwards in the lower jaw; and being brought by the revolving course into a horizontal line in both jaws, so that the molars duly oppose each other when developed for use. The imaginary pivot on which the grinders revolve is next their root in the upper jaw, and is next the grinding surface in the lower jaw; in both towards the frontal surface of the skull. Viewing both upper and lower molars as one complete whole, subject to the same revolving movement, the section dividing such whole into upper and lower portions, runs parallel to the curve described by that movement, the upper being the central portion, or that nearest the pivot, the lower the peripheral portion. The grinding surface of the upper molars is consequently convex from behind forwards, and that of the lower molars concave. The upper molars are always broader than the lower ones. The bony plate forming the sockets of the growing teeth is more than usually distinct from the body of the maxillary, and participates in this revolving course, advancing forwards with the teeth. The partition between the tooth in use and its successor is perforated near the middle, and in its progress forwards that part next the grinding surface is first absorbed, the rest disappearing with the absorption of the roots of the preceding grinder.

Structure.

There are few examples of organs that manifest a more striking adaptation of a highly complex and beautiful structure to the exigencies of the animal endowed with it, than the grinding teeth of the Elephant. We perceive, for example, that the jaw is not encumbered with the whole weight of the massive tooth at once, but that it is formed by degrees as it is required; the division of the crown into a number of successive plates, and the subdivision of these into cylindrical processes, presenting the conditions most favourable to progressive formation. But a more important advantage is gained by this subdivision of the tooth; each part is formed like a perfect simple tooth, having a body of dentine, a coat of enamel, and an outer investment of cement. A single digital process may be compared to the simple canine of a Carnivore; a transverse row of these, therefore, when the work of mastication has commenced, presents, by virtue of the different densities of their constituent substances, a series of cylindrical ridges of enamel, with as many depressions of dentine, and deeper external valleys of cement; the more advanced and more abraded part of the crown is traversed by the transverse ridges of the enamel inclosing the depressed surface of the dentine, and separated by the deeper channels of the cement; the forepart of the tooth exhibits its least efficient condition for mastication; the inequalities of the grinding surface being reduced in proportion as the enamel and cement which invested the dentinal plates have been worn away: this part of the tooth is, however, fitted for the first coarse crushing of the branches of a tree; the transverse enamel ridges of the succeeding part of the tooth divide it into smaller fragments, and the posterior islands and tubercles of enamel pound it to the pulp fit for deglutition. The structure and progressive development of the tooth not only give the Elephant's grinder the advantage of the uneven surface which adapts the millstone for its office, but, at the same time, secure the constant presence of the most efficient arrangement for the finer comminution of the food at the part of the mouth which is nearest the throat.

With regard to the *microscopic structure* of the peculiar modification of dentine called "ivory," this is characterised partly by the minute size of the tubes, which, at their origin from the pulp-cavity, do not exceed $\frac{1}{15000}$th of an inch in diameter; in their close arrangement, at intervals scarcely exceeding the breadth of a single tube; and, above all, on their strong and almost angular gyrations, which are much greater than the secondary curvatures of the tubes of ordinary dentine.

The dentinal tubes of ivory, as they radiate from the pulp-cavity, incline obliquely towards the pointed end of the tusk, and describe two slight primary curves—the first convex towards that end, the second and shorter one concave. These curves, in narrow sections from near the open base of the tusk, are almost obscured by the strong angular parallel secondary gyrations. The tubes divide dichotomously, at acute angles, and gradually decrease in size as they approach the periphery of the tusk.

The characteristic appearance of decussating curved striæ, with oblique rhomboidal spaces, so conspicuous on transverse sections or fractures of ivory, is due to the refraction of light caused by the parallel secondary gyrations of the tubes above described. The strong contour lines observed in longitudinal sections of ivory, parallel with the cone of the pulp-cavity, and which are smaller, circular, and concentric, when viewed in transverse slices of the tusk, are commonly caused by strata of minute opaque cellules, which are unusually numerous in the interspaces of the tubes throughout the substance of the ivory, and by their very great abundance and larger size in the peripheral layers of cement. The close-set lateral branches of the dentinal tubes unite with the tubuli of the cells. The decomposition of the fossil tusk into superimposed conical layers takes place along the strata of the opaque cellules, and directly across the course of the gyrating dentinal tubes. By the minuteness and close arrangement of the tubes, and especially by their strongly undulating secondary curves, a tougher and more elastic tissue is produced than results from their disposition in ordinary dentine; and the modification which distinguishes "ivory" is doubtless essential to the due degree of coherence of so large a mass as the elephant's tusk, projecting so far from the supporting socket, and to be frequently applied in dealing hard blows and thrusts. The central part of the tusk, especially near the base of such as have reached their full size, is occupied by a slender cylindrical tract of modified ivory, perforated by a few vascular canals, which is continued to the apex of the tusk. It is not uncommon to find processes of osteo-dentine or imperfect bone-like ivory, projecting in a stalactitic form[1] into the interior of the pulp-cavity.

The musket-balls and other foreign bodies which are occasionally found in ivory, are immediately surrounded by osteo-dentine, in greater or less quantity.[2] It has often been a matter of wonder how such bodies should become completely imbedded in the substance of the tusk, sometimes without any visible aperture, or how leaden bullets may have become lodged in the solid centre of a very large tusk without having been flattened. The explanation is as follows:—A musket-ball, aimed at the head of an elephant, may penetrate the thin bony socket and the thinner ivory parietes of the wide conical pulp-cavity occupying the inserted base of the tusk. The hole is soon healed and filled up, by ossification of the periosteum of the socket and of the pulp next the thin wall of ivory which has been perforated. The ball sinks below the level of this cicatrix, and the presence of the foreign body exciting inflammation of the pulp, an irregular course of calcification ensues, which results in the deposition around the ball of a certain thickness of osteo-dentine. The pulp, then resuming its healthy character and functions, coats the surface of the osteo-dentine, inclosing the ball, together with the rest of the conical cavity into which that mass projects, with layers of normal ivory. By the continued progress of growth the ball so inclosed is carried forwards to the middle of the solidified part of the tusk.

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[1] Haller seems to have been the first to notice these irregular internal deposits in the pulp-cavity of the elephant's tusk. *Elementa Physiologiæ*, tom. viii. p. 519.

[2] Cuvier, *Annales du Muséum*, tom. viii. p. 115 (1806). Goodsir, *Edinb. Philos. Trans.*, 1841, p. 97.

Should the ball have penetrated the base of the tusk of a young elephant, it may be carried forwards by the uninterrupted growth and wear of the tusk, until that base has become the apex, and be finally exposed and discharged by the continual abrasion to which the apex of the tusk is subjected.

Yet none of these phenomena prove the absolute non-vascularity of the tusk, but only the low degree of its vascularity. Blood circulates, slowly no doubt, through the prolongations of the pulp in the minute vascular canals which are continued through the centre of the ivory to the very apex of the tooth. And it is from this source that the fine tubular structure of the ivory obtains the correspondingly minute villi carrying the plasmatic colourless fluid by which its low vitality is maintained.

The matrix of the tusk consists of a large conical pulp, which is renewed quicker than it is converted, and thus is not only preserved, but grows up to a certain period of the animal's life. It is lodged in the cavity at the base of the tusk; this base is surrounded by the remains of the capsule—a soft vascular membrane of moderate thickness—which is confluent with the border of the base of the pulp, where it receives its principal vessels. The writer had the tusk and pulp of the great elephant at the Zoological Gardens longitudinally divided, soon after the death of that animal in 1847. Although the pulp could be easily detached from the inner surface of the pulp-cavity, it was not without a certain resistance; and when the edges of the co-adapted pulp and tooth were examined by a strong lens, the filamentary processes from the outer surface of the pulp could be seen stretching, as they were withdrawn from the dentinal tubes before they broke. They are so minute that, to the naked eye, the detached surface of the pulp seems to be entire, and Cuvier was thus deceived in concluding that there was no organic connection between the pulp and the ivory.

Each molar of the Elephant is formed in the interior of a membranous sac—the capsule, the form of which partakes of that of the future tooth, being cubical in the first molar, oblong in the last, and rhomboidal in most of the intermediate teeth; but always decreasing in vertical extent towards its posterior end, and closed at all points, save where it is penetrated by vessels and nerves. It is lodged in an osseous cavity of the same form as itself, and usually in part suspended freely in the maxillary bone; the bony socket being destined to form part of the socket of the tooth, the exterior of the membranous capsule is simple and vascular; its internal surface gives attachment to numerous folds or processes, as in most other Ungulate animals. The dentinal pulp rises from the bottom of the capsule, or that part which lines the deepest part of the alveolus, in the form of transverse parallel plates, extending towards that part of the capsule ready to escape from the socket. These plates adhere only to the bottom of the capsule; their opposite extremity is free from all adhesion. This summit is thinner than the base; it might be termed the edge of the plate, but it is notched or divided into many digital processes. The tissue of these digitated plates is identical with that of the dentinal pulp of simple mammalian teeth; it becomes also highly vascular at the parts where the formation of the dentine is in active progress. Processes of the capsule descend from its summit into the interspaces of the dentinal pulp-plates, and consequently resemble them in form; but they adhere not only by their base to the surface of the capsule next the mouth, but also by their lateral margins to the sides of the capsule, and thus resemble partition-walls, confining each plate of the dentinal pulp to its proper chamber; the margin of the partition opposite its attached base is free in the interspaces of the orifices of the dentinal pulp-plates. The enamel organ, which Cuvier appears to have recognised under the name of the internal layer of the capsule, is distinguished by its light blue subtransparent colour and usual microscopic texture.

For the details of the action of those parts of the complex matrix in the formation of the several tissues of the grinding tooth of the Elephant, reference may be made to the *Ossemens Fossiles*[1] of Cuvier and the writer's *Odontography*,[2] in which the theories of excretion and conversion may be contrasted.

SECTION IV.—*Application of Odontology to Classification.*

True teeth being restricted to the Vertebrate classes, their application to zoology is proportionally limited; but in them they form more or less important, if not essential, aids to the classification and grouping of species.

In this relation, however, as zoological characters, teeth possess different degrees of value in different classes, the lowest degree being in the class of Fishes, and the highest in that of Mammals.

Numerous rows of teeth, gradually succeeding and displacing each other, characterise the higher organized, or Plagiostomous Fishes, and particular modifications of form and size of their teeth distinguish the primary subdivisions of the Plagiostomous order. A few other groups are well defined by dental characters, as the Pycnodonts, Gymnodonts, Goniodonts, and Chætodonts. The teeth afford good characters for the sub-division of the Sea Breams (*Sparidæ*), and Cuvier[3] has availed himself of dental characters to establish four tribes of that natural family. But in most of the natural orders, and in many of the subordinate groups, the dental system is subject to very great diversity in regard to the form, number, and position of the teeth; and in some natural groups of Fishes, there is also a want of constancy in the structure of the teeth. There are extremely few genera of Fishes that can be characterised by a definite numerical dental formula, like that which is applicable to most of the Mammalian genera. Indeed, in the first introduction of true teeth into the animal series, regarded in the ascending order, they manifest, like the mouths of the *Polypi*, the stomachs of the *Polygastria*, the gills of the Nereids, and the generative organs of the *Tæniæ*, the principle of vegetative or irrelative repetition; and in many fishes are too numerous to be counted. The limits within which the teeth are applicable as means of classification in Fishes, have been attempted to be defined in the writer's *Odontography*. Traced from species to species, they are of great importance in the determination of the fossils of this class.

With regard to microscopic structure, certain of the modifications of dental tissues, defined in the introductory section of the present Essay, are peculiar to, and characteristic of, the piscine class. Unvascular, or fine-tubed dentine, forms the crown of the teeth in a few Fishes, but is more common in those of the higher classes, in which, however, it is always associated with enamel or cement, or with both substances.

With regard to the class *Reptilia*, the teeth serve to characterize smaller and more definite groups, as, *e. g.*, the venomous and non-venomous Ophidians, the acrodont, pleurodont, and thecodont Saurians. Certain genera, and even species, may likewise be known by peculiar forms of teeth; but these are exceptions, and it is rarely that a definite dental formula can be assigned as a generic character of a reptile. There is no decided modification of dental structure peculiar to any of the class of reptiles; the poison-fang is rather a modification of form. The labyrinthic structure reaches its maximum of complexity in the great extinct Sauroid Batrachianis of the Keuper sand-stone, but "it also exists at the base of the tooth in a few fishes,"[4] and specific instances of it in that class (*Lepidosteus* and a few other Sauroids) have since received illustrations in the works of Professor Agassiz[5] and Dr Wyman.[6]

The only constant and general character of the teeth of the cold-blooded classes of *Vertebrata* is derivable from the brief period of their existence in the individual, so that the few which develop roots have these always simple and undivided, usually hollow, and with the germ of a successor in or near them.

With the exception of the composite dental masses of the Chimæroids and the anomalous rostral teeth in *Pristis*, no existing species of fish or reptile could be said to have permanent teeth: no extinct species of either class has yet been found with teeth having divided roots implanted in sockets; and the sole evidence of perpetual growth by a persistent pulp, has but lately been given by the singular extinct Saurians of South Africa, with two long canine tusks in the upper jaw, which must have grown and been maintained throughout life, of due size and strength, like the tusks of the Boar and Walrus.[7]

Dicynodon.

In the mammalian class the value of the dental organs, as characters of classification, is much greater than in reptiles or fishes. Yet there is a difference in this respect in the different orders, and the dental system of the monophyodont *Cetacea* and *Bruta* has a much greater range of variation, and a less constant relation to the other characters on which the families and genera are founded, than in the diphyodont species. But, with respect to these also, the value of the teeth as zoological characters has been over-rated.[8]

It is true, indeed, that the most manifestly natural mammalian genera are those, the species of which are provided with absolutely similar molar teeth, and that those genera which include species with molars of different forms do not present the same character of unity. It does not follow, however, that by combining species of mammals with similar molars, a group will be formed perfectly analogous to those which may be considered as the most natural. Neither the molar teeth nor any other solitary character will serve to establish a natural classification.

The molar teeth will least mislead in this respect where their modification is most extreme, as when they are adapted to divide the flesh of animals, in which case they must of necessity be associated with the faculties and instruments for seizing and destroying prey.

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[1] Ed. 1835, 8vo, tom. i. pp. 514, 869.

[2] 4to, 1841-5, pp. 645-655.

[3] *Histoire des Poissons*, tom. vi. p. 5.

[4] *Odontography*, 1841, chap. ii., p. 201.

[5] *Poissons Fossiles, Notice sur les Sauroides*, Janvier, 1843.

[6] *Trans. Boston Society of Natural History*, August 1843.

[7] *Geological Transactions*, 2d series, vol. vii.

[8] M. F. Cuvier says:—"Cette recherche me fit reconnaître que tous les genres manifestement naturels, et admis comme tels par tous les Naturalistes, étaient formés d'espèces pourvues de machelières absolument semblables; que ceux qui comprenaient des espèces dont les mâchelières différaient, n'offraient point ce caractère d'unité qui était le partage des premiers; et, enfin, qu'en réunissant les espèces à mâchelières semblables on reformait des groupes parfaitement analogues à ceux que l'on pouvait considérer comme les plus parfaits." *Dents de Mammifères*, 8vo., 1825, p. ix.

But molar teeth may be similarly modified, and equally well adapted, for crushing vegetable substances, which substances may be sought for by one species on the dry land, by a second in marshes, and by a third in the sea, or on the banks of rivers. The grinding surface of the molar tooth, for example, may for this purpose be elevated into a pair of transverse ridges, and we find such molars in the Kangaroo, the Tapir, and the Manatee, as also in the extinct *Diprotodon*, *Nototherium*, and *Dinotherium*. The small anterior molars of the *Mastodon giganteus* likewise present this form. It would be difficult to select, from the Mammalian class, the constituents of a more heterogeneous group than would be constituted by the character which M. F. Cuvier has assigned as the true guide to the formation of the most natural and uniform genera in Mammalogy.

Even in regard to teeth adapted to carnivorous habits, were these characters to form the sole guides in classification, species of placental Mammalia would be associated with those of the implacental subclass; and M. F. Cuvier, in illustrating his generalization, observes:—"Les sarigues, les péramèles, et les dasyures se sont réunis aux Insectivores, &c. &c., et je crois avoir été conduit à ces modifications par des motifs légitimes."[1]

The molar teeth, which are best adapted for dealing with vegetable food, as in the Rodents and the hoofed Mammals, shew modifications of the enamel-markings of the grinding surface which are characteristic of families, of genera, and, in many instances, of species; and which are of the greatest utility to the Palæontologist from their conspicuous and well-marked features, and their constancy.

It is interesting also to observe, that in their more general appearance, the patterns of the upper molars are more symmetrical in the *Ungulata*, with hoofs in even numbers (compare figs. 115, 118, 120, 125), than in those with hoofs in odd numbers (compare figs. 117, 130, 132).

Sect. IV.—HOMOLOGIES OF THE TEETH.

Homologies of the Teeth.

The idea of a recognition of answerable teeth in different animals has prevailed, more or less vaguely, in Anatomy, from an early period of the science.

When "incisors," "canines," and "molars" were predicated of the dentition in different species, homologous teeth were recognised so far as the characters of those classes of teeth were defined and understood.

The Cuviers[2] went a step further, and distinguished the molar teeth into "false" and "true," into "carnassial" and "tubercular." De Blainville pointed out a particular tooth by the name of "principal," which he believed himself able to trace from species to species.[3]

The results of the writer's researches into the homologies of the teeth are given in his *Odontography* in the *Transactions of the British Association* for 1839, and in those of the *Royal Society* for 1850, p. 481.

The first step in this inquiry is the elimination of those classes of *Vertebrata* and orders of *Mammalia* in which homology cannot be predicated of individual teeth. This limits the work to the group of Mammals which the writer has termed "Diphyodonts."

Only in the Mammalian orders with two sets of teeth do those organs acquire fixed individual characters, supporting the application of special denominations; and this individualization of the teeth is eminently significative of the high grade of organization of the animals manifesting it.

Originally, indeed, the name "incisors," "laniaries" or "canines," "molars," "false molars," were given to the teeth in Man and certain Mammals, as in Reptiles, in reference merely to the shape and offices so indicated; but names of teeth can now be used as arbitrary signs, in a more fixed and determinate sense. In some *Carnivora*, *e.g.*, the front teeth have broad tuberculate summits, adapted for nipping and bruising, while the principal back-teeth are shaped for cutting, and work upon each other like the blades of scissors. The front teeth in the Elephant project from the upper jaw in the form, size, and direction of long pointed horns. In short, shape and size are the least constant of dental characters; and the homologous teeth are determined, like other parts, by their relative position, by their connections, and by their development.

Those teeth which are implanted in the premaxillary bones, and in the corresponding part of the lower jaw, are called "incisors," whatever be their shape or size. The tooth in the maxillary bone, which is situated at, or near to, the suture with the premaxillary, is the "canine," as is also that tooth in the lower jaw which, in opposing it, passes in front of its crown when the mouth is closed. The other teeth of the first set are the "deciduous molars;" the teeth which displace and succeed them vertically are the "premolars;" the more posterior teeth, which are not displaced by vertical successors, are the "molars," properly so called.

The premolars must displace deciduous molars in order to rise into place; the molars have no such relations. It will be observed in fig. 17 that the last deciduous molar (d 4) has the same relative superiority of size to d 3 and d 2 which m 3 bears to m 2 and m 1; and the crowns of p 3 and p 4 are of a more simple form than those of the milk-teeth which they are destined to succeed. This, however, is not a constant or essential character. Teeth of each of the kinds arbitrarily termed "incisors," "canines," "false molars," and "molars," have received other special names, having reference to certain peculiarities of form or other property. The "false molars" in the human subject have been called "bicuspids." The last upper premolar and the first true molar in the *Carnivora* are termed "sectorials," or "molaires carnassières." Teeth of an elongated conical form, projecting considerably beyond the rest, and of uninterrupted growth, are called "tusks;" such, for example, are the incisors of the Elephant, Narwhal, Dinotherium, and Dugong, the canines of the Boar, Walrus, and Hippopotamus. The long and large incisors of the Rodents have been termed, from the shape and structure of their cutting edge, scalpriform teeth, chisel teeth, "*dentes scalprarii*." The lower incisors of the Flying Lemurs (*Galeopithecus*), with the crown deeply notched like a comb, are termed "*dentes pectinati*." The canines of the Baboons, which are deeply grooved in front like the poison-fangs of some snakes, are "dentes canaliculati." The compressed crowns of the teeth of short-clawed Seals (*Stenorhynchus*) and of the extinct *Zeuglodon*, being divided into points like a saw, are "*dentes serrati*," etc. But a true knowledge of nature, a right appreciation of what is essential in her phenomena, tends to explode needless terms of art invented for unimportant varieties, and to establish those terms that are the signs of true species of things.

As most zoologists have adopted the Cuvierian system of nomenclature and homology of the teeth in Mammalia, it may not be superfluous to explain what is here deemed objectionable in that system. In it the molar series of teeth, or those that follow the canines, are divided, according to their form, into three kinds, "false molars," "carnassials," and "tubercular molars," and the generic dental characters of the Mammalia are formulized according to this system. Thus, the genus *Felis* has—"fausses molaires" $\frac{2.2}{2.2}$, "carnassières" $\frac{1.1}{1.1}$, "tuberculeuses" $\frac{1.1}{0.0} = \frac{8}{6}$.[4] This seems a true and natural way of expressing the homotypal teeth, or the answerable teeth in the upper and lower jaw. But to illustrate its error, the subjoined diagram (fig. 145) is appended, in which the dental

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[1] *Loc. cit.*, p. xi.

[2] G. Cuvier, *Leçons d'Anatomie Comparée*, tom. iv. (1836). F. Cuvier, *Dents des Mammifères*, 8vo. p. 77.

[3] *Ostéographie des Mammifères*, tom. i. p. 43.

[4] *Ossemens Fossiles*, 8vo. 1835, tom. vii. p. 14. *Dents des Mammifères*, p. 77.

Homologies of the Teeth.

system of the Cat-tribe (*Felis* V.) is associated with that of other Mammals, and in which the line marked "*Cuvier*" intersects the teeth in each jaw, called "carnassières," those anterior to them being the teeth called "fausses molaires;" those behind—a single tooth in the upper jaw of *Felis*—being the "tuberculeuses." In this genus the tooth (p 4) above chiefly plays upon the tooth (m 1) below, which has a similar sectorial or carnassial modification of form; they fit, indeed, almost as Cuvier describes, like the blades of a pair of scissors. The two teeth in advance of the carnassial in the upper jaw (p 3, p 2) in like manner are opposed to the same number of "fausses molaires" in the under jaw, and the canine (c) above plays upon the canine below; all seems fitting and symmetrical, save that the little tubercular (m 1) above has no opponent in the lower jaw. And, perhaps, the close observer might notice that, whilst the upper canine (c) glides behind its homotype below, the first upper false molar (p 2) passes anterior to the crown of the first false molar (p 3) below; and that the second false molar and carnassial of the upper jaw are also a little in advance of those teeth in the under jaw when the mouth is shut.

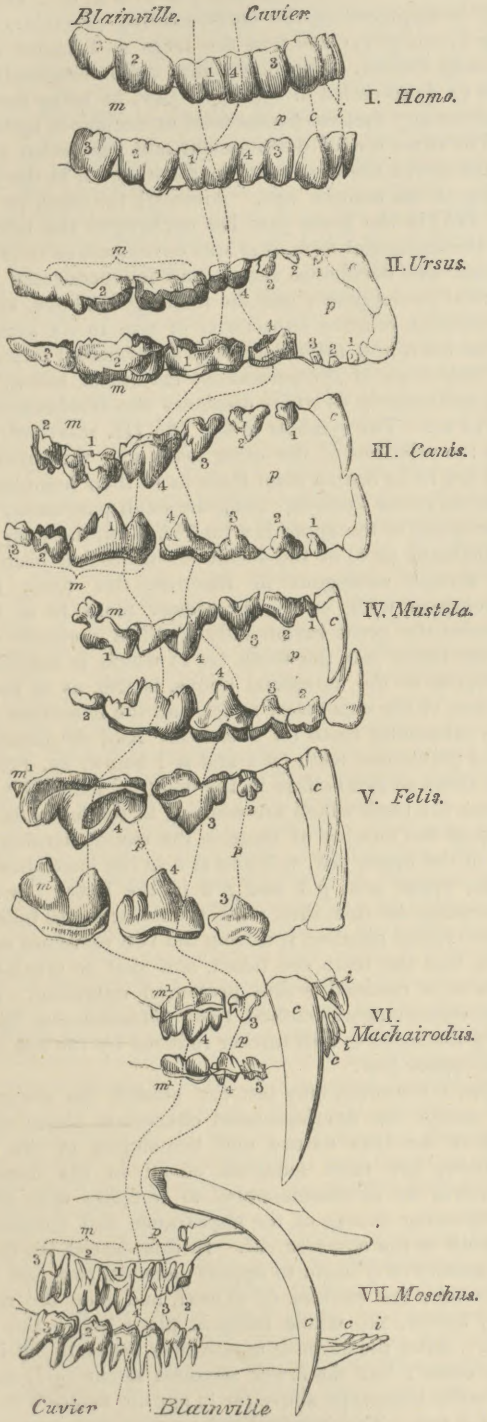

Fig. 145.
Homologies of Teeth.

Homologies of the Teeth.

In passing to the dentition of the Dog (fig. III. *Canis*), formulized by Cuvier as "fausses molaires $\frac{3.3}{4.4}$, carnassières $\frac{1.1}{1.1}$, tuberculeuses $\frac{2.2}{2.2} = \frac{12}{14}$,"[1] it will be observed that here the first upper false molar (p 1) differs from the first (p 2) in *Felis*, inasmuch as, when the mouth is shut, it preserves the same relative position to its opponent below (p 1, in fig. III.) which the upper canine does to the lower canine, and that the same may be said of the second and the third false molars; but that, with regard to the carnassial above (p 4), this tooth repeats the same relative position in regard to the fourth false molar below (p 4), and not to that tooth (m 1) which Cuvier regarded as the lower homotype of the carnassial; and, indeed, the more backward position of the lower carnassial is so slight that its significance might well be overlooked, more especially as the two succeeding tubercular teeth above were opposed to two similar tuberculars below.

How unimportant size and shape are, and how significant relative position is, in the determination of the homologies of teeth as of other parts, may be learnt before quitting the natural order of Carnivora; *e. g.* by the condition of the dental system in the Bear (fig. II. *Ursus*). Here the lower tooth (m 1), instead of presenting the carnassial character, and resembling in form the upper tooth (p 4), which is the homologue of the upper carnassial in the dog, has a tubercular crown, and corresponds in size as well as shape with the upper tooth (m 1), to which it is almost wholly opposed, and with the same slight advance of position which we observe in the lower canine as compared with the upper one, and in the four lower premolars (p 1, p 2, p 3, p 4) as compared with their veritable homotypes above. F. Cuvier divides the molar series of the genus *Ursus* into "fausses molaires $\frac{3.3}{4.4}$, carnassières $\frac{1.1}{1.1}$, tuberculeuses $\frac{2.2}{2.2} = \frac{12}{14}$."[2] The tendency in every thinker to generalise and to recognise Nature's harmonies, has led him here to use the term "carnassière" in an arbitrary sense, and to apply it to a tooth above (II. p 4), which he owns has such a shape and diminished size as would have led him to regard it as merely a false molar, but that the upper carnassial would then have entirely disappeared; and it has also led him to give the name "carnassière" to a tooth below (m 1), which he, nevertheless, describes as having a tubercular and not a trenchant crown. In so natural a group as the true Carnivora, it was impossible to overlook the homologues of the trenchant carnassials of the lion, even when they had become tubercular in the omnivorous bear; and Cuvier, therefore, having determined and defined the teeth so called in the feline genus, felt compelled to distinguish them by the same names after they had lost their formal specific character. And if, indeed, he had succeeded in discovering the teeth which were truly answerable or homotypal in the upper and lower jaws, the term "carnassial" might have been retained as an arbitrary one for such teeth, and have been applied to their homologues in

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[1] *Ossemens Fossiles*, tom. cit. p. 59. *Dents des Mammifères*, p. 95.

[2] Op. cit. p. 109.

Homologies of the Teeth.

Man, the Ruminant, or the Pachyderm, where they are as certainly determinable as in those aberrant Carnivores, in which they have equally lost their sectorial shape.

But the inconvenience of names indicative of such specialties of form will be very obvious when the term "tuberculeuses" comes to be applied to the three hindmost teeth in the *Hyænodon* (fig. 113), which teeth answer to the broad crushing teeth, *m* 1, *m* 2, and *m* 3, in the bear and some other existing *Carnivora*. The analogous term "molar" having a less direct or descriptive meaning, is therefore so much the better, as the requisite arbitrary name of a determinate species of teeth.

Had Cuvier been guided in his determinations of the teeth by their mutual opposition in the closed mouth, and had studied them with this view in the *Carnivora*, with the dentition most nearly approaching to the typical formula, viz. the bear, he could then have seen that the three small and inconstant lower premolars (*p* 1, *p* 2, *p* 3) were the homotypes of the three small and similarly inconstant premolars above; that the fourth false molar (*p* 4 below), which, as he observes, "alone has the normal form,"[1] was truly the homotype of the tooth above (*p* 4), which he found himself compelled to reject from the class of "fausses molaires," notwithstanding it presented their normal form; that the tubercular tooth (*m* 1) which he calls "carnassière" in the lower jaw, was the veritable homotype of his first "molaire tuberculeuse" above (*m* 1), and that the tooth in the inferior series, which had no answerable one above, was his second "tuberculeuse" (*m* 3) in the present Essay. The true second tubercular above (*m* 2) is, however, so much developed in the bear as to oppose both *m* 2 and *m* 3 in the lower jaw, and it might seem to include the homotypes of both those teeth coalesced. One sees with an interest such as only these homological researches could excite, that they were distinctly developed in the ancient *Amphicyon* (fig. 114), which accordingly presents the typical formula.

Thus the study of the relative position of the teeth of the bear might have led to the recognition of their real nature and homologies, and have helped to raise the mask of the extreme formal modifications, by which they are adapted to the habits of the more blood-thirsty *Carnivora*. But the truth is plainly and satisfactorily revealed when we come to trace the course of development and succession of these teeth. The weight which must ever attach itself to an opinion sanctioned by the authority of both the Cuviers, demands that a conclusion contrary to theirs, and which seems to be opposed by Nature herself in certain instances, should be supported by all the evidence of which such conclusion is susceptible.

It is proposed, therefore, first, to show how, in the bear, the writer's determinations of the teeth are established by their development, as well as by their relative position. As the question only concerns the molar series, the remarks will be confined to those teeth. In the jaws of the young bear, figured in cut 110, the first premolar is the only one of the permanent series in place; the other grinders in use are the deciduous molars, *d* 2, *d* 3, and *d* 4; *d* 2 will be displaced by *p* 2, *d* 3 by *p* 3, and *d* 4, by the tooth *p* 4, which, notwithstanding its size and shape, Cuvier felt himself compelled to discard from the series of false molars, but which we now see is proved by its developmental relations to *d* 4, as well as by its relative position and similarity to *p* 4 in the lower jaw (fig. 145, *Ursus*) to be veritably the last of the premolar series, and to agree not in shape only, but in every essential character, with the three preceding teeth called by Cuvier "fausses molaires." So, likewise, in the lower jaw, it is seen that the primitive deciduous series (*d* 1, *d* 2, *d* 3, and *d* 4) will be displaced by the corresponding premolars (*p* 1, *p* 2, *p* 3, and *p* 4); and that the tooth *m* 1, called carnassière by Cuvier, in the lower jaw, differs essentially from that (*p* 4) so called in the upper jaw, by being developed without any vertical predecessor or deciduous tooth.

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The same law of development and succession prevails in the genus *Canis*, as may be readily seen in the jaws of a dog of ten months' age. Although the tooth (*m* 1, III. fig. 145) in the lower jaw has exchanged the tubercular for the carnassial form, it is still developed, as in the bear, behind the deciduous series, and independently of any vertical predecessor; and the tooth (*p* 4) above, although acquiring a relative superiority of size to its homologue in the bear, and more decidedly a carnassial form, is not the homotype of the permanent carnassial below, but of that premolar (*p* 4) which displaces the deciduous carnassial (*d* 4). The symbols in fig. 145 III. sufficiently indicate the relations of the other teeth, and the conclusions that are to be drawn from them as to their homologies.

In the genus *Felis* (fig. 104), the small permanent tubercular molar of the upper jaw (*m* 1) has cut the gum before its analogue (*d* 4) of the deciduous series has been shed; but though analogous in function, this tooth is not homologous with, or the precedent tooth to *m* 1, but precedes the great carnassially modified premolar (*p* 4). In the lower jaw the tooth (*m* 1) which is functionally analogous to the carnassial above, is also, as in the dog, the first of the true molar series, and the homotype of the little tubercular tooth (*m* 1) above. And the homologies of the permanent teeth (*p* 4 and *m* 1 below, fig. 145, V.), with those so symbolised in the dog (fig. 145, III.), teach us that the teeth which are wanting in the feline, in order to equal the number of those in the canine dentition, are *m* 2 in the upper jaw, *m* 2 and *m* 3 in the lower jaw; *p* 1 in the upper jaw, *p* 1 and *p* 2 in the lower jaw; thus illustrating the rule, that, when the molar series falls short of the typical number, it is from the two extremes of such series that the teeth are taken, and that so much of the series as is retained is thus preserved unbroken. In the great extinct sabre-toothed tiger (*Machairodus*, fig. 145, VI.[2]), the series is still further reduced by the loss of *p* 2 in the upper jaw.

That the student may test for himself the demonstration which the developmental characters above defined yield of the true nature and homologies of the feline dentition, the most modified of all in the terrestrial *Carnivora*, he is recommended to compare with Nature the following details of the appearance and formation of the teeth in the common cat. In this species the deciduous incisors (*d i*) begin to appear between two and three weeks old; the canines (*d c*) next, and then the molars (*d m*) follow, the whole being in place before the sixth week. After the seventh month they begin to fall in the same order; but the lower sectorial molar (*m* 1) and its tubercular homotype above (*m* 1) appear before *d* 2, *d* 3, and *d* 4 fall. The longitudinal grooves are very faintly marked in the deciduous canines. The first deciduous molar (*m* 2) in the upper jaw is a very small and simple one-fanged tooth; it is succeeded by the corresponding

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[1] *Dents des Mammifères*, p. 111.

[2] *Machairodus*, from μάχαιρα, a sabre; and ὀδοὺς, a tooth. This generic name was imposed by Dr Kaup on the extinct animal which was armed with canine teeth, like that in the above figure (*c*). Such teeth, long, compressed, falciform, sharp-pointed, and with anterior and posterior finely-serrated edges, were first discovered in tertiary strata in Italy and Germany, and were referred by Cuvier to a species of bear, under the name of *Ursus cultridens*.

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tooth of the permanent series, which answers to the second premolar (*p* 2) of the hyæna and dog. The second deciduous molar (*m* 3) is the sectorial tooth; its blade is trilobate, but both the anterior and posterior smaller lobes are notched, and the internal tubercle, which is relatively larger than in the permanent sectorial, is continued from the base of the middle lobe, as in the deciduous sectorial of the dog and hyæna; it thus typifies the form of the upper sectorial, which is retained in the permanent dentition of several Viverrine and Musteline species. The third or internal fang of the deciduous sectorial is continued from the inner tubercle, and is opposite the interspace of the two outer fangs. The Musteline type is further adhered to by the young Feline in the large proportional size of its deciduous tubercular tooth (*d* 4). In the lower jaw, the first milk-molar (*d* 3) is succeeded by a tooth (*p* 3) which answers to the third lower premolar in the dog and civet. The deciduous sectorial (*d* 4), which is succeeded by the premolar (*p* 4), answering to the fourth in the dog, has a smaller proportional anterior lobe, and a larger posterior talon, which is usually notched; thereby approaching the form of the permanent lower sectorial tooth in the *Mustelidæ*.

When the premolars and the molars are below their typical number, the absent teeth are missing from the fore-part of the premolar series and from the back-part of the molar series. The most constant teeth are the fourth premolar and the first true molar; and these being known by their order and mode of development, the homologies of the remaining molars and premolars are determined by counting the molars from before backwards, *e. g.*, "one," "two," "three;" and the premolars from behind forwards, "four," "three," "two," "one."

Examples of the typical diphyodont dentition are exceptions in the actual creation; but it was the rule in the earlier forms of placental Mammalia, whether the teeth were modified for animal or vegetable food.

Not only the *Hyænodon* (fig. 113) and *Amphicyon* (fig. 114), but the *Dichodon* (fig. 118), *Anoplotherium*, *Palæotherium*, *Chœropotamus*,[1] *Anthracotherium*,[2] *Hyopotamus*,[3] *Hyracotherium*,[4] and other ancient (eocene and miocene) tertiary Mammalian genera presented the forty-four teeth, in number and kind according to that which is here propounded as the typical or normal dentition of the placental Mammalia.[5] When the clue is afforded, by the observed development and succession of the teeth, to their homologies, it infallibly conducts us to the true knowledge of the nature both of the teeth which are retained, and of those which are wanting to complete the typical number. We have availed ourselves of this in deciphering the much modified dentition of the genus *Felis;* and the same clue will guide us to the knowledge of the precise homologies of the teeth in our own species.

The discovery by the great poet Göethe of the limits of the premaxillary bone in Man leads to the determination of the incisors, which are reduced to two on each side of both jaws; the contiguous tooth shows by its shape as well as position that it is the canine, and the characters of size and shape have also served to divide the remaining five teeth in each lateral series into two bicuspids and three molars. In this instance the secondary characters conform with the essential ones. But since we have seen of how little value shape or size are, in the order *Carnivora*, in the determination of the exact homologies of the teeth, it is satisfactory to know that the more constant and important character of development gives the requisite certitude as to the nature of the so-called bicuspids in the human subject. In fig. 100, the condition of the teeth is shown in the jaws of a child of about six years of age. The two incisors on each side (*d i*) are followed by a canine (*c*), and this by three teeth having crowns resembling those of the three molar teeth of the adult. In fact, the last of the three is the first of the permanent molars; it has pushed through the gum, like the two molars which are in advance of it, without displacing any previous tooth, and the substance of the jaw contains no germ of any tooth destined to displace it; it is therefore, by this character of its development, a true molar, and the germs of the permanent teeth, which are exposed in the substance of the jaw between the diverging fangs of the molars (*d* 3 and *d* 4), prove them to be temporary, destined to be replaced, and prove also that the teeth about to displace them are premolars. According, therefore, to the rule previously laid down, we count the permanent molar in place the first of its series (*m* 1), and the adjoining premolar as the last of its series, and consequently the fourth of the typical dentition (*p* 4).

We are thus enabled, with the same scientific certainty as that whereby we recognise in the middle toe of our foot the homologue of that great digit which forms the whole foot, and is encased by the hoof, in the horse, to point to *p* 4, or the second bicuspid in the upper jaw, and to *m* 1, or the first molar in the lower jaw, of man (fig. 145, I.), as the homologues of the great carnassial teeth of the lion (*p* 4, *m* 1, fig. 145, V.) We also conclude that the teeth which are wanting in man to complete the typical molar series, are the first and second premolars, the homologues of those marked *p* 1 and *p* 2 in the bear (fig. 145, II.) The characteristic shortening of the maxillary bones required this diminution of the number of their teeth, as well as of their size, and of the canines more especially; and the still greater curtailment of the premaxillary bone is attended with a diminished number and an altered position of the incisors. One sees, indeed, in the carnivorous series, that a corresponding decrease in the number of the premolars is concomitant with the shortening of the jaws. Already in the *Mustelidæ* (fig. 145, IV.), the first premolar below is abrogated; in *Felis* also above, with the further loss of the second premolar in the lower jaw; the true molars being correspondingly reduced in these strictly flesh-eating animals, but taken away from the back part of their series.

The homologous teeth being thus determinable, they may be severally signified by a symbol as well as by a name. The incisors, *e. g.*, are represented in the present Essay (See figs. 20 and 118) by their initial letter *i*, and individually by an added number, *i* 1, *i* 2, and *i* 3; the canines by the letter *c*; the premolars by the letter *p*; and the molars by the letter *m*; these also being differentiated by added numerals. Thus, the number of these

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[1] *History of British Fossil Mammalia*, p. 416, fig. 164.

[2] Jobert, *Annales des Sciences*, t. xvii. p. 139.

[3] *Quarterly Journal of the Geological Society*, May 1848, p. 103, pl. viii.

[4] *Geological Transactions*, 2d series, vol. vi. p. 203.

[5] Thirty-eight instances are cited in the writer's memoir on "Pliolophus," *Quarterly Journal of the Geological Society*, May 1857. The seeming exception afforded by the oolitic *Plagiaulax*, on which much stress is laid by Lyell (Supplement to *Manual of Geology*, p. 21), bears upon the generalisation with about the same value as the abnormal dentition of *Proteles* does upon the generalised dental formula of the genus *Canis*. It is objected that "we ought, in every great family of the Mammalia, to find evidence of closer adherence to the archetype the farther we recede in time" (*ib.*, p. 22). And the *Plagiaulax* is cited as evidence to the contrary. But the force of the argument really lies in the suppression of the fact, that all the other known instances of the same great Marsupial family, from oolitic strata, do give evidence of such closer adherence to archetype. The type of the Diphyodont dentition is a modification of the wider Vertebrate type of dentition; and the great majority of known oolitic Mammals exhibit that greater degree of vegetative repetition of teeth (as in fig. 74), which the theory, rightly understood, would have anticipated.

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teeth, on each side of both jaws, in any given species, Man, *e. g.*, may be expressed by the following brief formula:—

$$i\,\frac{2.2}{2.2};\; c\,\frac{1.1}{1.1};\; p\,\frac{2.2}{2.2};\; m\,\frac{3.3}{3.3} = 32;$$

and the homologies of the individual teeth, in relation to the typical formula, may be signified by *i* 1, *i* 2; *c*; *p* 3, *p* 4; *m* 1, *m* 2, *m* 3; the suppressed teeth being *i* 3, *p* 1, and *p* 2.

If we were desirous of further testing the soundness of the foregoing conclusions as to the nature of the teeth absent in the reduced dental formula of man, we ought to trace the mode in which the type is progressively resumed in descending from man through the order most nearly allied to our own.

Through a considerable part of the Quadrumanous series, *e. g.*, in all the Old World genera above the Lemurs, the same number and kinds of teeth are present as in man, the first deviation being the disproportionate size of the canines and the concomitant break or "diastema" in the dental series for the reception of their crowns when the mouth is shut. This is manifested in both the Chimpanzees and Orangs, together with the sexual difference in the proportions of the canine teeth. Then comes the added premolar in the New World Monkeys, and the further additions in lower quadrupeds, until in the Hog genus we see the old primitive type of Diphyodont dentition resumed or retained.

The typical dentition is departed from in the existing Hippopotamus by the early loss of *p* 1, and the reduction of the incisors to $\frac{2}{2}:\frac{2}{2}$ in both jaws; in the extinct Hippopotamus of India, *p* 1 was longer retained, and the incisors were in normal number $\frac{3}{3}:\frac{3}{3}$; whence the term *Hexaprotodon* proposed for this interesting restoration by its discoverers, Cautley and Falconer.

The existing even-toed or artiodactyle *Ungulata* superadd the characters of simplified form and diminished size to the more important and constant one of vertical succession in their premolars.[1] These teeth in the Ruminants, *e. g.* (fig. 145, VII., *Moschus*, *p* 2, 3, 4,), represent only the moiety of the true molars, or one of the two semi-cylindrical lobes of which those teeth consist, with, at most, a rudiment of the second lobe, as Cuvier very accurately describes, and F. Cuvier figures in pl. 94 of his useful work, *Dents des Mammifères.* An analogous morphological character of the premolars will be found to distinguish them in the dentition of the genus *Sus* (fig. 20), in the Hippopotamus, and in the *Phacochœrus* (fig. 124), where the premolar series is greatly reduced in number: yet this instance of a natural affinity manifested in so many other parts of the organization of the artiodactyle genera has been overlooked in F. Cuvier's work above cited, although it is expressly designed to show how such zoological relations are illustrated by the teeth. Confiding in the accuracy of the Baron Cuvier's division of the hoofed quadrupeds into "Pachyderms" and "Ruminants," M. F. Cuvier separates the non-ruminant artiodactyles from the ruminant genera of the same natural division, by interposing the Tapir, Hyrax, Rhinoceros, and Elephant; whilst the Horse, which, in the size and complexity of its premolars, as well as in many other characters, agrees closely with the other perissodactyle Ungulates, is placed in close juxtaposition with the Ruminants.

Most of the deciduous teeth of the Ruminants resemble in form the true molars; the last, *e. g.* (fig. 121, *d* 4), has three lobes in the lower jaw, like the last true molar (*m* 3).

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Sufficient, it is hoped, has been adduced to prove that the molar series of the Diphyodonts is naturally divisible into only two groups, premolars and molars; that the typical number of these is $\frac{4}{4}:\frac{4}{4}$, $\frac{3}{3}:\frac{3}{3}$; and that each individual tooth may be determined and symbolised throughout the series, as is shown in the instances under cut 145. If anything were wanting to prove the artificial character of a threefold division of these teeth, and the futility of any other classification than that founded upon development, it would be afforded by the attempt to determine the homologous teeth, which is exemplified by the dotted line which traverses the series, and which crosses the teeth distinguished by the name "principales" in the great "*Ostéographie and Odontographie*" of De Blainville.

This author abandons the classification of the molar series adopted by the Cuviers, without assigning his objections to it, and proposes another, in which he divides the series into "avant-molaires, principales, and arrière-molaires;" he exemplifies this division by the human dentition, in which the five grinders on each side of both jaws are formulised as "two avant-molaires, one principale, and two arrière-molaires."[2]

With regard to the characters of these kinds of teeth, the avant-molaires are "simple or complex," the principale is "trenchant," and the arrière-molaires are "tuberculous." But as shape is not a constant character, especially in the "principale," the author proposes another from its position, describing it as "being implanted below the root of the zygomatic process of the maxillary bone" in the upper jaw; and stating that the tooth which opposes it below, and is in advance of it, is the lower "principale."

In defining the dentition of the genus *Felis*, M. de Blainville accordingly assigns one "avant-molaire," one "principale," and two "arrière-molaires" in the upper jaw; and one "avant-molaire," one "principale," and one "arrière-molaire" in the lower jaw.[3] In another part of the same work, he, however, proposes another formula, viz., two "avant-molaires," one "principale," and one "arrière-molaire" above; one "avant-molaire," one "principale," and one "arrière-molaire" below; but, taking either of these determinations, or the dental formulæ which he assigns to other carnivorous genera, and comparing them with his formula of the molar series in the Quadrumana and Man, we find that a tooth which displaces and succeeds a milk-tooth in one species is made the homologue of a tooth, which, in Man and Quadrumana, rises above the gum without displacing any predecessor; in other words, the "principale" is a premolar in certain genera, and a true molar in other genera. Reference may be made to the concluding pages of the chapter on the teeth of the Carnivora in the writer's *Odontography*, p. 514, for further proofs that a "molaire principale" does not exist in nature; that the characters by which it is defined by M. de Blainville are artificial; and that they fail in their application to determine the teeth in the series of placental Mammalia with deciduous and permanent teeth.

In the series of figures under cut 145, the line, "*Cuvier*," traverses the tooth or its homologue, from Man to the Ruminant, which Cuvier distinguished as the "molaire carnassière;" the other line traverses that tooth which M. de Blainville distinguishes as the "molaire principale;" the letters and numbers symbolise the teeth, and indicate their individual homologies, and the binary division of the molar series, which it has been one object of the present Essay to illustrate. To show how these symbols may be applied to the exposition of facts in the

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[1] See the writer's "Remarks on the Classification of the Hoofed Quadrupeds," in *Quarterly Journal of the Geological Society*, May 1848. The older Eocene genera, *e. g.*, *Lophiodon* and *Pliolophus*, manifest a minor departure from type in a less changed form of one or two of the hinder premolars.

[2] *Ostéographie*, tom. i., p. 43.

[3] *Ostéographie*, p. 43.

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comparative anatomy of the teeth, the difficult homology of the proboscidian dentition, and the complex and intricate subject of the succession of the teeth in the kangaroo, will be finally selected.

With regard to the homologies of the complex molars of the proboscidian quadrupeds, a species of insight which may come to be deemed, in the course of anatomical science, as of equal import to the knowledge of the formative process of parts, it may be admitted that the mere fact of the marked and disproportionate increase of size of the first of the three last molars (fig. 139, *m* 1) over its predecessor (*d* 4), the last of the first three that are developed, seems to be but a feeble support to the analogical evidence on which chiefly the three last molars of the elephant are here classed in a category distinct from that of their smaller predecessors. But the value of such indication and analogy will begin to be apparent when we examine the condition of dental development in the primeval forms of Proboscidians. It has already been shewn that the typical character of the Diphyodont dentition was more closely and generally adhered to in the genera that existed in the old tertiary periods in geology than in their actual successors; it became, of course, highly interesting to inquire whether the Miocene Mastodons, the earliest of the great proboscidian quadrupeds of which we have any cognizance, manifested any analogous closer adhesion to type than their elephantine successors, and whether they would afford any actual proof of the true deciduous nature of the first, second, or third molars, by the development of a vertical successor or premolar. Cuvier first ascertained the fact, though without appreciating its full significance, in a specimen of the upper jaw of the *Mastodon angustidens* from Dax, in which the second six-lobed deciduous molar was displaced by a four-lobed or quadricuspid premolar developed above it, and succeeding it vertically. The same important fact was subsequently confirmed by Dr Kaup, in observations of the *Mastodon angustidens* (his *Mast. longirostris*) of the *Miocene* of Eppelsheim.

This satisfactorily proves the true deciduous character of the first and second molars (fig. 139, *d* 2 and 3); and, that the third molar in the order of appearance (*d* 4) is also one (the last) of the deciduous series, is indicated, both by the contrasted superiority of size of the tooth (*m* 1), and the more direct evidence which a comparison with the dentition of the wart-hog (fig. 124) affords, that *m* 1, fig. 139, is the first of the true molars. The great extent and activity of the processes of dental development required for the preparation of the large and complex true molar teeth, would seem to exhaust the power in Proboscidians, which, in ordinary Pachyderms, is expended in developing the vertical successors of the deciduous teeth. In the miocene Mastodon above cited, this normal exercise of the reproductive force was not, however, wholly exhausted; and one premolar (fig. 139, *p* 3), of more simple form than its deciduous predecessor, was developed on each side of both jaws; but even this trace of adherence to the archetypal dentition is lost in the more modified Proboscidians of the present day. Another and interesting mark of adhesion to the archetype was shown by the development of two incisors in the lower jaw in the young of some of the Mastodons, by the retention and development of one of these inferior tusks in the male of the *Mastodon giganteus* of North America, and by the retention of both in the European *Mastodon angustidens* (fig. 140). No trace of these inferior homotypes of the premaxillary tusks have been detected in the fœtus or young of the existing elephants. In the gigantic *Dinotherium*, the upper incisors were suppressed, and the lower incisors were developed into huge tusks, which curved down from the symphysis of the massive lower jaw.

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The chief modifications of the marsupial dentition have already been described and illustrated. The observed phenomena of the development and change of the teeth led to the generalisation that the marsupial differed from the placental Diphyodont mammals in having four true molars, *i. e.*, $m.\ \frac{4.4}{4.4}$ instead of $m.\ \frac{3\ 3}{3.3}$; and also that they differed in having only three premolars, *i. e.* $p.\ \frac{3.3}{3.3}$ instead of $p.\ \frac{4.4}{4.4}$; the typical number of the grinding series, $\frac{7.7}{7.7}$, being the same. Since, however, there is reason to conclude that *m* 1 in the placental series, as, *e. g.*, figs. 17 and 124, is a continuation of the deciduous series of molars, which might be symbolised as *d* 5, and only becomes a permanent molar because there is no premolar developed above it, so we may regard the tooth marked *m* 1 in figs. 75, 76 and 78 as being an antecedent tooth of the deciduous series, rendered permanent by a like reason, the suppression, viz. of *p* 4. In other words, that *m* 1 in fig. 75 is the homologue of *d* 4 in fig. 17, and that the true homologue of *p*. 4 is not developed in the *Marsupialia.*

The homologues of the teeth of the Kangaroo are illustrated in fig. 146, according to this idea of them.

The permanent dental formula of both the *Macropodidæ* and *Hypsiprymnidæ*, according to the usual view, as given at p. 449, is—

$$i\,\frac{3.3}{1.1};\ c\,\frac{1.1}{0.0};\ p\,\frac{1.1}{1.1};\ m\,\frac{4.4}{4.4}=30.$$

According to the real state of things it is—

$$i\,\frac{3.3}{1.1};\ c\,\frac{1.1}{0.0};\ p\,\frac{1.1}{1.1};\ d\,\frac{1.1}{1.1};\ m\,\frac{3.3}{3.3}=30.$$

The canines, which are confined to the upper jaw, are small or minute when retained; and disappear after being represented "en germe" in most of the true Kangaroos.

The deciduous dentition of the great Kangaroo (*Macropus major)* is—

$$i\,\frac{3.3}{1.1};\ c\,\frac{1.1}{0.0};\ m\,\frac{2.2}{2.2}=18.$$

The canines are rudimental, and are absorbed rather than shed. The deciduous incisors are shed before the young animal finally quits the pouch; when this takes place, the dentition is—

$$i\,\frac{1.1}{1.1};\ d\,m\,\frac{2.2}{2.2}=12;$$

the upper incisors being *i* 1, the molars *d* 2 and *d* 3 of the typical dentition. This stage is exemplified in the lower jaw at A (fig. 146). The next stage shows the acquisition of *i* 2 in the upper jaw, and *d* 4 in both jaws, and the formula is—

$$i\,\frac{2.2}{1.1};\ d\,m\,\frac{3.3}{3.3}=18\ \text{(B, fig. 146).}$$

At one year old, the dentition is—

$$i\,\frac{3.3}{1.1};\ d\,m\,\frac{3.3}{3.3};\ m\,\frac{1.1}{1.1}=24;$$

the additional teeth being *i* 3 and *m* 1 (C, fig. 146), in which the demonstration of the true deciduous character of *d* 2 and *d* 3 is shown by the germ of their vertical successor *p* 3, which is exposed in the substance of the jaw. The next stage is the shedding of *d* 2, and the acquisition of *m* 2 (D, fig. 146). Then *d* 3 is shed by the ascent of *p* 3 into its place (E, fig. 146). Afterwards *m* 3 is acquired; and in the *Macropus gigas*, *p* 3, simultaneously pushed out (F, fig. 146).

Thus, four individuals of this species may be found to have the same number of molars, *i. e.* $\frac{4.4}{4.4}$; two of these individuals may seem, on a cursory comparison, to have them of the same shape, *e. g.*, as in C and E, fig. 146, or as in D and F. In fact, to determine the identity or difference in such instances, it requires that the substance of

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the jaws be examined, to see if the germs of successional teeth be present, as at *p* 3, C and D, or at *m* 3, E. The result of such examination may be to show that not one of the four Kangaroos with the $m\,\frac{4.4}{4.4}$ had the same or homologous teeth. The four grinders, *e. g.* may be—

d 2, *d* 3, *d* 4, *m* 1; as in C; or
d 3, *d* 4, *m* 1, *m* 2; as in D; or
p 3, *d* 4, *m* 1, *m* 2; as in E; or
d 4, *m* 1, *m* 2, and *m* 3; as in F.

The changes, however, do not end here. As age advances, *d* 4 is shed, and the molar series is reduced numerically to the condition of B; but, instead of *d* 4, *d* 3, and *d* 2, it consists of *m* 1, *m* 2, *m* 3.

Finally, *m* 1 is shed, and the dentition is reduced to the same numerical state as at A; the teeth, however, being *m* 2 and *m* 3. The order here described is not precisely that which is followed in some of the smaller species of Kangaroo. In *Macropus Benettii*, *e. g.* the acquisition of *m* 3 is not accompanied by the displacement of *p* 3; and a molar series of $\frac{5}{5}:\frac{5}{5}$ is long retained.

These symbols, it is hoped, are so plain and simple as to have formed no obstacle to the full and easy comprehension of the facts explained by means of them. If these facts, in the manifold diversities of Mammalian dentition, were to be described in the ordinary way, by means of verbal phrases or definitions of the teeth, *e. g.*, the second deciduous molar representing the fourth in the typical dentition, instead of *d* 4, and so on, the description of dental development would continue to occupy much unnecessary space, and would levy such a tax upon the attention and memory as must tend to enfeeble the judgment and impair the power of seizing and appreciating the results of the comparison.

Each year's experience has strengthened the writer's conviction that the rapid and successful progress of the knowledge of animal structures, and of the generalizations deducible therefrom, will be mainly influenced by the determination of the homology of parts and organs, and by the concomitant power of condensing the propositions relating to them, and of attaching to them signs or symbols equivalent to their single substantive names. In the writer's work on the *Archetype of the Skeleton*, he has denoted most of the bones by simple numerals. The symbols of the teeth are fewer in number, are easily understood and remembered, and, if generally adopted, might take the place of names. They would then render unnecessary the endless repetition of the verbal definitions of the parts, harmonize conflicting synonyms, serve as a universal language, and at the same time express the expositor's meaning in the fewest and clearest terms. The entomologist has long found the advantage of such signs as ☿ and ♀, in reference to the sexes of insects, and the like; and it is hoped that the time is now come when the anatomist may avail himself of this powerful instrument of thought, instruction, and discovery, from which the chemist, the astronomer, and the geometrician have obtained such important results.

(R. O.)

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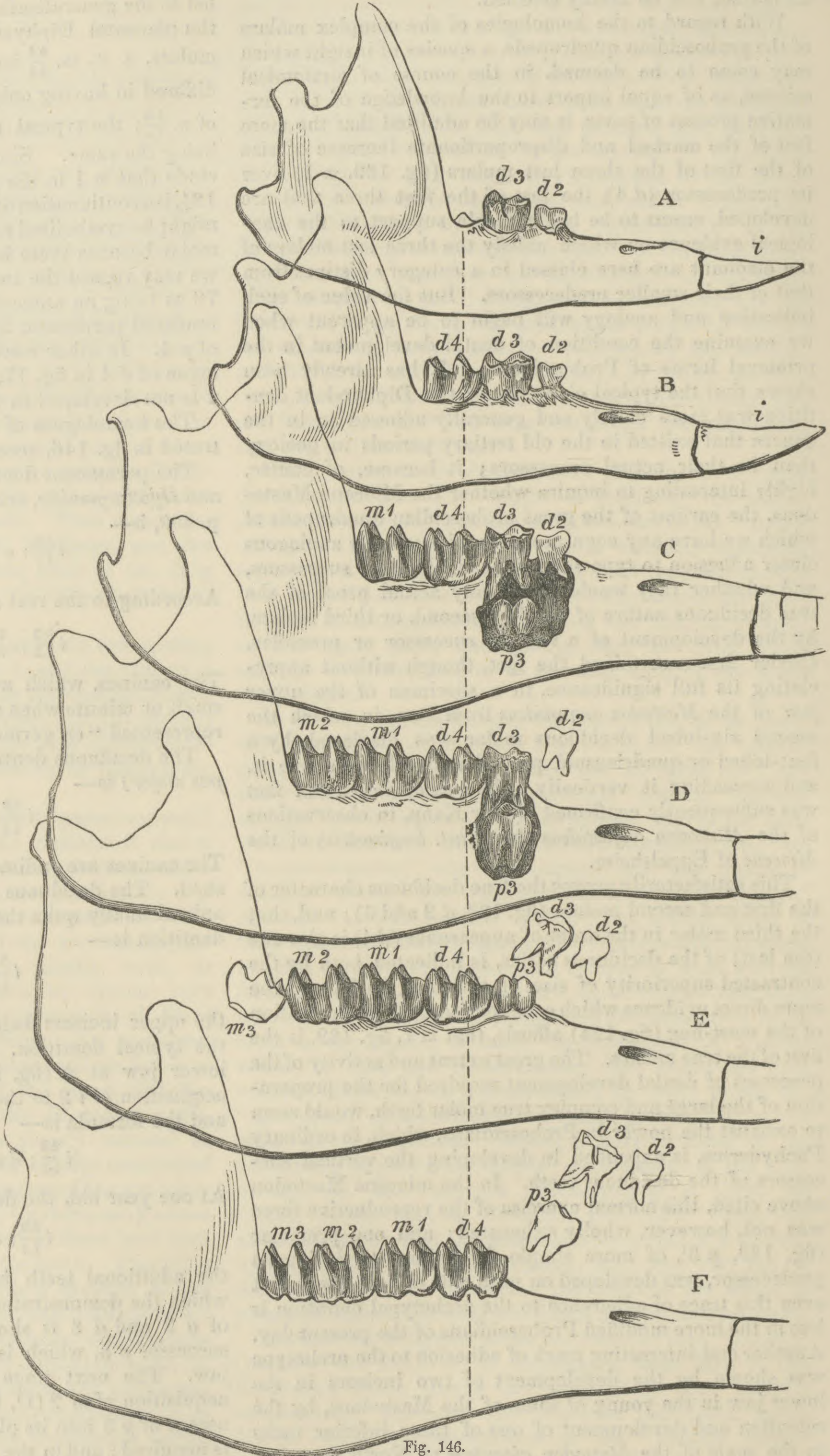

Fig. 146.
Development and Succession of the Molar Series, Kangaroo.