COMPARATIVE ODONTOLOGY

A. S. UNDERWOOD

STUDIES IN
COMPARATIVE ODONTOLOGY

STUDIES

IN

COMPARATIVE ODONTOLOGY

BY

ARTHUR S. UNDERWOOD, M.R.C.S., L.D.S.

PROFESSOR OF DENTAL SURGERY, KING'S COLLEGE, LONDON; MEMBER OF THE BOARD OF EXAMINERS IN DENTAL SURGERY, ROYAL COLLEGE OF SURGEONS OF ENGLAND; PRESIDENT OF THE ODONTOLOGICAL SOCIETY OF GREAT BRITAIN; ETC., ETC.

LONDON
BAILLIÈRE, TINDALL AND COX
8, HENRIETTA STREET, COVENT GARDEN
1903

PREFACE

THE immediate object of this book is to render the study of Comparative Odontology easier, and, I am tempted to hope, more attractive to the student. The study of the larger classical handbooks can never be dispensed with by anyone who really wishes to understand the subject, and I trust that a new way of putting things, and a new way of looking at them, may lead to a better appreciation of those standard works. I have endeavoured to intermix the unavoidable detail with broader considerations of great underlying principles, and have been at some pains to verify the facts from personal observation. The figures have been drawn for me by my wife direct from specimens at the various museums, where the kindness of the custodians has enabled her to have access to all that she needed in the way of specimens and invaluable hints. Some few of these drawings are from intentionally very diagrammatic drawings of my own, and the reader is requested to attribute any shortcomings to my sketches and any excellencies to the artist. Much has been left out, and much has been very lightly touched upon; in all cases my object has been to interest in the first place and instruct in the second, for it is my experience that once a student is interested in a subject its study is no longer a toil, but a delight, and the facts and details become as much part of his daily equipment as his hat and umbrella.

The little New Zealand lizard Tuatera is not a very entrancing object in itself, but its family history, stretching back to that dim twilight of existence before the mammalian race, renders it such a relic of forgotten times that human history seems hardly a week old as we look at it. The dragons of fable, the monsters of mythology, and the sea-serpents of the autumn press, are poor tame things beside those awful Dinosaurs and monstrous reptilians that the explorer is daily unearthing; and then comes the reflection that of all the storehouse of relics and wonders the earth contains, we know but a few pickings and scrapings here and there, and the stupendous mine of delight and wonder that remains to be explored overwhelms the imagination. It is a limitless field of research, and may it fall to the happy lot of readers of this little book to do something in it for themselves; for I firmly believe that, next to doing an unselfish kindness, the act of discovering something yields the greatest and keenest and most lasting joy of which the human being is capable.

I have not scrupled to make use of current handbooks, all that I could obtain—Flower and Lydekker, Tomes, Beddard, Gadow, the British Museum Catalogues, and others—and I wish to make this general acknowledgment to them all rather than continually to interrupt the text.

ARTHUR S. UNDERWOOD.

26, Wimpole Street,
London, W.
June, 1903.

CONTENTS

CHAPTER		PAGE
I.	GENERAL CONSIDERATIONS	1
II.	THE FORMS OF TEETH AND THEIR SUCCESSION	10
III.	ATTACHMENT OF TEETH	19
IV.	DIVISIONS OF THE SUB-KINGDOM VERTEBRATA	28
V.	FISHES	31
VI.	AMPHIBIA AND REPTILIA	48
VII.	AVES	64
VIII.	MAMMALIA	68
IX.	PROTOTHERIA AND METATHERIA	75
X.	EUTHERIA	81
XI.	UNGULATA	93
XII.	RODENTIA	107
XIII.	INSECTIVORA AND CHEIROPTERA	119
XIV.	PRIMATES	123
XV.	THE EFFECTS OF ENVIRONMENT UPON ANIMALS	133
XVI.	THE CHAIN OF LIFE	139
	INDEX	145

STUDIES IN COMPARATIVE ODONTOLOGY

CHAPTER I

GENERAL CONSIDERATIONS

THE world around us teems with life ; not only are we surrounded with innumerable living things that are big enough for us to see with our naked eyes—fishes, reptiles, birds, and mammals—but almost every object within our reach has only to be magnified a few diameters to disclose another *world* of life invisible to the naked eye. What this life exactly is, and where the line must be drawn that is to divide animal from vegetable life, are questions belonging to other departments of scientific inquiry than ours. It is sufficient for our purpose to know that what we mean by animal life is the life that feeds upon oxygen, carbohydrates, fat and albumin, and gives off as waste carbonic acid, water, and nitrates; while plant life feeds upon carbonic acid, water, and nitrates, and gives off oxygen, carbohydrates, fat, and albumin as waste. According to this simple definition, animal life exists in such an infinite variety of development that, at the first glance, it seems as though only one quality is constant in all its varied forms, and that is that each creature is provided with such peculiarities of shape and form as are most suited to its environment and habits. The second glance shows us that this suitability of the animal to its surroundings is not the result of chance, but of a great law of inheritance, whereby many of those creatures that are not so well fitted to their surroundings perish without giving birth to a new generation, and that particular kind of animal gradually ceases to exist, a process called *survival of the fittest;* also that we are observing a great process of evolution that is actually now in progress, only that the progress is so slow that human life—in fact, the period of existence of the human race—is hardly long enough to appreciate from actual experience the fact that there is any change at all.

The third glance shows us a more wonderful thing than either of the others—namely, that throughout all the marvellous variety of living forms there runs what I am tempted to call a family likeness, something of similarity that suggests a common ancestry for all animal forms, so that if we only possessed all the data it would be possible to make out a huge genealogical tree for all living creatures. We find two sorts of likeness—that which is called *homology*, and that which is called *analogy*. When we find a structure or organ which is morphólogically (in shape and structure) alike in two different creatures, however much disguised by special development, we call the likeness an *homology*, the organs *homologous*, and each the *homologue* of the other ; they need not do the same work, their functions may be widely different, as, for instance, in the case of the foreleg of a dog and the wing of a bird. If, on the other hand, we find different organs performing similar functions, the likeness is an *analogy*, the organs *analogous*, and each the *analogue* of the other, as in the case of the wings of birds and those of insects. Now, the paired fins of fishes are homologous to the limbs of man and quadrupeds, but their functions are very varied—the pectoral pair of fins are homologous of the forelegs of quadrupeds, and the pelvic pair of fins homologous to the hind legs of animals; but we find them subserving such diverse functions as swimming, flying (in Flying-fish), walking on the sea-bottom (in a teleosteous fish, *Malthe vespertilio*), and united in the Lumpsucker to form a suction valve to enable the animal to adhere firmly to rocks and stones. Now, just as the dissection of animals and the study of their component parts is called Anatomy, so the comparison of these homologies and analogies in different creatures is called Comparative Anatomy, and the study of life generally is called Zoology or Biology. In order to make the study easier, naturalists have divided up the subject into what they call classifications; but it cannot be too strongly impressed upon the student at the outset that these classifications are only conveniences at the best, that they are constantly being found insufficient and being remodelled and altered, each generation of investigators superseding the classifications and subdivisions of their predecessors, so that while the classifications are ephemeral and always subject to change and improvement, the laws of Nature which they attempt to describe are unalterable and do not change: it is only our knowledge of them that changes.

One great law which at present all naturalists accept is that of evolution, by which the most complex forms are formed by the constant development and improvement of the simplest.

'The classification now adopted by naturalists will,' to quote the words of Alleyne Nicholson, 'be better understood if we take an actual example and see how it is applied in practice. If we regard the domestic Dog, with all its subordinate varieties, as a single *species*, we have to notice, in the first place, that it is known technically by a *double* name, and is called the *Canis familiaris*. All species are thus known by "binomial" designations, the second name being like a man's Christian name, and being distinctive of the *individual*, whilst the *first* name is like a man's surname, and indicates the *group*—or, technically, "genus"—to which the individual belongs. The Dog, then, whilst individually recognised by the epithet *familiaris*, belongs to the genus *Canis*, in which are included other related species, such as the Wolf (*Canis lupus*) and the Jackal (*Canis aureus*). The genus *Canis*, again, belongs to the family *Canidæ*, including other genera, such as the Foxes (*Vulpes*). The family *Canidæ*, again, is one of a number of families, such as Lions, Tigers, and Cats (*Felidæ*), the Bears and Racoons (*Ursidæ*), the Hyenas (*Hyænidæ*), etc., which together constitute the order *Carnivora*, or beasts of prey. The Carnivora, again, constitute one of the many orders of quadrupeds which are distinguished by suckling their young and by other common characters, and which collectively constitute the " class " *Mammalia*. Finally, the class Mammalia is united with the classes of the birds, reptiles, amphibians, and fishes to constitute the great primary division of *Vertebrata*, or " vertebrate animals," since all these classes agree with one another in the fundamental character of possessing a backbone or " vertebral column," or an equivalent structure. Condensing the above, the zoological position of the dog, expressed in full, would be as follows :

Subkingdom, VERTEBRATA.
Class, *Mammalia*.
Order, *Carnivora*.
Family, *Canidæ*.
Genus, *Canis*.
Species, *Canis familiaris*.

'The species may have *varieties*, and if their peculiarities are permanent, and are handed down constantly by inheritance, then we get a race.'

These varied forms of living creatures are distributed over the face of the globe in such a manner that some are found in this tract of country and others in that: this is called their *geographical* distribution. Some are found in many lands, and may be described as widely distributed, but none, unless it be Man and the domestic Dog, are found everywhere. Some kinds of animals have a very restricted habitat, as, for instance, the Giraffe, which is only found in Africa; but it is to be noted that the more specialized an animal is, the more restricted is his area of distribution. This limitation of creatures to places is in a sense very easy to understand where the creature is terrestrial and the place an island, but the rule will be found to operate also in the case of birds, whose power of flight renders them indifferent to such barriers as a coast-line; it even operates in that most marvellous of all natural phenomena, the migration of birds. Here we have innumerable multitudes of creatures whose power of flight, enabling them, as it does, to regularly traverse a great portion of the world's surface over land and ocean to reach their breeding-place, renders them independent of all limits; yet so slavishly submissive are they to the laws that mark out their habitat that they always go from the same place to the same place, starting and arriving with practical punctuality and exactitude. As with the birds, so with the marine creatures, Whales, Seals, and Fishes; the whole watery world is open to them, but each kind is found in his proper place, wandering really but little. And this is true even of different *depths* in the great oceans, and is believed in this respect to be governed mainly by variations in *temperature* rather than variations of pressure; still, it is not invariably a question of temperature, as some birds certainly visit colder climates at times, and certain Indian monkeys periodically climb mountains into regions of comparatively low temperatures. It is also remarkable that places with very similar climates are inhabited by very different living creatures. Thus in tropical regions in Africa, South America, and Australia the climate is not very different, but we find Elephants, Apes, Leopards, and Guinea-fowls in the first represented by Tapirs, prehensile-tailed Monkeys, Jaguars, Curassows, and Toucans in the second, while in the third Kangaroos, Opossums, Thylacines, and Wombats flourish. Great mountain ranges sometimes form apparently insurmountable barriers—the Andes, the Rockies, and the Pyrenees all mark limits to the species. Apparently the animal world are very conservative in their habits : they do things because their forefathers did them for countless generations ; they also do them *at once*, without personal experience of the advantages of the act. The great things they do to live, their ways of moving, of feeding, and of breeding, are not learnt, they are born with them ; they can all learn, and often do learn, new ways, but the essential and necessary habits of life seem to be inherited. Man alone is the radical : he has to learn individually how to eat and how to walk—everything has to be proved and explained to him ; he goes where the fancy or the needs of the moment lead him, and his inherited instincts are constantly being remodelled to suit new surroundings. Not only are the creatures *geographically* distributed, but they are also *historically* distributed ; that is to say, that they not only have and have had their special places, but they also have and have had their special times, and the study of these times or periods is called *Palæontology*, which means the study of 'beings' in ancient or past times. The rocks and caverns of the earth's surface preserve many traces, such as teeth, skeletons, and fossils, and sometimes entire creatures preserved, flesh, hair, and all, in frozen mud, which show how in prehistoric times the fauna or living creatures were very different from what they now are. It is fairly easy within limits to decide, from the depth below the surface at which such remains are found, or the strata or geological surroundings in which they exist, to what period we may assign their existence as living races.* Thus in earliest times we find the invertebrata the dominant type ; later, in primary or palæozoic ages, the fishes abounded. In the secondary or mesozoic, first the reptiles, and then birds. Lastly, in kainozoic times (eocene, miocene, and pliocene systems, called

* See table of stratified rocks, p. 27.

'tertiary') birds and mammals, and in the comparatively recent kainozoic, pleistocene, or quaternary period the dominant type is man. It must not be forgotten that this evolutionary process which is going on, and has been going on always, is, to our reckoning of time, very slow. During the fifty to one hundred thousand years that have passed since the last glacial epoch very slight changes have taken place, and these affecting only the higher forms. Still, within the memory of man creatures have become extinct—the unwieldy Dodo among birds, the Rhytina (Sirenia) among aquatic creatures, have shared the fate of the Archæopteryx and the Mammoth.

In all this change and advance many forms have quite passed away; and as we noted that the animals which were most specialized had the narrowest *geographical limits*, so we observe that the most specialized creatures have also the briefest historical or palæontological career.

We shall also find that very similar specializations may arise from similar environment, like necessities of diet, and consequently kindred habits, without any immediate or even approximate common ancestry. Thus we find so peculiar a weapon as the persistent incisor of the old-world Rodent, part of which lies underneath all the premolar and molar series, reproduced in a Lemur (Chiromys) in the island of Madagascar and a marsupial (Wombat) in the continent of Australia. Mr. Bland Sutton, in his delightful book, 'Evolution in Disease,' notes that most variations are in a sense pathological, that the wart that eventually becomes the useful horn of a Rhinoceros was in its early beginnings only a wart, so it is possible that the canines of the Felidæ, the tusks of the Proboscidea and the Narwhal, and the rostrum of the Sawfish may have had their beginnings in pathological aberrations.

As we pass in our consideration of various dentitions from class to class and order to order, we shall find them marked off from each other by hard-and-fast lines, but we must always bear in mind that neither in the creatures nor in their organs do these strong lines of demarcation really exist. Typical forms will be found to fulfil definitions and to present great contrasts, but beside these typical forms will be innumerable gradations of form and function approaching and gliding into neighbouring types till classification reaches those borderlands where vagueness and apparent contradiction baffle the classifier, and the great and universal kinship of all living things becomes the one apparent fact.

One more word before we settle down to odontology, and that is a word of advice. If a student wishes to really understand the teeth of a creature, let him try to become familiar with the creature as a whole; let him see its stuffed skin, or the fossil remains of it, in the Natural History Museum in Cromwell Road, or observe it living, if possible, in the Zoological Gardens; let him read this book and Tomes' 'Anatomy,' with pictures of the actual creatures beside him, such as may be found in many excellent handbooks. This will not only make the task of memory much lighter, but it will make that a pleasure which would have been entirely a toil, and may even supply an endless resource of living interest for hours of leisure, and, indeed, for those after-years when the drudgery of life is done, and yet the trained mind craves for something worth doing to play at in its period of well-earned rest.

It will certainly save trouble in reading what is to follow if we spend a little time now in exactly understanding what is meant by the various long words that are in frequent use in odontology; they are not really so bad as they seem—in fact, it would be difficult to find simpler or more expressive terms when you once understand them. Most of them end in 'odont,' which means that they refer to the creature's dentition. Tooth-bearing creatures may be roughly divided into *homo-dont* and *hetero-dont*. *Homodont* is made up of a Greek word implying 'the same,' and means that the creature's teeth are all rather like each other, too much like each other to be divided into groups, as, for instance, in the Dolphin. *Heterodont* is formed from a Greek word signifying different, and is applied to creatures whose teeth differ so much from each other that they can be easily classed as incisors, canines, premolars, and molars, as, for instance, the Tiger or Man. Again, we find one set of creatures only possess one set of teeth during their lifetime, so we call them *monophyodont—mono*, single; *phy*, growth or eruption; and *odont*, *i.e.*, erupting a single set of teeth, as, for instance, the Dolphin. Other creatures produce two sets—a milk or deciduous set and a permanent set; these we call *diphyodont*, the prefix *di* indicating *two*—*i.e.*, erupting two sets of teeth, as Man, Tiger, etc. Others, again, produce an endless succession of teeth, many sets, and are called *polyphyodont*, the prefix *poly* meaning 'many,' as, for instance, the Shark, etc. We also find that homodont creatures are generally monophyodont or polyphyodont, and heterodont creatures are generally diphyodont, though there are plenty of exceptions; still, it is a rough general rule. Then there are a series of names which seek to convey the shape or appearance of the tooth—thus *mastos* means in Greek 'a nipple,' and mastodont means a creature whose teeth have cusps that in their rounded papilliform shape suggest nipples; *selenodont* is a term conveying the fact that when the tooth is worn down the islands of enamel enclose spaces more or less crescent-shaped or moonlike (*selene*, in Greek 'the moon'); when the cusps present blunt cones they are called *bunodont*, when the molars are short they are called *brachydont*, when longer *hypsodont*. Then, if attached to the *side* of the bony surface, they are called *pleurodont;* if right *on the top* of it *acrodont*. If a creature has many front teeth it is called *polyprotodont;* if it has only two it is *diprotodont*.

CHAPTER II

THE FORMS OF TEETH AND THEIR SUCCESSION

One of the first things that strikes the student of comparative odontology, when he begins to take an interest in teeth of various creatures and belonging to various periods, is the amazing variety of shape and tissue arrangement by which these organs are made to serve their proprietors in the many varied circumstances in which they live. In the molar of the Elephant and that of Capybara he finds a well-contrived grinding surface, always kept rough by a mazelike entanglement of tissues of varying hardness, whose different rate of wear keeps the flat surface from becoming smooth; in the incisors of rodents the same tissues, arranged with the hardest outside and the softest inside, maintain a constant chisel edge. The poison fang of the Viper, cunningly folded upon itself, provides a canal for its deadly secretion to travel to the wound it has inflicted. Some teeth are simple cones, some practical spears or lances, some equally practical millstones. Then, as the study grows, it is not so much the *difference* as the *likeness*, that is surprising; it is the same thing in many disguises—twisted and twirled, exaggerated in one place, aborted or insignificant in another, the family likeness is still plainly to be detected in all.

As we peep back along the ages of evolution we find that though at present we cannot be sure of the true order of inheritance by which the living creatures have arrived at their present form, still, we can form a fair idea that the general progress has been from a more or less general homodont and polyphyodont arrangement towards a heterodont and diphyodont or monophyodont condition. Now, though these changes have gone on together, we must consider them separately, and remember that, though the general change has been in a certain direction, it has been attended all along with constant digressions and excursions that have given rise to strange specializations, many of which have passed away, and many of which have gone on diversifying and have persisted. As the occasion is said to bring out the man, so the surrounding circumstances produce the animal: if the circumstances alter, the animal alters; if the circumstances cease, the animal becomes extinct.

It is also necessary to remember that, though the general evolution may have been upwards towards complication and specialization, there have also been frequent retrograde changes, degenerations of types, in which complicated forms have become simpler; and abortive, functionless, or retarded teeth afford traces of a falling away in the descendants from the better armed ancestral type. In fact, we are not by any means always sure whether to class some teeth as degenerations or as imperfect beginnings. All are agreed that the specializations we now see are the result of inheritance, but there is a doubt whether, as the Neo-Lamarkians hold, the progeny can inherit peculiarities acquired *during the life* of the parents, or whether what may be called pathological differences between members of one generation, giving some of them the advantage in the struggle for existence, decide the direction of evolution. Habits are certainly inherited, and habits must presumably be acquired—at first, perhaps, taught by the parent, but eventually inherited without teaching. It is also true that things that are pathological and detrimental in some animals are normal and useful in others.

Horns like that of Rhinoceros are found sometimes in cattle and sheep, and even domestic fowls. Another vexed question is whether the specialized molars of certain animals are the result of the specialized temporo-maxillary articulation or *vice versâ*. Some people have supposed that the forms of teeth were the result of a sort of pinching, squeezing, and moulding consequent on the movements of this joint; others, more reasonably, I think, conclude that the shape and consequent movements of the articulation is the *result* and not the *cause* of the molar and premolar specialization. The tooth structures are so unyielding, and their form is decided so early in life—moreover, the bones are so easily moulded, and wherever we have definite data we find them so plainly subservient to and dependent upon the teeth—that it is difficult to conceive the contrary as being the rule. The fact that the shape and development of the bones are very easily modified by the influence of the soft structures is well shown in the gigantic enlargements of the flat bones of the cranium in hydrocephalus, where, the undue amount of fluid increasing the distance between the advancing parietals, the bony formation continues till it meets the opposing side; or, to take an instance that is not pathological, the curves and ridges of the clavicle of a blacksmith as compared with the smooth and almost straight condition of the same bone in a delicate woman. Alterations in the shape and development of bones seem generally secondary to altered development and arrangement of other tissues.

Most naturalists agree that the many-cusped (multi-tuberculate) tooth of heterodont dentitions has arisen from the simple cone-shaped form. The attempts to explain how this has happened have given rise to some delightfully ingenious guessing which we call *hypotheses*. Thus, if we imagine a simple row of cones as representing an early parent dentition; then suppose, as we approach the back of the tooth-bearing bone, the cones to be a little crowded, and standing in double instead of single file; then in threes instead of twos; then imagine that the germs of these cones, being very close together, become fused into first double cones and then triple cones (the triple ones being arranged more or less in triangles), and their calcification to enclose the united pulps of the component parts or denticles, and we have a sketch of what may have been the process in producing a heterodont out of a homodont dentition.

The trituberculate theory of Cope and Osborn is derived from a study of certain of the earliest known mammals. In Dromatherium the teeth are a row of simple cones, in Amphilestes the back teeth are triconodont—*i.e.*, they have a high cone in the middle (*protocone*), a little cone in front (*paracone*), and a third little cone behind (*metacone*). In Spalacotherium these three cones, instead of being in a row, are squeezed into a triangle—in the upper jaw two outer and one inner, and in the lower jaw two inner and one outer. This arrangement is supposed by some to be due to a shortening of the jaw and consequent crowding of the denticles. The cones are in the lower jaw called *protoconid*, *paraconid*, and *metaconid* to distinguish them. Other smaller cones are presently added. Some authorities regard these mammals as a stage of degeneration from more complicated types. As a matter of fact, the evidence is really too slight and the gaps in the chain too huge to remove any of these views from the realm of conjecture.

The fusion of denticles, however it has come about, results after a little wear in the production of patterns on the surface, which are very constant in the different groups of creatures—the thin lines of enamel surrounding islands of dentine and surrounded by seas of cementum. It is well to study these patterns at the Natural History Museum, the Museum of the Royal College of Surgeons, and the excellent teaching museum at the Royal Dental Hospital, and observe how one has sprung from another by slight variations. To follow, for instance, the changes, so little in themselves, that have resulted in transforming the molars of primitive Proboscidea into later types until their present survivors the African and Indian elephants show two stages, the infinite complications of the latter reminding one of the molar of capybara, who has evolved through very different routes a somewhat similar organ, and yet at the same time recalling the still more elaborate tooth of Mammoth (*E. Primigenius*), who had in prehistoric ages anticipated this specialization. For another instance, to follow the transitions from the simple qradricuspid molar of the hog, through the unions and curvings of these same cusps, producing in turn the pattern of the Tapir, Rhinoceros, Palæotherium, and Horse. Thus, a simple pulp produces a simple tooth or denticle, which, when worn down, shows a ring of enamel enclosing dentine. Two such pulps side by side, and united or fused, look like the capital letter H, and present two rings on slight wear, but if worn down as far as the cross-bar present a dumb-bell-shaped island. Four of them, the two anterior and the two posterior, united rather high up, and the two outer ones lower down, present first four round islands, then two dumb-bells, then three sides of a square. These islands, curving, stretching, and embracing fresh tracts, result at last in a sort of capital letter B, with variations (see Figs. 7 and 8).

Then, as to the different modes of succession of teeth and the history of their evolution, we find the endless succession (polyphyodont), the two sets, milk and permanent (diphyodont), and the single set (monophyodont). It is generally supposed that all creation had polyphyodont ancestors, and that the diphyodonts have lost all but two sets, the monophyodonts one of those two ; but there agreement ceases and dispute begins. Some authorities, finding thickenings like the first stages of tooth-buds springing from the dental lamina both before the first dentition and after the second, regard these as abortive relics of a first and fourth set, a ‘ premilk ’ and a ‘ postpermanent ’ dentition in diphyodont animals

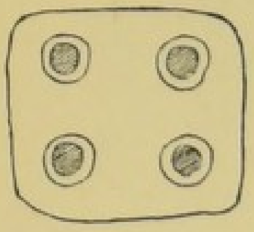


FIG. 1.

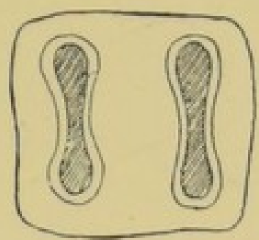


FIG. 2.

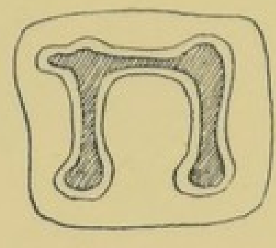


FIG. 3.

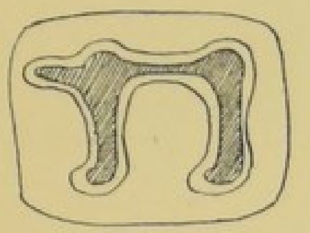


FIG. 4.

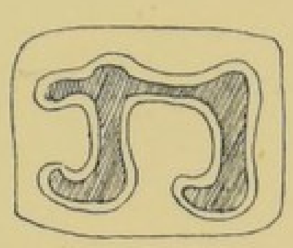


FIG. 5.

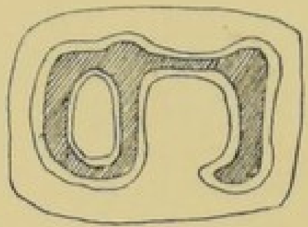


FIG. 6.

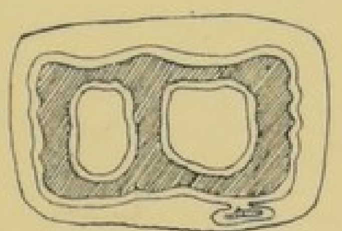


FIG. 7.

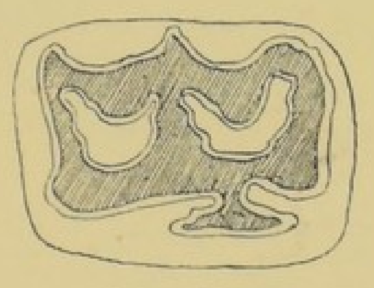


FIG. 8.

DIAGRAMMATIC REPRESENTATIONS OF THE EVOLUTION OF A MOLAR PATTERN FROM A SIMPLE TO A COMPLEX FORM.

Fig. 1.—Four denticles, showing islands of dentine surrounded by rings of enamel and embedded in cementum, as in hog. Quadricuspid pattern.

Fig. 2.—The two anterior cusps joined, and the two posterior likewise, forming a bilophodont pattern, as in tapir and dinotherium.

Fig. 3.—Outer cusps joined.

Fig. 4.—Forward production of the anterior external cusp.

Fig. 5.—The same exaggerated.

Fig. 6.—The anterior projections unite.

Fig. 7.—The posterior internal cusp joins anterior internal, and a small additional cusp appears.

Fig. 8.—Curving of the outer surfaces, showing something like the pattern of horse.

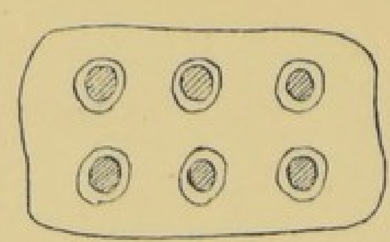


FIG. 9.

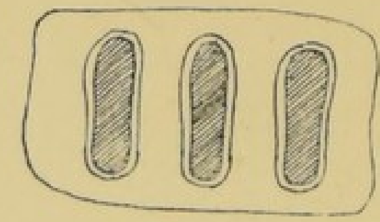


FIG. 10.

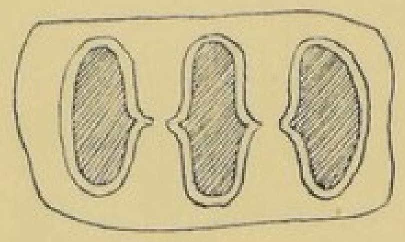


FIG. 11.

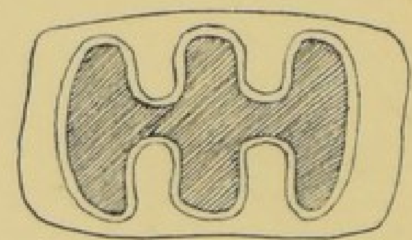


FIG. 12.

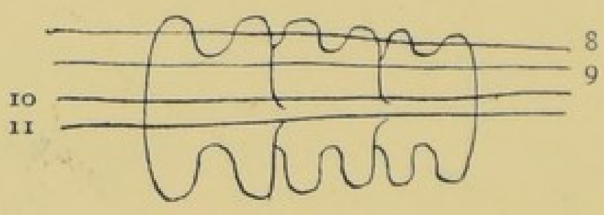


FIG. 13.

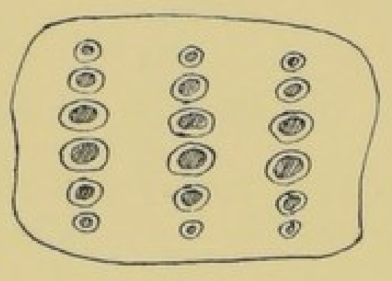


FIG. 14.

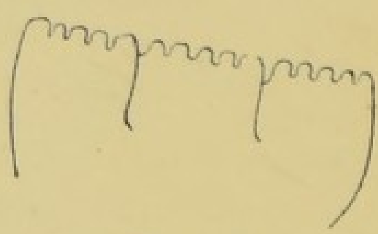


FIG. 15.

DIAGRAMMATIC REPRESENTATIONS OF PATTERNS PRODUCED BY DIFFERENT DEGREES OF WEAR.

Fig. 9 shows the cusps only worn as far as line 8 in Fig. 13.

Fig. 10 shows the pattern when worn down as far as line 9 in Fig 13.

Figs. 11 and 12 show the fusion of the separate denticles when the common pulp chamber is approached, the levels being indicated by lines 10 and 11 in Fig. 13. The patterns represent in a diagrammatic manner what may be seen in some of the simpler molars of the early ancestors of the elephant.

Figs. 14 and 15 show the scheme in the more complicated cuspings of the Indian elephant and his ancestor, *Elephas primigenius* (mammoth).

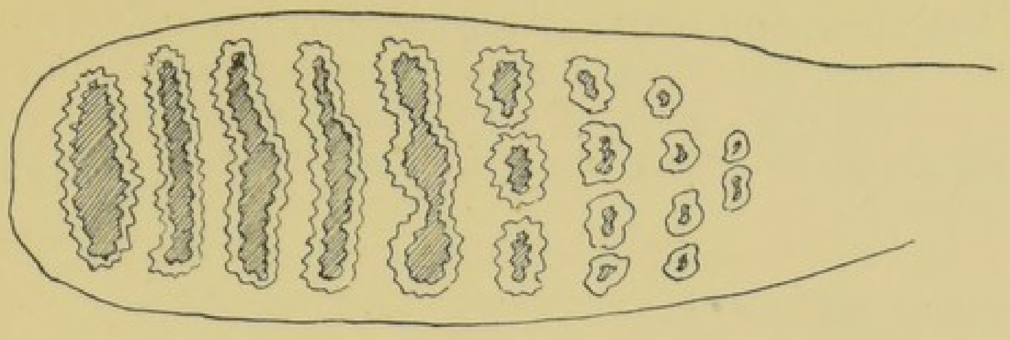


FIG. 16.

As the plates of the elephant's molar come gradually into use, the older plates are more worn than the younger ones, and we therefore see the stages in a single tooth, as shown in the diagrammatic representation of an Indian elephant's molar in Fig. 16.

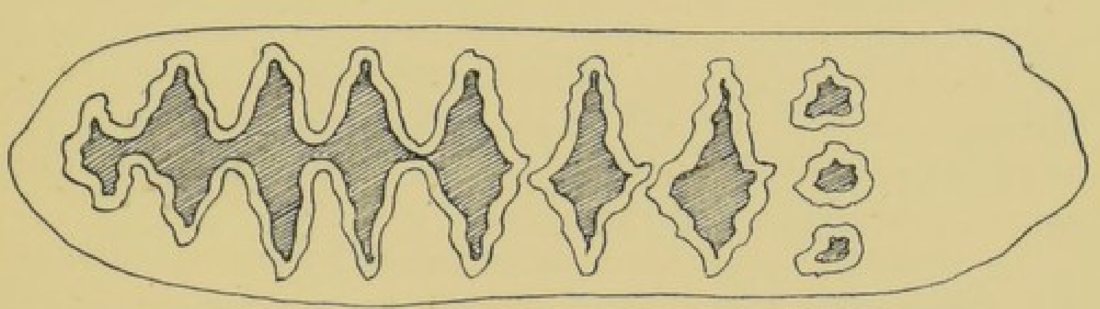


FIG. 17.

In African elephants the type is simpler, as shown in Fig. 17, but the stages of wear are still plain.

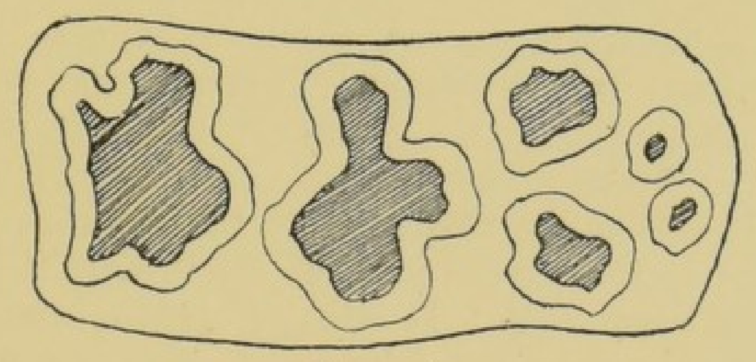


FIG. 18.

In mastodon the pattern is simpler still, as in Fig. 18.

In *Elephas primigenius* the type was still more complex than in Indian elephants, while in dinotherium the simplicity was much greater than even in mastodon, the molar being a simple bilophodont form like that of tapir, and the vertical succession causing the whole surface to wear at the same level at once.

(Tims, Rose, Kuckenthal, etc.); others refuse to acknowledge these thickenings as aborted tooth-buds unless they show some signs of calcification, which has never been shown in all four at once, though it has been shown in *three*.

Then the ten milk-teeth in Man are followed by permanent successors; but whether the three true molars belong to the milk set, or to the permanent set, or are the result of the fusion of milk and permanent germs, or are the result of the tail of the zahnleiste working off its superfluous energy, is as yet undecided. Tomes points out a fact that the other observers appear to have missed: that during infancy the milk-set could not extend farther back, because there was no jaw-space to extend into, the molar region being formed afterwards. Marsupials develop one set only, but whether a persistent milk-set or a permanent set is undecided, as is the nature of the one set in monophyodont mammals.

Because Man and some other animals possess a useful milk dentition, which serves them for purposes of mastication during a considerable period of immaturity, while others, as, for instance, the Bears, have a reduced number of milk-teeth, and retain them for a shorter period, and others, again, have only rudimentary milk-teeth that never are used at all, it would seem as if the one set, where there is only one, must be the permanent set. On the other hand, in marsupials only one tooth is replaced by a permanent successor, which looks as though it was the permanent set that had all but disappeared; in this class traces of calcified premilk-teeth have been discovered. It is by no means certain that the same rule has been followed in all cases of monophyodontism; possibly sometimes the milk series has persisted, sometimes the permanent. At present the subject is very nebulous and uncertain, and much of the theorizing is more remarkable for ingenious imaginings than anything else.

CHAPTER III

ATTACHMENT OF TEETH

It may be taken as a general fact that teeth never spring directly from the ordinary bone of the jaw. They often look at the first glance as though they did, but a careful examination always shows that there is something intervening. What it is that intervenes varies very much in different classes of animals, and perhaps more in the class of fishes than in any other—so much so that it might almost seem as though this question of *attachment* belonged especially to the description of that class, and most of the illustrative types will be found among the fishes. Between the true bone of the jaw and the teeth it supports there is almost always some special bony structure, which differs from the true bone of the jaw in this important respect—namely, that it is formed wholly and solely for the teeth; and when the latter are lost, it is always removed by absorption. Sometimes soft tissue of a ligamentous or periosteal character unites the tooth with its bone of attachment (Man, hinge teeth of fishes, etc.); sometimes the uniting tissue is itself *ossified*, or, more correctly speaking, *calcified* (anchylosed teeth of Fishes, Python, etc.); sometimes this intervening bone, which Tomes has aptly named *bone of attachment*, differs more or less in actual structure from the normal bone, and rather resembles osteodentine (Pike, Haddock, Mackerel); sometimes it is structurally like other bone (socketed teeth of mammalia); but it always exists only for the support of, and appears and disappears with, the teeth.

There are four sufficiently different forms of attachment to form a convenient classification :

Attachment by means of a fibrous membrane.
Attachment by an elastic hinge.
Attachment by anchylosis.
Attachment by implantation in a socket.

Attachment by a Fibrous Membrane.—This form of attachment is common in certain fishes, notably the Sharks and Rays (plagiostomi). In these fish the homology between the teeth and the dermal spines or placoid scales is well shown. Just as the skin covering the outside of the creature is continuous with the mucous membrane lining its alimentary canal, so are the epithelial growths upon the surface of the one continuous with and similar to those of the other. Both arise from epithelial invasions of the subepithelial tissue, which becomes more or less hardened by calcification. It has been shown that the mucous membrane moves slowly over the surface of the jaw-bone from the region below the tongue where the teeth are formed towards the crest or ridge of the jaw where they are used. They are bound down to the rotating mucous membrane by fibrous bands, and, as they pass the ridge where they are functional, drop off, to be succeeded by others.

Attachment by an Elastic Hinge.—Many fishes have hinge teeth, and more are being constantly discovered ; in fact, it would appear that wherever a family was provided with multitudinous, sharp, recurved cones anchylosed to the mandible, a good many members of the family carried this useful peculiarity one stage further by some adaptation of the bone of attachment calculated to permit an actual yielding backwards and inwards of the whole tooth, and abruptly arresting the return movement as soon as the upright position had been attained. But generally the hinged teeth are only few in comparison with the anchylosed teeth, which are the majority. The form of the hinge itself is modified according to the structure of the tooth, but it always permits the tooth to bend inwards towards the throat, and then, as it recovers its upright position, its outward movement is arrested at a certain point. The movement of the hinge simply intensifies the effect of the shape of the tooth itself. Such teeth are always slightly recurved cones, with sharp points and broader base. The fact that the points bend slightly backwards makes the mouth of the creature easy to enter, but impossible to retreat from. Every movement of the prey takes it further along towards the gullet of its captor ; in fact, the prey might struggle itself down its enemy's throat without the latter doing anything, and if some of the longer teeth yield somewhat inwards, this result is rendered all the more certain and rapid. Among the non-poisonous snakes the advantage of this shaped tooth to its possessor is well illustrated ; the long row of recurved points above and below once fixed in the prey, the jaws slide over it, every movement carrying the wriggling mouthful inwards, and all retrogression being instantly stopped by the backward curve. The hinge joint is an improvement on the fixed curve, and is arrived at by a slight modification of the last stages of the development of the teeth.

Thus, in the *Angler* (*Lophius piscatorius*) many of the teeth calcify throughout, and are finally anchylosed to a rough bone of attachment. But some large teeth near the front do not become so attached ; the front portion is completed into a sort of thickened buttress, which rests on, but is not joined to, the bone of attachment, while the back part is united to the bone by a thick elastic ligamentous tissue, so elastic that when the tooth is forced backwards it yields, and the front part is lifted off its pedestal, but when the pressure is removed it instantly resumes its upright position.

In the *Hake* the arrangement of the hinge is very perfect. It is like that of the Angler, only, lest the vessels going to its very vascular pulp (its tooth is composed of vasodentine) should be injured in the extreme movements of the tooth, they enter the pulp through a hole in the elastic ligament at the back, and are therefore not stretched when the tooth bends backwards. As in the Angler, the outer row are smaller and anchylosed, the inner large and hinged.

The *Pike* has the most ingenious contrivance of all. The shape of the tooth and the fact that the front surface is free from the bone of attachment and the back attached by a membrane it shares with the Angler and Hake; but the membranous attachment at the back is *not elastic*. The central portion of the pulp consists of osteodentine, which in the anchylosed teeth (the majority) calcifies to the bone of attachment, but in the hinge teeth the calcification is arrested halfway down the pulp chamber, and the uncalcified remnant of the pulp remains as thin elastic strands of tissue joining the calcified interior of the tooth with the bone on which it rests, and it is these elastic strands that pull the teeth back suddenly to an upright position.

Tomes describes two deep-sea fishes—*Bathysaurus ferox*, which has hinge teeth without special bony pedestals, and *Odontostomus hyalinus*, which has an arrangement very like the Angler. Anyone desirous of thoroughly exploring this very interesting subject should read his papers in the *Quarterly Journal of Microscopical Science* and the *Transactions* of the Odontological Society, on which almost all our knowledge of the matter is founded.

Attachment by Anchylosis.—In this form of attachment the teeth are firmly fixed by calcified substance to the *bone of attachment*. When, as often happens, the interior of the tooth is converted into osteodentine, it is difficult to say exactly where one tissue ends and the other begins. This anchylosis is the commonest form of attachment in fishes, and is also common among snakes. The structure of this bone of attachment, the existence and anatomy of which was first pointed out by Tomes, is not unlike very rough osteodentine ; its lacunal spaces are very large and irregular, and its substance is generally arranged in rough layers. If the reader wishes to observe it for himself, he need only grind down a portion of the jawbone and teeth of a Haddock or a Mackerel, and examine it unstained with a low power. Of its development little is known. Some observers have considered it to be analogous to cementum ; its entire dependence on the tooth (being removed when the tooth is removed) recalls somewhat the behaviour of alveolus. It may be also noted that though in anchylosed teeth there is no membranous tissue analogous to dental periosteum between the tooth and the bone proper, still, in the same mouth precisely similar teeth do possess something of the kind, as, for instance, the hinge teeth of the Pike, Angler, etc., and here the membranous tissue intervenes *between the tooth and the bone of attachment*. Moreover, in certain fish—as, for instance, the Haddock—the tooth does not sit fair and square on the top of the bone of attachment, but, tapering somewhat, fits partly inside it, and in the mackerel it approaches a socketed arrangement, the bone of attachment assuming more and more of an alveolar relation to the tooth.

The shape of the bones of attachment vary much in different creatures. In the *Frog* the inner part of the tooth has a little pillar of bone, the outer a special thickening on its outer side. The *Eel* has a little bone, shaped like a thick cup, on the rim of which the tube-shaped tooth rests. The *Cod* has a bone very like the Eel, only, instead of a flat surface resting on a flat surface, the tooth descends a little inside the bone. In the Mackerel there is a general groove in which the bases of the teeth are sunk, but between the teeth and the sides of the groove is specialized bone. In all cases the bones of attachment disappear when the teeth are lost.

Attachment by Implantation in Sockets.—This form of fixation is found in most mammals, the sockets being subservient to the teeth, as the bones of attachment are in anchylosed teeth. In some reptiles (Crocodiles) the teeth come up one after the other, and occupy sockets which already exist, which are not removed, and reformed with the development of each tooth. This fact, among others, has led Tomes to express a doubt whether such sockets are strictly analogous to the mammalian socket. Socketed teeth occur in some fish, such as the rostrum of Pristis, the Sawfish, and others ; but such sockets can hardly be described as analogous to the mammalian form. In fact, until more is known of their development, it is sufficient to note their existence as remarkable freaks of nature.

FIG. 19.

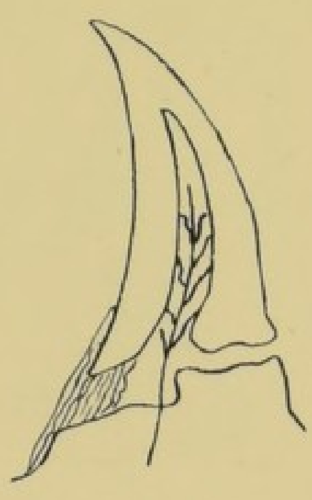


FIG. 20.

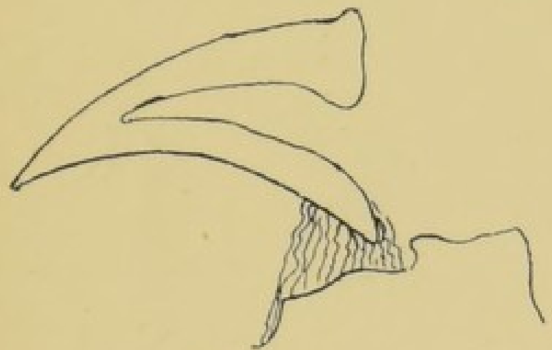


FIG. 21.

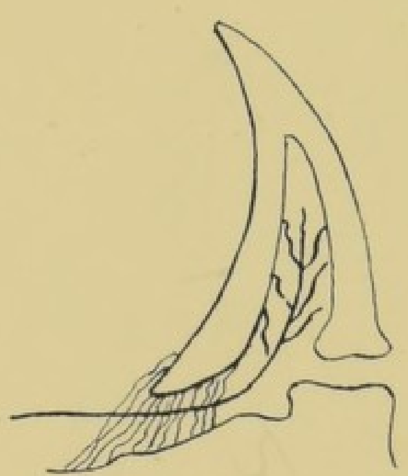


FIG. 22.

DIAGRAMS TO SHOW THE VARIOUS TYPES OF ATTACHMENT OF TEETH.

Simple recurved cone shown in Fig. 19 anchylosed to bone of attachment, as in the anchylosed teeth of hake.

Fig. 20 shows a hinge tooth, as in angler. The posterior part is attached by an elastic hinge. In front the thickened portion of the tooth is shown over the buttress of bone on which it rests, but to which it is not attached. The vessels are indicated entering from below.

Fig. 21 shows a similar tooth forced backwards. When the pressure is removed, the elasticity of the hinge will cause it to spring back to the position shown in Fig. 20.

Fig. 22 shows a hinge tooth similar to the last, only the vessels enter the pulp through the elastic hinge, as in the hinge tooth of the hake.

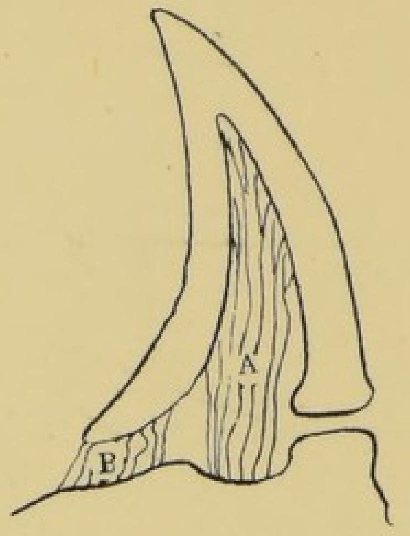


FIG. 23.

FIG. 24.

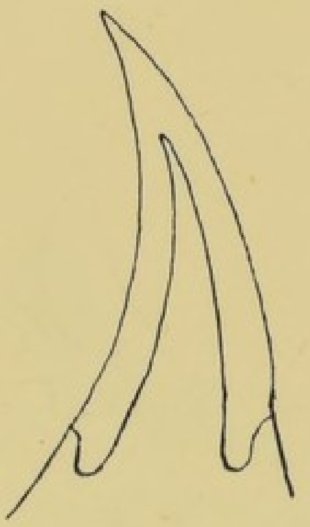


FIG. 25.

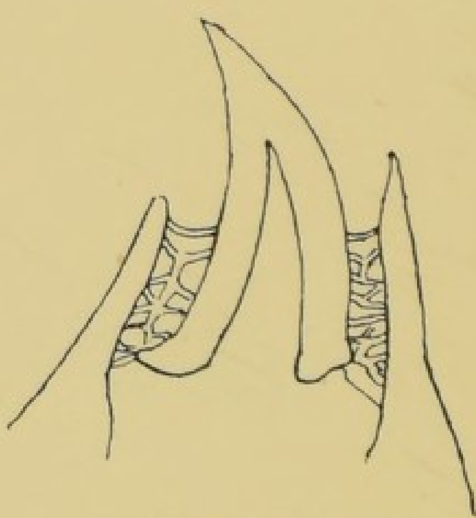


FIG. 26.

Fig. 23 shows the arrangement that obtains in the pike. The elasticity resides in the elastic fibres in the pulp (marked A), while those of the hinge (marked B) are non-elastic.

Fig. 24 shows anchylosis to a cup-shaped bone of attachment, as in the eel.

Fig. 25 shows an approach to a socket attachment, as in haddock. It will be seen that the buttress of the bone of attachment is so shaped that the tooth dips into it, and is not resting flatly upon it, as in Fig. 24.

Fig. 26 shows a still further approach to a socket, as in mackerel. Here the tooth is implanted in a groove, and attached by irregular bone to the inner sides of the groove.

TABLE OF STRATIFIED ROCKS,

SLIGHTLY ABRIDGED FROM THE CATALOGUE OF THE BRITISH MUSEUM.

Periods.		Systems.	Formations.	Life-Periods (Dominant type)
Cainozoic.	Quaternary.	Recent.	Terrestrial, Alluvial, Estuarine, and Marine Beds of Historic, Iron, Bronze, and Neolithic Ages.	Dominant type, Man.
		Pleistocene (250 feet).	Peat, Alluvium, Loess. Valley Gravels, Brick Earths. Cave-deposits. Raised Beaches. Palæolithic Age. Boulder Clay and Gravels.	
	Tertiary.	Pliocene (100 feet).	Norfolk Forest-bed Series. Norwich and Red Crags. Corolline Crag (Diestian).	Dominant type, Birds and Mammals.
		Miocene (125 feet).	Œningen Beds, Freshwater, etc.	
		Eocene (2,600 feet).	Fluvio-marine Series (Oligocene). Bagshot Beds } (Nummulitic Beds). London Tertiaries } (Nummulitic Beds).	
Secondary or Mesozoic.		Cretaceous (7,000 feet).	Maestricht Beds. Chalk. Upper Greensand. Gault.	
		Neocomian.	Lower Greensand. Wealden.	Dominant type, Reptilia.
		Jurassic (3,000 feet).	Purbeck Beds. Portland Beds. Kimmeridge Clay (Solenhofen Beds). Corallian Beds. Oxford Clay. Great Oolite Series. Inferior Oolite Series. Lias.	
		Triassic (3,000 feet).	Rhætic Beds. Keuper. Muschelkalk. Bunter.	Dominant type, Fishes.
Primary or Palæozoic.		Permian or Dyas (500 to 3,000 feet).	Red Sandstone, Marl, etc. Red Sandstone and Conglomerate.	
		Carboniferous (12,000 feet).	Coal Measures and Millstone Grit. Carboniferous Limestone Series.	
		Devonian and Old Red Sandstone (5,000 to 10,000 feet).	Upper Old Red Sandstone. Devonian. Lower Old Red Sandstone.	
		Silurian (3,000 to 5,000 feet).	Ludlow, Wenlock, Llandovery, and May Hill Series.	Dominant type, Invertebrata.
		Ordovician (5,000 to 8,000 feet).	Bala, Caradoc, and Llandeilo Series. Llanvirn, Arenig, and Skiddaw Series.	
		Cambrian (20,000 to 30,000 feet).	Tremadoc Slates. Lingula Flags. Menevian Series. Harlech and Longmynd Series.	
		Eozoic-Archæan (30,000 feet).	Pebidian, Arvonian, and Dimetian. Huronian and Laurentian.	

Range of Invertebrata and Plants in time
Range of Fishes in time
Range of Amphibia and Reptilia in Time
Footprints of Birds?—Range of Birds in Time
Range of Mammalia in time

CHAPTER I

DIVISIONS OF THE SUBKINGDOM VERTEBRATA

The animal world is divided for convenience of description into seven subkingdoms, of which six, which are classed together as *Invertebrata*, do not possess teeth, and do not therefore require any notice here. The seventh subkingdom is that of the *Vertebrata*, or animals possessed of a vertebral column ; and as it is in this subkingdom that teeth exist, it is with it alone that we have to do.

The vertebrata are divided into five great classes, beginning with the lowest and going upwards—Fishes, Amphibians, Reptiles, Birds, and Mammals. Representatives of all these classes exist now, and many forms have passed away and become extinct. The fact that teeth are very imperishable, and retain their form and structure for an indefinite time, notwithstanding geological changes that have destroyed most of the other traces of the animal world of bygone times, coupled with the fact that the lower orders of animals often erupt and shed countless numbers of teeth, has resulted in odontology being the most serviceable key in the possession of modern science for opening the door to the history of animal life in remote ages—sometimes, indeed, the only means we have of unravelling the many problems of palæontology.

The vertebrata did not make their appearance all at once, but followed each other in the great scheme of evolution through lapses of time that are so vast that it is difficult for the mind to grasp them even in imagination. The annexed table, which is abridged from the catalogues of the British Museum Natural History Department may give some idea of the present opinion of naturalists concerning the possible length of these periods and the order of the evolution of animal life therein; and it is important to remember how large a part odontology has played in working out these data.

It will be seen from the table that the plants and invertebrata have lasted from quite the beginning of the Primary or Palæozoic period (*paleos*, ancient, and *zoon*, life). About midway in this first epoch, which saw the awakening of life, vegetable and animal, begin the Fishes, lowest of the vertebrates. At the close of the Primary epoch Reptiles make their appearance, and much later, in the Secondary period, some doubtful traces of Birds, followed by later traces, of which there can be no doubt, towards the last third of the Secondary period, while the Mammalia appear at the beginning of the Secondary epoch. During the end of the Secondary and through the Tertiary epoch the dominant types are Birds and Mammals, while man appears as the dominant type in the Quaternary period. Marsh considers that all Mammals older than Tertiary times were probably insectivorous.

The Mammalia themselves are classified in three divisions: The *Prototheria*, the lowest type, including Echidna and Ornithorynchus, of which no extinct forms are known, and which seem to be a link between the higher reptiles and the mammalia. The *Metatheria*, the marsupials of which there are very early remains, and which some have supposed to be the type from which mammalia generally have descended; at any rate, they represent a low grade, and were once very widely distributed but are now confined to Australia and parts of America. Their young are not nourished by means of a placenta, but by means of a marsupium or pouch. Lastly, the *Eutheria*, comprising the placental Mammals.

The essential peculiarities of the vertebrata are :

1. *They possess a vertebral column* or spine, consisting of a chain or row of bony rings (sometimes cartilaginous through life), which are, so to speak, threaded upon the spinal cord or principal part of the nervous system, and protect it from injury. In proportion as the animal is higher in the scale of intelligence, so is the upper portion of its spinal cord developed and specialized (brain), and the upper rings of the bony case enlarged to cover it (skull). Thus the spinal cord is shut off from the alimentary canal and heart.

2. *They possess an internal skeleton*, to which muscles are attached.

3. *They never possess more than two pairs of limbs*, which are jointed to the body, and are turned away from that side of the body where the main masses of the nervous system are placed.

4. *They reproduce their kind by means of sexes*, which, with rare exceptions (certain fishes), are in different individuals. Mostly they produce eggs, from which the young are hatched (oviparous). Some retain the eggs within the body till the young are ready to be hatched (ovoviviparous). Some—and these the higher kinds—bring forth their young alive (viviparous).

CHAPTER V

FISHES

FISHES are the lowest class of the vertebrata; they are cold-blooded, possess gills, and when they possess limbs they are modified into the form of fins.

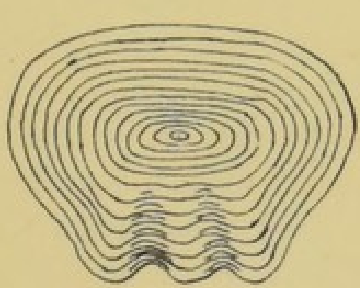


FIG. 27.—CYCLOID SCALE.

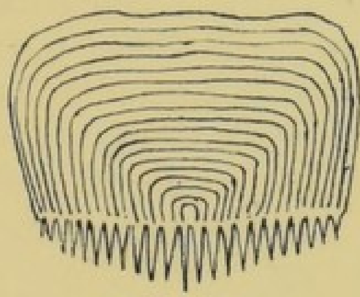


FIG. 28.—CTENOID SCALE.

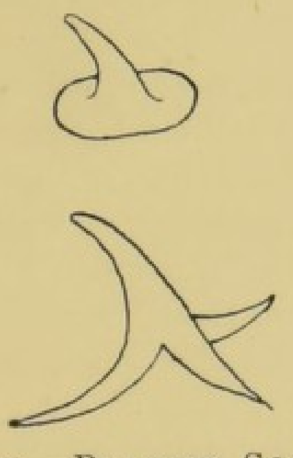


FIG. 29.—PLACOID SCALES.

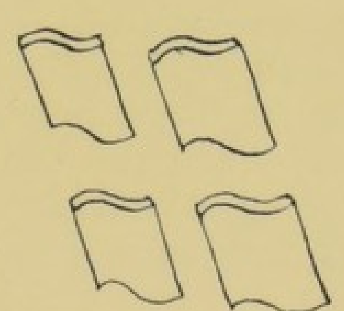


FIG. 30.—GANOID SCALES.

To assist and protect the fish in its rapid passage through the water, its body is generally covered with scales, of which there are four principal kinds. (See British Museum, Nat. Hist. Coll., Side Case in Hall.)

1. *Cycloid Scales.*—Thin, horny, flexible scales, with smooth, rounded outline (most common fishes).

2. *Ctenoid Scales.*—Thin, horny, flexible scales, with the back end fringed with projecting spines (perch, etc.).

3. *Placoid Scales.*—Bony grains, tubercles, or plates, often with projecting spines (Sharks, Skates, etc.).

4. *Ganoid Scales.*—Consisting of two layers—a deep bony layer and an outer layer—of polished enamel (Pipe fish, and American bony Pike and some extinct fishes).

In some fishes the internal skeleton is never converted into bone, or only partially so, but remains cartilaginous (Lampreys, Skates, Sturgeons, etc.).

The limbs of fishes may be absent, or there may be only one pair, or there may be two pairs, but never more. The limbs (except in Lepidosiren) are converted into fins —*i.e.*, expansions of skin stretched over the bones or cartilages, forming paddles : the pair which are homologous to the fore-limbs of animals and the arms of man are called *pectoral fins ;* the hind-limbs are called *ventral fins.* These limb-fins are called the *paired fins,* and spring from the internal skeleton ; the median fins are not paired, and are supported by bones not connected with the skeleton.

Most fish are oviparous, but some are ovoviviparous. The earliest evidence of a fish, probably plagiostomous, occurs in the upper silurian (see table, p. 27). From the Devonian to the cretaceous beds ganoids were abundant, many of which resembled modern Teleostei. In the Tertiary epoch teleostei almost entirely replaced the ganoids, and became and remain the predominant type of fishes.

Fishes may be divided into three subclasses:

1. *Teleostei,* with an ossified skeleton, comprising most existing kinds of fish.

2. *Palæicthyes,* skeleton, wholly or partly cartilaginous

comprising the Ganoid fishes and the Sharks and Rays (Plagiostomi).

3. *Cyclostomata* have no jaws, but a circular lip, comprising the Myxines and Lampreys.

Lastly, there is the Lancelet, which differs so much from both fishes and the general vertebrate type that it can scarcely be classed with any other creature.

The Teeth of Fishes.—Some fishes are quite edentulous (the Sturgeon, the Pipe-fish, and the little Sea-horse); very few comminute their food (Wolf-fish, some Rays, as Myliobates, Ætobates, etc.). Most fishes are homodont, and produce a countless succession of teeth. Their teeth are generally anchylosed to bones of attachment, but in a few cases are implanted in sockets (Sphyræna, Sargus, Lepidosteus, Pristis, File-fish), and sometimes, instead of separate sockets for each tooth, the whole row are implanted in a groove. In many of the fish whose general mode of attachment is by anchylosis a few teeth are attached by elastic hinges. Cementum is rare in fishes; tubed hard dentine, vasodentine (Hake, Cod, Flounder), and osteodentine (Pike) are common, and plicidentine not uncommon (Lepidosteus, Pristis, Myliobates, etc.); enamel is common. Sometimes tubed dentine, vasodentine, and even osteodentine are found in the same tooth, in which case the tubed dentine is formed first on the tip and outside, then the vasodentine, and lastly osteodentine, uniting the tooth to its bone of attachment.

TELEOSTEI

General Characteristics.—These fishes have an ossified internal skeleton with completely separate vertebræ. The skeleton more resembles dentine than true bone.

Number of Teeth.—Generally countless.

Form of Teeth.—Generally cones, more or less recurved.

Situation of Teeth.—Generally on most of the bones at the beginning of the alimentary canal, including the palatine bones right and left, and the vomer between them, the intermaxillaries, the branchial, lingual, median bones, the upper and lower pharyngeal bones, the lower jaw, etc. (Look at the skull of Pike in museum.)

Attachment of Teeth.—Generally by anchylosis, with or without a row of hinge-jointed teeth.

Structure of Teeth.—Generally hard dentine, often vaso- and osteodentine, with enamel tips.

Development of Teeth.—Each tooth is generally developed *de novo*, and not from a common lamina.

Uses of Teeth.—Generally for prehension, and not mastication.

A few strikingly peculiar forms of osseous fish will be now briefly discussed.

Chætodonts possess teeth as fine and nearly as flexible as hairs ; they consist of vasodentine, where there is room for canals, and have tiny, structureless enamel hooks at the tip. When teeth are very fine and close, they are called ciliiform ; when thicker, villiform. Their relative thickness and closeness has also been likened to the hairs of velvet, the bristles of a brush, and the teeth of a comb, called respectively 'dents en velours,' 'dents en brosse,' and 'dents en cardes.' The *Angler* (*Lophius piscatorius*), the *Hake* (*Merlucius*), and the *Pike* have specially interesting hinge teeth (see p. 19 *et seq.*), as have *Bathysaurus* and *Odontostomus*.

The Wolf-fish (*Anarrhicas lupus*) approaches very nearly to a heterodont dentition. Its back teeth, palatine and vomerine above and mandibular below, being rounded and lumpy, and adapted for crushing shell-fish, while four or five front teeth above and below, situated on the premaxillaries, are pointed, and used for tearing their prey (shell-fish and limpets) from their hiding-places on the rocks.

The Gymnodonts, or naked-toothed fishes (*gymnos*, naked), have a sort of beak above and below, not covered by lip, and formed of bone, with a row of teeth fused together, and fused to the bone at the edges. Behind this sharp edge, above and below, and somewhat separated from it, is a roundish, flat, rough mass, looking like one tooth above and one below. The teeth forming the

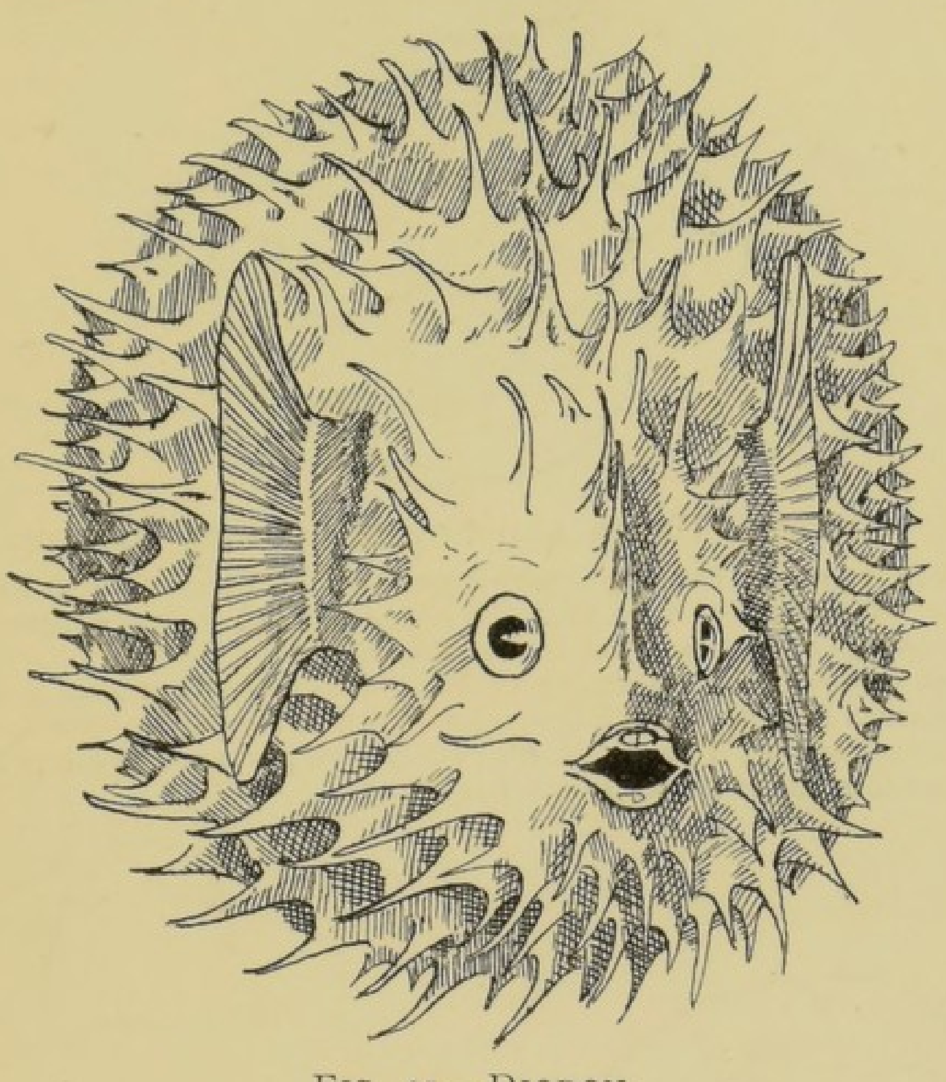


FIG. 31.—DIODON.

Fig. 31 represents a gymnodont fish (Diodon) when inflated When not inflated, the pointed scales lie much flatter, and the fish is less balloon-shaped and more fish-like. The figure is about one-fourth its natural size, but they vary greatly in this respect. The mouth is quite small, and is shown in the next figure enlarged.

beak and the denticles of the rounded mass behind them are embedded and joined together by a bone of attachment. I have endeavoured to illustrate the arrangement by a diagram. Both the marginal teeth and the blocks are formed of plates of dentine outside, with osteodentine behind, and the different hardness of the tissues results in the single marginal rows being kept

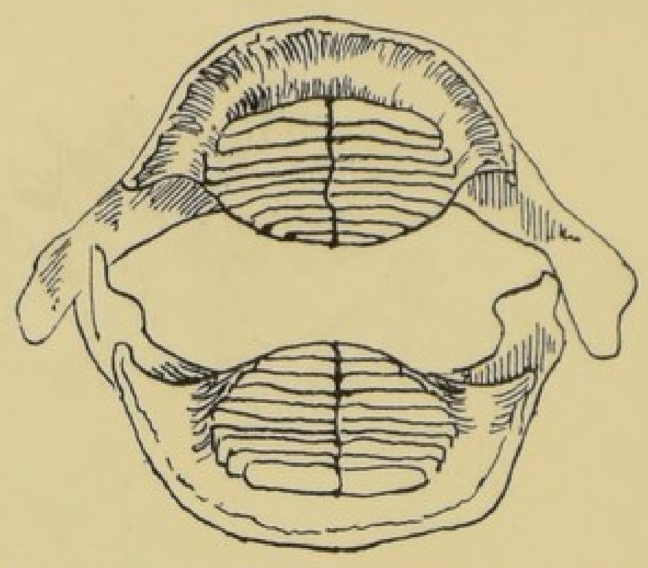


FIG. 32.—UPPER AND LOWER JAWS OF DIODON.

Fig. 32 shows the upper and lower jaws of Diodon about natural size. It will be noticed that the edges of both jaws are raised to a sharp elevation, and that inside this there is a kind of gutter, and then an oval mass consisting of flat plates; also that all the dental armature is situated on a special and distinct dentary bone or bone of attachment. The manner in which the parts are developed and come into use is shown in the next figure.

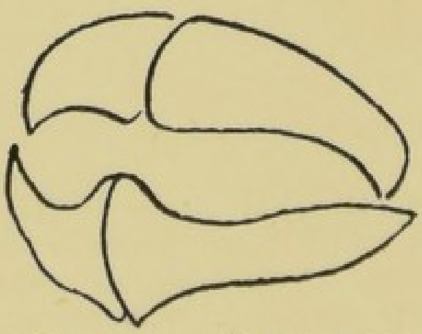


FIG. 33.—BEAKS OF TETRADON.

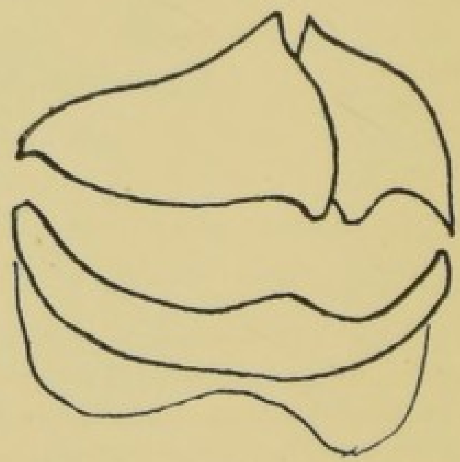


FIG. 34.—BEAKS OF TRIODON.

Figs. 33 and 34 show the divisions of the back portion of the jaw, which have earned for the first the name of Tetradon, or four-toothed, and for the second the name of Triodon, or three-toothed. In Fig. 34 the lower margin of the jaw is indicated by a line, which would, perhaps, cause confusion if unexplained.

sharp, and the blocks, which are composed of many such plates, being kept rough.

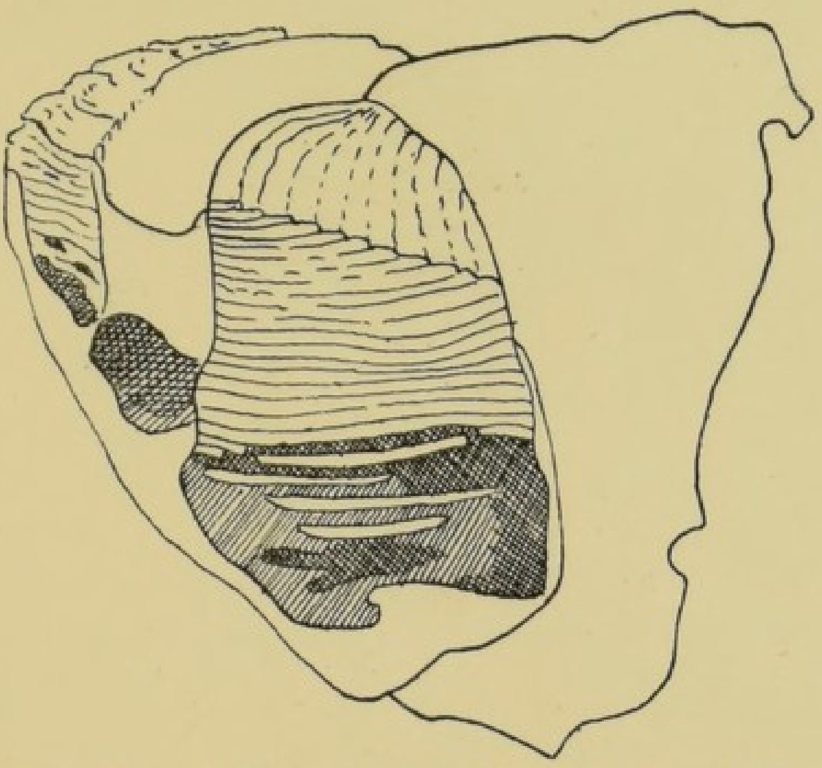


FIG. 35.—LOWER JAW OF DIODON DIVIDED.

Fig. 35 shows on a still more enlarged scale, for clearness' sake, the same tooth, divided about the situation of the median furrow. The edge denticles and the plates of the rounded mass are seen forming deep down in the mass, and pressing upwards, and wearing down as they reach the surface. This figure is necessarily somewhat diagrammatic.

The Parrot-fishes (Scarus, Pseudoscarus) are rather like the Gymnodonts, only instead of fused plates they have rows of more distinct teeth, shaped like human centrals, which as they wear down leave a surface in which rings of enamel, islands of dentine and cementum and jawbone all unite by a different rate of wear to procure a constantly rough surface. The marginal teeth are a series of superimposed cones of enamel-coated dentine, each one sticking into the base of its predecessor. They are surrounded by a substance called by some cementum, but which Tomes regards as bone of attachment. It will certainly be more and more the tendency to regard these calcified masses on which teeth rest as bones of attachment irrespective of their microscopical structure altogether.

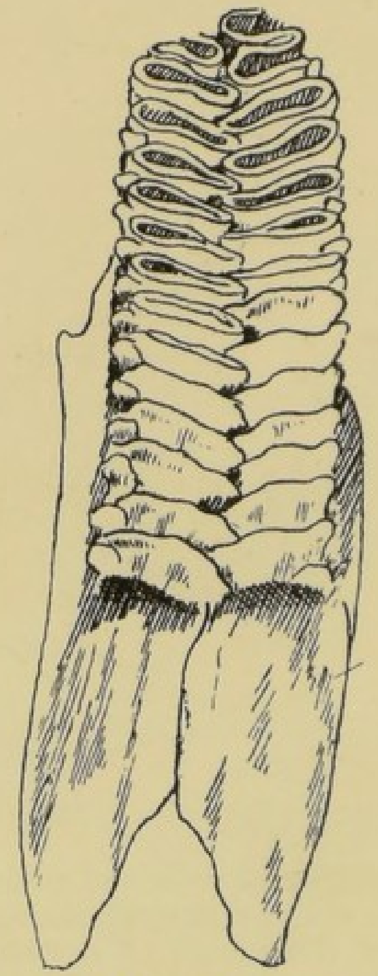


FIG. 36.—UPPER PHARYNGEAL BONE OF SCARUS.

Fig. 36 shows the upper pharyngeal bone of Scarus, the Parrot-fish. The denticles will be seen to be worn away in front, showing dentine in the midst of a rim of enamel. It will also be noticed that there are additional denticles on the outer side of the main rows. These sometimes attain a large size, and in one specimen at the British Museum are as large as the middle row. It will be noticed that the denticles interdigitate. The whole row is convex, the convexity being towards the reader.

The Sheep's-head-fish (Sargus) has curious 'human-shaped' incisors (the enamel of which is perforated by tubes opening on the outside) in front, and round crushing teeth behind. The incisor-like teeth are implanted in sockets.

Chrysophris aurata, a sparoid fish, has a very striking heterodont arrangement : a few large caniniform front teeth on the premaxillary and premandibular bones are anchylosed to the jaws, while above these, in cavities of reserve, are the successional teeth ; behind on either

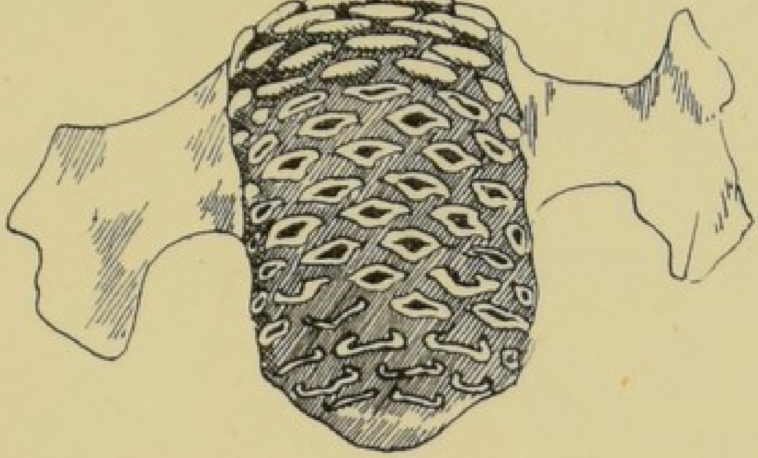


FIG. 37.—LOWER PHARYNGEAL BONE OF SCARUS.

Fig. 37 shows the lower pharyngeal bone of the same fish. It will be noticed that the teeth become worn down towards the front (the lower part in the figure), at first showing dentine in the centre, and afterwards imperfect rings of enamel, with bone of attachment in the centre. The whole mass is slightly concave from before backwards as well as from side to side, the concavity being towards the reader. This concavity corresponds to the convexity of the upper bone.

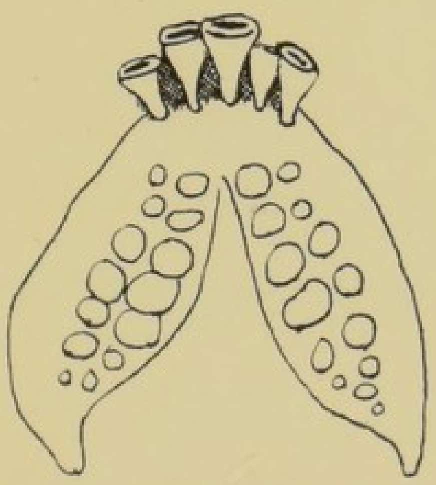


FIG. 38.—MANDIBLE OF SARGUS.

side, in what may be called the molar and premolar region, are a double row of rounded, dome-shaped teeth, which are reinforced from the inner side.

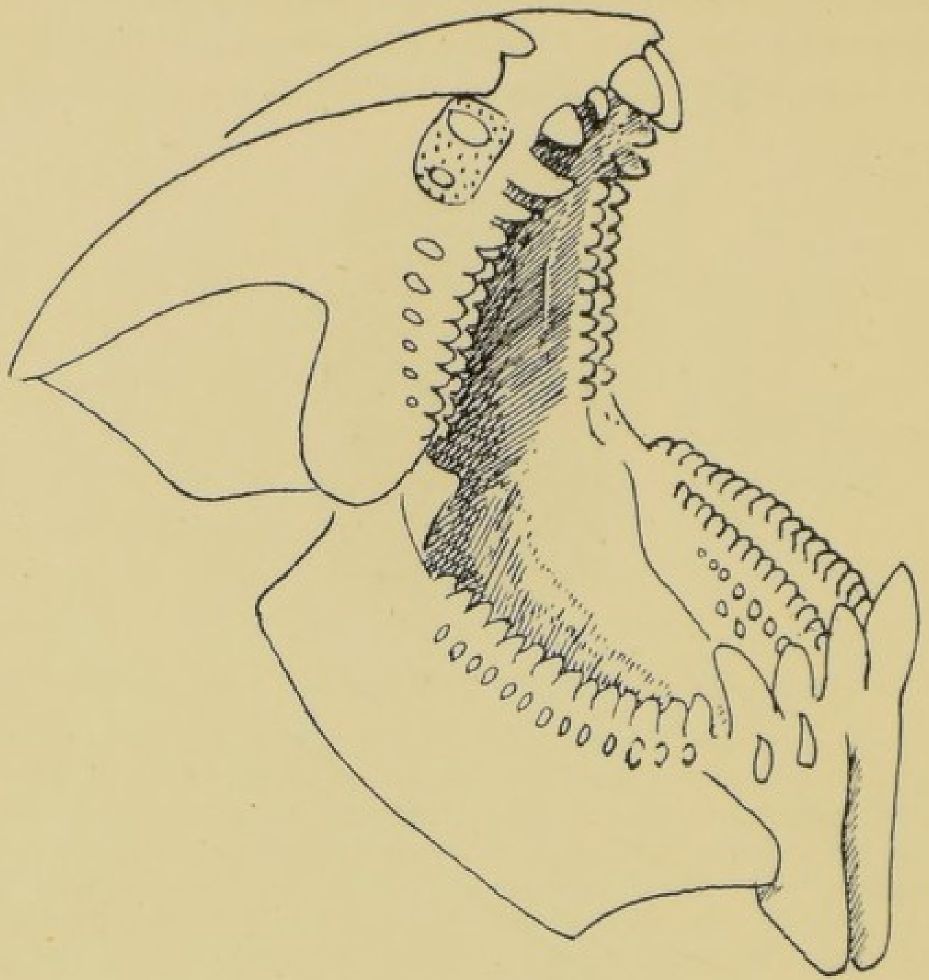


FIG. 39.—CHRYSOPHRIS AURATA.

PALÆICHTHYES

Palæichthyes, comprising the Sharks and Rays and Ganoid fishes.

General Characteristics.—They generally have a cartilaginous skeleton, which is sometimes partly ossified. To this order belong the majority of the fossil-fish remains of the Palæozoic and Mesozoic ages, while it is scantily represented among living fishes, and is evidently in the way of becoming extinct.

Number of Teeth.—Generally countless.

Form of Teeth.—Very various, often exactly resembling the placoid scales which protect the outer integument.

Situation of Teeth.—The jaws are generally covered with rows upon rows in various stages of development.

Attachment of Teeth.—Almost always fibrous, never anchylosed.

Structure of Teeth.—Hard dentine, osteodentine, and enamel.

Development of Teeth.—From a composite enamel organ the successive rows are formed deep down on the inner surface of the lower jaw, and are at first covered and protected by a long fold of mucous membrane, called the *thecal* fold. They are first formed lying with their points backwards, and as they move upwards and outwards, carried by the mucous membrane in which they are embedded, and to which they are firmly bound by fibrous bands, they assume an upright position, sometimes gradually, each row being more and more upright, as in Lamna; sometimes the rows remain incumbent until the movement of the mucous membrane has shifted them to the summit of the ridge, when they assume an upright position, as in the tropical white shark. The area where the young germs are formed is called the *area of tooth development.* This movement of the mucous membrane carrying with it the teeth was demonstrated by an accident which happened to a young shark. Its lower jaw was penetrated by the spine of a sting-ray, and, the spine remaining after some time, the teeth in front of the spot of the injury were found to be stunted and ill-developed in the track of a scar extending forwards and upwards, showing that they had once occupied the spot of the wound, and had moved onwards, mucous membrane, teeth, and all.

Uses of Teeth.—For prehension only, not mastication.

Arrangement of Teeth.—Generally in crescentic rows.

Peculiar Forms.—*Cestracion Philippi* is the only survivor of a type of Shark that was once very widely distributed. The front teeth are closely packed and very small, and are first formed with sharp points, which get worn down. About a third of the way backwards along the jaw there are much larger, flatter teeth, about three in each row, the furthest back being the biggest, and behind these again are a few smaller plates. These teeth consist of a sort of osteodentine, covered with a layer

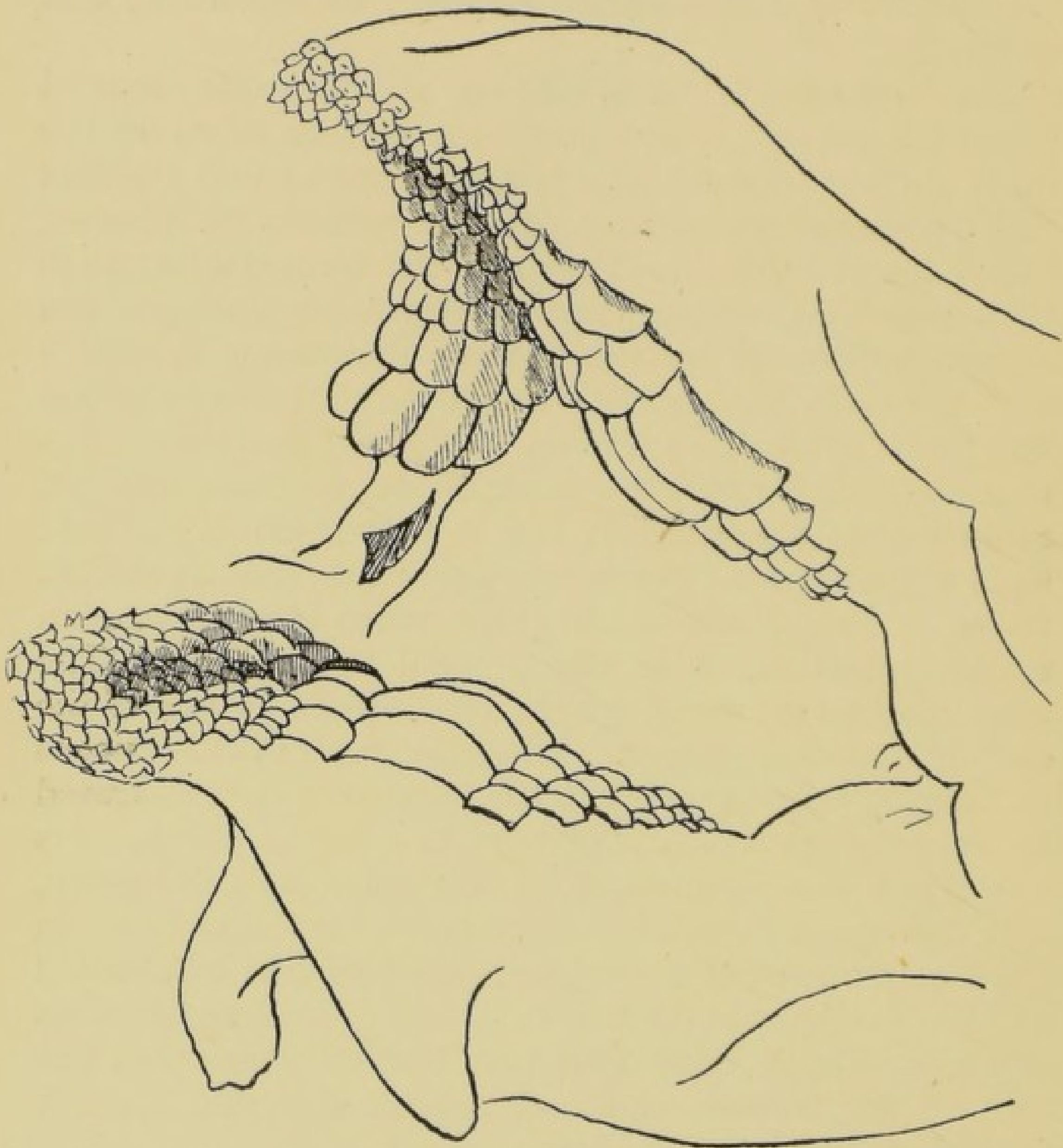


FIG. 40.—UPPER AND LOWER JAWS OF CESTRACION PHILIPPI.

consisting of bundles of fine tubes, which Tomes regards as curiously modified enamel.

Pristis, the Sawfish, is a Ray whose mouth is armed with unimportant blunt teeth, but whose snout is enormously and curiously developed. It is like a huge paper-knife with rows of teeth along the edges ; it may be any size, sometimes 6 feet long and 1 foot broad. It uses this snout to tear flesh off other fish or to rip open the abdomen of its victim, and feed upon the protruding soft parts and intestines. The teeth that are ranged along the edges of this rostrum, and which are homologically dermal spines, are in many ways peculiar. They are implanted in sockets, a very rare thing among fishes. They consist of plicidentine of a very special kind, almost exactly like that of myliobates, another ray, parallel denticles, in the centre of each of which is a prolongation of the pulp run from the centre to the circumference, and each denticle consists of a system of dentinal tubes which radiate from the central pulp. The denticles themselves are roughly hexagonal, viewed in transverse section. Lastly, these rostral teeth are not shed as fishes' teeth and spines usually are, but grow from persistent pulps.

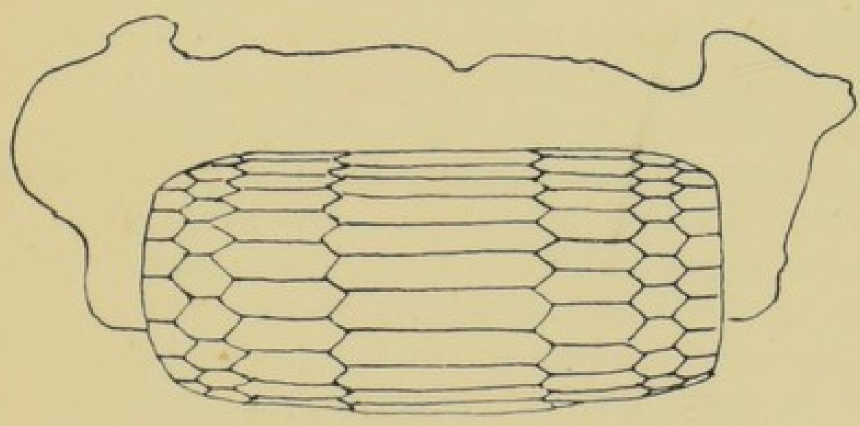


FIG. 41.—DENTAL PLATES OF ZYGOBATES.

Myliobates, Ætobates, and Zygobates, like other rays, have blunter teeth than the Sharks. They consist of flat plates looking rather like a tessellated pavement ; they are bigger in the middle and smaller at the sides. In Myliobates there is a single row of elongated hexagonal plates in the middle line, each plate, placed transversely to the mouth, being about six times as long as it is broad ; six or seven of these are in use at a time. On either side is a row of three equilateral hexagonal plates. The upper teeth are like the lower; they consist of plici-dentine almost exactly like that of Pristis. In Ætobates there are no side plates, but only the long central plates.

Among the ganoid fish the *Sturgeon* is edentulous, but possesses teeth in the larval stage.

Cyclostomata

Cyclostomata comprise the Lampreys (*Petromyzon*) and the Hag-fish (*Myxine*) and Bdellostoma.

General Characteristics.—In the larval stage the mouth is edentulous, and surrounded by an imperfect lip. The Lampreys feed on other fishes, sucking and boring their way in, and scraping off the flesh with their teeth. During the process they voyage as sort of uninvited guests with their host. Their skeleton is cartilaginous, without real jaws; the limbs are absent and the body eel-like.

Number and Arrangement of Teeth.—Round the suctorial mouth are rows of small conical teeth, two opposing teeth being somewhat larger than the rest.

Form, Attachment, Structure, and Development.—The teeth are conical, resting on little depressions in the epidermis. In one form of Lamprey (*Petromyzon marinus*) there is a series of these horny cones, one above the other; each one arises from its own little epidermal depression, and the horny substance is continually being formed at the base, and reinforces that which is worn away at the apex. In the young Lamprey the tooth sacs never contain odontoblasts, and the enamel organ forms horn.

In Bdellostoma, underneath the horny layer, is a layer of epithelium, and beneath this, again, a calcified layer, possibly dentine, formed by an odontoblast layer. This dentine contains both tubes and vascular canals. Whether this is a degeneration, and hints at ancestors that possessed jaws and calcified teeth, or whether it is the beginning of such an arrangement, is not certain, but the horny plates are *above* the teeth and not *below* them, as in Ornithorynchus. Another point of interest is that these horny plates may give a hint of the manner of the origin of the horny plates in chelonian reptiles.

While we are studying this lowest class of the sub-kingdom Vertebrata at any of our natural history museums, we cannot help being struck by the fact that, though fishes in general are armed with an endless succession of innumerable sharp, cone-shaped teeth, all fairly alike and therefore homodont, there are, notwithstanding, a great many wonderful exceptions in shape, number, and arrangement. Thus, Sargus (Fig. 38), with his five or six human-looking socketed incisors in front and his double row of mushroom-shaped back teeth, looks quite heterodont. Pagdius, whose molar region is armed like that of Sargus, and whose pre-maxillary and premandibular region carries a few caniniform tusks, and Wolf-fish, with his caniniform front teeth and his flattened molars, are neither of them homodont. Another sparoid fish, *Chrysophris aurata* (Fig. 39), has quite a striking differentiation into incisors and molars, and although the teeth in use are anchylosed to bone of attachment, the successional teeth are contained in cavities of reserve, which are beautifully shown in a specimen at the Royal College of Surgeons by removal of the outer plate of bone which covers them. Then the flat tessellated pavement which serves for crushing teeth in the Rays (Myliobates, etc.), and the similar broadening of the tooth mass in what may be called the molar region in *Cestracion Philippi*, with rounded instead of flat denticles, passing to pointed, shark-like teeth in front, show how a little modification of shape may be of immense service to its possessor. The Parrot fishes and the Gymnodonts illustrate convenient arrangement of tissues for producing rough grinding surfaces quite as complicated as those of the Ungulata.

Sometimes, as in the case of *Sphyræna barracuda*, the teeth differ markedly in size, but not in shape, in different parts of the mouth, a few very large front teeth, and behind these a row of small ones above and a row of larger ones below, increasing in size towards the back of the mouth.

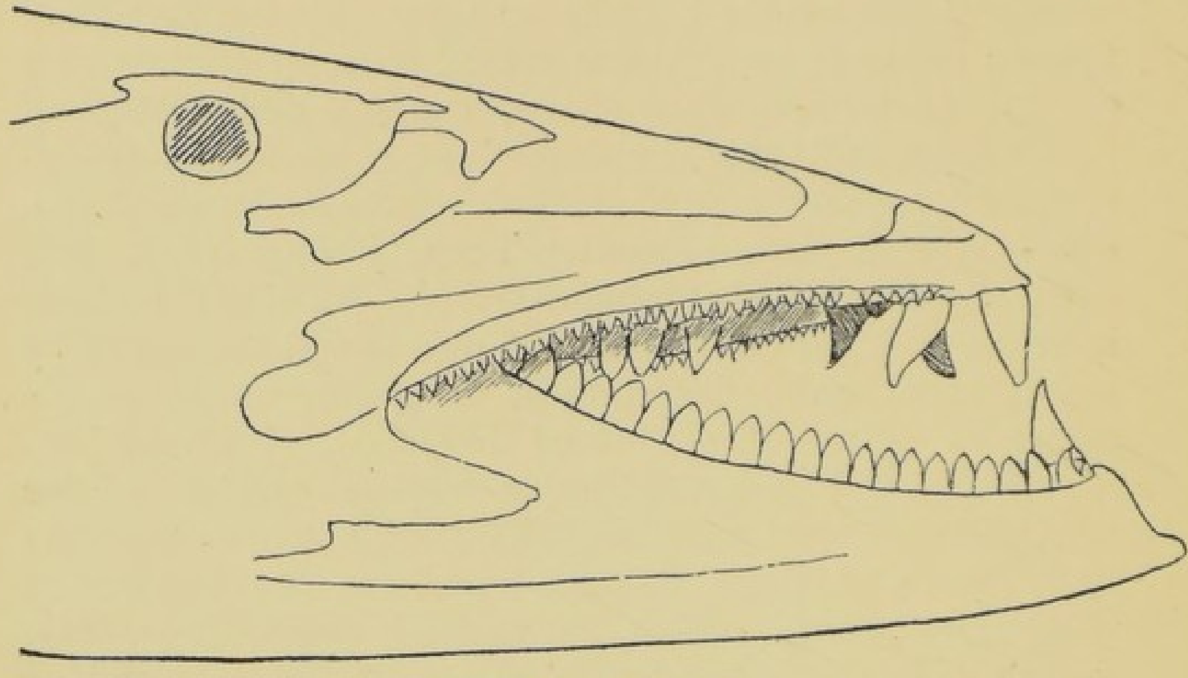


FIG. 42.—BARRACUDA PIKE (SPHYRÆNA BARRACUDA).

The File-fish has a few banana-shaped, socketed incisors squeezed together in front.

Amongst the recent additions at the British Museum is a fish called Chauliodon, whose dentition recalls the amazing and puzzling armature of *Sus babirusa*. This fish has lower front teeth, which rise far above his upper jaw and curve backwards at the tip.

The student will find many more interesting illustrations for himself as he wanders about the various collections, the point to bear in mind being that, although the peculiarities of a special fish do not matter much in themselves, the fact that they illustrate in a thousand different ways the adaptability of structure to environment, the absolute necessity to adapt or to become extinct on the part of every creature, is of supreme importance. The great rules that seem so universal and so unchanging that we call them laws become most wonderful and interesting when for some special advantage Nature lightheartedly disregards them, and shows by some marvellous exception her inexhaustible resourcefulness.

CHAPTER VI

AMPHIBIA AND REPTILIA

Amphibia

THE class we have just considered, the fishes, lived in the water, and breathed by means of gills or branchiæ. The class we shall presently consider, the reptiles, though in many respects but little raised in the animal scale, will be found to breathe by means of lungs. Between the two there exists a class that, though nearer in most respects to the reptiles than to the fishes, yet possesses some points of relationship to the latter class. The Amphibians start life as gill-breathing creatures, and during their life they undergo a change or *metamorphosis*, and are converted into lung-breathing creatures. The class comprises the Frogs and Toads (Batrachians), the Newts, Salamanders and Cœcilians, and some extinct forms. Most of them, as in the case of the Frog, begin as water-breathing larvæ (Tadpoles), with long fishlike tails and external gills, and later develop true lungs and become air-breathing. Generally, when the lungs are developed the gills disappear, but in some cases the gills are retained through life notwithstanding the development of lungs. In the Newts the long tail of the Tadpole stage is retained through life. In the Frogs and Toads the tail is lost when the mode of breathing changes. The heart is divided into three chambers, and the opening of the nose and mouth communicate at the back.

Number of Teeth.—Much fewer present at one time than in the fishes, but there is generally an endless succession.

Situation of Teeth.—On the maxillary, palatine, and vomerine bones; rarely on the parasphenoid.

Form of Teeth.—Mostly simple cones.

Attachment of Teeth.—Usually by anchylosis.

Structure of Teeth.—Enamel tips and hard dentine (plicidentine in an extinct form, *Labyrinthodon*).

Development of Teeth.—From a common lamina.

The Toads are edentulous; the Frogs have teeth in the upper jaw only, which, when the mouth is shut, pass down outside the lower jaw altogether. These teeth are anchylosed by a bone of attachment in the form of a tiny pillar. The succession of teeth is vertical, the new teeth being formed above the old ones, and working their way by absorption right into the middle of their predecessors. The Newt and Salamander have bifurcated enamel tips to their teeth; the Tadpoles possess horny plates instead of teeth. In an extinct form, Labyrinthodon, the plicidentine was of a very complicated pattern, resembling in its twistings and convolutions a garden 'maze.' The teeth of the Frog are coated with a layer of enamel, which is so thin that doubts of its existence have been entertained. The Newts and Salamanders have minute enamel tips, which are bifurcated. The Tadpole is armed with horny plates, like the Chelonians, as well as some very small spines on the inner side of the jaws, formed each by a single epithelial cell; all this horny apparatus is successional, and disappears when the true teeth are about to be formed.

Reptiles

General Characters.—The true Reptiles are a very interesting class from many points of view. The variations of their dentition and osteology to serve special purposes are very remarkable both in living and extinct forms; also, this class presents many illustrations of past history in the form of links between one type of dental

4

armature and another. At the same time, their variations are so strange that it is very difficult to class them in any order of gradual advance. Geological history records, as we see on p. 27, first the dominancy of simpler types, and then of more complex : plants and invertebrates ; then fishes, then amphibia, then reptiles, and lastly mammalia. So far, an order of advance ; but the serpents, in some respects a low type, appear very late, long after mammals and birds, and not long before man. They also show a curious retrogression in having lost their limbs. Reptiles are lung-breathing, and never at any time are possessed of gills or branchiæ. Their heart is mostly three-chambered, but sometimes four-chambered ; but the arterial and venous blood are still mixed, owing to the imperfect nature of the divisions, and the temperature of the creatures is therefore low (cold-blooded), scarcely raised above, and varying with, that of the surrounding atmosphere. They abound in warm climates, become rare in temperate, and disappear altogether in cold climates.

Their dentition is very varied ; not unfrequently horny plates are found doing the work of teeth, while the underlying bone is more or less shaped up to a resemblance to tooth shapes. These horny plates represent the epithelial or epiblastic part of the dental formation, the enamel organ product imperfectly calcified. The specialized underlying bone is homologous with the mesoblastic or dentinal portion. A little more perfect calcification of the former, and a little specialization in the calcification of the latter, would convert the formation into a tooth.

All reptiles are oviparous or ovoviviparous.

The true teeth in this class are mostly arranged in the form of a double row in the upper jaw, separated by a slight interval, into which a single row of lower or mandibular teeth bite. The outer of the two upper rows is situated on the maxillary bone, the inner on the palatine bone. Sometimes the teeth are anchylosed to the summit of the ridge of the jaw (acrodont); sometimes they are attached to the side of a groove, like trees on a mountain side (pleurodont); sometimes, especially in extinct forms, the back part of the jaws, are armed with true teeth, and the front protected by horny plates, a condition which is found in some extinct reptilian birds discovered by Marsh in Wyoming. Reptiles usually have an endless succession of teeth, but some extinct forms possessed only one set, such as the Theriodontia and Rhyncocephalia, of which latter class one living representative exists still (Hatteria or Sphenodon).

The living reptiles are divided into four classes :

Chelonia : Tortoises and Turtles.
Ophidia : Serpents.
Lacertilia : Lizards.
Rhyncocephalia : Hatteria or Sphenodon.
Crocodilia : Crocodiles, Alligators, and Gharials.

Chelonia.—The Tortoises and Turtles are a very ancient type of reptile. Their bony skeleton is curiously developed, a lateral expansion of the ribs forming sometimes a complete bony shield or carapace, as in the Tortoises, sometimes an uninterrupted one, as in the Turtles and Tryonichidæ. Over this bony expansion is a horny covering of epithelial origin (Tortoiseshell).

These reptiles have no true teeth, but their sharp-edged jaws are covered by horny plates, which are more or less shaped to suit the individual habits of the animal. Thus, in the Indian Water Tortoise (see Fig. 43) the jaw edges are shaped up into definite toothlike forms, on to which the horny plates fit. In the Brazilian Tortoise the bones participate to a less degree in the toothlike shape, while in the common Turtle the jaws are simply a sharp, straight edge, not forming points at all.

Ophidia.—The Serpents are a very aberrant type of reptiles. They appeared comparatively late in the world's history. The fore-limbs are almost always absent, and the hind-limbs generally so. The bones of the head, even the halves of the mandible, are not ossified together, but loosely united by elastic tissue, so that the mouth is capable of great distention, and objects much

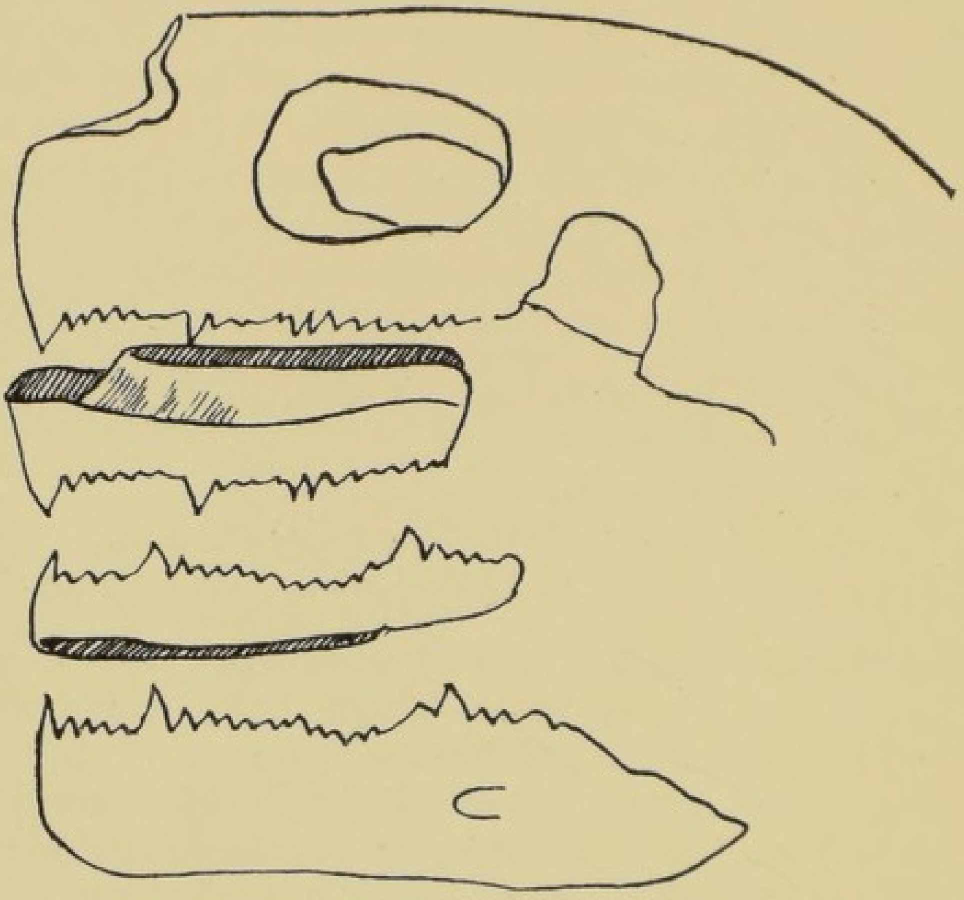


FIG. 43.—INDIAN WATER TORTOISE.

Fig. 43 is an outline drawing of the upper and lower jaws of *Hardella thurgi*, the Indian Water-tortoise. The jaws are widely separated, and the horny sheaths are shown as if just pulled off the supporting bone. It will be noted that both the bone and the sheath show very toothlike projections, and that a little more calcification would have rendered the plates passable teeth. This tortoise is especially tooth-shaped in his plates, and for this reason was chosen for drawing. Many chelonians have beaks which are not raised up into toothlike processes at all.

larger than the animal's head when at rest, can be swallowed. The teeth are generally two rows of recurved cones anchylosed to the bone above and one below.

The Serpents are divided into 'poisonous' and 'non-poisonous ' types, and intermediate or ' colubrine ' class. The poisonous Snakes have two highly-developed poison fangs in front, situated on the premaxillary bones, and a row, few and insignificant, of recurved teeth behind. The colubrine Snakes have more teeth, and of these some of the back ones are more or less grooved on the anterior internal aspect for the conveyance of salivary poison. The harmless snakes have many teeth, all about the same size and not grooved.

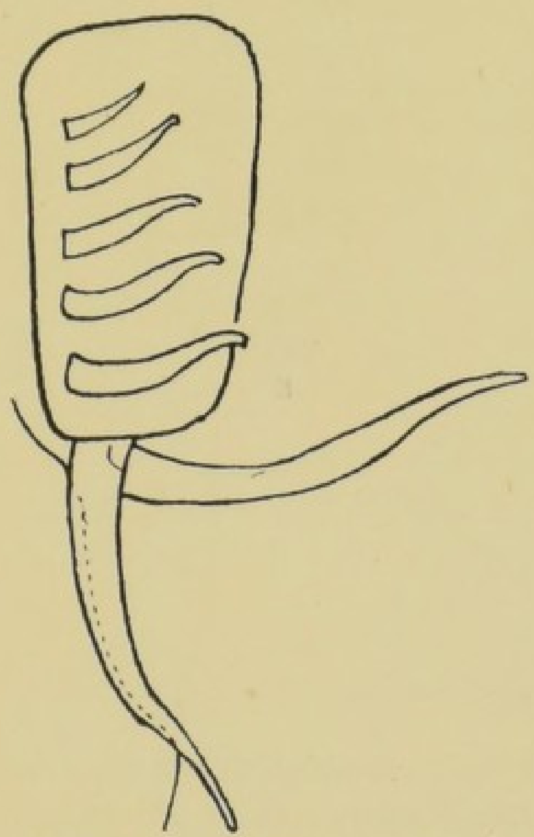


FIG. 44.—SIDE VIEW OF A POISON-FANG; A BRISTLE PASSING THROUGH THE CANAL.

The Poison-fang.—This very specialized organ is found in every degree of development and efficiency. In a Slow-worm described by Boulenger (*Ophisaurus*) there is a slight anterior groove, widest at the base of the tooth, and tapering and finally disappearing half-way down the tooth; it is seen best in the back teeth. In Heloderma, a poisonous Mexican lizard (the only one known), the upper and lower teeth have a fairly deep anterior groove. In the Viper and Puff-adder this groove is confined to the two upper premaxillary teeth, and it is not only much deeper, but the sides of the groove arch over it and meet in the middle line, so that for a great part of its course

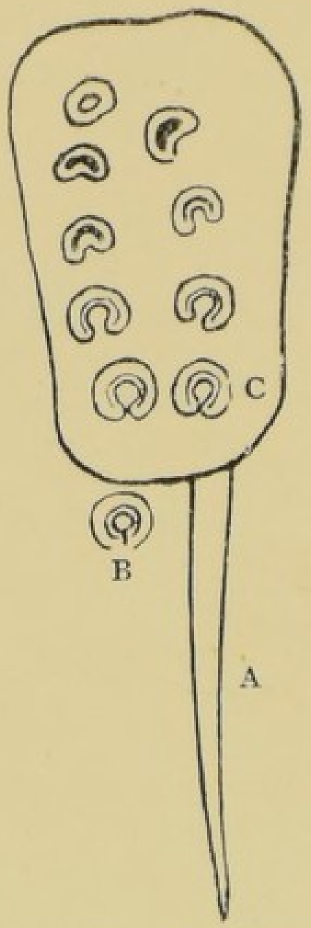


FIG. 45.—DIAGRAMMATIC REPRESENTATION OF THE DEVELOPMENT OF A POISON-FANG.

A, the fang in use; B, the successor ready to come into use; C, the successional germs gradually folding over to enclose the canal. The germs are formed recumbent, with their points backwards.

the groove becomes converted into a canal. The origin of this canal from a groove similar to that of Heloderma is shown in the developmental stages of the organ. There are always two sets of fangs in course of development in each premaxillary bone, each set consisting of seven or eight germs. The youngest germs show a slight

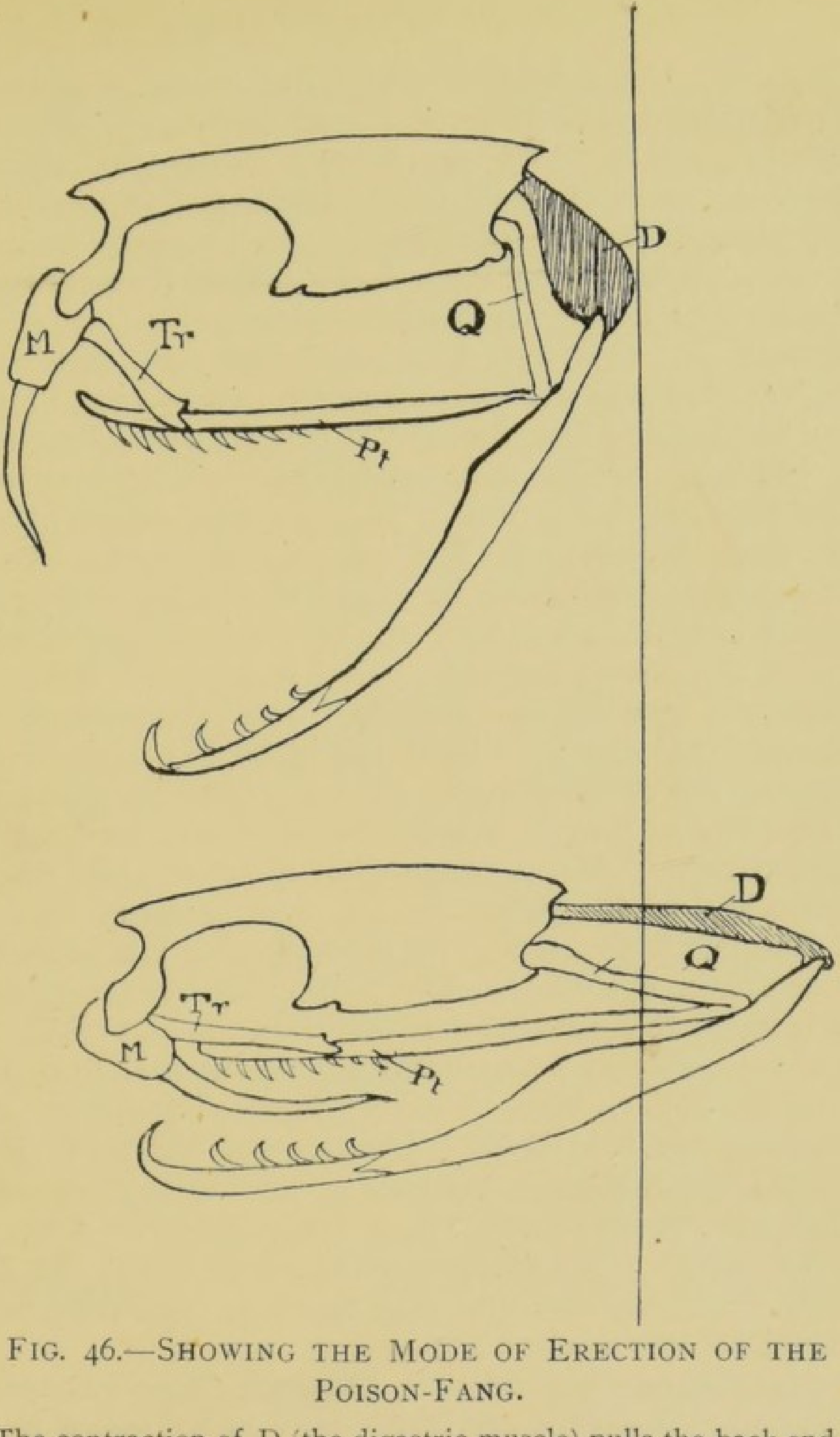


FIG. 46.—SHOWING THE MODE OF ERECTION OF THE POISON-FANG.

The contraction of D (the digastric muscle) pulls the back end of the mandible upwards and forwards, forcing forward the pterygoid bone (Pt), which carries forward the transverse bone (Tr), and causes the maxilla (M) and its fang to rotate, as in the upper figure. The same parts at rest are shown in the lower figure.

inflexion, which in the older ones becomes gradually deeper, until the sides curve over and meet, forming a groove. Thus there are in each bone two series of germs in every stage of development, and two perfected fangs ready for use, though only one is actually *in* use at a time, its neighbour lying ready prepared to spring up when it is lost. The fangs are recumbent when not erected for striking. The mechanism by which the poison-fang is erected is well shown in a beautiful model in the teaching museum at the Royal Dental Hospital.

The fang itself is anchylosed to the premaxillary bone, and both move together. The long fang, when at rest, lies flat along the upper jaw, pointing backwards towards the throat, and hidden by a fold of mucous membrane, which is tightened over it during erection, and helps to direct the poison down the canal or groove. When the digastric muscles contract and pull downwards and forwards the quadrate bone, the pterygoid, and palatine bones are pushed forwards, and the premaxillary is caused to rotate, so that it is levered downwards, carrying the fang with it. At the same time, the crotaphite muscle contracts on the poison gland, and squeezes out the poison, which is directed by the tightened mucous membrane down the canal. The pulp cavity in these fangs is reduced to a thin semicircular line (in section). The great number of germs prevents the animal from running the risk of being left for a space without its chief weapon, and is in itself a phenomenal arrangement for providing one tooth. The poison canal does not open at the point of the tooth, but a little short of it on the front surface, an arrangement which prevents the hole from being blocked up. The tooth is continued to an extremely fine enamel tip.

Lacertilia.—The Lizards, although they look rather like little crocodiles, are really more nearly allied to the snakes. They usually have two pairs of limbs, and the two halves of the lower jaw are more firmly united than in the ophidians. The common Slow-worm is an instance of a snakelike lizard, but in this creature there are rudiments of the limbs hidden under the skin, though they are functionless.

The teeth are developed in endless succession, the new teeth appearing on the inner side of the old ones, and undermining them. The teeth are generally cone-shaped, though sometimes modified into slicing organs. They often consist of a tip of ordinary hard dentine, which becomes fluted towards the base of the tooth, as in Varanus. The back teeth of Heloderma, the poisonous Mexican Lizard, have slight grooves on the anterior internal surface in both the upper and lower jaws. The Chamælions have rows of acrodont teeth round the jaw margins, which are not replaced by successional teeth.

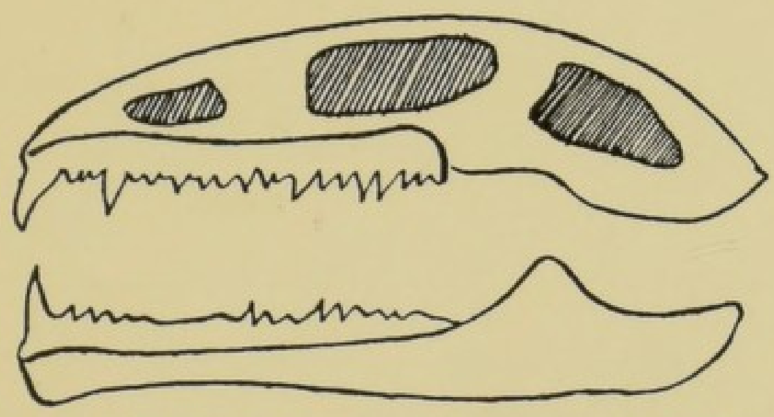
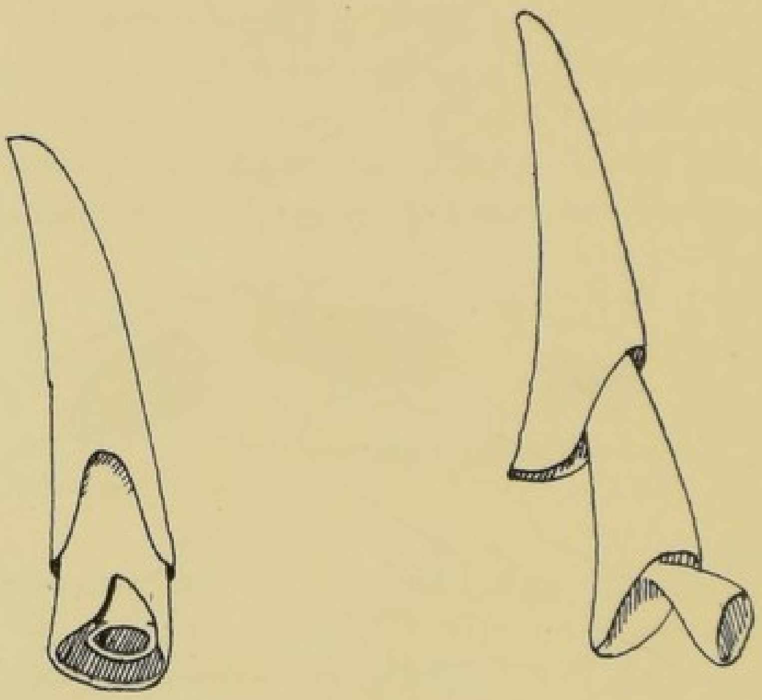


FIG. 47.—UPPER AND LOWER JAWS OF SPHENODON.

Fig. 47 shows in diagrammatic form the dentary bones, with their toothlike processes, of the only living representative of the prosaurian reptiles, known as Rhyncocephalia. They were so low in the reptile classes to be almost proreptilian, and to exhibit many amphibian affinities. Beddard describes Sphenodon or Hatteria (known in its native New Zealand as Tuatera) as 'the last living representative of bygone ages this primitive, almost ideally generalized type of reptiles, this living fossil.' Young specimens have a few small teeth on the vomers.

Rhyncocephalia.—The only living specimen is Sphenodon or Hatteria, known to the Maori natives as Tuatera. It is a large reptile about two feet long, and possesses a row of maxillary and a row of palatine teeth side by side, while some acrodont mandibular teeth bite between them. The premaxillary bones carry two large teeth, which look a little like rodent incisors, but which wear down until the bone is exposed, which then comes into actual use—a unique phenomenon. This bone was found by Tomes not to consist of dental tissues.

Crocodilia.—These reptiles show in many respects a higher type than other members of the class. Their chest is separated from the abdomen by a muscular



FIGS. 48 AND 49.—SUCCESSIONAL TEETH OF GHARIAL.

Figs. 48 and 49 show in two different aspects the arrangement of the successional teeth of Gharial—No. 2 inside the pulp of No. 1, and No. 3 entering that of No. 2. The method of replacement in crocodilian dentitions is shown here.

diaphragm; their heart is divided into four distinct cavities or chambers; their teeth are implanted in sockets. The Crocodiles proper are distinguished from the Alligators by having the fourth lower tooth, which is always large, passing into a notch in the side of the upper jaw, whereas in the Alligators it is received into a pit or depression. The Gharials have a long, slender snout. In the Crocodiles the successional teeth enter the pulps of their predecessors, and eventually occupy the same socket, which is not absorbed and re-formed for each tooth. In the Alligators and Gharials the new tooth is formed rather on the inner side, and works its way laterally into the substance of its predecessor. The first and fourth lower tooth and the third and ninth upper ones are specially developed.

Extinct Reptiles.—Of these there were many orders sufficiently wonderful to exceed the wildest imaginings of the most fanciful brain. The *Pterosauria*, or winged Lizards, with pneumatic bones and long jaws, toothed behind and beaked in front. The huge *Dinosaurians*, probably amphibious, one member of which family, from the Jurassic of Colorado—Atlantosaurus—is supposed to have been 80 feet long and 30 feet high, afford many varieties of dentition for study. The general type is more or less crocodilian. Sometimes the successional teeth are anchylosed to the inner side of the bone (pleurodont); sometimes, as in *Ichthyosaurus platydon*, they are held in a groove which is not divided into sockets, a condition found also in the extinct toothed bird Hesperornis. Sometimes the socket implantation is quite complete. One extinct Rhyncocephalian, *Hyperodapedon Gordoni*, has a very strange armature. The back teeth consist of several rows of simple, cone-shaped, anchylosed teeth, while in front, above and below, there appear to be two large curved incisors of a strictly rodent type. On closer examination, however, these projections prove not to be teeth at all, but incisor-shaped processes from the premaxillaries and mandible, composed not of dental tissues, but of bone, and possibly in the living state covered with horny plates. These horny plates are only supposed to have existed, and it is worth noting that the only living species of Rhyncocephalian, *Sphenodon*, though possessing back teeth and toothless but toothlike anterior portions of the jaws, does in youth develop rodent-like teeth on the premaxillaries, which wear down until, as no successional teeth appear to replace them, the actual bone of the jaw comes to be used as teeth.

Anomodontia.—These creatures possessed a very

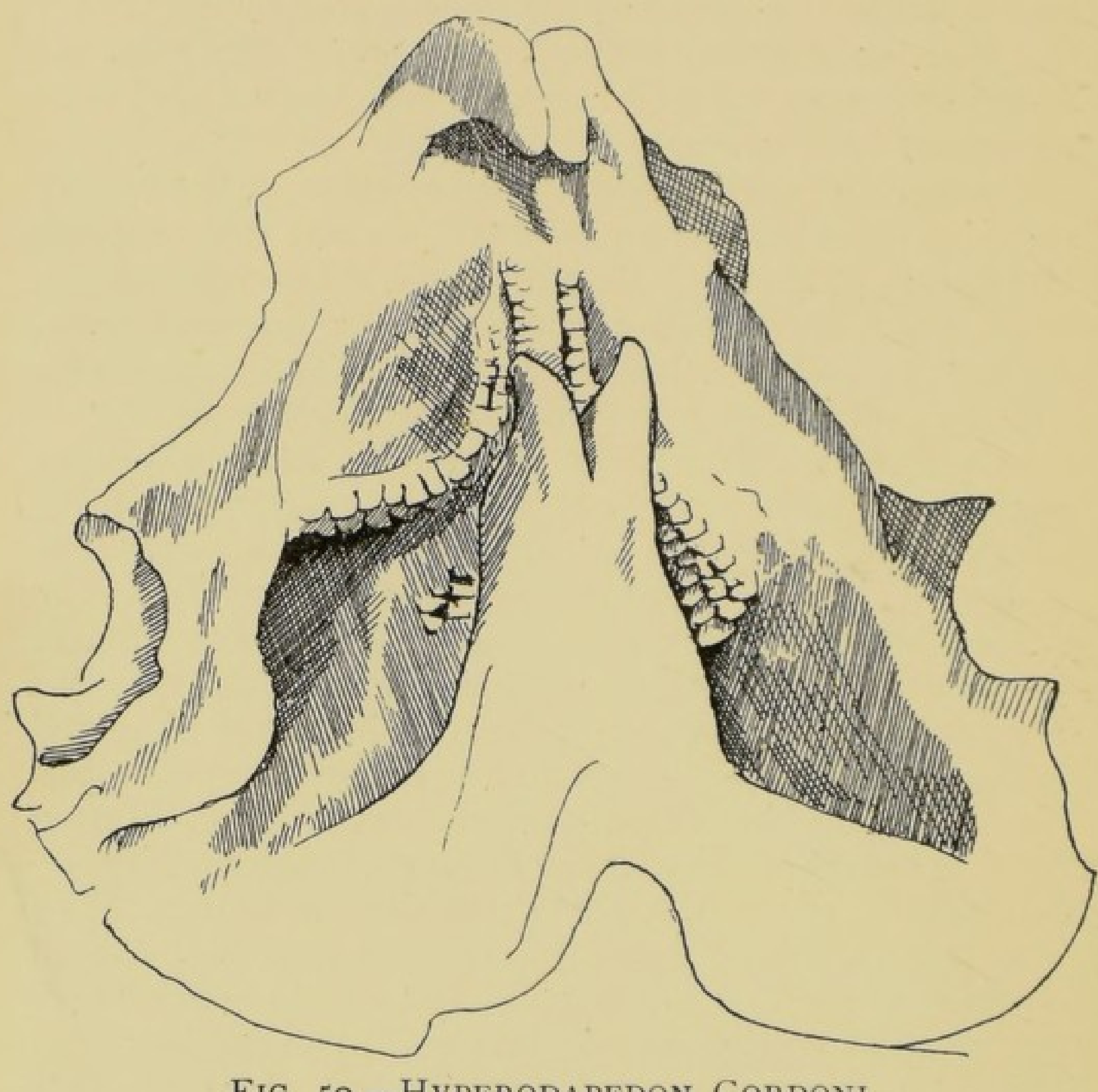


FIG. 50.—HYPERODAPEDON GORDONI.

Fig. 50 is drawn from a cast of the jaws of an extinct Rhyncocephalian, or beak-headed lizard, called *Hyperodapedon Gordoni.* To quote the guide-book of the British Museum: 'The dentition is very peculiar, the maxillary and palatine bones being provided with several rows of well-developed, low, conical teeth, closely set, and so arranged posteriorly as to form a deep longitudinal groove between two or more rows of teeth on each side for the reception of the marginal teeth of the mandible.' The front portion of the maxilla and mandible are produced into two very large tusks of bone above and below. These are not teeth, and yet they strikingly recall the huge incisors of rodents. They were probably clothed with horny beaks.

varied dentition, and displayed affinities with the extinct amphibians called Labyrinthodontia, from which they were most likely directly descended. They were also, in all probability, nearly related to the *Monotremata*, who are supposed to have been the ancestors in the direct line of the whole mammalian class. Their dentition is often very carnivorous in type. The *Dycynodons* (double dog-toothed) possessed a pair of huge, sharp-pointed, downward-growing tusks, of a walrus type, and no other teeth whatever; but the lower jaw was shaped like a beak, and probably covered with horn like that of the

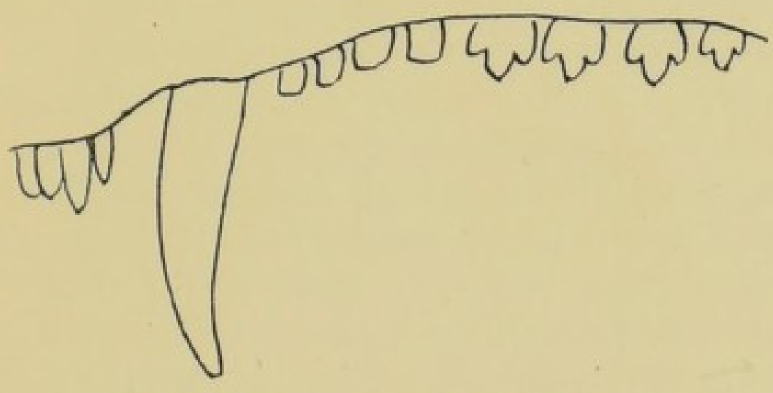


FIG. 51.—CYNOGNATHUS.

Fig. 51 shows the outline of the upper jaw of cynognathus, and illustrates the fact that the Anomodontia had arrived at a very specialized heterodont dentition.

chelonian reptiles. The *Theriodontia* possessed a very pronounced carnivorous dentition—incisors separated from the molars by well-developed canines (the lower biting in front of the upper); the back teeth easily divisible into premolars and molars, the latter being in shape not unlike the upper carnassial tooth of existing felidæ. There is no evidence of a milk dentition in these creatures. *Cynognathus*, a member of this order, possesses four incisors, a large canine, and nine premolars and molars. *Cynodraco* possessed eight incisors (lower) and a huge upper canine, like that of the sabre-toothed Tiger, which descended right down beside the lower jaw when the mouth was closed, the mandibular bone being specially developed to protect it.

The reader has only to wander round the galleries of the British Museum to observe for himself many more dental marvels among the extinct reptiles. To multiply instances here would simply result in mental confusion and possibly disgust. Enough has been written to show one point of supreme interest—namely, that these animals show points of relationship between many orders of creatures that evolution has by now divided very widely. Standing between the Fishes on the one hand and the Mammals on the other, in what may be termed the palæontologial social scale, we find them now with beaks like birds, now with successional teeth of a homodont type, and now with specialized monophyodont dentitions that would not disgrace a Tiger or a Wolf. Whereas, from the study of existing life, we come to associate heterodont or specialized dentitions with the mammalian class, we nevertheless find that evolution was capable of providing reptilians with all the essentials of rodent or carnivorous armature before the mammalian class itself existed. The interest of these very *different* dentitions lies in the *likenesses* traceable between one class of creature and another. It is also worthy of note—and the fact is nowhere more plentifully illustrated than in this reptilian class—that whereas useful peculiarities do descend by inheritance, and therefore certain similarities presuppose kinship, yet very peculiar and ingenious arrangements serving similar purposes may be evolved in creatures where relationship is so remote that it can scarcely be supposed to have much to do with the matter. Thus the dentition of the Lion, the Tiger, the Wolf, and the Bear lead us to infer some degree of common ancestry to have existed for these creatures at a comparatively recent date. But the Cheiromys (Madagascar), the Wombat (Australia), the common Rat (Europe), and the extinct Rhyncocephalian reptiles all have developed very similar rodent-like dentitions, though any common parentage must date back long before such rodent-like aberration commenced. So the extinct reptiles, the Theriodontia, the modern mammalian carnivora, and their prototypes among the Australian marsupials, can scarcely be supposed to have inherited their specialized dentitions from any common ancestor.

CHAPTER VII

AVES

No class of creatures appears to stand apart from the rest of the scheme of life more completely than that of the Birds. Their feathers and their flight, though the latter power is shared to a certain extent by a few mammalians (such as the Bats), and very imperfectly by some Fishes, and was not at all unusual among extinct Reptiles, are sufficient to place their possessor in a very isolated position to the casual observer. Their song is a phenomenon so marvellous as to have betrayed even Darwin into—if it may be said with reverence—some rather far-fetched imaginings, while their total lack of teeth, or even the suggestion of teeth, seems to add to the atmosphere of mystery and anomaly that surrounds them. When, however, we come to consider their skeletons and to study extinct forms, we find them so closely akin to the Reptilia that they are now generally regarded as being simply a very modified and aberrant reptilian type.

In a formation known as the 'lithographic stone,' of the date of the Kimmeridge clay (see p. 27), were found the remains of the most ancient bird of which we have any record at present. The creature's bones were preserved, and, owing to the fact that the stone was only soft mud at the time of the death of the bird, there were also perfect impressions of the feathers of the wings and of the tail. This bird is known as *Archæopteryx*, and possessed a long-jointed tail like that of a Lizard, with a pair of feathers springing from each joint. Its mouth was not armed with a horny beak, but with an upper and lower row of homodont teeth, crocodilian in type: they were socketed, smooth, pointed, and coated with enamel. In fact, except for the adornment of feathers, the remains might and would have been classed as reptilian. Comparatively recently Professor Marsh has discovered remains of many-toothed birds much more recent than Archæopteryx, and showing signs of the commencement of beaks, but still amply provided with teeth. He named the subclass *Odontornithes*, and divided it into two main subdivisions—the *Odontotornæ*, small flying birds with socketed teeth, type *Icthyornis*; and *Odontolcæ*, large wingless swimming birds, with teeth arranged in grooves, not divided, or only imperfectly divided, into sockets, type *Hesperornis*. All these remains possessed edentulous premaxillary bones, which were probably clothed with horny beaks.

Icthyornis had about twenty-one sharp-pointed recurved and flattened teeth in each jaw, above and below. The front part of the upper jaws were probably beaked. The middle teeth were the largest, and the succession and attachment resembled that of crocodiles.

Hesperornis were huge diving-birds, teeth implanted in a groove, with faint indications of subdivisions. The teeth reached to the front end of the lower jaw, but the premaxillaries were probably beaked. There were about thirty teeth in each lower jaw, and fourteen in the upper. In development they exactly resembled an extinct reptile, *Monosaurus*; the successional tooth was developed inside the base of the existing tooth.

All these teeth were coated with enamel. The dentine is hard, unvascular for the most part, with osteodentine at the base. In shape the teeth are simple recurved cones, not specially serrated. Though an aquatic bird, Hesperornis appears to have been closely allied to the

Ostriches, and may be regarded as a huge carnivorous swimming Ostrich; it attained a height of six feet.

Fossil birds of a more recent date have been discovered in the lower eocene clay, of which *Odontopteryx toliapicus* may be taken as a type. These creatures, which varied from forms about the size of an Ostrich to Vulture-like varieties not much bigger than a Blackbird, were provided with horny beaks, the edges of which were shaped like the teeth of stone saws, about a dozen large canine-like blades, with two smaller blades between each pair.

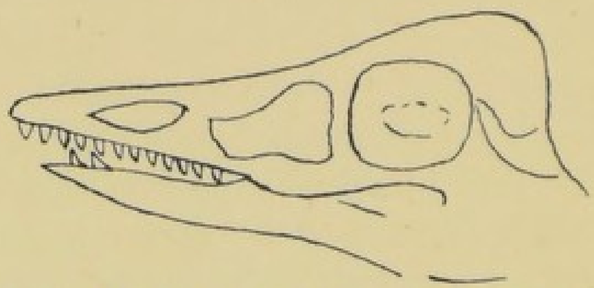


FIG. 52.—SHOWS HEAD AND TEETH OF ARCHÆOPTERYX.

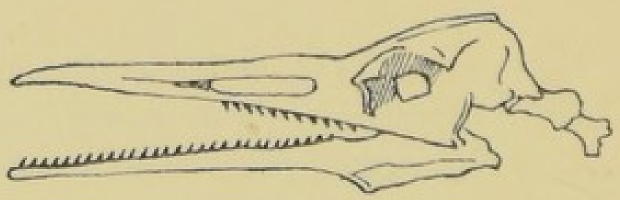


FIG. 53.—SHOWS HEAD AND TEETH OF HESPERORNIS.

A serrated edge to the bony beak is very noticeable in the Papuan wreathed Hornbill.

Thus from the earliest remains we find first a homodont crocodilian dentition in Archæopteryx; then the premaxillaries beaked but homodont teeth implanted in sockets, as in Icthyornis; then a similar arrangement, only with the teeth lodged in grooves, as in Hesperornis; then a specialized beak, as in Odontopteryx; and, lastly, the ridged beak of the modern Gander. In this connection it would be well to turn back to the chelonian reptiles, and observe the gradual simplification of the beak, following on very similar lines.

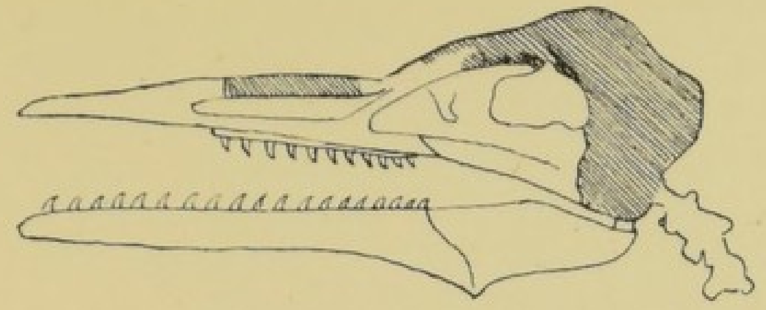


FIG. 54.—SHOWS HEAD AND TEETH OF ICTHYORNIS.

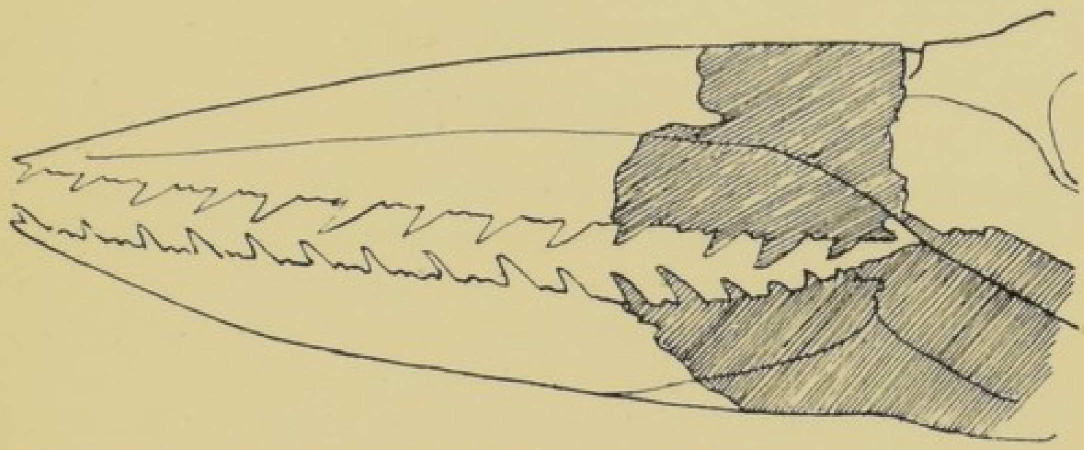


FIG. 55.—SHOWS SERRATED BEAKS OF ODONTOPTERYX TOLIAPICUS.

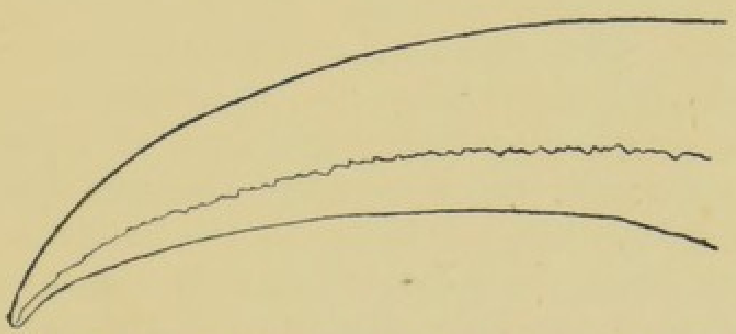


FIG. 56.—SHOWS SERRATED BEAK OF A HORNBILL.

CHAPTER VIII

MAMMALIA

The Mammalia are, as a whole, higher in the scale of life than any of the preceding divisions, and contain certainly the very highest developments, but it is in this class that the difficulties of the classifier become almost insurmountable. As soon as naturalists generally accepted the law of evolution as being the dominant factor in producing the various forms of life which we see around us, a natural desire arose to classify and arrange living forms with some relation to their position in the great genealogical tree of Nature which it was felt must have existed, and this has to some extent been done. The older divisions, which depended upon some noticeable peculiarity of the creatures, and had no reference to their real affinities, such as Pachydermata and Ruminantia, etc., were felt to be misleading and to mean really nothing. Owing to the immense space of time over which the process of evolution has spread, to the total disappearance of many intermediate and connecting forms, and to the extreme specializations which have from time to time arisen and disappeared with varying surrounding circumstances, this task has been beset with many difficulties, which, if not insurmountable, can still be scarcely said to have been surmounted. Thus we trace a gradual advance from Fishes through Amphibians to Reptiles; but Birds cannot be regarded as a step towards Mammalia, but only as an extremely marked aberration from the reptilian type.

The direct line of descent presents many unbridged gaps, but it may be assumed that those forms which were parent forms were not very specialized. At each stage of evolution many varieties wandered in different routes of specialization, while in the direct line there was a steady tendency to advance. Most likely the earliest mammalian forms had amphibian ancestors common to them and to the Reptile class, and these ancestors are supposed to have belonged to the Labyrinthodont group. The Anomodont reptiles, with their very mammalian dentition, were probably derived from the same stock, and the earliest mammalian forms probably belonged to the group of Monotremata.

Huxley divided the mammalian class into three great groups, which he named according to the relative ancientness—*Prototheria* (first beasts or original beasts), *Metatheria* (after or later beasts), and *Eutheria* (perfected beasts). In a broad sense these divisions represent a gradually ascending scale of organization, but it is impossible to so arrange the existing mammalia that each fresh subdivision should appear to be an advance upon those preceding it. Many groups present at the same time points of advance and points indicating retrogression, so that in accepting the classification in common use at the present time we must remember that it does not pretend to perfection, and is only the best that has been yet suggested.

Prototheria.—The only existing members of this group are the *Ornithorhynchidæ* and the *Echidnidæ*.

Metatheria include the *Marsupialia*.

Eutheria include the *placental Mammals*. To quote Flower and Lyddeker : ' Their affinities with one another are so complex that it is impossible to arrange them serially with any regard to natural affinities. Indeed, each order is now so isolated that it is almost impossible to say what its affinities are. . . . The Edentata, Sirenia, and Cetacea stand apart from all the rest in the fact that their dentition does not conform to the general heterodont, diphyodont type to which that of all the other Eutheria can be reduced, and which is such a close bond of union between them. In all three orders, however, some indications may be traced of relationship, however distant, with the general type. . . . The remaining Eutherian mammals are clearly united by the characters of their teeth, being all heterodont and diphyodont, with their dental system reducible to a common formula.'

The following classification is adapted from Flower and Lyddeker, and is only inserted here for reference, and not for committal to memory :

SUBCLASS I.—PROTOTHEREA

ORDER I.—**Monotremata.**

Fam. 1. *Ornithorhynchidæ*—Duckbill.
Fam. 2. *Echidnidæ*—Spiny Anteater.
Extinct forms : Plagiaulax, Polymastodon, Tritylodon.

SUBCLASS II.—METATHERIA

ORDER II.—**Marsupialia.**

Suborder I. Polyprotodonts (having many front teeth).
Fam. 1. *Didelphydæ*—Opossums.
Fam. 2. *Dasyuridæ*—Thylacine and Dasyures.
Fam. 3. *Peramelidæ*—Bandicoots.
Extinct forms : Dromatherium, Amphitherium, Spalacotherium, etc.

Suborder II. Diprotodonts (having two front teeth).
Fam. 4. *Phascolomyidæ*—Wombats.
Fam. 5. *Phalangeridæ*—Phalangers.
Fam. 6. *Macropodidæ*—Kangaroos.
Extinct forms : Diprotodon, Notothere.

SUBCLASS III.—EUTHERIA

ORDER III.—**Edentata.**

Fam. 1. *Bradypodidæ*—Sloths.
Fam. 2. *Myrmecophagidæ*—Anteaters.
Fam. 3. *Dasypodidæ*—Armadillos.
Fam. 4. *Manidæ*—Pangolins.
Fam. 5. *Orycteropodidæ*—Aard-varks.
Extinct forms : Megatherium, Glyptodon.

ORDER IV.—**Sirenia.**

Fam. 1. *Manatidæ*—Manatees.
Fam. 2. *Halicoridæ*—Dugongs.
Extinct forms : Rhytina, Halithere.

ORDER V.—**Cetacea.**

Suborder I. *Mystacoceti*—Baleen Whales.
Fam. 1. *Balænidæ*—Greenland Whale, etc.
Suborder II. *Archæoceti*, no living forms.
Extinct forms : Zeuglodonts.
Suborder III. *Odontoceti*—Toothed Whales.
Fam. 2. *Physeteridæ*—Sperm Whale.
Fam. 3. *Platanistidæ*—Fresh-water Dolphins.
Fam. 4. *Delphinidæ*—Dolphins, Porpoises, etc.

ORDER VI.—**Ungulata** (Hoofed Mammals).

Suborder I. Artiodactyla (even-toed).

A. *Suina—Piglike Artiodactyles.*

Fam. 1. Hippopotamidæ—Hippopotamus.
Fam. 2. Suidæ—Pigs and Peccaries.
Extinct forms : Oreodon, Anoplotherium, Dychodon, etc.

B. *Tragulina—Chevrotains.*

Fam. 3. *Tragulidæ*—Chevrotains.

C. *Tylopoda—Camels.*

Fam. 4. *Camelidæ*—Camels.

D. *Pecora—True Ruminants.*

Fam. 5. *Cervidæ*—Deer.
Fam. 6. *Giraffidæ*—Giraffe.
Fam. 7. *Bovidæ*—Sheep, Cattle, etc.
Suborder II. Perissodactyla (odd-toed).
Fam. 8. *Tapiridæ*—Tapirs.
Fam. 9. *Equidæ*—Horses.
Fam. 10. *Rhinoceridæ*—Rhinoceroses.
Extinct forms: Lophiodonts, Palæotheria, etc.
Suborder III. Toxodontia—no living forms.
Suborder IV. Hyracoidea—no living forms, only extinct Hyrax.
Suborder V. Proboscidea.
Fam. 11. *Elephantidæ*—Elephants.
Extinct forms: Dinotherium, Mastodon, etc.
Group **Tillodontia**—no living forms.

ORDER VII.—**Rodentia.**

Suborder I. Simplicidentata.
Fam. 1. *Sciuridæ*—Squirrels and Marmots.
Fam. 2. *Haplodontidæ*—Haplodon.
Fam. 3. *Castoridæ*—Beavers.
Fam. 4. *Myoxidæ*—Dormice.
Fam. 5. *Muridæ*—Rats, Mice, and Voles.
Fam. 6. *Hystricidæ*—Porcupines.
Suborder II. Duplicidentata.
Fam. 7. *Leporidæ*—Hares and Rabbits.

ORDER VIII.—**Carnivora.**

Suborder I. Carnivora vera, Fissipedes (with divided feet).
Fam. 1. *Felidæ*—Cats.
Fam. 2. *Hyænidæ*—Hyenas.

Fam. 3. *Viverridæ*—Civets and Ichneumons.
Fam. 4. *Canidæ*—Wolves and Foxes.
Fam. 5. *Ursidæ*—Bears.
Fam. 6. *Mustelidæ*—Weasels and Otters.
Fam. 7. *Procyonidæ*—Racoons, etc.
Suborder II. Carnivora Pinnipedia (web-footed).
Fam. 8. *Otariidæ*—Eared Seals.
Fam. 9. *Trichechidæ*—Walrus.
Fam. 10. *Phocidæ*—Seals.

ORDER IX.—**Insectivora.**

Fam. 1. *Macroscelididæ*—Elephant Shrews.
Fam. 2. *Erinaceidæ*—Hedgehogs.
Fam. 3. *Soricidæ*—Shrews.
Fam. 4. *Talpidæ*—Moles.
Fam. 5. *Galeopithicidæ* — Galeopithecus (once classed with the Lemurs and once with the Bats, but belonging to neither).

ORDER X.—**Chiroptera.**

Suborder I. Megachiroptera—Frugivorous Bats.
Fam. 1. *Pteropodidæ*—Flying Foxes.
Suborder II. Microchiroptera—Insectivorous Bats.
Fam. 2. *Vespertilionidæ*—Common Bats.
Fam. 3. *Phyllostomatidæ*—Vampires.

ORDER XI.—**Primates.**

Suborder I. Lemuroidea.
Fam. 1. *Chyromyidæ*—Aye-Aye.
Fam. 2. *Lemuridæ*—Lemurs.
Extinct forms : Hyopsodus.
Suborder II. Anthropoidea (manlike Mammals).
Fam. 3. *Hapalidæ*—Marmosets.
Fam. 4. *Cebidæ*—American Monkeys.
Fam. 5. *Cercopithecidæ*—Old-World Monkeys.
Fam. 6. *Simiidæ*—Gibbons and manlike Apes.
Fam. 7. *Hominidæ*—Man.

Many families and subdivisions have been omitted from the list in order to make it simpler. It is not desirable to try to commit to memory all these names and classes, but it may prove useful to be able to refer any animal about which we are reading to its appropriate place, and observe what its nearest relatives, living and extinct, happen to be.

CHAPTER IX

PROTOTHERIA AND METATHERIA

Prototheria

These creatures represent the lowest type of evolution of the mammalian class, and present many points of affinity with the Reptiles and Amphibia. They represent an early divergence from the main trunk of the genealogical tree, and, though not in the direct line of descent, are sufficiently near it to possess great interest for the zoologist. The sutures of the skull become completely obliterated in adult life, as in Birds. The mandible has no ascending ramus, and scarcely any coronoid process or angle, and its two halves are not united by bone. In the leg of the adult male there is an arrangement closely resembling the poison-fang of a Viper—a sharp horny spur perforated by a minute canal, and connected with a gland in the back of the thigh. There are rudimentary evidences of a similar spur in the young female, which, however, disappear with puberty. A case of this spur being used as a weapon and producing effects of local poisoning has been reported. These animals have been proved to lay eggs.

The *Echidna*, or spiny Anteater, a native of New Guinea, Tasmania, and Australia, is edentulous, and has no horny plates in its mouth ; its calcaneal spur and gland are smaller than those of Ornithorhynchus. *Ornithorhynchus*, also a native of Australia, possesses in early life twelve calcified teeth of a multituberculate type; these teeth are erupted and used, but are shed early, which accounts for the fact that their existence was not recognised until comparatively recently. Underneath these teeth the beak is armed with horny plates, which are ridged and tuberculated, and serve the animal as teeth throughout the greater part of its life. The dentine is abundantly supplied with interglobular spaces. The presence of large, irregular lacunæ has led Tomes to suggest that these teeth are a degeneration from some earlier and more complete form of tooth.

Metatheria

The marsupial animals, which were once widely distributed over the surface of the globe, are at present confined to the continent of Australia, which they practically monopolize, and some parts of South America. They present almost every variety of dental development, but they all possess certain characteristics, which serve to separate them from the Prototheria on the one hand and the Eutheria on the other. The young, when born, are nourished and preserved for some time in a pouch or marsupium, lined with teats armed with nipples, and are fed by milk injected into the mouth by the contraction of a muscle covering the mammary gland. They are therefore more strictly mammalian than the placental animals or Eutheria. As we noticed among certain extinct reptilians that adaptive modification tended to produce dental apparatus ranging between extremely herbivorous and very carnivorous types, so we find an almost infinite variation in this respect among the Metatheria. The teeth are always heterodont, but, except in Phascolomys, the number of incisors in the upper and lower jaw is never the same, and frequently exceeds the placental limit of three. The enamel is pretty constantly permeated by tubes, which are supposed to contain living matter continuous and connected with the dentinal fibrils. But the most striking dental peculiarity of the class is that, though they are heterodont, they are very nearly monophyodont, only one tooth on each side in the whole series having a deciduous predecessor. This tooth is always the hindermost of the premolar series, and sometimes remains in place and use until after all the other teeth, including the last molars, have erupted, while in other cases (as in Thylacine) it is quite functionless, and shed before any other tooth eruption takes place. Lastly, in some cases, as Wombat, Myrmecobius, and the Dasyures, there is no evidence of the existence of any such tooth at all. Controversy has occupied itself much with the question whether this deciduous tooth is homologous to the milk-tooth of placental mammals, also whether in those marsupials that possess a formula greatly exceeding the typical mammalian formula—as, for instance, the Opossums, with incisors $\frac{5}{4}$, and Myrmecobius, who has a total of fifty-six teeth—some of the series do not represent persistent milk-teeth. Some theorists have explained the existence of a milk and permanent set of teeth as the result of gradual crowding of the longer series of an earlier monophyodont dentition, and consequently have regarded the condition of marsupials as an early stage in the evolution of diphyodontism, such as we should expect to find in the lowest classes of mammals. That it is not a *degeneration* from diphyodontism is suggested by the fact that extinct marsupials do not possess a fuller milk set. It has also been suggested that the only tooth homologous to the permanent set of the placentals is the one which succeeds the only deciduous tooth, while all the rest of the teeth are homologous to milk-teeth. This view rests upon the existence of calcified tooth-germs, which become abortive on the lingual side of the germs of the functional teeth. The whole question hangs upon one point—namely, whether these germs are sufficiently differentiated to be regarded as really imperfect teeth. Leche and others think they are, Wilson and Hill think they are not. Rose has found calcified germs *preceding* the functional teeth in Wombat. Lastly, it has been suggested that the deciduous tooth is one of the same series as the rest, *crowded out*. Tomes gives a complete résumé of the different views, but does not state his own opinion.

Marsupials are divided into—

A. *Polyprotodontia*—incisors many and small, canines larger, molars with sharp cusps.

1. *Opossums* or Didelphidæ—incisors $\frac{5}{4}$.
2. *Dasyures* or Dasyuridæ—incisors $\frac{4}{3}$.
3. *Bandicoots* or Peramelidæ—incisors $\frac{4}{3}$ or $\frac{5}{3}$.

B. *Diprotodontia*—incisors not exceeding $\frac{3}{3}$, usually $\frac{3}{1}$, sometimes $\frac{1}{1}$. The first of these, upper and lower, large and scalpriform ; upper canines generally, lower canines always, absent; molars bluntly tuberculated or transversely ridged.

1. *Wombats* or Phascolomyidæ—incisors, growing from persistent pulps, large, scalpriform, and enamel-coated on the outer surface.
2. *Phalangers* or Phalangeridæ—three upper incisors and a canine with closed roots.
3. *Kangaroos* or Macropodidæ—three upper incisors, and often a canine with closed roots.

Among the Dasyuridæ, the Thylacine has a dentition very like the Dog, strictly carnivorous, with carnassial molars and large canines. Myrmecobius has an insectivorous dentition, and a formula of $\frac{4}{3}$, $\frac{1}{1}$, $\frac{3}{3}$, $\frac{5}{5}$, or $\frac{6}{6}=52$ or 56. Phascolarctus, a phalanger, presents a very rodent type, while the Wombats almost out-rodent the rodents themselves. *Thylacoleo carnifex*, an extinct Phalanger, had large upper and lower first incisors so caniniform in appearance that, coupled with the fact of his possessing lower premolars very like the lower carnassial teeth of old-world carnivora, they obtained for him a carnivorous reputation, which appears to be a little unfair. If he was carnivorous he was a disgrace to an otherwise innocent family, and was, moreover, misusing a rather rodent-like dentition. His formula was $\frac{3}{1}, \frac{1}{0}, \frac{3}{1}, \frac{1}{2}$. The absence of the lower canine would clear his character had he been placental. Another extenuating circumstance is the fact that one of the

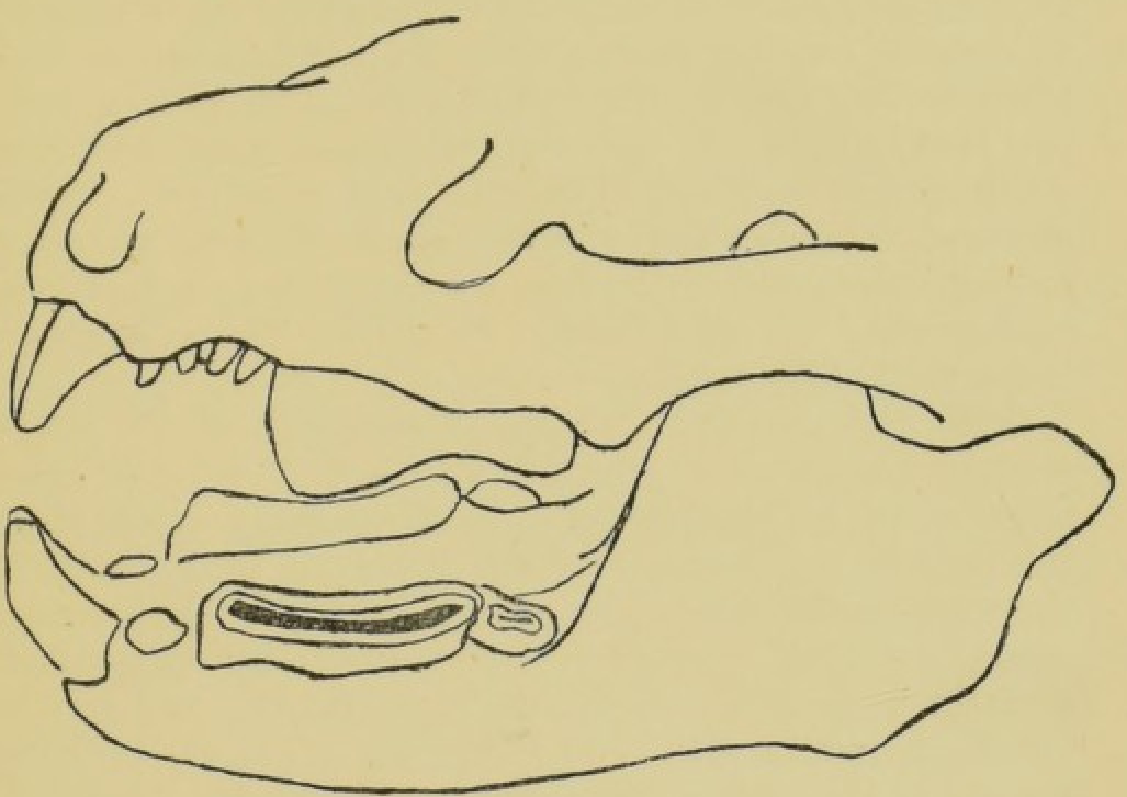


FIG. 57.—THYLACOLEO CARNIFEX.

Fig. 57 shows a skull (drawn from a cast) of an extinct diprotodont Marsupial, called *Thylacoleo carnifex*, and supposed by Owen to have been a true carnivore. The large incisors have a somewhat rodent appearance. The last premolar is enormous, trenchant, and bilaterally flattened. This tooth is exactly parallel to the corresponding premolar in *Hypsiprimnus*, the Kangaroo-rat, which points to the fact that Thylacoleo was not strictly carnivorous. Quite recently Mr. Broom has revived the opinion of Owen that Thylacoleo was a carnivore, so the matter cannot be regarded as settled.

Macropodidæ, *Hypsiprimnus*, the Kangaroo-rat, has very similar dentition, only more rodent in type, and its large, trenchant premolar is far from carnassial, and its habits herbivorous. The Kangaroos have two deciduous teeth, which are displaced by one large second tooth.

Another extinct marsupial, *Diprotodon*, was related on the one hand to the Phalangers and on the other to the Kangaroos. It was as big as a Rhinoceros, and its anterior and posterior limbs were not as disproportionate as those of existing Kangaroos. It had huge upper and lower rodent-like incisors; but though there was only one lower incisor on each side, the upper tooth had two smaller teeth beside it of similar form and type. *Nototherium*, a somewhat smaller creature, was peculiar among marsupials in having its mandibular symphysis anchylosed. In this family, as a rule, the symphysis is not united by bone.

With the exception of the Wombats, all the marsupials possess one striking histological peculiarity—namely, that their enamel is penetrated by tubes from the dentine. Sometimes these tubes go right through the whole substance of the enamel, as in the Kangaroos, sometimes less markedly, as in the Dasyuridæ, and sometimes, as in Myrmecobius, very slightly, and in the Wombats not at all. Von Ebner says that these tubes are not in the axes of the prisms, while Tomes considers that they are.

CHAPTER X

EUTHERIA

The remaining groups of animals which we have to consider all belong to the subclass Eutheria, the distinguishing feature of which is that the fœtus is nourished within the uterus of the mother by means of a placenta, for which reason the subclass are sometimes designated Placentalia. The Eutheria have multiplied in numbers and variety, and have attained higher degrees of development and greater specialization than the members of the other two subclasses, and consequently present a more extended and more varied field of study. Adaptive modification has produced some varieties as aquatic in their habits as Fishes, and others almost as aerial as birds. Extensive gaps in the genealogical tree render it impossible to arrange these animals in a perfect and unbroken ascending scale; still, common consent has given to the Edentata, the Sloths, Armadillos, and Anteaters the lowest place, then the Sirenia, aquatic herbivorous creatures, and the Cetacea, or Whales, Dolphins, and Porpoises. Equally easy has it been to assign the highest place to the Primates, including the Monkeys, and culminating in the anthropomorphoid Apes and Man, while between the two are numerous orders more or less allied to each other, displaying an infinite variety of specialization, but incapable at present of a thoroughly satisfactory arrangement.

Edentata

The Edentata are by no means all edentulous, as their name would seem to imply. They are homodont, and, except Tatusia and Orycteropus, monophyodont ; that is, their teeth are not succeeded by a second set. The teeth themselves are destitute of enamel, except in some fossil forms, have no complete roots, and grow from persistent pulps. In two genera there are no teeth at all, in all but one there are no incisors, and none of them possess central incisors, upper or lower. Dasypus has, however, rudimentary incisors which never erupt.

The Anteaters are edentulous. Some authorities say that they are without any rudimentary trace of teeth, while others interpret some epithelial thickenings as abortive germs; but, as has been seen, abortive germs are very difficult objects to be precise about. These edentulous creatures have long flexible tongues and huge submaxillary glands, which secrete a viscid saliva, and the tongue, coated with this saliva, readily picks up the insect food required.

All the order develop but one set of teeth (homodont), with the exception of *Tatusia peba*, the nine-banded armadillo and Orycteropus, the Cape anteater or Aard Vark, but in many of the toothed forms microscopical evidence has been traced of successional germs. The teeth generally consist of dentine and cementum, and sometimes a central portion of vasodentine. In Orycteropus there is a form of plicidentine resembling that of Myliobates and Pristis, and in the extinct gigantic Sloth Megatherium there is both vasodentine and vascular cementum.

The Sloths have fewer teeth than the armadillos. Although the order are homodont, some of them have hints at a heterodont arrangement. Thus Cholœpus had an upper and lower tooth of caniniform type, though the upper one closed *in front* of the lower.

In all probability the Edentata are descended from ancestors that possessed a fuller dental formula, and whose teeth were covered with enamel; in fact, some observers have seen, in the case of *Tatusia peba*, suggestions of a specialization of the ameloblasts, and one writer has gone as far as to describe a thin, structureless material covering the tooth of this creature. It seems that this nine-banded Armadillo (*Tatusia peba*) is full of suggestions of the evolution of the Edentata generally; its specialized ameloblasts suggesting that the teeth have degenerated from a form where enamel was present, while its successional teeth infer that the Edentata have degenerated from diphyodont ancestors. It is unusual to find diphyodont succession in teeth of a homodont form.

The *Sloths* have the central portion of their dentine vascular, and this is specially noticeable in some extinct forms, as in Megatherium. Both the three-toed Sloth (*Bradypus*) and the two-toed variety (*Cholœpus*) have $\frac{5}{4}$ teeth, but in Cholœpus the front tooth, upper and lower, which is situated in the region where we should expect canines, is somewhat specialized. It is separated from the other teeth, and is very large and caniniform, the upper shutting *in front* of the lower when the mouth is closed. The extinct Megatheria, which were all huge animals, had deeply implanted teeth, prismatic in form and composed of hard dentine, with a central core of vasodentine, and each denticle surrounded by a casing of cementum. These tissues, wearing down at different rates according to their different hardness, provided a constant rough surface. Two very ancient forms, called Promegatherium and Promylodon, are interesting as possessing bands of enamel on their teeth, which suggests the possible descent of the whole family from ancestors whose teeth were coated with enamel.

The ancestral forms of the Edentata class were possibly omnivorous, and became gradually divided into vegetable feeders (Sloths) and animal feeders (Anteaters). Cholœpus, the two-toed Sloth, had the front tooth in both upper and lower jaws large and caniniform, and separated from the rest by a diastema, but worn to a sharp edge, and the upper tooth shutting in front of the lower. A similar interval between the first tooth and its neighbours is found in the extinct mylodon. The extinct armadillo Priodon possessed as many as 100 teeth altogether.

Sirenia and Cetacea

Both these orders of animals have so far become adapted to an aquatic existence that they possess many points of resemblance, and were at one time regarded as closely related. They belong, however, to different types of the mammalian class, and their resemblances are more due to the Fishlike life and surroundings common to both than to any immediate relationship.

Sirenia

The fore-limbs are paddle-shaped, the digits being covered with skin, adorned sometimes with rudimentary nails. The mouth is generally armed with incisor and molar teeth, separated by a wide interval. The genus rhytina, which has recently become extinct, was edentulous, while some extinct forms possessed a distinctly heterdont dentition, Halitherium having a milk dentition, of which existing sirenians have no signs. In existing forms the incisor region is covered by horny plates. They are all herbivorous. The Dugong (*Halicore*) and the Manatee (*Manatus*) are the only living representatives of the order, the Rhytina having been exterminated during the last century.

The *Dugong* has five or six molar teeth above and below, which are not, however, all in place at the same time, the first having disappeared before the last is erupted. They are of semipersistent growth, and are probably degenerating. The front part of the upper jaw bends down at an angle of about 45 degrees over the corresponding portion of the mandible, bearing two large, straight, tusklike incisors, partly coated with enamel on the front and sides, and bevelled to a sharp edge. In the male these tusks grow from persistent pulps, the greater portion being buried in a deep socket. In the female, though present in a rudimentary form, they never erupt, and the pulp cavity is soon obliterated and converted into osteodentine (*cf.* tusk of female Narwhal). In the young animal there is a small deciduous incisor—

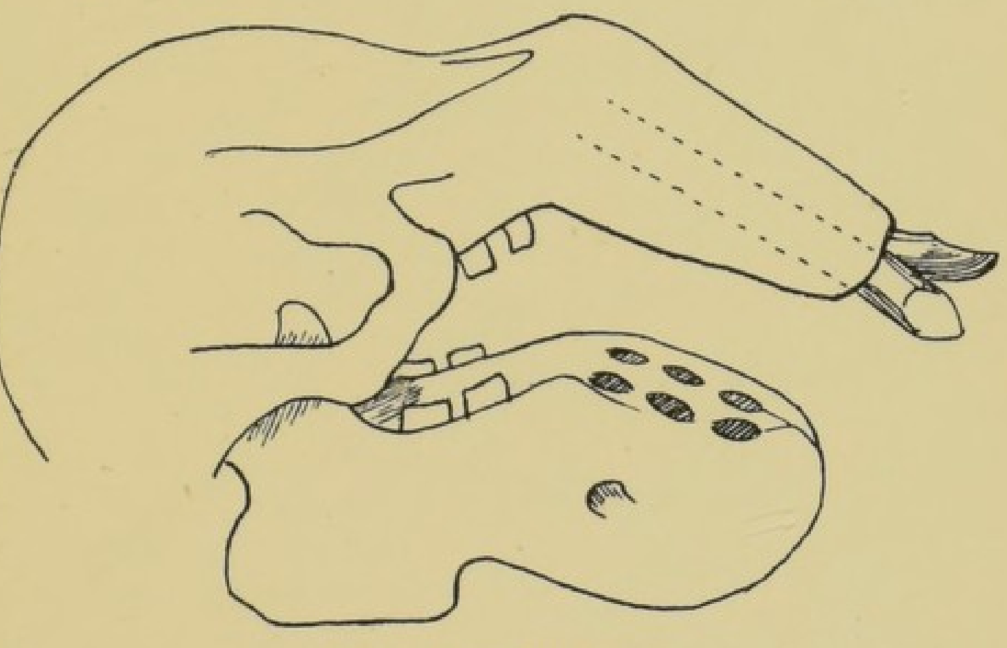


FIG. 58.—DUGONG.

The position of the sockets of the upper incisors is shown by dotted lines. The depressions in the upper surface of the front part of the mandible once contained abortive calcified teeth, which were covered by horny plates, and never erupted.

sometimes regarded as a rudimentary second incisor—on each side of the upper jaw. The front portion of the mandible, which is also deflected at an angle of 45 degrees, is covered by horny plates, under which, in the young animal, are four pairs of rudimentary conical teeth, lodged in wide sockets, which eventually become absorbed, but never are erupted or serve any useful purpose. The extinct Rhytina, though edentulous, possessed similar horny plates, as does the manatee.

The Dugong has no traces of nails in the fore-limbs. The molar teeth consist of ordinary tubed dentine, with a thin axis of vasodentine and a thick layer of cementum.

Manatee.—This creature has become interesting to the general public as the 'mermaid' of Aquaria. Its dentition consists of incisors $\frac{2}{2}$, rudimentary and covered by horny plates—these incisors do not erupt and become absorbed before maturity; molars about 44 ($\frac{11}{11}$ on each side) above and below; but as the front ones disappear before the

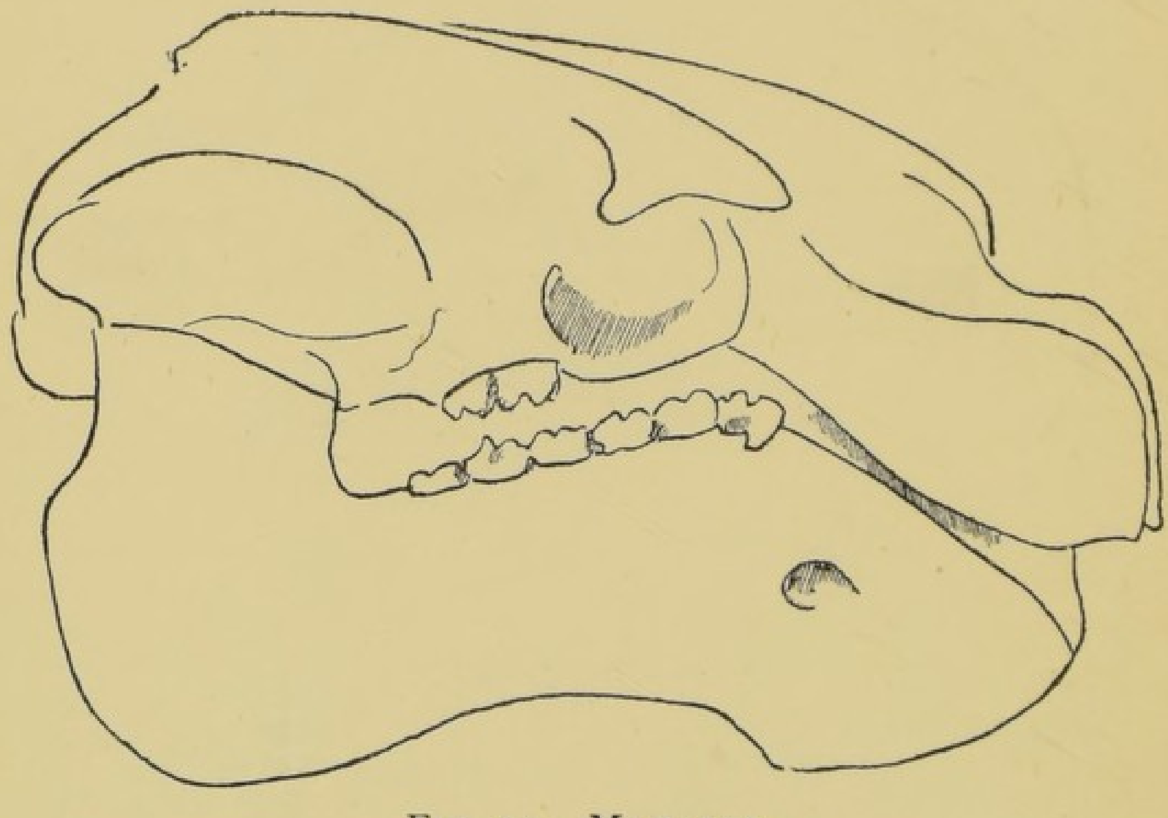


FIG. 59.—MANATEE.

back ones are perfected, there are only about $\frac{6}{6}$ in use at a time. They have enamel-covered crowns raised into transverse ridges, the upper with two ridges and three roots, the lower with three ridges and two roots. The ancestors of manatee are supposed to have had 3 incisors, 1 canine, and 3 premolars in each mandible, and traces of a milk dentition of i. $\frac{3}{3}$, c. $\frac{0}{1}$, m. $\frac{0}{3}$. Tomes has observed that the dentine is generally hard and unvascular, although traversed by a regular system of large vascular canals, abundant near the periphery. The tubes do not radiate from, or appear to be affected by, the presence of the vascular channels. The enamel has straight prisms.

The forward movement of the molar series, the fact of their being worn away and shed in front while they are being formed at the back of the series, their form and structure, and the situation of Dugong's tusks, all suggest proboscidean affinities, while in many respects recalling the dentition of Tapir.

Extinct Sirenians.—Halitherium resembled Dugong in dentition, but was less specialized. The tusks were smaller, the molars simple and single-rooted in front, three-rooted above, and four-rooted below at the back of the mouth. Prorastomus, a Tertiary fossil in Jamaica, had still more generalized characters—i. $\frac{3}{3}$, c. $\frac{1}{1}$, pm. and m. $\frac{8}{8}$. The incisors were small, and the canines (absent in living Sirenians) larger and enamel-coated.

Cetacea

These creatures are externally more Fishlike than the preceding class; they have no necks, and their teeth, when they possess them, are generally very numerous and very simple in form, and never preceded by a milk dentition. They are divided into the toothed Whales, or Odontoceti, and the whalebone Whales, or Mystacoceti. In the latter the teeth are replaced by transverse horny laminæ called *baleen*. Though living altogether in the water, they have to rise frequently to breathe, and the tail is therefore placed horizontally (in the same plane as the mouth) to assist the upward and downward movement, unlike that of Fishes, which is in a plane at right angles to the mouth. All the Whales are animal feeders: some feed on Fish and other denizens of the sea, both large and small; Orca, the killer Whale, sometimes spoken of as Grampus (from *grand poisson*), eating Porpoises and Seals and even Whales. Cachalot, the sperm Whale, is specially addicted to Cuttlefish, even the larger varieties.

The facts that certain extinct cetaceans possessed heterodont teeth, that rudiments of successional teeth have been found in Beluga and others, and that the abortive fœtal teeth of the enormous Baleen Whale Rorqual are not simple cones, but bifid in the middle and trifid at the back of the mouth, would seem to infer a heterodont and diphyodont ancestry for the Whales.

The *Mystacoceti*, or whalebone Whales, are chiefly distinguished by their plates of whalebone or baleen, which occupies the place, and to some extent serves the purpose, of teeth. Whalebone is a horny product of the epithelium of the oral mucous membrane, and is a sort of exaggeration of the transverse palatal ridges found in

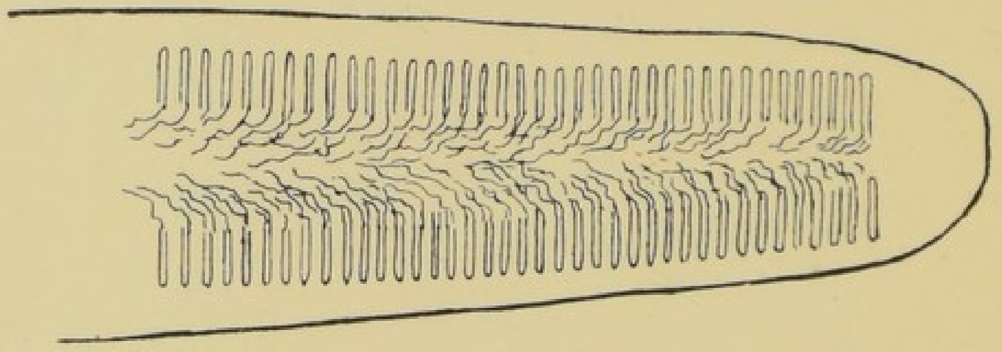


FIG. 60.—SHOWS THE ARRANGEMENT OF THE BALEEN PLATES.

all the Mammalia. Like these ridges, the 'plates' are transversely arranged on each side of the palate, inclining obliquely backwards at the outside. Each piece is roughly triangular, and attached by its broad end or base. The inner side of each piece is frayed out into countless threads, which form the straining apparatus. The plates are sometimes 12 or 13 feet long, and a single mouth may contain over 350. The plates grow from a dense fibrous and vascular matrix, which sends out thin processes into the base of each plate, and from these again threadlike vascular papillæ penetrate, and form the axes of the fibres of which the blade consists. Microscopically, each of these papillæ is coated with epithelial cells. The individual fibres are likewise bound together

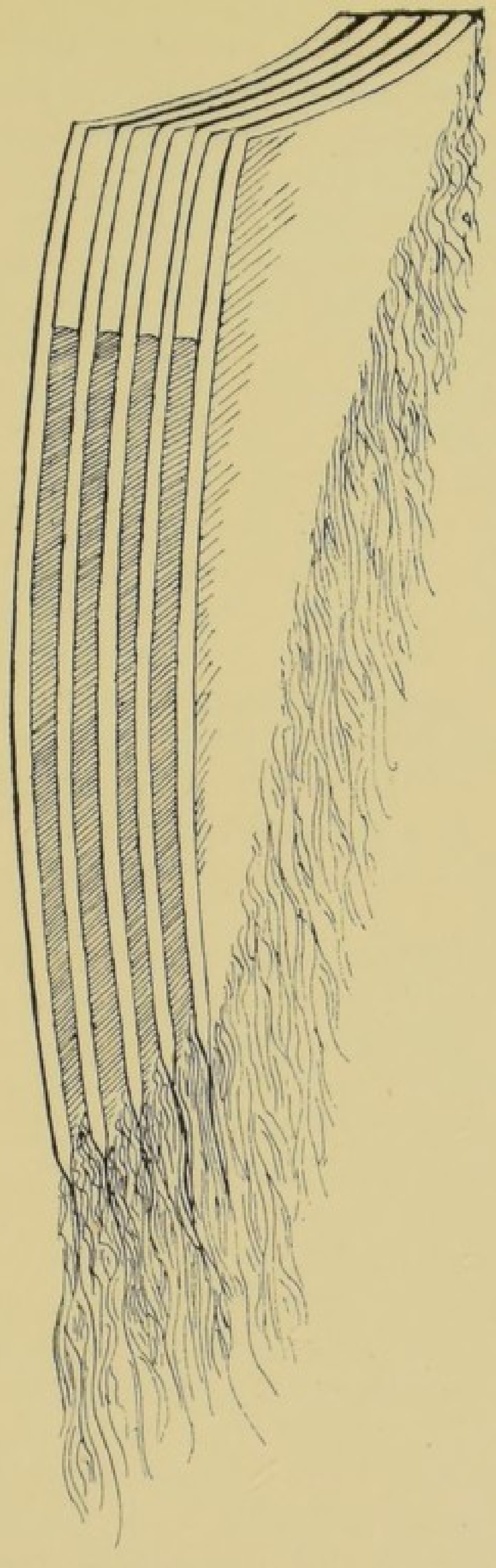


FIG 61.—SHOWS FIVE BALEEN PLATES CEMENTED TOGETHER AT THE TOP, AND ENDING IN A FRINGE ON THE INNER SURFACE.

by epidermic cells, which, presently disintegrating, allow the fibres to become free and form the fringe. Thus, the whole plate is only cornified, exaggerated buccal papillæ, cemented together for a space by epithelial cells, which, disappearing on the inner side, give rise to a fringe.

In the fœtal state these creatures possess rudimentary, abortive, calcified germs, which entirely disappear before birth. These germs are single in front, bifid further back, and trifid in the molar region.

Odontoceti.—The toothed Whales are not, with a few exceptions, very remarkable odontologically. As a rule, their teeth are numerous, simple cones, slightly recurved, and not preceded by a milk set. These teeth are mostly formed of tubed dentine, with tips or crown-coverings of enamel, and a root investment of cementum. The pulp cavities are eventually converted into secondary dentine. The dentine is noted for its concentric layers of interglobular spaces. Some extinct cetaceans possessed 350 to 400 teeth; the existing Dolphin has about half that number, while the Porpoise has half as many as the dolphin.

The *Physeteridæ*, of which the sperm Whale or Cachalot is a member, have twenty to twenty-five conical recurved teeth in the mandible, but no upper functional teeth, these latter being represented by abortive rudiments which never erupt or become functional. The lower teeth are implanted in a groove with imperfect septa. Cogia has two rudimentary upper teeth in front, and about ten each side in the mandible.

The *Ziphiinæ* have rudimentary non-erupting teeth in the mandible, except one, and rarely two, pairs, which are large, especially in the males; the upper jaws are edentulous. The pair of lower teeth curve upwards and inwards from their point of origin in what might be called the canine region, and arch over the upper jaw, so as eventually to cross each other above the upper jaw, and actually prevent it from opening properly. The advantage of this arrangement to the Whale, if any, has not been explained. The pulp cavity is eventually obliterated by rough osteo- and vaso-dentine. The last portion of the tooth to be formed is so indeterminate in structure that some authorities describe it as an anomalous dentine, while Tomes suspects it of being cementum. *Mesoplodon Layardii* is a good example of these peculiarities. At the end of each broad tooth there is a small pointed denticle, as shown in the figure.

In *Hyperoodon* the forward production of the jaws,

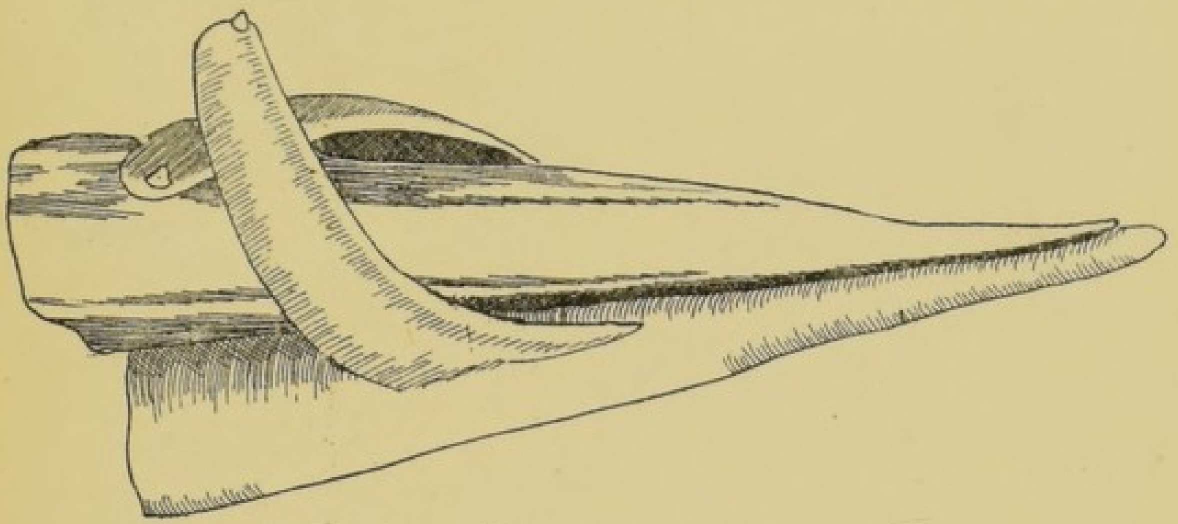


FIG. 62.—MESOPLODON LAYARDII.

Fig. 62 shows the front part of the skull of *Mesoplodon Layardii*. The tiny enamel-covered toothlet at the end of the great strap-shaped mass of osteodentine is like a little canine. The large straplike teeth arch over till they cross each other above the nose, as if to prevent the creature opening the mouth. The use and object of the arrangement is unknown.

coupled with the fact that the maxillary bones rise in a sort of forehead or crest, gives the appearance of a beak. There are two or four large enamel-covered teeth near the front of the lower jaw, and a dozen or so abortive rudiments in both jaws.

Among the *Delphinidæ*, the Narwhal presents a very curious and noteworthy dentition. Besides some irregular rudimentary teeth, this animal possesses in the upper jaw two spiral incisors, of which, in the male, one, usually the left, becomes enormously developed, sometimes attaining a huge length. The right incisor of the male usually remains rudimentary in its socket throughout life, though some rare museum specimens show that both *may* be developed in the same animal. In the female both tusks are rudimentary, and in the young animal there are traces of a second pair somewhat behind and on the outer side. The tusk is not covered with enamel.

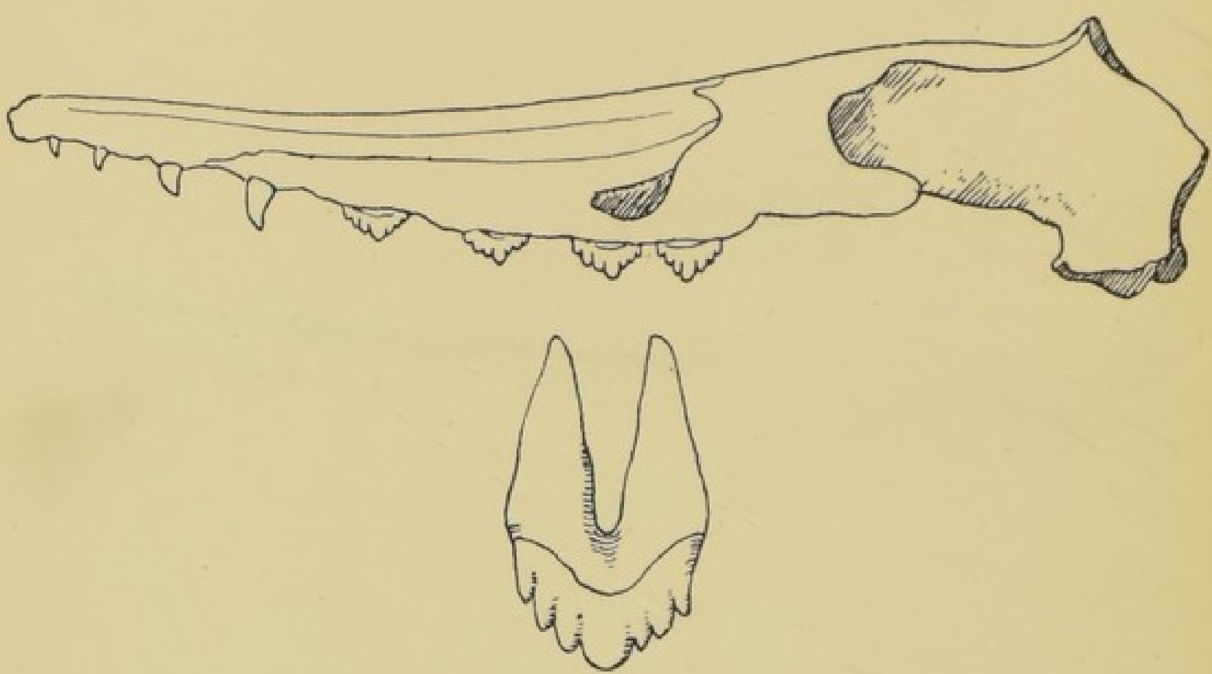


FIG. 63.—UPPER JAW OF ZEUGLODON, WITH ENLARGED TOOTH, TO SHOW THE YOKED SHAPE WHICH GIVES THIS WHALE ITS NAME.

Among extinct forms *Zeuglodon* had a formula of i. $\frac{3}{3}$, c. $\frac{1}{1}$, m. $\frac{5}{5}=36$. The back teeth had two roots and compressed crowns, with denticulated cutting edges, and a heterodont dentition. *Squalodon* had a somewhat similar dentition.

CHAPTER XI

UNGULATA

THE Ungulates, or hoofed animals, are all terrestrial, and almost all vegetable feeders; and though a few are omnivorous, none are strictly speaking predaceous, and all are heterodont and diphyodont. As a rule, the premolars and molars have two or more roots, and the more specialized the type, the less the size of the crown in proportion to that of the root. Those with short crowns are called *brachydont;* those with longer crowns, where the deep foldings of the enamel are lost to view, are called *hypsodont;* those with blunt, cone-shaped teeth are called *bunodont;* while those whose worn cusps are crescent-shaped are called *selenodont.* The order is divided into:

1. The *Artiodactyle ungulates—i.e.*, those with an even number of toes, no toe predominating in size, including cattle, deer, pigs, hippopotamus, etc.

2. The *Perissodactyle ungulates—i.e.*, those with an uneven number of toes, some one toe predominating in size, as horses, tapirs, rhinoceros, etc.

Many divisions of this order are provided with horns, and it is very unusual when this is the case to find the animal also provided with highly-developed canine teeth, the doubled weapon not appearing to be necessary. Throughout the class as now existing the vegetable diet is evidenced by the absence of canines, and sometimes of upper incisors, and by the full number, large size, and roughened surfaces of the premolar and molar series. The extinct ancestors of the modern ungulates possessed the full typical mammalian formula.

Artiodactyle Ungulates

These are divided into Bunodonts or Suina (Pigs and Hippopotamus), and the Selenodonts or ruminants (Camels, Sheep, Oxen, and Deer).

The chief points in which the modern artiodactyla differ from their ancestors of the Tertiary period are: the adoption of a bunodont or selenodont form of molar, gradual change from brachydont to hypsodont type, loss of the upper incisors, and development of canines into tusks.

Suina.—Hippopotamus has full typical formula, less two incisors. The front teeth grow from persistent pulps, and are very large, with slight sockets; the enamel covering is partial, longitudinal strips in the upper and caps in the lower teeth; the cutting edges are worn to a sort of chisel form. The pattern of the molars, when worn, resembles a double trefoil. Existing forms are only found in Africa, but in Pleistocene and Pliocene periods these creatures were spread over all Europe and Asia. There are extinct forms with incisors $\frac{3}{3}$, in one of which, *H. Palæindicus*, the outer pair are very small and plainly disappearing. In still earlier forms the three incisors are of equal size.

Pigs have the full formula of 44. The outer incisors are small. The canines are large and three-sided, enamel-covered on the outside, and grow from persistent pulps. The upper canines curve upwards, and the lower ones do the same, but with a wider sweep, until the inner surface of the lower tooth rubs against the outer anterior surface of its upper antagonist, with the result that the mutual friction creates a smooth, sharp-edged opposing surface on each tooth. These canine tusks are greater in the male than the female, and their growth is arrested by castration. The molar series increase in size from before backwards; this increase is very marked in the wart-hog, the last molar being greater in surface than all the other molars and premolars put together. There is no sexual difference of size in the tusks of the Wart-hog (*Phacochœrus*). In *Sus babirusa* the upper canines, which are destitute of enamel, form an immense arch, reaching back almost to the animal's eye. The formula is reduced to 34, one incisor above and two premolars above and below being missing. The use of these monstrous weapons is unknown, but must have reference to sexual warfare, as the male creatures alone possess them. Probably they were once useful, and were then kept in check by wear, but are now, under changed conditions, unnecessary, and hence monstrous; a Beaver's or Rabbit's incisor will grow in much the same way if the opposing tooth be removed.

Suidæ.—The Peccaries (Dicotyles) differ from the Pigs in wanting incisor 3 in the upper and premolar 1 in both jaws. The upper canines point downwards, and have sharp back edges. A Pleiocene animal, Hyotherium, is a generalized form allied to both Pig and Peccary.

Anoplotherium, an extinct Eocene animal, appears to have possessed a very generalized character. Its forty-four teeth were of uniform height (as in Man alone of existing mammals), arranged in an unbroken series, with no diastema. The crowns of the molars were selenodont. It had a long and powerful tail, and either two or three toes on each foot.

In *Oreodon*, another Eocene ungulate, the fourth tooth from the front in the upper jaw was caniniform and large, but there was a large caniniform tooth in the mandible which was *fifth* from the front, and bit behind the upper canine, and was therefore a specialized first premolar. This peculiarity should be compared with a similar arrangement in the Mole.

Selenodont Artiodactyla.—The *Camels* (Tylopoda) and *Llamas* have the following dental characters in common: They have the full number of upper incisors in youth, of which the outer pair alone persist; the lower canines stick up somewhat, though the incisors are procumbent;

the molars are selenodont and hypsodont, but the anterior premolars are simple cones. These animals, in many respects so obviously related and yet so widely separated geographically, are united through an extensive generalized ancestry, whose existence has been brought to light in very recent years by Leidy, Cope, Marsh, and others. Thus a gradual series of change may be traced, going from old to older deposits, till an ancestral type is reached common to all the Artiodactyla. Thus Plianchenia (a Pliocene llama) had three lower premolars, Procamelus four, while the Miocene Protolabis had the full formula.

The ruminant Artiodactyles present many interesting features. Sheep, Oxen, Antelopes, Deer, in common with Camels and Chevrotains, 'chew the cud,' or ruminate. Their stomach is divided into four distinct compartments, the last of which is the scene of gastric digestion, and performs the work of the human organ. The first compartment, or paunch, receives the food immediately after it has been swallowed, and there a softening process takes place, after which the bolus is regurgitated into the mouth, where it is submitted to the process of mastication by the molar teeth before being finally swallowed and digested. Another feature of interest in this group is the possession of horns. The Ungulata are the only animals that possess horns, and this remarkable feature of the class obtains an added interest for the odontologist from the fact that, excepting in the case of a few deer, these weapons to some extent take the place and perform the functions of excessively developed canine teeth, so that it is a very rare exception among living things to find specialized canines and horns coexisting. There are two kinds of horns among the Ungulata, which at first sight appear wholly distinct—namely, the hollow horns of cattle and Antelopes and the solid horns of Deer. The former are hollow masses of cornified epithelium, resting upon a bony protuberance from the forehead ; they are persistent throughout life, and are often found in the female animal as well as in the male. The latter are solid, bony-excrescences shed once a year, and, with the exception of the Reindeer, peculiar to the male animal. A more careful observation shows, however, that the difference is one of degree, and not one of kind, and, though in extreme cases the relationship may be hard to trace, the apparent differences are due to the fact that though the bony base and its epithelial covering enter into the formation of both kinds of horn, in the hollow-horned creatures it is the epithelial portion that attains great specialization, and in the solid-horned deer it is the bony or subepithelial tissue that plays the more important part. Thus in the Rhinoceros the epithelial structures are exaggerated into what is practically a mass of matted and cornified hair resting upon a bony base. In the Giraffe a pair of bony excrescences, at first separated from, and afterwards anchylosed to, the skull, are covered by ordinary skin. In the Antelopes the bony core is surmounted by a horny mass of modified skin. In the Deer the bony core is itself exaggerated and sometimes branched ; this is at first covered by a layer of skin technically known as velvet, which is eventually torn off, leaving the horn proper of bare bone, which is itself eventually shed. In the extinct Sivatherium it has been supposed that a link between the two arrangements existed, as his posterior pair of horns, of which the bony cores were branched, were most likely invested with a horny sheath which were not shed. It is also true that the primitive forms of some animals, of which the living representatives are provided with horns in both sexes, show that once only the males possessed these appendages, and that the females have obtained them by inheritance. Apparently only Artiodactyles have prospered with paired horns, Perissodactyles so armed having had but a comparatively short existence.

Most of the Ruminants, solid or hollow-horned, lack the upper incisors and canines, having the formula, i. $\frac{0}{3}$, c. $\frac{0}{1}$, pm. $\frac{3}{3}$, m, $\frac{3}{3}$. In the place of the upper front teeth there is a tough pad of thickened gum, between which and its lower incisors the animal tears the grasses on which it feeds. Three members of the Cervidæ have well-developed upper canines—the musk deer (*Moschus*), Swinhoe's water deer (*Hydropotes*), and the Indian muntjac (*Cervulus*).

I am assured by a friend who has observed the animal in the act that the Muntjac employs his long upper blade canines in dividing the jungle grass with a backward mowing action; also that without such an apparatus it would be impossible for so light a creature to effect a passage through the jungle at all. The absence of these teeth in the female would suggest that they are also used in sexual warfare.

The premolars of Ruminants are like the molars, only smaller and simpler in form; the milk dentition is well developed, and the cementum covers the entire tooth, and in course of wear comes to occupy all the interstices between the folded enamel of the denticles.

Perissodactyle Ungulates

So called because the middle digit is pre-eminent; sometimes, as in Rhinoceros, the second and fourth digits are present, but subsidiary; sometimes, as in Tapir, the fifth is also present; sometimes, as in Horse, the middle or third digit is all that remains. The living representatives of the suborder are Tapir, Rhinoceros, and Horse. The teeth are generally lophodont, and more rarely bunodont. The formula is generally nearly complete, and in the horse, if we regard the small tooth which is early lost from the canine region as a permanent tooth, actually so. The Tapir is one premolar short in the lower jaw, while the formula of Rhinoceros is rather obscure, owing to the rudimentary and ephemeral character of the incisors. Tomes gives i. $\frac{?}{?}$, c. $\frac{0}{1?}$, pm. $\frac{4}{4}$, m. $\frac{3}{3}$.

The Perissodactyles, like the Artiodactyles, are mostly vegetable feeders, and in both the premolar and molar series increase in size as they go backwards; in both the ever-broadening surfaces are kept constantly rough by the interlacing of the enamel pattern surrounding islands of dentine and surrounded by seas of cementum. These patterns are constant to each creature, and as a rule more complicated in modern forms than in the ancestral types As fresh discoveries of lost or extinct intermediate forms are made, it becomes more and more interesting to attempt to trace the gradual evolution of such a complicated labyrinth as the upper molar pattern of the modern horse. As the brachydont molar of the older type became elongated into the modern hypsodont form, and the folds of enamel deepened and involved, something like the following changes in surface pattern may be supposed to have taken place. Let us imagine first four denticles fused together so as to form a quadritubercular bunodont molar; it is plain that a little wear would cause a pattern of four rings of enamel—two outer and two inner. If the two outer cusps were joined by the deepening wear, and then the internal and external cusps united in the same way, something like the small printed letter 'n,' or, in dental jargon, a bilophodont condition, is arrived at; such a form is shown in the molar tooth of Tapir (Figs. 1 to 8). If the line of union between the external and internal cusps be crescentic, with the rounded side forwards, the molar of rhinoceros is suggested, and if the posterior horns of the posterior crescent run together, there is the condition in molar 1 of Rhinoceros. Just before these points join, the two original outer cusps lean a little towards the inner ones, so that the outer line is no longer straight, but rather like the letter W, as seen in the upper molar of *Palæotherium magnum*, while the same arrangement in a less marked degree is seen in *Rhinoceros antiquitatis* (right upper molar). When the anterior crescent merges in the front part of the posterior on its internal side, or, in other words, the internal cusps join, two islands of cementum are imprisoned, and an inner tubercle and a little irregularity of outline give us the well-known pattern of the Horse's molar.

The incisor of the Horse is peculiar in being invaginated or having a deep pit in its cutting surface, which, of course, adds to the roughness and utility of the worn tooth ; this pit or ' mark,' as it is called, is filled with débris of food, and gradually wears away altogether ; it is not so deep in the lower as in the upper teeth. The mark disappears by wear soonest in the centrals (between six and seven years old), which are earliest cut, in the second incisors between eight and nine, and is altogether gone at twelve years old. The molars of Horse, though very long, do not grow from persistent pulps coincidently with the elongation of the molar teeth and the increasing complexity of surface pattern ; the Horse's genealogical tree shows the gradual disappearance of all the toes but one, the third. In Eocene times Orohippus had four toes, of which the third was longest and biggest, just like the modern Tapir. The Miocene Miohippus had three—the predominant one in the middle—just like the modern Rhinoceros. In Pliocene times these lateral digits had become, in pliohippus, nearly as rudimentary as in the modern Horse. The changes in the root and crown of molars and toes are graphically shown in a plate on p. 414 of Tomes' ' Dental Anatomy,' 1898.

Subungulata

Allied to the *Ungulata vera* are a number of families, most of them extinct, whose exact place in relationship to existing orders is not easy to assign. Fresh discoveries are daily being made, chiefly in South America, but at present it will be sufficient in an elementary work like this to notice a few general points of interest. Among the various groups it will be noticed that strange and almost monstrous specializations have arisen, and that these extreme forms have not prospered. Possibly the special environment which rendered such forms convenient has never been, geologically speaking, of long duration, and the more extreme the specialization, the less capable it is of adaptation to new or changed surroundings ; and the possession of unwieldy weapons which were no longer required must have handicapped the race of creatures in the general struggle for existence, and doomed them slowly but surely to extinction.

Hyracoidea.—This suborder has been relegated to a place by itself, owing to the puzzling nature of its affinities. Its molar and premolar teeth, of which it has the full number, resemble in pattern those of Rhinoceros, with whom it was at one time classed. Its upper incisor is of a rodent type—a large curved tooth of persistent growth, triangular in section, with the apex of the triangle pointing forwards; the anterior surfaces are enamel covered. The two lower incisors have 'straight, procumbent, awl-shaped, and trilobed' crowns, but do not grow from persistent pulps. The outer lower incisors are large, the inner ones small.

Dendrohyrax has a molar pattern like that of Palæotherium.

There is a wide diastema between the incisor and premolar teeth. Hyrax is the 'coney' of the Bible.

Proboscidea.—Of this once varied and widely distributed suborder only one member survives—namely, the Elephant. This survival of an ancient type presents many interesting dental characteristics. Allied to many groups, yet differing widely from all, the Elephant combines a highly specialized dentition with some anatomical signs of a simple, early, and generalized type. Certain extinct forms from South America appear to point to a close relationship between the true Proboscidea and some primitive type of Ungulata. The Proboscidea derive their name from the long flexible nose or proboscis at the end of which the nostrils are situated. They possess huge incisors of persistent growth, never more than one pair in each jaw, and generally only in one jaw; no canines; large molars of more or less complicated transverse ridge patterns, increasing in size towards the back of the mouth. The incisor teeth or tusks are slightly curved upwards in Elephant, very much so curved both upwards and outwards in Mammoth (*E. primigenius*), and almost straight in Mastodon. The tusks have milk predecessors, which are early shed. The mass of the tusk consists of fine tubed dentine, which is called in trade ivory, and is specially elastic, because of the fineness of the calibre of the tubes and their very flexuous course ; it contains only 60 to 64 per cent. of lime salts, and nearly twice as much organic matter as human dentine. Ivory is also remarkable for the concentric rows of interglobular spaces which traverse its substance, as in certain cetaceans. The chemical composition of the molar dentine does not resemble that of the tusks, but is more like that of human dentine. The tusk is first formed with an enamel tip, and coated with cementum ; the latter wears away when the tooth is erupted, and the enamel cap does not last long. The African Elephant has larger tusks than the Indian variety. The pulp cavity in the adult animal does extend into the erupted portion of the tusk, but in the implanted portion the walls gradually become thinner as the area of formation is approached, so that bullets, spear-heads, etc., have often entered the growing pulp through the thin walls, and been carried forwards with the growing mass until they have come to occupy the central part of a solid mass of ivory. The female animal has much smaller tusks. The tusks of Mammoth are found in great quantities in the frozen mud of Siberia, and form a considerable item in the ivory trade.

The functional molar teeth of Elephant are six in number on each side, above and below, with one rudimentary one in front of the series, generally regarded as three milk and three permanent teeth. They are formed at the back of the jaw, and gradually move into place forwards and downwards ; thus the front portion of each tooth is in use while the back part is still unerupted. The front members of the series are shed as their successors advance to take their place, so that only two teeth are in use at one time. These teeth consist of several united denticles or plates of dentine, with a common pulp cavity coated with enamel, and the whole mass embedded in cementum ; the plates are transverse, and are, when first formed, prolonged into little cusps. The teeth increase in size from before backwards; thus in the Indian Elephant (which has more plates than the African) the molars have in order about 4, 8, 12, 14, 16, and 24 plates each. To thoroughly understand the eruption, form, and variety of proboscidean molars the

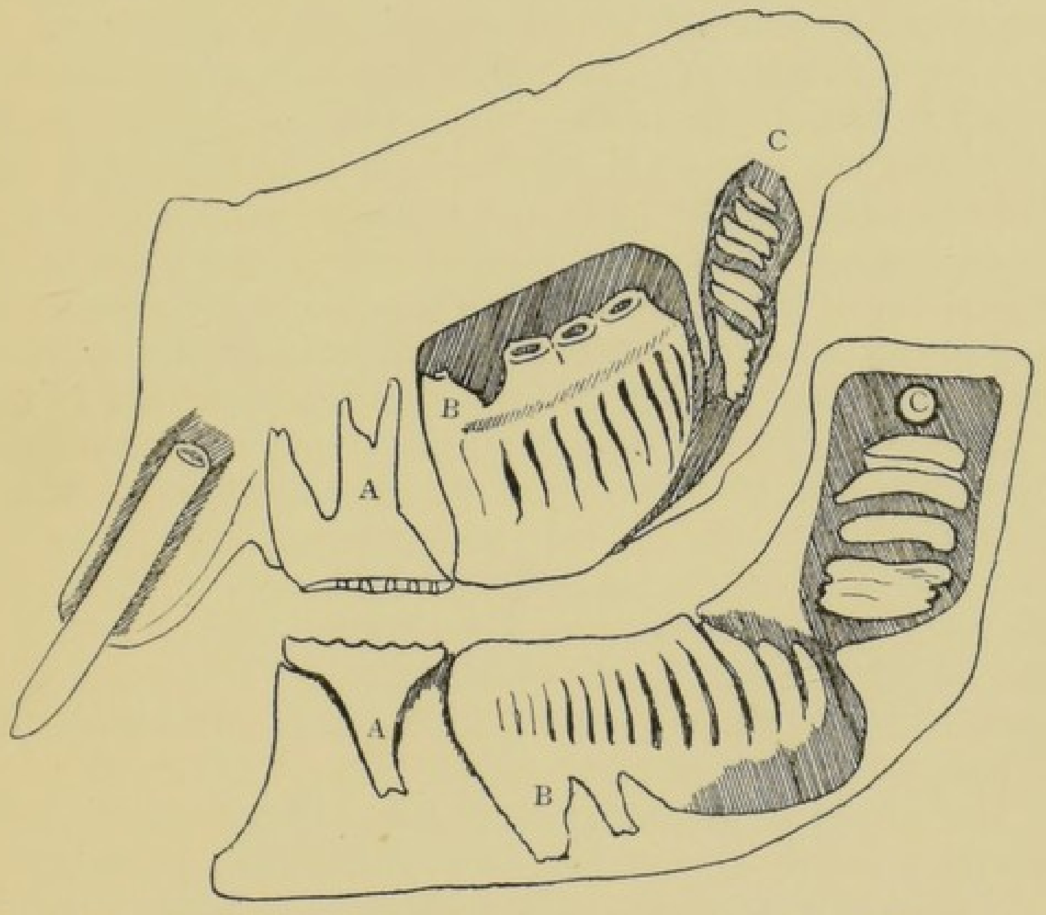


FIG. 64.—SHOWING THE DEVELOPMENT OF THE TEETH OF A YOUNG ELEPHANT.

A, A are the penultimate milk molars; B, B are the ultimate milk molars; C, C are the coalescing plates of the antepenultimate molars. The indicating letters are of necessity placed a little away from the object, but all the plates in the shaded crypt will presently coalesce to form the antepenultimate or first molars.

student should take his Tomes' 'Dental Anatomy' to the British Museum in Cromwell Road, and read the description with the specimens before him.

Extinct Proboscideans.—The evolution of the complicated molar of the modern Indian Elephant becomes more simple when considered side by side with the molars of his ancestors. Thus in Dinotherium, which had a vertical succession, the cusps were short and thick and the plates few. In Mastodon the plates increase in number; in the modern African species the increase in number and length of the cusps becomes greater, while in Mammoth and his Indian descendant the length, narrowness, and individual complication of the plates go on increasing. As the common pulp chamber recedes further from the surface it is reached more slowly by the process of attrition; thus in Mastodon and the modern African Elephant the wear gradually shows lozenge-shaped islands of dentine surrounded by enamel, which eventually run together in the middle line; in mammoth and the modern Indian variety the deepest wear only discloses narrow transverse islands, while the earlier stages, when only the tips of the cusps on each plate are laid bare, shows a transverse series of rings (see Figs. 9-18, pp. 16, 17). Dinotherium had no upper incisors, but only a lower pair, which bent downwards. Mammoth (*E. primi-genius*) had huge upper incisors, but no lower ones. These upper incisors curved upwards and outwards in a gigantic double curve, and sometimes attained a length of 15 to 18 feet.

Mastodon, a later Tertiary animal, possessed rudimentary lower incisors and huge straight upper tusks.

Amblypoda or Dinocerata were a remarkable race of huge Ungulates recently discovered by Marsh in the Eocene formations of Western North America. They were as big as Elephants, but not possessing trunks. Their foreheads were ornamented with three pairs of bony protuberances, possibly surmounted by horns of Rhinoceros type; their dental formula was $\frac{0}{3}, \frac{1}{1}, \frac{3}{3}, \frac{3}{3} = 34$. The upper canine was a huge curved, sharp tusk laterally compressed, similar in form and position to that of Moschus. These tusks were smaller in the female. The brain-case of these creatures was disproportionately small.

Toxodontia.—These creatures existed most likely from

Miocene to Pleistocene times. Their zoological position is hard to define, as they have points of resemblance with the Ungulates, the Edentates, the Rodents, and

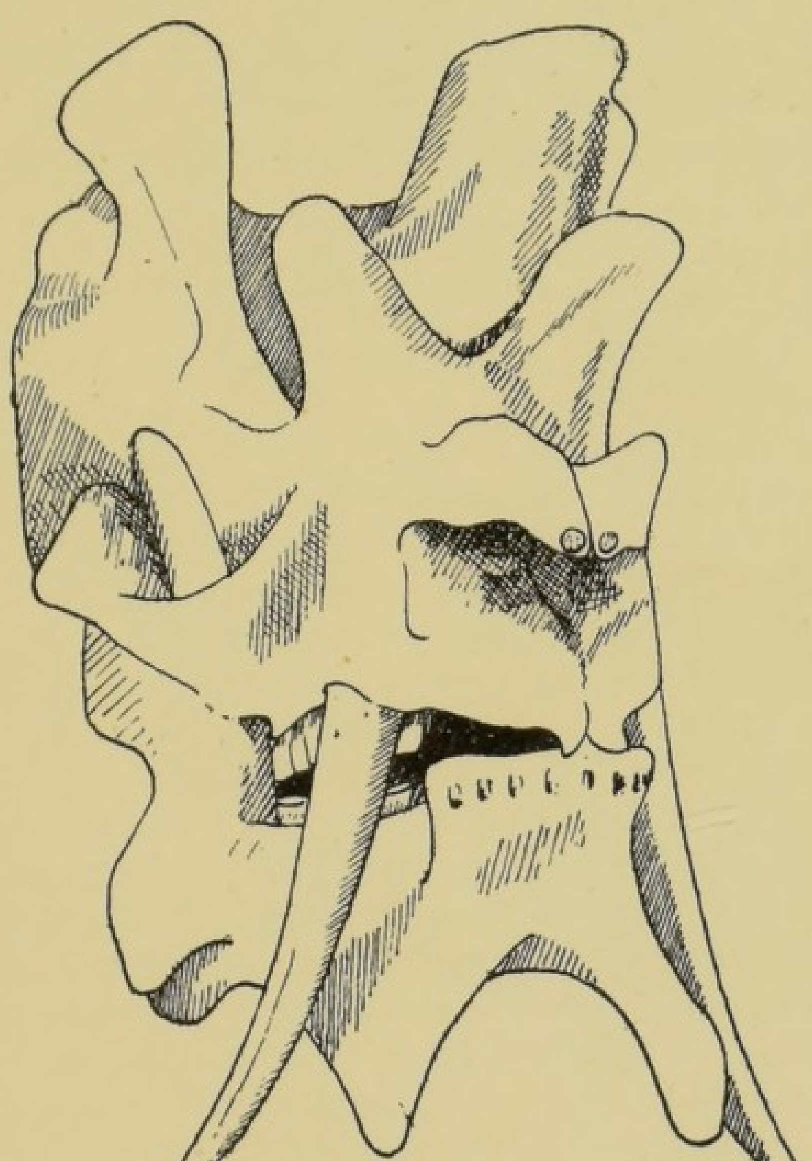


FIG. 65.—SKULL OF DINOCERAS.

This shows a front view of the skull of Dinoceras, one of an extinct division of mammals known as amblypoda. The six horn-cores are very peculiar, but more so still are the combination of herbivorous cheek-teeth and such an alarming tusk. This weapon was about 12 inches long, and half-way down shaped like a modern sword-bayonet, and yet the creature is not supposed to have been carnivorous. The reader will recall a somewhat similar canine in a water-deer, and will note that, on the authority of an Indian sportsman who has frequently witnessed the performance, I have stated that the deer in question uses his canines principally as scythes to free his way through the tangled brush.

the Hyracoidea. Toxodon was as big as a large Rhinoceros. The skull is rather equine in appearance, and it possibly possessed a short trunk. The formula, as given by Beddard, is i. $\frac{3}{3}$, c. $\frac{0\text{-}1}{1}$, pm. $\frac{4}{3\text{-}4}$, m. $\frac{3}{3}$. The teeth grew from persistent pulps, and the molars arched over; whence the name toxodon, or bow-shaped 'tooth.' The incisors were somewhat of a rodent type, prismatic

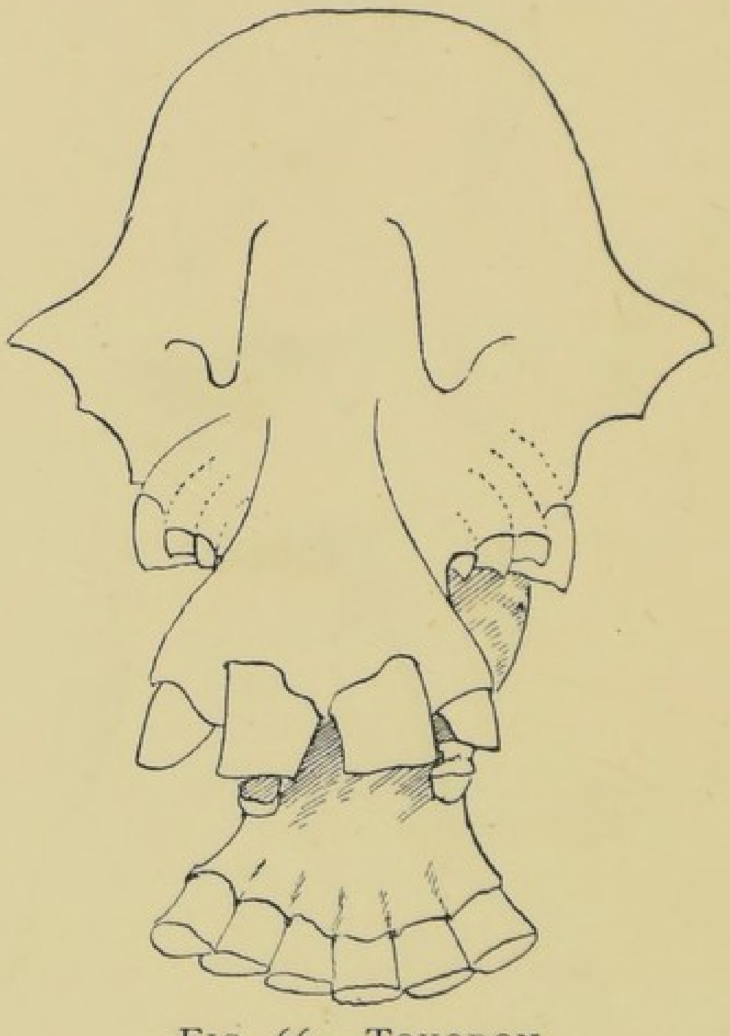


FIG. 66.—TOXODON.
The dotted lines show the curving of the molar roots.

in shape, and partly enamel coated. The molars also had a partial investment of enamel.

Nesodon was about the size of a Sheep, and had the full eutherian formula, the molar pattern recalling that of Rhinoceros. Typotherium, in appearance and dentition, resembled Capybara, but possessed two lower incisors.

CHAPTER XII

RODENTIA

THE most distinctive characteristic of the order of Rodents is their dental armature. They are mostly small animals, and are distributed all over the world, and, partly owing to their small size, their more or less nocturnal habits, and their general adaptability to any circumstances and almost any diet, have thriven and multiplied in any place where they have found a habitat, as has been strikingly illustrated since the introduction a few years back of Rabbits to Australia. Rodents never have canine teeth, but they possess an upper and lower pair of highly specialized incisors, growing from persistent pulps, covered on the outer surface with enamel, and sharpened by mutual wear to a chisel edge, and called for this reason scalpriform. The roots of these incisors often reach far back in the jaw beneath the cheek teeth. The molar series vary from two to six above and below on each side. Some families, as the Muridæ, are monophyodont, and have no milk dentition at all, while others, as the Rabbit (*Leporidæ*), have three milk molars. The latter animal has a milk incisor in the upper and lower jaw. It is a curious fact that so specialized a dental arrangement as rodent incisors have been evolved in the island of Madagascar among the Lemurs (Cheiromys), and in the continent of Australia among the Marsupials (Wombat), where no indigenous rodents existed, and where circumstances of isolation by wide tracts of sea render it very difficult to imagine any common ancestry with the old-world rodents. Similar necessities of diet and surroundings have apparently produced similar dentitions by separate lines of evolution.

The great incisors are often stained a reddish yellow on the outer surface, and this stain is found in the unerupted portion of the tooth. Where the incisors are wider than they are thick the gnawing powers are

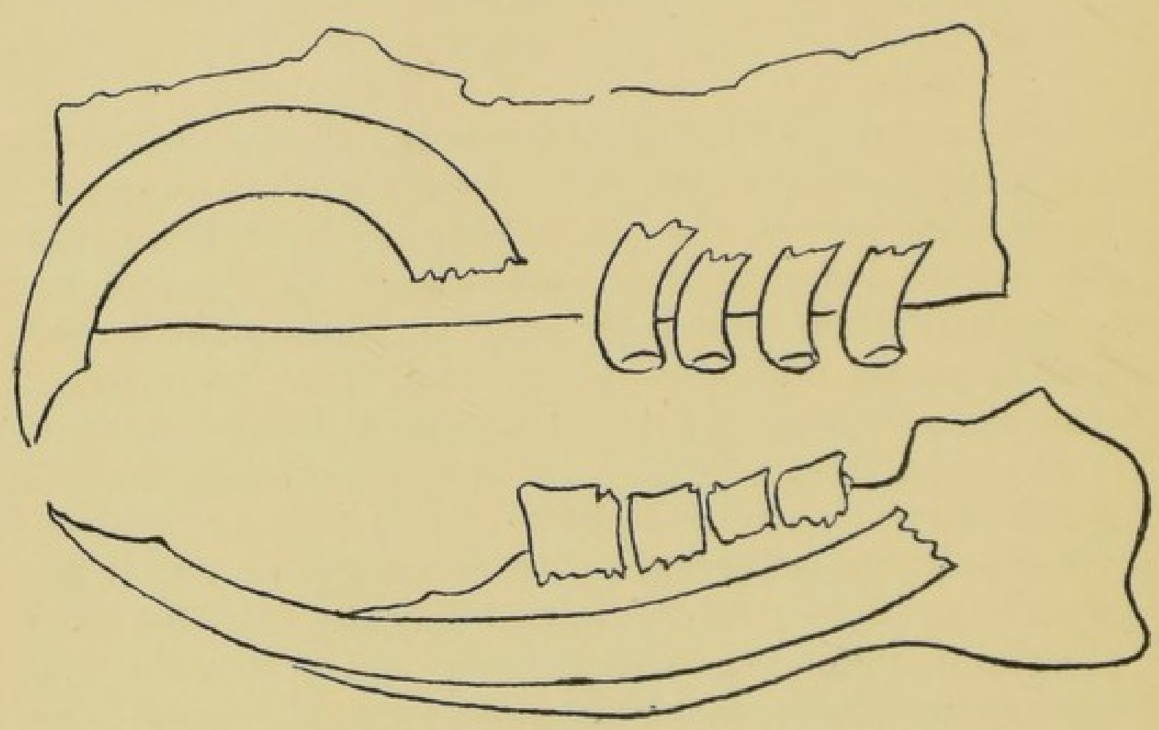


FIG. 67.—UPPER AND LOWER JAWS OF RODENT.

Fig. 67 shows in outline the arrangement of teeth in a typical Rodent. The toxodont shape of the molars should be noted.

feebler, and where they are thicker than they are wide —*i.e.*, where the antero-posterior diameter exceeds the lateral, the gnawing power is strongly developed. The molar series vary from two (Hydromys) to six (Rabbit), but the usual number is four. They are either bunodont or lophodont, and wear down to patterns often very complicated and distinctive, the complicated molar of Capybara recalling, on a small scale, the Elephant's molar.

The incisors are used for many purposes that have no direct reference to alimentation, and the buccal cavity is divided into two chambers by a hairy ingrowth behind the incisor region, which prevents the chips and fragments produced by the gnawing process from getting into the alimentary canal. The Rodents are divided into Simplicidentata, or those with one pair of upper incisors, and Duplicidentata, or those with an additional second smaller pair behind the big one. The enamel of Rodents is divided into two layers, except in the Leporidæ. These layers are formed by the sudden bending of the prisms at a point about a third of the thickness of the enamel mass. On the inner side of this point the fibres of alternate layers often pursue opposite directions, so that when two or three layers are seen together a sort of criss-cross pattern is produced, while in the outer portion they all run parallel. In the Porcupines the individual fibres are wavy as well. It has been stated that there are tubes in the enamel of Hares which do not communicate with the dentinal tubes, but in Jerboa they apparently do. The variations in the enamel patterns of Rodents are sufficiently constant and marked to render it possible to identify the species from a section of incisor enamel.

In Rodents of mixed diet, such as Rat, the molars have closed roots; in others, as Capybara, the molars, as well as the incisors, grow from persistent pulps, the surfaces being kept constantly rough by the mingling of the various tissues. These persistent molars are always curved, so that the pressure does not act directly upon the forming pulp.

Among living Rodents are animals of infinite variety of habits, many burrowing like the Marmots and Rats; some aquatic, as the Voles, or Water-rats, and the Beavers; some arboreal, as the Sciuridæ or Squirrels; while Anomalurus and the flying Squirrels (Pteromys) possess an arrangement of the integument which, acting somewhat after the manner of a parachute, enables the animal to 'fly' or glide through the air a distance of 80 to 100 yards.

It will be observed that among existing Rodents some have additional abortive incisors and brachydont molars, while in unborn Leporidæ there is a third pair of upper incisors, which are soon lost. These facts become doubly interesting when we consider the dentition of some extinct Eocene mammals called *Tillodontia*, whose dentition throws light upon the evolution of the modern Rodent.

The incisors in these animals were large, of persistent growth, and enamel coated on the outer surface, and in the later forms the first and third pair have disappeared; but in Esthonyx, the earliest known form, all three incisors are present in the upper jaw, but only two in the lower; it is even doubtful if the large incisors grew from persistent pulps, probably they did not. Anchippodus preserves traces of the upper first pair of incisors: incisor 2 is large and of persistent growth, incisor 3 has disappeared; while Tillotherium, the most recent form, possessed a typical rodent dentition. In all the canines are present, though in Tillotherium they are very small. It is therefore obvious that the large rodent incisor, where only one is present, is incisor 2.

Carnivora

This order consists mostly of fierce predaceous animals of flesh-eating proclivities, provided with a dental armature suited to their mode of life, and adapted to the purity or mixed character of their flesh diet. The incisors are, as a rule, pointed, six in number above and below, arranged in a straight line, small in the middle and increasing in size towards the canine region. The canines are very large, pointed, and slightly recurved teeth, the lower biting in front of the upper, so that there is an interval or diastema between the last upper incisor and the upper canine for its reception. The flesh diet necessitates the action of tearing and slicing the food rather than grinding, so that we find the premolar and molar series reduced in number and modified in shape; the inner tubercles have almost disappeared, and the outer ones have been exaggerated into trenchant blades. This specialization of the back teeth is particularly conspicuous in the fourth premolar in the upper jaw, and its antagonist, the first molar, in the mandible. These teeth are called 'carnassial' or 'sectorial' teeth. In pure flesh feeders the teeth behind these carnassial teeth are poorly developed or altogether absent; in the more mixed feeders they are broader and more tuberculated. Thus in the Felidæ the upper fourth premolar has very little inner tubercle, but the three outer cones rise into laterally compressed pinnacles, the middle one being the largest; in the dogs and bears these points are not so marked. The lower carnassial or first molar in the Felidæ has only two bladelike cusps of fairly equal size, so that the whole crown, viewed laterally, recalls the shape of the capital letter M, the V-shaped space between the two receiving the large middle cusp of the upper fourth premolar. In the dog this tooth has two additional smaller cusps, while in the bear the second cusp (or protoconid) loses its pre-eminence, while No. 4, the 'talon' or hypoconid, rivals it in size. The roots of all these teeth are closed, and vary in size and number according to the developments of the crown which they support. In the British Museum Natural History Department at Cromwell Road are several models in which the homologies and evolution of these parts are shown, the various cones being differently coloured to render their study easier. As a rule there are no teeth of persistent growth among the carnivora, the single exception being the tusks of the aquatic member of the order, the walrus, and these cease to grow in old age, when the pulp cavity becomes obliterated. Existing Felidæ show a reduction of the back teeth, as represented by the formula $\frac{3}{3}$, $\frac{1}{1}$, $\frac{3}{2}$, $\frac{1}{1}$, the upper molar being so insignificant that it hardly counts as a tooth. Among extinct Carnivora there are remains which show a still greater specialization; thus among the sabre-toothed tigers, or Machærodonts, *M. næogeus* had only two upper premolars, while smilodon had a still further reduced series, $\frac{3}{2}$, $\frac{1}{1}$, $\frac{2}{1}$, $\frac{0}{1}$, the upper molar having altogether disappeared. These extinct monsters were about the size of tigers, and possessed enormous upper canines, laterally compressed, with sharp, sabre-like posterior edges; whence their name. These tusks were so long that when the animal's mouth was closed they descended far below the lower jaw, which was flattened to allow of their passage. What the environment of such a race can have been to render such weapons advantageous is doubtful; whatever it was it did not last long geologically speaking, and with its disappearance these fearful monsters that it had called into existence became extinct. One interesting fact, however, remains, that though the specialization of Machærodus is so extreme, and its existence on the earth's surface so comparatively brief, it nevertheless was geographically very widely distributed. Remains have been found in many parts of England, in Germany, France, Italy, South America, and in the Siwalik Hills in India; also this, the most extreme of carnivorous types, occurred as far back as Eocene times.

The order *Carnivora* are divided for convenience into the Terrestrial Carnivora, or *Carnivora fissipedia* (with divided toes), and the Aquatic Carnivora, or *Carnivora pinnipedia* (web-footed). The first division comprises:

1. *Æluroidea*, or catlike Carnivora, including *Felidæ*, the true cats, *Viverridæ*, the civets, and *Hyænidæ*, the hyenas, among whom may be placed Proteles, the Aard wolf of South Africa.

2. *Cynoidea.*—Dogs, wolves, and foxes.

3. *Arctoidea.*—Bears, Mustelidæ or weasels, Procyonidæ or racoons.

The second division, or *Carnivora pinnipedia*, must be regarded as having branched off from the terrestrial Carnivora, and having acquired, together with aquatic habits of life, certain anatomical distinctions, dental and other.

Carnivora Fissipedia.—This group of mammals, though presenting always a type of dentition suggestive of predaceous habits, vary greatly in the intensity of their specialization, and though isolated instances may be quoted, such as the flesh-feeding Arctic fox and the herbivorous Italian fox, whose dentition is indistinguishable (Tomes), yet the general rule holds good that throughout the series the mode of life and diet are indicated by an appropriate dentition. Thus the bears

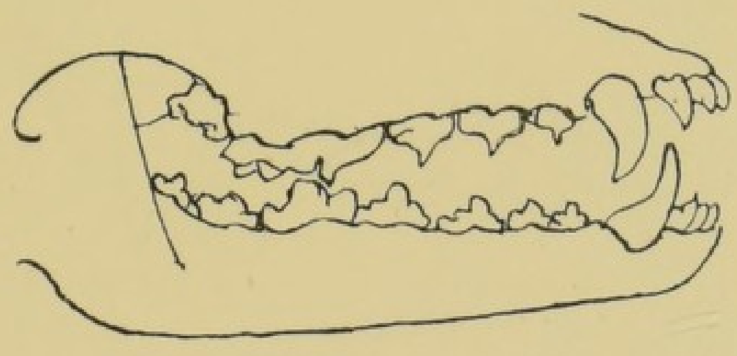


FIG. 68.—DOG (CARNIVORA FISSIPEDIA).

have a fuller molar and premolar formula than the true cats ; moreover, the back teeth are broader and flatter, to suit the mixed diet. The hyenas have very stout and strong teeth, in both jaws suited to the crushing of bones and dismembering of carcases killed by fiercer and bolder beasts, while the pure Felidæ have large, sharp canines, and slicing instead of grinding back teeth. The larger and sharper the upper canines, the more predaceous is the animal, and the more the snap of the jaws in seizing the prey is required, the greater will be the development of the temporal muscle, and consequently that of the coronoid process of the mandible ; coincidently the zygomatic arch will be wide, to allow the requisite space for the huge temporals to contract. The

8

shock of this act of seizing a living, struggling prey requires a very solid setting for the temporo-maxillary joint; hence in pure flesh feeders the condyle of the lower jaw is a transverse rod fitting into a transverse tunnel (the glenoid cavity) on the temporal bone. The strong masseters, which assist in the operations of slicing performed by the carnassial teeth, are inserted into solid bony masses in the mandible. The straight row of six incisors help to tear the flesh from the bones. In such

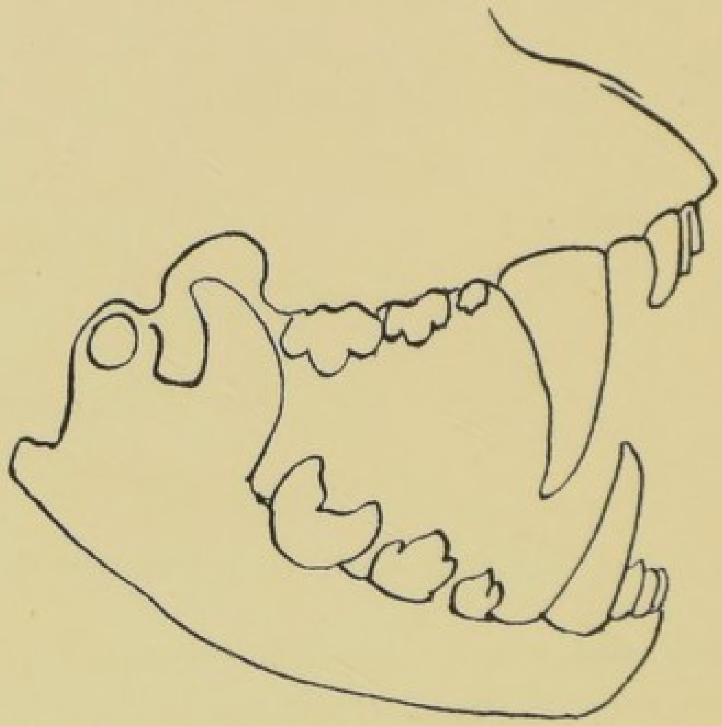


FIG. 69.—TIGER (CARNIVORA FISSIPEDIA).

skulls (examine an adult tiger's skull while reading this) lateral movement is impossible and undesirable, so the external pterygoids are insignificant, and the external pterygoid plate reduced to a mere spicule of bone; the joint is a pure hinge. A glance at the huge external pterygoid processes and flattened glenoid cavity of a ruminant will form an instructive contrast. Now let us consider the peculiar adaptation in the case of the extinct carnivore Smilodon, to take an extreme case. For a long time it was supposed that this creature's upper canines were so long that he could never open his mouth wide enough to use them, and this grotesque idea has actually been elaborated into the quaint suggestion that Smilodon and the Machærodonts generally became extinct because they *were literally handicapped out of existence by their huge tusks!* Some writers have suggested that they used the tusks with their mouths shut,

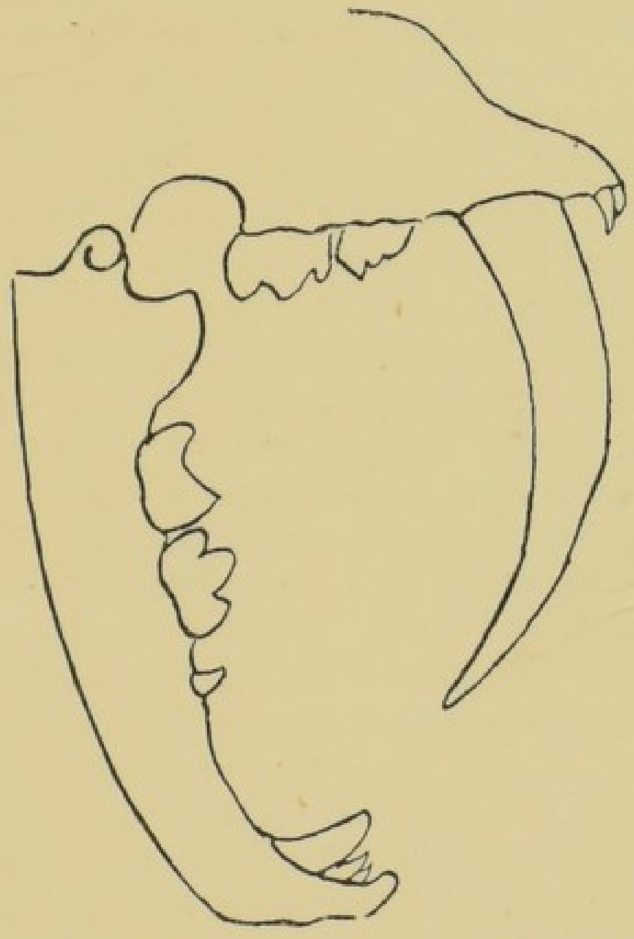


FIG. 70.—MACHÆRODUS (CARNIVORA FISSIPEDIA).

others that they employed them for climbing trees, and others that they were aquatic creatures, and used these weapons after the manner of Dinotherium. There is no reason to suppose they were aquatic; moreover, the sharp points and razor-like posterior edge of these canines would have led to many an awkward tumble in any arboreal exploits. It has been recently shown by W. D. Matthew (' Memoirs of the American Museum of

8—2

Natural History,' 1902) that these extinct carnivores *could* open their mouth so far that the under surface of the mandible touched the chest, that the upper canines were used for piercing the pachydermatous hides of their contemporary ungulates, and, by dividing the great vessels, causing their prey to bleed to death. The sterno-cleido-mastoid muscles were greatly developed, so that the striking was done with the mouth wide open ; moreover, the coronoid process and condyle and angle of the mandible were *reduced* in size, as were the *lower* canines. The decrease in size of the muscles of closure was accompanied with a reduction in the molar and premolar series. These animals had short massive fore-legs, and their lower jaw opened beyond a right angle. They were probably not swift of foot, neither were their unwieldy prey. The disappearance of these monsters coincided with the disappearance of the thick-skinned, slow-moving perissodactyle ungulates on which they preyed. There were many varieties of them, Smilodon representing the extreme specialization, the Machærodonts, Hoplophoneus, and Archælurus becoming gradually less specialized, until in the immediate progenitors of the modern Felidæ we find the premolar series and the lower canines becoming more developed, the upper canines shorter and thicker, the sterno-mastoids less powerful, and the muscles closing the jaws more so ; while in the hyenas, whose ancestor Hyænodon had a full formula, stumpy strength takes the place of sabre-like sharpness, and in the bears crushing and grinding is added to the raptorial or seizing development of the canines. The Aard wolf of South Africa (Proteles) is peculiar for the abortive and widely separated character of his cheek teeth. Among the Canidæ it is noticeable that long snouts are often attended with supernumerary teeth, and in Otocyon, a foxlike creature, there is a formula of 46 to 48 teeth. Among the Civets there is a subfamily Eupleres, with small canines and canine-like anterior premolars, and a molar series of insectivorous type. Another member of the group, Cynogale, is partially aquatic, short-tailed, and web-footed.

The Bears (*Arctoidea*) have blunt, non-retractile claws and blunt canines, while the molars and premolars are broader and more adapted to trituration of food than those of their more carnivorous relations. In the Otters (*Lutrinæ*) we find an interesting feature—namely, a carnivorous family in the act of becoming, as it were,

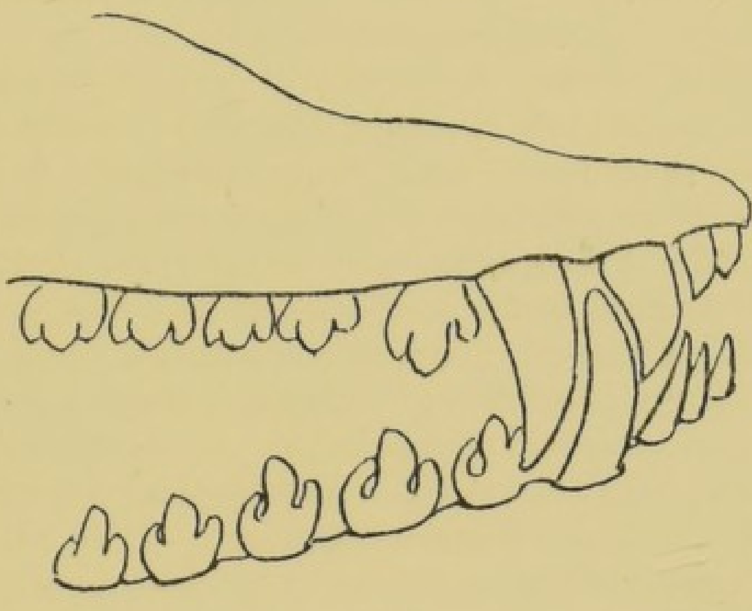


FIG. 71.—LEOPARD SEAL (CARNIVORA PINNIPEDIA).

The varying sizes and shapes of the canines should be noted, also the numbers and shapes of the cheek teeth.

It will be seen that the sabre-toothed tiger has his mouth open, so as to allow the use of the great upper canine.

aquatic. The Sea-otter, whose dental formula shows a loss of a lower incisor ($\frac{3}{2}, \frac{1}{1}, \frac{3}{3}, \frac{1}{2}$), possesses webbed hind-feet, and progresses on land by a series of short springs, reminding us of the movements of a seal; the tail is flattened and short, the molar teeth are compressed and blunt, the ears are small. This creature is becoming gradually more and more aquatic, seeking refuge from the fur-hunter by abandoning the shore as a breeding-place, and living and breeding on masses of floating sea-weed far out to sea.

Carnivora Pinnipedia.—The Seals, Sea-lions, and Walruses are undoubted carnivora, which, while in many anatomical points displaying a common origin with the Arctoidea, have by a long aquatic existence acquired fishlike developments, which cause them to resemble in external configuration the great families of aquatic mammalians, the Sirenians and Cetaceans. In the one case herbivorous, in the other carnivorous, groups have become gradually aquatic in their habits, and, in varying degrees, have become fishlike in form.

The digits become webbed and the limbs shortened, until paddles or even fins take the place of feet and legs. The nails disappear, and the phalanges increase in number. The milk dentition becomes feeble, and is shed earlier in the Pinnipedia, just as in the Cetaceans the milk dentition is more pronounced and the permanent enfeebled. There is a tendency towards a homodont and monophyodont condition. The back teeth appear to be increasing in number, a change due to the division of the existing teeth (Kükenthal). The incisors of Pinnipedia are nearly always reduced in number. The external ear, which is small in the sea-lions, is absent in seals, while the hind-limbs of the former are not so useless for land progression as in the case of the latter animals. What is called the 'ursine lozenge' in the cerebral structure as well as the lobulated form of the kidney, are distinctive of the Bears and Otters among terrestrial Carnivora, and both distinctions are shared by the Pinnipedia.

The *Otariidæ* (sea-lions) have a habit of rattling shingle in their mouths, and producing a form of attrition round the teeth which is, I think incorrectly, termed erosion. The Walrus has huge upper canines, sometimes 30 inches long, which exist in both sexes, and are used for progression as well as combat. The milk formula is generally given as $\frac{3}{3}$, $\frac{1}{1}$ pm. and m. $\frac{5}{4}$, and the adult formula as $\frac{1}{0}$, $\frac{1}{1}$ m., $\frac{3}{3}$, but observers are not quite agreed upon the point.

CHAPTER XIII

INSECTIVORA AND CHIROPTERA

Insectivora

It is sometimes supposed that up to the end of the Secondary period the mammalian class were insectivorous, and that the carnivora did not make their appearance until Tertiary times. It is at any rate certain that existing Insectivora represent a very ancient order of creatures, which has remained comparatively unaltered in its dentition for a very long period. In common with other survivals of early times, such as the Marsupials, the Edentates, and the Cetaceans, the Insectivora possess a more or less rudimentary milk dentition, the Shrews having only seven rudimentary milk teeth, which never become functional. The permanent teeth often present the full mammalian number, forty-four, and the molars are of a trituberculate type. They are mostly *small* and *nocturnal* creatures, 'Two circumstances which may have had something to do with their survival from past ages, as may have also their modification to so many and diverse modes of life; for everything points to the antiquity of the group' (Beddard). Geographically, they are very widely distributed, ranging over the whole world, with the exception of the Australian continent and parts of South America. Their teeth are strong, well-developed, and heterodont, though much confusion has arisen in their classification, owing to some members of the group possessing caniniform premolars with two roots, the lower tooth biting *behind* the upper antagonist, as in the mole. The mole seems to have treated the rules of the naturalist with unkind disregard, as he appears to have four lower incisors, the fourth, which should have been tall and caniniform, remaining insignificant and incisor-like, while the tooth behind it, which has two roots, and ought to have been like a first premolar, is specialized into what is to all intents and purposes a canine! The extinct ungulate, Oreodon, must have conspired with the ancestor of the Mole to lay this trap to bewilder the classifier of modern times. Mesonyx, an Eocene Insectivore, had large canines biting in the ordinary way, trituberculate molars and very simple premolars. From such simple early types it is easy to fancy the elaboration necessary to evolve either a carnivorous or an insectivorous type of dentition. While in many Insectivores the milk dentition is feeble and more or less functionless, in some, as the Tenrec (*Centetes*) of Madagascar, the Elephant-shrew (*Macroscelides*) of Africa, and Tupaia, a squirrel-like, oriental creature, it is well developed. Galeopethicus, a creature whose skin is extended between the limbs and body, so as to enable it to perform the same sort of aerial flight as the flying squirrel, has been sometimes classed with the Lemurs and sometimes with the Bats, but is now regarded as an aberrant Insectivore. Its milk molars are in use at the same time as its true molars, which fact has been used as an argument in favour of regarding the true molars as the end of the milk-set. Its lower incisors are divided by a number of longitudinal grooves into a sort of comblike mass, quite peculiar to itself.

The Shrews have very specialized incisors, curved and pointed, with, in the upper, one, and in the lower more than one, additional sharp cusps. The long, somewhat procumbent lower incisor encases the lower jaw at its base.

The molar teeth of the order are covered with pointed cusps, sometimes many, arranged in a pattern like the letter W, sometimes fewer, arranged like the letter V.

In some families the dentinal tubes penetrate the enamel (Tomes), especially in the Shrews. In Galeopethicus there is no penetration, but a marked granular layer in the outer layer of the dentine.

Chiroptera

The Bats are peculiar among mammals in having their fore-limbs developed into true wings. The bones of the hand are prolonged to an immense length and tenuity, the middle phalanx and metacarpal bones being nearly twice as long as the radius or ulna. Over these bones the skin is stretched so as to form a wing. The hind-legs are abortive and small, and only used to hang to a branch while the animal sleeps, head downwards. The Bats are of varied habits as regards diet, and are divided into insectivorous, frugivorous, and sanguinivorous groups, armed with appropriate dentitions ; but though at one time, on account of certain structural peculiarities, they were classed among the Primates, it is now customary to regard them as a very aberrant offshoot of the Insectivora. The milk teeth do not resemble their permanent successors in form ; they are slender, sharp, recurved cusps, and are usually shed early, sometimes even before birth, while occasionally they persist until the permanent teeth are in use. The permanent teeth vary much in form, as might be expected from the varying character of the diet of the different groups, but they always have distinct roots. In the Insectivorous groups the sharp-pointed cusps of the cheek teeth, arranged in the 'W' pattern, are common, while the frugivorous forms often have longitudinal grooves and hollows, and the blood-sucking Bats have a special arrangement of the upper incisors. Although they present a low type of brain development, the sense of touch is marvellously acute, so much so that by its means alone these animals, when deprived of the senses of sight, hearing, and smell, can yet avoid threads hung about a room in which they are flying. Some species are provided with curious expansions of the skin of the nose surrounding the nasal apertures, and known as the 'nose-leaf.' This nasal appendage is accompanied by a special development of the superior maxillary division of the fifth pair of nerves, the whole forming an elaborate and highly perfected organ of touch comparable to the complicated organ of hearing by which sound-waves are collected and appreciated. Although fossil forms are found in deposits of the Eocene period, they are true Bats, and not transitional forms, and give no hint of the origin of the order.

Bats are divided into the *Megachiroptera*, or big Bats, of frugivorous habits, and the *Microchiroptera*, or small Bats, mostly insectivorous, a few being frugivorous and a few sanguinivorous, or blood-sucking.

The *Megachiroptera*, or frugivorous Bats, have generally a formula of $\frac{2}{2}$, $\frac{1}{1}$, $\frac{3}{3}$, $\frac{3}{3}$; the incisors are small, the canines large. The *Microchiroptera* have often an additional lower incisor and upper premolar. One variety, Pteralopex, of the Solomon Islands, has additional cusps on the canine, recalling the insectivorous canine.

In the true blood-suckers or Desmodont division the formula is reduced to $\frac{1}{2}$, $\frac{1}{1}$, $\frac{2}{3}$, $\frac{1}{1}$ or $\frac{0}{0}$. The upper incisors are very large and trenchant, and fill all the space between the canines; the premolars are long, flat, and sharp, and the molars diminutive or absent. They are the only known mammals that subsist entirely on a diet of blood. The sharp incisor inflicts a wound like that caused so frequently in shaving, and the blood is drawn off from the exposed capillaries. *Desmodus rufus* is a typical example. The incisors, though broad and sharp, are raised towards the middle line into two extremely sharp points, giving the exposed part, when seen from the front, a sort of triangular shape; the canines are long and sharp, the premolars small, and the molars absent. The intestinal openings are of very small calibre, too small to admit the passage of solids, and the stomach is shaped much like the rest of the intestine, excepting for a diverticulum at the cardiac end.

CHAPTER XIV

PRIMATES

It is a little difficult to decide quite satisfactorily the limits of this order. Once upon a time the Bats were included in it, and still the Lemurs are generally admitted, though in many respects, especially when viewed together with fossil forms, bearing a closer affinity to the Insectivora, while, at the other end of the list, Man, with his pre-eminent cerebral development, seems almost to demand an order to himself. Still, it must be remembered in connection with such difficulties that, if we really could obtain specimens of each gradation in the course of ages of evolution, the relationships would so gradually diverge in the genealogical tree of living things, and so imperceptibly shade off from one intermediate form to its nearest neighbour, that, though extreme varieties would differ as profoundly as we see them do now, there would be no possibility of drawing the line of classification, because there would be no place to draw it. It is only the presence of gaps in our chain of life—our ignorance, in fact, of intervening periods of natural history—that makes classification possible, and every added fact and fresh discovery will tend to confuse rather than to define groups. The classifications do not *exist* as binding laws upon the animal world. They simply represent the attempt to point out the differences between extremes where the connecting links are missing.

At present we agree to include the Lemurs, the Monkeys, and Man in this great and highest group of all, though some authorities would like to separate off the Lemurs.

'The number of primitive characters seen among the Primates, even in Man himself, is remarkable' (Beddard); yet if we consider that in the case of this order the process of evolution has progressed, as it were, in the direct line greatly because of the adaptability—that is, in the general as contrasted with the special type of the ancestral forms—and, further, that at no period have monstrous specializations sprung up to meet unusual phenomena of environment, specializations that, when the circumstances that called them into being have passed away, rendered their possessors unfitted for the struggle of existence in new surroundings—when we consider these facts we shall expect and not be surprised to find early Eutherian characteristics common in this highest development of Eutherian life. Thus the five digits in both limbs, the plantigrade walk, the presence of clavicles, etc., are relics of a peculiarly adaptable ancestry; and it is adaptability which confers longevity upon a type. When we come to Man we find the struggle for existence is gradually more and more carried on by cerebral rather than by physical development, and it is in the direction of the brain rather than in that of the teeth and limbs that evolution is progressing; in fact, these primeval weapons begin to show signs of a retrograde change.

The dentition of Primates is diphyodont and heterodont, the formula being pretty generally $\frac{2}{2}$, $\frac{1}{1}$, $\frac{2}{2}$, $\frac{3}{3}$. The series seems in a fair way to be further reduced in man, the last molar in civilized races showing, by its late and capricious eruption, its tendency to appear dwarfed and misshapen, and its not infrequent suppression, that it is no longer a quite regular member of the series, while the second upper incisor or lateral is also beginning to follow suit, so that civilized man of the future has been assigned a formula of $\frac{1}{2}$, $\frac{1}{1}$, $\frac{2}{2}$, $\frac{2}{2}$ = 26. The molars are usually larger than the premolars, and the last molar, except in civilized man, the largest of all.

Lemuridæ.—This suborder is very ancient, and was widely distributed at the beginning of the Tertiary period. They are now only found in the island of Madagascar and some parts of Africa and Asia. Their dentition varies, like that of the Bats, according to their varying diet, presenting insectivorous, carnivorous, frugivorous and, in the aberrant Aye-aye, markedly rodent types. The upper incisors are generally small, the lower long and procumbent; the upper canine pointed; the lower first premolar caniniform and biting behind the upper canine; the premolars and molars sharp cusped and laterally compressed. In some fossil forms the lower caniniform tooth bites *in front* of the upper. The procumbent lower incisor only needs increase of size and depth of socket to approach the rodent type.

This dentition is fully attained in the case of Chiromys (Aye-aye), whose enormous upper and lower incisors, in form, structure, and development, out-rodent the rodents themselves. Its great incisor development is attended by a coincident reduction in number and size in the rest of the series, the formula being $\frac{1}{1}$, $\frac{0}{0}$, $\frac{1}{0}$, $\frac{3}{3}$ = 18. The lower incisor tooth consists largely of enamel. There are two milk incisors, the deciduous formula being $\frac{2}{2}$, $\frac{1}{0}$, $\frac{2}{2}$, all very small.

Extinct Forms.—A number of extinct Lemuroids have been discovered lately in Europe and America, of very generalized form, so generalized that it is a moot point whether they are nearest to the Lemurs or to the Insectivora. Some of these animals were of large size, Megaladapis having a skull as big as that of a tiger. In most of these fossils, which belong to Eocene times, the dental formula was much fuller, Adapis having $\frac{2}{2}$, $\frac{1}{1}$, $\frac{4}{4}$, $\frac{3}{3}$. Its lower canine was a well-developed tooth, biting in front of its upper antagonist; the lower incisors have upright crowns. The generalization of these forms warrants the belief that they may have been the common ancestors of both Lemurs and Monkeys.

Anthropoidea.—This group includes all the rest of the Monkeys and Man. As its name implies, all the members of the group bear a more or less striking resemblance to Man. In all of them the cerebrum or brain begins to overlap and conceal the cerebellum. There are two great divisions of the ape world—the *Catarrhine*, or old-world Monkeys, and the *Platyrrhine*, or new-world Monkeys. These names are indicative of the position

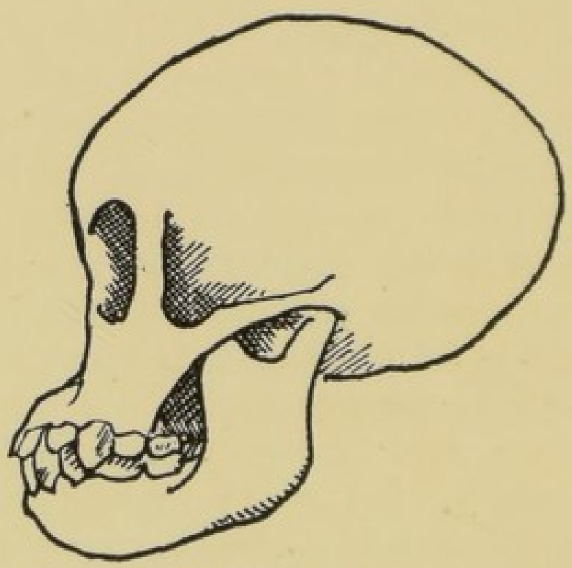


FIG. 72.—SKULL OF YOUNG ORANG-OUTANG. (AFTER BEDDARD.)

These four figures (Figs. 72, 73, 74, and 75) show the alterations in prognathism and in the facial angle of which the text speaks.

of the nostrils, which in the old-world varieties look *downwards* and are close together, and in the new-world types are lateral and separated by a broad septum. The Catarrhine monkeys have, like Man, a formula of $\frac{2}{2}, \frac{1}{1}, \frac{2}{2}, \frac{3}{3} = 32$. The new-world kinds have an extra premolar above and below—$\frac{2}{2}, \frac{1}{1}, \frac{3}{3}, \frac{3}{3} = 36$. The Catarrhines have either no tails, like Man, or if they have these appendages they are never prehensile. The Platyrrhines have prehensile tails. These divisions appear to be of very ancient date, no fossil forms of an intermediate or annectant type having been described, so that naturalists have suggested that the two divisions were diphyletic, or evolved from separate stocks, and not from an immediate common generalized ancestry; remains of both are found as early as the middle Miocene period. At present all the apes are found in tropical or subtropical regions; the wider distribution of prehistoric times may mean simply a wider tropical region, not a more adaptable form of ape.

All the Anthropoidea have their eyes so placed that

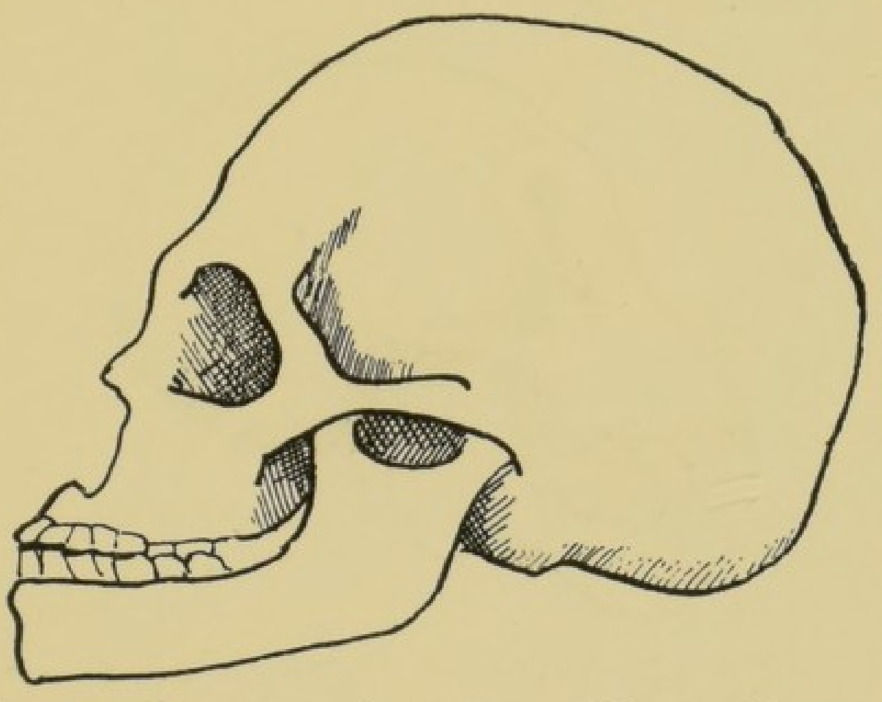


FIG. 73.—SKULL OF AUSTRALIAN NATIVE FEMALE. (DRAWN FROM THE SKULL.)

they look forwards, and though they are occasionally closer together, they are never relatively farther apart than in man. The ears are large, sometimes pointed; a relic of this point exists in Man, who possesses a soft pendant lobule, of which a rudiment exists in Gorilla. The nose is sometimes wide and flat, sometimes long and pointed, and occasionally, as in Hoolock, quite aquiline. The lips are thin except in Orang. The pollex is most like that of Man in Chimpanzee, and Man alone has his great toe longer than the other toes. Many apes have flat nails, and all the order are completely covered with hair. In Man this covering is very slight except in certain parts, of which the male beard is a good instance. Many Apes possess beards, and long hair is found on the head in several varieties. The proportion of the size of the brain-case to the size of the face is a fair index to the position of the animal in the scale of intelligence, though in the case of Gorilla it is somewhat masked by the huge superciliary ridges of the adult male, while in smaller varieties of ape the necessary brain space gives a somewhat misleading proportion.

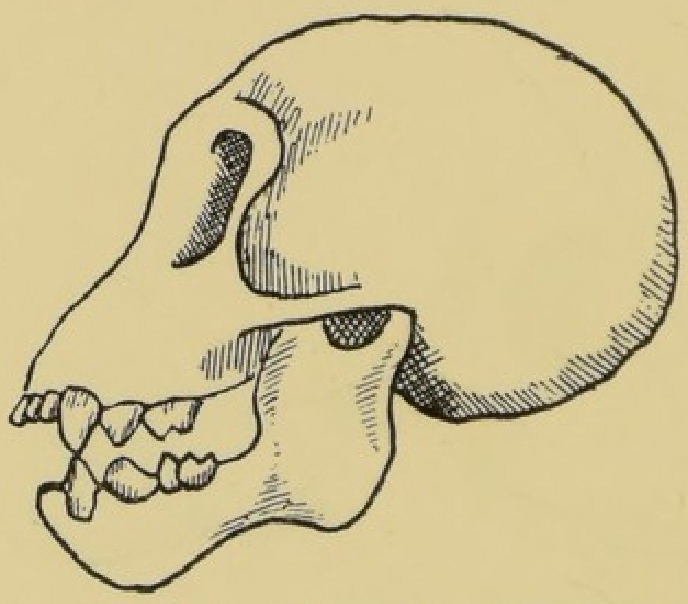


FIG. 74.—SKULL OF YOUNG GORILLA.

Among the old-world apes the lateral incisors are generally smaller than the centrals; the canines are large, pointed, and come into position last of the series (in the male)—*i.e.*, after the third molars; in the female they follow the second molar, but precede the third. The premolars are often three-rooted, and the first lower premolar sometimes looks like a smaller canine, and sometimes, as in the baboons, lies with its crown pointing backwards, so that its anterior surface is bitten upon by the upper canine. The lower molars are frequently five-cusped, the fifth cusp being at the back and slightly on the outer side, the third molar being usually the largest. The order of eruption of the milk dentition is as in man.

The comparison of the teeth of Man with those of the higher apes, Gorilla, Chimpanzee, and Orang is very instructive. The formula is the same, the order of eruption nearly the same, except that in the male apes the permanent canine is rather late, appearing either simultaneously with or just after the wisdom-tooth, while in the lower orders of mankind the third molar is earlier and more regular in its appearance, and better

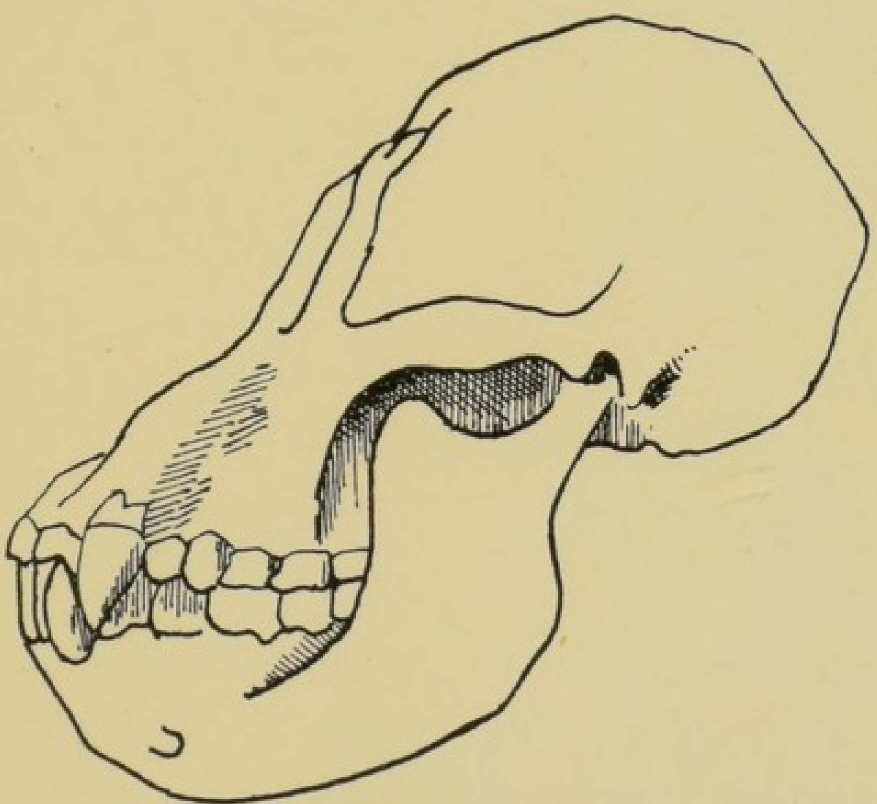


FIG. 75.—SKULL OF ADULT ORANG-OUTANG. (AFTER BEDDARD.)

developed than in the civilized races. It may be as well to go over the points of difference seriatim.

1. *The Facial Angle.*—The preponderance of the cranial over the facial portion of the skull in Man is best measured by Flowers' 'Dental Index'— that is, by a comparison of a line drawn from the foramen magnum to the naso-frontal suture, called the cranio-facial axis,

with the length of the tooth-bearing portion of the jaw. This is in effect comparing the development of the base of the brain or thinking apparatus with the masticating apparatus (see 'Aids to Dental Anatomy,' p. 76 *et seq.*).

2. *The Parabolic Curve.*—The teeth of Man are arranged in curve so that the upper wisdom-teeth are

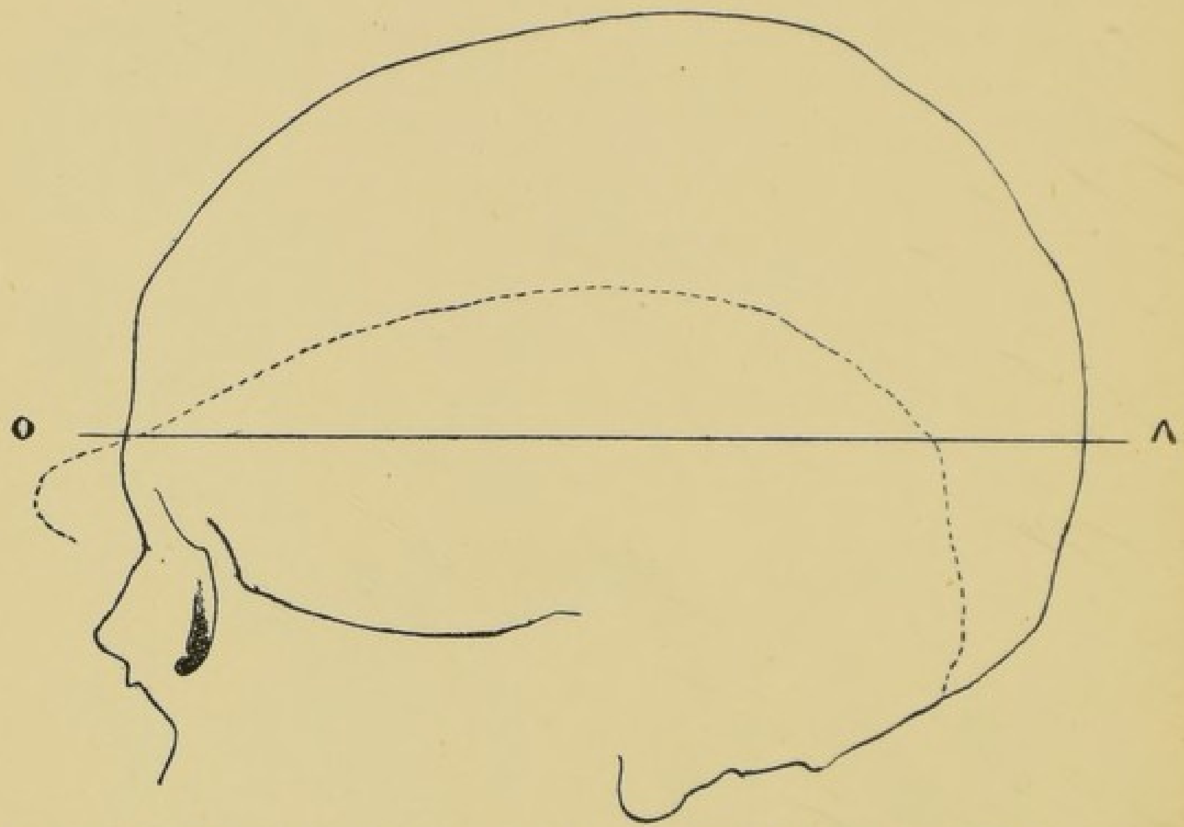


FIG. 76.—CRANIAL CAPACITY OF MAN AND PITHECANTHROPUS.

This shows an outline of a civilized and intellectual type of skull, with a dotted line to show about where the outline of the skull of pithecanthropus would have come in comparison. A line has been drawn from the ophryon just above the superciliary ridge in front to the lambda behind, to show the relative cranial capacity. This drawing is very hypothetical, and is merely intended to illustrate the idea in the text, and not to prove anything.

farther apart than the second molars, and these latter than the first molars. In the Apes the great size of the canines and parallel or non-divergent arrangement of the cheek teeth cause the whole jaw to assume an oblong shape. The maxillo-intermaxillary suture is not obliterated in the ape.

3. *The Shape and Size of the Teeth.*—In Man the row of teeth is fairly level, no one tooth rising above its fellows. In the Apes the canines are large and pointed, and rise above the level of the other teeth. In Man the molar teeth are subequal in size, and in civilized Man the third molar is somewhat smaller than the second, and does not possess a fifth cusp. In the Apes the last molar is the largest, with rare exceptions, and the first premolar is often caniniform.

4. *Date of Eruption.*—In Man the third molar is the last to erupt, in the male Gorilla the canine is later, or as late.

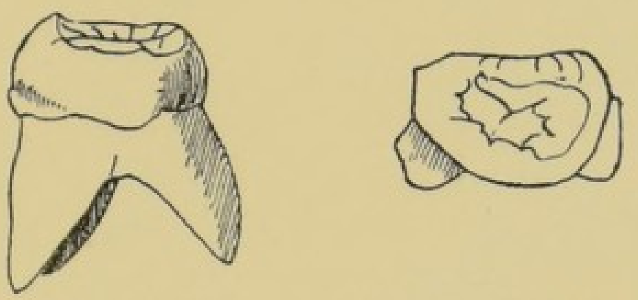


FIG. 77.—PITHECANTHROPUS ERECTUS.

Showing the molar (side view and crown view) of *Pithecanthropus erectus*. They were copied from the illustration in M. Dubois' article. The tooth is described as a third upper molar, and it will be noticed that there is no approximation of the roots, nor any sign of deficient development.

5. *Diastema.*—In Man there is no diastema, all the teeth touching their neighbours. In the Apes the large lower canine bites into a diastema between the upper outer incisor and upper canine.

6. *Sexual Difference in Dentition.*—In Man there is none. In the Apes the male possesses larger canines.

8. *Premolar Roots.*—In Man the premolars have generally one or, at most, two roots. In the Ape the upper premolars have frequently three roots and the lower two.

Among fossil Anthropoidea one of the most interesting is certainly a form known only by the upper part of the calvarium, two teeth, and a femur. It was discovered by Dubois in some Pliocene or early Pleistocene deposits in Java. The name of *Pithecanthropus erectus* was given to the fragments, and it is a doubtful point whether it was a very manlike Ape or a very apelike Man, but the name implies the latter. It stood erect about 5 feet 6 inches in height. Its cranial capacity was more than a third greater than that of any known anthropoid Ape. The profile of its skull seems midway between that of neanderthal Man, and a young Chimpanzee.

CHAPTER XV

THE EFFECTS OF ENVIRONMENT UPON ANIMALS

It will have been observed by the student of the foregoing pages that the jaws and teeth of an animal are gradually modified to suit the special diet on which it thrives. The form of the animal, the length and strength of its limbs, its claws, its cutaneous covering, the development of its organs of special sense, even its colour, are all likewise gradually rendered fitter and fitter for what we call its *environment*—that is, its surrounding circumstances, such as the temperature in which it lives, the kind of creatures on which it preys or which prey upon it, its botanical and geological surroundings. The story of animal life is one, therefore, of constant improvement, each generation becoming, so to speak, a little better than its fathers. It will be useful to pass in review some of the modifications which have thus gradually arisen, and to regard them from a more or less panoramic point of view.

Diet.—Animals, as we know them, now subsist upon very varied dietaries. Some eat flesh, and are called *Carnivorous*, and of these some kill their prey, and are called, therefore, predaceous, like the great Cats, while others feed upon carrion, like the Hyenas ; others, again, like the Bears, vary their carnivorous diet with less cruel repasts. Then there is the great class of animals whose diet is confined to insects, and who are called *Insec-*

tivorous; and, again, the other families whose food is wholly vegetarian, and to whom the name of *Herbivorous* has been given. Another series of families are called *Rodent*, from their gnawing habit of obtaining sustenance.

The modifications of the jaws and teeth that illustrate a carnivorous diet are very marked. The fact that the mandible moves upon a pure hinge-joint—as all these creatures want to do is to bite and not to grind their food—has resulted in the condyle of the lower jaw being lengthened from side to side, and fitting into a tunnel-shaped glenoid cavity. The condyle of a Tiger is like an inch and a half cut off a lead-pencil for shape, and fits into a corresponding deep groove or glenoid cavity in the temporal bone. There being no lateral movement possible, the external pterygoids are small, and not attached to the interarticular fibro-cartilage. The external pterygoid plates of the sphenoid bone are for the same reason mere spicules of bone. The zygomatic arch is wide, to admit of the contraction of the huge temporal muscles, and the coronoid process is greatly developed. In the machærodonts, who did not bite so much as strike with their upper canines, the attachments of the temporal were not so exaggerated as were the mastoid processes of the temporal bone, which afforded attachment to the enormous sterno-cleido-mastoid muscle.

The reduced molar series, with the upper fourth premolar and lower first molar squeezed and flattened up to a sharp-edged trenchant or slicing blade; the enormous canines for stabbing the prey; the sharp, straight row of incisors for tearing the flesh from the bones, all illustrate the flesh-feeder. Extinct Hyænodon and the modern Hyenas, whose habits are less combative and whose diet is mostly dead things, have stouter, blunter teeth, with a slightly fuller molar series. The Arctoidea (Bears, Racoons, etc.), whose habits are mixed and whose diet is not confined to flesh, have their large fighting canines supported by a fuller, wider, and blunter series of cheek teeth, temporo-maxillary joints capable of some lateral movement, and consequently larger external pterygoids.

The *Insectivorous* creatures have many premolars and molars bristling with sharp cusps, pointed, sharp incisors, and long tongues, with excessively-developed salivary glands, the submaxillaries being specially developed.

The *Herbivora* are in most respects the exact opposite of the carnivora. The pterygoid attachments are very large, the glenoid cavity and condyle very flat, while the excessive lateral movement is guarded from the danger of dislocation by the attachment of some fibres of the external pterygoid muscle to the interarticular fibro-cartilage.

The upper incisors are generally absent, a tough pad of gum occupying their place, against which the lower incisors bite in tearing the herbage. The canines are small or absent, their function as weapons being frequently performed by horns. The premolars and molars are in full number, large, broad, flat, and kept conveniently rough by the intertwining of the tissues of varying hardness, enamel, dentine, and cementum, which, by their different rate of wear, maintain a constant inequality of surface. The parotid glands are greatly developed.

The *Rodentia*, or gnawers, move their jaws forwards and backwards; their condyle and glenoid cavity is consequently lengthened antero-posteriorly. Their weapons, the great incisors, are very large, and, the strain to which they are exposed requiring great firmness, their roots are deeply embedded, while persistent growth compensates for their continual wear. The tissues are so arranged that the edge is always sharp, the enamel in a thin coat covering the front and sides, behind it the dentine, and at the back the softer cementum. The modification of the temporo-maxillary joint to suit special diet is well illustrated during the milk and permanent dentition of the human subject. While the act of sucking is all that is needed to maintain life no lateral movement is required, and the glenoid cavity is deeply concave. When with the advent of the permanent teeth mastication becomes a necessary preliminary to nutrition, and consequently a lateral movement, the cavity becomes shallower and the condyle flatter.

The limb development is equally conspicuous. Among the Carnivora, compare the short, massive fore-limbs of the machærodonts—whose slow, lumbering, thick-skinned prey necessitated, not speed, but strength, to destroy them—with the slender limbs of the modern chetah, who outruns the deer itself ; or, in the same order, the gradual adaptation of the limbs to an aquatic existence, hinted at in Potamogale and the Otters, pronounced in the shortened, webbed extremities of the Sea-lions, and finally perfected in the fishlike tail of the true Seals. Then note the similar series of changes in the Herbivorous families, leading to the fishlike hinder extremities of the Sirenia and the Cetaceans ; the cutaneous developments that have produced the armour of the armadilloes, the carapace of the Chelonians ; the quills of Porcupine, Hedgehog, and Echidna, the fur of animals, and the scales of fishes. The variations in the organs of sense are sufficiently interesting : the tactile apparatus of the Bats, or the olfactory powers of the Polar bear ; but in no respect is the general law more strikingly illustrated than in the adaptations of colour which combine to render the various groups of living creatures imperceptible in their native surroundings.

The chapter upon this subject in Wallace's 'Darwinism' is well worth a quiet perusal by anyone who wishes to become intimate with the mysterious wonders of evolution, but a few words upon the subject may not be out of place here. The moment one's attention is called to the fact, it becomes obvious that a great many animals closely resemble in colour the prevailing tints of their natural home, and the convenience of this arrangement to the animals themselves is sufficiently obvious. Whether a creature belongs to the great majority who are constantly preyed upon by others, or to the terrible few who, though they need not fear attack, still rely for their daily food upon approaching their prey unseen, the necessity for concealment is equally urgent. The Lion and the Antelopes are both sand-colour, the one for purposes of pursuit, the others for those of escape ; but lion cubs are spotted, possibly because the ancestral types of the great Carnivora, whose prey were slow-footed ungulates, did not need the stealthy approach that the hunter of the modern antelope requires.

The striped body of the Tiger, though at first sight in museums a somewhat gaudy object, is specially adapted for concealment in the jungle of faded reeds where he lurks. The arborial Carnivora, Leopard, Ounce, etc., counterfeit the effect of leaf shadows in their mottled skins. The denizens of primeval forests, who live mostly in a perpetual twilight, resemble the creatures of nocturnal habits in assuming a neutral-tinted garb, while the green and gay-tinted tropical birds resemble the tropical foliage amongst which they live, and the brilliant tints of the humming-birds render them inconspicuous among the dazzling blossoms of their native aloes. In the bird world, and to a large extent in the animal world too, the under parts are lighter in tint than the upper surfaces, which compensates the effect of the light striking from above and the shadow cast by the under parts, a fact that is curiously illustrated by a model at the Natural History Museum of an all-white bird and a bird the same size and substance which is gray on the upper surface, the latter being much the more difficult to see. The colouring of birds' eggs, especially those who lay among stones, and the plumage of the defenceless young, renders them almost indistinguishable on the shingle, some excellent examples being shown at the Natural History Museum. Lastly, the white coat of creatures that visit arctic regions, which is in some cases actually assumed each winter, are conspicuous instances of protective colouring. In this latter case the exception seems to aptly illustrate the rule ; for the great carrion Crow, whose size, ferocity, and power of flight render it indifferent to enemies, while its food, being dead carrion, requires no stealth to approach, maintains its black dress, and does not trouble, if the expression may be allowed, to assimilate its dress to its surroundings.

CHAPTER XVI

THE CHAIN OF LIFE

It may be useful to incur the risk of a little repetition in the endeavour to take a bird's eye or panoramic view of some of the groups of facts and deductions that have of necessity been detached and separated in the more systematic account.

In point of time we find about the middle of the Primary period traces of a dominant population of fishes (at first, Elasmobranch). Among these fishes, though most of their dentitions are homodont, still specialization shows itself here and there, and in the fossil fish gallery at Cromwell Road there are plenty of specimens which show a useful, even a pronounced, differentiation. Gorgonicthys, a fish of Palæozoic or Primary times, had a lower incisor-like tooth standing alone, and quite 6 inches in height. Most of these tribes of varying fishes varied in more and more fishlike directions; some, indeed, varied very little, and *Cestracion Philippi*, an Australian shark, is the unaltered descendant of a once numerous and widely-distributed race. Towards the close of this great first period some of the fish world varied in a new direction—that is, in the direction of being able to inhabit to some extent land as well as water. Gill-breathing became modified by the addition of a rudimentary lung, pectoral fins became adapted somewhat to progression on land, and a race of Amphibians appeared. These in their turn varied in many directions, and some, as was the case with the fishes, seemingly content with their progress, remained amphibian through all the succeeding ages to this day. But among those ancient Amphibia were a group called Labyrinthodonts, and these creatures, whose footprints seem so human-like, apparently had descendants with whom gill-breathing was a thing of the past, and whose limbs and dentition suited them to a terrestrial existence. These early Reptilia again varied in many reptilian directions: in some the limbs remained short and sprawling, and the dentition more or less homodont, and from these sprang the lizards and crocodiles; in some the skeleton and integument became spread out into flattened protective plates, and the sharp teeth, no longer of service, degenerated into horny plates, as in the Chelonia (Tortoises and Turtles); in some the phalanges of one finger grew to an enormous length, carrying with it a stretched integument which enabled its possessors to fly, as in the great batlike reptiles called Pterodactyles, while in others the dentition degenerated in the front part of the jaw into a horny beak, and the homodont-pointed teeth remained at the back part. Much later, well on in the Secondary (Mesozoic) period, traces of specialization in the direction of flight, combined with a gradual replacement of the teeth by horny beaks, are found in the aberrant group of reptiles that commenced the divergence that ended in the class of birds, while much later still, possibly as recently as the first hints at a human race, the limbs disappeared, or remained only as rudimentary relics, and the group of serpents appeared on the scene. Meanwhile, to step back to the end of the Primary period and the beginning of the Secondary, a strange group among the descendants of those ancient amphibian Labyrinthodonts were being specialized in the direction of a mammalian type. The body was being raised higher by lengthened limbs, the dentition was displaying heterodont specialization. These bygone Reptiles are called Theriodonts or Theriomorpha. The great canines of Cynognathus, the molar roots of Tritylodon and Diademodon (which should be examined at the Museum while reading this chapter), show this early heterodontism very well; the teeth are getting settled on the maxillaries and mandible. Probably an intermediate race akin to the Monotremata paved the way for the first appearance of the Mammalia proper. An ancient variation produced the Marsupialia, which are not generally supposed to stand in the true line of descent, but to be an early offshoot from the common Monotrematous stock. At the end of the Secondary period the Mammalia began to become the dominant type, and increased and varied according to changing circumstances of environment throughout the Tertiary (Eocene, Miocene, and Pliocene) and Quaternary (Pleistocene) periods. Some of the vegetable eaters drifted back towards aquatic habits, and the mammalian Sirenia and Cetacea suggest in varying degrees a retrograde series of changes both in limbs and dentition, from limbs to paddles, and thence to fins, and from heterodontism to homodontism, though the exact position of the whales is hard to fix. Among the flesh-eaters and predaceous creatures the Seals and Otters also show a similar retrogression towards a fishlike type. The terrestrial creatures also vary according to their needs. Carnivorous, Herbivorous, and Rodent types of dentition appear, all of which might have been built up by modifications of the simple row of cones of homodontism. Some teeth rise into prominence as canines, generally at a convenient point about the front corners of the jaw; further back two or three cones become fused into one mass, and a tricone tooth appears: if the middle cone is the highest, and the whole three are laterally compressed, we have a flesh-eating or carnassial type of molar; if several cones get crowded together so as to form a double row and then fuse, we get a wide mass, which, on grinding down, displays the varied patterns of the Herbivorous molar; if the food of the animal is best obtained by a gnawing action of the front teeth, the tendency is for these teeth to become larger with deeper implantation. To form such a large tooth longer time is required, so that the period of growth is prolonged; the nourishment which would have formed several front teeth is all appropriated by the big baby, so its neighbours wither and die off in early youth, a diastema marking their quondam situation; meanwhile, the wear and tear constantly requiring fresh growth in the big incisor, the tooth formation is prolonged till it becomes persistent. The creature whose enamel is most conspicuous on the front and sides of his incisors gets the pull over less favoured rivals; therefore this arrangement becomes constant, and we have a typical Rodent dentition.

In the dawn of the Tertiary epoch, in early Eocene times, the non-marsupial or Eutherian mammals were differentiated, 'and were represented by forms from which it is possible to derive at least the existing Carnivora, Insectivora, Artyodactyla, and Perissodactyla. These were the Creodonta and the ungulate Condylarthra' (Beddard). Gradually specialization proceeded, reaching its height in Miocene times, since when there has been a gradual 'decline in mammalian variety.' The process of extinction is still at work, and in very recent times we have witnessed the disappearance of the Rhytina and the Quagga. The first Mammals were apparently smaller than their descendants, the tendency being to increase in size, and this tendency is very plainly shown in the case of those creatures whose pedigree is fairly continuous and complete, as, for instance, the Horse. Though many extinct groups attained great size prior to extinction, these are supposed to have wandered from the direct line of descent, which was small in size, and each great step in the story of evolution appears to have been taken by small and comparatively unspecialized groups; in fact, huge size and extreme specialization are generally the forerunners of extinction, illustrating adaptability to extreme and comparatively short-lived conditions of environment.

One somewhat difficult fact at first sight in all this very imperfect chain of evidence is the size of the creatures. The earliest Mammals, of which we possess traces, were all very small, not larger than a small rat, while the remains of the Theriomorpha are those of creatures varying in size between a bear and a wolf. It is probable, however, that, though special members of all the groups attained large size, they always had very small relations, and it was apparently from the smaller forms that the progressive evolution arose, while the larger forms generally represented varieties in which evolution had led into bypaths of development, destined with altering circumstances to suffer extinction.

The Tertiary period marks the appearance of a new force in the struggle for existence which is destined to triumph over all the rest. The strength, ferocity, size, and terrible weapons of the old-time creatures were accompanied by a very immature brain development. As the world grows older, the little bulbous swelling of the spinal cord, which guides and directs all this physical machinery, begins to expand. Compare the brain of the monstrous Tinoceras with that of a small ape! With the increase of brain power comes a knowledge of how to use physical advantages to a better purpose; the hand is no longer only an instinctive paddle or claw or hoof; the possibilities of prehensile uses, guided by an improved cunning, give advantages to their possessors over those creatures who can only hide or pursue under cover of protective tint disguises. The hands that can throw projectiles, that can build hiding-places and defences, the brain that can use the subjected strength of others less cunning, were the weapons with which Evolution armed the creatures who, in this last prehistoric period, emerged from apedom, and began in the dim twilight of Kainozoic times to lay the foundations of society of human kind, and the great and final victory of mind over matter.

INDEX

A.

AARD VARK, 71, 82
Aard wolf, 112, 116
Acrodont, 9
Adapis, 125
Æluroidea, 112
Ætobates, 33, 43, 44
Alleyne Nicholson, 3
Alligators, 58
Amblypoda, 104
American bony pike, 32
Amphibia, 29, 48, 68, 75, 139
Amphilestes, 13
Amphitherium, 70
Analogy, 2
Anarrhicas lupus, 34
Anchippodus, 110
Anchylosed teeth in fishes, 19, 20
Anchylosis, 22
Angler, 21-24
Anomodontia, 60, 61, 69
Anomalurus, 109
Anoplotherium, 71, 95
Ant-eater, 71, 81-83
    spiny, 70, 85
Antelope, 96, 97, 137
Anthropoidea, 73, 126, 127
Ape, 5, 73, 81, 126, 128
    compared with man, 130
Aquatic carnivora, 112
Archæoceti, 71
Archæopteryx, 7, 64, 66
Archœlurus, 116
Arctic fox, 113
Arctoidea, 112, 117, 134
Armadillo, 71, 81-83, 136
Artiodactyle, 71, 95-97
    ungulate, 93
Atlantosaurus, 58
Attachment, bone of, 19, 33
    by a fibrous membrane, 20
    by anchylosis, 22, 33
    by an elastic hinge, 20
    by implantation in sockets, 23, 33
Aves, 28, 64, 75
Aye-aye, 73, 125

B.

Balænidæ, 71
Baleen, 87, 88
    plates, 88
    whale, 71
Bandicoot, 70, 78
Barracuda pike, 46
Bat, 64, 73, 121, 122, 136
    blood-sucking, 121
Bathysaurus ferox, hinge teeth in, 22, 34
Batrachian, 48
Bdellostoma, 44
Bear, 4, 18, 62, 73, 112, 113, 118, 133, 134
Beaver, 72, 94, 109
Beddard, 57, 106, 119, 124, 126, 129, 142
Beluga, 88
Birds, 28, 64, 75
    extinct, 7, 58
    in mesozoic ages, 6
Blood-sucker, 122
Bone of attachment, 19, 33
Boulenger, 53
Bovidæ, 72
Brachydont, 9, 93
Bradypodidæ, 71
Bradypus, 83

 10

Brazilian tortoise, 51
Bunodont, 9, 93

C.

Cachalot, 87, 90
Camel, 72, 95, 96
Camelidæ, 72
Canidæ, 4, 73, 116
Canines of Telidæ, 7, 114-117
Canis aureus, 4
familiaris, 3, 4, 112, 113
lupus, 4
Capybara, 10, 14, 106, 107, 109
Carnivora, 4, 63, 72, 109, 110, 112, 118, 119, 133, 136, 137
fissipedia, 112
pinnipedia, 73, 112, 117
terrestrial, 112, 118
Cartilaginous skeleton in certain fishes, 32
Castoridæ, 72
Cat, 4, 72, 133
Catarrhine monkey, 126
Cattle, 72, 93, 96
Cebidæ, 73
Centeles, 120
Cerbidæ, 72, 98
Cercopithecidæ, 73
Cervulus, 98
Cestracion Philippi, 41, 42, 45, 139
Cetacea, 70, 71, 81, 84, 87, 90, 118, 119, 136, 141
Chætodont, 34
Chain of life, the, 139
Chamæleon, 57
Chauliodon, 46
Cheiromys, 7, 62, 107, 125
Chelonians, 49, 51, 136, 140
Chetah, 136
Chevrotains, 71, 96
Chimpanzee, 127, 129
Chiroptera, 73, 121
Cholœpus, 82, 83
Chrysophris aurata, 38, 40, 45
Chyromyidæ, 73
Ciliiform, 34
Civet, 73, 116
Classification, method of, adopted by naturalists, 3
Cod, 23, 33
Cœcilian, 48
Cogia, 90
Comparative Anatomy, meaning of the term, 3
Condylarthra, 142
Coney, 101
Cope, 13, 95
Creodonta, 142
Crocodile, 24, 58
Ctenoid scales, 31
Curassows, 5
Cuttle-fish, 87
Cyclostomata, 33, 44
Cynodraco, 61
Cynogale, 117
Cynognathus, 61
Cynoidea, 112

D.

Dasypodidæ, 71
Dasypus, 82
Dasyures, 70, 77, 78, 80
Dasyuridæ, 70
Deer, 72, 93, 96-98
Delphinidæ, 71, 91
Dendrohyrax, 101
Denticles, the fusion, resulting in patterns, 13
Dentine in fishes, 33
Desmodont division of bats, the, 122
Desmodus rufus, 122
Diademodon, 141
Dicotyles, 95
Didelphydæ, 70, 78
Dinoceras, 105
Dinocerata, 104
Dinosaurians, 58
Dinotherium, 17, 72, 104
Diodon, 35
Diphyodont, 9, 10, 14
Diprotodon, 80
Diprotodonts, 9, 70, 78
Distribution of Animals, the geographical, 4
of animals, the historical, 6
Divisions of the subkingdom vertebrata, the, 33
Dodo, 7
Dog, 3, 4, 112, 113

Dolphin, 9, 71, 81, 90
Dormice, 72
Dromatherium, 13, 70
Dubois, 132
Duckbill, 70
Dugong, 71, 84-87
Duplicidentata, 72, 109
Dychodon, 71
Dycynodon, 61

E.

Eared seals, 73
Echidna, 29, 70, 75, 136
Echidnidæ, 69, 70
Edentata, 69, 71, 81, 82, 105
Edentates, 119
Eel, 23
Elasmobranch, 139
Elastic hinge, attachment by an, 20
Elephant, 5, 10, 14, 17, 72, 101, 102
Elephantidæ, 72
Elephant-shrew, 120
Elephas primigenius, 14, 101, 104
Enamel in fishes, 33
Environment, the effects of, 133
Eocene insectivore, 120
  period, the, 6
Equidæ, 72
Erinaceidæ, 73
Esthonyx, 110
Eupleres, 116
Eutheria, 30, 69, 70, 76, 81
Evolution, 2, 3, 28
  of molar pattern, 14-17
Extinct birds, 64
  cetacea, 71, 90
  creatures, 7
  eocene, 95, 110
  eutheria, 71
  insectivore, 120
  lemuridæ, 125
  metatheria, 70
  pleistocene, 132
  pliocene, 132
  proboscideans, 103
  prototheria, 70
  reptiles, 58, 65, 68
  sirenia, 71, 87
  ungulata, 71, 72, 120

F.

Facial angle, the, 129
Felidæ, 4, 7, 72, 111-113, 116
Fibrous membrane, attachment by a, 20
File-fish, 33, 46
Fins of fishes, 32
Fishes, 2, 5, 6, 28, 29, 31, 64, 68
  anchylosed teeth in, 19, 20
  attachment by anchylosis in, 22
  calcified teeth in, 19
  dental enamel in, 33
  division of, 32
  earliest evidence of, 32
  fins of, 32
  hinge teeth in, 19, 20
  teeth of, 33
Fissipedia, carnivora, 72, 113
Flounder, 33
Flower and Lyddeker, 69, 70
Flowers' dental index, 129
Flying-fish, 2
Flying-fox, 73
Forms of teeth and their succession, 10
Fox, Arctic, 113
  Italian, 113
Frog, bone of attachment in, 23

G.

Galeopithecus, 73, 120, 121
Galeopithicidæ, 73
Gander, 66
Ganoid scales, 31
Ganoids, 32, 33
Geographical distribution of animal life, 4
Gharials, 58, 59
Giraffe, 5, 72, 97
Giraffidæ, 72
Glyptodon, 71
Goose, 66
Gorgonicthys, 139
Gorilla, 127-129
Grampus, 87
Greenland whale, 71
Guinea-fowl, 5
Gymnodonts, 34, 35, 45

H.

Haddock, 19, 23
Hag-fish, 44
Hake, 21, 33, 34
Halicore, 84
Halicoridæ, 71
Halithere, 71
Halitherium, 84, 87
Hapalidæ, 73
Haplodon, 72
Haplodontidæ, 72
Hare, 72, 109
Hatteria, 57
Hedgehog, 136
Heloderma, 53, 57
Herbivora, 135
Herbivorous, 134
Hesperornis, 58, 65, 66
Heterodont, 8, 9, 11-13
Hill, 78
Hinge, attachment by an elastic, 20
Hinge-teeth, 19, 21, 22
Hippopotamidæ, 71
Hippopotamus, 71, 93
  palæindicus, 94
Historical distribution, 6
Hominidæ, 73
Homodont, 8, 11, 13
Homology, 2
Hoofed mammals, 71
Hoolock, 127
Hoplophonus, 116
Hornbill, Papuan-wreathed, 66
Horns, 12, 93, 96, 97, 104
Horse, 14, 72, 93, 98, 99, 142
Huxley, 69
Hyæna, 4, 72, 112, 133, 134
Hyænidæ, 72, 112
Hyænodon, 116, 134
Hydromys, 108
Hydropotes, 98
Hyopsodus, 73
Hyotherium, 95
Hyperodapedon Gordoni, 59, 60
Hyperoodon, 91
Hypsiprimnus, 79
Hypsodont, 9, 93
Hyracoidea, 72, 101, 106
Hyrax, 72, 101
Hystricidæ, 72

I.

Ichneumon, 7
Ichthyosaurus platydon, 59
Icthyornis, 65, 66
Indian water tortoise, 51
Inheritance, 11
Insectivora, 119, 133, 135
Insectivore, extinct, 120
Invertebrata, 28

J.

Jackal, 4
Jaguar, 5

K.

Kainozoic ages, the, 6
Kangaroo, 5, 70, 78-80
  rat, 79
Kidney, the lobulated form of, 118
Kückenthal, 18, 118

L.

Labyrinthodontia, 49, 61, 140
Lacertilia, 55
Lamna, 41
Lamprey, 32, 33, 44
Lancelet, 33
Leche, 78
Leidy, 95
Lemur, 7, 73, 107, 124, 126
Lemuridæ, 125
Lemuroidea, 73, 125
Leopard, 5, 137
  seal, 117
Lepidosiren, 32
Lepidosteus, 33
Leporidæ, 72, 107, 109, 110
Limitation of creatures to place, 5
Lion, 4, 62, 137
Lithographic stone, the, 64
Lizard, 55
  poisonous, 53, 57
  winged, 58
Llama, 95
Lophiodonts, 72
Lophius piscatorius 21-24
Lumpsucker, 3
Lutrinæ, 117

M.

Machærodonts, 115, 116, 136
Mackerel, 19, 22, 23
Macropodidæ, 70, 78, 79
Macroscelididæ, 73
Macroscelides, 120
Malthe vespertilio, 3
Mammalia, 4, 68, 141
Mammals, 28, 29
  placental, 69
Mammoth, 7, 14, 101, 102, 104
Man, 4, 7, 9, 18, 19, 73, 81, 124, 126, 127, 129, 130
Manatees, 71, 84, 86
Manatidæ, 71
Manatus, 84
Manidæ, 71
Manlike mammals, 73
Marmoset, 73
Marmot, 109
Marsh, 29, 65, 95, 104
Marsupial, 7, 18
Marsupialia, 69, 70
Marsupials, 63, 78, 107, 119, 141
Mastodon, 17, 72, 101, 104
Mastodont, 9
Matthew, W. D., 115
Median fins, 32
Megachiroptera, 73, 122
Megaladapis, 125
Megatherium, 71, 82, 83
Merlucius, 34
Mesonyx, 120
Mesoplodon Layardii, 91
Mesozoic ages, the, 6
Metacone, 13
Metatheria, 29, 69, 70, 76
Microchiroptera, 73, 122
Migration of birds, the, 5
Miocene period, the, 6
Miohippus, 100
Molar patterns, 17, 18
Mole, 73
Monkey, 73, 81, 124, 126
  catarrhine, 126
  platyrrhine, or prehensile-tailed, 5, 126
Monophyodont, 9, 10, 14
Monosaurus, 65
Monotremata, 61, 69, 70, 141
Moschus, 98, 104
Muntjac, 98
Muridæ, 72, 107
Musk deer, 98
Mustelidæ, 73, 112
Myliobates, 33, 43, 45, 82
Myoxidæ, 72
Myrmacobius, 77, 78, 80
Myrmecophagidæ, 71
Mystacoceti, 71, 87, 88
Myxines, 33, 44

N.

Narwhal, 7, 85, 91
Neo-Lamarkians, 11
Nesodon, 106
Newt, 48, 49
Nicholson, Alleyne, 3
Notothere, 70
Nototherium, 80

O.

Odontoceti, 87, 90
Odontolcæ, 65
Odontopteryx toliapicus, 66
Odontornithes, 65
Odontostomus, 34
Odontotornæ, 65
Ophidia, 51
Ophisaurus, 63
Opossum, 5, 70, 77, 78
Orang-outang, 126, 127, 129
Orca, 87
Oreodon, 71, 95, 120
Ornithorhynchidæ, 69, 70
Ornithorhynchus, 29, 45, 75
Orohippus, 100
Orycteropodidæ, 71
Orycteropus, 82
Osborn, 13
Osteodentine in fish, 33
Ostrich, 66
Otariidæ, 73, 118
Otocyon, 116
Otter, 73, 117, 118, 136, 141
Ounce, 137
Oviparous, 30
Oxen, 96

P.

Pachydermata, 68
Pagdius, 45
Paired fins, 32
Palæicthyes, 32, 40
Palæontology, 5
Palæotheria, 72
Palæotherium, 14, 99
Palæozoic ages, the, 6, 29
Papuan-wreathed hornbill, 66
Parabolic curve, the, 130
Paracone, 13
Parrot fishes, 36, 45
Patterns of molars, resulting from the fusion of denticles, 13
of molars, resulting from degrees of wear, 16
Paugolins, 71
Peccaries, 71, 95
Pecora, 72
Pectoral fins, 32
Peramelidæ, 70, 78
Perissodactyla, 72, 97
Perissodactyle ungulates, 93, 98
Petromyzon, 44
Phacochœrus, 95
Phalangeridæ, 70, 78
Phalangers, 70, 78
Phascolarctus, 78
Phascolomyidæ, 70, 78
Phascolomys, 76
Phyllostomatidæ, 73
Physeteridæ, 71, 90
Pig, 71, 93, 94
Pike, 19, 22, 23, 33, 34
Pinnepedia, 116-118
Pipefish, 31
Pithecanthropus erectus, 130, 132
Placentalia, 81
Placoid scales, 31
Plagiaulax, 70
Plagiostomi, 20
Platanistidæ, 71
Plates of elephant's molar, 17
Platyrrhine monkeys, 126
Pleurodont, 9
Plianchenia, 96
Plicidentine in fishes, 33
Pliocene period, 6
Pliohippus, 100
Poison fang of the viper, 10
Poison fangs, 53-56
Poisonous lizard, 53
Polar bear, 136
Polymastodon, 70
Polyphyodont, 9, 14
Polyprotodont, 9, 70
Polyprotodontia, 78
Porcupine, 72, 109, 136
Porpoise, 71, 81, 90
Potamogale, 136
Primary ages, 6, 29
Primates, 73, 81, 121, 123
Priodon, 84
Pristis, 24, 33, 44, 82
Proboscidea, 7, 103
Procamelus, 93
Procyonidæ, 73, 112
Promegatherium, 83
Promylodon, 83
Prorastomus, 87
Prosaurian reptiles, 57, 58
Proteles, 112, 116
Protocone, 13
Protolabis, 95
Prototheria, 29, 69, 70, 75, 76
Pseudoscarus, 36
Pteralopex, 122
Pterodactyles, 140
Pteromys, 109
Puff-adder, 53
Python, 19

Q.

Quagga, 142
Quaternary period, man in the, 29

R.

Rabbit, 72, 95, 107
Racoon, 4, 73, 112, 134
Rat, 62, 109
Ray, 20, 33, 40, 44, 45
Reindeer, 96, 97
Reptiles, 28, 29, 49, 64, 75, 140
extinct, 58, 65, 68
Rhinoceridæ, 72
Rhinoceros, 72, 97-99
antiquitatis, 99
Rhinoceros' horn, 7, 12, 14, 93
Rhyncocephalia, 57, 59, 62

Rhytina, 7, 71, 84, 85, 142
Rodent, 7, 105, 107-109, 134
Rodentia, 72, 107, 135
Rorqual, 88
Rose, 18, 78
Rostrum of pristis, 24, 33, 44, 82
Ruminant artiodactyles, 96
Ruminantia, 68, 72, 97, 98

S.

Salamander, 48, 49
Sargus, 33, 38, 39, 45
Sawfish, 7, 24, 42
Scales in fishes, 20, 31
Scarus, 38, 39
Sciuridæ, 72, 109
Sea-horse, 33
Seal, 5, 73, 117, 118, 136, 141
Seal, leopard, 117
Sea-lions, 117, 118, 136
Secondary epoch, doubtful traces of birds in the, 29
Selenodont, 9, 93, 95
 artiodactyla, 95
Serpent, 51
Shark, 9, 20, 33, 40, 41, 139
Sheep, 72, 96
Sheep's-head fish, 38
Shrew, 73, 120
Simplicidentata, 72, 109
Simiidæ, 73
Sirenia, 70, 71, 81, 84, 87, 117, 136, 141
Sivatherium, 97
Skate, 32
Sloth, 71, 81-83
 the three-toed, 83
 the two-toed, 83
Slow-worm, 53, 55
Smilodon, 116
Snake, 23
Socketed teeth, 19, 23, 24
Soricidæ, 73
Spalacotherium, 13, 70
Sparoid fish, a, 38
Sperm-whale, 71
Sphenodon, 57, 59
Spines, 20
Spiny ant-eater, 71
Sphyræna barracuda, 33, 46
Squalodon, 92
Squirrel, 72, 109
Stratified rocks, table of, 27
Sturgeon, 32, 33, 44
Subungulata, 100
Succession of teeth, 14
Suidæ, 71, 95
Suina, 71
 hippopotamus, 94
Survival of the fittest, 2
Sus babirusa, 46, 94
Sutton, Bland, 7
Swinhoe's water-deer, 98

T.

Table of stratified rocks, 27
Tadpole, 48, 49
Talpidæ, 73
Tapir, 5, 14, 72, 87, 93, 98, 99
Tapiridæ, 72
Tatusia, 82
 peba, 82, 83
Teeth, attachment of, 19
 in man, 129
 of birds, 65
 of fishes, 33
 socketed, 19
 the forms and succession of, 10
Teleostei, 32, 33
Tenrec, 120
Terrestrial carnivora, 112, 118
Tertiary period, the, 6, 29
Tetradon, 37
Theriodont, 140
Theriodontia, 61, 63
Theriomorpha, 140, 143
Thylacine, 5, 70, 77, 78
Thylacoleo carnifex, 78, 79
Tiger, 4, 9, 62, 114, 134, 137
Tillodontia, 72, 110
Tillotherium, 110
Tims, 18
Tinoceras, 143
Toads, 48, 49
Tomes, 8, 18, 19, 22, 24, 36, 42, 58, 76, 78, 80, 86, 91, 98, 100, 103, 113, 121
Toothed whales, 71
Tortoise, 51, 140

Toucan, 5
Toxodon, 106
Toxodontia, 72, 104
Tragulidæ, 71
Tragulina, 71
Triodon, 37
Trituberculate, 13
Tritylodon, 70, 141
Tryonichidæ, 51
Tuatera, 57
Tupaia, 120
Turtle, 51, 140
Tusks, 102, 115
Tylopoda, 72, 95
Typotherium, 106

U.

Ungulata, ungulates, 71, 92, 96, 101, 104, 105
Ursidæ, 4, 73
Ursine lozenge, the, 118

V.

Vampires, 73
Varanus, 57
Ventral fins, 32
Vertebrata, 4, 28
    the essential peculiarities of, 30
Vespertilionidæ, 73
Villiform, 34
Viper, 53
Viverridæ, 73, 112
Viviparous, 30
Voles, 109
Von Ebner, 80
Vulpes, 4

W.

Wallace's 'Darwinism,' 136
Walrus, 73, 117, 118
Wart-hog, 94
Water-rat, 109
Weasel, 73, 112
Whale, the killer, 87
Whalebone, 88
Whales, 5, 81
    Baleen, 71, 88
    Greenland, 71
    sperm, 71, 87, 90
    toothed, 71, 87, 90
    whale-bone, 87, 88
Wilson, 78
Wolf, 4, 62, 73, 112
Wolf-fish, 33, 34, 45
Wombat, 5, 7, 62, 77, 78, 80, 107

Z.

Zeuglodon, 92
Zeuglodonts, 71
Ziphiinæ, 90
Zoological position of dog, 4
Zygobates, 43

ERRATA.

Page 18, *line* 1, 'Kuckenthal' *should read* 'Kückenthal.'
Page 32, *last line*, 'palœicthyes' *should read* 'palæicthyes.'
Page 40, *line* 1 *and heading*, 'palæichthyes' *should read* 'palæicthyes.'
Page 73, *line* 33, 'Simudæ' *should read* 'Simiidæ.'
Page 120, *line* 19, 'Ma roscelides' *should read* 'Macroscelides.'

THE END

BAILLIÈRE, TINDALL AND COX, 8, HENRIETTA STREET, COVENT GARDEN

COOPER'S Pathological Inebriety: Its Causation and Treatment. Crown 8vo. Pp. xvi+152. Price **3s. 6d.** net.

CROSS & COLE'S Modern Microscopy.
With chapters on special subjects by various writers. Fourth Edition, Revised and Enlarged. Demy 8vo. Pp. xviii+326, with 113 Plates and other Illustrations. Price **6s.** net.

DIEULAFOY'S Text-Book of Medicine.
Translated by V. E. Collins and J. A. Liebmann. In 2 volumes. Second Edition. Royal 8vo. Pp. xxiv+2156, with 9 Coloured Plates and 99 Illustrations. Price **25s.** net.

FRENCH'S Medical Laboratory Methods and Tests.
Third Edition. Pp. viii+202, with 88 Figures, plain and coloured. Leather, gilt tops. Price **5s.** net.

GRAY'S Diseases of the Ear.
Demy 8vo. Pp. xii+388, with 53 Plates, of which 37 are Stereoscopic, and 70 other Illustrations. Price, with **Stereoscope, 12s. 6d.** net.

GREEN'S Pathology.
Eleventh Edition. Royal 8vo. Pp. x+642, with 350 Illustrations. Price **15s.** net. (*University Series.*)

HARSTON'S Care and Treatment of European Children in the Tropics. Crown 8vo. Pp. xvi+232, with 17 Plates, plain and coloured. Price **7s. 6d.**

HYDE'S Diseases of the Skin.
Eighth Edition. Royal 8vo. Pp. xxviii+1126, with 58 Plates and 223 Illustrations, Plain and Coloured. Price **25s.** net.

JELLETT'S Manual of Midwifery.
Second Edition. Demy 8vo. Pp. xiv+1210, with 17 Plates and 557 Illustrations, plain and coloured. Price **21s.** net. (*University Series.*)

JONES' Papers of Psycho-Analysis.
Demy 8vo. Pp. xvi+432. Price **10s. 6d.** net.

KANAVEL'S Infections of the Hand.
A Guide to the Surgical Treatment of Acute and Chronic Suppurative Processes in the Fingers, Hand, and Forearm. Royal 8vo. Pp. xiv+448, with 133 Illustrations. Price **15s.** net.

KERR'S Operative Midwifery.
Second Edition. Royal 8vo. Pp. xiv+704, with 299 Illustrations, mostly original. Price **21s.** net.

KNOCKER'S Accidents in their Medico-Legal Aspect.
A Practical Guide for the Expert Witness, Solicitor, and Barrister, by leading Medical Authorities. Royal 8vo. Pp. xxviii+1266. With 206 Illustrations, Plates, and Diagrams. Price **30s.** net.

KRAEPELIN'S Lectures on Clinical Psychiatry.
Authorised Translation of the Second German Edition. Revised and Edited by Thomas Johnstone, M.D. Edin., M.R.C.P. Lond. Third English Edition. Pp. xviii+368. Price **10s. 6d.** net.

LAKE'S Handbook of Diseases of the Ear.
Fourth Edition. Demy 8vo. Pp. xiv + 286, with 4 Coloured Plates and 48 original Illustrations, and 77 Figures in the text. Price **7s. 6d.** net.

LAMB'S Diseases of the Throat, Nose, and Ear.
Third Edition. Crown 8vo. Pp. xvi + 352, with 55 Illustrations. Price **7s. 6d.** net.

LAMBKIN'S Syphilis: Its Diagnosis and Treatment.
Demy 8vo. Pp. viii + 196. Price **5s.** net.

MACEWEN'S Surgical Anatomy.
Demy 8vo. Pp. xii + 452, with 61 Illustrations, plain and coloured. Price **7s. 6d.** net.

McKAY'S Operations upon the Uterus, Perineum, and Round Ligaments. Second Edition. Demy 4to. Pp. xviii + 454, with 148 original Plates. Price **10s. 6d.** net.

McKISACK'S Dictionary of Medical Diagnosis.
Second Edition. Demy 8vo. Pp. xii + 590, with 76 Illustrations. Price **10s. 6d.** net.

MARSHALL'S Syphilology and Venereal Disease.
Second Edition. Demy 8vo. Pp. xii + 560, with 18 Illustrations. Price **10s. 6d.** net.

MAY & WORTH'S Diseases of the Eye.
Third Edition. Demy 8vo. Pp. viii + 428, with 336 Illustrations, including 22 Coloured Plates. Price **10s. 6d.** net.

MINETT'S Diagnosis of Bacteria and Blood-Parasites.
Second Edition. Fcap. 8vo. Pp. viii + 80. Price **2s. 6d.** net.

MONRO'S Manual of Medicine.
Third Edition. Demy 8vo. Pp. xxii + 1024, with 42 Illustrations, plain and coloured. Price **15s.** net. (*University Series.*)

MUMMERY'S After-Treatment of Operations.
Third Edition. Crown 8vo. Pp. x + 252, with 38 Illustrations. Price **5s.** net.

ONODI'S Optic Nerve and Accessory Sinuses of the Nose. Translated by J. Lückhoff, M.D. Small 4to. Pp. viii + 102, with 50 original Plates and Illustrations. Price **10s. 6d.** net.

PICKERILL'S The Prevention of Dental Caries and Oral Sepsis. Medium 8vo. Pp. xvi + 308, with 56 Illustrations, mostly original. Price **7s. 6d** net.

ROBERTS' Surgery of Deformities of the Face, including Cleft Palate. Royal 8vo. Pp. viii + 274. Price **12s. 6d.** net.

ROSE & CARLESS' Manual of Surgery.
Eighth Edition. Demy 8vo. Pp. xii + 1406. With 12 Coloured Plates and 581 Illustrations. Price **21s.** net. (*University Series.*)

SCHMIEDEN'S The Course of Operative Surgery.
Translated from the Second German Edition and Edited by ARTHUR TURNBULL, M.A., M.B., B.Sc. GLASG. Royal 8vo. Pp. xx + 346, with 435 Illustrations, mostly coloured. Price **12s. 6d.** net.

SIMON & BASE'S Manual of Chemistry (specially adapted for Students of Medicine, Pharmacy, and Dentistry). Tenth Edition Royal 8vo. Pp. xviii + 774, with 64 Chemical Reactions in colour, and 82 other Illustrations. Price **15s.** net.

STARR'S Organic and Functional Nervous Diseases.
Fourth Edition. Royal 8vo. Pp. 970, with 30 Plates, plain and coloured, and 323 Figures in the text. Price **25s.** net.

STEVEN'S Medical Supervision in Schools.
Demy 8vo. Pp. x + 268, with 40 Illustrations. Price **5s.** net.

STEWART'S Manual of Physiology.
Sixth Edition. Demy 8vo. Pp. xx + 1064, with 2 Coloured Plates and 449 Illustrations. Price **18s.** net. (*University Series.*)

TIBBLES' Foods : their Origin, Composition, and Manufacture. Demy 8vo. Pp. viii + 950. Price **18s.** net.

TURNER'S Radium : Its Physics and Therapeutics.
Crown 8vo. Pp. x + 88. With 20 Plates and other Illustrations. Price **5s.** net.

VULPIUS' The Treatment of Infantile Paralysis.
Translated by ALAN H. TODD, M.B., B.S., B.Sc. LOND. Royal 8vo. Pp. x + 318, with 243 Illustrations. Price **10s. 6d.** net.

WHEELER'S Operative Surgery.
Second Edition. Demy 8vo. Pp. xiv + 296, with 157 Illustrations. Price **7s. 6d.** net.

WHITLA'S Medicine. In two volumes. Pp. 1900. Price **25s.** net.

„ **Materia Medica.** Ninth Edition. Pp. xiv + 674, with 23 Illustrations. Price **9s.** net.

„ **Dictionary of Treatment.** Fifth Edition. Pp. x + 1204. Price **16s.** net.

WILLIAMS' Minor Maladies and their Treatment.
Third Edition. Crown 8vo. Pp. viii + 396. Price **5s.** net.

WITTHAUS' Manual of Toxicology.
Second Edition. Royal 8vo. Pp. x + 1262, with 36 Illustrations Price **30s.** net.

YOUNGER'S Insanity in Everyday Practice.
Second Edition. Crown 8vo. Pp. viii + 124. Price **3s. 6d.** net.

LONDON :
BAILLIÈRE, TINDALL & COX, 8, HENRIETTA ST., COVENT GARDEN.