RESEARCHES

ON THE

DEVELOPEMENT, STRUCTURE, AND DISEASES

OF

THE TEETH.

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THE TEETH.

BY

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TO THE MEDICAL PROFESSION.

Gentlemen,

Before the fatal seizure of my late lamented husband, he had just completed the MS. of a Treatise which I have now the satisfaction of presenting to you—the result of long professional inquiry, and patient investigation. He was impressed, no doubt, with its general usefulness—had pursued the occupation with undiminished ardour to the end—and I can assert in the most unqualified manner, that its production before the public was his first—his unchanging aspiration.

With this knowledge, and the desire of carrying out to the utmost the wishes and intentions of one of the best of men, I have committed these pages to the press, and to your especial notice and acceptance. While encouraged by something beyond a natural reliance upon their author and his probably well-founded pretensions—risking, likewise, slight inaccuracies, deprived of revision, which may be supposed incidental to every posthumous publication—I still hope for countenance in my act from your favourable judgment upon it, to the high importance of which I could not be insensible.

I am, Gentlemen,

Your obedient and much obliged,

Marian Nasmyth.

CONTENTS.

CHAPTER I.

GENERAL PHYSIOLOGY OF THE DENTAL SYSTEM.

HAVING already, in my Historical Introduction to Odontology taken a brief, but comprehensive survey of our present state of knowledge with regard to this subject, I now proceed to the more immediate purpose of my treatise, namely, the elucidation of my own investigations and researches into this important branch of physiological science.

The plan which it is my intention to pursue in these pages, is, firstly, to describe the form and structure of the jaws and teeth; secondly, to point out the nature and organisation of their formative organs; and, thirdly, to explain the manner and progress of development of the formative organs, and of the teeth; illustrating these topics with physiological and practical considerations and suggestions whenever the opportunity may occur.

Were it not that the importance of a thorough knowledge of the anatomy and physiology of the teeth, to those who are engaged in their practical management, cannot be too strongly or too frequently urged, it might be considered unnecessary to dwell upon a subject so self-evident; but I cannot forbear from endeavouring to impress upon the minds of my readers that such a knowledge forms the very basis of sound surgical practice, and that without it the surgeon would be incompetent to perform the most simple operations on the teeth with a proper regard for the safety of his patient. The physiology of the teeth, teaches us the cause of their shape and arrangement, their admirable adaptation to the office which they fulfil, and the manner in which their function is effected—considerations which enlighten the mind in regard to our practical duties, and at the same time elevate the soul in delighted contemplation of the beauty, harmony, and sublimity of our material organisation.

The teeth are the primary agents in the assimilation of our food, serving to prepare it by mastication for those important chemical and vital processes which are to be completed in the rest of the alimentary system. It is, therefore, not presuming too much to affirm, that they are not only necessary to our comfort, but even to our very existence. They are equally necessary as agents of nutrition to the rest of the animal kingdom, howsoever they may be modified to suit the peculiar and changing conditions of animal existence. Illustrations of these peculiarities will be found distributed through the following pages, wherever they are calculated to elucidate the leading subject of the present treatise, namely, the anatomy and physiology of the human teeth. We are dependent also upon the sanatory condition of the teeth for our personal health, for our power of perfect vocal articulation, and for the beauty of the human countenance. Surely no stronger argument can be needed to prove the importance of dental anatomy and physiology, and no labour bestowed upon the subject by the scientific investigator can be regarded as too searching or too great.

The teeth are small, white, and hard bodies, projecting into, or out of, the cavity of the mouth, and, in some instances, into that of the fauces and stomach; and surrounded at their base by mucous membrane, from which they appear to arise. In man they are situated on ridges (alveolar processes) of the superior and inferior maxillary bones, being implanted by means of roots in cavities termed alveoli. The general form of a tooth is either conical or wedge-like, or a combination of both. It is the chief agent, as I have previously observed, in mastication, and is assisted in that function by the cheeks, the lips, and the tongue. The teeth are rendered capable of performing their crushing or triturating office by means of the powerful jaws in which they are fixed, and of the powerful muscles which move the lower against the upper jaw.

In reference to conformation a tooth is divisible into two parts, one which appears above the level of the mucous membrane, and is termed the crown, and one which lies beneath the level of that membrane, being lodged in the alveolar process, and is called the root. The line of demarcation between these parts, a point which is never strongly marked, and in some instances is altogether arbitrary, is the neck of the tooth.

When examined with reference to its component tissues, a recent tooth is found to possess three different structures; an external hard and dense portion, the calcareous crust; a soft vascular and sensitive part, which is enclosed in a cavity in the interior of the former, the pulp; and a thin membrane, which invests the crown of the tooth, the dental capsule. The calcareous crust is extravascular and extraneurous, but possesses a remarkable and peculiar internal organisation; the pulp is obviously highly vascular, and endowed with exquisite sensibility; and the capsule, though presenting a state of atrophy in the adult, is both vascular and sensitive in the earlier periods of life.

Five different and characteristic tissues are recognised in the intimate structure of the calcareous crust of teeth, namely, 1. *cortical substance*, also denominated crusta petrosa, or cementum; 2. *enamel*, or adamantine substance; 3. *ivory;* *

* The term *ivory* having been originally bestowed upon the substance of the teeth of certain animals, and being well understood, appears to me to be the best designation for the analogous structure in the teeth of man. Different authors have suggested other appellations, such as "proper tooth substance;" "bone of the tooth;" "osseous substance of tooth;" "tooth bone;" "dentine," &c. But all these terms are fully as objectionable, if not more so, than ivory, the most objectionable of all being "dentine;" and

4, *corpuscular ivory ;* and 5, *canalicular ivory,* the two latter being, in truth, modifications of the preceding or true ivory. Of these tissues three are constantly to be found in the teeth of man and the higher mammalia; and the fourth, namely corpuscular ivory, occasionally. The fifth is met with only in particular animals. As respects the proportion which they bear to each other the different substances present great variety, such variety having reference to peculiarities of habits, and to the exigencies of the different groups of animals in which they are found. The investigation of these differences constitutes a curious and interesting subject of zoological inquiry.

The differences above referred to, as occurring in the structure of a tooth, are generally recognisable by the naked eye, but the characteristic appearances of the particular tissues are only to be distinguished by means of the microscope. In the tooth of man the enamel is met with on the crown, for here alone are its functions required; in many animals, however, where the tooth is liable to be worn away, and the worn surface is still called upon to perform the office of the entire tooth, the enamel is found existing on the root. The most constant of the dental tissues throughout the animal kingdom is the ivory, either in its true or canalicular state. It is a production of the pulp, being formed by the deposition of calcareous matter in the cells constituting its peripheral surface. The cortical substance is formed in a similar manner by deposition within the cells of the dental capsule, and the enamel is produced by an especial organ, which is developed from the internal surface of the same capsule.

By chemical analysis we determine the hard parts of a tooth to be composed of calcareous salts, deposited in a framework

for the obvious reason, that it is not only an uncalled for addition to our already overcharged scientific nomenclature, but that it conveys, by its terminal syllable, the idea of the substance referred to being an elementary principle, which is not the case. The enamel and cortical substance are clearly as much entitled to the designation "dentine" as ivory.

of animal tissue, the animal framework being the bond of union between the calcareous elements, and serving to maintain the solidity of the entire organ.

In reference to their form, and to the office which they fulfil, the teeth are divided into three classes, namely, incisors, canines or cuspidati, and molars, the latter again being divided into large and small, or true and false molars.

Among the inferior classes of the animal kingdom teeth are met with, possessing a very simple type both as relates to form and organization. But in following the animal series upwards to the highest classes, we are far from meeting with a gradual perfection in the dental organs. They present, as might be expected, a considerable range of variety, both in respect of situation and development: in certain tribes being remarkable for their number and general distribution over the walls of the mouth, and in others being partially or entirely wanting; or, more correctly, being so modified in appearance and structure as to lose all the characters of the teeth of higher animals. In one form or other dental organs exist in all the vertebrate classes of animals, and also in many of the invertebrata.

The number of teeth is subject to great variety in the different classes and families of animals; in man, at the adult age, there are thirty-two, sixteen in each jaw. Of this series, the incisors occupy the anterior part of the mouth, and are succeeded by the canines, the incisors and canines together constituting the *oral* teeth. Behind the canines follows a range of molars or grinders, constituting the *buccal* teeth.

The incisors have received their distinctive appellation from the functions which they fulfil of incising, that is, of cutting and dividing the food. The canines are so named from their conspicuous appearance and position in the canine race, as well as in all carnivorous animals; their purpose is obviously one of prehension, holding and tearing the food or prey. The molars, as their name implies, (*mola*, a mill,) are grinders, and are intended to comminute the food, and reduce it, with the aid of the salivary secretion, to a soft pulp.

The canine teeth may be regarded as performing the most simple of the offices of teeth in the animal economy; namely, that above referred to, of prehensile organs, holding or tearing the prey or food. Accordingly, in certain animals which are so organized as to be able to gorge their prey entire without the necessity for division or comminution, these are the only teeth with which the jaws are provided. For example, the teeth of fishes and serpents are of this kind, so also are those of many of the Saurian reptiles. Prehension by means of the mouth is an attribute necessary to all animals, from the lowest to the highest; and, in the latter, as in man, it is to these simple prehensile dental organs that the term canine has been given. In the canine genus, as well as in the entire order of carnivora, they are formidable organs, and are capable of being used as weapons of offence and defence. Their position in the mouth is such as to give them a powerful hold upon any substance which they may have transfixed, and their position admits of their exercise without any interference with the axis of vision, a consideration of no trifling importance.

When food or prey is transfixed by the canine teeth, and thus firmly held, the incisive or cutting teeth are brought into a favorable position for use. But whether employed in this way, or in the absence of canines, the incisor teeth with their sharp edges close upon each other like the blades of scissors, and so effect the division of the food. The position of the incisors in the anterior part of the mouth is the most distant, and consequently the weakest point of the lever, represented by the lower jaw. Their sharpness, however, is a sufficient compensation for this disadvantage, and in addition to that, being only called upon to separate such portion of food as can be conveniently submitted to the act of mastication, the power which they are capable of exerting is perfectly adequate to the purpose to be fulfilled. The incisors are admirably adapted, by their wedge-like shape, for the penetration and easy division of food, or for cropping, nipping, or cutting, according to the exigencies of particular animals.

The mouth of man may be regarded as presenting the type of the various forms of teeth met with in the whole animal kingdom. For example, it has been already shown that in certain animals the teeth are all of the same class, and that this class is represented by the canine teeth of man. In other animals, again, there are no canine teeth, but there may be incisors, and wherever incisors exist molars will also be found. The reason is obvious ; canine teeth take no share in the act of mastication ; they are, as it were, mere providers to the other teeth, while the incisor teeth are essential to the molars, and the latter no less so to the incisors.

The principle on which the molar teeth of carnivorous animals is constructed is that of a combination of simple cones. In ruminating and graminivorous animals, the molar teeth are convoluted. In the elephant, and other mastodontoid animals, they are composed of a number of cones or wedges, bound together at the base ; and a similar conformation is observable in the incisors of certain animals, as of the flying lemur. The crowns of the molar teeth in carnivorous animals are surmounted by prominent tubercles or cusps. In graminivora, these cusps, although they exist in the young animal, are completely worn away by the constant attrition of their food, and the grinding force which is necessary to reduce it to a state of pulp. In man, and in other omnivora, the cusps or tubercles, though less prominent than in carnivora, are permanent, and generally remain during the whole period of life.

The roots or fangs of the teeth offer varieties in configuration not less marked than those which distinguish the crown ; these varieties having reference to the habits and customs of the animals, the nature of the medium in which they reside, and the kind of food on which they subsist; in the latter instance as calling for the employment of a greater or less degree of force in the act of mastication. In man, the fangs of the teeth are conical, and the same form is traceable throughout the whole tribe of omnivora. Indeed there is no shape so perfectly adapted to resist the concussions necessarily communicated to the teeth in the various acts attendant upon the division, prehension, and mastication of animal food, as that of the cone. The conical form is most suitable for the distribution of vibrations through the whole extent of the fang, for their dispersion in the loose and cellular alveolar process in which the fang is embedded, and moreover for admitting into the interior of the tooth the blood-vessels and nerves which are destined for the pulp, without danger of injury from the pressure exerted on the crown. It is only when a fall, a blow, or some violent accident has been received, that injury from irregular concussion is likely to accrue, and laceration of the blood-vessels and nerves entering the apex of the fang, with a consequent destruction of the vitality of the tooth.

Under the violent force used by certain animals in procuring or comminuting their food, for example, by the monkey in cracking hard huts, or in the dog and hyæna in crushing bones, there can be no question that irregular shocks are communicated to the teeth; but the dental organs are so well fitted in their sockets in these animals, and are so admirably contrived to resist such concussions, that no injury results from the effort. Graminivorous animals, however, are not exposed to similar trials, and in them the fangs of the molar teeth are almost as broad as the crowns. Moreover, this conformation is suited to the purpose of affording a strong and steady base to the teeth, and a perpendicular support in whatever direction the jaws may be moved.

Again, the fangs offer a modification in position, which is beautifully adapted to the peculiar wants of the animal. In the upper jaw the axis of the incisor is directed forwards and downwards, in the lower upwards and forwards. From a combination of form and position, the superior incisors, moreover, are placed a little in advance of those of the lower jaw, so as to pass in front of the latter when the mouth is closed; thus producing the scissor-like action of the incisors. A similar arrangement occurs in the position of the canine teeth, and with a similar result.

In contemplating the arrangement of the teeth of aquatic and amphibious animals, we are struck with the beauty of adaptation which is maintained between them and the prey upon which they feed. A strong and vigorous fish, encased in its smooth and polished armour of scales, must of all kinds of living prey be the most difficult to hold, and the most perfect form of prehensile organs must be requisite for such a purpose. Of such organs we have examples in the dental apparatus of the dolphin, the crocodile, the shark, and the lepidosteus. Their formidable rows of jagged and pointed teeth prove to us also that their prey are capable of making strenuous and desperate resistance. Indeed, it is no uncommon occurrence for the teeth of these animals to be sacrificed in their fierce encounters, and to be broken or torn out in the course of their violent struggles.

Nature has, however, bountifully provided for such accidents by apportioning to them a multiple series of teeth, which are at all times ready to fill the places that may be vacated by the loss of their predecessors. Such a dental economy as that to which I am now referring is exemplified in the jaws of the shark, and in those also of the crocodile. As another modification for resistance, the teeth of many fishes, in advanced life, become anchylosed to the jaws, and can no longer be separated without extreme violence: in the pike this state of the teeth and jaws is not unfrequently observed.

Energetic action in the habits of animals is indicative of activity and power in the assimilative organs, and not less of integrity and efficiency in the dental apparatus. Of this proposition we have evidence in the number and strength of the teeth in the animals above referred to. The whale, on the other hand, although possessing the advantage of warm blood, and an aerial respiration, is sluggish and inactive in its habits, and toothless in relation to its dental economy. Lions, tigers, and other predaceous carnivora, possess a formidable armament of powerful teeth, while the dental apparatus of herbivorous animals is as little offensive as their food is simple, and their characters harmless and gentle. A parallel observation may be made with regard to man,—a well-developed mouth, furnished with strong and healthy teeth, is naturally associated with perfect powers of mastication, and an efficient and complete digestion. Nutrition under these circumstances is favourably performed; the whole system acquires a vigorous tone, and the muscular energies are active and powerful. Moreover, if the teeth be well formed, perfect, and properly arranged, the whole osseous system will in general be found to present a strong conformation, and the chest a full and vigorous developement.

While it is difficult to single out any portion of animal organisation which may exhibit more obviously than another the manifestation of an all wise and intelligent design, it must be admitted that the economy of the dental organs, in their relation to the instincts of animals, is not among the least remarkable illustration of the benevolent decrees of a bountiful Providence. The carnivorous races would be incapable either of procuring or of using their appropriate food, were they possessed of any other form of dental apparatus than that which is peculiarly their own; and the simple transfer of the teeth of carnivora to the ruminant would be destructive of its existence. The docile horse, whose instincts lead him to crop the humble produce of the plain, has no teeth which can compare with the sharp and powerful tusks of beasts of prey, yet the conspicuous character of his race, velocity of motion, is as clearly shown in the construction of his oral teeth, as though it were written upon them in letters of brass. His strong and powerful incisors are obviously intended to enable him to gather quickly, and in the few moments allowed him for repose, his hasty meal, that he may be ready on the instant to flee before his pursuer, and gain, by enduring speed, that which was denied him in cunning and in strength. How differently provided is the ponderous and clumsy ox; his incisor teeth are small and weak, deficient entirely in the upper jaw, performing slowly their appointed office, while his strength lies less in his speed than in the powerful defensive organs which surmount his head.

The conformation of the dental apparatus of man is beautifully fitted to the purposes of masticating a mixed animal and vegetable diet, and at the same time of contributing to a perfect vocal enunciation; and it may be fairly presumed than any other conformation or arrangement of teeth would have imperfectly fulfilled these important functions. If the human mouth, for example, had been furnished with the large and irregular teeth of carnivora, articulation must have suffered in proportion, and in like manner had the teeth been fashioned on the principle of those of herbivora, the power of masticating animal substances must have been sacrificed.

CHAPTER II.

DESCRIPTIVE ANATOMY OF THE MOUTH AND JAWS.

THE mouth is the aperture of entrance of the alimentary canal, and performs important offices in relation to digestion, respiration, and vocalization. As an organ concerned in digestion it is an agent of prehension, that is, of holding and receiving the food; and the sole agent in mastication. A third act attendant on digestion is performed in the mouth, namely, insalivation, and by it also the first stage of deglutition is effected. In the act of prehension, the lips take a considerable share, and to this end they are endowed with exquisite sensibility; they are distensible in order to yield to an extent commensurate with the bulk of the morsel received, and they are possessed of muscles which enable them to resume their original shape when the cause of distension ceases.

The cavity of the mouth is bounded *above* by the hard palate, that is, by the palatal processes of the superior maxillary and palate bones; by the alveolar process with its teeth, which bounds the hard palate laterally and in front; and, externally to the alveolar process, by the mucous membrane in its transit from the base of the gums to the cheek. The hard palate or roof of the mouth is concave, and rises obliquely from the front to the back part of that cavity; it is also narrower in front than behind. When divested of its soft parts, it presents in front, directly behind the median incisor teeth, a large opening, the anterior palatine or incisive foramen; and behind and to the sides near the last molar teeth, a pair of openings, the posterior palatine foramina. Below, the cavity of the mouth is bounded by the tongue; the mucous membrane in its course from the under part of the tongue to the lower jaw, where it covers in, and conceals the sublingual glands and mylo-hyoid muscles; the alveolar process with the teeth of the lower jaw; and externally to the latter, the mucous membrane, in its transit from the base of the gums to the cheek. In front, the boundaries of the mouth are the lips; on either side the mucous membrane of the cheek, which invests the buccinator muscle; and behind, the soft palate and the fauces, or aperture of communication with the pharynx.

The head is divisible into two principal portions,—the cranium, or cavity for the reception of the brain; and the face, a complex framework for the maintenance and protection of several of the more important organs of sense, namely, of sight, smell, and taste, together with, as we have already seen, the organs concerned in the preliminary acts of digestion.

OSTEOLOGY OF THE FACE.

The face admits of division into an upper and an under portion; the former is composed of thirteen bones, namely, two superior maxillary, two palatine, two inferior turbinated, the vomer, two nasal, two lachrymal, and two malar; and the lower jaw of one only, the inferior maxillary. As the maxillary and the palate bones alone enter into the formation of the mouth, I shall confine myself to the description of these.

SUPERIOR MAXILLARY BONES.

The superior maxillary bones are situated in the middle and anterior part of the face, of which they form, with their accessaries, the intermaxillary bones, the largest share. They assist, also, in the formation of the orbits, nose, and mouth, and contain in their interior a large cavity, the maxillary sinus or antrum highmorianum. In the adult, the intermaxillary bones are anchylosed to the superior maxillary, and then they constitute with the latter only a single pair of bones. Each superior maxillary bone offers for examination a superior or orbital surface; an inferior or palato-alveolar surface; an internal or nasal surface; an external or jugal surface; an anterior or facial surface; and a posterior or zygomatic surface.

The superior or orbital surface constitutes the chief share of the inferior wall or floor of the orbit. It is triangular in shape, the apex of the triangle being directed backwards, and being articulated with the orbital process of the palate bone. The plane of this surface presents an obliquity from within outwards, and from behind forwards, and at its posterior part is a deep groove, three or four lines in length, which terminates in front in the infra-orbital canal. The direction of this canal is obliquely downwards and forwards, and it opens on the face at about a line or a line and a-half below the inferior margin of the orbit, by the infra-orbital foramen. From the infra-orbital canal there proceeds a small passage which runs downwards and inwards in the substance of the bone towards the incisor and canine teeth, and is intended for the transmission of the nerve which supplies those teeth. The inferior wall of the infra-orbital canal not unfrequently makes a convexity into the maxillary sinus, and is separated from it by a thin lamina of bone; at other times this separation is absent, and the inferior surface of the nerve is invested by the mucous lining of the antrum. The inner border of the orbital surface is notched in front, where it articulates with the lachrymal bone, and assists in the formation of the nasal duct; and behind, this notch articulates with the pars plana of the ethmoid. Externally, this surface articulates with the malar bone; anteriorly, it is bounded by the prominent margin of the orbit, and also articulates with the malar bone; and posteriorly it presents a rounded border which forms the inferior boundary of the spheno-maxillary fissure. The inferior, or palato-alveolar surface, is bounded externally by the alveolar process, which from the front sweeps outwards and backwards, and then backwards and inwards. The palatine portion of this surface, the palatal process, is concave towards the mouth; grooved behind for the posterior palatine nerves and vessels, perforated by numerous minute apertures for the passage of blood-vessels, and broader behind than in front. At the anterior part of its inner border is a notch, which, with a corresponding one in the opposite bone, constitutes the boundary of the incisive foramen.

The anterior or facial surface presents in its upper part the infra-orbital foramen, and above this the inferior border of the orbit. If a line be dropped perpendicularly from the side of the forehead across the infra-orbital foramen, it will be found to intersect also the supra-orbital foramen above, and the mental foramen below; these three foramina being the openings of egress upon the face of the terminal branches of the three divisions of the fifth pair of nerves. Immediately below the infra-orbital foramen is a shallow fossa, for the origin of the levator anguli oris muscle. This fossa is bounded in front by the ridge caused by the prominence of the alveolus of the canine tooth, and behind by a larger ridge, which is continuous above with the malar process. In front of the ridge caused by the fang of the canine tooth, and immediately over the alveoli of the incisors, is a shallow groove, the incisive or myrtiform fossa, for the origin of the depressor labii superioris alæque nasi muscle. Above, and to the inner side of the canine fossa, is the ascending or nasal process of the superior maxillary bone. The direction of this process is, in the first place, upwards and forwards, then vertically upwards; and it terminates above in a jagged border, which articulates with the internal angular process of the frontal bone. It is perforated by numerous openings for the transmission of blood-vessels to the nose, and upon its orbital aspect presents a deep fossa for the lachrymal sac. The lachrymal fossa is separated from the facial surface of the bone by a prominent ridge, which is continuous with the inferior margin of the orbit, and posteriorly is bounded by a thin edge, which articulates with the anterior border of the lachrymal, and with the ascending process of the inferior turbinated bone. The curve of the nasal duct is due to the anterior convexity of the ascending process of the last-named bone.

The posterior surface of the superior maxillary bone has received the name of " tuberosity ;" it joins superiorly, at a right angle, the orbital surface of the bone, and presents in this situation the commencement of the infra-orbital groove. Inferiorly it is continuous with the posterior termination of the alveolar process, and is bounded in front by the ridge previously referred to, which descends from the root of the malar to the alveolar process. This surface is pierced by numerous openings, which are the orifices of canals for the transmission of the nerves and vessels of the upper teeth ; some of these canals pass obliquely downwards, and forwards, in the first instance, and then upwards and inwards, so as to make the circuit of the exterior and inferior wall of the antrum, and terminate in the alveoli of the anterior bicuspid and canine teeth, while others pass more directly downwards to the posterior bicuspid and molar teeth.

The external surface of the upper jaw bone articulates with the malar bone. It presents anteriorly a thick and prominent ridge, which looks upwards and backwards, and supports the articulating border of the malar bone above, while it rests against that bone inferiorly. Behind this ridge is a deep fissure, which receives the malar bone, and behind the latter a strong ascending process, which articulates with the orbital process of the malar bone. This portion of the maxillary bone constitutes the outer wall of the antrum.

The internal surface of the superior maxillary bone is divided into two portions, one of which is horizontal in direction, and forms part of the floor of the nose, while the other is vertical, and contributes to the formation of the outer wall of the nasal cavity. The horizontal portion is smooth, being coated in the living body with mucous membrane. It is continuous externally with the base of the vertical portion, and internally presents a ridge which, with a corresponding ridge of the opposite bone, bounds a groove for the reception of the inferior border of the vomer. Anteriorly this ridge is prolonged in the form of a sharp process of triangular shape, the nasal spine. The horizontal portion is narrow in front, and bounded by a sharp concave ridge, and behind it is serrated and bevelled upon its upper aspect, for the articulation of the palatal process of the palate bone. In the anterior part of the horizontal portion near the median line, and at about two lines from the anterior margin of the bone, is the aperture of the anterior palatine canal. This canal, after a short course, opens into an irregular cavity, with which the canal of the opposite side also communicates, the inferior termination of the irregular cavity being the foramen incisivum.

The vertical portion of this face of the bone consists of two principal parts, one being in front, and constituting the anterior nasal process; the other behind, the internal nasal process. The anterior nasal process is smooth at its base, where it joins with the horizontal process, and in the fresh subject supports the mucous lining of the nose. At the height of two or three lines from its base is a rough horizontal ridge, which gives attachment to the inferior turbinated bone, and is about half an inch in length. Above this ridge the nasal process increases in breadth, and then contracts into a narrow and thick portion, which articulates with the internal angular process of the frontal bone. The anterior margin of the nasal process articulates superiorly with the nasal bone, and inferiorly gives attachment to the lateral nasal cartilage; posteriorly it is thin, and articulates with the lachrymal process of the inferior turbinated bone. This latter border, with the process of the inferior turbinated bone just described, and the descending process of the lachrymal bone, constitutes the internal wall of the ductus ad nasum. Behind the anterior nasal process is a deep groove, which is bounded internally by a thin and concave lamina of bone, the internal nasal process. This process articulates superiorly with the orbital process, and is continuous behind with the tuberosity, and below with the palatal process. With the inferior turbinated bone it forms the internal wall of the antrum, and it is pierced by an irregular aperture, which communicates with the latter. The opening of the antrum in the living body presents much variety, both in direction and position, sometimes looking obliquely forwards, at other times obliquely backwards, and being sometimes in the anterior, and sometimes in the posterior portion of the internal nasal process. The aperture opens into the middle meatus of the nose, and is about the diameter of a crow-quill. In the cranium, deprived of its soft parts, the foramen frequently measures from thirty to forty lines in circumference.

The palatal process of the superior maxillary bone measures at its anterior part from seven to ten lines in thickness. In this situation its articulating surface presents a fluted appearance, from being composed of a number of grooves and ridges arranged alternately, and in an oblique direction. Farther back, where this border is not more than two or three lines in depth, the flutings are vertical, their purpose being to afford a secure means of articulation with the opposite bone. Near the anterior part of this border, and at its inferior margin, is a notch, converted into the incisive foramen by the opposite bone. In the upper part of this sulcus may be observed the inferior termination of the anterior palatine canal, the superior aperture being situated, as before described, in the anterior part of the nasal aspect of the palatal process. Thus there is a separate canal in each superior maxillary bone, while the common opening of these canals inferiorly is the incisive foramen.

Antrum Highmorianum.

The antrum or maxillary sinus is a cavity of considerable size, and of a triangular form, situated in the interior of the superior maxillary bone; its apex being directed outwardly towards the malar process, and the base inwardly towards the nose.

This cavity is bounded in front by the facial portion of the bone, which is oblique in the direction from within outwards and backwards, and in the substance of its wall is the canal previously described, which gives passage to the nerve destined to supply the incisor and canine teeth. On the inner surface of this wall there is a prominent ridge formed by the infra-orbital canal, and sometimes this canal is defective towards the antrum in its osseous boundary. The direction of the ridge is downwards and forwards. Occasionally the place of the canal for the nerve of the incisor and canine teeth is replaced by several grooves on the surface of the bone. The anterior wall of the antrum is thin, and admits of being easily perforated in operations practised upon this cavity. The measurements of the anterior wall of the antrum are from twelve to fifteen lines across its middle, and from six to eight lines above and below this point.

The posterior wall of the antrum forms externally the posterior boundary or tuberosity of the superior maxillary bone. It is concave internally, and occasionally presents a cellulated aspect. Inferiorly it is continuous with the alveolar process, a few lines in advance of the last molar tooth; but in the early periods of life it will be remembered that the molar teeth are developed within this wall. The substance of the posterior wall is traversed by numerous canals for the passage of nerves to the molar and bicuspid teeth.

The internal or nasal wall of the antrum is formed conjointly by the internal nasal process, inferior turbinated bone, and nasal portion of the palate bone. The external nasal process is pierced by an opening of communication with the nose, and in front, where it is continuous with the anterior wall, several large cellulated fossæ may frequently be found. The internal nasal process is exceedingly thin, especially that part of it which forms the antral boundary of the nasal duct.

The superior or orbital wall is oblique in direction, in correspondence with the orbital process by which it is formed, and is so thin that tumours or collections of matter within the antrum are liable to make injurious pressure on the cavity of the orbit.

The inferior wall of the antrum, formed by the base of the alveolar process is narrow, and somewhat deeper in level than the floor of the nose. It is frequently divided into two or three compartments by transverse ridges, and occasionally the fangs of the two anterior molar teeth project through it into the cavity of the antrum.

Of the alveoli of the superior teeth.

The alveolar process is composed of two strong walls, of which the internal is thicker than the external. They are connected together by transverse processes, which perform the double office of ties to the walls and of septa to the sockets of the teeth. The arch formed by the alveolar process of the upper jaw is smaller in its radius than that of the lower; but the edges of the teeth of the former describe a more extended arch than those of the latter. In order that this purpose may be effected, the teeth are placed obliquely, the axis of their fangs and, consequently, of their sockets, being directed upwards and inwards. The alveoli are conical in their shape, and pierced at the apex by small openings for the passage of the nerves and vessels of the tooth. For the ten anterior teeth, there is only a single alveolus to each, but for the molars the alveolus is tripartite.

The alveolus of the *central incisor* is irregularly oval in shape, and offers some variety in the measurement of its several diameters. For example, the antero-posterior diameter is about one-third greater than that from side to side; while the lateral diameter is one-third greater in front than behind. The septum which intervenes between it and the corresponding tooth is double the thickness of that which separates the other teeth, and is divided into two parts by the suture of union of the superior maxillary bones. This septum forms the anterior boundary of the incisive foramen. The alveolus extends by its apex to the base of the nasal process, and its anterior wall, remarkable for its thinness, is not unfrequently incomplete.

The alveolus of the *lateral incisor* is rounder in its peripheral outline than that of the preceding, the antero-posterior diameter being not more than one-tenth greater than the lateral. The alveolus is also less deep than that of the central, and the partition between it and the latter is thinner than that which divides it from the alveolus of the canine tooth. The anterior wall of the socket of the lateral incisor is much thinner than that of the palatal wall.

The alveolus of the *canine tooth* is oval in shape like those of the incisors, the antero-posterior diameter being the deeper of the two by about one-tenth, and being directed backwards with a slight inclination inwards. It is the deepest of all the alveoli, and mounts upwards beyond the level of the floor of the mouth into the root of the nasal process, corresponding by its apex with the strong anterior wall of the antrum of Highmore. From its position at the angle of the anterior range of teeth it forms a considerable prominence on the facial surface of the superior maxillary bone, and divides the incisive fossa which lies in front from the canine fossa which is situated behind it. Its anterior wall is exceedingly thin and sometimes imperfect; and of its lateral septa, the internal or that by which it is separated from the lateral incisor, is the thickest.

The alveolus of the *first bicuspid tooth* is constricted at its middle, and at its deeper part is divided into two cells, of which the external is the larger. These cells are intended for the reception of the bifid fang of the tooth, and their size corresponds with that of the roots. The alveolus extends less deeply into the jaw than the socket of the canine, but equals that of the second bicuspid, and the septum which divides it from the latter is thicker than the one by which it is separated from the canine tooth.

The alveolus of the *second bicuspid tooth* is oval in shape, not constricted in the middle, or, if so, to a very trifling extent, and not divided into cells by a median septum like the preceding.

The alveoli of the *three molar teeth* are tripartite, two of the cells being external, and one internal, and not unfrequently the internal cell exhibits a tendency to division into two, but is rarely divided completely. The posterior of the two external cells is the smallest and the internal the largest, and occasionally these two cells communicate and are then occupied by a broad and strong fang formed by the confluence of the corresponding roots. The alveolus of the first molar is more immediately connected with the antrum of Highmore than those of the other teeth, and not unfrequently projects into that cavity. Advantage is taken of this relation in perforating the antrum when such an operation is necessary, and its importance must not be overlooked in the treatment of the fangs when diseased. For perforating the antrum, the anterior external, or the internal cell of this tooth, would be selected, and these correspond with the most dependent part of the cavity. It may also be reached through the alveolus of the second bicuspid, and even through that of the first, but in either case the perforation must be made in an oblique direction backwards, and the deeper part of the cavity would not be attained. The alveoli of the molar teeth present considerable variety in relation to the development and arrangement of the fangs, which they are intended to receive; in some instances the latter are divergent, in others convergent, and in a third case they are so closely compressed as to assume the appearance of a single fang. When the fangs are much spread asunder they necessarily offer an obstacle to the removal of the tooth; but when they converge and embrace between them a portion of the alveolus, the difficulty of removing them is greatly increased.

Structure of the superior maxillary bone.

The superior maxillary bone is composed of two lamellæ, external and internal, between which the teeth are implanted and the antrum is developed. In the palatal process these two layers are separated by cancellous structure, and in front the inferior layer is directed downwards and forwards so as to constitute the posterior wall of the alveolar process. The superior layer, forming the floor of the nose, is separated from the inferior layer in front by a cancellated space of from six to eight lines in depth, and at the anterior margin of the nares is continued downwards into the external wall of the alveolar process. Prolonged upwards this superior layer forms the internal surface of the ascending nasal process of the bone, and posteriorly, the internal nasal process. The external wall of the alveolar process is continued upwards into the malar process, forming the strong external wall of the antrum; while posteriorly, it constitutes the thin posterior boundary of the bone. The orbital process is frequently separated into two layers by the infra-orbital canal.

INTERMAXILLARY BONES.

These bones are situated, as their name implies, between the pair of superior maxillary. They were first accurately described by Goëthe, and by some authors are considered merely in the light of centres of ossification of those bones. In animals, however, they are always quite distinct from the maxillary bones and easily separable from them. And I cannot admit that their early anchylosis to the maxillary bones in man is a sufficient reason against their being described as distinct bones. Moreover, almost every skull presents traces, more or less distinct, of these bones.

The idea of the fœtal character of the inter-maxillary bones, and the notion so prevalent among anatomists, of the persistence of these bones being a characteristic of animals inferior to man in the scale of organisation, have led to their neglect as a demonstration of conditions of much importance in practice, and of interesting considerations in relation to some points of the study of man. These bones serve most importantly to render the upper jaw pliant during the actions of the mouth in the early years of life; and they are also of high account in promoting by their growth the latitude necessary for the proper arrangement of the teeth. As a means, also, of preventing concussion of the teeth, they are valuable accessories in the mechanism of the mouth.

In the fœtal skull, at the point of junction of the posterior with the middle third of the foramen incisivum, a fissure may be observed which passes upwards into the anterior palatine canal on each side, and may be traced onwards to the floor of the nasal cavity. Having reached the latter situation, it inclines obliquely backwards and outwards for the distance of about a line, and then bends forwards and upwards for a space of two or three lines to the base of the nasal process of the superior maxillary bone, terminating upon the latter at one or two lines below the ridge for the inferior turbinated bone. If the foramen incisivum be again examined, another fissure will be observed on the oral surface of the palate, passing directly outwards to the alveolus of the canine tooth, and curving gently backwards in its course. The portion of bone which lies anteriorly to these fissures on each side, and which supports the incisor teeth, is the inter-maxillary bone; from the latter circumstance it has likewise been called *os incisivum*.

PALATE BONES.

The palate bones contribute to the formation of the mouth, the nose, and the orbit. Each bone is divided into two portions, one being horizontal, the other vertical in direction.

The horizontal or palatal portion forms the posterior part of the bony palate; it is smooth upon its under surface, and unmarked by those numerous foramina which are so conspicuous in the palatal process of the superior maxillary bone. Near its posterior margin is a prominent semilunar ridge, which subsides towards the middle line; and immediately in front of the outer limit of this ridge is the posterior palatine foramen. The upper surface of the palatal process is smooth and concave; rising inwardly to form the boundary of a groove constituted by the two bones for the reception of the vomer, and outwardly, as a thin and delicate process which enters into the construction of the inner wall of the antrum. The anterior border of the process overlaps the palatal process of the superior maxillary bone to the extent of about a line; and posteriorly, it presents a semilunar border, becoming thicker towards the median line, and forming with its fellow bone a prominent spine, the azygos process. Externally, this curved border terminates in a thick and irregular process, the tuberosity. The tuberosity of the palate bone is received into the forked space between the extremities of the pterygoid plates, and forms part of the pterygoid fossa, presenting to this fossa a concave surface.

The vertical or nasal portion of the palate bone is between twelve and fifteen lines in length, and from six to eight lines in breadth. By its internal surface it forms part of the external wall of the nose, and at about one-third from its base presents a horizontal ridge which gives attachment to the inferior turbinated bone. Above this point the internal surface arches inwards towards the middle line, where it comes into relation with the edge of the expanded base of the vomer.

The external surface of the nasal process is divided into two portions, the anterior forming part of the internal wall of the antrum, the posterior articulating with the maxillary bone. The distinction between these parts is very evident, the former being smooth, and in the living body invested by the mucous lining of the antrum; the latter being irregular and scabrous. The anterior portion, moreover, is frequently concave. Near the posterior border of the external surface is a deep groove, converted by the tuberosity of the maxillary bone into a canal, the posterior palatine; and in the upper part of the nasal process is a deep notch or foramen, the spheno-palatine foramen. The spheno-palatine foramen is bounded in front by a square-shaped process, the orbital, which is in opposition anteriorly with the superior maxillary, and internally with the ethmoid bone. This process is hollowed in its interior into cells which communicate with those of the ethmoid, and the nasal portion of the bone anteriorly and inferiorly to this process is occasionally so thin as to admit of a communication between the anterior and the ethmoidal cells. The process behind the orbital is the sphenoid; it is in opposition with the root of the pterygoid process, and between this and the sphenoidal process of the palate bone is a foramen, the pterygo-palatine.

INFERIOR MAXILLARY BONE.

The inferior maxillary bone constitutes the whole of the osseous framework of the lower jaw, and is situated below the other bones of the face. It is composed of two symmetrical halves, which are separate bones in the young subject, but in the adult are firmly united together.

For convenience of description, each lateral half of the bone may be considered as being divisible into two portions—a horizontal portion, the proper body of the jaw; and a vertical portion or ramus. The former of these portions contributes largely to the formation of the mouth, and gives support to the teeth; while the latter is adapted for the attachment of muscles and for articulation with the temporal bones.

The body of the bone presents two surfaces and two borders for our examination. The external surface is convex, and fluted in its upper half, by the projection of the fangs of the teeth. The surface of bone covering these prominences is smooth and terminated above in an abrupt border, the summit of the external wall of the alveolar process; and behind the last molar tooth, the border of the external wall of the alveolar process is continuous with that of the internal wall. The external surface of the body of the lower jaw is crossed by a line which descends from the base of the coronoid process obliquely forwards to the anterior part of the bone, where it gradually subsides. The surface immediately above this line, and the line itself, give attachment to the buccinator muscle, and more anteriorly, to the depressor anguli oris. A depression on either side of the ridge which marks the symphisis or line of union of the lateral halves of the jaw, is the seat of origin of the depressor labii inferioris, and the elevated surface immediately below and to the inner side of this depression supports a cushion of fat, and forms the prominence of the chin. A little further outwards, in a line with the posterior bicuspid tooth, and about half an inch above the base of the lower jaw, is the mental foramen. The direction of this opening is backwards and upwards, and it gives exit to the terminal vessels and nerves from the dental canal. Occasionally the mental foramen has been found double.

The internal surface of the body of the bone is likewise divided into two parts by an oblique ridge, the mylohyoidean, which commences at a point posterior to the last molar tooth and descends to a tubercle situated upon the inner surface of the symphisis, near the base of the jaw. This ridge gives attachment to the mylohyoideus muscle. The surface of bone above this ridge enters into the formation of the cavity of the mouth; it is smooth and triangular in shape, bounded superiorly by the internal wall of the alveolar process, and coated in the living subject with mucous membrane. In the posterior angle of this surface is a prominence occasioned by the root of the last molar tooth, and at its anterior and inferior angle, two pairs of tubercles for the attachment of the genio-hyo-glossi and genio-hyoid muscles. The surface of bone below the mylohyoidean ridge is also triangular. It is bounded, inferiorly, by the base of the jaw, and behind, by the rough surface which gives attachment to the internal pterygoid muscle. Near the anterior angle of this surface is a rough and oval-shaped impression for the attachment of the anterior portion of the digastricus muscle; and near its base a slightly hollowed plane, against which the submaxillary gland rests. The superior border of the body of the lower jaw is the alveolar process, which arches backwards on either side to the base of the coronoid process. In the alveolar process are situated the sockets or alveoli of the sixteen teeth of the lower jaw, which are conical cavities pierced, inferiorly, by small openings for the passage of the blood-vessels and nerve of the tooth.

The alveolus of the *median incisor* tooth is broadest in its antero-posterior diameter, and the septum of division between the two median incisors is, as in the upper jaw, thicker than that which separates them from the lateral incisors.

The alveolus for the *lateral incisor* varies in the direction of its axis from a postero-anterior to a postero-antero-external inclination. Its orifice is rather broader in front than behind, and is indented on its outer side; the indentation corresponding with a vertical groove on the outer surface of the fang of the tooth. On the inner side this indentation is scarcely perceptible. The anterior wall of the alveolus is slightly convex; the posterior, concave; and the lateral septa are thicker behind than before.

The alveolus of the *canine* or cuspid tooth is much larger than that of the incisors or bicuspides. Its figure is conical, and somewhat compressed laterally; and it has a slight indentation on each side which corresponds with a line of depression on the fang of the tooth. The anterior wall of the socket is directed downwards and backwards, and the posterior vertically downwards. Hence the axis of the canine tooth is different from that of the incisors, being inclined upwards and forwards. The anterior wall of the socket of this tooth is remarkable for its prominence, projecting more than any other of the dental series, and for the extreme tenuity of its osseous substance. The orifice of the alveolus is oval in shape, and nearly twice as broad in front as behind.

The alveoli of the preceding teeth occupy nearly a transverse line from side to side of the mouth. The remaining portion of the alveolar process has a direction backwards and a little outwards, and contains the alveoli of the two bicuspid and three multicuspid or molar teeth.

The alveolus of the *anterior bicuspid* tooth is considerably smaller than that of the canine. The direction of its vertical axis is obliquely inwards, and that of its antero-posterior diameter obliquely outwards and forwards. It is conical in form, and compressed laterally; the external surface is flat, and the internal somewhat concave. The shape of the aperture of the socket is oval, the anterior and posterior edges being slightly indented.

The alveolus of the *posterior bicuspid* tooth is a little larger than that of the anterior, but smaller than the socket of the canine. The direction of its vertical axis is downwards and backwards; hence, the fangs of the two bicuspids are separated frequently to the extent of three or four lines,—a circumstance of considerable importance in the practical management of the teeth. The palato-buccal diameter of the socket is directed obliquely outwards and forwards, and its aperture is less indented on its anterior and posterior margins than that of the anterior bicuspid.

The alveolus of the *anterior molar* or first multicuspid tooth is divided into two cells by a septum which crosses it obliquely from without, inwards and backwards. The septum is thick towards its centre, where it forms an anterior and posterior convexity: and it is perforated by numerous apertures, varying in size from one-third to one-fourth of a line, for the transmission of the vessels of the cancellous structure. It is also thicker at its middle than at the upper margin, or at the base. Of the cells for the reception of the fangs, the anterior is somewhat larger than the posterior, and the direction of the axis of both is obliquely backwards. The aperture of this socket is quadrilateral in shape, the internal margin being slightly shorter than the external; the anterior margin also is indented by a vertical ridge, which projects from the face of its wall.

The alveolus of the *second molar*, or median multicuspid tooth, is a little smaller than that of the first, and is divided by a median transverse septum (occasionally wanting) into an anterior and posterior cell. The anterior of the two cells is the larger; it is compressed from before backwards and slightly constricted in the middle. The posterior cell is oval in shape, not so deep as the anterior, and more obtuse externally than internally. The aperture of this socket is quadrilateral, and rather narrower on the lingual than on the buccal side.

The alveolus of the *posterior molar*, or third multicuspid tooth offers considerable variety both in conformation and size. It is always smaller and shallower than the sockets of the two preceding molars; is sometimes divided into two separate cells, and at other times is a simple conical cavity. Its direction is obliquely backwards, and occasionally it is almost horizontal.

The sockets of the molar teeth of the lower jaw have all a direction outwards; their crowns have consequently a slight inclination inwards. This position corresponds accurately with the direction of this part of the body of the jaw. The last molar is separated from the base of the coronoid process by a shallow concave depression.

The inferior border of the body of the lower jaw is called the base. From the middle line in front it follows a direction, at first directly outwards, and then outwards and backwards to its termination in the angle of the bone. At about the middle of its course, at a point corresponding with the situation of the anterior and middle molars, the base expands; and beyond this point, as far as the angle, is considerably narrower. The base of the jaw extends about an inch beyond the posterior molar tooth, and in consequence of the obliquity of the vertical axis of the bone above described, and that of the ramus, a line drawn from one angle of the lower jaw to the other would measure from ten to fifteen lines longer than one stretched between the posterior extremities of the alveolar arch. When placed on a flat plane, the base touches the surface by two points only; namely, by the angle, and by the summit of a convexity corresponding in situation with the bicuspid teeth.

The ramus of the inferior maxilla has an inclination upwards and backwards from the posterior part of the body of the bone, and is divisible into two surfaces and four borders.

The external surface is rough and uneven for the attachment of the masseter muscle, and is bounded anteriorly by a line which ascends from the base of the bone obliquely forwards to the margin of the coronoid process, and posteriorly by a rounded border, which is continuous inferiorly with the angle of the jaw, where it presents a rough process, and a notch, and superiorly expands into the condyle. At a little above the middle of this surface of the ramus, a prominence is frequently observed, which marks the situation of a depression on the internal surface immediately above the dental foramen.

The internal surface of the ramus is also rough and uneven for the attachment of the internal pterygoid muscle. At about its middle, that is, about nine lines posteriorly to the last molar tooth, is a large opening, the inferior dental foramen. This foramen is the aperture of a canal which passes obliquely downwards and forwards in the substance of the bone, and transmits the inferior dental nerve and vessels. Below the foramen, and forming its lower lip, is a rough plate of bone, the spinous process, for the attachment of the internal lateral ligament; and directly behind this process is a deep notch, which is continued downwards and forwards on the surface of the bone as a shallow groove, the sulcus mylohyoideus, for the mylohyoidean nerve, a branch of the inferior dental. The groove may be traced along the bone for a distance of about fifteen lines, and frequently it divides into two channels near its termination. The surface of the jaw in front of this groove is smooth, and is invested by the mucous membrane of the mouth.

The ramus of the jaw terminates superiorly in an anterior and posterior prominence. The former of these is the coronoid process, and the latter the condyle. The coronoid process is thin and triangular, its apex being directed upwards and the base being lost in the ramus of the bone. Externally this process is flat, and internally somewhat convex; posteriorly it presents a sharp margin, which is continuous with a concave sweep, the semilunar or sigmoid notch; and anteriorly another margin, which passes obliquely forwards, and divides into two ridges, which descend along the anterior border of the ramus, leaving a groove between them. The external of these ridges is continuous at the base of the coronoid process, with the oblique line which bounds the external surface of the ramus anteriorly; the internal is lost in the internal margin of the alveolar process. The internal surface and anterior border of the coronoid process give attachment to the tendon of insertion of the temporal muscle.

The condyloid process, or condyle, surmounts the posterior border of the ramus, and is the medium of articulation of the lower jaw with the cranium. It is a rounded oblong process, separated from the ramus of the jaw by a constriction termed the neck, and having its long axis directed inwards and backwards. The outer and anterior border of the neck is continuous with the semilunar or sigmoid notch which intervenes between the condyle and coronoid process; while the surface, internal to this, presents a shallow triangular depression for the attachment of the external pterygoid muscle. The condyle is convex from before backwards, as well as from side to side, and in elderly persons is frequently flattened on its upper surface. On its anterior aspect it is separated from the neck by a well-marked ridge, and behind is continuous directly with the posterior border of the ramus.

The inferior maxilla offers much diversity of structure at different periods of life. In the adult it is composed of an external layer of dense and compact bone, enclosing a cancellous structure. At the base of the jaw the compact structure is frequently a line and a half or two lines in thickness. At about two lines above this compact structure is situated the dental canal imbedded in cancelli; and above the latter are other cancelli, among which the alveoli are excavated. In the infant state the bone below the dental canal is generally only about a line in depth. The angle of the jaw undergoes great modification throughout life. The angle of the infantile stage is about 150^0; at adult age it is generally rectangular; and in edentulous old age it again returns to the infantile angle of 150^0.

PERIOSTEUM.

The bones are invested by a strong fibro-vascular membrane, the periosteum, which is closely adherent to their surface, and is possessed of a rich plexus of capillary vessels for the maintenance of their vital actions and nutrition. When minutely injected, the capillary network of the periosteum presents numerous oval meshes, around which the larger vessels are found, and towards which the latter appear to converge. These meshes correspond with the apertures of the Haversian canals, and the intervening parts of the membrane are occupied by a close and delicate network of capillaries of uniform size. (Plate I., fig. 1.)

ARTICULATION OF THE LOWER JAW.

In the consideration of the various articulations of the animal body, we are called upon to examine, firstly, the extremities of the approximated bones; secondly, the cartilage which covers those extremities; thirdly, the ligaments which bind them together; fourthly, the synovial membrane which provides for the cavity of the joint a surface of perfect smoothness; and fifthly, in some articulations, an interarticular cartilage; this latter structure being present in the articulation under consideration, namely, the temporo-maxillary.

The articular surface of the inferior maxilla is situated on the superior face of the condyloid process. It is convex in various degrees at different periods of life, being most so in infancy; and it approaches to a more or less flattened plane in old age. Moreover, it changes its aspect during growth and as age advances, having a direction obliquely forwards and upwards in the young subject, directly upwards in the adult, and again in old age obliquely upwards and forwards. In the adult the articulating surface measures from nine to eleven lines in its longitudinal, and from four to six lines in its antero-posterior diameter: and is prolonged farther downwards externally than internally. The appearance which it presents in old age of being worn down, is not an uncommon character of the extremities of bones which are subject to considerable and continued pressure, such as the external extremity of the clavicle, &c.

The articular cavity into which the condyle of the inferior maxilla is received, is situated on the temporal bone, and is termed fossa condyloidea. Its measurement from within outwards is about ten lines, and from before backwards about four. It is bounded anteriorly by a ridge, the articular eminence, which extends obliquely inwards and backwards from the root of the zygoma to the extremity of the spinous process of the sphenoid. The articular eminence is slightly concave on its posterior aspect, and the concavity of the fossa condyloidea is greatest at the base of this eminence. The condyloid fossa is broader externally than internally, and is bounded posteriorly by a fissure, the glenoid, which serves to separate it from a shallow depression, the fossa parotidea.

It is interesting to note the remarkable changes, in respect of form and size, which take place in the condyloid fossa at various periods of life. For example, in the fœtus it is a very slight depression, without particular eminence, and occupying the same plane as the adjoining surfaces of the temporal and sphenoid bones; the articular eminence at this early period being undeveloped. In the child the articular eminence gradually rises, while the condyloid fossa becomes more and more depressed. But it is only at adult age, and at a period even more advanced, that the form of the fossa corresponds exactly with that of the condyle, and the articular eminence offers signs of being moulded on the head of the latter. In old age, the eminentia articularis has sometimes the appearance of being worn by the pressure of the condyle.

The cartilage covering the head of the condyle, and lining the floor of the condyloid fossa, the true cartilage of the articulation, or cartilage of incrustation, is remarkable only for its extreme thinness as compared with that of other joints of the body.

The interarticular cartilage, or fibro-cartilage, is placed, as its name implies, between the surfaces of articulation presented by the condyle and condyloid fossa; and the special office which it performs is that of assisting the cartilages of incrustation in breaking the force of the concussions communicated to this joint by the frequent and prolonged action of the muscles of mastication. In the adult the interarticular cartilage measures from eight to nine lines in its longitudinal, and from four to six lines in its transverse diameter; it is biconcave, occasionally pierced in its centre by an oval aperture, and broader at its central than at its peripheral extremity.

The vessels of the fibro-cartilage are a rich plexus, which occupies its circumference, and from which small vessels are sent inwards towards its centre. These latter vessels are distributed on the synovial membrane, and after a short course give off capillaries, which form an arborescent plexus of extreme delicacy and beauty. (Plate I. fig. 2.) In the central part of the cartilage, where the greatest amount of pressure is exerted during the action of the jaw, vessels are not found.

The ligament usually described as being the chief bond of union of the bones entering into the construction of the temporo-maxillary articulation, is the external lateral. But this, in reality, is only a part of an extensive capsular ligament; a ligament heretofore imperfectly described, both as respects its attachments and relations.

To obtain a full and complete examination of the capsular ligament, it is necessary that the dissection should be made in a well-formed adult subject. The zygoma, for this purpose, should be divided at about an inch anteriorly to the external auditory process, and all the soft parts in front of the section carefully removed. In the next place, the coronoid process should be cut through and raised, together with the tendon of the temporal muscle. Then the ramus of the jaw should be divided at about an inch below the condyle, and removed with the muscles and soft parts connected with it. When these preparatory steps of the dissection have been performed, we are enabled to reach the joint and perform the dissection of the capsular ligament effectually.

The capsular ligament is composed externally of numerous strong fibres which are attached above to the tubercle of the zygoma, and below to a tuberosity on the outer aspect of the condyle of the inferior maxilla. Of these fibres the middle are longer than the anterior and posterior, and the entire fasciculus constitutes the ligament usually described as the external lateral. Behind the tubercle is a fasciculus of fibres, which passes backwards to be attached to the external auditory process; and from this fasciculus a series of lax fibres proceed, which are continuous with those of the external lateral ligament. From the margin of the condyloid fossa, corresponding with the Glaserian fissure, other lax fibres proceed, which constitute the posterior portion of the capsular ligament. Internally the posterior fibres are continuous with fibres which are attached to the spinous process of the sphenoid; and anteriorly, similar fibres are connected with the anterior margin of the eminentia as far outwardly as the tubercle of the zygoma. From this extensive line of attachment the fibres descend to various points of insertion around the circumference of the condyle. The anterior fibres, which are extremely loose, are connected in the first instance with the anterior border of the interarticular cartilage, and are then prolonged downwards to the anterior border of the condyloid process; being intersected in their course by transverse fibres, which serve to augment the strength of this part of the ligament. The fibres placed internally to the joint form so distinct a fasciculus, as to deserve separate consideration under the name of the *true internal temporo-maxillary ligament*, to distinguish them from that expansion which goes by the name of internal lateral ligament. From their superior attachment, the internal fibres pass in a direction downwards and backwards, to be inserted into the inner extremity of the condyle of the lower jaw. The posterior fibres are attached inferiorly to the posterior border of the condyle. Having so extensive a superior and inferior attachment, and surrounding the joint on all sides, the capsular ligament necessarily possesses considerable power in influencing the movements of this articulation.

The other ligaments described in connexion with the articulation of the lower jaw, are the internal lateral and stylo-maxillary. They are both processes of fascia; the former descending from the spinous process of the sphenoid, and being attached inferiorly to the spinous process which forms the lip of the inferior dental foramen; the latter proceeding from the styloid process to the angle of the inferior maxilla.

The MUSCLES of the lower jaw are divisible physiologically into two groups, one of these being destined to perform the movements by which the food is received and retained within the mouth, and another to effect the complex movements required in mastication. The former of these groups is composed of a number of muscles, which, from their attachment to the lips and integument, contribute also as agents in expression, to give character to the human countenance, and thus become an index of the mind. The latter, the proper masticating muscles, are eight in number, namely, the temporals, masseters, pterygoids, and buccinators.

The *temporal* muscle is situated in the temporal fossa, and is covered in by a dense fibrous membrane, the temporal fascia. The temporal fascia is attached superiorly to the temporal ridge, and separates inferiorly into two layers, one of which, the external, is inserted into the outer border of the zygomatic arch. The other, the internal, or deep layer, is separated from the preceding by a quantity of adipose and areolo-fibrous tissue, and is inserted into the inner border of the same arch.

The fibres of the temporal muscle take their origin from the surface of the temporal fossa, and from the internal aspect of the temporal fascia, and are inserted by means of a strong and broad tendon into the coronoid process of the lower jaw. The direction of the greater part of the fibres is downwards and forwards, the coronoid process being situated in the anterior part of the temporal fossa; some few, however, pass vertically downwards to this attachment. The tendon, white and shining, is about an inch in breadth at its insertion, but above this point it spreads out so as to assume in miniature the shape of the entire muscle.

The *masseter* muscle, of rhomboidal figure, is situated upon the ramus of the lower jaw, at the inferior and posterior part of the face. In structure it consists of two portions, which arise from the inferior border of the zygoma and malar bone. The most superficial of these portions is tendinous both on its external and internal aspect, and passes obliquely downwards and backwards, to be inserted into the lower part of the ramus of the inferior maxilla, extending as far as its angle. The deeper portion, more posterior in position than the preceding, arises immediately in front of the capsule of the temporo-maxillary articulation, and descends with a very slight inclination forwards to be attached to the ramus of the jaw above the preceding.

The *internal pterygoid* muscle is situated on the inner side of the ramus of the lower jaw. It arises from the pterygoid fossa, and passes obliquely downwards and backwards, and somewhat outwards, to be inserted into the lower part of the ramus of the inferior maxilla as far as its angle.

The action of the three preceding pairs of muscles is to approximate the maxillæ, and move the lower jaw transversely on the upper, and consequently to bruise substances placed between the teeth.

The *external pterygoid* muscle is placed in a horizontal position behind the coronoid process and tendon of the temporal muscle, and superficially to the origin of the internal pterygoid. It arises by two heads, from the surface of the external pterygoid plate, and from the spine which separates the temporal from the pterygoid fossa, and passes directly backwards to be inserted into the depression in front of the neck of the lower jaw, and into the anterior margin of the interarticular cartilage. The small triangular space which intervenes between the two heads of this muscle, serves for the transmission of the internal maxillary artery.

The external pterygoid muscles, when in action, move the lower jaw forwards so as to produce a grinding of the inferior against the crowns of the superior teeth. When acting singly, the lower jaw is moved laterally against the upper.

The *buccinator* muscle is situated on the side of the face, forming a considerable proportion of the cheek. It is quadrilateral in shape, and arises, superiorly, from the alveolar process for an extent corresponding with the space between the anterior molar tooth and the tuberosity of the superior maxillary bone; inferiorly, from the alveolar process of the lower jaw for a similar extent; and posteriorly, from a fibrous raphé common to it and the superior constrictor muscle, one end of this raphé being attached to the inferior extremity of the internal pterygoid plate, and the other to the posterior termination of the inferior maxilla. From this extensive origin the fibres converge to the angle of the mouth, where they are continuous with those of the orbicularis oris.

OF THE TONGUE.

The tongue is composed principally of muscular fibres disposed in different directions, and invested by mucous membrane.

On its superior surface the mucous membrane presents innumerable minute projections or papillæ, each being invested by a distinct sheath of epithelium. These papillæ, I shall have occasion to show, offer a very close analogy in structure to the pulps of the teeth. Indeed, the analogy does not rest here only, for just as the pulps are organs for the production of the teeth, so in some animals, as in birds, the papillæ of the tongue are the source of formation of horny appendages, which perform the offices of teeth, and bear a close relation to those organs.

The posterior part or dorsum of the tongue is furnished with numerous submucous glands, which are situated for the most part behind the papillæ, and yield up their secretion under the influence of the pressure of the food in its course through the fauces; some of these glands, however, of smaller size, are situated in front of the preceding, and extend occasionally as far as the middle of the tongue.

Of the *papillæ* of the tongue the largest are situated at the root of that organ, and are arranged in two columns, which have a direction from before backwards and inwards, and meet at an acute angle so as to have the appearance of the letter V reversed. These papillæ are conical in shape, and embedded in deep fossæ, or cup-shaped cavities, on the surface of the tongue; their base being directed upwards, and their apex in the opposite direction. The base of these papillæ rises to the level of the surrounding mucous membrane, and some of them measure in breadth three-quarters of a line, while their apex or pedicle scarcely exceeds a fourth part of that size. Each papilla is surrounded by a deep circular groove, and the latter is provided with a thick muscular margin. In the bottom of this groove numerous small orifices may be detected by careful examination. From the appearance which these papillæ present, of being embedded in cup-like depressions, they have been named papillæ calyciformes. Another name which they possess, namely, papillæ circumvallatæ, is derived from the consideration of the groove which surrounds them; while from their lentil-like resemblance, when viewed on the surface, they have been denominated papillæ lenticulares. (Plate II. fig. 4, a.)

In front of the papillæ calyciformes, and covering the whole of the remainder of the tongue, are numerous short, thick, and cylindrical papillæ, the papillæ conicæ. (Plate II. figs. 1, 2, 3, and fig. 4, d. d.) Intermingled with these in considerable numbers are threadlike prolongations of the mucous membrane, improperly denominated papillæ filiformes. (Plate II. fig. 4, c.) They are, in reality, similar in form and structure to the villi of the small intestine, and would be designated more appropriately by that name. A fourth kind of papillæ are met with on the tongue of the child, but are lost in the adult. They resemble somewhat in shape the papillæ calyciformes, having an enlarged extremity and slender pedicle, and are scattered among the other papillæ at distances of two or three lines. These are the papillæ fungiformes. Besides the papillæ, there are other elevations of the mucous membrane upon the lateral borders of the tongue which have the form of elongated vascular fringes or plaits.

The papillæ of the tongue are composed of a plexus of capillary vessels and terminal loops of nervous filaments, held together by areolo-fibrous tissue. In the papillæ conicæ of the fœtus, the capillaries constitute a coarse net-work, (Plate II. fig. 1,) and at the apex of each of the papillæ is a vascular ring, which gives the idea of an aperture (Fig. 1, a. figs. 2, 3). The capillaries proceed from a small central artery which runs through the middle of the papilla, and they terminate in a vein which takes its course by the side of the artery (Fig. 3). In the papillæ filiformes or villi of the tongue, the capillaries form a simple loop (fig. 4, c.) ; in the papillæ conicæ of the adult, the loops are tortuous and plexiform (fig. 4, d. d.) ; while in the papillæ calyciformes the latter arrangement is still more strongly apparent (Fig. 4. a).

Beneath the mucous membrane of the tongue is a layer of condensed cellular tissue of almost cartilaginous density. This layer is thickest at the middle line, and becomes gradually thinner towards the edges of the tongue, and it extends from the line of papillæ calyciformes forwards to within an inch of its apex. The vessels which are distributed to the mucous membrane pierce this fibrous layer in order to arrive at their destination.

OF THE MUCOUS MEMBRANE OF THE MOUTH.

The mucous membrane of the mouth presents considerable variety of structure and appearance when examined upon different localities, as upon the cheeks, lips, palate, gums, and tongue. In essential structure, however, it is everywhere the same, being composed of a fibro-vascular substratum, the corium, being developed on the surface into minute papillary elevations, and having as an investment an epithelial covering. The corium of mucous membrane differs from that of the external integument or skin, in its greater degree of tenuity, and in the possession of a smaller quantity of fibrous tissue.

In the fœtus the skin is remarkable for its extreme vascularity, and for the modifications which the vessels undergo at various periods of fœtal life. The consideration of this subject is foreign to my present purpose, but I cannot forbear the remark, that the great vascularity of the skin of the fœtus would lead me to believe that some important function is fulfilled by the approximation of so large a quantity of blood with the amniotic fluid.

The mucous membrane of the mouth has connected with its under surface numerous small submucous glands, which present a close similarity of structure in whatever situation they are examined, and are analogous in the manner of distribution of their vessels to the salivary glands. They differ from the mucous crypts which are mere depressions in the membrane, by the possession of a distinct secreting parenchyma.

To ascertain the nature of the secretion produced by these little glands, I everted the lip, and made pressure on the membrane, but no fluid escaped. I then, after drying the surface completely, laid a small piece of paper on the membrane, and, in the course of a minute, I found numerous small and isolated drops attached to it. Upon examination of these drops with the microscope, I found them to contain globules, and several large epithelial scales; the latter being most probably derived from the mucous membrane.

Upon the alveolar processes, near the necks of the teeth, the mucous membrane becomes thick by the increase of fibrous tissue, and by the addition of a large supply of blood-vessels, and constitutes the gums. The gums are often from one half to three quarters of a line in thickness; they are firmly attached to the periosteum of the edge of the alveolus, and they lie in close contact with the neck of the tooth. From their high degree of vascularity, and their peripheral position, the gums offer an important means of discovering the state of health of the general mucous membrane, and of the constitution of the individual. Representations of the microscopic structure of the gums are seen in Plate III., figs. 1, 2, 3, 4, the two former being taken from the adult subject, and the two latter from the fœtus.

OF THE BLOOD-VESSELS OF THE MOUTH.

The chief sources of distribution of blood to the textures entering into the composition of the mouth, are the external and internal maxillary, and the lingual arteries, all of them being branches of the external carotid.

The EXTERNAL MAXILLARY, also termed the *facial* or labial artery, is embedded near its origin in the sub-maxillary gland, which it supplies with numerous branches. On the body of the lower jaw it gives off branches to the anterior part of the parotid gland, and to the masseter and buccinator muscles; the branches of the latter, after piercing the muscular fibres, ramifying in the corium of the mucous membrane, and constituting in that situation an intricate network, (Plate III., figs. 1, 2, 3; Plate IV., figs. 1—5,) from which the capillaries of the papillæ and sub-mucous glands are supplied. From its anterior aspect the artery sends branches forwards to be distributed to the chin, and to inosculate with the terminal branches of the inferior dental artery, after its escape from the mental foramen. These branches supply the integuments and muscles of the chin, as well as the periosteum and substance of the bone. At the angle of the mouth the *inferior coronary artery* arises from the facial and passes onwards in a tortuous course near the free border of the lower lip, to inosculate with its fellow of the opposite side. From this artery the smaller vessels are derived which supply the mucous membrane of the lip, (Plate IV., fig. 1,) and which, by their numbers, give rise to distension of the lip, under the influence of excitation in the circulation. The distension of these vessels, both in the upper and lower lip, is sometimes so great as to suggest the idea of the presence of an erectile tissue, which, indeed, the arrangement of the capillaries closely resembles. Above the angle of the mouth the facial gives off the *superior coronary artery*, which proceeds in a similar tortuous course onwards to the middle line of the lip, and inosculates with its fellow of the opposite side. This artery, like the inferior, supplies the mucous membrane and sub-mucous glands, and is a source of the rich network of capillaries so characteristic of this membrane. After giving off these branches, the facial artery ascends by the side of the root of the nose, and loses itself at the angle of the eye by inosculation with a branch of the ophthalmic artery.

The LINGUAL ARTERY is destined chiefly, as its name implies, to the tongue, and gives off several branches in its course, to be distributed to that organ and to adjacent parts. The first of its branches is the *dorsalis linguæ*, which ramifies in the root of the tongue, supplying the numerous mucous glands which exist in that situation, as well as the epiglottis and neighbouring part of the fauces. The *sublingual* is a large branch of the lingual, which is distributed to the sublingual salivary gland and adjacent mucous membrane. The lingual artery, after having given off these branches, is termed the ranine, and is continued forwards in a serpentine course along the under surface of the tongue to its tip. It sends branches to the mucous membrane in its course, and numerous branches to the muscular substance, which, after ramifying in the latter, are distributed to the papillæ of the tongue. (Plate II.)

The INTERNAL MAXILLARY ARTERY is possibly more interesting to the dental anatomist than the preceding, as being the source from which the maxillæ and teeth are chiefly supplied.

Originating from the termination of the external carotid, this artery runs horizontally forwards behind the neck of the lower jaw; it next passes inwards between the two heads of the external pterygoid muscle, and then enters the spheno-maxillary fossa, where it terminates by dividing into several branches.

The *inferior dental* is the first of the branches of the internal maxillary, arising near the inner side of the condyle of the inferior maxilla; this artery passes obliquely downwards to the inferior dental foramen. It then enters the canal situated in the interior of the jaw, and takes its course to the mental foramen, where it divides into two branches, one which escapes by that foramen to supply the muscles and integument of the chin, and one which is continued onwards to the symphisis, and gives branches to the incisor teeth. In its course along the dental canal, the inferior dental artery furnishes small twigs to the roots of the teeth. These twigs enter the foramina in the bottom of the sockets and in the apices of the fangs of the teeth, and are distributed to their sockets and pulps. Previously to entering the inferior dental foramen, the artery gives off a small branch, the *mylo-hyoidean*, which runs forwards in the groove previously described, (page 28,) to be distributed to the mylo-hyoid muscle and adjacent mucous membrane. The next branches of the internal maxillary artery are muscular twigs, which are distributed to the muscles of mastication, namely, temporal, masseteric, pterygoid, and buccal. The last is a considerable branch, which is also distributed to the submucous glands and mucous membrane of the cheek.

On reaching the superior maxillary bone, the internal maxillary artery gives off several branches, which take a tortuous course downwards on the tuberosity of that bone, and enter its substance through numerous apertures on the surface; of these branches, some are distributed to the posterior molar teeth, while others pass along the external and inferior wall of the antrum, and after supplying the mucous membrane of that cavity, terminate in the middle teeth. Other twigs, given off from the superior dental branches, are destined to the posterior part of the gums of the upper jaw.

The next branch of the internal maxillary is the *infra-orbital*, which accompanies the superior maxillary nerve, and near the infra-orbital foramen gives off a branch, which descends in the substance of the bone, to be distributed to the incisor and canine teeth, and to the anterior part of the lining membrane of the antrum.

Another branch of the internal maxillary artery having relation to the mouth, is the *posterior palatine*. This artery descends in the posterior palatine canal to the posterior palatine foramen, whence it emerges, and is distributed to the hard and soft palate. Other small branches of the internal maxillary supply the mucous membrane of the pharynx and soft palate with their numerous submucous glands.

OF THE NERVES OF THE MOUTH.

The FIFTH PAIR of nerves is the principal source of innervation of the structures entering into the composition of the mouth, and of this pair the middle and inferior divisions in particular.

The middle division of the fifth, or SUPERIOR MAXILLARY NERVE, after issuing from the Casserian ganglion, passes out of the cranium through the foramen rotundum; it then crosses the spheno-maxillary fossa, and entering the orbit runs forwards in the infra-orbital canal, and emerges upon the face at the infra-orbital foramen. In its course through the spheno-maxillary fossa, it sends downwards one or two filaments, which communicate with the spheno-palatine or Meckel's ganglion.

The branches of Meckel's ganglion are, the spheno-palatine or nasal, the Vidian, and posterior palatine. The latter nerve descends to the posterior palatine foramen through the canal of the same name, and passing forwards in its course, is distributed to the hard and soft palate. The termination of this nerve communicates at the incisive foramen with a branch of the spheno-palatine.

The *superior dental nerves* are also given off from the superior maxillary while that trunk is situated in the spheno-maxillary fossa. They pass downwards on the tuberosity of the bone, and, entering canals in its substance, are distributed to the three or four posterior teeth; their terminal filaments passing into the foramina, situated at the apices of the fangs. The most anterior of these nerves sends a small branch forwards, which forms a loop in the substance of the bone with a branch from the anterior dental nerve.

The *anterior dental nerve* is given off by the superior maxillary while the latter is situated in the infra-orbital canal, and after passing for the distance of a few lines in that canal, it enters a small canal especially destined for it in the anterior wall of the bone. The nerve then passes down towards the incisor teeth, and divides into filaments for the supply of those teeth, the canine, and the bicuspids. The most posterior of the filaments of this nerve forms a loop of communication with the superior dental.

The filaments of the dental nerves, which are situated in relation with the antrum, pass to their destination between the bone and mucous membrane. The terminal filaments of the infra-orbital nerve are distributed to the muscles and integument of the cheek and upper-lip, and also to the mucous membrane of the latter.

The INFERIOR MAXILLARY NERVE is the largest of the three divisions of the fifth pair, and is remarkable for having associated with it the entire of the motor root. This peculiarity gives rise to a difference in the manner of distribution of its branches; for while the first and second divisions of the fifth send branches to muscles which communicate the faculty of sensation only, the power of motion requiring the aid of the facial nerve; the third division, possessing within itself a motor power, is enabled alone to bestow upon muscles the double faculty of motion and sensation.

Emerging from the cranium through the foramen ovale, the inferior maxillary nerve gives off several muscular branches of small size, and three larger branches, namely, the auricular, gustatory, and inferior dental. The muscular branches are, the deep temporal, two or more in number, the masseteric, the pterygoid, and the buccal. The buccal nerve, larger than the rest, gives filaments to the temporal and external pterygoid muscle in its course downwards to the buccinator; and, after supplying the latter, its terminal filaments are distributed to the orbicularis, levator anguli oris, and depressor labii inferioris, as well as to the mucous membrane of the mouth and integument. This nerve communicates with the facial. The pterygoid nerve supplies the internal pterygoid muscle.

The *auricular* or *superficial temporal nerve* passes backwards from its origin, and enters the parotid gland, where it communicates with the facial nerve. It then ascends between the meatus auditorius and condyle of the lower jaw to the temple, and divides into filaments which accompany the branches of the temporal artery, and supply the integument of the side and vertex of the head; while in the parotid gland the nerve sends branches to the external ear and meatus.

The *Gustatory* or *lingual nerve*, soon after its origin, sends a branch of communication to the inferior dental, and receives one from the facial, the chorda tympani. The nerve then descends with a gentle curve to the side of the tongue, lying in the first instance between the ramus of the jaw and internal pterygoid muscle; then, between the mucous membrane of the mouth and submaxillary gland; and near its termination, on the hyoglossus muscle and sublingual gland. In its course the gustatory nerve sends filaments to the submaxillary ganglion, to the mucous membrane of the floor of the mouth, to the gums, and is distributed finally to the papillæ of the tongue. On the hyo-glossus muscle it communicates with the hypo-glossal nerve.

The *Inferior dental nerve*, the largest of the three large branches of the inferior maxillary, passes directly downwards to the inferior dental foramen, lying, in the first instance, between the two pterygoid muscles, next between the internal pterygoid and the ramus of the jaw, and then between the latter and the internal lateral ligament. After entering the canal in the lower jaw, the nerve takes its course beneath the level of the fangs of the teeth to the mental foramen, where it divides into two branches,—an external branch, the proper continuation of the nerve, and the internal. Previously to entering the inferior dental foramen the nerve gives off a small branch, the mylo-hyoid, which passes downwards in the osseous groove of the same name, and is distributed to the mylo-hyoid muscle, the genio-hyoid, the anterior belly of the digastric, and the sub-maxillary gland. In the dental canal, the nerve sends filaments to the fangs of the molar and posterior bicuspid teeth. Beyond the mental foramen, the internal branch supplies the anterior bicuspid, the canine, and the incisors. The external branch, which escapes from the bone at the mental foramen, is distributed to the muscles of the lower lip and chin, the mucous membrane, and the integument.

The FACIAL NERVE, or *portio dura* of the seventh pair, is the proper motor nerve of the face, and sends numerous branches to the muscles of the masticatory apparatus. This nerve emerges from the cranium at the stylo-mastoid foramen, crosses the styloid process, pierces the substance of the parotid gland, and divides into branches, which spread out upon the face in a radiated manner, under the name of *pes anserinus*. The ascending filaments of this nerve are distributed to the temple and muscles in the region of the orbit, and the descending may be traced downwards upon the neck.

OF THE SALIVARY GLANDS.

The salivary glands are an apparatus of considerable extent situated in close proximity with the mouth, and pouring their secretion into that cavity. I have already referred to the existence of small glandular organs placed beneath the mucous membrane, the submucous glands, which secrete a fluid for the purpose of lubricating the mucous membrane. But the office of the salivary glands is more immediately connected with the function of digestion, the saliva, by its admixture with the food during mastication, being intended to moisten the mass, and convert it into a soft pulp proper for deglutition, and the subsequent process of chymification. The salivary glands, six in number, are the parotid, the submaxillary, and the sublingual.

The PAROTID GLAND, named from its position immediately in front of the ear, is the largest of the salivary glands, and may be described as consisting of two portions—a superficial or anterior, and a deep or posterior part. The anterior portion is in contact by its external surface with the integument, and lies upon the masseter muscle. Superiorly, it extends to the lower border of the zygoma; inferiorly, almost to the base of the jaw; anteriorly, it is occasionally prolonged to the anterior border of the masseter. It is from this aspect of the gland that Stenon's duct is given off. The posterior or deep portion of the gland is deeply embedded between the external ear and sterno-mastoid muscle behind, and the posterior border of the ramus of the jaw in front, and is continuous in the latter position with the superficial portion. It is in relation by its external surface with the integument; internally, or deeply, with the styloid process and muscles: superiorly, with the fossa parotidea of the temporal bone: and inferiorly, with the posterior belly of the digastric muscle and stylo-maxillary ligament. By its posterior border it is in relation with the external auditory process, meatus auditorius, mastoid process, and sterno-mastoid muscle: and in front, with the capsule of the lower jaw, as also with its condyle and ramus. The substance of the gland is traversed longitudinally by the external carotid artery and temporo-maxillary vein, and transversely by the auricular and facial nerves.

The SUBMAXILLARY GLAND is intermediate in point of size between the parotid and the sublingual. It is a rounded lobulated gland, situated beneath and partly behind the body of the lower jaw at its posterior part, in a triangular space bounded by the attachment of the mylo-hyoid muscle above, and the digastric muscle below, and occupying the posterior portion of this triangle. The gland is covered in superficially by the cervical fascia and platysma myoides which intervene between it and the integument; and above, by the body of the lower jaw and internal pterygoid muscle. It rests on the hyoglossus and part of the mylo-hyoid muscle, and is separated behind from the inferior angle of the parotid gland by the stylomaxillary ligament. By its posterior and upper border it supports the facial artery which lies in a groove upon its surface; and in this situation it is in relation with the submaxillary ganglion and its branches.

The excretory duct of the submaxillary gland, Wharton's duct, issues from its anterior and deep aspect, and passes forwards between the mylo-hyoid and digastric muscle in the first instance, and then between the sublingual gland and genio-hyo-glossus to open upon a prominent papilla by the side of the frænum linguæ. This duct is liable to the formation of salivary concretions within its canal.

The SUBLINGUAL GLAND, the smallest of the salivary glands, is situated by the side of the base of the tongue in the anterior part of the mouth. It is covered in above by the mucous membrane, and rests upon the mylo-hyoid muscle. The ducts of this gland, seven to ten in number, open upon the crest of the ridge which runs backwards and outwards from the papilla of the submaxillary duct.

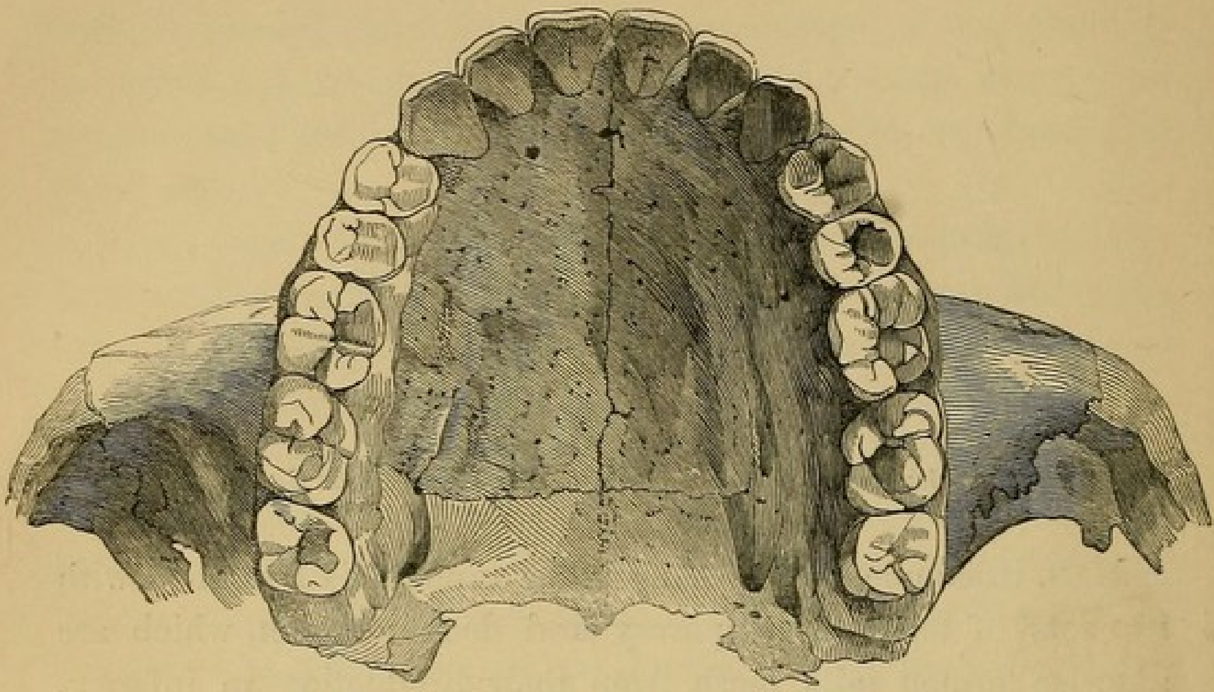
CHAPTER III.

DESCRIPTIVE ANATOMY OF THE TEETH.

Man, in common with many other animals, is furnished with two sets of teeth, a temporary and deciduous set, which are likewise termed milk teeth, from their production in infancy, and their performance of the offices required during childhood; and a permanent set, which succeed these, and are adapted to the size of the jaw, and wants of the individual during riper years. The number of the temporary set is twenty, and of the permanent set, thirty-two; consequently the entire number of teeth possessed by man during his life-time is fifty-two. Of this latter number twenty succeed and rise from the jaw into the places of corresponding milk teeth, but the remaining twelve are without predecessors. Certain varieties and irregularities in the number and form of the teeth are occasionally met with, which will be noticed as we proceed.

The teeth are arranged in the alveolar processes in the form of an arch; they are of nearly equal height, parallel by their external and internal surfaces, and in mutual apposition by their lateral borders. In animals, although the arch is maintained, the teeth are more or less unequal in point of height, and separations between them occur in certain situations. When the teeth are arranged with perfect regularity, the surfaces of lateral contact are small, and are indicated by a flat and smooth part, polished by mutual attrition. The degree of

FIG. 1.*

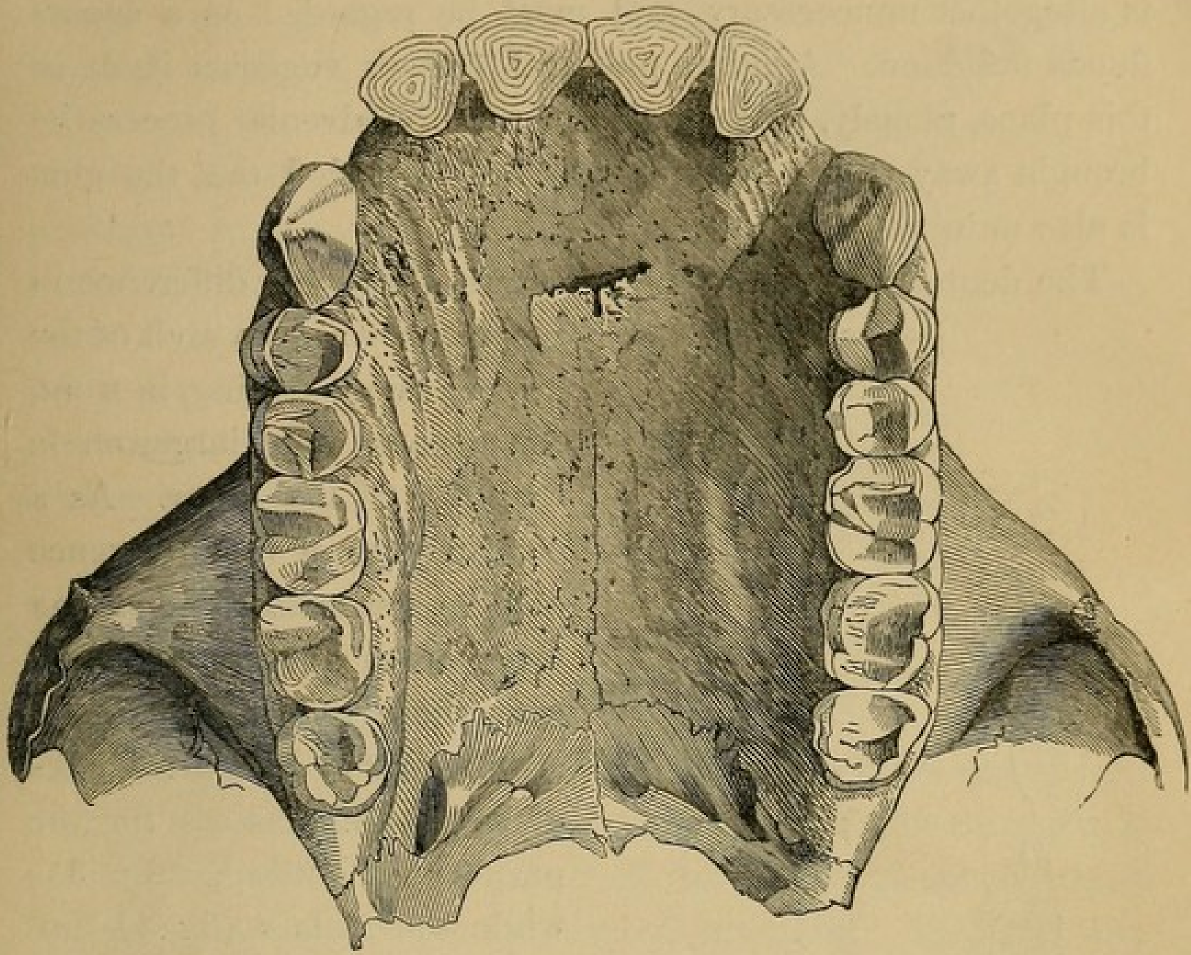


attrition is however very trifling, and never occasions inconvenience or decay, in consequence of the actions to which they are submitted being resolved into forces which act in a radial direction to the central axis of the mouth. But whenever any irregularity of arrangement exists, the concussions received by the teeth are liable to act in opposition to the radial direction of the muscular forces, and to give rise to injury of the enamel, and subsequent decay.

The connexion between a tooth and the alveolar process is technically termed gomphosis, (γομφος, a nail,) from a comparison between its relation to the jaw and that of a nail driven into a piece of wood. The root of the tooth is not, however, grasped by the alveolus with the degree of force which the above comparison would suggest; on the contrary, there is room between the surface of the fang and that of the alveolus

* Fig. 1. The superior dental arch of sixteen teeth. The form of a well-curved arch is seen in this figure, as well as the arrangement of the teeth; and may be compared with the widely different curve of the dental arch in the highest group of inferior animals exhibited at fig. 2.

FIG. 2.*



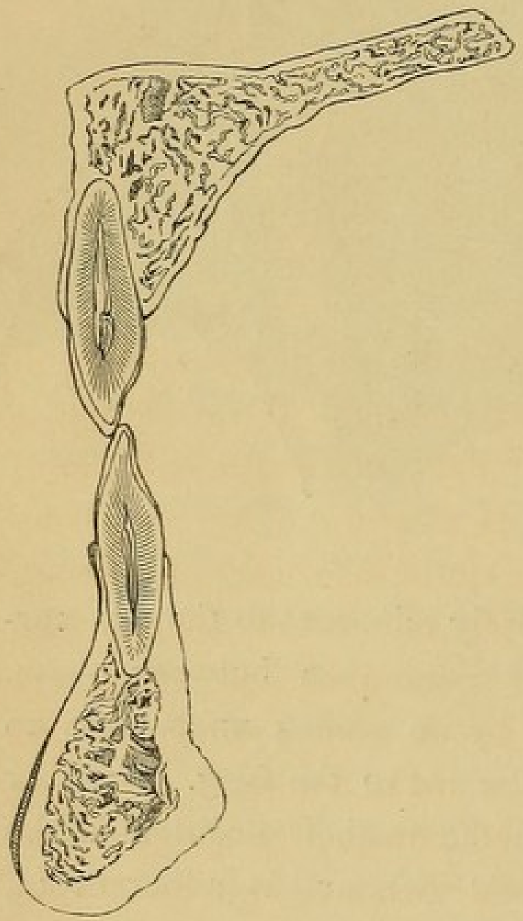
for a thin membrane, which is closely adherent to the two surfaces, and serves as a bond of connexion between them. When a tooth is extracted, it is by no means uncommon to find portions of this membrane adherent to the fang. Another agent in the maintenance of the teeth in their position is the gum. The gum lies in close contact with, and is adherent to, the neck of the tooth; but the adhesion is not so great as that which subsists between the former and the periosteal covering of the alveolar process. Hence the operation frequently prac-

* Fig. 2. The superior dental arch of a chimpanzee. The form of this arch is very different from that of man, as exhibited in fig. 1, the difference consisting in the straightness of the lateral or buccal portions, and in the existence of a space between the lateral incisor and the canine tooth. The large size of the crown of the canine is a conspicuous character in this jaw, as is also the worn state of the incisors.

tised of lancing the gums previous to the extraction of a tooth is altogether unnecessary, and must be regarded as a superfluous infliction. Another practical remark suggests itself in this place, namely, that if no portion of the alveolar process be brought away with a tooth, it may be concluded that the gum is also uninjured.

The dental arches of the two jaws offer some difference in respect to size, the arch of the upper jaw presenting, in front, the segment of a larger circle than that of the lower. As a consequence of this difference of form, the incisor and canine teeth of the upper jaw close over those of the lower, and are thus fitted like the blades of a pair of scissors for the purpose of cutting, (fig. 3); while the molars (fig. 4) are brought in apposition by the surface of their crowns, and are therefore placed in the best position for triturating and pounding. Occasionally, it is true, as an exception to a general rule, we meet with

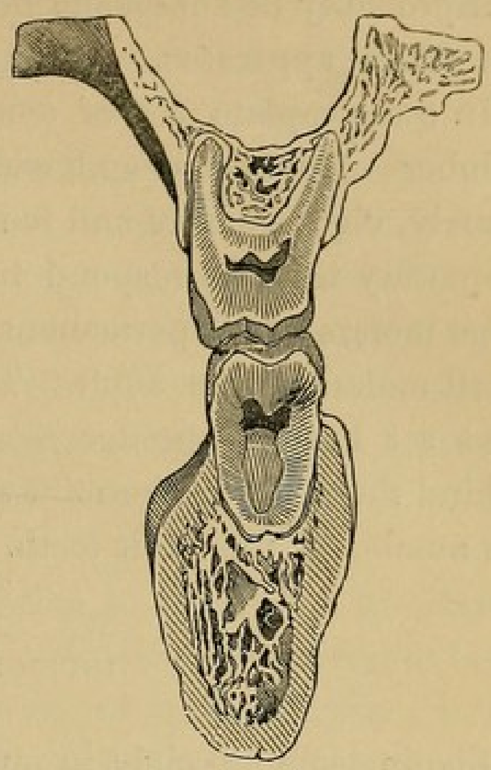
FIG. 3.*



* Fig. 3. In this figure the mode of approximation of the central incisor of the upper and lower jaw is shown. The section is carried through the teeth and jaws, and exhibits the cavities for the pulp of the former and the cancellous internal structure of the latter.

It will be observed, that although the axis of the socket of the under tooth looks slightly forwards, the arrangement for an incisive function is given by the direction of the free portion of the tooth or crown, which is thrown backwards, so as to cause the point of contact with the upper to be in the centre of the axis of the tooth.

FIG. 4.*



cases in which the molar teeth of the upper project slightly beyond those of the lower jaw.

It is a curious and beautiful provision with regard to the teeth, that their perfect adaptation and action is not only necessary for the proper mastication of the food and perfect articulation, but also for the maintenance and preservation of the teeth themselves. Thus, if a tooth be lost, and its pressure on an opposite tooth be thereby removed, the latter will rise in its socket and overtop the neighbouring teeth. The cause of this elevation is a congested and thickened state of the periosteal membrane of the alveolus, dependent on loss of pressure. Again, if one class of teeth be called upon to perform the duties of another, both necessarily suffer. For example, the oral teeth being employed in the office of reducing and comminuting the food, are soon worn down, displaced, and injured; and the molars of the upper jaw, when from irregularity of arrangement they project beyond those of the lower jaw, are all damaged by the performance of actions for which they were never designed. These considerations serve to explain the mutual dependence subsisting between the dental arches—a dependence so complete, that a partial irregularity in one necessarily occasions a corresponding deviation in the other; and these primary displacements

* Fig. 4, shows the mode of approximation of the crown of the molars, together with the conical form of those teeth; the cavitas pulpæ is laid open in both. Above the expanded fangs of the superior molar is the floor of the antrum of Highmore. In this section, the lower molar exhibits only one of its fangs. The outer surface of the teeth and jaws is to the left of the figure.

will probably be succeeded by injurious disturbance of the entire dental apparatus.

In the complete set of temporary teeth there are the same number of incisors and canines as in the permanent set, namely, eight incisors and four canines. The remaining eight temporary teeth correspond in appearance and office with the large molars of the permanent set. They are succeeded by the small molars of the adult. The large grinders of the permanent set have no predecessors; they are produced altogether behind the range of the milk teeth, and it is they that increase the number of the adult teeth.

INCISOR TEETH.

The incisors are eight in number; four being placed in the superior, and four in the inferior jaw. The pair of these teeth situated near the median line are the central incisors, while the succeeding pair are the lateral incisors, or simply the laterals.

The central incisors are placed in the middle and most anterior part of the maxillary arches. Those of the upper jaw occupy the greater part of the alveolar portion of the inter-maxillary bones, and their roots extend upwards on either side of the inter-maxillary suture to within two lines of the floor of the nose. The central incisors of the lower jaw are situated in the corresponding position in the inferior alveolus, stretching downwards by means of their fangs on each side of the symphysis. Beneath the extremities of their roots, the lower jaw is about three-fourths of an inch in depth and about half an inch in thickness.

The lateral incisors are situated on either side of the central incisors, between them and the canine teeth; the superior occupying a position immediately beneath the alæ of the nose, and the inferior one which corresponds with the middle third of each lateral half of the prominence of the chin. The fangs of the superior laterals extend to nearly the same distance from the floor of the nose as the central incisors, while the inferior are one line and a-half longer than the central incisors of the lower jaw.

The crowns of the superior central incisors are broader than those of any other of the front teeth; indeed, they are inferior in breadth to the large molars only in the proportion of 16 to 18. The average measurement of the crowns of the central incisors of the upper jaw is four lines.* The inferior central incisors are the smallest teeth of the set, measuring about two lines and a-half in breadth, and bearing a relation to the superior central incisors of 10 to 16.

The superior laterals are inferior in breadth to the central incisors in the proportion of 12 to 16, their measurement being about three lines. The inferior lateral incisors have a nearly similar admeasurement, and their relation to the central incisors of the same jaw is as 12 to 10.

An incisor tooth has rarely more than one fang, which is pretty equally conical throughout its entire length. (Fig. 3, page 56.)

The length of a superior central incisor is greater than that of any other tooth, with the exception of the canine, to which it stands in the relation of 48 to 52. Its average measurement is one inch, namely, twelve lines; while the measurement of an inferior central incisor is not more than ten lines, being the shortest of all the teeth.

The length of a superior lateral compared to the superior central incisor is as 46 to 48; measuring on an average eleven lines and a-half. The length of the inferior laterals is nearly similar to that of the superior.

The relative length of the crown and the root is about equal in the superior central incisors, but this rule is subject to many varieties. The relative length of the same parts in the inferior

* The English line, namely, one-twelfth of the English inch, is the measurement adopted throughout the volume. The comparative numbers are multiples by four of those admeasurements.

central incisor is four lines for the crown and six lines for the fang.

In the lateral incisors, both upper and lower, four lines and a-half may be regarded as the length of the crown, and seven lines as that of the fang.

The anterior surface of the crown of a central incisor is convex, both longitudinally and transversely. In the former direction the convexity is greatest as we approach the free edge; in the latter, namely, transversely, near the outer border of the tooth. There is also a difference in the respective elevation of the outer and inner borders, the latter being superior to the former. Moreover, the face of the crown is frequently marked by longitudinal ridges.

The posterior surface of the crown of the superior cental incisor is concave, the concavity forming a small segment of a hollow sphere, and having a direction slightly outwards. This concavity favours the reception of the crowns of the lower incisors behind those of the upper jaw, while the necessary approximation of the two arches is properly maintained. In early life the posterior surface of these teeth is raised into undulations, which assist in the mastication of food at a period when the molars are incomplete.

The surfaces of the crown of the incisor meet at an acute angle along the summit * of the tooth, and constitute a sharp cutting edge, which is characteristic of the class. This edge is slightly convex, and at an early period of life, when the jaws are comparatively weak, it is surmounted by small cusps, which are the prominent terminations of the longitudinal ridges on the face of the tooth above referred to. The central incisors have generally three of these cusps, and the lateral incisors only one. This arrangement forms a curious provision for the wants of the individual at a period of life when the dental system is imperfect, and the muscular energies weak; the sharp

* The crown of a tooth, whether of the superior or inferior jaw, is spoken of throughout the work as its superior, and the fang as its inferior portion.

serrated edge which the incisor teeth then present being that which is best adapted to divide the food with the least pressure, and, consequently, with the least expenditure of muscular force.

As, however, the permanent teeth gradually advance towards their completion, these cusps are worn away, and a new principle is introduced, by virtue of which the sharpness of the edge of the incisors is still maintained. The principle here alluded to is the constant attrition of their summits against the food, and a consequent thinning and sharpening of the cutting edge, so that, by a simple operation of nature, continued use is accompanied by a continued perfection of the organ, and a more perfect adaptation to its appropriate offices.

The mode of action of the cusped border of the young tooth, and the sharp edge of that of the adult, may be illustrated by reference to artificial mechanics; but the conversion of one form of instrument into another adapted to a new state of things, such conversion being effected by use alone, is a phenomenon which nature solely can accomplish.

The powerful machine employed for planing metals, the introduction of which has constituted an era in mechanical science, may be looked upon as an exemplification of the action of the cusped edge of the young incisor. While the cutting edge of the adze and of the common plane may be regarded as analogous in its operation to the edge of the adult incisors at a later period.

The crowns of the incisors are in contact by their lateral borders only for a small extent of surface; the point of contact being near the free edge of the teeth. Below * this point the lateral borders gradually increase in breadth and recede from each other, so as to form a triangular space, of which the base is bounded by the gum, and the apex is directed upwards towards the free edge of the teeth. The same conformation is apparent in regard to the rest of the teeth of the series. This arrangement is a beautiful provision for preventing the impac-

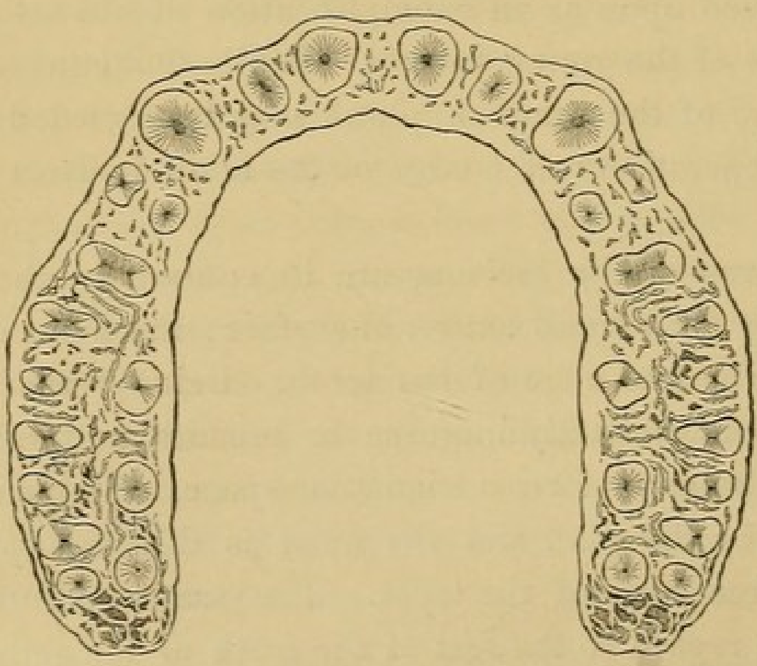
* See note at page 60.

tion of particles of food between the teeth, for when such matters collect in this situation they are generally very easily displaced by the action of the tongue or by currents of air or fluid forced through the triangular spaces. When, however, the aid of a toothpick is required, it should be used with care, for one boundary of the interdental space, it must be remembered, is formed by a vascular and sensitive organ, the gum. From want of caution in this respect considerable injury is often done to the teeth.

The enamel of the crowns of the incisor and canine teeth terminates towards their neck, both on the anterior and posterior surface, in a graceful curve; the convexity of the curve being directed towards the gum. At this point the enamel ceases abruptly, and rests upon the concave margin of the gum, which is thus protected from injury during the act of incising the food. This arrangement further bestows considerable beauty on the teeth, the convex border of the pearl-like crown being, as it were, bedded on the concave and crescentic margin of the florid gum.

The necks of the incisor teeth are somewhat broader in

FIG. 5.*



* Fig. 5. A horizontal section of the alveolar process and roots of the teeth of the upper jaw. The large size of the fangs of the central

front than behind, and have a pyriform section, or rather, perhaps, an oval section slightly compressed on the sides. This peculiarity of form prevails to a greater or less degree in all the teeth, and is dependent on the arched construction of the jaws.

The fang of the central incisor tooth is a cone, flattened on the two sides and on the anterior surface, convex posteriorly, and pierced at the apex by an opening, sometimes by two, for transmission into the cavity of the tooth of the vessels and nerves of the pulp. The fang of the lateral incisor forms an exception to this description, in being convex instead of flat on the anterior surface; in other points it agrees accurately with the preceding. A transverse section of the fang of the incisor tooth gives an antero-posterior diameter greater than the transverse, measured near the anterior surface, in the proportion of 12 to 11; and measured near the posterior aspect, in the proportion of 12 to 9. This greater breadth of the fang near its anterior limb, which has been adverted to before, has reference to its relation with the convex aspect of the dental arch; and it has also a physiological purpose as supporting that part of the crown of the tooth on which the larger share of duty falls.

The direction of the fangs of the incisor teeth of the upper jaw is obliquely upwards and backwards, forming, as it were, a continuation of the segment of a circle described by the incisors of the lower jaw when the latter are in action, the centre of the circle being at the condyle of the jaw. The fangs of the inferior incisors are disposed in the direction of the segment of a circle having a similar centre, but on account of the greater projection of the superior dental arch a shorter radius.

The lateral incisor teeth approach, in their general appearance, their shape, and especially in the greater transverse con-

incisors and still larger canines, contrasts strongly with the sections of those of the other teeth made on the same plane. The root of the anterior bicuspis is seen to be double; that of the second, single; and the roots of the molars consist of three each, the internal being the largest.

vexity of their anterior surface, to the canines. At an early period, moreover, they present, like the canines, a solitary cusp upon their free edge. Their crowns occupy a lower level than the central incisors or the canines between which they are placed, and they fulfil in their physiological character a function intermediate between the two,—a function partly for the division, and partly for holding the food.

The bare inspection of the incisor teeth,—their diminutive size, their situation immediately within the lips, their position at the extremity of the lever formed by the lower jaw, their relation to the tongue in the exercise of its functions,—is sufficient to carry conviction to the mind, that their power must be small, and their office, as far as force is concerned, necessarily limited. But this deficiency of power is compensated by their greater freedom of movement, and the more perfect direction of their action. The latter conditions render them important agents in vocal articulation. They possess, besides, another recommendation, in their physiognomical importance, as contributing to bestow beauty and expression on the countenance. These considerations are sufficient to explain the anxiety which is felt by the dental practitioner in the preservation of the incisor teeth, and the care and attention which he devotes to secure the adoption of every means which may insure their health and perfection.

Although it is quite true that in man and many other animals the force exerted by the incisors is by no means great, yet in certain orders of mammalia, as rodentia and pachydermata, the incisor teeth are very powerful instruments. The hare, the rat, the beaver, animals belonging to the rodent family, and the horse, a pachydermatous animal, are instances in illustration of this position. In rodentia, the incisors continue to grow during the whole period of life: hence the wearing away caused by constant attrition is immediately repaired.

The lower jaw is a lever of the kind denominated, of the third power; that is to say, the power is applied between the

8

fulcrum and the weight; and as the incisor teeth are placed at the extremity of this lever, they are necessarily the weakest in their action of the whole dental series. The sharpness of their edge in some degree compensates this defect, and the mode of their action is such as to remedy the deficiency in a still further degree. For example, they divide the food by a peculiar gliding action of the superior over the inferior teeth; from their diversity of length the lateral incisors come into play when the central incisors have half accomplished their task; and from the want of correspondence of the edges of the incisors of the two jaws, two sections are performed at the same moment.

CANINE TEETH.

The canine, cuspidate, or lacerating teeth, are four in number; two in each jaw.

The canine tooth is placed between the lateral incisor and first small molar at the extremity of the range of oral teeth, and at the point of junction of the latter with the buccal teeth. In this position the canines project somewhat from the dental range, and constitute, as it were, angles or corners to the dental arch. The upper canine is situated immediately beneath the nasal process of the superior maxillary bone, and its root extends into that process to a point higher than the plane of the floor of the nose. On the anterior surface of the maxillary bone the root of the canine forms a considerable prominence, and the depressions on either side of that prominence have received particular names; that in the front being termed fossa incisiva; and that behind, fossa canina. The projection of the canine teeth bears reference to the important physiological purpose which they fulfil, as holding and seizing organs, and that peculiarity also tends to give expression to the countenance.

The inferior canines are situated midway between the symphisis of the inferior maxilla and the mental foramen, and their roots occupy about one-half of the depth of the jaw.

The breadth of the crown of the upper canine tooth is somewhat greater than that of the lower; the transverse measurement of the former being about four lines, and of the latter three and a-half.

The fang of a canine tooth is generally single, but is occasionally found double; more frequently it is curved or undulated; a form which probably depends on its peculiar crowded position in the jaw, and the close apposition of the roots of the neighbouring teeth.

In length, a canine tooth measures about thirteen lines, the inferior being slightly shorter than the superior; hence, the canines are the longest teeth of the dental series, and their strength is proportionate. The crown of an upper canine measures about six lines, and its fang seven; while in the lower canines the length of the crown and fang is about equal.

The breadth of the neck of the canine teeth as measured in front is three lines; behind, two lines; and from before backwards, four lines.

The anterior surface of a canine tooth is convex both horizontally and vertically, and is marked in the middle by a ridge which terminates at the summit of the crown in a cusp; on either side of this median ridge is another, less strongly raised, and without a cusp. The posterior surface of the crown is very oblique, and crossed by transverse undulating ridges, which are more strongly developed in the teeth of the upper than in those of the lower jaw. The summit of the tooth is more obtuse than in the incisors, from the greater inclination of the posterior surface of the crown, the angle formed by this surface being between 45 and 50 degrees. The oblique inclination of the latter is obviously caused by the great antero-posterior diameter of the neck of the tooth.

The pyramidal shape of the crown of a canine tooth, its tubercular summit and sharp edges, the great breadth of its neck, and the vertical direction of its root, are all of them conditions favourable to the particular function of these teeth. The fang is an immediate prolongation of the crown, and tapers very regularly and gradually to a pointed extremity. It is flattened on the sides, and exhibits in the latter situation a groove which indicates a tendency to division into two portions —a condition occasionally observed. The enamel of the crown presents the same arched termination at the neck as the incisor teeth, but the arch is more deeply cut.

The purpose of the canine teeth is that of transfixing and holding solid food placed in the mouth, while the neighbouring teeth accomplish its division. This function is facilitated during the period of youth by the presence of the cusp previously referred to, on the summit of the crown. In the adult this cusp is worn away, and by so much the canine tooth loses its penetrating power; but the deficiency is compensated by the augmented strength of the muscular apparatus of the jaw.

BICUSPIDATI, SMALL GRINDERS OR MOLARS.

The small molars are eight in number, namely, two on either side in each jaw; they are called bicuspidati, from possessing two cusps, which surmount their crown; and small grinders or molars, from their function in relation to the trituration of the food.

In position the small molars follow the canines, being placed between them and the large molars; and they form the commencement of the lateral portion of the dental arch. (Fig. 1, page 54.) Their point of contact with neighbouring teeth, as well as between themselves, is about one line below the summit of their cusps. The upper bicuspidati are implanted in that portion of the maxillary bone which corresponds with the fossa canina, the root of the anterior tooth being generally imbedded in the solid portion of the bone, while that of the posterior extends more or less nearly to the maxillary sinus, (antrum maxillare,) and sometimes penetrates the floor of that cavity, and projects into its interior. The inferior small molars are situated immediately over the mental foramen, the root of the anterior tooth lying slightly in front of that opening, and that of the posterior descending directly towards the foramen, or inclining slightly behind it. The extremities of the fangs approach to within half an inch of the base of the jaw.

The bicuspidati have generally but one fang; occasionally, however, the anterior and superior small molar has two, one being imbedded in the external, the other in the internal wall of the alveolar process, and being separated from its fellow by cancellous osseous tissue. (Fig. 5, page 62.) The fangs of this tooth frequently diverge very considerably. The single fang of the bicuspid tooth is always marked upon its lateral aspect by a groove, indicative of a tendency to division into two, (fig. 5, page 62,) and is often curved.

The crowns of the small molars present some diversity in regard to relative size; that of the anterior is frequently larger than the posterior, (fig. 1, page 54,) but sometimes the reverse is the case. The external or buccal surface of the crown measures at its broadest part three lines and a half, and the opposite, or lingual side, about one fourth of a line less. The neck of these teeth, both on the outer and inner aspect, measures only two lines. The anterior and posterior surfaces of the crown and of the neck measure four lines in breadth. The smallness of the antero-posterior diameter of the necks of the bicuspid teeth is a character of much importance in reference to their practical management. In proportion to the size of their crowns, the neck of these teeth is more slender than in any other of the dental series, and the danger of fracture during extraction by so much the greater. The length of the entire tooth is eleven lines, three lines and a half appertaining to the crown, and the rest to the fang.

The buccal and lingual surfaces of the small molars present a regular convexity, this convexity being more strongly defined in the upper than in the lower teeth. The enamel, as on the crowns of the canine teeth, forms a deep arch at its inferior margin, and the arch is greater on the outer than on the inner side.

The summit of the crowns of the small molars is capped by two well-defined tuberculated cusps, external and internal, the latter being the smaller. In the upper teeth these cusps exactly surmount the axis of each half of the tooth, but in the lower they overhang their respective axes, and give to the entire tooth the appearance of inclining inwards towards the cavity of the mouth. The cusps on the superior teeth are separated from each other by a notch, which is deep in the centre of the crown, and bounded before and behind by a deep ridge, which runs from one to the other cusp. On the crowns of the lower teeth the notch is intercepted in its middle by a connecting ridge between the cusps, and the portions of the notch before and behind the median ridge form two small fossæ. Whenever there are two fangs to the bicuspid tooth, the internal is always the smaller, in correspondence with the smaller size of the inner cusp.

The small molars present in their general appearance those transitional characters which link them to the teeth between which they stand: for example, on the crowns of the anterior pair there is an indication of the small lateral cusps which distinguish the summit of the canine, while on the crowns of the posterior pair the cusps are rounded and flattened like those of the true molars; there is also in the latter a certain squareness of form which is characteristic of the molar series. In their functions also they occupy an intermediate place, serving to hold and transfer solid food, by virtue of the obliquity of position of the inferior cusps, and to grind it by virtue of the breadth of their crowns.

LARGE MOLARS OR GRINDERS.

The large, or true molars, differ materially from the teeth heretofore described, not merely in function, but also in form and arrangement. They are situated in the posterior part of the mouth, at a distance from view, and under the immediate influence of those powerful agents in mastication, the temporal and masseter muscles. Their mechanical modifications are also peculiar, for instead of passing their antagonists when the jaws are closed, they meet by the broad faces of their crowns, and like mill-stones, from which they take their name, grind the food between their approximated surfaces. The other teeth of the dental apparatus have, as a general rule, only one fang, but these have two and three. The large molars are brought into action by the simple closure of the mouth, but their functional operation calls for the exercise of a series of rotatory movements.

The molar teeth are twelve in number, six in each jaw, three being placed at each extremity of the dental arches. The first of these teeth, from before backwards, is the first molar; the second is known as the second molar, and the third as the dens sapientiæ, from its irruption after the age of puberty.

They are situated behind the small molars, and form the last of the range of buccal teeth. In relation to the rest of the teeth comprising the dental series, the large molars represent the lower portion of a regular elliptical arch. (Fig. 1, page 54.) This conformation is a peculiarity of the dental apparatus of man, for in animals the large molars have rather the appearance of the perpendicular bearings of an arch, of which the span is constituted by the anterior teeth. (Fig. 2, page 55.) The regularity of the dental arch in man is a condition necessary to the perfect adaptation of the teeth of the two jaws, and to the proper performance of the functions of mastication.

The point of contact of the large molars is situated at about a line below the level of the face of the crown, and about midway between the buccal and lingual surfaces of the tooth.

The superior molar teeth have two external fangs, and one internal, the former being compressed and flattened, and the latter rounded. (Fig. 5, page 62.) The two external fangs are imbedded in the external wall of the maxillary bone, while the internal root is directed obliquely inwards, and occupies the internal wall of the alveolus, and the base of the palatal process. In the space left by the divergence of the extremities of these fangs, is situated the floor of the maxillary sinus, or antrum of Highmore; (fig. 4, page 57;) and not unfrequently the roots of the molars project into this cavity. The degree of divergence of the fangs of these teeth may generally be inferred from the prominence of the cheek bones, being great when the latter project considerably, and vice versâ. The posterior molars of the upper jaw, the dentes sapientiæ, are placed at the extremity of the alveolar process, as far back as the posterior palatine foramen, and their crowns are not unfrequently directed outwards.

The inferior molars have two fangs, anterior and posterior, which are imbedded in the substance of the maxilla, a little internal to its axis, and are prolonged downwards to within half a line of the dental canal: the distance between their points and the base of the jaw varying from one half to one third part of an inch. The fangs of the last molar are situated in the base of the coronoid process of the inferior maxilla. When the cheek-bones are prominent, and, as a consequence, the fangs of the superior molars diverge considerably, the lower jaw usually corresponds in breadth, as do the roots of the molar teeth.

It not unfrequently happens that the fangs of the molar teeth, both of the upper and lower jaw, approximate at their extremities, and in this manner embrace the osseous partition which is placed between them. When this occurs, an obstacle to the extraction of the tooth is created, and on the removal of the tooth the partition is found clasped between them. Sometimes the anterior external, and the internal fang of the upper molars, are connected by means of a broad plate, and now and then all the three fangs are conjoined in a single mass. Occasionally the two fangs of the lower molars are similarly connected together.

The crowns of the molar teeth are quadrilateral in shape, and have the appearance of being composed of tubercles separated by curved furrows. (Fig. 1, page 54.) Their corners are rounded, in the lower jaw rectangular, and in the upper alternately acute and obtuse; and their broad surface, in consequence of the arched arrangement of the teeth, is broader than the lingual. The sides of the crown of the superior molars are more equal than those of the inferior, the bucco-lingual diameter being usually a little less than the antero-posterior. The number of tubercles or cones surmounted by cusps on the crowns of the molar teeth is usually four. In the lower molars they occupy a more equal extent of surface than in the upper, and are consequently more regular in size. In the latter the posterior and internal tubercle is the smallest. The tubercles are separated by furrows, which terminate abruptly, and have the appearance of artificial cracks; the transverse furrow is continued for some distance upon the corresponding surface of the crown, and divides it more or less equally into two portions. It has already been explained that the superior molars have three roots; now the transverse groove on the buccal surface of the crown corresponds with the two external roots, and the divided lingual surface, although surmounting the inner and single fang, is indicative of the double composition of that root. When the lingual surface of the crown is divided unequally by this groove, the two elements of the single fang will be found of disproportionate size. The tubercle of the inferior molars present a similar correspondence with the division of the fangs; and the size of the tubercle, in this way, becomes a pretty certain guide to the size of the roots of a molar tooth.

When the molar teeth are viewed with reference to their mutual action, each pair of opposing teeth will be found to represent a cone, whereof the apex corresponds with the points of the fangs of the lower molar, and the base with the expanded fangs of the upper. (Fig. 4, page 57.) The fangs are supported in their places by an arrangement similar to buttresses, which, while they maintain the teeth securely in their position, exert no pressure upon the roots. Indeed, in no other way would it be possible for the teeth to sustain the multiplied concussions of a long life without injury and destruction.

In the approximation of the surfaces of the crowns, the tubercles of the upper molars are received into the furrows and hollows of the lower, and vice versâ; an arrangement beautifully suited to the purposes for which these teeth are intended. Moreover, this irregularity of surface is well adapted to perform the additional office of a floor, on which the trituration of the food, and its perfect admixture with the salivary fluid, may be effected.

The first and second upper molars correspond in respect of size of the triturating surface of their crowns with those of the lower jaw, but the crowns of the superior wisdom teeth are always smaller than those of the inferior. The average lateral breadth of the crown of the first molar is five lines; that of the second molar half a line less; and the breadth of the superior wisdom teeth about four lines. The superior wisdom teeth present considerable variety in the dimensions of their crown, the latter being oftentimes not larger than the crown of a small molar.

The entire length of a molar tooth ranges between eight and thirteen lines, while the depth of the enamel of the crown is not greater than three lines and a half, and forms a regular margin around the circumference of the neck. The irregularity of the roots of these teeth in point of length, figure, and direction, indicates the utter impossibility of determining beforehand the amount of resistance which will be offered to their removal from the jaws, and renders it a matter of imperative necessity that the operator should possess considerable power, and such manual dexterity as will enable him to apply his force in the most suitable direction.

The mechanical disposition of the molar teeth is beautifully fitted to the purposes which these organs have to fulfil; for example, the first act of mastication, consisting in the closure of the lower against the upper jaw, while it secures the food, makes its greatest force of pressure against the outer limb of the crown of the superior molars, that limb which we know to be supported by two out of the three roots of the tooth. Again, when trituration ensues, the ramus of the jaw is drawn inwards, and the chief amount of pressure is transferred to the outer limb of the lower molars, where the greatest strength of fang exists. The process of trituration naturally takes an inward direction, in order that the food, when sufficiently masticated, may be transferred to the cavity of the mouth, and there formed into a bolus fitted for deglutition; and the direction of the grinding surfaces of the crowns is adapted to this purpose. The inner borders of the crowns of the upper molar teeth are rounded in shape, and a similar conformation is evident on the opposite borders of those of the under-jaw.

Arguing from the above premises, in conducting the manual operations on the teeth, we perceive the necessity, in executing the removal of a lower molar tooth, of directing our force outwardly, because it is in the outward limb of the tooth that the greatest bulk of root is found. And in extracting a superior molar, the direction of the force should be downwards and outwards, as conforming to the line taken by the fangs.

In following out the preceding description of the human teeth, corroboration of the various points discussed will be abundantly met with in the teeth of inferior animals, and the most minute particulars in the conformation of the former will find apt illustration among the latter.

CHAPTER IV.

GENERAL AND MINUTE ANATOMY OF THE TEETH.

In general and minute structure teeth are composed of two primary and dissimilar portions; the one being vascular and soft, and termed the pulp, the other extra-vascular, hard, and calcareous. The latter, also, is a compound substance, being made up of three separate and distinct tissues, namely, ivory, cortical substance, and enamel.

Ivory, the most generally distributed of the dental tissues, offers three varieties to our observation. One of these is composed of a regular series of fibres and cells, and on this account may be termed *fibro-cellular;* it is the most perfect kind of ivory, and extensively met with in the animal kingdom. In its most characteristic form it is exhibited in mammalia and reptilia; and forms the largest portion of the substance of the teeth of man. (Plate V. figs. 3, 4, 5.)

The second variety of ivory is found in the teeth of fishes and some few other animals, as Orycteropus.* It is traversed in a vertical direction by numerous canals, and this being its distinguishing feature, I have termed it *canalicular.*

The third variety results from the conversion into ivory of that portion of the pulp which remains after the completion of the fibro-cellular kind, and is consequently in immediate con-

* Historical Introduction, Plate C, 1.

nexion with the latter. Examples of ivory of this description are met with in the teeth of the walrus, sloth, &c. (Plate V. figs. 2, 3.) Occasionally, also, it is seen as the product of a morbid action,—a circumstance which I had occasion to explain in a paper read before the Royal Medical and Chirurgical Society in January, 1839, and published in the 22nd volume of the Transactions of that Society. In the paper referred to I remark, " When the growth of the tooth is completed, the primary function of the pulp ceases; but in teeth of which the period of growth is unlimited, its action of course only terminates with their vitality. It occupies a small cavity in the interior of adult teeth of limited growth, and a conical cavity at the root of those of which the growth is unlimited. In the former case, one or more additional fangs may be formed by its subdivision into processes, whilst in the latter, the arrangement of the structures at the base of the tooth is the same as in its entire length. In some of the lower animals, being surrounded by the ivory which itself has secreted, it is normally converted into an earthy structure, the appearance of which is intermediate between ivory and bony substance.

" In man and other animals where the ossification of the pulp is the sequela of disease, the appearances presented possess many of the characteristics of true bone; but still is not generally so similar to it as is the ossific growth produced by the capsule of the fang.

" The substance under consideration, the nature of which has not hitherto been dwelt upon, partakes much of the fibrous character of the ivory, being composed of irregularly radiating filaments, blended with small calcigerous cells, in which ossified vessels are seen to ramify. The conversion into osseous matter is sometimes partial, and sometimes general throughout the tissue. In the longitudinal section, (plate VI. fig. 3, *b*,) the bony pulp completely fills up the cavity of the crown, and that in the fang. In the transverse section, (plate VI. fig. 7, *b*,) the cavity of the crown is only partially occupied; and in the longitudinal section, (plate VI. fig. 1, *b*,) the ossification seems to have commenced in the centre of that portion of the pulp which is contained in the fang; and in this case a cavity has been formed round the ossified portion.

"In the lower animals a similar ossification takes place when the functions of the part are interfered with; examples of which are often met with in the tusk of the elephant, hippopotamus, cystophera proboscidiana, and in the teeth of many other animals. The ossified pulp in the human subject is of frequent occurrence, and is generally, and indeed in every case where I have met with it, the sequela of long-continued disease, either of the tooth itself, or of some part of the mouth: though there is no direct evidence to prove that ossification of this structure may not take place without previous morbid symptoms. The predisposing cause, however, of the process is often at a considerable distance, and frequently shows itself when the actual or other cautery has been used to allay the sensibility without actual destruction of the internal membrane. Very frequently it supervenes on resistance to complaint, or on the determination on the part of the patient to retain a tooth which has given pain in stopping.

"The process is always accompanied by pain, and by a peculiar uneasiness of the tooth itself, which is shared also by the surrounding parts. As it frequently takes place without any co-incident external decay, the only possible relief is often withheld, as there are no infallible diagnostic symptoms warranting a decided opinion; and the patient is left to suffer, till the malady having crept on to the external capsular membrane, affords to the careful observer a decided demonstration of its existence."

When the above-described kind of ivory is the result of disease, it commences to be formed within the pulp by one or more independent centres of growth, and occasionally these centres by their conjunction completely fill the cavitas pulpæ. But however perfectly this process is effected, the newly-formed substance, though closely compressed against the surface of the normal ivory, is never connected with it organically.

Sometimes in the tusk of the elephant we meet with this variety of ivory occupying a considerable extent of the cavitas pulpæ, and presenting some curious modifications of appearance, one while resembling beads variously arranged, and another while having the form of stalactitic projections. Beads of this kind are occasionally seen embedded in the substance of the fibro-cellular ivory, thereby indicating that they were formed originally in the body of the pulp, and became surrounded by the normal ivory during growth. From possessing corpuscles similar to those of bone, disseminated through its substance, I have named this variety *corpuscular ivory.**

The CORTICAL SUBSTANCE is always found on the peripheral part of the tooth, forming a layer of investment around it, and lying in close apposition with the enamel or ivory. In the elephant it constitutes a considerable and important portion of the molar teeth,† as it does also in other genera of pachydermata, and in ruminantia. This substance has distinct offices to perform in the teeth of other animals besides those enumerated, and in the course of the present pages I shall have occasion to explain my reasons for concluding that the cortical substance is present in the teeth of all animals, though sometimes existing only in a rudimentary form. In treating on this subject in a paper communicated to the Royal Medical and Chirurgical Society, and published in the 22nd volume of the Transactions of that Society, (page 310,) I have denominated the layer in question the "*persistent capsular investment.*"

The cortical substance usually occupies only the exterior

* The affinity in appearance between this kind of ivory when the product of disease and that of normal growth may be seen at Plate C. 3, illustrating the Historical Introduction to this work. Fig. 1 represents a section of the tooth of the walrus, showing its normal condition; and fig. 2, a section of the tusk of the elephant altered by diseased action.

† Plate C. fig. 3, *a*, Historical Introduction.

of teeth, but in some animals, as in the elephant, it enters into the formation of their mass, and serves to hold together the other structures of which the teeth are composed. In consequence of performing the latter function it has been named *cementum*. When the cortical substance, in conjunction with the enamel and ivory of one of the convoluted teeth of pachydermatous animals is subjected to the attrition consequent on the mastication of vegetable food, it is worn away more speedily than the other dental substances on account of the greater softness of its texture In like manner the ivory yields to attrition sooner than the enamel, and the three substances therefore present a series of alternating ridges of different degrees of elevation,—an arrangement beautifully adapted to the perfection of a triturating organ, and calculated to maintain the operative condition of the teeth.*

Two important offices in the teeth of animals are fulfilled by the cortical substance. The one is that already described of yielding to attrition in such wise as to enable the crown to maintain a permanently sharpened surface for the purpose of grinding; the other is that of giving support to the enamel. The latter function is illustrated in the incisors of rodentia, and particularly in those of the beaver, where this substance possesses the peculiar reddish brown hue so characteristic of the teeth of that animal and its allied genera.

It is the cortical substance which bestows the dark colour on the teeth of the herbivorous animals, and wherever it exists its presence is indicated by a greater or less degree of darkness of tint. Even on the teeth of infants, particularly in such as have been reared upon vegetable food, this substance is discernible by the brownish or greenish tinge which it obtains. The property possessed by the cortical substance of retaining colouring matter within its porous interstices offers a means by which it may be detected, and at the same time constitutes an obvious mark of distinction between it and the subjacent enamel. The

* Historical Introduction, Plate C. 4, fig. 3.

appearance in the teeth of horses denominated " mark of mouth" is due to the presence of cortical substance. As I have before remarked, the cortical substance has no organic connexion with the enamel or ivory against which it lies, and being softer than both is easily detached by means of a knife. It does not appear liable to decay like the other structures of a tooth, but is subject to removal by absorption. In its intimate structure it presents the characteristic corpuscles and canals of bone, the latter being filled with ossific matter, but otherwise resembling Haversian canals. It has been erroneously affirmed that " its chief use is to form the bond of vital union between the denser and commonly unvascular constituents of the tooth and the bone in which the tooth is implanted."* But a very superficial inspection will serve to prove that such a purpose cannot be fulfilled by the cortical substance; that no vital union, for example, can exist between it and the enamel, and as little between it and the ivory of the root of a tooth. I must repeat, that there is no organic connexion whatever between it and the other dental tissues ; its union is merely one of mechanical contact, and its purpose purely mechanical.

The ENAMEL is the least constant and most sparingly distributed of all the dental tissues,—in some animals serving only to supply the teeth with a hard edge to divide their food. In man, it covers the crown of the tooth, and ceases at the neck, being about half a line in thickness on the grinding surface of the crown, and becoming thinner upon its sides. On the teeth of the hippopotamus and elephant, it varies from half a line to one-fourth of an inch in thickness.

This substance is the hardest and most solid of all the animal textures, and contains the largest proportion of calcareous matter. It is so dense as to be capable of receiving a very fine polish; it turns the edge of cutting instruments, and elicits sparks when struck with steel. When, however, its adhesion to the ivory is in any way disturbed, it is then easily broken,

* Owen's Odontography. Introduction, p. 21.

and may be chipped away with little force. This is the principal agency by which it is destroyed in decay of the teeth, the ivory beneath becomes softened or removed, and fracture of the enamel speedily ensues. When exposed to the influence of a moderate heat, the enamel cracks away from the ivory, and it is readily acted on by acids.

In structure, enamel is composed of cells which are arranged in regular rows, forming composite fibres placed at nearly right angles to the surface of the ivory, the original nuclei of the cells not being persistent. It has been stated by authors that an analogy subsists between enamel and bone, but I cannot yield my assent to this opinion. The fact of both these tissues being composed of calcareous matter can be no ground of analogy, and this is the only resemblance which exists between them.

FIG. 6.*

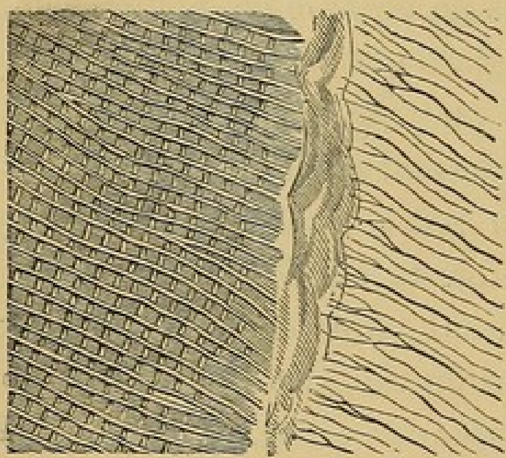
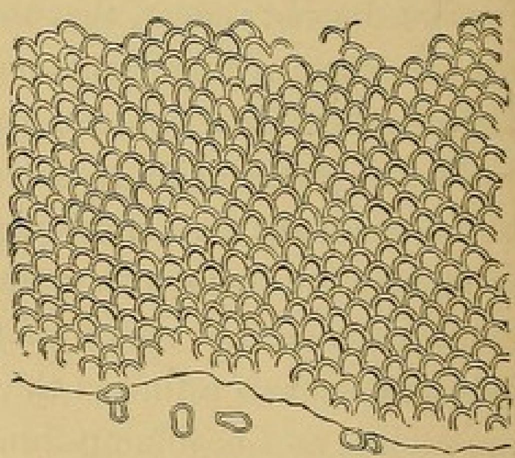


FIG. 7.†



In a memoir read at the meeting of the British Association in 1839, I took occasion to observe that the structure of enamel

* Fig. 6. The appearance of the enamel when viewed in a vertical section. The structure to the right is the ivory, and the uneven marking which crosses the section vertically the boundary between the enamel and the ivory.

† Fig. 7. The enamel seen on the face of a vertical section. The peculiar form displayed by the cells I believe to result from their position and mutual adaptation.

was much more simple than that of the other dental tissues, being in truth nothing more than a mass of cells arranged in rows, and fitted closely together, but held only slightly in contact by a thin web of membrane. Hence the enamel is more brittle than either the ivory or cortical substance, but at the same time it is harder than either.

Ivory is darker in hue than enamel, and has more or less of a yellowish tint,—it is always covered on its exterior by an investment of the latter substance or of cortical substance; being softer than enamel, it yields more quickly to the action of attrition, but from possessing the quality of toughness in a greater degree, it is better adapted to the purpose of forming the body of the tooth. The toughness and comparative softness of ivory have been made available for the necessities and luxuries of man from the earliest to the present times, amongst the rudest inhabitants of the earth as amongst the most refined, and ivory has been employed in the production of some of the most elegant of our manufactures. The workman is aware that ivory possesses a kind of grain running in the vertical direction of the tooth. He compares this grain to the course of the fibres in wood, and he knows full well that a carving made in the direction of the grain will be smooth, while in the opposite it will be rough. When ivory falls into a state of decomposition, it splits into concentric plates corresponding with the vertical direction of the tooth. Of this change we have a common example in the fossil teeth of the mammoth; and again, occasionally, in human teeth in a state of decay. A transverse section of ivory exhibits a beautiful arrangement of concentric circles crossing each other in every direction; acids dissolve ivory, but less quickly than enamel, and it becomes softened and destroyed by what is termed natural "decay," as well in the deciduous as in the permanent teeth. The destruction of ivory is also evinced in the removal of the fangs of the deciduous teeth, and sometimes of the permanent teeth, by absorption.

In the historical introduction to this work, I have furnished a report of the state of opinion among physiologists in regard to the structure, organization, and vascularity of the teeth, and have partially developed my own views on the same subject. In this place, therefore, it only remains for me to discuss, in the first place, the nature of the new doctrines relating to the structure and physiology of the teeth; secondly, the kind of evidence on which these doctrines rest; and thirdly, the practical deductions which have been obtained from the consideration of these doctrines.

Ivory has been regarded as a structure composed of minute branching tubes, which radiate from the surface of the pulp to the periphery of the tooth, where they terminate; in some instances by communicating with cells resembling the corpuscles of Purkinje. The central extremities of these supposed tubes originate by open mouths on the walls of the cavitas pulpæ, and their canals, though more or less filled with calcareous matter, are accredited with the function of affording passage to certain fluids. Moreover, the authors of this doctrine affirm that the material which connects and binds the tubes together, the intertubular substance, is amorphous and structureless.

The evidence in support of the above view of the structure of the teeth, advanced by its authors, is the appearance which it presents when viewed with the microscope, the assumed injection of the tubes from the blood-vessels, the permeation of the tubes by ink, and the passage along them of bubbles of gas disengaged during the action of acids on the ivory. As a practical inference drawn from the preceding premises, it has been argued that the tubes are the medium of transit of a nutritive fluid from the pulp to the substance of the tooth, and that, when a tooth has been submitted to the ordinary operation of stopping, a calcareous fluid is poured out by the cut extremities of the tubes, and forms a hard and permanent layer between the stopping and the incised surface.*

* Athenæum. Meeting of the British Association at Newcastle, 1838.

Such are the views which were entertained by physiologists relative to the teeth up to the period when my own researches commenced, and as my labours, prosecuted with the expectation of corroborating these doctrines, have led me to results widely differing from those of my predecessors, I deem it necessary to lay before my readers the course which I have adopted in pursuing my investigations. In my early observations I followed the plan described by Retzius,* and I exerted myself to facilitate and improve the mode of demonstrating microscopically the structure of the teeth. I found that the means best adapted for this purpose were slips of glass, of a size suited to the microscope, ground upon the edges; thin glass for covering the preparation; Canada balsam as colourless as possible; a small spirit lamp; files; and a water-of-air stone, or hone.

Having all the needful appliances at hand, I proceeded to make a thin section of the tooth to be examined, by means of a fine saw, and after polishing it on one side, placed that side upon a thin bed of Canada balsam, spread out to the size of the section on a slip of glass, and prepared for its reception by being previously heated over the flame of the spirit lamp. I then pressed the section firmly against the glass, so that when the balsam had cooled the preparation might be fixed sufficiently firmly to admit of being filed and polished on its free surface. When this part of the process was effected, the section was covered with a fresh layer of Canada balsam and a thin piece of glass, and the preparation was then complete. But sometimes it was found necessary to render the section thinner than is contemplated in the above description, in which case a fresh slip of glass, with a bed of heated Canada balsam, was prepared, and the newly-polished surface of the section laid against it. When the balsam had become cool, and the section firmly united to the new slip of glass, a gentle heat was applied to the old slip, so as to loosen its connexion with the

* Historical Introduction, page 49.

section, and the glass was withdrawn. The free surface was again filed and polished to the requisite extent, and covered as before with a layer of Canada balsam and a slip of thin glass. In the case of fossil teeth, it was found necessary to have recourse to the grindstone to make the sections sufficiently thin.

Prosecuting my inquiries upon sections of teeth prepared according to the above plan, I was enabled to examine all the appearances which had been described by preceding authors; but, in the progress of these observations, it became evident to me that certain of the appearances were consequent upon the manner in which the preparations had been made. These ideas, at a subsequent period, I had ample opportunity of verifying, and the results to which they gave rise shall be communicated to my readers anon.

It has long been known that the teeth are composed of two essential chemical constituents, namely, earthy salts and animal matter. To ascertain the relative proportion of these substances, I had recourse to my respected and distinguished friend Dr. Thomas Thomson, Regius Professor of Chemistry in the University of Glasgow, a gentleman whose talent and indefatigable zeal in forwarding the interests of science are as justly appreciated as they are extensively known. From Dr. Thomson's analysis it appears that the quantity of animal matter is very considerable, and it is evident that it is contained chiefly in the fibres, or, as they have been termed, the tubes of the ivory. It follows, therefore, that the interfibrous or intertubular substance differs greatly in composition and physical properties from the fibres or tubes, and as a consequence of this difference, that under the influence of friction, the two substances will be unequally reduced, the harder material will necessarily form a series of prominences on the abraded surface, and the surface will assume the appearance of an undulated plane. Moreover, this irregularity will be increased in the ratio of the difference of density of the two substances.

We see examples in evidence of the truth of these remarks in the wearing of the paving stones in our streets, and in the reduction of the triturating surfaces of the crowns of the grinders of the elephant; and in truth they are constantly passing before our eyes among the most familiar objects of our daily existence.

Armed with these reflections, I soon discovered that in consequence of the difference of density between the fibres and interfibrous substance, these parts actually presented on the face of a section the condition which I have just explained. That in a section made parallel with the fibres, the latter sunk below the level of the interfibrous material in the form of undulating furrows, the intervening substance constituting as many prominent ridges; and that, in a section made in the opposi te di rection, the fibres presented themselves in the form of points hollowed out of the interfibrous material. Again, when these sections were put up, the varnish and balsam, while they levelled the surface, served to define more distinctly the irregularities. From these observations, therefore, I came to the conclusion that the appearance of a tube results from the hollowing out of the fibrous portion, while the surrounding interfibrous matter maintains a higher level.

Again, it occurred to me that as the ivory is constantly subject to conditions which tend to wear away the surface, and consequently to expose the open extremities of the so-called tubes, instances must have been observed, during the many years in which the teeth have been carefully studied by the dental practitioner, in which the hardening fluid above referred to was effused by the gaping apertures of the tubes. I sought diligently for evidence of such effusion, being desirous of giving the hypothesis, however repugnant to my reason it might be, the advantage of careful investigation; but I was unable, after due attention, to discover any appearance which could diminish my unbelief. Indeed it did appear to me most unaccountable that an organ like the tooth, subject to mnch violence and continued abrasion, should be furnished with tubes through which a constant transit of fluid was taking place, from the pulp towards the surface.

Again, Retzius and his followers remark that when a section of a tooth, made transversely to the direction of the fibres, is viewed upon a dark ground, a white spot is perceptible in the area of each of the so-called tubes. Now, this is the fact, but the inference to be drawn from it is directly opposed to that which Retzius endeavours to establish; for it is quite evident that if we view an object pierced by an aperture upon a dark ground, the area of the aperture, instead of being white, should be black, while the contrary proves that it is no hole at all.

When we compare the diameter of one of these fibres in a transverse section with that which it presents in its longitudinal course, the two measurements will be found to be exactly the same. But it would be otherwise if the fibre were really a tube, for then the diameter, as taken in the longitudinal direction, should be the greater of the two, from including the parietes of the tube as well as its canal, which is not the case.

With respect to the passage of air-bubbles along the supposititious tubes of ivory, when that substance is subjected to the action of muriatic acid, and the inference therefrom deduced, that therefore they are tubes, it is hardly necessary for me to say more than that such observations can only be made with a microscope of low power, and as the acid acts equally upon the calcareous matter distributed through the tissue of the teeth, the evolution of bubbles of gas from the interfibrous substance must necessarily obscure the chemical changes taking place in the minute dental fibres of animal tissue. I might adduce as another argument against the inference drawn from this experiment, the exceedingly minute calibre of the supposititious tubes, and the improbability of the disengaged gas making its way along them in bubbles at all.

To satisfy myself more fully on this point, I submitted portions of ivory to the action of muriatic acid, and succeeded in isolating the so-called tubes from the tissue in which they were imbedded. Now, it appeared to me that if they were indeed tubes, they would be liable to collapse when their hardening calcareous material was withdrawn. But I have never seen them in a collapsed condition, although I have searched industriously for such an appearance. Again, I have placed portions of this animal fabric of the ivory in the field of the microscope, and subjected it to pressure under a magnifying power of an eighth of an inch focal distance, but I could never succeed in flattening the fibres in the manner that would occur had they been tubes, although the pressure which I employed was sufficient to crush ivory. The only marked effect produced on them was their disintegration in the form of rows of granules. But this experiment admits of another and an important illustration, which is, that if the fibres be tubes capable of receiving injection, they must be filled with fluid when withdrawn from the acid, and at the time of being examined with the microscope, and consequently it is to be expected that the contained fluid will be seen to flow out of them when pressure is used. But this effect does not follow, which is another reason for concluding that the fibres are not hollow.

It must not be imagined that I wish to undervalue experiments of this sort, undertaken with a view of testing the structure of the teeth; so far from that being the case, I have myself conducted similar operations. Very important results may undoubtedly be obtained by testing the tissue by means of decomposition. With muriatic acid I have obtained some highly interesting results; some of which were communicated to the British Association in 1839; then I observed,—

"When teeth are submitted to the action of acid, for a period long enough to allow the earthy matter to be all taken up, I find that the animal residue consists of solid fibres, and if the decomposition be allowed to continue, these fibres present a peculiar baccated appearance.

"The appearance of the ivory when the earthy matter has been almost entirely removed by acid, but where the cells still retain their position, general appearance, and connexion with each other, is shown in fig. 8.

FIG. 8.*

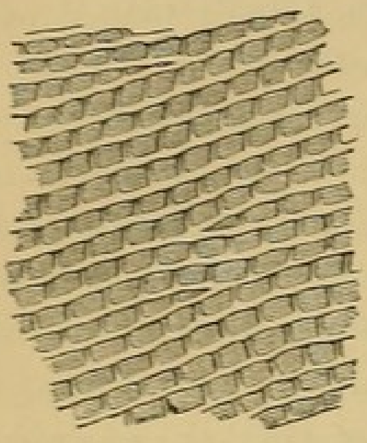


FIG. 9.

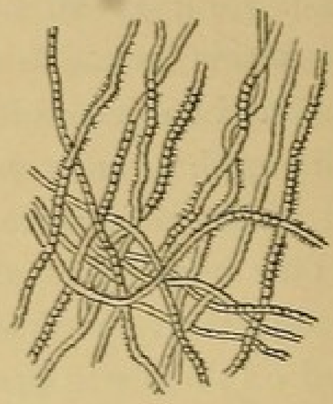


FIG. 10.

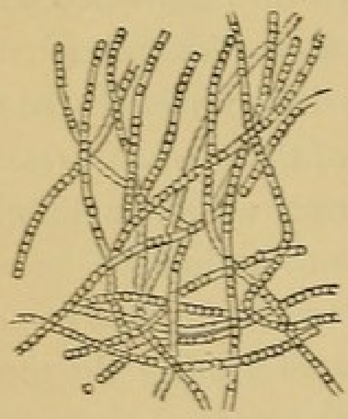
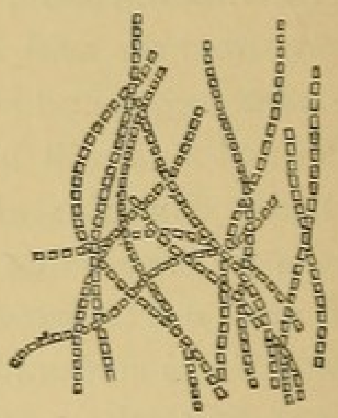


FIG. 11.



* Figs. 8, 9, 10, 11, and 17, exhibit the changes produced in human fibro-cellular ivory by immersion in muriatic acid three parts diluted with water. This series of views constitutes a kind of analytical examination of that tissue. After the immersion has continued for about six hours the ivory has the appearance of a network of cells, (fig. 8,) arranged in a linear order and bounded by parallel walls, these latter being the ivory fibres. The spaces between the parallel fibres are crossed by transverse lines, which are the boundaries of the individual cells.

After longer immersion the transverse lines or septa of the cells disappear, or traces of them only remain, as in fig. 9.

At a later period, the transverse septa disappear entirely, and the fibres

"Fig. 9 represents a more advanced stage of decomposition, where there seem to be attached to each fibre minute lateral filaments, which I presume to be the remaining portions of the emptied cells.

"Figures 10 and 11 depict the appearances presented when decomposition has so far advanced as to have rendered the fibre interrupted or baccated. Fig. 10 represents the fibre of a human tooth, and fig. 11, that of the elephant in this state.

FIG. 12.*

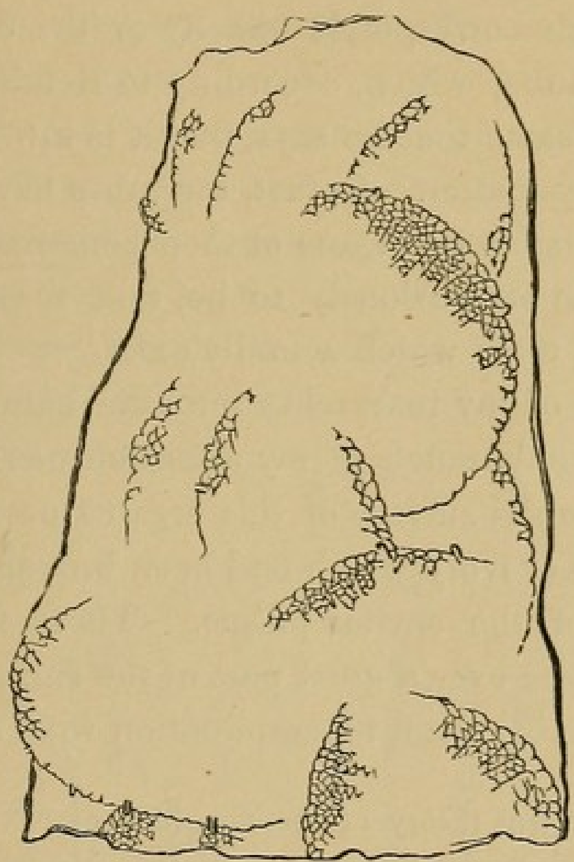


exhibit their composition of nuclei arranged in a linear series, and constituting the baccated fibre, fig. 10.

The three preceding figures represent the structure of the ivory of the human tooth; fig. 11 exhibits the baccated ivory fibre of the tooth of the elephant.

* Fig. 12 exhibits the surface of the pulp of a tooth, on which, at various points, the cells of which its structure is composed are seen. They constitute so many reticulations, having a definite arrangement, and presenting the type of organisation of the pulp.

"It may be useful to compare these cells in fig. 8, after they have been deprived of their earthy contents, with their state previous to the reception of the earthy matter as delineated in pulp, fig. 12. In the reticulations shown on the surface of this pulp, the cells are collapsed, lying one above another, but after having been deprived of earth, they will be observed to be rigid, and to retain the erect distended form which they acquired by the deposition within them of ossific matter.*

"The general appearance of the fibres thus treated is exactly similar to that of the fibres of cellular tissue generally, and the diameter of each corresponds exactly to the diameter of the calibre of the tube, which, according to Retzius, is pervious, although at the same time he says, that it is always more or less filled with earthy matter. In fact, the tubes have been said to be principally visible by means of their contents, the reason of which appears to me obviously to be, that these contents are the only part of them which actually exist."

In the course of my researches into the nature of the components of the teeth, much of my attention was bestowed upon the pulp, and on the surface of this organ I occasionally found minute portions of ivory which had been broken away from the inner surface of the cavitas pulpæ. These fragments were sometimes strewed over a great part of the surface of the pulp, and upon subjecting them to examination with the microscope,

* To indicate the true theory of the formation of ivory, nothing more is required than the display of these appearances. No "excreted" or "exuded" substance can possibly present an animal tissue arranged in regular connected cells. It is quite evident that these cells, whilst receiving a supply of earthy matter during the process of transition, must remain in connexion with, and indeed continue to form part of, the pulp. It would be absurd to suppose that a regularly cellular structure can be "excreted;" but it would be still more ludicrous to maintain, that after such cells have been excreted, that is to say, after all connexion between them and the pulp has ceased, they still possess the power or means of deriving from the blood the materials requisite for their transition into ivory, and of carrying on that process in their isolated state.

I discovered that they presented all the peculiarities of ivory with the advantage of displaying its natural cleavage undisguised by artificial preparation. Having established this point to my satisfaction, I set about contriving a mode of obtaining such fragments as these apart from the pulp, and I effected my purpose by pounding a tooth in a mortar until it was reduced to a coarse powder. I then fixed a few particles of this powder by means of Canada balsam to a glass slide, and putting them in the field of the microscope, found them to be very beautiful thin sections of the ivory, exhibiting the structure of that substance with great fidelity, and adapted to examination by the highest magnifying powers.

It was quite evident to me, from the examination of preparations made in this way, that the so-called tube was in reality a solid fibre, composed of a series of little masses succeeding each other in a linear direction, like so many beads collected on a string. (Plate VII. fig. 2, and woodcuts 13, 14, 15, 16.) I could frequently distinguish the separate portions of the fibre very distinctly, at other times not so clearly, and the diameter

FIG. 13.*

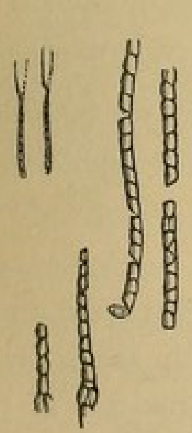


FIG. 14.

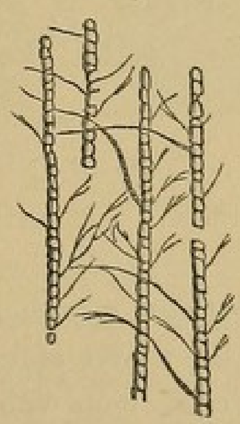


FIG. 15.

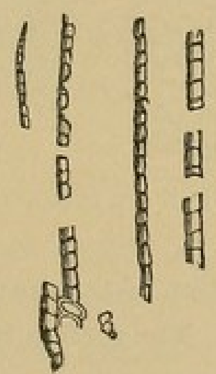
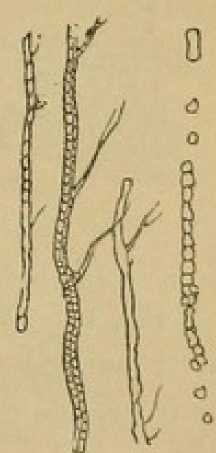


FIG. 16.



of the fibre corresponded with the admeasurement assigned by others to the so-called tube. It was quite obvious, also,

* Figs. 13, 14, 15, 16. Baccated ivory fibres :—of the ourang-outang (13) cynocephalus (14); mandril (15); and loris (16).

that the baccated appearance of the fibre was its natural character, and could not in any way be produced by the mode of preparation adopted. In the transverse sections procured according to this method the solidity of the fibre is undeniable; nothing like an aperture can be perceived; although with an imperfect focus, a dark or semi-transparent appearance of the divided fibre may be observed. Occasionally in these sections a single fibre becomes isolated near the edge of the preparation, in which case its solidity is rendered still more perceptible, and its alleged tubularity as strongly disproved.

I have thus endeavoured to prove that the fibres and the interfibrous material of ivory have a compartmental or cellular composition, (figs. 17, 18, 19,) that the former are, in fact, rows of persistent nuclei belonging to the cells of the latter, and that these elements are associated in such manner as to constitute a tissue, in which all appearance of separate parts is generally lost. This latter state is in reality a condition necessary

FIG. 17.*

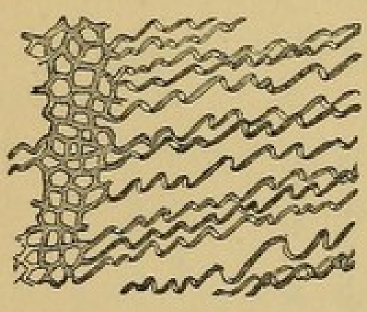


FIG. 18.†

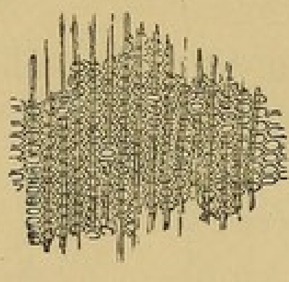
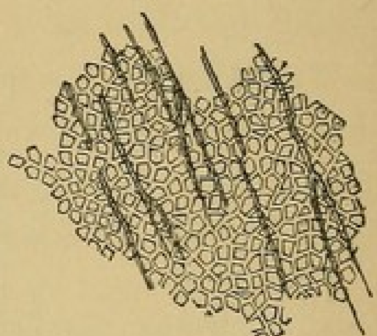


FIG. 19.‡



* Fig. 17. A portion of the recent tooth of a young subject acted on by dilute muriatic acid. The section includes a part of the pulp as well as of the ivory, and the fibres are seen to be continuous with the parietes of the cells.

† Fig. 18. A thin section of the fossil tooth of the Megalichthys. In this figure the form and arrangement of the fibres and cells are distinctly perceived.

‡ Fig. 19. Portion of the fossil tooth of the lamna. The peculiar arrangement of the fibres and cellular structure of the ivory is well seen.

to the perfection of the organ, for when any appearance of the cellular construction of a tooth is accidentally met with, there also will be frequently found a tendency to decay, and the development of decay is thus shown to hold a relation with imperfection in the formation of the tooth. In fact, this display, to which we are indebted for a demonstration of the original composition of the fibre, is evidently a partial arrest of development; the tissue being in its most perfect state when so closely aggregated that the compartments are not discernible.

Another corroboration of these views was obtained from the prosecution of some experiments suggested by the perusal of a paper by M. Dujardin, published in the third volume of the Comptes Rendus, in which the porosity of ivory was affirmed upon results deduced from the examinations of thin shavings of that substance; I had myself previously made observations on shavings of ivory, and had thrown away much time and some money in endeavouring to make slices of teeth by a single cut. I failed, however, in both my objects; my examinations of shavings were unsatisfactory, and my experiments in slicing equally so. But seeing some curious observations reported by M. Dujardin, I was induced to repeat my examinations with additional care. I then found, as M. Dujardin had reported, that ivory is porous; but I ascertained further, that its porosity was due to its cellular composition,—a circumstance of which that gentleman was not aware.

The method which I pursued in order to obtain the shavings, was to place a portion of ivory in a lathe, in the longitudinal direction of the tusk, and then by means of a sharp tool cut shavings from the surface, and others from the extremity of the piece. The former, as a matter of course, presents transverse sections, and the latter longitudinal sections of the fibres. The force employed in the process of cutting the shavings has the effect of dislocating the elements of which the tissue is composed, and displaying most distinctly the coincidence of the natural cleavage of the ivory, with the boundaries of the cells of which it is composed. The shavings from the surface offer few points of interest in this particular, merely indicating a granular structure separated by minute interstices. But in the transverse shavings not only are the lines of transverse cleavage seen to correspond with the boundaries of the cells, but the longitudinal cleavage is shown to follow the course of the fibres themselves, these latter being in every case connected on one side with a linear system of interfibrous cells.

The cleavage in a longitudinal direction takes place at regular distances, leaving betweem them narrow ribbon-like slips, corresponding with the position of the fibre. (Plate VII., figs. 3, 4, 5.) It was evidently this cleavage that suggested to the mind of M. Dujardin the idea of porosity upon which he founded his theory.

That a structure such as I have now endeavoured to describe should admit of permeation by fluids, in the direction of its fibres, and exhibit appearances of being injected, as reported by Retzius, Muller, and others, cannot be regarded as remarkable, when we reflect that the fibre is merely an aggregate of nuclear bodies arranged in a linear series, and organically attached by one side only to the calcareous matter of their cells. Moreover, the difficulty is still further dispelled when we reflect that this observation was made on teeth which had been for some time dead, and had become dried. Indeed, nothing is more easy than to produce that appearance, by steeping a tooth for a short period in any coloured solution, as, for example, an infusion of saffron.

In reviewing the formation of a tooth, and the relation which its component parts bear to each other, both in their arrangement and composition, we cannot repress a sentiment of admiration at the beauty and perfection of its structure. We see, for example, the more highly organized tissue of the ivory protected from the influence of external agents by a dense and impermeable covering, the enamel, while the ivory itself is so constructed as to present a denser conformation at the periphery than at the central part of the tooth. In the former situation the fibres are minute, and interlace with each other; in the latter they are longer, and arranged in a parallel direction. The interfibrous substance, upon which, as I have already shown, the great strength of the ivory depends, is consequently more abundant at the surface than near the centre. Again, in the construction of the latter substance, we have evidence of admirable adaptation; it is not solid throughout, but composed of small masses packed together in cells, and constituting a series of arches from the neighbourhood of the pulp to the periphery of the tooth, the little masses being accurately adjusted to each other, and having an imbricated arrangement. Indeed, the plan of arrangement of these little masses is so remarkable and characteristic in different animals, as to constitute an important element in the establishment of an odontographic index. In plate VII. will be seen the appearances exhibited by the ivory of the elephant's tusk, and also of the human tooth, from which the difference in the shape and arrangement of their component cells will be obvious; an illustrative example of the remark which I have just made.

The concentric arrangement of these cells is obviously the cause of the laminated decomposition which occurs in teeth. Again, these cells present a perfect analogy with cells in other situations, differing from tbe cells of epithelium only in the nature of their contents, and in the lateral position of the nucleus. The nuclei, moreover, are sometimes double, as occasionally occurs in epithelium.

If the tissue of the ivory were composed of a series of tubes, with necessarily shut extremities, there would be no possibility of the entrance of injection into them, either of coloured or uncoloured fluid. It is moreover quite evident that so soon as the tissue had lost its natural moisture, these tubes would become filled with air, and the air having no means of exit, fluid of any kind could not be made to enter them. Taking the view of the structure of the tissue which I have pointed out, the possibility of fluid permeating the whole mass is quite admissible from its general porous nature.

In one of my memoirs entrusted to the British Association, in 1839,* I remark, regarding the cellular structure of the ivory, which I then first pointed out, in opposition to the observations of Retzius and his followers, that, " in whatever aspect we view the formative organs of the tooth, and the dental tissues themselves, and whether we examine the latter during the process of their development, or after their formation has been completed, we are everywhere met by appearances which denote a cellular or reticular arrangement."

The cellular arrangement here pointed out is quite different from, and independent of, that feature of the structure of the teeth which Retzius denominated by the same name. This is evident from his own account of it, for says he, " The proper dental substance examined in thin polished lamellæ consists of a uniform structureless (structurlos) substance, and of fibres passing through it." Again : " The calcareous salts of the tooth exist not merely in the tubuli, but also in the intermediate substance which contains, at all events, the greater part of the calcareous earth, either chemically united with the cartilage or deposited in it in an invisible manner." Referring to the so-called tubuli of the ivory of the teeth, Retzius observes, that the tubes diminish considerably in their course, and, " as it were, disappear, or terminate in small, irregularly circular, scattered cells." In another place, he remarks, that " the minuter branches seemed to terminate in small angular cells, similar in appear-

* See Athenæum and Literary Gazette of the period ; also these Memoirs published separately.

ance to the small calcareous cells in bones," (corpuscles of Purkinje.)

It will be at once seen by these quotations that the reference made to cells by Retzius, is of a totally different nature to the cellular framework of ivory, discovered and propounded by me.

CHAPTER V.

DEVELOPEMENT OF THE FORMATIVE ORGANS OF THE TEETH.

THE developement of the teeth in their early stages is an inquiry of comparatively recent origin, M. Serres (in 1817) having been the first to devote especial attention to the subject.* Subsequently to his researches, the investigation has been continued by Arnold, Purkinje, Raschkow, and Mr. John Goodsir. In 1831, Professor Arnold announced his observation of the developement of the molar teeth in sacs formed by the mucous membrane of the mouth.† He remarks:—"In an embryo at the ninth week, we can perceive on the projecting edges of the gums in both jaws a deep furrow, with ten depressions on its floor; a little later the surface is flat, and perforated by many openings communicating with small sacs into which fine bristles may be passed. At the third month the sacs of the second molars may be seen communicating with the cavity of the mouth by small holes. The openings of the remaining sacs are soon closed by the mucous membrane of the mouth. The sacs of the permanent teeth are also formed immediately from the mucous membrane of the mouth, partly at the fourth month of fœtal existence, partly towards the end of that period, partly at birth; once only, in a newly-born child, I observed," he says, "behind the most prominent edge of the gums, several openings, which led to the sacs of the in-

* Historical Introduction, p. 29.

† Ibid. p. 124.

cisors and canines, and which are usually obliterated before birth."*

Subsequently to the publication of the researches by Arnold, Purkinje and Raschkow, in a thesis defended by the latter, put forth a doubt in reference to the developement of the dental sacs from the mucous membrane. "Very recently," writes Raschkow, "Arnold advanced an opinion on the subject of the dental follicles, widely differing from the views entertained by preceding writers. According to him, the dental follicles take their origin from the mucous membrane of the cavity of the mouth, and this membrane is reflected for that purpose into fissures in the upper and lower maxilla. He contends that in the human embryo, even at the ninth week of pregnancy, a fissure far from diminutive may be discerned in the prominent margin of the gum, having ten deeper depressions in each maxilla. At a later period, as many apertures are perceived, which lead to small sacs. These are easily permeated by a probe. Even up to the third month the continuity of the dental follicle appertaining to the second molar tooth, and the mucous membrane of the mouth, is perceptible: but the apertures of the other dental follicles are closed at an earlier period and are separated from the mucous membrane of the mouth. Arnold asserts that he has seen this both in the milk teeth and in the permanent ones; indeed, he once saw in a newly-born infant, in the most prominent margin of the gum, several apertures which led to the sacs of the incisor and canine teeth." * Purkinje and Raschkow proceed to state that they were unable to find the apertures alluded to, either in the human fœtus or in any other animal. They still maintain the opinion that "the dental follicle is distinct from the gums in its origin."†

In 1839, the investigations of Mr. John Goodsir were pub-

* Salzburgh Medicinische Zeitung, 1831, p. 236.

† Melematale circa mammalium dentium evolutionem, Jacobus Raschkow. Vratislavicæ, 1835, p. 19.

lished, in a paper entitled, "On the Origin and Developement of the Pulps and Sacs of the Human Teeth." * In this paper the subject is treated in the fullest and most comprehensive manner, and although pursued without any knowledge of the researches of Arnold, the results are strikingly in accordance with the observations of that author. The general deductions obtained by Mr. Goodsir are as follow :—

1st. The first rudiment of a tooth is a slight prominence (papilla) of the mucous membrane, which lines the floor of a groove situated in the alveolar arches. This prominence is a "tooth-germ."

2. The dental groove in which the papillæ, or tooth germs, are situated, becomes divided into small compartments surrounding each tooth germ, such compartments being the "dental follicles."

3. The "dental follicles" become closed at their apertures of communication with the mouth, and are thereby converted into "dental sacs:" the contained papilla, at the same time, obtaining the name of "pulp."

4. The developement of the tooth takes place within the dental sac.

5. The tooth is extruded through the sac on its eruption through the gum.

I shall now proceed to the elucidation of the observations I myself have made on the development of the teeth, taking in their order the four prominent stages of the process, namely, the papillary, follicular, saccular, and extrusive stage.

PAPILLARY STAGE.

If the alveolar arches be examined in an embryo measuring from one inch to one inch and a half in length, a groove lined by mucous membrane will be found on their superficial borders. Moreover, on the floor of this groove may be de-

* Edinburgh Medical and Surgical Journal, January, 1839.

tected one or two papillæ formed by a prominence of that membrane. At a later period other papillæ will be added to those first observed, until the whole number in each jaw amounts to twenty; these are the germs of the twenty milk or deciduous teeth.

It is somewhat remarkable that Purkinje and Raschkow should have failed to discover the groove and papillæ here described. They were fully aware of the extent of the observations of Arnold, and they remark, "We have examined fœtal calves and lambs, but we have never seen the mucous membrane of the mouth dip into the alveolar groove, and in the grooves are never discovered the deeper recesses which Arnold describes." This observation explains the cause of their want of success, for in similar researches conducted by myself, into the structure of the jaws of fœtal calves and lambs, a like failure resulted, and I felt inclined to admit the conclusion of the inaccuracy of the statements of Arnold and Goodsir. But prosecuting the subject further, and directing my attention to the jaws of the human embryo, I succeeded to my entire satisfaction.

Having removed the most posterior of the papillæ of the alveolar groove, together with its adjacent mucous membrane, from an embryo measuring one inch and a half in length, I subjected them to examination with a microscopic power magnifying 340 diameters. They both presented a similar structure, being composed of cells having a rounded form, and loosely aggregated together. The tissue of the papilla was somewhat denser than that of the mucous membrane, and the line of demarcation between the two was quite perceptible. On submitting them to compression under a higher magnifying power, the loosely aggregated arrangement of their globular cells was still more apparent. On the surface of the papilla the cells were collected into little clusters of six or seven; and on the mucous membrane the superficial cells were somewhat elongated. The cells were very irregular in point of size.

FOLLICULAR STAGE.

The bud-like papilla of the mucous membrane described in the preceding paragraph is the pulp of the tooth in a rudimentary state. At first, it alone occupies the dental groove, but after a time the mucous membrane around its base grows upwards in the form of a fence, and the papilla becomes isolated in a small membranous cavity, *its proper follicle.* After a time the follicle becomes deepened by the still further growth of the mucous membrane; the latter rises above the level of the papilla, and the margin of the follicle gradually contracts until it closes over the papilla, and conceals it from observation. By this change the follicle is converted into a *sac,* and the papilla becomes entitled to the designation *pulp.*

At an early period of the follicular stage, when the apex of the papilla rises above the level of the surrounding fence of mucous membrane, a small quantity of whitish matter may be detected in the groove between the papilla and the follicle,—this is the *enamel organ.* Not unfrequently the whitish matter has the appearance of granules, which seem to have been separated from the surface of the follicle. These granular masses have a pearl-white aspect, and are soft and friable. Under the microscope they are seen to be composed of cells which separate from each other on the slightest compression. The cells offer considerable variety in respect of size and shape, some being small and round, others large and flattened, and furnished at one extremity with a delicate prolongation; while others, again, are elongated and narrow, and have a defined and regular margin. They contain nuclei and nucleoli, and are covered on the interior by minute granules, which are also found in considerable abundance in their interstices.

At a subsequent period, when the embryo measures from three inches and a half to five inches in length, and the apertures of the follicles, though still remaining open, are exceedingly small; the whitish matter is increased in quantity, and forms a kind of belt around the papilla, to within a short distance of its apex. Later still the belt extends over the crown of the papilla, and completely covers it, forming, as it were, a kind of hood.

In the numerous examinations which I have made of the stages of growth of the teeth here described, the enamel organs did not appear to me to be attached either to the papilla or to the surface of the follicle. This may probably arise from the circumstance that all the embryos which I dissected had been kept for some time in diluted spirit of wine.

According to Raschkow, the hood is found in the lamb and calf, and is composed of angular granules connected together by minute threads of filamentous tissue; he therefore calls it the "grano-filamentous structure." Upon the under surface of the hood he finds a membrane formed by the conversion of the granular portion; to this membrane he assigns the name of *enamel membrane*, and to the granular layer which rests upon it, that of *enamel organ*.

In my own investigations made with the aid of one of the best microscopes of modern construction, and with a magnifying power of one-tenth of an inch focal distance, I found the enamel substance to be composed of cells of three different kinds.

The first kind of cells are found in the interior of the organ, and compose its loose, soft, and easily compressible texture. They are flattened and triangular in form, and connected to adjacent cells by means of delicate filaments prolonged from one of their angles. These appendages have no analogy with the filaments of areolo-fibrous tissue, as declared by Raschkow. I have seen them in connexion with the cells of other tissues, and the error on the part of this observer must have arisen from the use of low microscopic powers.

The second kind of cells are oval in shape, and form an envelope to the preceding. They are situated both upon the superficial and deep aspect of the latter.

The third kind of cells occupy the deep stratum of the enamel organ, lying in contact with the dental papilla. They are narrow and oblong in shape, and are arranged closely side by side, one of their extremities being in relation with the papilla, the other being directed outwards. They are firmly connected together, and have a radiated position in respect of the papilla. It is to the layer formed by these cells that Raschkow has assigned the name of enamel membrane. Taking this view of the construction of the enamel organ, I cannot perceive any grounds for the division of it into two parts suggested by the description of Raschkow. It is obviously nothing more than a single organ, and the difference in the form and arrangement of the cells must simply be regarded as a transition of the first and second kinds into those of the third. The latter being in the state of preparation for the reception of the calcareous salts.

The mucous membrane which rises in the form of a ring fence around the papilla developed from the dental groove is the future *dental capsule.* At an early period it is difficult to determine to what extent the internal surface of the growing follicle differs in structure from mucous membrane. That it does so may be inferred from the change in function which it assumes; and at a later period, when the follicle is about to close, the difference in its organic character becomes strikingly obvious. For example, it is white, silvery, loose, and rugous, and easily falls into folds, and under the microscope offers the appearance of a number of minute cells possessing characters widely different from those of the epithelium.

A portion of the internal lamina of the dental capsule placed under the microscope shows it to be composed of layers of cells loosely arranged, and separated by interspaces equal to half the diameter of the cell. These cells are oval in shape, and provided with one or more distinct nuclei, and they contain in their interior a small quantity of granular matter. The internal lamina of the dental capsule maintains but a slight degree of adhesion with the enamel organ, and possesses no vessels. Subjacent to it is a net-work of blood-vessels supported by a web of areolo-fibrous tissue formed by the interlacement of fine homogeneous filaments, among which nucleated cells are not unfrequently observed. The margin of the follicle around its contracted orifice is thin, and composed of areolo-fibrous tissue and blood-vessels; sometimes I have seen a single large blood-vessel forming a ring in this situation. Upon the surface of this margin, externally, are found epithelial cells; internally, the capsule-cells just described, and along the rim of the aperture, a fringe of fine cells.

During the early stages of growth of the dental follicle, the papilla which it surrounds offers no indication of the presence of blood-vessels; but at a later period, and before the follicle finally closes, vessels may be detected in the interior of the papilla, and admit of being injected without difficulty. These vessels are numerous and of moderate size, and after ramifying freely in the substance of the papilla, terminate on its surface in a series of minute capillary loops. The papilla still continues to be composed of nucleated cells, but at the point corresponding with the apex of the crown some modification in the arrangement and appearance of the cells may be perceived. Thus, upon the apices of the papillæ of the molar teeth may be seen a layer of tissue in which the cellular appearance is obliterated. In the papillæ of the incisor teeth, I have observed that the cells have a linear arrangement, and are placed at right angles with the surface; and in one instance I perceived a small mass of dense material, which had the resemblance of a centre of ossification.

SACCULAR STAGE.

The saccular stage commences with the closure of the constricted aperture of the neck of the follicle. By this means the open follicle is converted into a closed sac, and the papilla which it contains becomes entitled to the designation *pulp*. Coincident with these changes the space between the pulp and the sac becomes filled with a fluid secretion which distends its cavity, and often produces a conspicuous enlargement in the situation of the rudiment of a tooth.

When the sac of a molar tooth is carefully opened, two pulpy substances will be observed within it. One of these is attached to the floor of the alveolar groove, and is the pulp; the other is connected with the internal surface, and is the enamel organ. These two substances are opposed to each other in position and form, and are mutually adapted by their approximating surfaces. The pulp is reddish in hue and firm in texture; the enamel organ is whitish and pearl-like in appearance, and soft in consistence.

That portion of the internal surface of the dental capsule which corresponds with the grinding surface of the crowns of the molar teeth presents several little projections, which correspond with the depressions on that surface. These prominences have not heretofore been described, and their structure is obviously the same as that of the capsule, of which indeed they are processes.

On the part of the capsule corresponding with the sides and neck of the crown, is a flat portion of the enamel organ which is destined to the formation of the enamel in that situation. This lamina has a well-defined inferior border. At a later period in the growth of the enamel organ, the appearance which it presented of a gelatinous mass is lost, and the substance contracts into a membranous layer. At this time, also, the prominences from the internal surface of the capsule have enlarged and have become vascular, and more closely adherent to the enamel organ. Some writers have inferred from this appearance that the enamel organ itself becomes vascular;*

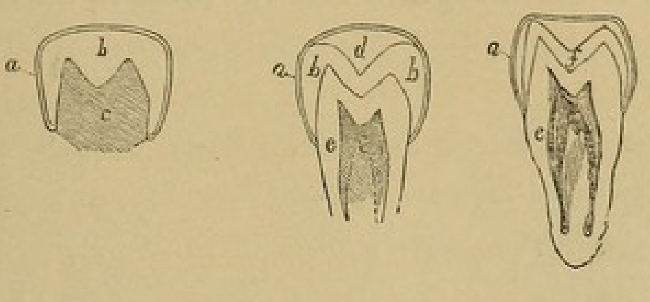
* Raschkow, in a note appended to his researches, remarks that he has

but this is not the fact, it is simply that portion of the capsule which lies in contact with the enamel organ that presents the vascularity referred to.

The dental capsule being originally, as we have seen, a production of the mucous membrane of the alveolar groove, is attached by its external surface to the neighbouring soft parts by means of loose areolo-fibrous tissue. Blood-vessels ramify very freely in this tissue, and from the interlacement which they there form numerous capillary loops are given off which extend into the superficial portion of the membrane. These vascular loops are separated from the enamel organ by a delicate layer of cells, the characters of which have been already explained.

Not the least interesting of the features attendant upon the developement of the teeth, is the relation which the capsule bears to the pulp and to the tooth at various periods of its

FIG. 20.*



observed the enamel organ to receive blood-vessels in certain parts, and believes the parenchyma of the organ to be pervaded by capillary vessels. The conclusion which he deduces from this observation is, that the enamel organ was from the beginning joined to the capsule.

* Fig. 20. A diagram showing the relation of the capsule to the crown of the tooth during the growth of the latter.

A. The capsule enclosing the pulp only.

B. The tooth a stage more advanced, a crust of ivory being formed.

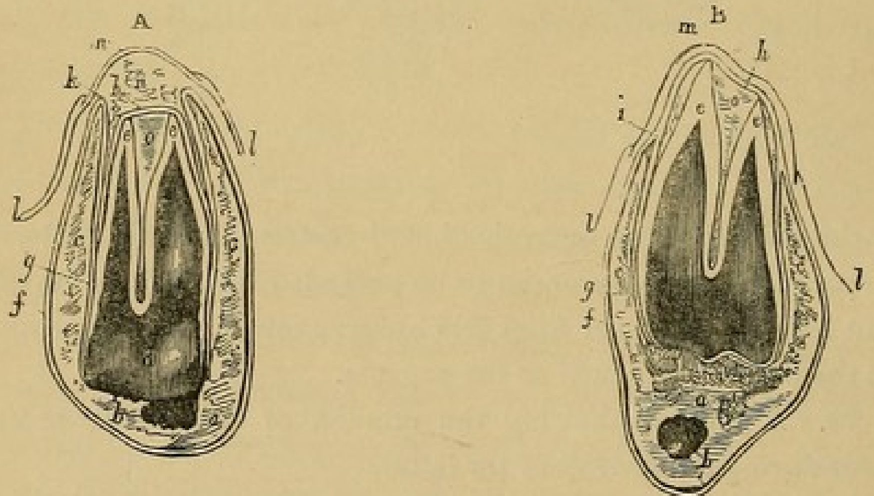
C. The formation of the tooth completed. It is now fit for eruption.

a. The capsule. *b*. The space occupied by the enamel organ. *c*. The pulp. *d*. The process of the capsule which gives form to the indented surface of the crown. *e*. The ivory. *f*. The enamel of the crown.

growth. In the follicular and early periods of the saccular stage previously to the commencement of formation of the ivory, the capsule is continuous with the base of the dental papilla* ; and at a subsequent period, when the ivory of the crown forms a complete covering to the pulp, the same arrangement takes place. But at a more advanced stage in the growth of the tooth, when its formation has proceeded beyond the limit of the crown, the capsule attaches itself closely around the neck, and the connexion between these structures is so firm, that any attempt to effect their separation generally results in the laceration of the membrane. The continued growth of the tooth carries the capsule upwards with the rising alveolus to the under part of the gum which now stretches over it ; where, pressed upon by the surface of the crown, it becomes atrophied and absorbed. No portion of the capsule seems to pass down into the alveolus.

The periosteum of the alveolus is the next of the structures in relation with the teeth that calls for our examination. This membrane along the margin of the alveolus is closely connected

FIG. 21.†



* It passes upwards over it, forming a distinct envelope, separated from the layer of mucous membrane externally.

† Fig. 21. Sections of the growing tooth of the fœtal calf, showing the relations of the young tooth and jaw, and of their membranes.

A. The tooth still buried within the jaw.

with the mucous membrane of the mouth, and in this situation passes into the cavity of the alveolus and lines its surface. It is closely adherent to the osseous wall of the alveolus, and is furnished with blood-vessels, which pass into the substance of the bone. Internally, it is connected with the external surface of the dental capsule by means of loose areolo-fibrous tissue. As growth proceeds, and the dental capsule gradually becomes thin, it unites with the periosteum, and the two membranes are inseparably blended together, forming only a single layer. The coalescence of these membranes and the thinning of their structure, which at the same time ensues, is associated with the production of the cortical substance of the tooth.

The internal alveolar periosteum at the early periods of life is composed of areolo-fibrous tissue, supporting in its web a number of minute blood-vessels and numerous corpuscles or cells of various size and form.

Raschkow has described air-cells entering also into its composition, but this appears to me to be erroneous; and the source

B. The tooth further advanced in growth, its summit rising above the level of the alveolar process.

a. The body of the jaw. *b.* The canal for the transmission of the dental vessels and nerve. *c c.* The walls of the alveolar process. *d.* The pulp of the tooth. *e e.* The ivory and enamel forming the crust of the young tooth. *f.* The external periosteum. *g.* The internal periosteum, or periosteum of the alveolus, blended with the capsule of the tooth, and constituting the "capsulo-periosteal" membrane. *h.* That portion of the capsule which covers the crown of the tooth. *i.* In figure B. the capsule is seen to be continuous with the periosteum both of the exterior of the jaw and alveolus along the margin of the wall of the latter. *k.* In figure A. the external periosteum is continuous with the internal periosteum along the edge of the wall of the alveolus, and may be said to be continued from the exterior into the interior. *l l.* The mucous membrane of the alveolar portion of the gum. *m.* The mucous membrane forming the crest of the jaw through which the tooth extrudes. *n.* The submucous areolo-fibrous tissue of the crest of the jaw. *o.* The process derived from the internal surface of the capsule which gives form to the summit of the crown of the tooth.

of the error I conceive to be the air-bubbles diffused through the tissue during the forcible separation of the tooth from its alveolus. As the tooth advances towards complete developement the alveolar periosteum ceases to exist as a separate membrane, and is then, as before described, blended with the dental capsule. This compound membrane lining the alveolus performs the office of nutrient membrane to the two structures (the bone of the alveolus on one side, and the cortical substance on the other) between which it lies, and for this reason, as well as from the nature of its composition, appears to me to be entitled to the name of *capsulo-periosteal membrane.*

ERUPTIVE OR EXTRUSIVE STAGE.

The progressive growth of the tooth brings its capsule and crown into relation with the under surface of the gum, and causes a certain amount of pressure upon that structure. This pressure is attended with absorption both of the gum and of the coronal portion of the capsule, and the crown of the tooth then emerges from its concealment. The further elevation of the tooth to its proper level is the result of a continuance of the process of growth taking place in the root.

The eruption of the milk-teeth, according to Serres, takes place in the following order:

Central incisors . .	6th to 8th month.
Lateral incisors . .	7th to 10th month.
First molar . . .	12th to 14th month.
Canines	15th to 20th month.
Second molar . . .	20th to 30th month.

As a general rule, the teeth of the lower jaw precede those of the upper. The lateral incisors, however, form an exception to this principle, for those of the upper jaw make their appearance in the majority of cases before the lower.

When the eruption of the teeth is accomplished, the capsule is to be found in a state of atrophy on the enamel or cortical substance of the extracted tooth, in the development of either of which it may have been employed. On the enamel of the human tooth, the carnivora, and others, it is extremely attenuated, but yet easily demonstrable by means of immersing the tooth in diluted muriatic acid. The existence of this terminal membrane I pointed out in a paper read to the Medical and Chirurgical Society, on the 22nd of January, 1839, and published in the 22nd volume of their Transactions. In that paper I observe:—

"The term, cutting of a tooth, has hitherto been employed to designate its protrusion through the capsule and the superimposed integuments. Respecting this process Cuvier thus expresses himself:—'Elle (la capsule) est percée à son sommet par l'evolution de la dent, mais ses bords s'attachent aux gencives, et en deviennent en quelque sorte la continuation." * This description of Cuvier has been, I believe, universally adopted; but my researches have led me to the conviction that it is erroneous, and that it is by a process of absorption, and not of disruption, that the tooth is emancipated.

"The want of uniformity in the structure of the teeth, as described by anatomists generally, has long appeared to me to be inconsistent with the simplicity of the laws of nature. In the works of most authors on this subject we find it stated that, in the teeth of man, of the quadrumana, the carnivora, and indeed in simple teeth of all kinds, the enamel is protruded, and continues without any external covering whatever; whilst, in several other cases, there is described as existing on the same substance a dense coating of what is termed crusta petrosa. It struck me as remarkable that a texture so constituted as the enamel should be in many cases exposed, divested of any tenacious covering, to the concussion of hard bodies, whilst in others it was provided with a dense, protecting investment; and the unaccountable nature of this diversity stimulated me to inquire into the subject.

* Des Dents des Mammifères, p. xxiv.

"Some years ago, I observed detached portions of membrane floating on the surface of the solution in which human teeth had been submitted to the action of acid. These were so delicate, and were separated with such facility, that it was some time before I could satisfy myself as to the part of the tooth to which they had appertained. After a minute and careful examination, however, I was able to demonstrate with the greatest certainty, that they were derived from the external surface of the enamel, and that they were continuous with the structure covering the fang, which latter is itself continued into the chamber of the tooth. I afterwards succeeded in tracing this covering on the whole surface of the enamel and fang of the tooth in one continuous envelope; and eventually I was enabled to remove it from the crown of the tooth in the form of a distinct coat or capsule. This covering, which I proved to exist externally to the enamel, I have termed 'the persistent dental capsule.'

"The method of demonstrating the existence of this capsule is very simple. It is of course most likely to be found in a perfect state on the crowns of teeth which have been recently extruded; but on almost every tooth a remnant may be found which has not been destroyed by attrition. The teeth require merely to be macerated in muriatic acid, diluted to one-eighth of its ordinary strength, and, in the course of a few minutes generally, it will be found to be loosened from the surface; and, as soon as it is once partially separated, it may easily be altogether detached. In all cases where this covering has been removed by means of acid, it has, of course, the appearance of a simple membrane, in consequence of the earthy deposits having been dissolved, and of there being only present the animal tissue. The structure and appearance of the covering, detached in this manner from the enamel, are the same in every respect as those observed in the capsule of the unextruded tooth; consisting, like it, of two layers, fibrous externally, and having on its internal surface the peculiar reticulated appearance common to both. (Plate 5, fig. 6.)

"On first conducting these experiments I considered that the covering thus detached must necessarily be either a production of the capsule, or the entire capsule itself, or a part of it in a state of atrophy, ossified, and adhering to the enamel by means of the ossific matter deposited in it, or interposed between it and the enamel.

"On examining carefully fine sections of several teeth under the microscope, I perceived here also that the structure in question was continuous with the crusta petrosa on the fang of the tooth. In the incisor of the ox, and in some other simple teeth, the characteristic ossific corpuscles of the crusta petrosa, as pointed out by Purkinje, are occasionally evident. (Plate 5, figs. 4, 5, *a*, *a*.)

"Müller, in his Physiology, states that the crusta petrosa is a secretion from the saliva. His words are, 'This new substance is the cement or crusta petrosa. It seems to be merely a deposit from the salts of the saliva, and to be essentially the same as what is called tartar on the human teeth.' * To prove the fallacy of this opinion, I have shown in Plate 5, fig. 1, the microscopic appearance of the crusta petrosa of the elephant's grinder, where its organic nature, and the analogy in structure to bone is quite evident from the existence of the characteristic corpuscles of Purkinje, and the numerous ramifying canals in a state of ossification, and having a definite direction. I believe Müller is the only exception, however, to its being acknowledged on all hands that the crusta petrosa emanates in some way from the capsule. According to some authorities it is a direct product of the latter; whilst others state that the capsule is converted into the crusta petrosa, which, in this case, would be neither more nor less than the capsule in an ossified state. According to my investigations, therefore, the enamel of human and of all other teeth, simple as well as compound, is covered by a distinct capsular investment. This capsule in

* This quotation occurs in the first edition of the work referred to. It is corrected in the second by the translator, Dr. Baly.

the compound teeth of some animals, as, for instance, those of the ruminantia, &c., has been long noticed under the name of cementum or crusta petrosa. The cementum always contains corpuscles or cells, the peculiar character of which is shown in several of the plates. These corpuscles exist in the persistent enamel-capsule of the incisor of the ox, and some others; but I have not hitherto been able to discover them in that of the human subject, and therefore, in the present stage of the investigation, I think we are only entitled to designate it capsular, and not range it under the general head of crusta petrosa: although it is directly continuous with it, and in all other respects analogous. However, whether it is to be included under the collective appellation of crusta petrosa or not, we have in it a very interesting example of the uniformity of the laws of nature, inasmuch as it would then be general throughout the animal kingdom.

" In pursuing this branch of the inquiry, I detected in the composition of the teeth another structure which I believe has never yet been noticed, and of which, if I mistake not, the consideration will be found to be of no little importance and interest. I allude to a layer of substance distinct in its appearance, situated externally to the crusta petrosa, where that is considerable. Its existence in the elk, ox, bradypus, dasypus, kangaroo, hippopotamus, elephant, &c., is shown by specimens in my possession. The appearance of it on the tooth of the Bradypus tridactylus is seen at *d,* Plate 5, fig. 3. It varies in colour from pale yellow to dark brown, and is of a laminated structure. Its thickness is very various, and seems to have a certain ratio to the thickness of the crusta petrosa. It may be possible that this investment is the cartilage of the crusta petrosa, but the darkness of the material has hitherto prevented me from observing any other peculiarity in its structure than that of the laminated appearance. The persistence of such attenuated textures as we see developed on the incisors of man and most other animals, as well as this ultimate investment of the crusta petrosa which I have just alluded to, must generally be of short duration on that part of the tooth which is subjected to attrition: and, as all will acknowledge also who have attempted to make microscopic sections of teeth, there is the greatest difficulty in preserving in their integrity the peripheral tissues of these organs; and the accidental fracture and destruction of the substances of which I have just treated is, doubtless, the cause of their existence having escaped the extensive and vigilant researches of Retzius, Purkinje, Fraenkel, and others. Hence, too, I should not be justified in asserting that the latter of the two structures which I have pointed out exists only in the animals above enumerated: for, as we arrive at still greater perfection in making sections of teeth, we shall probably find that it exists in many other cases where we have not yet been able to demonstrate it. It would be interesting to inquire into the relation which this tissue bears to the capsule, but I should not at present be warranted in pronouncing an opinion on this point, as my own investigations with regard to it are at present incomplete.

"The appearance and structure of the ultimate peripheral investments of the teeth of all animals are very interesting, and present diversities in the respective groups which extend even to characteristic peculiarities. A consideration of these, however, would necessarily be far too extensive a subject to enter upon at present.

"The views and observations which I here communicate have not, I believe, been any of them anticipated; but there is a remark made by Fraenkel in his inaugural dissertation, published in 1835, which, in justice to that acute observer, ought to be recorded here as the only approach to anticipation which I have been able to discover. The passage I allude to is at sect. ix., and is as follows:—speaking of the cortical substance, he says, 'In the incisor of an old man we found the whole root surrounded with this substance, which at the extremity was very thick, and as it ascended thence, became thin by degrees, and extended onwards to that place, where the adamantine substance began; moreover, on one side, ascending higher up, it coated a small portion of the adamantine substance itself, and like a single layer could easily be removed.'

"I now proceed to the second section of my subject, viz., the consideration of that part of the capsule and capsular investment which is extended over the fang. The persistence of this portion of the capsule itself is manifested throughout the whole of the life of the tooth, from the circumstance that the crusta petrosa is produced during all periods of the existence of its vitality. There the capsular investment is generally limited to a thin crust, even in those animals where the crown is densely coated with cementum, so that in many cases an abrupt line marks the point where the enamel joins the fang. In the human tooth, however, the osseo-membranous covering is much thicker round the fang than round the enamel, and the portion which invests the former increazes in size, in a ratio somewhat in proportion to the age of the individual.

"The functions of the capsular membrane are of great importance at the period when the temporary teeth are removed to make room for the permanent series, inasmuch as it is the agent by which this removal is effected.

"Where the temporary tooth has continued in a healthy state, and in vigorous vitality, its absorption proceeds with perfect regularity, and without causing any inconvenience, provided the new tooth is so situated as to exercise in its progress a regular pressure on the root of its predecessor. This pressure would seem to be necessary to the process of absorption, for we almost constantly find that the milk-teeth persist, where from irregularity in the arrangement or growth of their permanent successors, it is not directly applied. In such cases, should the temporary tooth continue healthy, there seems to be no limit to its persistence; and I have seen instances in which it has remained in the perfect exercise of its functions till a very late period of life; the permanent tooth being then either altogether deficient, or remaining encased in the jaw: or forcing its way up laterally in the same row, as is shown in a model in my possession, where the under centre-incisor is seen retaining its position, and producing the apparent anomaly of the existence of five incisors in the human jaw.

"Where the tooth is diseased, the capsule investing the fang is also affected, and is disabled from performing the function of absorption. In this case, the fangs of the temporary tooth only partially disappear, and generally maintain their position, notwithstanding the pressure which the growing tooth exerts upon them. Sometimes they remain so firmly wedged between their permanent successors, that it becomes a difficult matter to disengage them. The portion of the capsular membrane under consideration, seems to be the only agent capable of effecting the process of absorption; and we may have ocular demonstration of its performing this, by withdrawing carefully a deciduous tooth when it is near falling off. The fangs will then be found to have almost disappeared, and only a small portion of the membrane to remain; the latter is observed on the spot from which the tooth has been removed; it is in connexion with the pulp, and the whole is highly vascular, and retains an exact impression of the surface of the tooth which was opposed to it. As absorption can only be carried on by the surface in immediate contact with the part absorbed, it follows that this membrane must be so organized as to be able to effect that process. The fangs of the permanent teeth are subject to a similar action, being often absorbed, but in a very imperfect manner.

"The normal exercise of the function of absorption by the capsular membrane may with facility be observed on the fangs of the temporary teeth of the lower animals; and also, to cite a curious instance, in the gradual loosening and separation of the anterior molars of the elephant, which are removed by its means. I have in my possession a tooth of the cachelot whale, furnishing an example of abnormal absorption. I have dwelt thus long on this process, because Retzius, and some of his followers, deny that it ever takes place, either normally or abnormally. The former thus expresses himself on the subject: 'The crown of the advancing tooth appears to have pressed itself into the extremity of the deciduous one. I have carefully examined how this appearance is produced, and have come to the decided conclusion, that neither tabescence, absorption, or erosion takes place.' This opinion having been circulated and sanctioned by Müller and others, who advocate the tubular system of the teeth, I have thought it necessary to communicate the above details, which I think completely refute it. I am at issue, also, on this point with Cuvier and Rousseau, the latter of whom thus expresses himself on the removal of the milk-teeth: 'Elles (les dents de la seconde dentition,) exercent sur ces alveoles une pression si forte qu'elles privent les dents de lait, en comprinant les nerfs et les vaisseaux qui s'y rendent, de la faculté de recevoir les fluides qui jusque-lá les avaient vivifiés.' (Rousseau, p. 71.)

"Where the milk-tooth is withdrawn, as above described, before the process of absorption is completed, the membrane remains behind; but the contrary takes place when it has invested the fang with a peculiar bony structure; in this case, it is generally found adhering to the adventitious matter, with which it comes away. This leads me to notice a formation which throws great light on the analogy between the functions of the different portions of the capsular membrane. I allude to the increment on the fang which is generally termed an exostosis, and which assumes all kinds of shapes, as may be seen in Plate 6, figs 1, 3, 6, *a*, *a*. The general texture of its internal structure, however, is uniform, as may be seen by the appearances shown in the longitudinal and transverse sections given in the above figures, and resembles true bone, though it has characteristic peculiarities, as may be seen from the highly magnified portion shown in fig. 5. The appellation, exostosis, as applied to a product of the ivory of the tooth, always seemed to me to imply a higher order of vitality in that substance than it actually possesses.

"The morbid action producing this enlarged growth of cementum, or peculiar enlargement, generally called exostosis, may have a variety of causes, but it is generally induced by exposure to the atmosphere, or by the presence of some foreign body in contact with the internal membrane, when it has been denuded of its natural covering by ordinary decay. In this latter case, there is generally great pain referred to the tooth itself; but the jaw and surrounding parts often suffer to such an extent, that cerebral congestion, rheumatism, ear-ache, tic-douloureux, &c., are often supposed to exist, and the patient is submitted to the routine-treatment for these affections, without, of course, any permanent alleviation. Individuals of a sanguine, scrofulous diathesis, seem to be peculiarly liable to this form of disease, and females, I think, are more so than men.

"Teeth which have lost their antagonists, frequently protrude from their sockets, and then the capsular membrane of the fang often throws out a considerable earthy growth, which, though it produces but little local pain, is attended with morbid symptoms, manifesting themselves in other parts. A similar growth often takes place when the teeth of adults have been forced out of their natural position, by oblique pressure from an antagonist tooth. I have known several instances where all the teeth, as far as I could ascertain, were thus affected. This growth occasionally renders them very difficult of extraction, for by enlarging the fangs, it of course causes them to be wedged more tightly in the socket. I am not acquainted with any mode of arresting this malady, and have never known an instance where any other treatment except extirpation has been of the slightest avail. The existence of these bony growths may sometimes be detected, though never very easily, by a slight alteration in the colour of the tooth, and by its yielding a little more than natural in one direction, when steadily and forcibly pressed; in some cases the enlargement takes place in one fang more particularly, and then the tooth protrudes from the socket in an oblique direction.

"On the necks of teeth notches are frequently seen, into which the nail or the point of a small instrument may be inserted, but not without causing a very acute sensation, derived, as it appears to me, from the vessels of the capsule covering the fang. Whether the absorption of the alveolar process, following the exhibition of mercury and other mineral medicines, be the work of the membrane under consideration, I have not been able to determine.

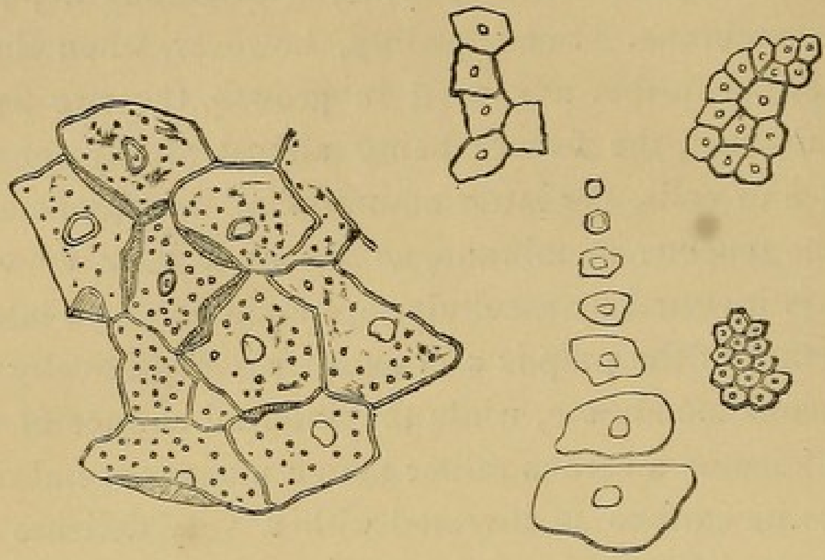
"The absorption of the fang, and the deposition of osseous matter on its surface, are comparatively slow processes, from the gradual operation of their causes, but in cases of what is called alveolar abscess, disease is much more rapid, and its effects violent and sudden; here the fang is found dead and denuded of its membrane, which in a thickened state, at some distance from its surface, forms part of the suppurating sac.

"When disease has once invaded this membrane to any extent, we may palliate it by other remedies, but the only effectual cure is extirpation of the tooth, the true exciting cause. Where the teeth of the patient have suffered either from neglect or bad treatment, and present various stages of decay, the bone surrounding them is affected; a quantity of decomposed serous matter is constantly being swallowed; the breath becomes horribly fœtid, and in an emaciated countenance, an enfeebled frame, and an irritable habit, we mark the effects of suffering the mouth to be converted into a charnel house of diseased bone. The maladies which I have hitherto glanced at, may truly be considered as benign, when compared with others which must be regarded as their sequelæ, but which do not fall within the scope of the present paper."

The MUCOUS MEMBRANE has been frequently adverted to in the description of the changes which take place during the developement and growth of the teeth. This membrane indeed performs an important part in that process, and undergoes some remarkable modifications; for example, the first trace of the future tooth, the dental papilla, is originally a part of the mucous membrane. Subsequently, however, when the papilla has somewhat further advanced in growth, the two tissues are entirely distinct, the former being almost wholly composed of corpuscles or cells, the latter maintaining its fibrous character. Again, the mucous membrane, as far as I have been able to observe, is invested by a cellular epithelium. At a later period the structure of the pulp is still more characteristically different from mucous membrane, while the internal surface of the capsule has become a serous rather than a mucous membrane. At this stage its surface is invested with a very delicate layer of cells, totally different from those of epithelium. This change is coincident with a greater degree of vascularity of the internal layer of the capsule, and a greater laxity of the extra-capsular cellular tissue. I have before remarked that the non-vascular layer of the capsule of certain authors is in reality the enamel organ, a structure consequently wholly distinct from that membrane. The external layer of the follicular fold maintains its mucous structure as a permanent character, and eventually becomes the investment of the alveolar arches, the gum. The gum at this stage is remarkable for its hardness and density of structure, and on this account has been regarded by some anatomists, although very inaccurately, as of a cartilaginous nature. Around the necks of the teeth the gum is highly vascular, and is furnished with large villous prolongations; (Plate 3, figs. 1, 2;) it is continuous by its deep border with the external and internal periosteum, and is covered externally by a thick and firm layer of epithelium.

The EPITHELIUM, or terminal investment of the mucous membrane, (figs. 22 and 23,) is a tissue of much interest, and one which deserves a special description. In my researches into the component structures of the jaws my attention was early directed to this layer, and in order to establish its proper relation to the protective coverings of other surfaces of the

FIG. 22.*

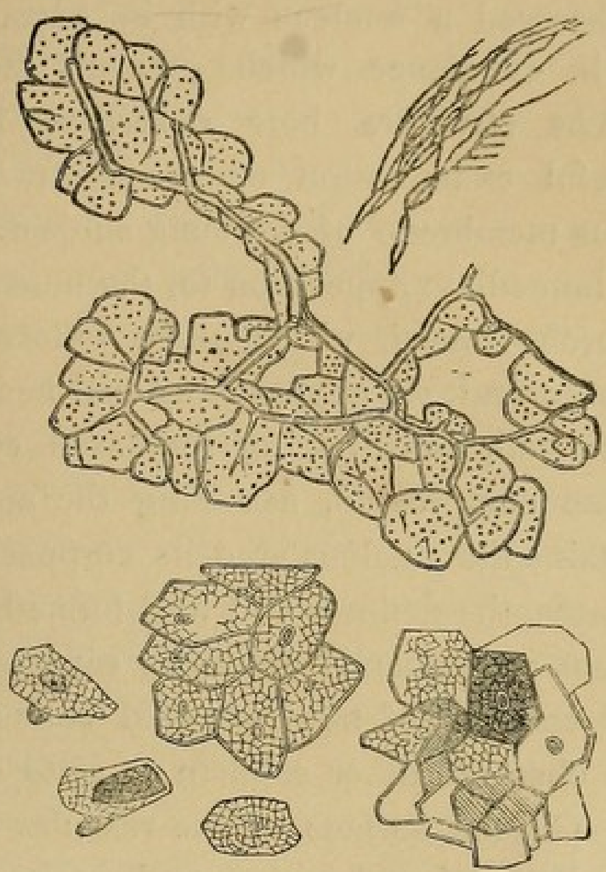


body, I was induced to examine it on the various mucous membranes, and also on the skin. In my third memoir, communicated to the British Association in 1839, I observe :—

" The epithelium is a layer of substance destitute of vessels, which covers the vascular surface of mucous membranes. Though destitute of vessels, it cannot, however, be considered as inorganic, as I shall presently show. If the surface of a mucous membrane (for instance, the conjunctival, or the buccal) of a living animal be slightly rubbed, it will be found, on microscopic examination, that numerous small particles have been detached from it. At the first glance they present precisely the appearance of scales, for they are flat bodies with a thick portion, or nucleus, in their centre, and with very thin and transparent margins. It was Leeuwenhoek who first gave to these bodies the name of scales. They are found not unfre-

* Fig. 2. Scales of epithelium, highly magnified. On the left of the figure a number of scales are seen grouped together in the manner in which they are found when first separated from the mucous membrane. A nucleus and a number of granules are seen in most of the scales. On the right are several groups of cells in progress of developement; and below, is a series of cells, showing the progressive stages of developement from the state of granule to that of the complete scale.

FIG. 23.*



quently with a curved margin, and without a central spot or nucleus, and their surface often presents numerous transparent points, with very fine lines. The nucleus of the scale generally contains a small body, which has been termed the nucleus-corpuscle. But, by this simple method of observation, we do not obtain an insight into their true structure. If we remove the secretion from the surface of an irritated mucous membrane, we shall find another class of bodies, which differ from these first mentioned, in being smaller and more globular. They have a nucleus of the same size as that of the so-called scales,

* Fig. 23. Epithelial scales, with the connecting bands of gelatinous substance usually found when examined with the microscope. In the upper part of the figure, the mucus is shown with the fibrous character which it sometimes assumes. In the lower part of the figure groups of cells are seen in which their cellular internal structure is exhibited.

and also a nucleus-corpuscle; but the surrounding structure is in the form of a cell, and is much smaller. Here and there may also be observed a nucleus with its accompanying corpuscle, lying in substance which presents no appearance of a cell. The structure here described may also be seen on a careful examination of a section of the epithelium and mucous membrane of a young subject. On the surface of, and in immediate apposition to, the mucous membrane, are seen numerous nuclei, which, more externally, are surrounded by a cell; and, on approaching still nearer to the surface, we find this cell, from having increased considerably in size and become compressed, assuming the appearance of a scale, which retains the nucleus and its corpuscle of primitive size. In the fœtus, the defined and well-formed scales of the epidermis are not unfrequently distinctly seen externally; the *rete malpighii* consists of newly-formed cells; and between the two may be observed other cells in a state of progressive developement. On the surface of the vascular mucous membrane, minute cells are found with a nucleus in their interior, round which the cells grow; and this, in short, is the process of developement of the minute bodies which constitute the epithelium. An interesting subject of investigation, and one which, I believe, has not been entered upon by those who have hitherto treated of this department of anatomical science, is the manner in which the component parts of the epithelium are connected. The cells on the surface of the mucous membrane are separated from each other by considerable spaces, which are occupied by a gelatinous substance, interspersed with minute granular bodies. But the scales forming superficial layers of the epithelium are separated by very minute linear spaces; but are still connected together by a translucent, gelatinous substance. This latter displays considerable elasticity, as is rendered evident by an attempt to lacerate the epithelium in a moist state, if the latter be examined at the same time by the aid of a magnifying power. Each time that the laceration is attempted, the membrane yields, and the scales separate to a certain extent, but regain their original position on the cessation of the effort to draw them apart. In some instances a fibrous structure is evident in the gelatinous substance between the scales. The scales towards the free surface are distinctly observed to overlap. The gelatinous substance, above alluded to, presents distinct granular bodies, which give to the epithelium, *en masse*, a rather dense aspect, the individual scales being sometimes covered by these granules; the latter can, however, be separated from the scales by compression: by which means, indeed, the granules themselves may be made entirely to disappear. In certain parts of the epithelium of the calf, distinct fibres are observed, which pass over the surface of the scales and connect them together, thus forming a very delicate net-work. This appearance is most evident upon compression of the thick epithelium on the anterior part of the alveolar arch of the upper jaw. In these cases where the small scales, or small clusters of scales, are being continually thrown off, as on the surface of the body and of the mucous membranes of man and animals generally, the scales composing the external layer will be found to overlap each other, and thus the gradual pressure of scales below, which are increasing in size, is the cause of the throwing off of these cuticular lamellæ. After these have been detached, their place is occupied by newly-formed scales. But there is another form in which the external layer of cuticle is removed, viz. in a continuous layer. The cuticle of the frog is composed of minute scales, the borders of which do not overlap, but are held in direct apposition, so as to form one lamina, which has a beautiful continuous tessellated appearance. This layer, covering the whole body, is thrown off entire by frogs and efts. I am disposed to believe that it is this covering which, according to naturalists, is swallowed by the animal after having been thrown off. As soon as this layer is removed, another lamina of scales is seen on the surface of the animal's skin. If, after the death of a frog, it be immersed in water, this thin, external, translucent layer, generally separates; but, upon prolonging the maceration, another lamina is found to be gradually separating from the cutis, which is dense, and sometimes measures a quarter of a line in thickness. Internally it will be found to be composed of very numerous cells, while externally the regular series of scales is evident. The tessellated lamina, alluded to above, evidently takes its origin from this layer of cuticle. An examination of specimens, and a consideration of the facts which I have related, cannot, I think, lead to any other conclusion, than that the cuticle and epithelium are organised tissues. It would appear that they are formed from a fluid secretion on the surface of the vascular corium; the various stages of developement being, 1st, the formation of nuclei and corpuscles; 2nd, that of cells; 3rd, the growth of the latter, effected by vital imbibition; 4th, their compression and gradual conversion into minute lamellæ, or scales. In short, it appears a rational conclusion, that the component parts of the cuticle and epithelium have within themselves a power of growth; and it remains for pathologists to determine what share the derangement of this function has in the production of cutaneous diseases. Another argument in favour of the organic nature of the epithelium is derived from the circumstance that, under certain modifications, it presents various vital phenomena, among which may be mentioned ciliary motion.

"I now proceed to describe my researches. *On the structure and developement of that portion of the epithelium which lines the cavity of the mouth.* In the fœtal subject, previous to the extrusion of the teeth, it forms on the alveolar arch a dense projecting layer, distinguishable from the surrounding membrane by its whiteness, and by the existence on its surface of ridges and sulci, having a waving course and a variable direction. The alveolar epithelium is thicker in proportion to the youth of the subject examined. It is most prominent where it corresponds with the molar teeth; its internal surface is concave, receiving the projecting mucous membrane. This disposition presents various objects for investigation. Firstly, as regards its composition :—It is made up of a mass of scales, lying one on the surface of the other. This disposition shows that the terms ‘ dental cartilage,’ or the ‘ cartilage of the gum,’ which have hitherto been applied to the structure, give an erroneous idea of its true nature, for cartilage always presents the corpuscles discovered and described by Purkinje. As in other portions of the epithelium, the external scales here are the larger, and this holds good generally, until we come to the surface of the vascular mucous membrane, which presents simple cells with their corpuscles. In the interior of this alveolar epithelium, where it corresponds to the molar teeth, small vesicles may be frequently observed, varying in size from one-fourth to one-eighth of a line in diameter. They appear to the naked eye to be transparent; under the microscope their parietes are found to consist of attenuated scales, and their cavity to contain a fluid abounding in minute granules and cells.* The internal surface of the epithelium, covering the alveolar arch, frequently presents concavities or indentations, which are from a line and a half to three or four lines in circumference; they correspond to projections from the mucous membrane, formed by a larger species of vesicle. The latter is deeply implanted in the vascular mucous membrane. The parietes of the vesicles are composed of a very delicate membrane; they contain a transparent fluid, which coagulates on the application of heat, or acid, or on immersion in spirit; and in this fluid float numerous globules and scales, similar to those of the epithelium generally. The *internal* surface of the alveolar epithelium also presents numerous fringed processes, measuring

* The vesicles here alluded to are most probably those which Serres describes as glands for the secretion of tartar: they are very numerous, even after the extrusion of the incisor teeth of the calf, and are seen with great facility internally.

from one line to one line and a half in length, and half a line in breadth, which sink into the substance of the subjacent mucous membrane. Under the microscope these fringes are found to be composed of elongated scales connected together and forming masses, which divide and subdivide until they attain such an extreme tenuity that the most minute terminations consist but of two scales in marginal apposition. If the epithelium be carefully separated from the surface of the mucous membrane, corresponding to the unextruded molar teeth, and placed in water, or in diluted spirit of wine, for some little time, its internal or attached surface presents these fringes much enlarged, and forming a mass more considerable in size than the dense epithelium itself. The epithelium covering the mucous membrane of the palate presents transverse rugæ, corresponding to those of the mucous membrane. If these palatal rugæ of the epithelium of the calf be carefully examined from the internal surface, with a magnifying power of one-inch focal distance, each will be found to consist, or to be composed of, numerous depressions, or *cul de sacs*, which receive prolongations or pointed processes of the subjacent mucous membrane. They are of extreme tenuity, and when viewed by the aid of high magnifying powers, are observed to consist of distinct scales."

Although it contains no blood-vessels, the epithelium receives its nutrition from the blood circulating in the capillary vessels of the mucous membrane, and it follows from this circumstance that if from any cause the blood should become morbidly altered in its qualities the epithelium will suffer accordingly. Many of the appearances which the surface of the tongue presents under the influence of disease, and which offer to the medical practitioner so valuable a guide to diagnosis, are in reality nothing more than alterations in the epithelium, resulting from vascular changes in the papillæ of that organ. In like manner the dental practitioner becomes familiar with morbid states of the epithelium of the mucous membrane of the alveolar arches and gums.

CHAPTER VI.

GENERAL AND MINUTE ANATOMY OF THE DENTAL CAPSULE AND PULP.

THE vascular constituents of a tooth are its capsule and pulp. The structure of the capsule in its developmental stages has been described in the preceding chapter ; in the present, therefore, it remains only to examine that membrane in its perfect condition. When the dental capsule has attained its complete growth, it is found to have entering into its composition a very beautiful and intricate plexus of capillary vessels. Upon the inner surface of this richly vascular layer are a number of cells arranged in a similar manner to those which I have described as being situated on the surface of the pulp, and equally distinct in their figure ; a circumstance which indicates an analogy in mode of formation between the tissues in question. In one of my Memoirs, read at the meeting of the British Association in 1839, I remark :—

" Conceiving that there existed a great analogy in the productions of the capsule and the pulp, I searched for the appearances displayed by the internal or productive layer of that membrane, and found them analogous to the external or productive layer of the pulp.

" But this analogy is not confined to the enamel and ivory, for the membranous investment which I lately discovered as investing the enamel of the teeth of man and other simple teeth, displays a similar arrangement."

Externally to the vascular plexus the capsule is fibrous and dense, insomuch so that an analogy has been thought to subsist between it and the periosteal covering of bones. I have examined periosteum with great attention to determine, if possible, the analogy referred to, and it appears to me that such is not the case. The capillary system of periosteum has an arrangement so widely different from that of the dental capsule, that no comparison can be drawn between the two, the periosteum being remarkable for its great resemblance, in the distribution of its blood-vessels, to bone. (Plate 1, fig. 1.)

The PULP is a firm and opalescent mass, corresponding exactly in form with the external figure of the tooth, and situated within the internal chamber of that organ. In pursuing my inquiries into its structure I have had recourse to various methods for displaying its composition, the chief of which are *maceration*, *injection*, *compression*, and *desiccation*. The first of these methods is the best suited for the display of the general internal structure of the tissue; the second is the proper means for examining the blood-vessels; the third, the nerves; and the fourth, the formation of ivory cells on its surface.

The results which I obtained from the method by maceration, I reported to the British Association in 1839, in the following words :—

"Having convinced myself of the existence of the peculiar cellular structure of the tooth, I entered with great interest on an examination of the organ by which it is produced, viz. the pulp.

"On examining the internal structure of the pulp generally, the number of minute cells presenting themselves in a vesicular form is very remarkable; they seem to constitute indeed the principal portion of its bulk. These vesicles vary in size from the smallest perceptible microscopic appearance, probably the ten-thousandth part of an inch in diameter, to one-eighth of an inch, and are evidently disposed in different layers throughout the body of the pulp. They are of various shapes, as is shown in figures 24 and 25.

FIG. 24.*

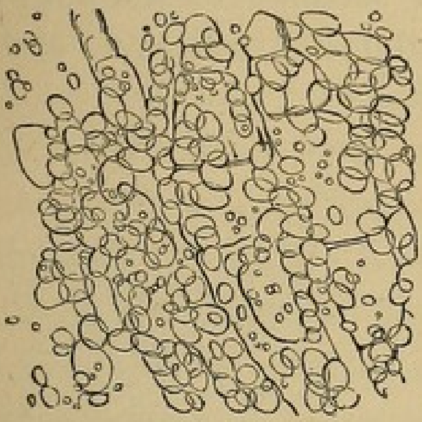


FIG. 25 †

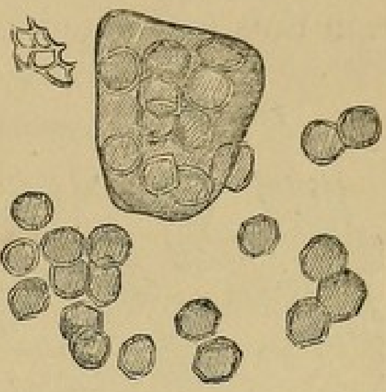
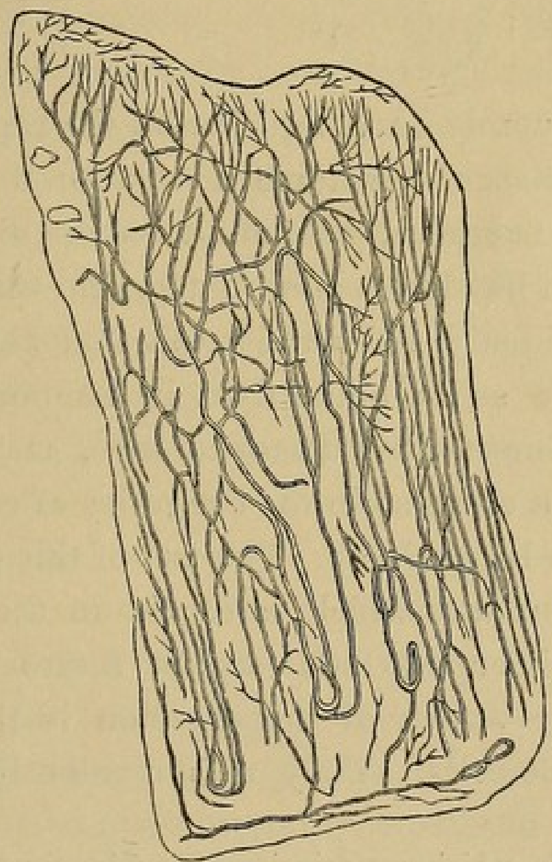


FIG. 26.‡



* Fig. 24. A portion of the body of the pulp, showing its cellular composition.

† Fig. 25. A portion of the superficial layer of the pulp, showing an appearance of vesicles ; this appearance is by no means infrequent.

‡ Fig. 26. A pulp partially injected, showing the arrangement of the

"When thin layers of macerated pulp are examined, they present an irregular reticular appearance, and are found to be interspersed with granules. The parenchyma is traversed by vessels of which the direction is generally vertical. (Fig. 26.) The appearance of these cells in sections of the pulp which have been thus macerated are exhibited in figures 27 and 28.

FIG. 27.*

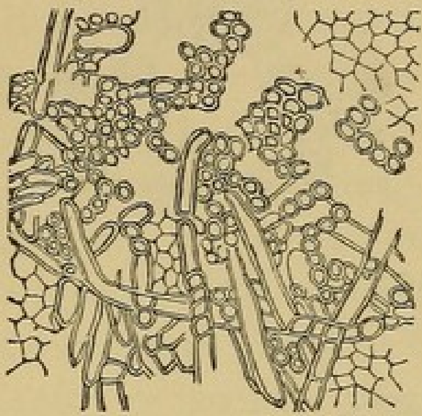
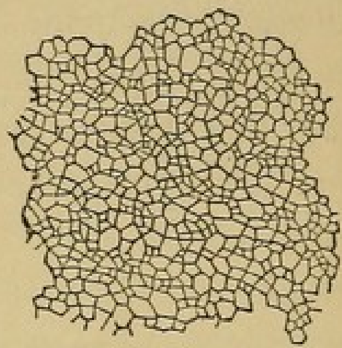


FIG. 28.†



"I have frequently been struck with the rapidity with which the pulp diminishes in volume, and with the extent of this diminution. Sometimes, indeed, it would appear in a short space of time to be almost annihilated, and this seems to take place more decidedly, when the tooth has been in a healthy state, and more so in adult than in temporary teeth. This shrinking, or almost total disappearance, may, I think, be accounted for by a collapse in the congeries of cells of which we find the pulp to be made up. The use of this peculiar arrangement, and the purpose which it serves in the economy of the part, will furnish curious subjects for future inquiry. A subject also highly worthy of investigation is the nature of the contents of these cells. They must evidently be filled either

larger blood-vessels, which run principally in a longitudinal direction. The capillaries connected with these vessels are seen in Plates VIII. and IX.

* Fig. 27. A portion of the body of a pulp in which the cells are seen variously arranged and intermingled with portions of blood-vessels.

† Fig. 28. A portion of the body of a pulp, showing another variety in the arrangement of the cells of which its parenchyma is composed.

with air or fluid, but they are so extremely minute that I have not yet been able to ascertain which.

" After repeated and careful investigation, I have convinced myself that they constantly exist on the surface of the pulp which is in apposition to the ivory, and which is essentially concerned in its developement.

" By comparing, however, the diagram fig. 28 with fig. 29, it will be seen that these vesicles are present at the surface of the pulp in a modified, more regular, and more distinctly cellular form than in its interior: and with this additional difference, that throughout the substance of the pulp they present ill-defined layers, whereas, at its surface, they are arranged in reticular leaflets, to be hereafter described."

The surface layer of the pulp is the part which is chiefly concerned in the formation of the regular fibro-cellular ivory; but ivory cells are also to be found occasionally in the interior of its mass. And these latter cells constitute by their aggregation the irregular bodies which I have described in a previous chapter under the name of corpuscular ivory.

Injection of the vessels of the pulp exhibits the high degree of vascularity of this tissue, and at the same time the beautiful arrangement of its capillaries. (Plates 8 and 9.) The method that I pursued in making these injections is a modification of the plan termed " double injection," in which solutions of two salts are thrown into the vessels, and produce decomposition in that situation. In following the steps of the process as described by its projector, M. Doyere, in the " Comptes Rendus," (vol. xiii. p. 73,) I found much difficulty in filling the vessels completely with the solid deposit, and the results of the injection were always uncertain. Seeing this obstacle to success, it occurred to me to mix gelatine with the solutions, and thus ensure the proper distension of the vessels. Upon trial, my plan turned out to be an important improvement upon that of M. Doyere, and enabled me to obtain some admirably injected preparations. I use for this purpose the gelatine sold in the shops under the name of "Dufavilles," and dissolve it in the proportion of half an ounce of gelatine to half a pint of water; and the solution thus obtained I mingle with a similar quantity of each of the saline solutions. The salts which are employed in composing this injection are chromate of potash and nitrate of lead, the latter being far preferable to the sulphate of the same metal. The solutions are used warm; the preparation to be injected should also be warm, and when all is ready, the solutions are thrown into the vessels separately. The subject best fitted to afford a perfect injection of the pulps of the teeth is a fœtus at the full time, the fluids being injected into the vessels of the funis. The injection should be repeated until no more fluid can be introduced. The gelatine transudes through the vessels in considerable quantity, but the colouring matter remains behind, and the transfused gelatine, from its transparency, offers no obstacle to the full examination of the vessels.

Much has been said of an analogy between ivory and bone, and every comparison that can be instituted with a view to elucidate the amount of affinity existing between them must therefore be interesting. The cavity of the pulp in the interior of a tooth has been likened to a large Haversian canal, and the pulp to its contents, but there is evidently no affinity in point of vascularity. On the other hand, the papillæ of the mucous membrane of the mouth very closely resemble the pulps of the teeth in the distribution of their vessels, and thereby corroborate the generally received opinion of the tegumentary nature of the teeth.

The method of examining the pulp of a tooth by compression is that which is best calculated to demonstrate its nerves. For this purpose the shell of the tooth must be broken and the pulp very carefully removed. The manner of breaking a tooth with this object in view is to place it in a vertical position in a vice, and to increase the pressure until the crust breaks, which it usually does in two longitudinal halves. Every particle of broken ivory is then to be cleared away, and the pulp subjected to compression. By this means the nerves are seen to be arranged in fasciculi of filaments which become separated by the force of compression, and which form a series of simple loops. The distribution of the nervous filaments of the pulp is shown in Plate 10, fig. 1.

Respecting the sensibility of the teeth there is a curious practical observation which is sufficiently well known, and may be easily verified. If the point of an instrument be pressed on the surface of the ivory at the neck of the tooth a very acute sensation of pain is often experienced. The first bicuspid tooth not unfrequently offers an opportunity for making this experiment; the enamel is worn away from the neck by habitual friction with the brush across the tooth, and the ivory is consequently exposed. Now if the edge of the nail or the point of a toothpick be inserted into the groove so produced, the sensation referred to will be immediately evinced. What, we may ask, is the seat of this pain? It does not exist in the enamel, and the enamel possesses a very trifling proportion of animal substance. The ivory, on the contrary, contains numerous fibres of animal matter composed of the nuclei of cells arranged in a linear order, and these must be the agents of transmission of the sensation; although it must be admitted that no direct communication can be discovered between them and the nervous filaments; the fibres of the ivory must therefore be regarded as not only endowed with the functions of absorption, nutrition, and secretion, but also with that of sensation.

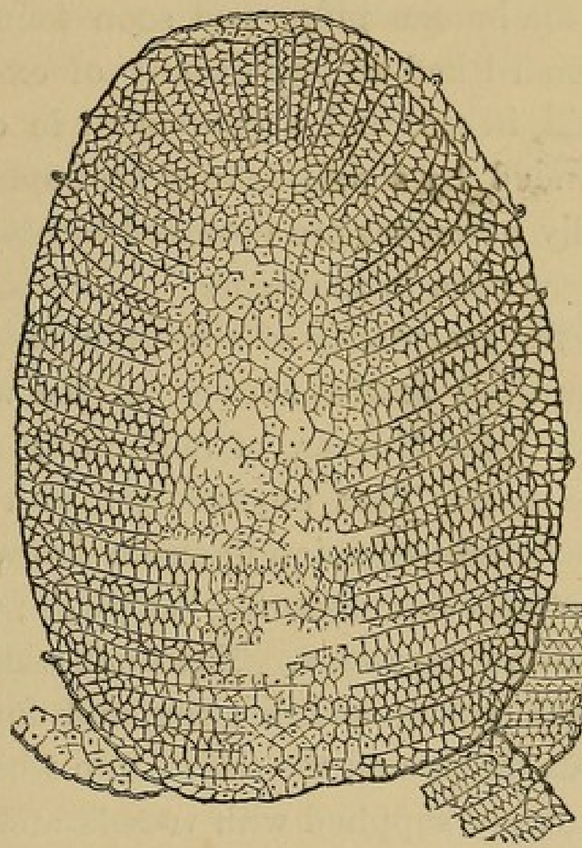
The fourth method of examining the pulp to which I have referred, namely, that by desiccation, offers the best means of observing the surface immediately concerned in the formation of the ivory cells. To effect this object the shell of the tooth must be broken, and the pulp, after being carefully removed and cleared of loose fragments of ivory, laid on a glass and allowed to dry. It is then to be examined as a transparent object. The results of my researches into the formation of ivory conducted on this plan were communicated to the British Association in 1839. In that communication I remark :—

"Much diversity of opinion has always existed respecting the connexion of the pulp with the ivory of the tooth; and as to whether the ivory be simply a product of the pulp, or a transformation of its substance. Although this is by far the most interesting point in dental physiology, and involves the grand question of the manner in which the tooth is formed, as well as that of its arrangement and conformation, it is notwithstanding less understood, has been less studied, and is consequently more obscure, than any other part of the subject. The vague style in which authors discuss, or rather dismiss this topic, shows how little has been really done to elucidate it. I must confess that I devoted myself to its examination for a long time before I was fortunate enough to obtain any light wherewith to guide my steps to the discovery of its true bearings, nor am I yet certain to what extent this knowledge of the structure of the transition portion of the pulp will be found to facilitate our comprehension of the whole complicated process by which the ivory is developed."*

* Although, from an examination of the diagrams, figs. 12, 17, 29, and the figures in chapter 10, it is distinctly demonstrated that the interfibrous substance of the ivory is formed by the deposition of calcareous matter in the cells of the reticular surface of the pulp, I cannot boast of being able fully to unveil that interesting process. The cells for the reception of the earthy matter are displayed, but—how is this matter arranged in those cells? How is it, in the first place, derived from the blood, and introduced into them? What are the causes of the characteristic varieties of the interfibrous cellular substance in different classes of animals? What is the precise degree of importance of the reticular cellular organization observed on the surface of the pulp with regard to the process of transition, besides the fact that it presents cells into which the earth is deposited? Do these reticular cells form a system containing circulating fluids, from which the calcareous material of the tooth is eliminated? How are these cells connected together, both in their transition state, and in the pulp, as well as when they have passed into the

"The formative surface of the pulp displays a regular cellular arrangement, which I have denominated reticular, and which may be described as resembling a series of skeletons of leaves. (Figs. 12 and 29.) It is not easy to obtain a preparation where the appearance is so perfect as to allow of a clear sketch of the consecutive parts of it being taken. The drawing I now present to your notice (Fig. 12) is the most perfect I have been

FIG. 29.*



state of ivory? These, and many other similar questions, remain to be solved before our comprehension of the process of the formation of ivory can be said to be complete.

* Fig. 29. One of the small compartments of ossifying cells represented on the surface of the pulp, fig. 12, considerably magnified. The cells are more distinctly seen than in fig. 12, and towards the centre are undergoing transformation into ivory cells. The appearance of central points in the latter is due to the aggregation of granules of calcareous matter in that situation, and not to the presence of a nucleus; the nucleus of the cell being in contact with the wall of the latter, and forming a prominence in that situation.

able to obtain, and is from the tooth of a calf. The compartments of the reticulation are seen to be oval, and overlap one another. On insulating one of these compartments or leaves, (fig. 29,) we find that its structure is curious and regular. These beautiful reticulations have peculiar diversities in different animals, but their general arrangement is always the same. The radiating rows of cells in the leaflet of the pulp of the calf extend to the margin of the leaflets, but the sheep offers an exception to this general law. I first observed the reticulations in the human pulp, and soon found them in all other animals which I had an opportunity of examining, varying, as I have said, in size and arrangement in different cases. They are surrounded by a well-defined scolloped border, from which occasionally processes are observed to project at regular intervals, as may be seen in the figure."

Reflecting on the vascularity of the pulp as just described, we cannot be surprised at the success of the well-known experiment made by John Hunter, of implanting a human tooth in the comb of a cock. That physiologist, with good reason, founded his expectations of union upon the known facility with which adhesion of vascular organs takes place; and the result fully warranted his anticipations. The tooth which he selected for the purpose was young and healthy, and furnished with a large and vigorous pulp; and the tissue into which he inserted it, was one abundantly supplied with vessels and nerves. The conditions were judiciously selected, and perfectly suitable to the object; and an examination shows that a vascular communication has been set up between the comb and the pulp on the one hand, and between the former and the peridental membrane on the other. Indeed the union of the comb and peridental membrane is in itself a proof of the vascularity of the pulp, for experience teaches, that when the vitality of the pulp is destroyed, separation of the peridental membrane succeeds. Now, in Hunter's preparation, preserved in the College of Surgeons, injection thrown into the vessels of the comb has filled those of the pulp, and likewise of the peridental membrane.

The experiment of Hunter, successful as I have shown, from the able selection of the conditions under which it was performed, has given rise to much discussion, and has led also to some mischievous practice in dental surgery. It has been inferred, that because a tooth has formed a vascular union with the comb of a cock, the same result would therefore follow the insertion of a living tooth into the socket from which another tooth had just been removed. But how different are the conditions in the two processes; in the one a young tooth, a vigorous pulp, and a vascular and elastic matrix, capable of closing around the fang; in the other, if even a young tooth, with a well-organised pulp be chosen, the matrix, an osseous crypt, is necessarily but feebly supplied with vessels and nerves, and the collocation is imperfect. The transfer of the experiment to practice must therefore of necessity be a failure, and we have another instance of the necessity of reflecting fully upon all the circumstances involved before a successful experiment on vital organisms be put in practice under different circumstances and opposite combinations. The experiment of Hunter, considered in the abstract, is beautiful and satisfactory; but Hunter must not be made responsible for so unphilosophical a practice as that of the transplantation of teeth.

CHAPTER VII.

DEVELOPEMENT OF THE PERMANENT TEETH.

THE developement of the permanent teeth has been made the subject of a recent and interesting demonstration by Mr. Goodsir. Previously to Mr. Goodsir's researches, all anatomists, with the exception of Hunter, believed that the sacs of the secondary teeth derived their origin from those of the milk-teeth. Mr. Fox, Mr. Blake, and Mr. Bell, advocated this view, while Mr. Hunter, without arriving at any definite conclusion as to the manner in which the process was effected, was of opinion that the two sets had a separate origin. Mr. Goodsir has solved this important question by his lucid explanations, and has distinctly shown that the two sets have an independent origin, and are each developed in a separate groove.

In early infancy, the jaws, only imperfectly grown, are incapable of supporting the teeth requisite for the performance of the functions of adult life. Hence, an infantile and temporary set is developed, which is intended to give place at a subsequent period, when the osseous system is further advanced in growth, to a range of larger and stronger teeth. For the sake of convenience in description, I shall speak of these teeth according to the numerical position which they occupy on each side of the dental arch. They are eight in number, and of these eight the five anterior are developed on the inner side of the deciduous range, and the three posterior in the same line with and behind the latter.

The first of the permanent teeth which offers signs of development is the anterior molar. The papilla of origin of this tooth is perceptible so early as the sixteenth week of fœtal existence, when it may be discovered by attentive examination behind the fifth and most posterior of the deciduous teeth. At about the twentieth week, the follicle which surrounded the papilla will be found to be closed, and to have assumed the character of a sac. At later and successive periods, the sac, with its contained papilla, increase further in size, and within the sac a quantity of gelatinous matter may be observed, similar to that which has been previously described as existing in the sacs of the temporary teeth. At the period of birth, the first molar of the lower jaw will be found embedded in the root of the coronoid process, directly behind the deciduous range.

At about the fourteenth or fifteenth week of fœtal existence, certain depressions or fossæ of a crescentic form may be perceived, upon the inner side of the apertures of the deciduous teeth. These fossæ correspond by their curve with the inner segment of the open follicles near which they are placed, and by a plan of developement first pointed out by Mr. Goodsir, they become the basis of a *secondary dental groove.* The fossæ make their appearance in regular order from before backwards, those of the incisors being formed first, then the canines, and afterwards the bicuspids. The follicles of the deciduous teeth at this period are still open, but their closure is in course of being effected, by the production from the mouths of the follicles of little folds of mucous membrane, which are calculated to perform the office of valves or *opercula* to the apertures. The closure of the follicles takes place in regular order from before backwards, and the margins of the opercula gradually grow together, but without the occurence of organic adhesion. As the secondary dental groove advances in development, its surface becomes rough and flocculent, and its walls gradually approximate, and finally unite; the union taking place from behind forwards. By this change the secondary dental groove is converted into a closed cavity, in the floor of which the small crescentic fossæ of mucous membrane previously described remain embedded as *cavities of reserve* for the developement of the permanent teeth.

The cavities of reserve of the five anterior permanent teeth, at this early period, are minute compressed sacs, having their surfaces in contact, and lying between the sac of the corresponding deciduous tooth and the inner wall of the gum. The cavity of reserve for the second and third molar teeth has a different position, being situated immediately beneath the free border of the gum. At about the seventh or eighth month of fœtal existence the cavities of reserve of the five anterior permanent teeth have sunk more deeply into the jaw, and have become placed beneath rather than behind the sacs of the deciduous teeth.

A change in the form of the cavities of reserve of the two anterior permanent teeth begins to be apparent at about the fifth month of fœtal existence. They become pyriform in shape from dilatation of their distal extremities, and across their floor a small transverse fold, which occupies the position of the edge of the future permanent tooth, is developed. This little fold is the germ of the permanent tooth. At the same time that the germ of the future pulp is in course of developement, two little processes of mucous membrane are produced from near the proximal extremity of the pyriform pouch; these are the opercula of the follicle, anterior and posterior, and upon their approximation the cavity of reserve is converted into a dental sac. The dental sac continues to recede still further from the edge of the gum, and becomes more and more deeply embedded in the loose areolo-fibrous tissue which surrounds the sac of the corresponding deciduous tooth. The relation of the sac of the permanent to that of the temporary tooth, gives to the former the appearance of being produced by a kind of gemmiparous growth from the latter, and is calculated to mislead those who have not observed the process of formation through its progressive stages. Mr. Goodsir makes the following remark on this connexion of the two sacs, with which I perfectly agree. "It was the imbedding of the permanent in the walls of the temporary tooth-sacs which deceived Dr. Blake, and led him to suppose that the former derived their origin from the latter." Mr. Fox supported the same view of the subject; and Mr. Bell in his own work,* and more lately in his Notes in Palmer's edition of Mr. Hunter's Works,† has strongly urged the same doctrine. Mr. Bell has stated that Mr. Hunter's "account of the manner in which the permanent teeth are formed is exceedingly imperfect;" but it is evident that if the account of the origin of these teeth given in the text be correct, Mr. Hunter was not in error when he supposed both sets to have an independent origin. Mr. Hunter was so correct a thinker that he did not account the circumstance of contiguity to be a proof of dependence. He was apparently ignorant of the origin of both sets, and in his usual cautious manner when *describing structure* makes no observation on the subject.

The dental groove is originally developed in an alveolar groove, and as the sacs advance in growth, septa are produced between them. The septa of the dental groove are formed by the union of the opposed surfaces of the walls of the gum, and the septa of the alveolar groove by osseous lamellæ which grow from above downwards, and in their early state resemble bridges thrown across between the sacs. At the sixth month of fœtal existence these osseous septa effect the entire separation of the dental sacs. As the dental sacs increase in bulk a corresponding increase takes place in the breadth of the jaw, and when the sacs of the permanent teeth occasion obvious prominences behind the sacs of the deciduous set, niches are formed for their reception in the internal wall of the alveolus. The whole jaw at this period gains an increase of volume and

* Anatomy, &c., of the Teeth, p. 61. † Vol. ii. p. 37.

strength, but not proportionally so in length. Thus the first permanent molar appear sunk into the base of the coronoid process in the under jaw, and into the tuberosity of the maxilla in the upper, and this appearance is due merely to the increase of material around them.

This is the position of the sac of the first molar at the eighth month, or full period of fœtal existence, and the cavity of reserve has been proportionally elongated. At a later period the jaw begins to lengthen, and by the time the infant has reached its eighth or ninth month the alveolar arch has become elongated to a degree sufficient to permit the sac of the first permanent molar to resume its proper position in the dental range, while the cavity of reserve for the second and third molars is left behind in the space previously occupied by the sac of the first molar.

With the growth of the fangs of the deciduous teeth the enlargement of the sacs of the permanent set advances in an equal degree, and as the deciduous teeth rise to their ultimate position the jaw, the permanent sink more deeply into its structure. The niches in which the sacs of the permanent teeth are lodged at the same time extend their margins until they form a septum between the permanent and the deciduous sacs, and the sacs of corresponding teeth of the two sets are only connected by their proximal ends. At a later period, this remnant of the early connexion of the two sacs also ceases; the septum of the osseous crypt of the permanent tooth constitutes the inner wall of the alveolus of the milk tooth, and the constricted aperture through which the sacs of the teeth once communicated becomes transferred to the inner wall of the alveolar process. In the dried preparation this aperture may be observed close to the margin of the alveolus of each of the deciduous incisor and canine teeth. In relation to the deciduous molars there are no such apertures, for the opening of communication between them and the permanent sacs takes place at the bottom of the alveolus, and not upon its side.

It will be recollected that the cavity of reserve in which the permanent teeth are developed, was originally a process of the mucous membrane of the mouth ; a rudiment of this communication subsists, even until the eruption of the permanent teeth, under the form of a fibrous cord which occupies the aperture above described, being connected on the one hand with the dental capsule, and on the other with the deep layer of the mucous membrane. This fibrous cord is generally solid, but occasionally presents a tubular structure, from enclosing in a persistent form a part of the unobliterated extra-follicular compartment of the original cavity of reserve. It is, in fact, that portion of the gum which contains the line of adhesion of the follicles of the permanent teeth, lengthened into a cord by the retirement of the pulps of the latter into their deep position in relation with the deciduous teeth. These cords with their canals and foramina retain their original position during the developement around them of the other structure of the jaw, either that they may perform the office of guides (" gubernacula") or paths for the teeth, (" itinera dentium,") or more probably in obedience to a law which appears to be general in the developement of animal organisms, " that parts, or organs, which have once acted an important part, however atrophied they may afterwards become, yet never altogether disappear so long as they do not interfere with other parts or functions." *

The sacs of the permanent teeth derive their vessels in the first instance from the gum, and afterwards from the sacs of the deciduous set. When the separation between the deciduous and permanent teeth takes place, the vessels of the latter become surrounded by osseous matter and lodged in distinct and separate canals.

It has been already observed that by the eighth or ninth month of infantile life the jaws have become elongated to an extent sufficient to enable the first permanent molar tooth,

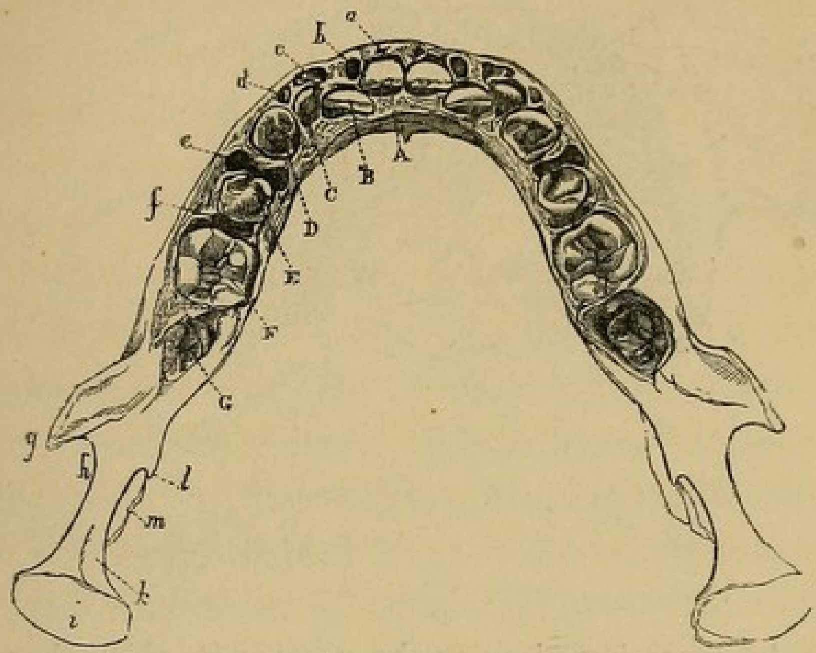
* Goodsir.

which was previously embedded deeply in the maxillary tuberosity of the upper, and in the base of the coronoid process of the lower jaw, to resume its proper level in the dental range. At the time of occurrence of this change, the cavity of reserve which occupied until now a position immediately superficial to the crown of this tooth, falls back into the vacant space, and begins to enlarge. In the fundus of this cavity the papilla of the second permanent molar is developed, and as it advances in growth gradually assumes the character of a pulp, while the mucous membrane which surrounds it passes through the respective stages of follicle and capsule. A portion of the cavity of reserve still remains pervious, one extremity being attached to the summit of the capsule of the first permanent molar, the other being connected to the summit of the second, and the intermediate portion lying in contact with the deep surface of the gum.

When the sac of the second molar attains its complete developement, and the jaw by its farther growth furnishes the proper amount of space, the second molar moves from its deep position, in the same manner as did the first, and gains its proper level in the dental range. This movement is accompanied by a repetition of the enlargement of the cavity of reserve, and by its retreat as before into the unoccupied alveolar space. Synchronous with this change is the developement of the papilla of the last or wisdom tooth; afterwards, the production of a closed capsule and pulp takes place as before, and lastly, at the age of nineteen or twenty years the movement of the dental sac into the range occupied by the other teeth is effected. The developement of the wisdom tooth completes the permanent set, and consumes the remainder of the cavity of reserve. While at the same time it is the last tooth produced in the *secondary dental groove.*

When the crowns of the permanent set are completely formed, the relation which they bear to the deciduous set is shown in the accompanying figures.

FIG. 30.*



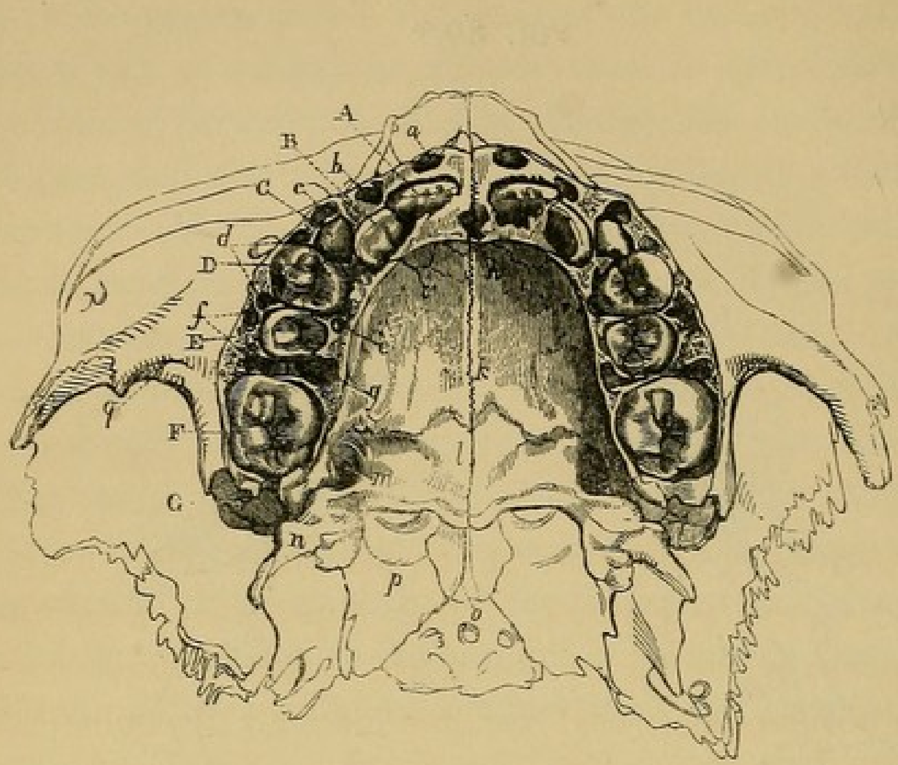
* Fig. 30. A lower jaw, showing the position in which the permanent teeth rise from the bone in relation to the deciduous set. The upper part of the alveolar process has been removed in order to effect this demonstration.

A. The crown of the central permanent incisor. B. The crown of the lateral permanent incisor. C. The crown of the permanent canine. D. The crown of the first permanent bicuspid. E. The crown of the second permanent bicuspid. F. The crown of the first permanent molar. G. The crown of the second permanent molar seen at the bottom of a deep socket.

a. The bottom of the sockets of the central deciduous incisor. *b*. The bottom of the socket of the lateral deciduous incisor. *c*. The bottom of the socket of the deciduous canine tooth. *d*. The bottom of the socket of the anterior fang of the first deciduous molar. *e*. The bottom of the socket of the anterior fang of the second deciduous molar. *f*. The bottom of the socket of the posterior fang of the second deciduous molar.

g. The coronoid process of the lower jaw of one side. *h*. The semilunar notch. *i*. The condyle. *k*. The neck of the condyle. *l*. The process to which the internal lateral ligament is attached. *m*. The angle of the bone.

FIG. 31.*



* Fig. 31. An upper jaw showing the position in which the permanent teeth rise from the bone in relation to the deciduous set. The summit of the alveolus has been removed in order to show the crowns of the permanent teeth more clearly.

A. The central permanent incisor. B. The lateral permanent incisor. C. The permanent canine. D. The permanent first bicuspid tooth. E. The permanent second bicuspid. F. The permanent first molar. G. The permanent second molar imbedded in the tuberosity of the superior maxillary bone.

a. The bottom of the socket of the central deciduous incisor. *b*. The bottom of the socket of the lateral deciduous incisor. *c*. The bottom of the socket of the deciduous canine. *d*. The bottom of the sockets of the two external roots of the first deciduous molar. *e*. The bottom of the socket of the internal root of the first deciduous molar. *f*. The bottom of the sockets of the two external roots of the second deciduous molar. *g*. The bottom of the socket of the internal root of the same tooth.

h. The anterior palatine foramen. *i*, *i*. The intermaxillary suture. *k*. The suture which unites the palatal processes of the superior maxillary bone. *l*. The palatal process of the palate bone. *m*. The posterior palatine foramen. *n*. The pterygoid process. *o*. The vomer. *p*, *p*. The posterior nares. *q*, *q*. The malar process of the superior maxillary bone.

CHAPTER VIII.

ON THE TEETH AS AN INDICATION OF AGE.

THE periods of irruption of the deciduous teeth have been stated in a previous chapter. Their appearance constitutes so many epochs in the life of the infant, having reference to progressive development, and is attended with physiological and pathological conditions of considerable interest. The process is frequently painful, frequently attended with severe local suffering, and occasionally with constitutional disturbance of great intensity.

The eruption of the permanent teeth is also accompanied with more or less pain and local irritation in the mouth. It is remarkable for its regularity, as may be perceived by inspection of the following table:—

Order of eruption of the permanent teeth.

First molars . . .	7th year
Central incisors . . .	8th "
Lateral incisors . . .	9th "
First bicuspids . . .	10th "
Second bicuspids . . .	11th "
Canines	12th "
Second molars . . .	13th "

The teeth of the lower jaw preceding by a few weeks those of the upper.

The appearance of the teeth above the level of the gums takes place with so much regularity both with regard to succession and time, as to constitute an important means of ascertaining the age of the individual during the early periods of life. Indeed, the teeth may be considered in this sense as of the highest practical value in determining medico-legal questions bearing upon age. A curious instance of this application of the principles contained in the above table occurs in a paper communicated to the Academy of Science of Paris, in 1815, by Baron Cuvier.*

" Dargenville," observes that philosopher, " in his Oryctology, has represented somewhat coarsely a human head of extraordinary size and thickness, which is at present in the collection of our distinguished colleague, M. de Jussieu.

" Dargenville regarded it as a petrifaction, which had either become swollen and solidified in the earth, or having been softened and enlarged during life, had become solid and compact after death by the infiltration of calcareous fluids.

" Other figures of this head, representing different views, but less exact than those of Dargenville, are contained in the memoirs of Guettard.

" But the most precise account which we possess, is that of a learned physician of Paris, M. Jadelot, published in 1799, with engravings. In this paper we find the description, weight, dimensions, and chemical analysis of this curious relic. The author regards it a monstrosity, resulting from a disease which has given rise to softening and swelling of the bone, and considers its density and strong appearance to be due to the presence of carbonate of lime deposited after death, and subsequent to interment. He thinks also that the teeth, which are buried within the jaws, have been forced into that position by the pressure of mastication. M. Jadelot's essay, although perfectly clear and precise in its detail, formed no obstacle to the

* Nouvelles observations sur une alteration singulière de quelques têtes humains, in the Memoires du Museum d'Historie Naturelle. Vol. ii.

advancement of an opinion by Mr. Edward Stern, in 1818, that the head in question must have belonged to an extinct race of giants, whose mental faculties were greatly inferior to those of men of the present day, but to whom the writer, nevertheless, attributes works which imply some intellectual power, such as Stone Henge at Salisbury, and other monumental remains, which pass by the name of Celtic.

" A distinguished physician, Dr. Windelstadt, adopted the opinion of Mr. Stern. He states that this head must have belonged to a preadamite giant thirteen feet* high. And M. Ballenstedt agrees with these authors, and finds in this extraordinary relic a capital argument in favour of his system, of the existence of a race of giants in the primæval world.†

" Dr. Moll of Nimwegen, the Dutch translator of M. Ballen stedt, denies, it is true, the origin of this head in the ancient world, but nevertheless believes it to have belonged to a man in health, possessed of gigantic proportions, and having a stature of nine or ten feet.‡

" An anatomist of the highest rank, M. de Soemmering, in vain contended that it was, as had been described by M. Jadelot, a diseased head; in vain he supported his argument by reference to a similar head, preserved for a long time in the electoral museum of Bonn, and at present in that of the Grand Duke of Hesse at Darmstadt; to a third described by M. Jourdain in his treatise on the surgical diseases of the mouth; to a fourth at Charkow, and to several other specimens, more or less analogous, reported by Sandifort, Baillie, Malpighi, and Haller.

" In vain he cited the case of a living person suffering under a similar disease, and declared that a well-known physician,

* French.

† M. Ballenstedt's work is entitled, " Nouvelle preuve de l'Existence des Giants dans l'Ancien monde dans le Archives des Decouvertes Relatives au Monde Primitif."

‡ French.

M. Wedekind, died of the same disease. M. Ballenstedt maintained in reply, that it was the head of a giant of the primæval world.

"I was most astonished in this long discussion that none of the eminent men who had taken part in it, thought of ascertaining what might have been the age of this and of the analogous heads; nevertheless, this was a point so closely related to the question at issue, that Dr. Moll, among other reasons which he advanced to prove that the head was not in a morbid condition, alleges that similar diseases are very rare in adults; but he admits, at the same time, without further examination, that the head is that of an adult. M. Jadelot, and M. Soemmering, do not appear to have thought at all of giving an opinion in reference to age.

* * * * * * *

"We are not well acquainted with the precise place in which the head belonging to M. de Jussieu was disinterred; all that is said with regard to it is, that it was found at a depth of fifteen feet* under ground, among the hills of the village of Sacy, at two leagues' distance from Rheims; but there is nothing authentic in this statement; we have no knowledge as to who made the discovery, nor as to the persons who witnessed it. This uncertainty doubtless contributed greatly to increase the vague conjectures which have been circulated in reference to its origin.

"As regards the Darmstadt head, we know positively that it was found in an ossuary at Billerbeck, in the Bishopric of Munster, whence it was sent to Bonn for the museum of the Elector of Cologne, the Bishop of Munster. It remained there for some time, and was thence transferred to Darmstadt.

"It is therefore certain that the latter is not fossil, and equally so that it belongs to the present creation.

"The first aspect of these heads gave me the impression that they did not belong to adults; and feeling the importance

* French.

of determining this question, I set to work to verify this first impression.

" The age of a skull, whatever deformity it may present in consequence of disease of the osseous system, may always be pretty nearly ascertained by the appearance and number of the teeth.

" The reason is obvious; the teeth are not developed like bones, by intus-susception, but grow like shells, by juxta-position, and their structure, when once formed, is neither susceptible of inflammation nor of alteration from internal change. Whatever takes place in the bones around has no influence upon them, and their own especial disorders in like manner produce no immediate impression on the bones. Applying these considerations to the skulls in question, I found in that obtained from Darmstadt, the alveoli of six teeth on each side, namely, two incisors, one canine, and three molars half closed. In the lower jaw, of which only the left half was found, the alveolus of the third molar was not at all apparent.

" This observation suggested at once that the individual was of the age of six or seven years, and that the teeth which had occupied the alveoli were milk-teeth.

" In fact, it is at about the sixth or seventh year that the first permanent molar, or the third on each side, begins to make its appearance. And at about the same period the front teeth begin to fall, and give place to the permanent set.

" The inference which I was thus enabled to draw from the appearance of the alveoli of the skull from Darmstadt, was confirmed by the examination of the teeth of the specimen preserved in the collection of M. de Jussieu.

" This head has also six alveoli on either side in each jaw, the sixth being wanting on the left side of the superior maxilla. It was, therefore, of about the same age as the Darmstadt cranium, but, by a fortunate chance, two of its molar teeth are preserved, the second of the left side of the upper jaw, and the second of the right side of the lower.

" Nothing was more easy than to ascertain whether these were milk-teeth or permanent teeth, since the second molar of the two dentitions presents so great a difference of character.

" Indeed, in man, as well as in the majority of quadrupeds, the deciduous molars have a more complex form,—a form more closely resembling the posterior permanent molars than those which succeed them; and the purpose of this difference is easily understood, namely, that the deciduous molars have to fulfil the offices of the posterior permanent molars, until the latter have attained their proper size.

" Therefore, in man, the first deciduous molar of the upper jaw has a strong tubercle on the inner side of its crown, and a notch dividing it into two lobes internally; and the second, four tubercles arranged obliquely. The first deciduous molar of the lower jaw has four tubercles, but little prominent; and the second five, whereof three are external, and two internal, and both the latter are slightly bilobed. In other words, the second deciduous molar in each jaw resembles the first posterior molar, or the permanent tooth which is produced behind it, and not the tooth which is rising beneath it, and occasions its fall.

" The latter are in fact the bicuspides, the teeth with two large tubercles on their crowns, one placed internally and one externally; in the teeth of the lower jaw, the tubercles being a little more grooved than in those of the upper.

" The roots of these teeth are also different, those of the milk molars being more numerous and more widely spread out than those of the bicuspides.

" Guided by the preceding data, I examined the teeth with their shortened fangs of the cranium preserved in the collection of M. de Jussieu.

" The second molar of the upper jaw still remaining in its place, has four tubercles and a fractured crown, and referring to the alveolus of the opposite side of the jaw; it has also three fangs considerably spread asunder. And although so complicated, and occupying the second place, it is undoubtedly a deciduous molar.

" The tooth in front of this molar presented the same character, and the spaces for the three fangs are quite obvious in its alveolus. Behind the first described was a third molar, which is broken, but which has left three roots. This is the first posterior molar in the seven-year tooth: it can be no other. It is indeed only at the age of seven years that there can be seen in the upper jaw, at one and the same time, three molars standing in a row, each possessing three fangs, for before this period the first permanent molar has not risen, and later the two milk-molars are replaced by the bicuspids, which have but one root, or at most two. It is thus that the second posterior molar, which has also three roots, follows the first: but the third, or wisdom tooth, has never the same number. Thus, then, after the age of seven years, or thereabouts, there are never more than two molars with three fangs situated together.

" The tooth of the lower jaw has its five tubercles, exactly similar to a lower milk-molar, and the crown somewhat worn, which proves that it had been in use for some time. Indeed, if seen alone, it might have been asserted that this tooth was not a milk-molar, but the first permanent molar, for these teeth are very nearly alike, as we have already stated. But the latter supposition is not admissible, inasmuch as in that case there would not be a sufficient number of teeth in front of it. The depressions situated immediately in front of this tooth are not two alveoli, but the cavities for the two roots of the same tooth, and the presence of two roots, separated as far as the neck, shows that the tooth in question was a milk-molar, and not a bicuspid.

" The canine tooth of this side is broken off, and not driven into the jaw, as was thought by M. Jadelot.

" As respects the incisors, this idea is still more inapplicable.

" The alveoli of all the incisors are well marked, and in their proper place; they are also partly closed, which shows that the teeth which they contained have been shed.

"The tooth which remains imprisoned within the jaw, near its inferior border, has its cutting edge quite perfect, and the denticulations of a permanent incisor. Therefore it has never been used, otherwise it would have presented some indication of being worn, such as we have already seen in the existing molar.

"From its integrity, and the existence of an alveolus, which is the certain sign of another incisor having preceded it, I conclude that this tooth, so far from having been pressed back into the softened bone by the force employed in mastication, was, on the contrary, prevented from issuing from its cell by the density and thickening of the bone.

"Close to the latter tooth is another and larger cell, which probably also contained a tooth, which must have fallen out when the jaw was broken at this point.

"I feel persuaded that if the jaw were opened in this situation, other teeth would be discovered which have been equally unable to escape.

"The surface of the jaws, examined with care, confirm all that the teeth and the alveoli denote. Behind the alveoli of the incisors are seen the traces of apertures which belong to the cells of the permanent teeth; but these openings are almost obliterated by the swelling of the bone.

"There remain also in the upper jaw well marked traces of that section which is a vestige in man of a section of a suture, which in almost all animals forms the line of separation between the incisive bone and the superior maxillary. This trace is of great importance, as denoting most accurately the position of the canine, and enabling us to determine that the next tooth behind, namely, the first molar with three roots, is in reality a deciduous molar.

"If I mistake not, then, everything combines to prove that the crania under examination are the skulls of children who have died at the epoch of change of the teeth, and in whom the change was incapable of being accomplished.

* * * * * * *

"The teeth are indeed larger than those of a child of the age which I have assigned, but they do not exceed the dimensions of those of an adult of ordinary stature."

From the great regularity attendant upon the process of eruption of the teeth, an ingenious and important application of its principles has been made in this country by my talented friend Mr. Saunders. Mr. Saunders was selected, with others, to determine the question, how far the teeth might be trusted as a test of age in children, with a view to the acquirement of some certain means of ascertaining the age of factory children.

In reference to this question, Mr. Saunders has shown that the normal number of permanent teeth apparent in the jaws at the age of nine years is twelve, namely, five incisors, and two molars in each. That deviations from this number occasionally occur, the most frequent being the absence of one of the lateral incisors, then the absence of both in one or other of the jaws; a more rare deviation occurring in the minimum of cases, namely, in a proportion of seven per cent. is, the absence of all the lateral incisors, or the absence of two laterals and one central. These latter cases, he observes, "occur but rarely, so that unless a child exhibits unequivocally the general aspect and strength, it cannot be considered as being of nine years of age. Thus, then," he continues, "the examination of the teeth at the age of nine years is exceedingly simple, virtually resolving itself, indeed, into the observation of the eight teeth situated in the anterior part of the mouth."

Regarding the age of thirteen, the second period referred to by the Factories Regulation Act, Mr. Saunders observes, "Both epochs are well marked by the appearance of important teeth; the first by the developement of the incisor and first molar teeth, the second by that of the cuspid and second molar; the intervening period being occupied in the developement of the bicuspid teeth, which are subject to much greater irregularity in the time and order of their eruption." At thirteen years the full complement of teeth is as follows: namely, eight incisors, four canines, eight bicuspids, and eight molars, making in all twenty-eight. "The most important teeth to be observed at this period are the cuspid or canine and the second molar, the seventh tooth from the centre of the mouth."

"The more frequent deviations will be found to occur in the second molar teeth, one or more, and in some instances the whole of which will not have made their appearance." As a most common deviation, Mr. Saunders gives the absence of canines, the absence of two of the posterior bicuspids, and the absence of one of the second molars. The next deviation which he cites, is marked by the absence of one of the canines, of three of the posterior bicuspids, and two second molars. The minimum deviation exhibits an absence of one of the posterior bicuspids and all the second molars.

In the latter case, "if the cuspid teeth be fully developed, and the child present the ordinary physical appearances belonging to the age, it may be considered as having attained its thirteenth year, because occasionally, though rarely, (such cases having a proportion of scarcely more than two per cent.,) this deviation is encountered. More frequently one or more of the second molar teeth may be observed just emerging from the gums, but in comparatively few cases will the whole be found fully developed, an appearance which belongs to the fourteenth year. More rarely still the cuspid teeth will be deficient; in these cases, which are, however, seldom encountered, the decision must depend on the degree of developement of the second molar teeth; if these are present, as the period of their eruption is subsequent to that of the cuspid teeth, and provided the physical appearances coincide, the child may be presumed to have attained its thirteenth year." *

* Medical Gazette, vol. ii., 1837-38, p. 492.

From his collected observations, Mr. Saunders draws the following conclusions :—

" Thus, then, it appears that of 708 children of nine years of age, 389 would have been pronounced, on an application of this test, to be near the completion of their ninth year ; that is, they presented the full developements of that age. But on the principle already stated, that of reckoning the fourth tooth as present where the three are fully developed, a still larger majority will be obtained, and, instead of 389, the proportion will be as follows :—of 708 children, no less a number than 530 will be fully nine years of age. What, then, are the deviations exhibited by the remaining 178 ? They are the following :—126 would be pronounced eight years and six months, and the remaining 52 eight years of age ; so that the extreme deviations are only twelve months, and these only in the inconsiderable proportion (when compared with the results obtained by other criteria) of 52 in 708.

" Again, of 338 children, of thirteen years of age, no less than 294 might have been pronounced with confidence to be of that age. The remaining 44 would have been considered as follows :—36 in their thirteenth, and eight near the completion of their twelfth year."

My own observations agree, as far as the general principle is concerned, with those of Mr. Saunders ; but it must be borne in mind that differences of circumstance, such as of climate, situation, and food, exert a powerful effect upon the animal organism. With like conditions, like results might be expected ; but opposite conditions, though seemingly trivial, give rise to important diversities. For an illustration of the truth of these observations, we need go no further than the elephant. In a preceding chapter I have referred to differences of specific gravity of the ivory obtained from this animal. These differences have reference to relative modifications in the proportions of the earthy and animal material, and depend originally on diversities of climate, locality, and food. Similar peculiarities of condition are calculated in the same manner to affect the human race.

The value of a knowledge of the stages of dentition in the horse is well known, and the information which it conveys is usefully applied in determining the age of that animal. But there is another fact which is also well known to those who are conversant with the natural history of horses, which is, that if a young horse be placed at an early period on hard food, the developement of the teeth will be so much quickened, that in the course of a short time the teeth will exhibit the characters which distinguish an animal a year older than the horse in question really is. For this reason, race-horses taken up early from grass are frequently found to have advanced a year in mark of mouth beyond their proper age. The same observations apply to children. Where infants have been supplied at an early period with hard food, and are encouraged to make early attempts at mastication, the teeth come forward more regularly, and at an earlier period, than they otherwise would. This effect obviously depends upon the stimulus conveyed to the formative organs by frequent pressure. And as a secondary cause, the increased flow of saliva, by contributing to the more perfect preparation of the food, and the consequent more complete digestion, furnishes a richer and more nutritious chyle for the elaboration of the blood, and the developement of all the tissues of the body, including the teeth. It is, therefore, a practical consideration of much importance in relation to health to encourage early and complete mastication in the young subject.

CHAPTER IX.

ON THE TEETH AS AN INDICATION OF THE PROGRESSIVE IMPROVEMENT OF THE HUMAN RACE.

THERE is another important view in which the anatomy of these parts, in their progressive developement, may be considered; one which bears intimately on the subject of ethnology, and which, in consequence, I took the opportunity of laying before the Ethnological Society of London in the following communication.*

" Glancing at the different degrees of developement in man which come within notice, and the various features found to be prevalent, and made use of, with a view to characterize the varieties of man, we find them to be numerous, and to produce much diversity of appearance.

" When we observe the difference between the European and the negro in colour; the long, flowing, light-coloured hair of the Caucasian, and the black woolly hair of the negro; the well-balanced, elevated, and finely-symmetrical cranium of the Caucasian; the extremely prominent and well-furnished mouth of the negro, and the pinched perpendicular mouth, supplied with irregularly-arranged and imperfectly-organized teeth of common life—the question may well be asked,—Has man descended from a state of perfection, or risen from a low and deficient condition of developement?

* On the human mouth, read April 23, 1845.

"The arguments which have been advanced on this subject have generally tended towards the adoption of one or other extreme in the scale of developement, with a view to solve the difficulties regarding the original stock whence mankind have sprung. Here we must exclusively take into consideration possibilities, and these so far only as they are consistent with the experience and evidence of facts within our reach. We have to contemplate the natural scene of existence into which man must originally have been ushered. The developement compatible with the due fulfilment of the exactions required from such a being, in such a state of existence, must, in my opinion, have been perfect, and one well-balanced both in its moral and physical attributes. A mind of morbid sensibility, such as highly cultivated social life in all ages presents, would have sunk under the exactions inevitable to such a state. It would not have been able to exert the requisite force to combat them, and it would have been too sensitive to have allowed man to have acted as a creature of simple instinct.

"If, on the other hand, the developement of his physical frame and moral attributes had been of a low standard, he would neither have been possessed of strength and vigour adequate to contend with the peculiarities of his state of existence, nor have had mind to comprehend, nor judgment to regulate it. He would have been totally defenceless against the violence of the elements, and the attacks of the animated creatures around him,—man being naturally defenceless, and deriving all his power from the regulation and direction of his rational faculties. If the origin of mankind had really been that of a low and degraded scale of developement, even if such a state were compatible with his existence, it does not seem to me that emancipation from it could have been possible. I am, therefore, at issue with Dr. Pritchard in the opinion expressed by him, that it must be concluded that the process of nature in the human race is the transmutation of the characters of the negro into those of the European. Such a view is not the result of my researches.

"I hope to show that there is no difficulty in supposing a derivation from one original stock, and that certainly the origin of the varieties in the developement of the mouth must have been from a perfect type. The capability of the existence of man in different climates is only bounded by the extreme limits of the globe; his assimilative functions are omnivorous; his powers of articulation unlimited; and his physical capabilities combine all the possible modifications of the lower animals whose spheres of action are terrestrial. His mental powers are of the highest order; and, when we see that the inferior animals are endowed to so great an extent with plasticity and power of accommodation to circumstances, surely we cannot possibly deny to man a power of individual and hereditary adaptation adequate to fit him for the perfect enjoyment of such versatility.

"In regard to the form of the head, which presents the most notable ethnological marks, various points have been attended to—in fact, the relative proportions of every salient part. In reviewing the observations which have been made thereon, so far as they are connected with ethnology, no feature seems to me to bear so instructively on the solution of the various difficult problems involved in this study as the form of the mouth, and the developement of the teeth. Everything would appear to yield to the necessities of existence, and the varied materials for sustaining that existence, the manner of procuring these materials, and their situation and nature. The mouth is the original and essential constituent of the apparatus for the assimilation of these materials, and in the lower animals it is peculiarly and beautifully adapted to their exigencies. In the mouths of men, too, we observe a medium type fitted to every peculiarity of terrestrial existence, and capable of performing every office exacted from the mouth in all the lower animals. Just as those peculiarities are exacted by external circumstances and situation, so we have a display of corresponding peculiarities of organization. As I have said on another occasion, it is a remarkable fact, that no other conformation of mouth than that of man, could admit at once of perfect articulation and mastication of his varied food. This organ may be regarded as fulfilling a most essential part in his intellectual life; for it is not only in him, in common with all other animals, the essential and original element of the apparatus of assimilation, but it is also the organ of intellectual expression, and, as such, is equally indispensable to the existence of the race, and an essential agent for the improvement of man's condition, and for his communion in social life. From mere observation, therefore, of the conformity of developement of the anterior chambers of the head, with the presentation of the anterior portion of the mouth, we may be led to the general conclusion, that those of weak intellect were forced originally to emigrate to the more inhospitable quarters of the globe, for we find that the inhabitants of these climates are generally possessed of a low developement of forehead, with a protruded jaw; while those still inhabiting the position of the original stock possess an elevated forehead and a perpendicular jaw.

"Blumenbach raised the maxilla into a place of importance by taking his characteristic diameters of the cranium from the conjoint form of the frontal and maxillary bones; and he regards them as the most important points on which the general character of the head depends. The facial angle of Camper is a subject which still retains much interest, though that interest might probably have passed away had it not comprehended within its range the comparative developement of the anterior or intellectual portion of the brain. Still, the interesting features of that portion of the subtending lines of the angle connected with the mouth, although not neglected, yet, in my opinion, require more consideration than has hitherto been allotted to them. That acquiescence in the harmony of nature, which seems to be irresistible, might probably call forth an assent to the accuracy of these general remarks; but, however close the reasoning on hypothetical principles may be, science demands demonstration from facts before we can freely or fully yield our assent to any proposition. We must inquire if deviations in the character of the mouth are simply the effect of deviations in the habits of individuals composing races; whether they are partial, and appear in individuals only, or general, and amount to a national or tribe characteristic. We know that the osseous portion of the animal frame is modelled by the soft parts, and that, in fact, the bones may be considered as mere passive accessories, affording points of attachment as well as protection to the soft parts, which are the springs by which the animal machine is worked in all its complicated movements. That passive character, however, offers, in its nature, a direct demonstration of the amount of activity of the soft parts connected with such portion of individual structure. In the present case it must be evident, and the instruction derived from the developement of these parts must be regarded as direct. We must seek for the origin of the characteristic differences amongst the various groups of mankind, in causes which are natural, general, and indispensable to the existence of man in his particular position. We must also look for the origin of certain appearances in manners and customs. The form of the mouth, and the condition of the teeth, must be studied, in reference to the habits of infancy, as regulating the developement, particularly as to the kind of food consumed, and weight must also be given to the effects of hereditary transference of character.

" The relative perfection of developement of the organs generally, and the teeth especially, is affected by other causes, viz., the circumstances connected with general developement, such as the periods of womanhood and marriage, and the habits of life, particularly of females. The nature of the food will always materially regulate the state of the teeth throughout life.

"There is a practical fact of fundamental importance, in reference to this inquiry, which will materially explain and illustrate the points under consideration. It is this, that the natural action of the lower jaw upon the upper may push out, evert, or expand the arch of the latter; but, on the other hand, it is impossible by any habitual or natural act performed by the mouth, or by the individual in any way, to bring in, or to contract that arch, so as to produce, out of the prominent jaw of the negro, the vertical or perpendicular jaw of the Caucasian. The prominent character may, therefore, be derived from the vertical, but the vertical never can be produced out of the prominent, by any habit or exercise of the function of the organ.

"The causes which produce the prominent developement are palpably of common occurrence, and matters of every-day observation; and this feature of a race can only be reclaimed by the ameliorating influences of successive generations, in abstinence from practices which give rise to the eversion. Unless, indeed, the perpendicular mouth had been the original presentation of mankind, there is no exercise in which these organs could be employed, so as to develope such a feature; but I hope presently to show that the constitution of the parts individually, and of man and his manners generally, all conspire to the production of the prominent mouth from the vertical type.

"The vertical mouth is said to be the original developement of the infant negro; the advanced mouth of the adult negro, therefore, is not congenital but factitious. We are also told, that the progeny of the negro of the southern provinces of the United States, owing to the different circumstances in which it is placed, has not the advanced mouth and its concomitant features after the second or third generations. It will be necessary, however, to show that these parts are of such a plastic

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nature as to admit of this factitious developement. Their habits and exactions will also require to be considered, for the purpose of ascertaining how they become plastic, and are factitiously modelled out of their congenital arrangement; and, with a view to understand the nature and extent of the plasticity of the osseous portion of the organ, I shall now describe the anatomy of the mouth, and show how far these parts are under the influence of the moulding and controlling powers of the muscles, in the performance of the functions required of them. As I do not, however, intend to give here a strictly anatomical demonstration, nor yet a physiological disquisition, what I shall say will consist more of a general explanation of that which is necessary to be attended to, with a view to understand my theory, than anything else. I have already alluded to the complicated nature of the operations exacted of the mouth in articulation and mastication.

" The degree of perfection in developement of all the different portions of the mouth, must regulate the degree of perfection with which the work to be performed by it is accomplished. Perfectly distinct articulation is not compatible with the prominent jaw of the uncivilized, neither is it compatible with the irregularly developed mouth of the civilized; nor is it possible for the diversified exercise of the organ in the different actions exacted for the division, comminution, and grinding of food to be well performed by such mouths, as social life is every day furnishing in endless variety. The irregularity of the teeth in such mouths causes the one jaw to become locked within the other, and thereby prevents such latitude of action as is adequate to the due performance of these varied duties. Mastication is performed by means of one portion of the mouth being passive, and the other active; the under jaw, consisting of bone and muscle, is the active, the upper jaw the passive portion; but although, collectively, the under jaw is active, yet this is again resolvable into a single portion acted upon, namely, the solid bone, and a number of parts producing the action, or in which the power resides, namely, the muscles. The force employed is that of a lever of the third order, the principal force being exerted by the powerful temporal muscles inserted into the coronoid processes, and situated between the fulcrum, residing in the condyles, and the weight to be overcome produced by the substances for comminution, placed between the teeth, in any situation around the dental arch, but always anterior to the power exerted by the temporal muscles. Other muscles (the masseter and pterygoid) inserted into the under jaw, and deriving their origin from points of the bones forming the superior portion of the face, may be looked upon more in the light of controlling powers than otherwise. At the same time, they afford a certain direct assistance in elevating the under jaw, but their characteristic sphere of action is in varying and regulating the chief power produced by the temporal muscles. The principal duty of the remaining large muscle of the under jaw, the buccinator, is that of perfecting the parietes of the mouth. It forms an antagonist to the tongue in receiving the food into the mouth for mastication, and in retaining it within the influence of the grinding apparatus. This beautiful piece of machinery, taken as a whole, may be considered in the light of an inverted hammer and anvil, the hammer performing its work on the anvil of the superior jaw; and the machinery is perfect.

" But these parts, aided by the muscles connected with the chin, the tongue, the lips, and the fauces, have another duty of great delicacy and extent to perform, namely, that of articulation. This very essential function is the result of the combined action of all the muscles, through peculiarly delicate modifications, directed on the air that has been undulated into a sonorous state in its passage through the rima glottidis. In addition to this general view of the machinery and uses of the mouth in man, it will be necessary to examine, a little more minutely, the constituents of the skeleton of the mouth, and learn how that enduring portion in which the shape or ethnographic signs reside and become permanent is affected in different tribes, by the exercise of the functions exacted from the various parts. In this point of view, it may be useful to consider the mouth under three aspects: anterior, posterior, and median. We shall, in that way, be better able to appreciate the peculiar mechanism displayed in its contrivance.

"Let us first inquire what are the different duties demanded of these parts, and then point out how their performance is provided for. 1. There are certain duties exacted by all mankind of the mouth, namely, seizing, dividing, and comminuting or grinding the food. For each of these actions there exists a central point of energy. The central point of energy for the act of seizing, resides in the median division, where the canine tooth is situated. That tooth has the most powerful single fang of any tooth in the whole dental range; and, from possessing a strongly pointed cusp, is peculiarly fitted for the act of transfixion. The canines are most conspicuously marked in some of the lower animals, and are known by the name of tusks. They are also powerfully marked in carnivorous animals, such as the dog, from which, indeed, they have obtained their appellation; but they are not less so amongst the feline and other carnivora. The canine tooth presents a marked feature in the countenance of all animals possessing it. Its position is beautifully adapted for seizing securely, without interfering with the vision of the animal, whilst he is grappling with his prey, it being placed aside, and not in the direct line of vision. This is a matter of great importance when these teeth require to be brought energetically into action, as the duties exacted of them are of primary importance, and must precede those of the others. On each side of this latero-median and essential tooth, are teeth which are of an intermediate character. The lateral incisor teeth, anterior to the canine, partake of a mixed character, of the canine and central incisor, and the small grinders or bicuspides, on the other side, are intermediate in character betweem the canine and the true molars or grinders; thus the canines at each corner pierce and transfix whatever is placed within their sphere of action, and hold it fast, while the anterior and intermediate accessories, the lateral incisors, divide it anteriorly, and the acute and compound cuspidated small grinders divide it posteriorly. The other two divisions of the dental range contain within each respectively a centre sphere of energy also, but very different in object. The anterior portion possesses the central incisors, but the power of their full action is not adapted to transfix, divide, and tear, in a manner similar to that exercised by the powerful tooth we have just alluded to. They are the most distant from the power which acts on the jaw; and in the upper jaw they present a broad and chisel-shaped cusp, instead of the pointed and piercing cusp of the canine tooth, and the root even of the upper central incisor is about-one-third less than that of the canine. On the whole, then, they have only about one-third of the power which the canine teeth have; and they are, consequently, only applicable to the division of small objects, which, as their name implies, is their true duty, assisted by the lateral incisors. The posterior division contains the machinery peculiarly adapted to the process of grinding or comminution. There is a central sphere of activity here likewise. That resides in the first large grinder, which is the standard tooth of division or comminution, crushing everything with great force upon which it is brought to act. In this duty it is materially and most efficiently assisted by the two small grinders in front, and the second and third large grinders behind. The centre of its action nearly corresponds with the centre of the great moving power of the jaw; so that there is a great concentration of force in this division. Such, then, are, generally, the duties exacted from these parts throughout all the races of mankind; and, having already explained the machinery by which the fulfilment of these duties is provided for, I come now to point out some peculiar considerations connected with the skeleton of the mouth, which will assist in explaining the ethnological signs exhibited in these parts.

"The most recognizable ethnological features are to be found in the anterior division, which presents, on the one hand, the prominent jaw and everted teeth of the negro, more particularly; and, on the other side, the crowded and irregularly-arranged teeth and perpendicular jaws of the Caucasian tribes. Both the other divisions of the dental arches, however, display, in like manner, characteristic features corresponding with these two states of existence, and which I shall endeavour successively to bring under attention. The anterior portions of both jaws may be considered as concentric arches. The arch formed by the edges of the teeth in the upper jaw being produced from a little longer radius than that formed by the edges of those in the under, it is evident that if these two arches are forcibly brought into approximation, the external arch of the superior jaw, with its contents, must yield outwardly; because, by forcibly applying the crown of an arch to the internal portion of another arch, you obviously afford to the internal arch an incontrollable mechanical advantage. It is also evident, that the forcible retention of any substance between these two arches must increase the intensity of the mechanical advantage, and the tendency of the lower to evert the upper. If we reflect on the peculiar anatomy of the parts, it will be seen, too, that the superior jaw yields to a much greater extent than the inferior. The median suture of the arch of the under jaw is soon consolidated; whereas, there remains a permanently ununited suture in the upper. But its plasticity is still further provided for, and in a more efficient way, by the presence of the intermaxillary bones, which, as their name implies, are situated in the centre between the bones of the true maxilla. These bones have not been generally recognized as separate existences in the adult human subject, though it is universally admitted that they are present in infants, and that they are occasionally to be found distinct throughout life. Some authors have even asserted that the absence of these bones forms a characteristic in man. But they are of practical importance; and although, if carefully searched for, may be recognized throughout life, yet it is quite sufficient for my present purpose to know that they are recognized in early life, as that is the period at which the characteristic features are given to the osseous framework, and which continue to the end of our existence. Separate centres of ossification are to be met with here; and the radiations of these ossific growths are directed to the maxillary bones on each side, the median suture dividing them in the median line. The transverse suture runs almost directly across the palate from the centre of the one alveolar process of the canine tooth to the other, comprehending, in that manner, the whole of the anterior region of the dental range, and implicating, in developement, the centre of activity of the central region of the arch. The intermaxillary bones thus effect, by their presence, such a form of arrangement as to admit of great plasticity in the anterior arch of the mouth.

" I have already briefly adverted to the ordinary duties required of the teeth situated in the anterior portion of the mouth; and a moderate exercise of these may be considered their particular duties in a somewhat advanced stage of cultivated human existence. If these teeth are duly exercised, and proportionately with the others, we have then a developement properly fitted for all social requisitions, at once affording the power of perfect articulation and perfect mastication. Articulation is entirely performed in this region of the mouth; and although mastication, properly so called, is not performed here, yet it is materially interfered with by any deviation from a regular arrangement even in this quarter. Thus, where there is an excess of luxury and indolence in social life, we find, from the want of functional exercise, that the jaws are not duly developed, and that early anchylosis of the different sutures is the result. From the osseous portion not being properly developed, space is not afforded for the accommodation of the second set of teeth. The second or permanent teeth, in the early stage of infantile existence, are arranged in the jaw behind the temporary teeth, and, consequently, in the arch of a circle of a shorter radius than that in which their predecessors are placed; and, being of larger dimensions, and confined within a smaller compass, they are forced to overlap each other in the very early and unextruded state. The indolence of the system will thus permit these teeth to creep into external existence in fœtal arrangement, and they really do appear in that condition in the heads of a great proportion of the adults of civilized life. In such cases, unless corrected by art, the mouth approximates a carnivorous type, and inertness of comminution or grinding in the posterior or true masticating region is the consequence, from the impossibility of using the jaws in such an operation. Articulation, also, is sometimes materially interfered with from the unequal surface produced by the irregular arrangement of the anterior teeth upon which the tongue has to act. These irregularities of arrangement are some of the penalties of the irrational habits of social existence, and are never to be found amongst uncivilized races. Amongst races existing in a good climate, and where there is no deficiency of exercise or nourishment, a perfect developement of the mouth, as well as of all other parts, follows. There is then a regular symmetrical arrangement of the teeth, the best adapted for perfect articulation, and for mastication, leaving the teeth perfectly arranged, and fully developed. The entire range then forms a perfect parabola, each tooth standing nearly perpendicularly to the portion of the alveolar ridge to which it is attached; and that, it is evident to me, is their normal developement. That disposition is to be found in the vertical mouth of the Caucasian races, which, in my opinion, must have been the original developement of mankind; and from which there is no difficulty in tracing all the varieties of the human species which have ever appeared on the face of the earth.

"Having attempted to explain the deviations from this type in the dental organs of social life by neglect of the exercise of the functions of the parts, I shall next endeavour to show how abuse, in a contrary line of habit, produces a developement in an exactly opposite direction. I have described the arrangements which afford an extensive latitude of plasticity in the upper jaw, admitting of the parts to be modelled by the exercise of their ordinary functions. But in uncivilized life, extraordinary functions are called into action, and a great excess of energy is also thrown into those of an ordinary description.

" The ordinary duties required of the mouth in civilized life, as I have observed, are a moderate exercise of power for division, tearing, and comminution or grinding. In uncivilized life, however, there are superinduced upon these more powerful exactions, which have a great controlling influence over the developement of the parts. Man, in the uncivilized state, has but few instruments or tools to assist him in operations of any kind, and his teeth are ready substitutes, which on all occasions, from infancy to old age, he most unscrupulously resorts to. He attacks the roughest materials of all kinds with his teeth. He uses them to form and to fashion those materials in all sorts of ways; and thus his mouth has a prehensile character. He also uses his teeth as instruments for punishing his enemies, seizing his prey, and separating the assimilative portions of his food from those which are not. In fact, they assist him on all occasions, and the forcible tearing which is habitually exacted from him, owing to his want of artificial instruments, and the little assistance he derives from cooking, tends, most decidedly, to evert both the upper and the under jaw. Even at the earliest period of uncivilized existence, habits prevail which powerfully contribute to that extra developement which produces the prominent mouth. We learn from actual observers, that the uncivilized mother suckles her offspring for the protracted period of two years or more, and that the prominent mouth does not exist in infancy; but its developement is assisted by the habit of long sucking, which acts powerfully on the then very plastic condition of the bones of the jaw. Indeed, in social life, we have frequent examples of the modified effect of habits giving a like tendency in infancy to the protrusion of the anterior portion of the upper jaw, such as the child being allowed to suck its tongue or its fingers, or having to be fed for a long period from a hard bottle.

"Acts calculated to have an effect in moulding the jaw are not limited to infancy; they may extend throughout life; and the prominent developement will always be found in proportion to the ratio of power of the under jaw; and we have not only seen how well the anatomical arrangement of the osseous parts admits of these mouldings, but we must be satisfied that the design is perfect in allowing of such modifications; otherwise they would have been constantly exposed to injury by force from without, and concussion from within. This plasticity, however, is limited. An examination of the skeletons of individuals with prominent jaws will demonstrate that it is a simple modelling of the original quantity of material which is effected. Beyond a full and perfect developement of the parts, there is no peculiarity excepting the eversion of the material, or the placing of it in an altered position.

"To form the mouth of any other animal than man, difference of structure, and a different specific quantity of material, become necessary. There is an accumulation of effect in particular directions, occasionally discoverable, which produces aberrations so extensive that they cannot be explained but upon the admission of the principle of hereditary transmission. Thus, in what I have stated, and in what may follow, it is not to be understood that the effects described as occurring are to be attributed entirely to the exercise of the functions of the parts during one generation, but as being the result of a succession. What the appreciable effect in one generation may be it is impossible to determine upon the data which we at present possess.

"If it be fully confirmed that the mouth of the infant negro is not prominent, it will be interesting to study the extent of the hereditary influence, and the period of developement of that influence. I have hitherto alluded principally to the circumstances attending the developement of the anterior portion of the mouth, including the incisors and canines; but characteristic habits of different races produce also corresponding deviations in its posterior region. A crowded state of the teeth, from want of due expansion and developement of the bones in which they are implanted, producing an irregular pressure of one against another in the progress of growth; and a faulty organization of the dental tissues, increased by that irregularity, are amongst the effects of constitutional inactivity, depending on the habits of social life. But there is one serious evil which is only known in social life; and that is, the derangement interfering with the functions of the mouth, which is occasioned by the arrested developement of the jaw, causing a deficiency of room for the developement of the wisdom tooth. This, at times, causes great distress; and even death, by a slow process of torture. If that tooth at last struggle into external existence under such difficulties, it is, in a great majority of instances, found to be worthless, and only a source of torment to its possessor. On the other hand, however, we find that the rude uncivilized tribes of mankind possess a bold, well-developed, and healthy organization of structure in all the parts, and one free from irregular pressure. The wisdom tooth in them is so well developed, free in its position, and healthy in its structure, as to have induced some naturalists to consider themselves warranted in regarding it as a feature of approximation to the monkey tribe, although its good condition is nothing more than a feature of healthy developement. The capabilities of this section of the mouth being limited simply to that of comminution, or grinding, it is not so much subject to the effects of abuse as the anterior portion of the dental range. Perhaps the only abuse of it is, that of exercise on food calculated to wear away the grinding surface of the teeth. The Hindù, the ancient Egyptian, and others, present examples of these surfaces being entirely worn away; and even of the teeth in the anterior and median portions of the mouth being reduced to truncated forms. The cause of this peculiar effect appears to be the roughness and grittiness of their food, and, in some cases, the almost exclusive consumption of food of a vegetable character. This is a powerful reason why man ought to be considered an omnivorous animal.

"Notwithstanding all I have said in favour of the more perfect developement of the mouth in the rude and uncivilized tribes, they are, nevertheless, not altogether exempted from the ordinary diseases of the teeth. Independent of the habits I have referred to as affecting the arrangement of their teeth, and the developement of their jaws, natural decay and disease occur, which we may refer to the state of health of the parents, the period of procreation, the circumstances under which their systems are at the time of production, and the inadequate nature of their nourishment, more especially in the early stages of existence. The general correctives of all these evils of developement are energetic exercise, both of body and mind—residence in a healthful climate, pure air, and a due supply of wholesome and nourishing animal and vegetable food,—not only in regard to individuals, but to successive generations. Combe remarks that 'no object can be presented to the philosophic mind more replete with interest than an inquiry into the causes of the differences of natural character.' Every one must feel the force of this remark, and not only assent to its truth, but also to the converse of the proposition, and agree that nothing can yield more pleasure to the philosophic mind than an inquiry into the effects which the natural character, with its accompanying habits and customs, produces on the human frame. I am persuaded that a study of the latter, conducted on proper principles, and elucidated by practical facts, would tend to the explanation of phenomena which have hitherto been referred to erroneous origin.

"The circumstances by which man is surrounded in uncivilized life do not afford opportunities for the cultivation and enjoyment of the higher faculties; and, accordingly, we find that a low retiring forehead is a concomitant of the prominent mouth. Another marked concomitant is that feature of countenance which is produced by the high cheek bones. The osseous frame-work of that prominence is composed of the portion of the superior maxillary bone in which the grinding teeth are implanted, and the true cheek bone or malar, which, with the zygomatic process of the temporal bone, forms the arch through which the temporal muscle or powerful levator of the under jaw passes. The first of these portions, namely, the portion of the superior maxillary bone, containing the molar teeth, is surmounted by the antrum or hollow ball of the cheek. The fangs of these molar teeth embrace the floor of this hollow, in the manner of beams or joistings. It is evident, that as these teeth are powerfully developed, the fangs will be strong and divergent, and thus increase the volume of the ball of the cheek. The exactions of uncivilized life produce that effect, and we, therefore, have this consequence. With the increase of this ball, we have a consequent protrusion of the bones which rest on this portion of the superior maxillary bone, namely, the malar, and through it the zygomatic process of the temporal. There is, however, a powerful concomitant increment to the protrusion of these latter bones, by means of the powerful action and developement of the temporal muscle passing under it, and exercising its force with its consequent increase of bulk in expanding that arch.

"Although we have many well-authenticated cases recorded of these peculiar features of the human countenance being somewhat reclaimed or ameliorated by improvement in the circumstances of succeeding generations, yet there appears to be a greater and longer-continued tendency to the extra developement of these than of any other. The prominent features in the high cheek bones of mountaineers are generally quite characteristic. The Scotch and Welsh Highlanders of our own country are familiar examples. Exposure to a pure atmosphere produces in them keen appetites, which, by encouraging a vigorous mastication, may keep up the hereditary tendency. The concomitant of the flat nose with the prominent mouth, may be accounted for from the inversion of the superior portions of the intermaxillary bones forming the root of the nose; and this arises from the eversion of the inferior borders in which the teeth are placed. The bones thus, as it were, tilted, and receiving no permanent increase of material as they grow, equivalent to form new structures, are pressed upward and backward, and produce this derangement of feature by the inversion of the superior portions of the intermaxillary bones. The same causes will serve to explain the increased distance between the eyes of the uncivilized races, produced by the flattening and lateral expansion of the nasal bones; this being a necessary consequence of the expansion of all the other bones of the face.

"With regard to the other extreme of developement which is generally to be observed in the mouths of civilized men, the concomitants are obvious, and quite as marked as those attending uncivilized men. It must accord with the experience of all, that precocity of intellect is very generally accompanied by an arrest of physical developement and a languid constitution. When we meet with such an arrest of developement and unhealthy secretion in the system generally, we must expect to find a similar arrest of developement in the maxillary bones containing the cavities in which the teeth are lodged. This will occasion a deficiency of space for the proper arrangement and developement of these organs, which, it is curious to remark, under all circumstances, follow the same train of growth as to size. They will also generally be found to be faulty in their structure when they arrive at maturity, or even as soon as they make their appearance externally.

"In addition to the ordinary diseases of the teeth called decay, the effeminacy of social life, the almost exclusive and unremitting exercise of the mental faculties, and a consequently superinduced morbid, nervous susceptibility, cause disease to appear in the sockets of the teeth, which produces their expulsion, although the bodies of the teeth themselves may be perfectly sound. That peculiarity of which both modern and ancient social life affords abundant examples, is frequently found to have existed in the sockets of the teeth of the ancient Egyptians,* but never to have been observed in races of men who have followed a natural course of life. I may remark here, that in the descendants of those who have lived long in social life, the cheek bones are not elevated, from the absence of encouragement to a powerful developement of their basis; but the nose is elevated, owing to its root not being compressed as in the prominent mouth, and this feature is increased in its proportionate appearance from the absence of such a prominency.

"While that protrusion of the mouth is uncommon in civilized society, yet two varieties of malformation may occasionally be met with. The one caused by the projection of the upper jaw to a considerable extent over the under; and the other by that of the under beyond the upper. Generally speaking, both cases arise from an arrest of developement in the jaw where expansion of the arch is deficient. The projecting upper jaw, however, as I have already stated, is very often the result of a habit of sucking the tongue or finger in infancy.

* Morton's Crania Americana.

"It would be impossible, within my present limits, to appeal largely to history in support of all these facts and hypothetical enunciations; but if it were, I should hardly conceive it would be necessary, as a slight reflection must supply to the recollection of every one abundant general proofs in support of them, and which, on such an occasion as the present, is all that can be required. In conclusion, I cannot help simply remarking, having abstained for the sake of brevity from making many illustrative observations, as well as referential remarks upon the different points glanced at, that there is a curious train of results of peculiar forms of the mouth affecting the articulation of sounds, which it would be very interesting to study and to trace throughout all their modifications. The effects of the modifications are so very striking and decided, that I have no doubt an investigation into them would lead to many useful and interesting results."

Relation in respect of developement between the cranium and face.

The relation in degree of developement between the cranium and face offers some variety at different periods of life, and considerable diversity amongst animals; these differences mainly depending on the extent of developement of the organs of smell and mastication. The comparative size of the cranium and face is also an indication of the relative proportion of the brain to the inferior organs of sense above referred to, and hence becomes a means of estimating the proportion subsisting between the mental and the animal faculties. The facial line of Camper, and the angle which it forms with the base of the cranium, are the most simple of the numerous means which have been adopted to determine this proportion. The ancients were fully aware of the importance of this measurement, and entertained the belief that an angle approaching to a right angle was an indication of a generous nature, and it was admitted to be a conspicuous mark of beauty. Indeed, in the statues and models of their heroes and divinities, we find them exceeding nature in this particular, and carrying their admiration of the principle beyond the precise limit of truth. Among the lower animals the facial angle of Camper is found to become more and more acute as we descend in the series of mammifera, and from the latter pass on to birds, reptiles, and fishes. But it must not be inferred that a mere elongation of the snout necessarily betokens deficient intellect, for this character simply indicates the existence of a highly developed organ of smell or mastication, without reflecting on the relative smallness of the brain. On the other hand, the great prominence of the anterior part of the cranium of the elephant, which gives him an aspect of superior intelligence, has no reference to the size of the brain, but to the unusual dimensions of the cells of the cranium ; an organization having relation to the huge size and great weight of the teeth, tusks, and trunk, which require large muscles to support and move them, and an extensive surface of attachment for their origin.

Bearing then in mind that the variation in the facial angle has reference to the developement of the mouth and nose, as well as to that of the brain, it may be interesting to glance at the relative admeasurement of this angle in several of the races of man, and in the higher quadrumana. For example, the measurement of Camper's angle in the

European is	80^0
Mogul	75^0
Negro	70^0
European infant . . .	90^0

The difference between the infant and adult European is plainly referrible to the deficient growth of the face in the former, and not to superiority in cerebral developement. In illustration of this point I may remark that the angle in the

Chimpanzee, adult, is . . .	35^0
Chimpanzee, young . . .	67^0

Ouran Outan (Pongo), adult . .	40^0
Ouran Outan, young, previously to the exchange of the deciduous for the permanent teeth	65^0

In many animals the facial angle is modified by the amount of expansion of the frontal sinus. This circumstance obviously affects its fidelity as a measurement of the developement of the brain, and in like manner it is open to the objection of giving no idea of the breadth of the cerebral organ.

CHAPTER X.

DEVELOPEMENT OF IVORY.

WITH the data before us contained in the preceding chapters, in elucidation of the structure of the ivory, and of the various organs engaged in the formation of the teeth, we are now in a position to enter upon an inquiry into the mode in which the ivory is developed; and, I may remark, at the outset of this inquiry, that I am not aware of any further advances into the investigation of the intimate changes concerned in this process having been made since the details of my researches were communicated to the public in 1839, in a paper read before the meeting of the British Association.

Being at that time desirous of satisfying myself with regard to the nature of the tissues which were constantly passing under my notice, and wishing to verify the observations which had recently been made on the continent, I instituted a series of examinations for that purpose. The results of these observations having betrayed to me facts novel in themselves, and seemingly of importance, I hastened to place them under the protection of the British Association in 1839. In my communication to that body, I established by demonstration, the *cellular structure of the ivory*, the *cellular structure of the parenchyma of the pulp*, and the regularly organised *cellular structure of its peripheral portion* and the *transition of this peripheral layer into the cells of ossific matter* composing the ivory. In treating on this subject I was anxious to lay before the British Association an anatomical demonstration of these structures, so as to leave little room for hypothesis in any theory that might be subsequently adduced. The great practical question which I desired to determine was, whether the ivory of a tooth was or was not organised; and if it were, what was the nature of that organisation? This question I decided by establishing, in the first instance, the cellular structure of the interfibrous material. This point of structure had not hitherto attracted the attention of physiologists, but being once established, it constituted a true basis wherefrom to start in following out the stages of developement of these textures; and it at once annihilated the notion of growth by exudation. I expressed myself on this subject to the following effect:—

" The writings on the subject by Retzius, Muller, and others, leave us to conclude that the interfibrous substance does not present any traces of peculiar conformation:—but I am disposed to believe that it is not only organized, but so differently and characteristically so in different animals, as to be capable of affording valuable aid to the naturalist in classifying the animal kingdom.

" In illustration of this subject, I beg to refer to the drawings, showing the characteristic varieties of this conformation. (Figs. 18 and 19, page 94.) The beautiful characteristic varieties of this cellular conformation in different classes of animals, show the delicate nature of the process of transition by which it is produced.

" My attention was first drawn to the structure of the interfibrous substance on examining a delicate section of the fossil tooth of a rhinoceros, by the aid of a very high magnifying power; and I must here remark, that those who repeat these investigations, the results of which I am about to detail, will find it necessary to make use of a magnifying power of one tenth of an inch focal distance, and of the most perfect kind, with an achromatic condenser of the light. The instrument with which I have conducted my researches, and upon the accuracy of which I place the greatest reliance, is that of Mr. Powell.*

In the section of the tooth of the rhinoceros to which I have just alluded, will be observed an appearance of cells or compartments. This I at first imagined might arise from fractures of the material, but on examining other sections of fossil teeth, and at the same time seeking whether this cellular appearance could be observed in recent teeth, I was enabled to demonstrate that in every case this peculiar appearance was that of real structure."

The nature of cell-life, at the time I made these observations, had been but little studied; nevertheless, the general phenomena presented by cells were sufficiently known to make me aware of the interesting nature of the above discovery, and I felt persuaded that further research would tend to harmonise the observations made upon the other portions of the tissue of teeth. I examined carefully the minute structure of the so-called tubes or fibres of different kinds of ivory, and in reference to this examination I remark:—

"I have also made researches into the structure and composition of the fibres of different teeth, and have generally found that these present an interrupted or baccated appearance, as if they were made up of different compartments,—an obvious concomitant of the cellular structure of the interfibrous material. The size and relative position of these portions or divisions of a fibre differ in various series of animals. In the human subject, for instance, each compartment of the fibre is of an oval shape, and its long small extremity is in apposition

* All the anatomical observations detailed in these memoirs were frequently repeated, were verified by the eyes of others, and the preparations were faithfully copied by my talented artist. It may require some practice, and a certain degree of proficiency in manipulation, to produce and examine such preparations of the pulp and ivory in the human subject, but they will not fail to be attained by those who devote themselves perseveringly to the subject.

to the one next adjoining. The long axis of the oval corresponds with the course of the fibre. In some species of the monkey tribe the fibre appears to be composed of two rows of compartments parallel to each other. In the orang-outang the fibre is composed of rhomboidal divisions, and in the baboon, they are oval like those of the human subject, and the surfaces of the long axes are in apposition. In fact, each class of animals seems to have a distinct characteristic appearance, but all are similar in respect to the general baccated appearance. A few examples of this structural arrangement are seen in figures 8, 9, 10, and 11, page 90, showing its appearance after the earthy matter has been removed."

Continuing these investigations, it appeared to me to be quite evident that the animal matrix of this cellular structure must have its origin in the pulp. I therefore directed my attention to the intimate composition of that organ, and found the cells displayed in a most interesting and clearly defined manner in the superficial stratum of the pulp. In relation to this structure, I observed, in the paper already referred to:—

" Having thus uniformly found appearances denoting cells or compartments in all these states and stages, I became doubly eager to investigate the structure of the pulp, with a view to discover the nature of the process by which this cellular structure is produced, and the source from which it is derived." The conclusion deduced from my investigation was, " that the pulp is cellular throughout its entire structure.

" I at first experienced great difficulty in submitting to minute examination the superficial portion of the pulp ; that is to say, that portion of it where its transition into ivory takes place; but I at length succeeded in obtaining a clear view of it, and found it to present the beautifully interesting reticulated cellular appearance which is represented in the series of drawings, figures 12, 24, 25, 27, 28, and 29.

" Having ascertained that this reticular conformation was constant, I proceeded to study it with confidence, and soon found that it was essentially concerned in the process of the developement of the ivory, and in the production of the fibres of the latter, as well as of the interfibrous substance."

"Thus, there is a remarkable uniformity in the structure of the formative tissues of the tooth, and of the dental substance itself; for not only is the interfibrous material cellular, but the pulp, which is the organic framework of the ivory, and the internal or productive layer of the capsule, also uniformly present a reticulated or cellular appearance."

I have already, in Chapter VI., stated my views with regard to the nature of the connexion subsisting between the pulp and the ivory, and I may render this subject more evident by referring to the following wood engravings, which illustrate the transition of the pulp into the ivory by a solidification of its cells.

FIG. 32.*

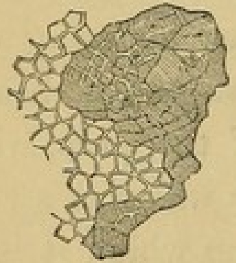


FIG. 33.

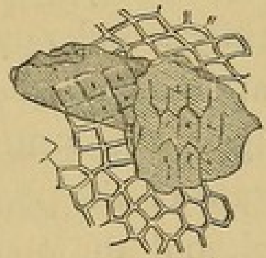
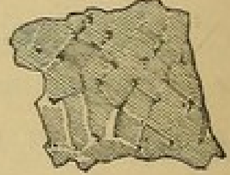


FIG. 34.



* Figures 32 and 33 exhibit the manner in which the cells of the pulp are converted into the ivory cells; and also serve to illustrate the communication subsisting between the pulp and the ivory.

Fig. 34. A small portion of pulp completely transformed into ivory.

Fig. 35. Another figure, exhibiting the conversion of the superficial layer of the pulp into ivory cells. The crystals seen on the figure are accidental formations.

Fig. 36. Another figure, exhibiting the same change.

Fig. 37. A portion of the pulp of a young tooth, exhibiting different stages of transition into ivory. The appearance of a nucleus is due to the aggregation of particles of calcareous matter in the centre of each cell.

FIG. 35.

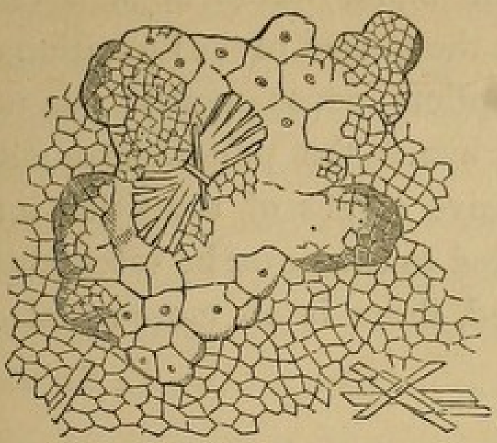


FIG. 36.

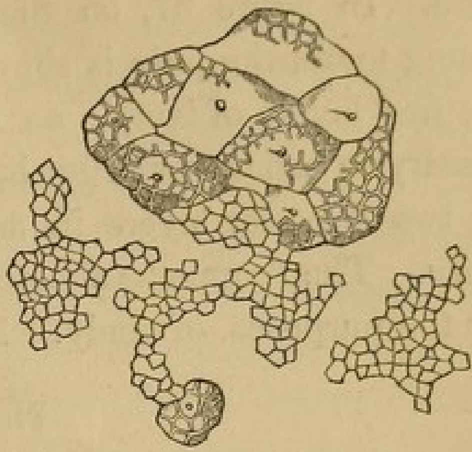
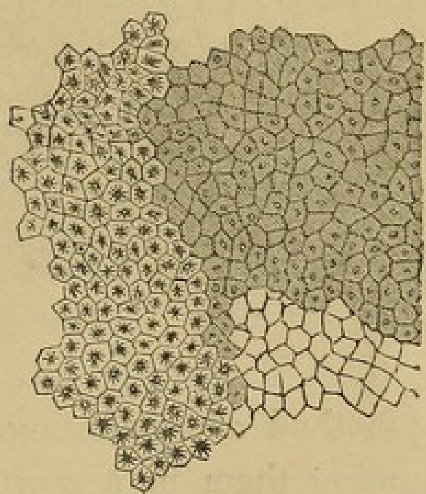


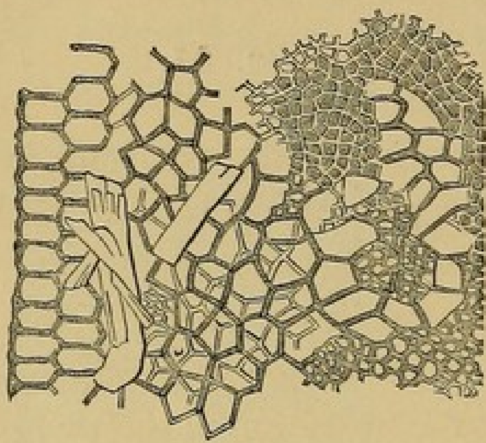
FIG. 37.



On the surface of the pulp are found innumerable detached cells, with central points. Generally, these cells form a regular and complete coating, studded with points, which are placed at intervals, corresponding in extent to the intervals between the fibres. (Figures 32, 33, 34, 35, 36, and 37.)

" It is almost unnecessary to state that it is impossible to obtain a clear view of the surface of the pulp after the process of the formation of ivory has commenced without breaking away or forcibly separating in some manner, the superincumbent crust of ivory from the pulp beneath; and in this disruption the ivory is always somewhat shattered, and the surface of the pulp is found with separate cells and cellular fragments of all shapes, and in every stage of transition, strewn over it. In figures 32, 33, 34, 35, 36, and 38, are seen fragments of this kind. In figure 37, on the other hand, which is of a very young tooth, the pulp is shown at the period of the formation of the first layers of ivory; no disruption, consequently, was necessary in order to exhibit it, and hence the pulp is seen with its two superior layers in successive stages of transition into ivory. The fragments above alluded to can never be too minute for the purposes of study. Indeed, there is no more satisfac-

FIG. 38.*



tory and interesting method of examining all hard organized bodies, than by pounding them in a mortar;† fragments thus produced present themselves under an infinite variety of aspects, and display, in the most various and complete manner, the structure of these tissues. Such particles will never be too small for observation in the focus of the instruments of the present day. With respect to the preparation of anatomical specimens like the above-mentioned, where the formative sur-

* Fig. 38. A portion of the peripheral layer of the pulp, showing the shape and arrangement of the cells which compose it. Some crystals of earthy salts suffused from the ruptured transition cells are seen lying on the surface of the preparation towards the left, and on the right is seen the transition of the cells into those of ivory. The cellules evolved in this process present themselves under all aspects, and correspond with the position in which the structure is viewed.

† See observations on this method of examining ivory at page 93.

face of the pulp is shown by the removal of the ivory, I may observe that considerable patience and perseverance, and an abundant supply of subjects of investigation, are indispensable before they can be properly made; and that even great proficiency and experience will not always insure success, which necessarily depends, to a certain extent, on fortuitous circumstances, such as the nature and state of the subject, the direction and degree of the fracture, &c. It sometimes happens that out of a great number of fresh-drawn teeth, not one available preparation of this kind can be made. The pulp and the ivory being in positive union, the separation at the proper point seldom occurs. When, however, the industry of the inquirer is at length rewarded by a successful preparation, he will be gratified by a view of phenomena of the highest general physiological interest, the importance and full bearings of which could only be glanced at in the present memoir.

" It has been asserted that no preparations can be made from mammalia showing the transition of the pulp into ivory. Such a statement can only have originated in inexperience or in ill success, arising from causes hinted at above; since the number of such preparations of the most satisfactory kind which are in my possession, (and which I am always glad to exhibit to any person who may feel a wish to see them,) are a sufficient evidence to the contrary.

" A comparison between the superincumbent perfect ivory, and the formative substance of the pulp beneath, is always easy, because portions of the former, at an early stage at any rate, remain adherent to the latter, and fragments of the dental bone are found strewn over it, more especially in human teeth, as shown in the preceding figures.

" The cellular conformation of the fragments found on the surface of the pulp is always evident, and in size and appearance they are perfectly accordant with the cells of the pulp. (Plate 10, figs. 3 and 4, and fig 39.)

" At an early stage of dental developement, the reticulated or cellular appearance of the pulp is particularly beautiful. When merely a thin layer of the ossific matter has been deposited on its surface, the pulp may with great facility be drawn out entire, together with the former, laid on a glass, compressed a little, and examined with the high powers of the microscope. The different layers of cells will then be seen, and the transi tion into ivory may be observed. (See figure 37.)

FIG. 39.*

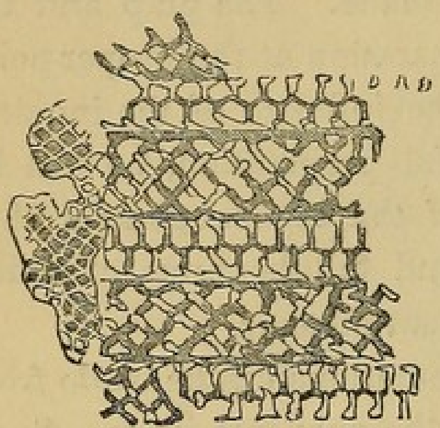
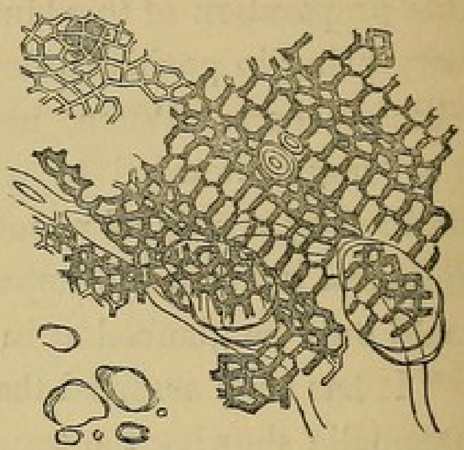


FIG. 40.†



"The wood engraving (figure 12) represents the general arrangement of the reticular leaflets of the surface-portion of the pulp. In figure 29 is seen a beautifully organized single leaflet of this reticular surface, in the pre-existing cells of which the earthy matter is in course of deposition, and the

* Fig. 39. A portion of the layer of transition pulp cells where the ossification has commenced to thicken their parietes, and where the bulbous point marking the nucleus is generally visible in some part of these parietes. The portion to the left-hand is most advanced in ossification, and displays the cellules with which the cells are filled up during that process. The bulbs or nuclei above alluded to are more distinctly displayed when the pulp has been submitted to diluted muriatic acid, which empties the transition cells of their earthy contents.

† Fig. 40. A view of the peripheral layer of the pulp with the cells in a partial state of ossification. The deposit is seen to collect in the first instance around the walls of the cells, which consequently become thickened. Capillary blood-vessels are seen running under these transition cells.

process of ossification is seen to be gradually extending from its centre towards its circumference. Figure 40 shows the blood-vessels coursing beneath the reticular formative surface. This drawing is an exact copy of the preparation, in which, as is seen, the blood-vessels have been ruptured in two places, in separating the ivory from the pulp, owing to the close connexion between the reticular surface and the ivory already formed. Pulp, figure 36, and Plate 10, figure 4, together with figures 17, 32, 33, 35, 36, 37, 38, 39, and 40, are a selection from the interesting preparations which I have made for the purpose of elucidating the process of the formation of ivory. They display under various aspects the different appearances, some constant, the others incidental, which present themselves on the removal of the superincumbent ivory from the surface of the pulp beneath. The whole appearances denote the existence of a peculiar system of cells external to the peripheral ramifications of the blood-vessels, the functions of which are highly interesting, and the study of which will ultimately lead, I think, to the unveiling of many vital processes connected with the growth of animal tissues, which are at present shrouded in obscurity."

After determining that the interfibrous substance was the result of a transition of the cells of the peripheral layer of the pulp into the compartments composing the ivory, it became interesting to be able to trace out the manner in which the fibre was produced. The theory of cell-life and constitution being at that time in its infancy, I did not feel confident as to the developement of this structure. That the fibre was formed by a series of nucleolar bodies derived successively from separate cells was quite evident, and also that these nuclei were situated in the boundary of the cells I was quite satisfied. It is true that the frequent appearance of nuclei in the centre of the cells puzzled me for some time, but I was enabled by perseverance to overcome this obstacle and discover the cause of the appearance referred to. It need hardly be stated that the transition cells of the pulp resemble in structure the cells found in other situations. They are composed of a membrane, a cavity, and a nucleus. At first sight it is difficult to determine the precise situation of this latter essential constituent of a cell. The number of minute corpuscles scattered through the substance of the pulp is one cause of the difficulty, and, moreover, in certain portions of the structure the nucleus is decidedly central. Figure 37, page 191, is an example of this position of the nucleus, the calcification taking place at the peripheral portion of the neck of the tooth. Beyond this point, however, the nucleus assumes a lateral position. In the report of my investigations to the British Association I refer to this subject.* An observation subsequently made on the structure of the ivory still further elucidates the position of the nucleus, and the correspondence between the cells of ivory and those of other tissues.

In the quotations which precede I have endeavoured to substantiate my belief in the cellulated structure of the pulp, the well-marked cellular arrangement of the superficial layer of the pulp, and the conversion of these superficial cells of the pulp into ivory by the deposition in their interior of calcareous salts. I have, moreover, declared that the boundaries of the individual cells constitute a net-work on the superficial layer of the substance of the pulp, that the constituent nucleus of these cells is situated in the cell membrane or reticular wall; and that the fibres of the ivory are composed of these nuclei. The nuclei are persistent; they are arranged in linear succession, and become confluent without experiencing any other transformation than that of passing from the body of the pulp to the body of the ivory. They are thus imbedded in osseous structure, but still retain their character of animal tissue, and they constitute the baccated fibre which is discernible with more or less distinctness in all fibro-cellular ivory. All this is a plain demonstration of the transition of the substance of the pulp into that of ivory by means of ossific deposition. The converse of this demonstration, namely, the existence of

* See page 96 of this volume.

signs of the above-described origin in the perfect ivory has been already fully established. It will be seen, also, that the above demonstration was made in the month of August, 1839, and the Academy of Medicine of Paris, to whom my researches were referred for judgment, close their report with the following observations:—

"This new fact," namely, the cellularity of the ivory, "is elicited very clearly by Mr. Nasmyth's preparations, and its importance is increased by the source and origin of the cellulated structure being shown to be the primitive areolar constitution of the pulp, and by the repetition of a similar primitive arrangement of the molecules entering into the composition of the enamel.

"If these last-mentioned facts possess considerable interest in an anatomical point of view, we have endeavoured to show that in a physiological light, their interest is much greater, since their immediate effect is to substitute for the hypothesis of the excretion of the ivory, the more natural one of an internal secretion, or transformation of the pulp.

"After these considerations, and in compliance with the resolutions contained in the Report, your Committee has the honour to propose that the approval of the Academy be signified to Mr. Nasmyth, and that he be invited to publish as early as possible the application of his researches to the study of the fossil remains of animals. The Committee would also have requested the insertion of his paper in the 'Recueil des Savants Etrangers,' if the author had not expressed his intention of publishing it shortly." *

The most interesting part of modern physiological investigation is that which proves the processes of nutrition, growth, and all other organic changes, to be resident in a system of minute extra-vascular bodies called cells, possessed of a vitality peculiar to themselves. It is in these pigmy laboratories that

* Comptes Rendus Hebdomadaires des Séances de l'Academie des Sciences, vol. xv. p. 1070.

all the operations required for the perfection of organic structures are carried on. The blood-vessels and their capillaries are simply the feed-pipes of this curious system, conveying to them the material of nutrition, but taking no part in its elaboration. Every step, therefore, in advance, which shall have the effect of improving our acquaintance with these minute bodies must be of importance. It was my conviction of this fact that prompted me to consider the observations which I had made of the continuous cellular structure of all the tissues of the teeth of sufficient interest to merit the attention of the British Association. The demonstration of these views stood forth in bold relief by the side of the prevailing opinion of the secretion of the ivory by the pulp ; and my further researches into the same subject, continued to the present time, tend only more strongly to convince me of the close affinity subsisting between the dental and other organised tissues of the animal frame.

The rapid advance which has been latterly made in our knowledge of the phenomena of cell life has revealed an inexhaustible field of philosophical inquiry. The Messrs. Goodsir, in allusion to this fact, very truly remark :—" The ultimate secreting structure then is the primitive cell, endowed with a peculiar organic agency according to the secretion it is destined to produce." " It consists, like other primitive cells, of three parts, the nucleus, the cell-wall, and the cavity. The nucleus is its generative organ, and may, or may not, according to circumstances, become developed into young cells. The cavity is the receptacle in which the secretion is retained, till the quantity has reached its proper limits." *

These opinions are the result of observations by those genmen, extended into organs of every kind, and prosecuted in a variety of members of the animal kingdom, and may be very fitly applied to the elucidation of the subject before us. It is

* Anatomical and Pathological Observations, by John Goodsir, F.R.S.E., and Harry D. S. Goodsir, M.W.S., 1845.

evident that the nucleus is the essential operative element of all the actions of organic life, and that it is in it that all the movements of change concerned in the taking up and elaboration of materials are performed. "The nucleus," Mr. Goodsir remarks, "is the part which effects this, namely, the important function of separating and preparing the secretion contained in the cell cavity." The value of these minute extra-vascular bodies is, therefore, very considerable, and the observation of the peculiar secretion of earthy material contained in the cells of dental tissues would, without other evidence, lead to the conclusion that a similar agent must be present in them. In one of my memoirs, communicated to the British Association, I remark upon the conformity of structure subsisting between the pulp and the ivory, and demonstrate the fact by reference to the appearance of reticulations in the latter. My theory indeed is most simple; the cells of the pulp are converted into ivory cells by the deposition within them of earthy salts, and the cells so converted, with their nuclei, are the perfect ivory; moreover, the nuclei assume a peculiar arrangement, and constitute the structure which I have described and demonstrated under the name of baccated fibre.*

In my demonstration of the transition structure of the pulp to the British Association, I felt and expressed a diffidence in deducing from that examination all the phenomena which appeared to be involved in its metamorphosis. I felt that the doctrine of cell-life and cell-function was still in its infancy; and the vast addition to our knowledge on this topic, made since 1839, fully justifies my anticipations. The following quotation from Mr. Goodsir's work gives a correct idea of the progress made in this department since the period referred to. "A primitive cell absorbs from the blood in the capillaries the matters necessary to enable it to form, in one set of instances, nerve, muscle, bone, if nutrition be its function; milk, bile, urine, in another set of instances, if secretion be the duty assigned to it."

* See page 93.

Now the transition cells of the peripheral portion of the pulp must evidently perform a mixed function, combining the processes of absorption, nutrition, and secretion. They are in close relation with the blood-vessels on the one hand, and the newly-formed perfect ivory on the other. And there is no other structure present which can absorb the plasma of the blood, eliminate its formative material, and appropriate the elements of secretion. In all these respects, therefore, the pulp-cells fulfil the conditions required of centres of nutrition in other organs. Moreover, these cells are distinctly perceived to possess a nucleus attached to the cell-membrane or membranous boundary of the cell, a structure which renders the analogy complete. In the subsequent stage of progress of the cell, its interior becomes filled with calcareous salts, and is thus transformed into solid ivory, while the nucleus, as in many other organised structures, remains persistent, and retains its animal composition. It is these nuclei in their totality which constitute the baccated fibres of the ivory.

It is hardly necessary to observe, that in nature's operations, which we can explore only in their results, and in which the living process is not within the reach of human eye, our only information must be deduced from carefully-conducted examinations of appearances which present themselves at progressive stages of the advance towards completion. When I communicated my researches to the British Association in 1839, I felt at a loss to comprehend fully the meaning of appearances which I found to be constant and positive in relation to the developement of the fibre of ivory. But the examinations made since that period into the laws which govern vital phenomena, render the explanation of these appearances both obvious and simple. In the memoir to which I have so frequently referred I remark:—

" It appears to me that the framework of the reticulation, or cells of the pulp, constitutes the fibres of the tooth, which, while in this *state*, are spirally coiled, and fit into one another.

At all events, the diameter of these *fibres of the reticulations* is precisely that of the fibres of the ivory; the points or projections rising from the framework correspond to the *centres* of the cells, and may be traced to belong to their structure. The fibres composed of granules of animal matter, and which I describe as the framework of the reticulations, become, upon the deposition of ossific matter within the cellules of those reticulations, the fibres of the ivory. The only change which they appear to undergo during the process of transition, is, that they are then drawn out from the coiled-up state in which they exist between the collapsed cells of the reticulations into the more longitudinal but still spiral form in which they are found in the ivory. This will be fully understood by an examination of the wood engraving, fig. 17, page 94. The fibres of the ivory are frequently very spirally curved, like those of the pulp, and as we should conclude they must be from the manner of their *evolution*. Figure 17 shows the appearances presented by a portion of a recent tooth, which has been submitted to the action of acid. Part of the pulp is visible in connexion with the ivory, and the spiral fibres are seen as they are evolved on the surface of the former. It appears to me, on microscopic examination, that this convoluted fibre is made up of single successive granules, which are developed one after the other from the body of the pulp, until the fibre is complete. I have, moreover, already shown that the fibre of decomposed teeth is resolved into separate granules or compartments.

“ The manner in which the osseous matter is deposited in the cells of the interfibrous substance, I have not been able to discover. It would appear, however, that these cells are subdivided into minute cellules, for they present the appearance of being filled with granules in certain progressive stages of developement.*

* In shavings obtained from the perfect tooth, according to the process described at page 95, the granular appearance of the interfibrous material of the ivory is also very distinctly perceived.

"In whatever aspect we view the formative organs of the tooth, and the dental tissues themselves, and whether we examine the latter during the process of their developement, or after their formation has been completed, we are everywhere met by appearances which denote a cellular or reticular arrangement.

"I must allow that these views of the formation and structure of the teeth are both bold and novel, but I do not claim for them infallibility; I simply submit them to the Association as the results of actual observation."

"I think that the view I have taken of the subject more satisfactorily explains than any other, facts of daily experience. The laminated arrangement of the osseous cells explains the concentric fracture of the tusks of the mammoth and of other teeth, when left to decompose spontaneously. The cells being in imbricated apposition, and held together by earthy salts, being moreover arranged in layers conformably with the periphery of the pulp, must be regarded as concentrically laminated. The existence of this structure explains the phenomena daily noticed by ivory-cutters, and also Mr. Hunter's experiments of feeding animals with madder, the result of which is incompatible with any other theory of the structure of dental bone.

"No view hitherto taken of the structure of dental bone has afforded a satisfactory explanation of the ordinary morbid appearances of the tooth, but many of these I think may be explained, if we regard the latter as cellular. Still I do not conceive that I have in any way exhausted the subject; far from it. I am quite alive to the imperfect nature of my researches, and am prepared for correction on many points, when more extended and varied investigations shall have been undertaken."

The repeated observations with which I have continued to engage myself since the presentation of my memoir to the British Association have tended to confirm and harmonise my first investigations, although they have made but little addition to the manner of demonstration. I have, however, succeeded in illustrating one point of considerable importance by the observation of sections of ivory made with the turning lathe in the manner described in a preceding part of this volume. In my demonstration before the British Association, I felt persuaded that the fibre was connected with the lateral wall of the ivory cell; but the whole of the conditions of that connexion were not clear to me until I had obtained the demonstration above referred to, in the perfect ivory of the tooth of man and of the elephant. In my early investigations I had observed only cells with central nuclei, but now I am constantly meeting with cells which have the nucleus in other positions; so that the demonstration of rows of lateral nuclei, unchanged in their original constitution, and invested by the calcareous matter of their cells, becomes self-evident. These cells may now clearly be perceived fitted compactly into each other, and by their close union constituting the solid substance of ivory. It is a slight arrest of this perfection of developement which gives us the opportunity of tracing the nucleolar origin of the fibre, by leaving the nuclei imperfectly confluent, and occasioning the appearance of a row of beads, a structure to which I have assigned the term "*baccated.*" The observation which I had previously made of the filling up of the cells by means of cellules, while in their transition state, is also occasionally displayed in the perfect ivory when examined in the thin shavings procured by the latter. (Plate 7, fig. 4.)

In a preceding chapter I have described the position of the nucleus of the pulp and ivory cell to be lateral; that is, it is in contact with that wall of the cell which corresponds with the laterally adjoining cells; and I have demonstrated this position of the nucleus in perfect ivory by means of thin shavings.* The membranous network formed by the connexion of the cell membranes of the pulp and of the ivory I have termed in

* Page 95.

my memoir "reticulations;" and that linear portion of the network or "reticulation," which corresponds with the position of the nuclei, I consider as the part which becomes the fibre of the ivory, the nuclei being, as I have before observed, persistent, and retaining their animal organisation. In the pulp this linear portion of the reticulation is more or less spiral in its direction; in the ivory it is less so, but the spiral character is still apparent, and it is this peculiarity which gives rise to the undulated appearance of the fibres of the ivory. The measurement of the breadth of the nucleus corresponds accurately with the diameter of the ivory fibre.

The nuclei of the cells of the enamel organ are not persistent, but vanish completely in the enamel cells. The reason of this disappearance I consider to be the cessation of the functions of these cells, a condition rendered absolute by the atrophy of the capsule, and their consequent isolation from their proper vascular organ. In the ivory, on the other hand, the nuclei maintain their relation with the vascular pulp, and their continuity amongst themselves.

In my examination of the structure of the teeth, I have detected appearances which would seem to indicate a process of calcification in the fibres of the ivory; in some instances the calcareous matter seeming to be deposited in the substance of the nuclei, in others between them, and in both cases bestowing an obvious opacity on the fibre. A change, to which the preceding may be regarded as analogous, is known to occur in that kind of ivory which I have termed "canalicular," and also in the crusta petrosa. In both of these tissues canals are observed, which are plugged up with solid earthy matter, but which, at an earlier period of the growth of the tooth, must have been pervious.

The different kinds of ivory must necessarily possess a perfect organic resemblance in their mode of developement. For example, the subdivisions of the pulp in canalicular teeth perform each a similar function to the entire pulp of the fibro-cellular kinds; and the canals, of which traces remain behind in the fully-formed teeth, are simply the cavities in which the different portions of the ramified pulp were contained, but which have become eventually obliterated by the deposition of ossific matter. I have already, so far back as the month of January, 1839,* demonstrated an analogous change in the human tooth, by which the cavitas pulpæ becomes gradually filled up and obliterated.

* In my paper on the structure, physiology, and pathology of the persistent capsular investment and pulp of the tooth, published in the 22nd volume of the Transactions of the Royal Medical and Chirurgical Society.

CHAPTER XI.

CHEMICAL COMPOSITION OF THE TEETH.

THE arrangement of the materials which constitute a tooth, and the forms of the parcels in which these materials are made up, having been examined, together with the deviations from their regular arrangement which have fallen under my observation, we have so far exhausted the powers and aid of the microscope. This instrument, in its modern modifications, has done much for minute investigation, and serves to conduct to the province of a still more elevated and subtile mode of inquiry into nature's minute handiwork, namely, Chemistry. Our inquiries are naturally led in this direction after having obtained a knowledge of the shape of the minute parcels of matter which compose the organized cellular structures which have just engaged our attention, and I feel pleasure in being able to place before my readers an original account of the constituents of the teeth furnished by such eminent men as Dr. Thomas Thomson, Regius Professor of Chemistry in Glasgow College, in conjunction with his nephew, Dr. R. D. Thomson. The acknowledged talents of these gentlemen are a sufficient guarantee for the authenticity of these records, and for the confidence which may be reposed in them. According to their analyses, the chemical constituents of the teeth are as follows:—

In the following tables the substances have, with the exception of those employed for testing the specific gravities, been dried at the temperature of 212°. The quantity of water which the ivory naturally contains varies from 10 to 14 per cent.

TABLE I.—Enamel.

	1. Human Temporary.	2. Human Adult.	3. Human Adult.	4. Hindoo Adult.	5. Elephant.	6. Hippopotamus.
Specific Gravity	2·711	2·621	2·688			
Organic matter	8·218	3·76	6·160	5·573	6·80	4·102
Phosphate of lime	} 90·489	85·00	89·160	89·821	82·55	83·630
Phosphate of magnesia			·260	0·205	1·65	0·850
Carbonate of lime	0·831	} 11·24	4·010	3·578	7·65	10·620
Chloride of sodium	} 0·240			0·743	1·05	0·800
Chloride of potassium						
	99·778	100·00	99·59	99·920	99·70	100·000

TABLE II.—Ivory.

	7. Human Temporary.	8. Human Adult.	9. Hindoo Adult.	10. Elephant Fine.	11. Elephant Coarse.	12. Walrus External.	13. Walrus Internal.	14. Hippopotamus.
Specific Gravity	2·090	2·105		1·728	1·794	1·909		1·866
Organic matter	31·55	28·20	26·81	45·65	44·00	39·28	38·16	33·41
Phosphate of lime	} 61·23	60·16	66·42	} 52·30	54·35	52·80	59·04	55·90
Phosphate of magnesia		1·66	0·62		1·13	2·10	0·67	1·19
Carbonate of lime	4·71	7·04	5·63	1·35	1·33	4·38	1·02	9·14
Chloride of sodium	} 2·51	2·66	0·10	0·06	0·09	0·69	0·53	0·36
Chloride of potassium								
	100·00	99·72	99·58	99·36	100·90	99·25	99·42	100·00

Nos. 4 and 9 represent the composition of the teeth of the inhabitants of Bengal, living on a vegetable diet, and may be compared with the European or carnivorous tooth.

One fact observed by the application of chemical tests to the teeth is, that the enamel resists the action of acetic acid, and probably of other acids, better than the ivory, being a proof of the superior resistant nature of that particular structure, which is more immediately exposed to the chance of being affected by destructive agents. The amount of organic matter in Nos. 1 and 3, of the enamel, may have been partially derived from a slight intermixture of ivory. The method which I adopted for separating the enamel from the ivory was to heat the tooth, and plunge it, while hot, into cold water; the enamel is then found to crack off.

TABLE III.—Comparative table of teeth and bones.

	15. Ox Tooth, temporary.	16. Ox Tooth, permanent.	17. Tiger Tooth.	18. Whale rib.	19. Human Thigh-bone.
Specific Gravity . .				2·102	
Organic matter . .	29·16	23·45	31·49	37·96	35·93
Phosphate of lime . .	67·54	74·88	63·67	52·81 (phosphate of lime and phosphate of magnesia together)	51·12
Phosphate of magnesia .	0·76	0·83	0·52		0·63
Carbonate of lime . .	1·62	1·03	3·64	9·46	9·77
Alkaline chlorides . .	trace	trace	trace	0·17	0·59
	99·08	100·19	99·32	100·40	98·04

Nos. 15, 16, and 17 enable a contrast to be formed of animals living on vegetable and animal food. The teeth, in these cases, were used entire, without separating the ivory and enamel. A portion of the difference in the amount of the animal matter, in No. 16, may be attributable to the presence of a portion of enamel. The quantity of alkaline chlorides present in different kinds of teeth is always so inconsiderable, and yet constant, that there can be little hesitation in tracing their origin to the saliva with which the teeth must be always saturated, as is obvious from their absorptive power.

TABLE IV.—Composition of teeth in caries and of tartar.

	20. Caries.	21. Caries.	22. Tartar.
Specific Gravity . .	1·633		
Organic matter . .	62·00	62·78	20·59
Phosphate of lime . .	32·20	34·79	73·30
Phosphate of magnesia .	2·23		3·93
Carbonate of lime . .	2·24	1·11	0·28
Alkaline chlorides . .	1·28	0.52	0·14
	99·95	99·20	98·24

The considerable amount of chlorides found in the decayed portion of ivory, as shown in the above table, is a striking fact, and it may be asked whether it does not go far to prove that the salts are really chemically united with the organic matter of the teeth. If these salts were not retained by means of some such inclusion of that nature, the chlorides or soluble salts ought to be dissolved out of the softened tissue by the fluids of the mouth when the ivory has been brought to such a state as that which exists in the decayed portion of a tooth. Dr. R. D. Thomson makes the following remark:—" I suspect the earths to be in combination with the animal matter but not the chlorides; for on calcining the teeth, the latter are easily washed out with water. In some forms of plants it is considered that portions at least of the uncombined salts may be removed by washing before calcination."

There is, however, another view which may be taken of this matter, and that is, the possibility of these chlorides being absorbed from the fluids of the mouth. This latter hypothesis may be well conceived, since it is determined that the absorbent power of the ivory is about $7\frac{1}{2}$ per cent., a fact which I ascertained by drying a cylinder of ivory at the temperature of

70°, and then submitting it under the exhausted receiver of the air-pump to immersion in distilled water. It weighed when dry 100·90 grains, and after immersion, 108·34 grains, the difference being 7·44. The surface moisture was of course wiped off. The porous structure of the ivory has been shown in the drawings contained in the previous chapters of this work.

The conformity of the specific gravity with the proportion of earthy constituents in any individual structure is a fact deserving of attention, although this is less obvious in the preceding tables, from the circumstance of the specific gravities having been taken before the removal.

Dr. R. D. Thomson, in his observations on the table of constituents, remarks that "it is probable that the quantity of carbonate of lime may increase in some instances from the absorption of carbonic acid from the air and fluids external to the tooth, and its union with the excess of base in the phosphate of lime, which is a basic salt." The probability of this hypothesis is supported by the observation of the absorbing power of ivory mentioned above. Dr. R. D. Thomson further remarks on this head, "The bone-earth phosphate is a remarkable combination consisting of one atom of acid with $2\frac{2}{3}$ atoms of lime, [$2\frac{2}{3}$ Ca. O+3 $P.O_5$.]

Some practical deductions may be derived from the above observations. Thus if we investigate the developement of one family, that of the elephant, spread over a great extent of the surface of the globe, we find the same specific organization producing a great diversity of results simply from exposure to the different circumstances of climate, soil, and food. The extent of this diversity may be judged of from the following table:—

SPECIFIC GRAVITY OF IVORY.

Ceylon	1·812
African, white	1·847
„ green	1·811

African coarse white	1·724
Siam	1·788
Bombay, fine	1·737
„ coarse	1·772
Cape Coast	1·742

It is curious to observe how these chemical examinations are corroborated by the practical experience of the mechanical or mercantile qualities of the different kinds of ivory, as may be seen from the following observations derived from Mr. Russell, one of the most intelligent dealers in that article in London, and as they serve to regulate his purchases, they may be relied on; it is evident that they must be real, and that they must arise from causes which are natural and constant. We, therefore, cannot doubt the influence of similar causes on all animal groups, and are thus enabled to demonstrate the benefit that may arise from the culture of the human species in regulating the perfection of the developement of the teeth.

The first in density is Ceylon, and is derived from the countries around Ceylon. This ivory resembles Siam in quality, but does not run so regular as the latter. In size, the Ceylon teeth are much smaller than those of Bombay, seldom exceeding 70 or 80 lbs., and averaging generally 30 or 40, while the Bombay sometimes run to 180 lbs., but this is an extreme weight. Ceylon teeth have more of what is called green in them than those of Bombay, and resemble African teeth in that respect. The price much the same; the difference betwixt them not being generally known amongst buyers. There is, however, a difference of value amounting to *6d.* per lb. (from the smaller quantity of green) in the Ceylon teeth. It is generally used for the same purposes as Siam.

African ivory is found to hold a place next to that of Ceylon, in specific gravity, although, in commerce, it has the credit of being the heaviest. It is possessed of the cleanest grain, and sells at the highest price. It is brought from the Gold Coast, and is principally used for cutlery, fancy turnery, combs, &c.

There are three different appreciable qualities derived from the different portions of each tooth.* The first or heaviest kind of white ivory is that obtained from the point of the tooth; what is called green, and has a pellucid appearance, is derived from the centre of the tooth, and is the most valuable portion, and the coarse white is from the outside of the same portion; and although heavier, not so much esteemed.

The ivory next in density is that from Siam; it is next in estimation for quality and texture, and obtains nearly the same price in the market as African ivory. It is principally used for the same purposes as the African, but is not so valuable from its supposed inferiority in weight which the specific gravity shows to be real. It is principally green, but does not keep its colour so well as African green, changing to all shades, sometimes to a pinky hue. Siam teeth are more diseased than any of the others that are brought to market, yet the diseases attacking these teeth do not run so extensively through the whole texture of the tooth, and thus do not deteriorate the tooth so much for use.

The ivory next in density is that of Bombay; it displays two qualities in its structure which are applied to different purposes. The fine quality is from the internal part of the tooth, but is of less specific gravity than what is denominated coarse, and derived from the exterior. The rationale of this fact is evident from the structure of ivory. The peripheral portion of ivory has finer fibres than the interior. The fibre being the animal or light portion necessarily betrays a less specific gravity than that where the substance is more exclusively earthy. The peripheral cells of the ivory are also larger than the internal, which accounts for what is called the coarseness of grain in that part. It is observed that the specific gravity of the point

* In such a bulk of material as the elephant's tusk there is an opportunity of observing the peculiarity of character in the structure of the different portions of the tooth; accordingly we find that the point of the tooth is the most dense, and that the outside is denser than the interior; protection and resistance being more required in the point and the external portion than in the central portion.

of the tooth in African ivory is great, and also that of the peripheral portions, demonstrating the presence of a greater proportion of hard concrete matter in those parts which are exposed to the contact of hard substances.

The Bombay teeth are used for cutlery, turnery, and combs, but principally for pianoforte keys; no other kind is so well adapted for that purpose, it being so white and opaque, or *dead*, as it is called. It, however, very soon gets yellow, and it has no tint of green. There are larger and heavier teeth derived from this market than from any other, running sometimes to the weight of 180 lbs. per tooth. The Bombay ivory is softer than the kinds previously noticed. The quantity annually consumed in London for pianoforte keys is about twenty tons. Its price is much the same as that of the other kinds.

The ivory from the Cape Coast having a specific gravity of 1·742, is invariably white and coarse. It is held in commerce to be the lightest kind, and has the character of being marked by a number of yellow concentric rings. Its price is low, and although coming from Africa, is not recognized as African ivory.

Pursuing the deductions obtained from a consideration of the specific gravity, particularly that exhibited by the decayed portion of human ivory, conjoined with the proportion of its constituents, we may infer that the greater the density of the teeth of individuals the less likely are they to decay. That the character of the structure of teeth is regulated by the climate, food, and habits of individuals, may, I think, be fairly deduced from the circumstance of such variety of density being displayed by the teeth of the single family of the elephant spread over a great extent of the surface of the globe, as shown above. The practical inference fairly deducible from the latter observation is, that attention to proper regimen and to the general treatment and health of mankind, will contribute directly in favour of the perfect and healthy developement of their teeth. That circumstances of this kind do act directly in regulating the developement of the teeth of man we see demonstrated by the difference of specific gravity found betwixt those of the native Indian having entirely a vegetable food, and of the European living on a mixed animal and vegetable diet; the former having a less density than the latter seems to warrant the inference that animal food is more favourable to the perfect developement of the earthy structures. It is remarked, also, by veterinary surgeons, that the developement of the teeth of horses is somewhat affected by their food; when fed on hard food the teeth being more easily developed than on soft.

The temporary teeth being meant only to remain for a short period, do not require such density of structure as those provided for the life of the individual, and the low degree of density of the temporary set may explain their great proneness to decay.

From the analysis of decayed ivory contained in the above table, we learn that the alteration in the decayed portion is simply a withdrawal of the earthy matter; but how that process originates or is carried on are obscure but interesting questions. All deviations from the regular structure of the perfect ivory I consider to be proximate causes of the commencement of the process, as tending to facilitate the withdrawal of the solid earthy constituents of the ivory. When the process is once commenced, there is no difficulty in conceiving how it is continued, unless arrested in its progress.

This subject must always be considered as one of permanent practical importance, and therefore any direct observation with regard to it extremely valuable. Those who have considered the subject have generally viewed it altogether as a vital process, or altogether as a chemical one. In our consideration of this subject, we must bear in mind that the tooth is composed of organised animal and earthy matter. In the exclusively vital process the result would be a derangement in the constitution of the earthy salts, so as to allow them to be decomposed and taken up by the system or the saliva in its ordinary state. The exclusively chemical process, or that capable of being produced by the putrefaction of the food collected about the teeth, would necessarily act on the animal matter, and produce its destruction. Whichever of these processes occurs, a certain degree of faultiness, as it appears to me, must exist in the tooth to admit of the particular part being affected.

All the congenital deviations which I have previously noticed I consider capable of laying the foundation of natural decay. The interrupted nature of the fibre, as not enabling an intimate communication betwixt the active organs of the cells prevents, I presume, the free transfer of the nutrient plasma of the blood, or its proper elimination for the nourishment of the cells, and thus, from want of a due supply, the vacuum becomes filled by the moisture absorbed from without, a power which, as we have seen, is great in this tissue. These fluids from without are neither nutrient nor preservative, and consequently destruction is established and maintained. The other deviations from the perfect structure consist principally of the introduction of small masses of abnormal matter throughout the body of the ivory, sometimes in irregular portions, and sometimes in regularly defined characteristic corpuscles of bone or cortical substance. These two latter substances never being required or intended to resist the atmosphere in the same degree as regular ivory, cannot be expected to withstand decay when exposed; consequently we find that teeth possessed of irregular masses dispersed through the body of the ivory are subject to decay. Again, although ivory be exposed by being chipped or worn, it does not necessarily go to decay, but resists powerfully the decomposing effects of external causes, provided no congenital defect exists.

In regard to the developement of the process of decay, it appears to me that in most cases it is a combination of vital and chemical processes. It cannot be considered exclusively under the influence of either, but at the same time I consider it more the effect of vital than of chemical action. Without any deficiency in the original organisation of the tooth, I consider it quite possible for a faulty vitality to originate decay; but the simple presence of food, without any natural deficiency in the tooth, I consider incapable of producing that effect. If, however, there be also the presence of a foreign body, such as may be used for false teeth, then I know it to be possible, and unless great care and cleanliness be practised, that effect is sure to follow. The earthy salts which are deficient in proportion, must be decomposed or brought into solution by the assistance of a vital process, so as to render them capable of being carried off in a fluid state, or acted on by the saliva. Decay commences in the peripheral portion of the ivory, at the greatest distance from the vascular pulp. If, therefore, there is a change produced, this must be carried on through the agency of the tissue interposed betwixt the diseased part and the source of vitality, the pulp. The precise portion in which this must be enacted being the nucleated fibre.

This subject, in my opinion, requires a deeper consideration than at first sight we might be led to give it, on searching for the sources of decay. In the first place, the vital processes of the animal economy are continually carrying on a universal change in the whole system. The materials of the body are in a constant condition of progression or replacement by one process or another, and a supply of new material is constantly going on. When these processes are balanced, the functions of the part are perfect; but if there be a subtraction of material without an adequate supply, decay of the part must succeed. We have in the tissue of ivory a cellular structure, furnished with organised animal matter, in the presence of the rows of persistant nuclei, surrounded by the parcels of earthy matter which form the characteristic of the structure. We have, therefore, analogous constituents to other tissues, where the processes of replacement or absorption of old, and nourishment of new parts goes on; we cannot, then, deny this tissue the exercise of similar functions. If, then, the absorption by the system goes on to a greater extent than the renovation, we must have a consequent deterioration of healthy constitution in the structure. Decay will be developed in the different portions of the tooth in an inverse ratio to the power of resistance. The more perfectly the structure is organised, the greater will be the power of resistance. I have pointed out the deficiencies in structure which occur, so far as I have been enabled to notice them.

The interrupted appearance of the nuclei composing the fibre; the masses of animal matter distributed throughout the substance of the ivory; the deficiency of cohesion noticed betwixt the enamel and ivory; the peculiar cellular appearance resembling vesicles, with no appearance of nucleus or fibre. In fact, any deviation from the normal structure of perfect ivory seems to predispose to natural decay. These congenital faults supply a mechanical source of decay, by allowing the permeation of the fluids of the mouth, mingled with food, to enter through any minute orifices generally present in the undulations of the enamel. The fluids and food become stagnant in these cavities, get putrid, and encourage a like process in the animal matter of the ivory around, and thus deprive that portion of the tissue of its vitality and support.

That interference with the vitality of ivory must determine such portion to destruction by decay, is palpably demonstrated by the change observed to take place on that substance when made use of for artificial teeth, whether derived from the teeth of men, or those of the lower animals. Ivory in its vital state, even although worn down, is frequently seen to exist in the mouth in perfect integrity, throughout a very extended lifetime, of probably eighty years; but when deprived of its vitality, and introduced into the mouth, it is often decomposed in twelve months, sometimes even less, showing evidently the dependence there is in this tissue on the vital influence to its proper preservation.

That there is a peculiar system of nourishing fluids throughout every cellular structure there can be no doubt. If the normal state of this tissue be that of a compact confluent fibre, made up of the closely adapted nuclei of the constituent cells, it is evident that any deviation from that perfect structure must interfere with the complete fulfilment of the functions of these cells, and of course of the general integrity of the tooth, by not supplying its substance sufficiently with outward nourishment.

The tusk being always immersed in the fluid saliva, it is of some interest to inquire into the constituents of that fluid, as well as of that peculiar production of the cavity of the mouth called tartar. When the saliva is in a perfectly healthy state, it is often slightly acid, and contains, according to Mitscherlich, the following salts, in 99½ parts of water.

Chloride of potassium . .	0·180
Potash, combined with lactic acid .	1·094
Soda, combined with lactic acid .	0·024
Soda, combined with mucus . .	0·164
Phosphate of lime . . .	0·017
Silica	0·015
	0·494

When these salts are perfectly suspended in the water of solution, there is no action on the teeth; but if there be any excess either of acid or of earth, there results an appreciable effect in the mouth. If the acid be in excess, there is frequently a partial erosion of the surfaces of the teeth, and a great increase of any decayed portions which may exist. If the earth be in excess, it falls from the state of solution, and is deposited on the teeth in the form of paste, which gradually gets hard and brown, and obtains the name of tartar. The chemical composition of this substance, as given in the table, displays constituents quite conformable to such an origin, and therefore there seems no reason for searching after any other. The animal matter, I have no doubt, consists principally of epithelium, which must necessarily collect in any portion of the mouth not much exposed to the action of the tongue and lips. M. Serres, in his interesting little work on the teeth, expresses his opinion that there are submucous follicles existing exclusively for the purpose of the secretion of the tartar. This, however, does not seem to admit of proof. Another theory has lately been promulgated by M. Mandl, of Paris, an account of which is contained in the "Comptes Rendus."

PYROPIN.

I have frequently observed a very peculiar looking substance occupying the pulp cavity, of almost a black colour, but it is in reality of a remarkably dark rich ruby red, and of a brittle consistence. I have noticed considerable masses of it, as large as nuts; and one which I gave to Dr. R. D. Thomson was about three inches long, and three quarters broad, and about half an inch thick. This piece, from the tooth of the elephant, was attached to the wall of the cavity by one end. I have often seen the same material in the pulp chamber of the walrus, and I have also seen it in the cavity of the temporary tooth of the tiger. The tooth which contains this substance is generally very irregular in its structure, and has the marks of diseased action, and a faulty developement, together with the appearance of sinuses running throughout the body of the ivory. The very dark portion of the material displays no structure when examined by the microscope, but the portion attached to, or in the immediate neighbourhood of it, where it has sometimes a semi-membranous appearance, displays under a quarter of an inch object glass a series of shriveled cells, of the same appearance as the irregular ivory immediately in connexion with it. From its position and connexion, and its conformity with the ivory, I am inclined to think that it is a portion of the dried pulp which was in a modified state from disease. Dr.

Thomson has been so good as to examine it, and the account which he gives of it is as follows.

"This substance is found occasionally in the teeth of the elephant, occupying the hollow portion of the interior pulp cavity. It possesses a fine ruby colour, and is sometimes tough, but when of the finest hue is brittle. Sections of it exhibit occasional traces of the remains of organization. It is insoluble in water, and thus differs from glue or gelatine, to which it has some affinities in its physical aspect. It seems also to contain sometimes minute quantities of glue, if we may judge by the smell on the application of moisture; but it never possesses the adhesive nature of glue. The composition of pyropin, by two analyses, is as follows:—

	1.	2.
Carbon	53·33	53·50
Hydrogen	7·52	7·66
Nitrogen	14·50	38·84 (Nitrogen, Oxygen, Sulphur)
Oxygen	24·65 (Oxygen, Sulphur)	
Sulphur		
	100	100

"When pyropin is boiled in water, the liquid is not precipitated by infusion of nut-galls,—a proof that it contains no gelatine or glue; neither is it precipitated by acetate of lead. The colour of pyropin is not altered by this treatment, with the exception that a few scanty flocks of membranous-looking matter float in the fluid. When broken into coarse powder it has a rich ruby red, whence the name by which it has been distinguished—from pyropus, a *ruby*. In fine powder it is brown. A small portion of it dissolved in hot alcohol was deposited on cooling in the form of ferruginous flocks. Whether it be a derivative from the blood, since it leaves a slightly red ash, or from the pulp, is a question still open to inquiry."

Plate I.

Fig: 1.

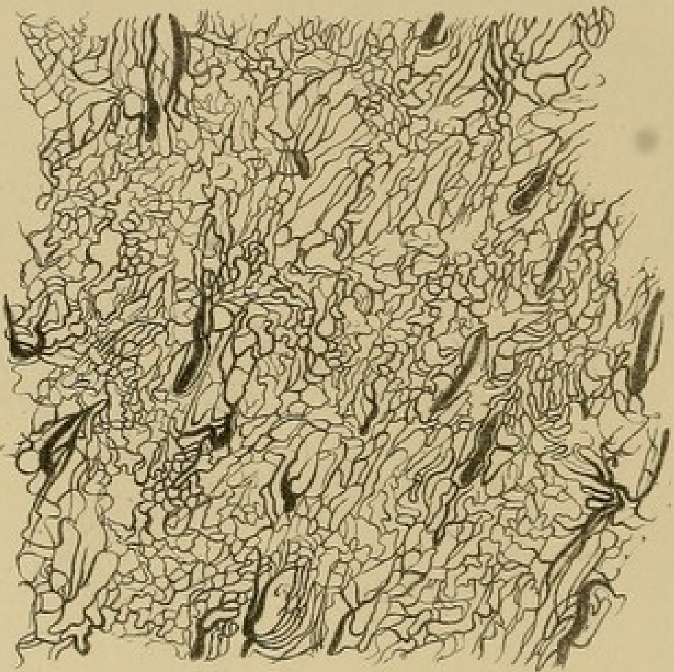
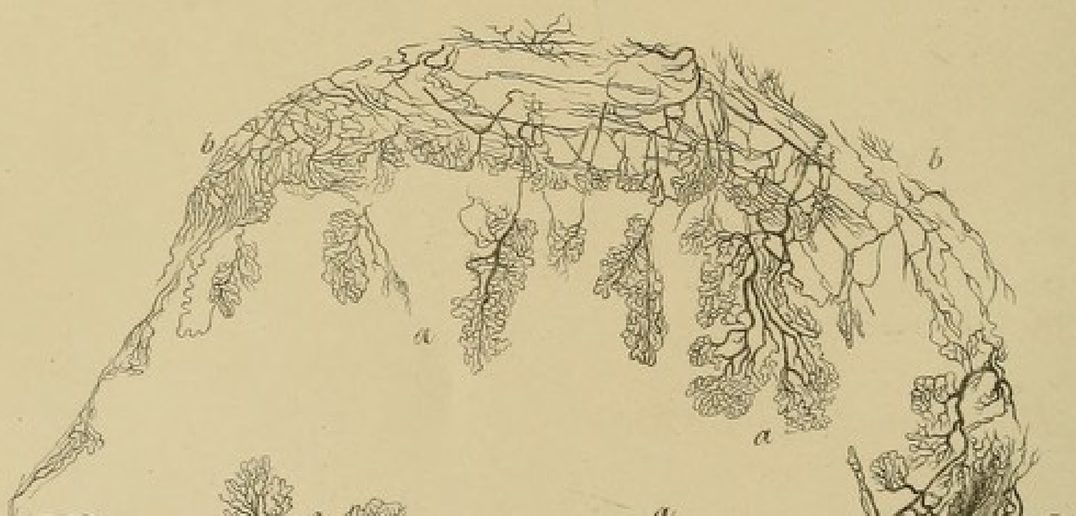


Fig: 2.



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DESCRIPTION OF THE PLATES.

PLATE I.

VASCULARITY OF PERIOSTEUM AND OF THE FIBRO-CARTILAGE OF THE ARTICULATION OF THE LOWER JAW.

Fig. 1. A portion of periosteum from the cranium of a fœtus at the full term, minutely injected. The larger areolar spaces, as *a a*, correspond with the situation of the Haversian canals of the bone. At these points the vessels are larger than the minute network of the surrounding portion of the membrane, and are formed by the convergence of the capillaries of the latter.

Fig. 2. The interarticular fibro-cartilage of the articulation of the lower jaw; from a fœtus. The synovial membrane covering the substance of the cartilage is minutely injected. The little arborescent plexuses, *a a*, correspond with minute arteries which are sent upwards from the peripheral plexus, *b b*. The vessels do not extend into the central part of the cartilage, against which the greatest amount of pressure is exerted during the action of the jaws.

PLATE II.

VASCULARITY OF THE MUCOUS MEMBRANE OF THE TONGUE.

Fig. 1. Papillæ of the tongue of the fœtus, minutely injected. The papilla, in the upper part of the figure at *a*, has the appearance of being perforated by a small opening at its apex. A similar appearance may be observed in several of the papillæ.

Fig. 2. Exhibits a lateral view of one of the papillæ conicæ, with the apicial aperture *a*.

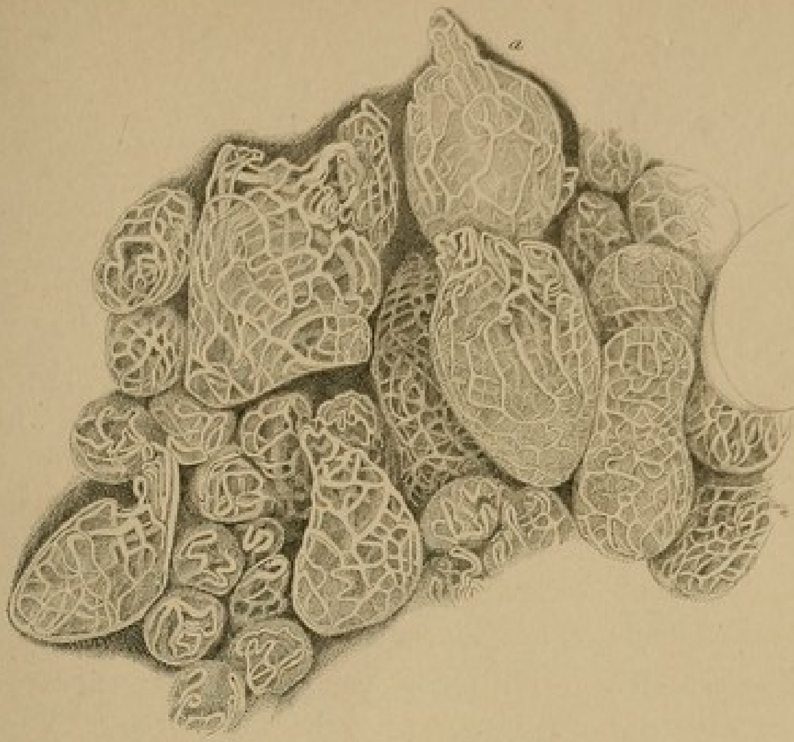
Fig. 3. In this figure the aperture *a*, at the extremity of a conical papilla, is also shown. The mode of distribution of the vessels is well seen. It is evident that the erection of these papillæ must be produced by the simple distension of their vessels.

Fig. 4. A portion of the surface of the tongue of the adult, showing the manner of distribution of the capillary vessels in the papillæ at that age.

a is a calyciform papilla. *b b* the groove around it. *c* filiform or villous papillæ. On the left of the figure at *d d* several conical papillæ are seen, presenting a variety of forms.

Plate 2.

Fig. 1.



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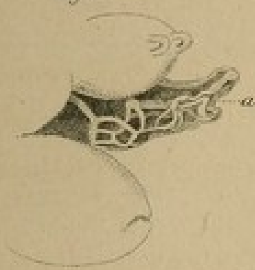


Fig. 3.

Fig. 4.

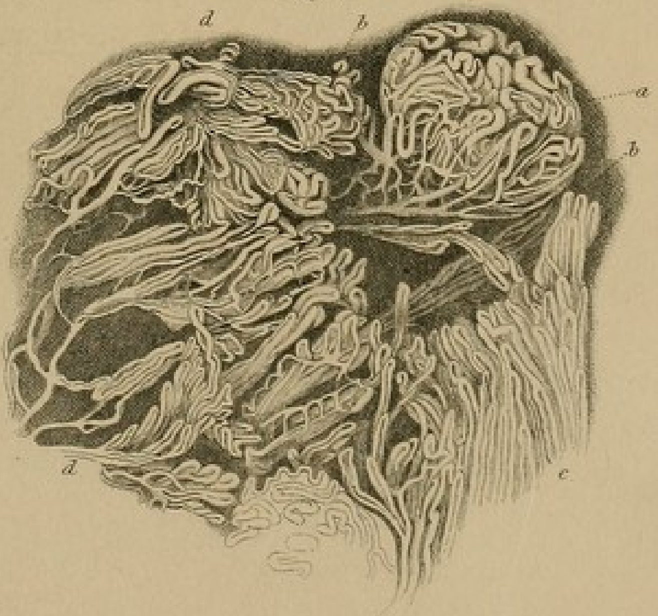
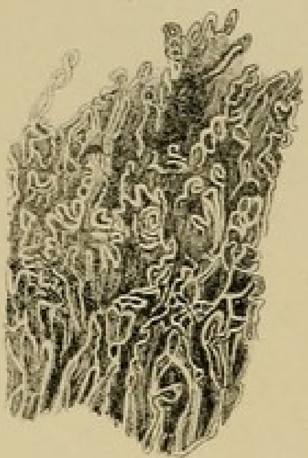


Plate III.

Fig: 1.



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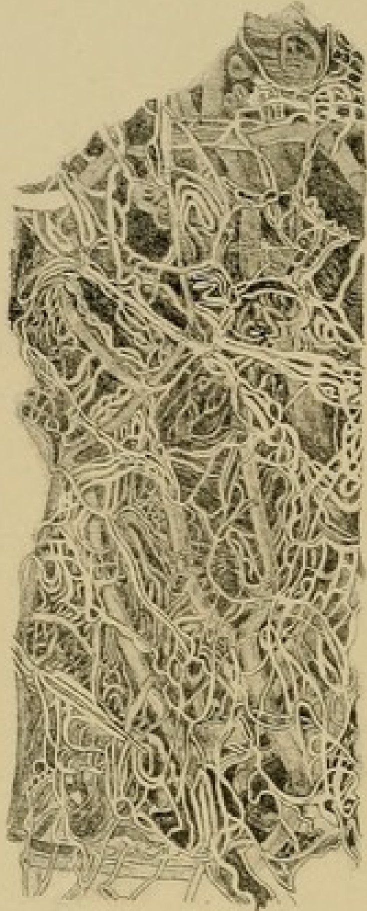

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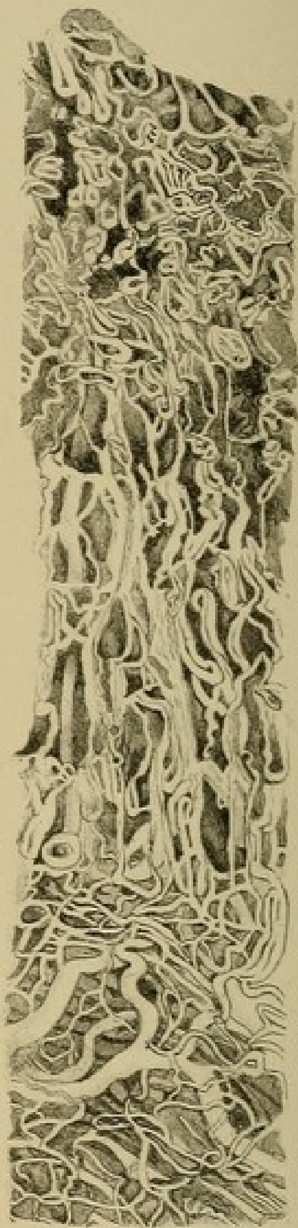

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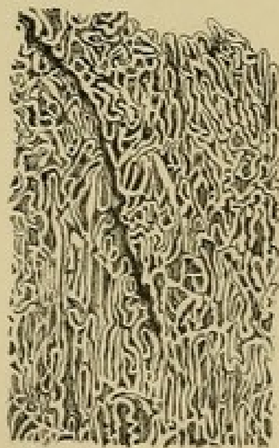


Fig: 2.

Fig: 6.

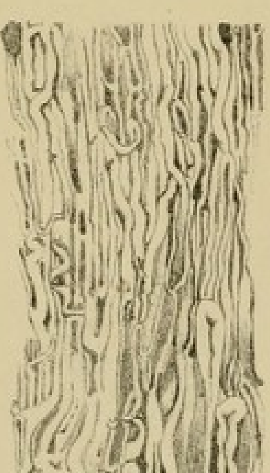


Fig: 7.

PLATE III.

VASCULARITY OF THE MUCOUS MEMBRANE OF THE MOUTH AND NOSE.

Fig. 1. A portion of the gum of the adult, showing the papillæ minutely injected. The figure is magnified thirty-eight diameters. The capillary vessels are tortuous, like those of erectile tissue.

Fig. 2. Separate papillæ from the same preparation, magnified seventy-five diameters.

Fig. 3. A portion of the mucous membrane of the gum and palate of the human fœtus, minutely injected, and magnified seventy-five diameters. The larger vessels are seen forming the deeper stratum in this figure. The spaces of considerable size, seen here and there in the superficial plexus, correspond with the position of submucous glands.

Fig. 4. A portion of the gum and adjacent mucous membrane of the human fœtus, minutely injected, and magnified about one hundred diameters. In the upper part of the figure the papillæ are seen; and in the lower part the plexuses formed by the larger vessels.

Fig. 5. A portion of the mucous membrane of the nose of the human fœtus, minutely injected. The intricate plexus formed by the capillary vessels presents a different character from that of the mucous membrane of the mouth, the capillary vessels being more minute and their meshes smaller. The figure is magnified seventy-five diameters.

Fig. 6. Another portion of the Schneiderian mucous membrane from the posterior part of the nose of the same fœtus. The size and arrangement of the capillary vessels is widely different from the preceding. The figure is magnified seventy-five diameters.

Fig. 7. The plexus formed by the larger vessels in the vascular portion of the capsule of a growing tooth.

PLATE IV.

VASCULARITY OF THE MUCOUS MEMBRANE OF THE MOUTH.

Fig. 1. A portion of the mucous membrane of the middle of the inner part of the upper lip of a fœtus, minutely injected. Magnified forty diameters.

a a. The papillæ are beautifully exhibited in this portion of the lip, the part corresponding with the red border. They are seen to become gradually smaller towards the middle of the figure, at *b*, where the capillary vessels form an intricate plexus with close meshes. *c.* In the lower part of the figure the plexus is coarser, the large circular spaces corresponding with the numerous submucous glands which are found in this situation.

Fig. 2. A portion of mucous membrane from the side of the lower jaw and cheek of a calf, showing the arrangement of the capillary vessels, and the appearance of the papillæ. The figure is magnified forty diameters.

Fig. 3. A single papilla of the cheek of the calf, minutely injected. The figure is magnified eighty diameters.

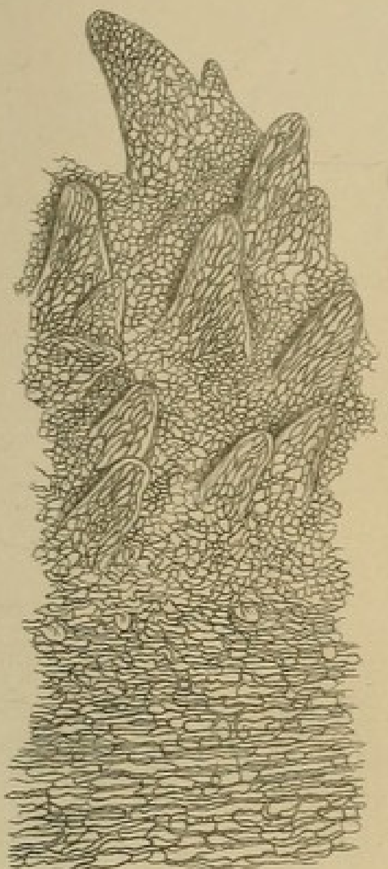
The capillary network composing this papilla is beautifully exhibited. The arrangement of the vessels is seen to be subservient to the functions of the membrane, as enabling the papillæ to become erected by distension, and to constitute a rugous surface, favourable to the operation of sucking, and to the detention of the nipple of the mother within the mouth.

Fig. 4. A portion of the mucous membrane of the inside of the lip of the human fœtus, minutely injected, and magnified forty diameters. The difference of calibre of the deep and superficial stratum of capillaries is shown in this figure.

Fig. 5. A small portion of the free edge of the upper lip of the human fœtus, showing the arrangement of the capillary vessels entering into the composition of the papillæ. The figure is magnified forty diameters.

Plate IV.

Fig: 2.



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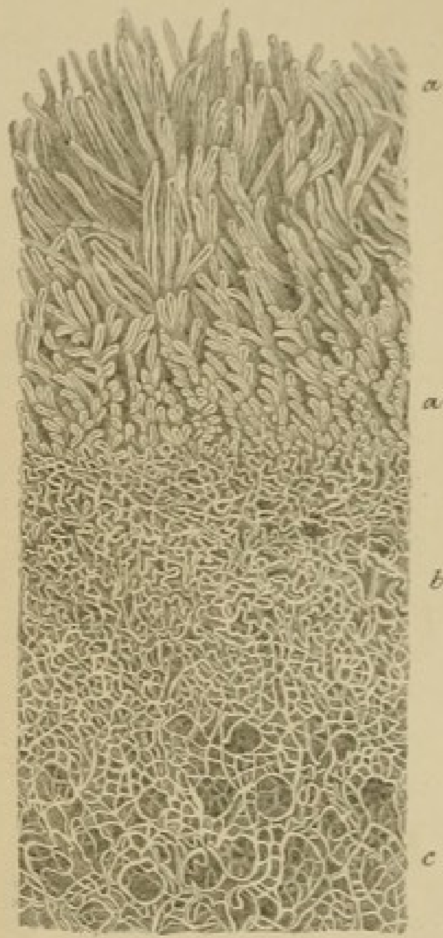

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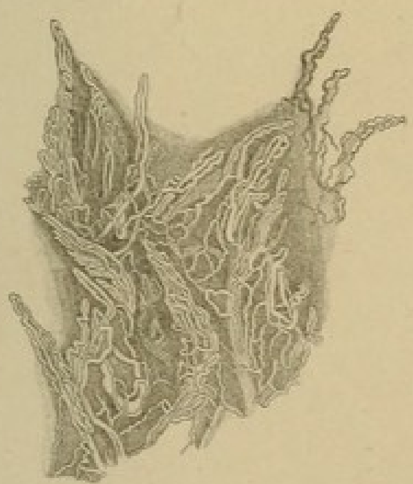

Fig: 4.

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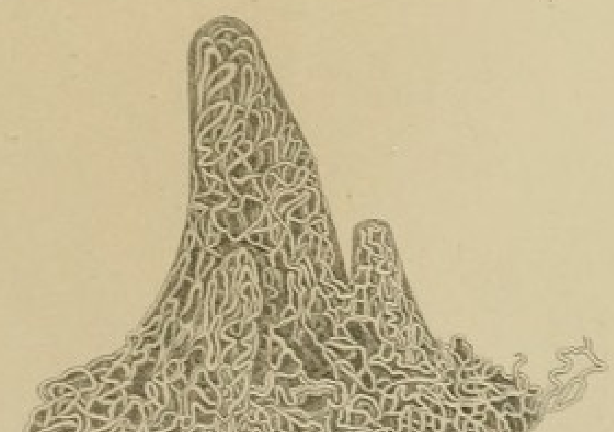

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Plate V.

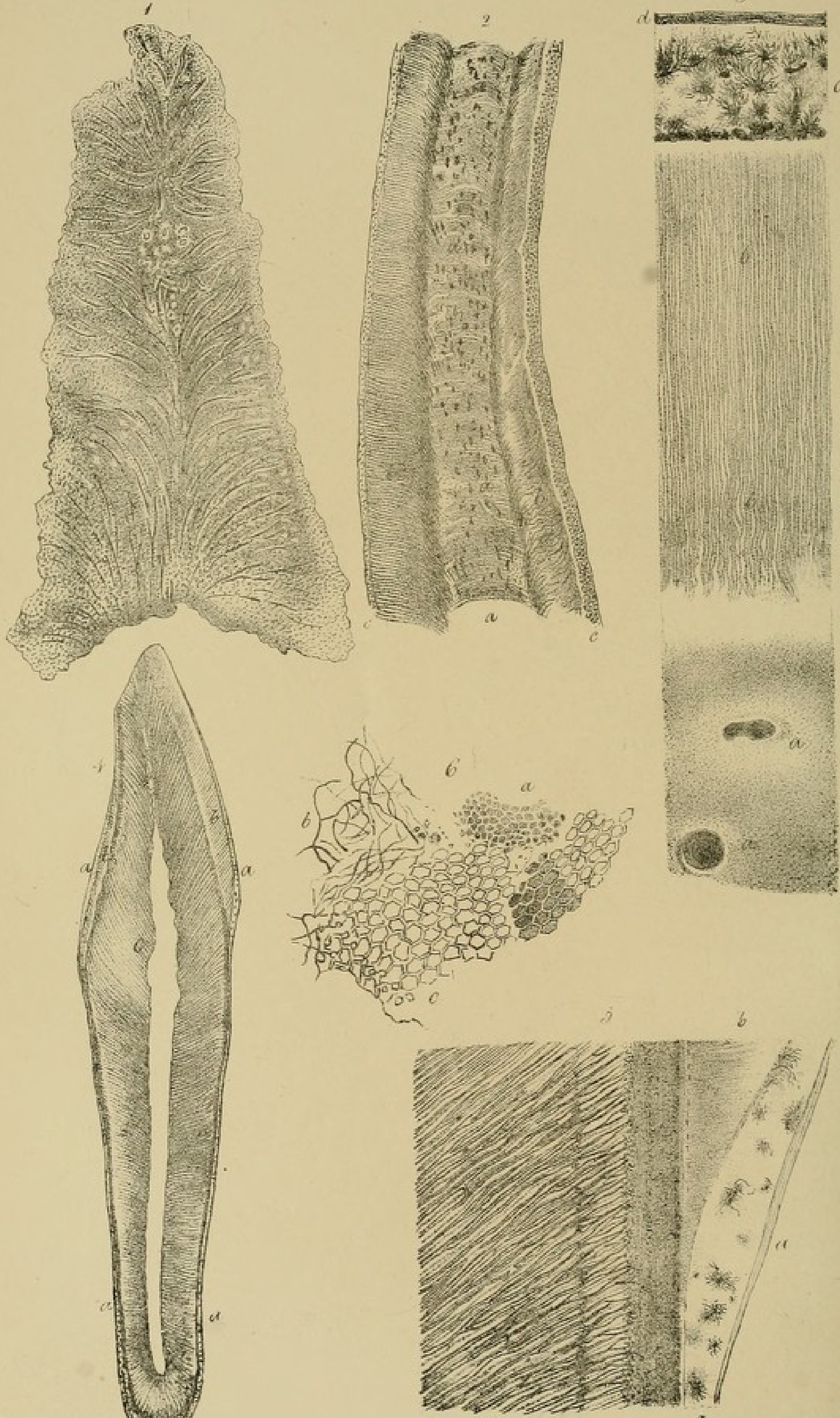

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PLATE V.

STRUCTURE OF THE TEETH.

Fig. 1. A transverse section of the crusta petrosa of the elephant's grinder, showing the microscopic appearance of the bony corpuscles and ramifying vessels in an ossified state.

Fig. 2. A longitudinal section of the tooth of the bradypus didactylus.

a a. The ossified pulp. *b b.* The ivory. *c c.* The crusta petrosa, on the surface of which there is a thin membrane visible, when viewed under a high magnifying power.

Fig. 3. A transverse section of the tooth of the bradypus tridactylus, highly magnified.

a a. The ossified internal membrane. *b b.* The ivory. *c.* The crusta petrosa. *d.* The membrane external to the crusta petrosa.

Fig. 4. A longitudinal section of the incisor of an ox.

a a. The capsular investment of the crown, external to the enamel, continuous with that on the fang, both having the characteristic corpuscles of crusta petrosa. *b b.* The enamel. *c c.* The ivory.

Fig. 5. A highly magnified view of a portion of the same tooth as the preceding, including a portion of the crown and of the fang. The references are the same as in Fig. 4. The osseous corpuscles in the capsular investment are distinctly shown.

Fig. 6. A highly magnified view of the reticulated appearance of the internal surface of the capsular investment of the enamel of the human tooth.

a. Cells filled with enamel. *b.* Some of the fibres of the fibrous layer. *c.* Distinctly formed polygonal cells.

PLATE VI.

STRUCTURE OF THE TEETH.

Fig. 1. Longitudinal section of a decayed human large grinder. There is a large growth of crusta petrosa on the fang at *a a* ; and a partial ossification of the pulp at *b*.

Fig. 2. A portion of a human tooth ; the capsular investment, *a a*, is seen to be prolonged from the enamel upon the fang of the tooth.

Fig. 3. A longitudinal section of a decayed human large grinder, where there is a total ossification of the pulp at *b* ; and a large growth of crusta petrosa on the fang, at *a a*.

Fig. 4. A portion of the internal membrane of a human tooth ossified.

Fig. 5. A portion of the crusta petrosa of Fig. 1, highly magnified. *a*. The ivory. *b b*. The crusta petrosa.

Fig. 6. A transverse section of the fangs of a diseased human grinder of the upper jaw, where there is a considerable growth of crusta petrosa, as seen at *a a a*.

Fig. 7. A transverse section of the neck of a diseased human grinder ; the ossification of the pulp nearly fills up the chamber as seen at *b*.

Plate VI.

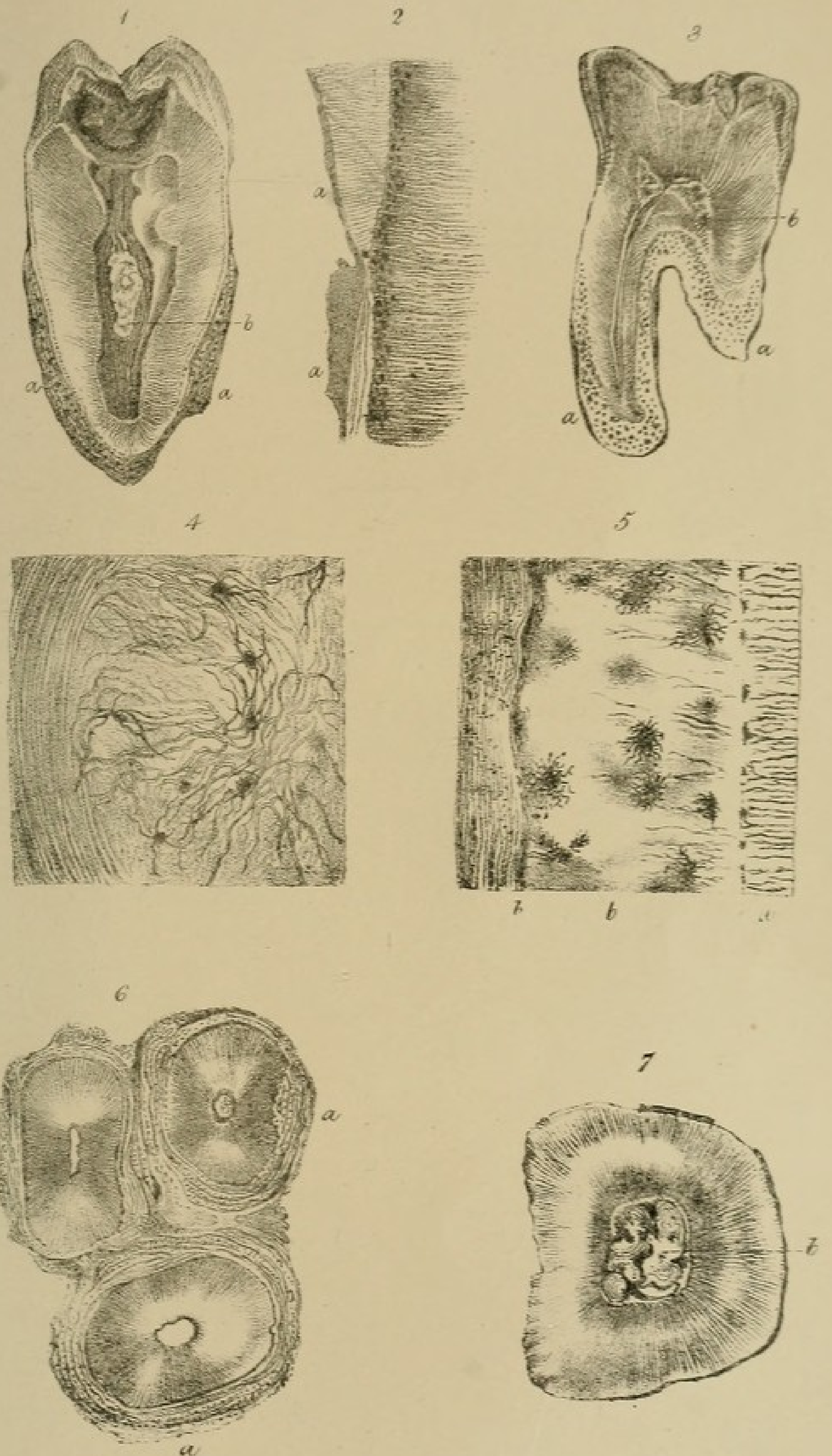

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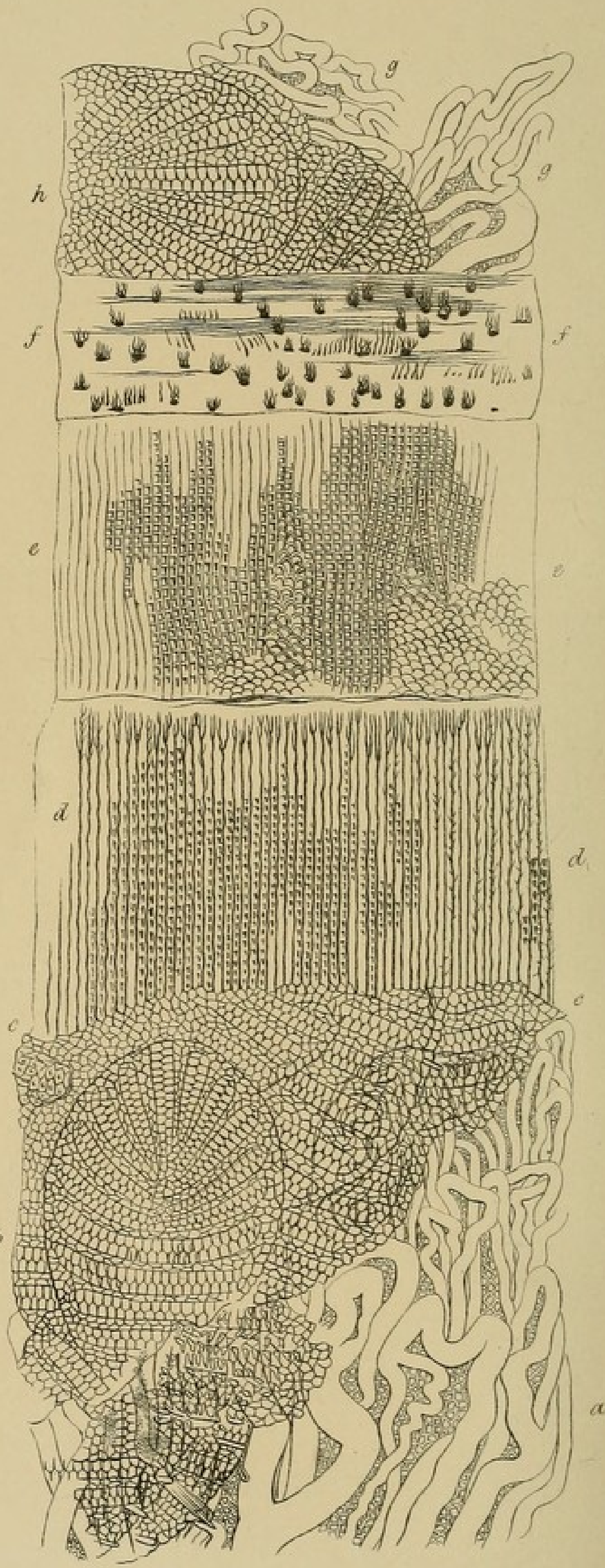
Fig. 1.



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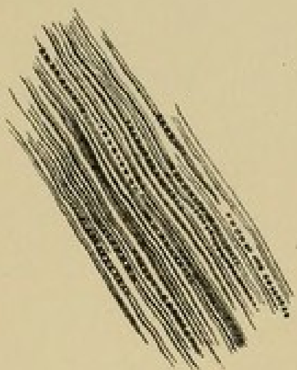
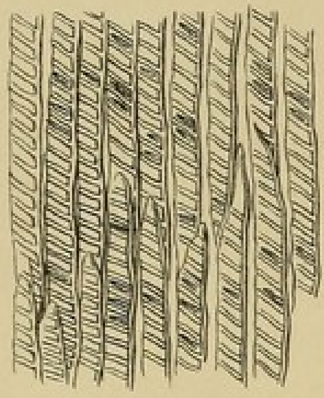


Fig. 3.



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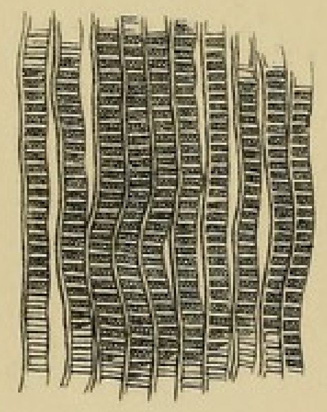

Fig. 5.

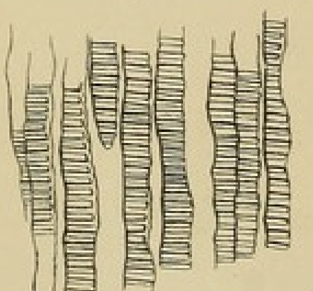

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PLATE VII.

ANATOMY OF THE VARIOUS TISSUES WHICH ENTER INTO THE COMPOSITION OF A TOOTH.

Fig. 1. A diagram, showing at a glance the various structures entering into the composition of a tooth, together with their relative position and magnitude. *a a.* The blood-vessels and capillaries of the pulp, between which the cellular structure of that organ is seen. *b b.* Reticulations of cells in process of conversion into ivory, and occupying the peripheral portion of the pulp. In the line between *c c*, the transition of these cells into the structure of ivory is more clearly exhibited. *d d.* Ivory. *e e.* Enamel. *f.* Cortical substance. *g g.* Vessels of the corpuscles. *h.* Reticulations showing the conversion of the persistent capsule into bone.

Fig. 2. Fibres of the ivory of the human tooth, showing their baccated structure.

Fig. 3. Fibres of the ivory of human tooth very much magnified. This view of the structure of ivory is obtained by making thin shavings of the structure by means of the lathe.

Fig. 4. Fibres of the ivory of the tusk of the elephant.

Fig. 5. Fibres of the ivory of the tusk of the elephant.

PLATE VIII.

VASCULARITY OF THE PULP.

Fig. 1. The upper surface of the pulp of a temporary molar of the human fœtus, minutely injected. The larger vessels are seen in the deeper part of the pulp and the capillaries on the surface. The defined portions of great vascularity correspond with the spots over which the small caps of ossification existed. The pulp is magnified about twenty diameters, but a part of the vascular structure is drawn with a magnifying power of one hundred diameters.

Fig. 2. A portion of the same pulp more highly magnified. The capillaries are seen passing off from the arterial branches, and after pursuing a tortuous and plexiform course, converging to form the venous trunks.

a. An arterial trunk.

b. A venous trunk

The figure is magnified one hundred diameters.

Fig. 3. Another portion of the pulp of a large molar of the human fœtus minutely injected. The larger vessels are seen forming the deep and the capillaries the superficial stratum. The figure is magnified one hundred diameters.

Plate VIII.

Fig. 1.

Fig. 3.

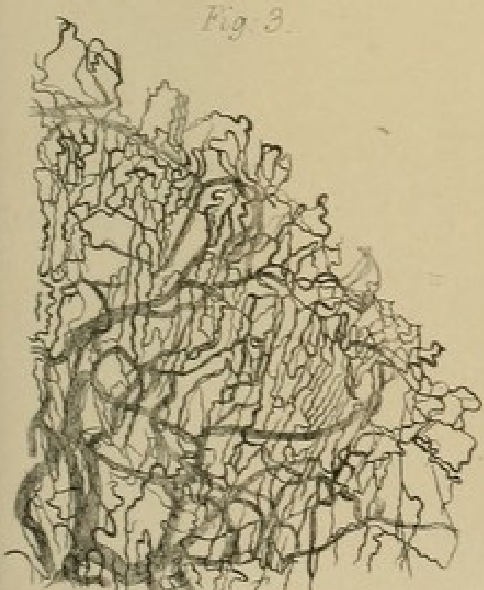

Fig. 2.

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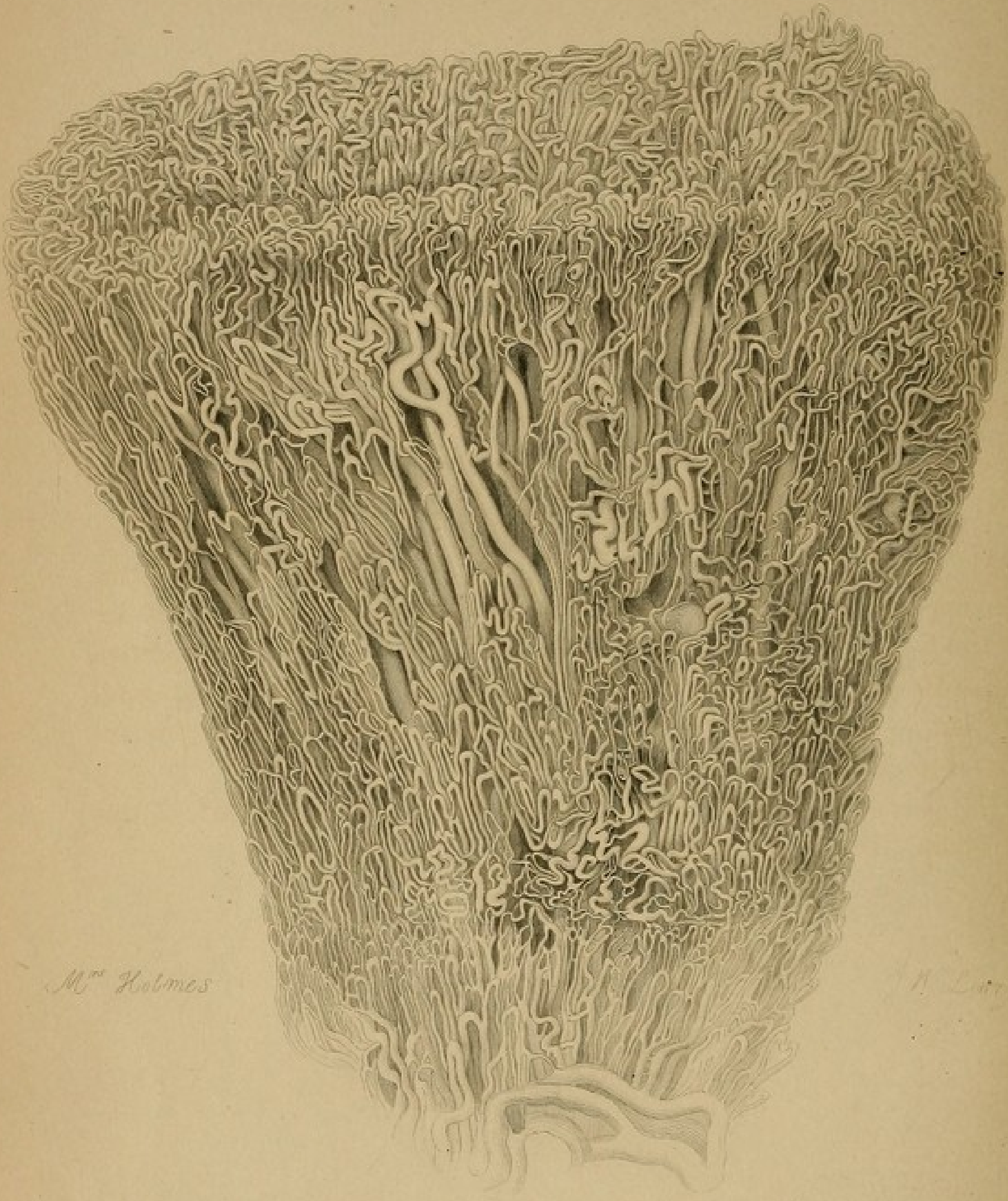
Plate 9



Mrs Holmes

H. Lair

PLATE IX.

VASCULARITY OF THE PULP.

This figure is drawn from a preparation of the pulp of one of the upper central incisor teeth minutely injected. The deeper vessels are of large size: they are the arteries and veins, and their communication with each other is maintained by the beautiful series of looped capillaries which form a densely matted surface upon which the reticulations of transition cells are developed.

The small figure at the bottom represents the natural size of this pulp.

PLATE X.

NERVES OF THE PULP AND STRUCTURE OF IVORY.

Fig. 1. The pulp of an adult bicuspid tooth, showing its nerves and their manner of distribution.

The figure is magnified twenty times.

Fig. 2. A portion of the pulp which has been macerated in diluted muriatic acid. The small bodies are the nuclei of the transition cells of the pulp.

Fig. 3. The peripheral or transition cells of the pulp, passing into the condition of ivory cells. The nucleus is seen to be parietal.

The preparation is taken from the growing tooth of the calf.

Fig. 4. A portion of the surface of the pulp from the young tooth of a calf, showing transition cells in various stages of conversion into ivory. It is from a portion of pulp in this stage that the preparation of fig. 2 has been made.

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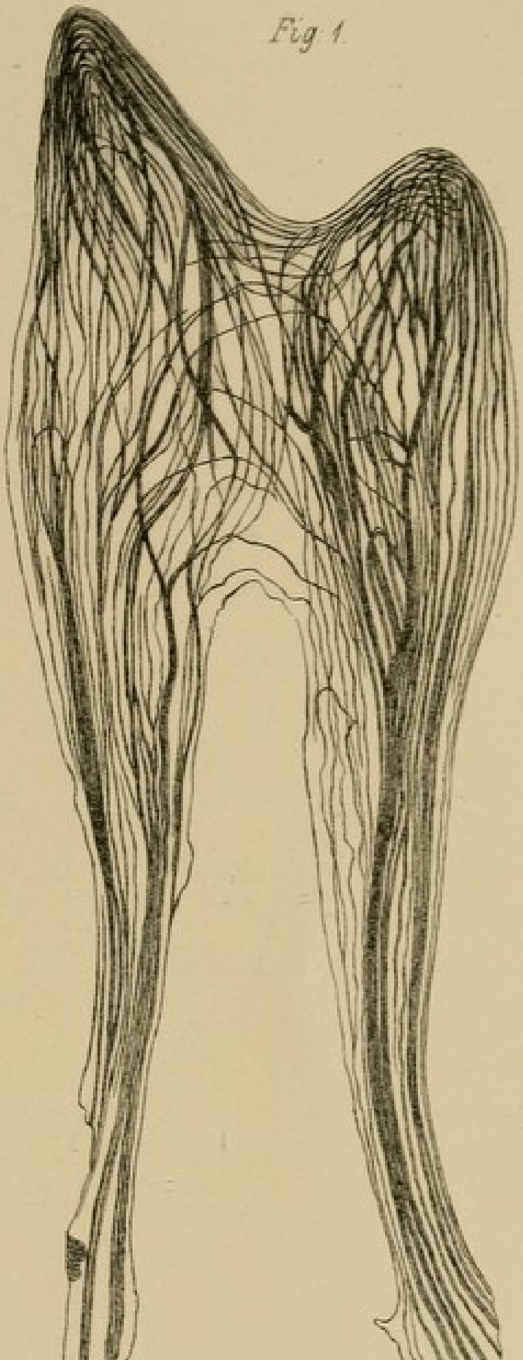
Plate X.

Fig 1.



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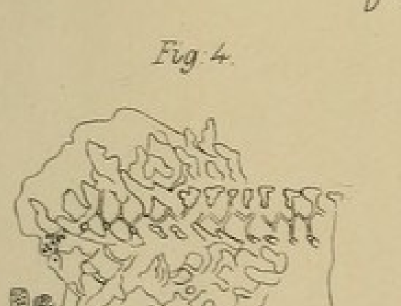

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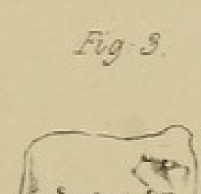

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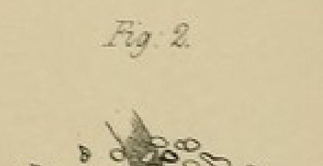

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