## THE PHYSIOLOGY OF DIGESTION

### I. MASTICATION

I PROPOSE in this and the following papers to give an account of the physiology of digestion, or, in other words, to describe the operations to which food is submitted, and the alterations it undergoes, before it is absorbed into the system and becomes adapted to the nourishment of the body.

With this end in view, it will be expedient to divide the alimentary or digestive tract into a series of sections, each comprising a portion in which certain definite and, in general, well-ascertained processes are effected. The first of these is clearly the mouth, where the food, provided it be not already of a fluid nature, is ground to a pulp and mingled with saliva, or, in other words, where it undergoes mastication and insalivation.

In order to prevent the ingestion of substances that, from their temperature, hardness, acridity, putrefaction, or other chemical or physical properties, are inappropriate as articles of food, the mouth, or vestibule of the alimentary canal, is guarded by three sentinels that, were due attention paid to the impressions derived from them, would rarely be found to mislead: *Touch*, possessed to an exquisite degree by the ruddy lips and tongue; *Taste*, possessed by the tongue and palate; and *Smell*, which, though comparatively neglected by man, is constantly

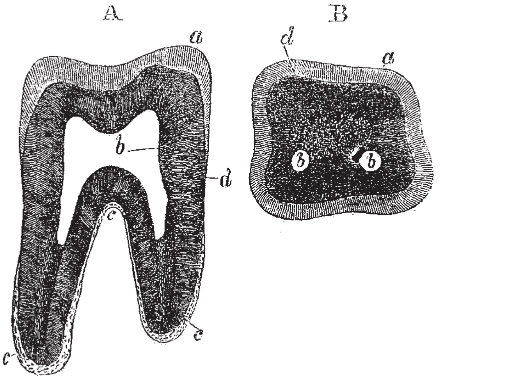


Fig. 1.—A, vertical; B, horizontal section of a bicuspid tooth; *a*, enamel of the crown; *b*, pulp cavity: *c*, cement of the fangs; *d*, dentine: magnified three diameters.

employed by animals as a means of discriminating suitable from unsuitable substances.

The act of mastication is designed to comminute the food, and thus to present a larger surface to the action of the several digestive fluids, saliva, gastric and intestinal juices, &c., as well as to render it more readily capable of incorporation with them. It is more important that it should be thoroughly performed in the case of vegetable than of animal food, since the latter is usually of a softer and more succulent nature, besides being already analogous in composition to the body; whilst the nutritive material contained in the former is enclosed in firm cell-walls that are slowly dissolved in the act of digestion, and requires the action of the several fluids to be long continued before it is fitted for nutrition; and it is accordingly found that the means for effecting such comminution is far more complete in the vegetable than in the animal feeders. In a teleological point of view it is interesting to notice that in the infant living on milk, which does not require mastication, no teeth exist till the fourth or fifth month.

*Mastication* is accomplished by the movements of the jaws, the margins of which are very generally armed with teeth. Amongst Mammalia the teeth are only absent in the whalebone whales, the anteater, manis, and echidna—many rows of small, sharp, hard, epidermal spines situated on the palate and base of the tongue, however, supplying their place in the last-named animal, whilst the two former may be said to live on animal food that is already, in proportion to the bulk of their bodies, extremely comminuted. Teeth are indeed absent in the whole group of Birds, and in the Chelonia, doubtless in the former case on account of their weight, which would interfere with flight, but their place is supplied in both by the cutting beak and in the latter also by the powerful gizzard. They are absent in the toad amongst Amphibia, and in the sturgeon, paddlefish, pipefishes, ammocete and amphioxus amongst Fishes, but are elsewhere constantly found amongst the Vertebrata; they are very frequent also amongst the Invertebrata, though many live by sucking the juices of the animals on which they subsist.

In regard to the teeth of man, it need only here be mentioned that they are twenty in number in the child, and thirty-two in the adult; that the six front ones, namely, the four incisors and two canines in each jaw, are chiefly employed for cutting and tearing the food; and the remaining back teeth, including the four premolars and the six molars, for pounding and bruising it. The teeth are the hardest parts of the skeleton. Four parts may be distinguished in them—(1) the pulp, which, occupying a cavity (*b*) in their centre, is extremely small in quantity, and contains an artery vein and nerve; (2) the dentine (*d*), which forms the greater portion of the tooth and confers upon it its general configuration; (3) the enamel (*a*), which caps the

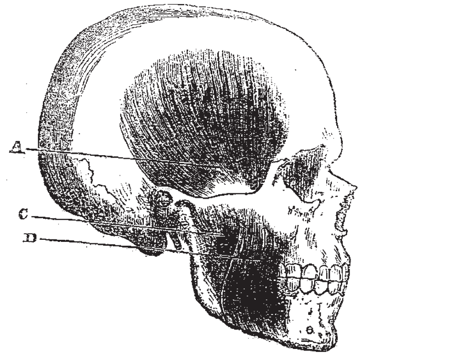


Fig. 2.—View of the external muscles of mastication. A, temporal muscle; D, superficial; and C, deep portion of the masseter muscle.

free or exposed surface of the tooth, or that portion which projects beyond the gum; and (4) the cementum (*c*), which invests the fang.

The Dentine (*d*) is composed of a series of tubes traversing a homogeneous matrix, and extending from the pulp cavity to the outer limit of the dentine. The course of these tubes is undulatory, and they give off numerous branches as they pass outwards. It is difficult to trace their minutest ramifications even with high powers of the microscope. Their interior is occupied by delicate solid threads called dentinal fibres, which, however, it has recently been shown by Neumann are not in immediate contact with the matrix, but are separated from it by a resisting membrane or dentinal sheath. The presence of these fibres accounts for the sensitiveness which it is well known the dentine when exposed possesses, whilst there can be no doubt they are subservient to the slow processes of nutrition which are continuously taking place in even the most superficial parts of these hard organs.

The Enamel (*a*) is composed of a series of six-sided, solid prisms, which contain scarcely more than 2 per cent. of organic matter, but consist almost exclusively of phosphate and carbonate of lime. In the rabbit, rat, squirrel, and all Rodentia, it forms the cutting edge of their chisel-shaped incisor teeth.

The Cement (*c*) is a peculiar kind of nonvascular bone, and though small in quantity and comparatively unimportant in man, enters largely into the composition of the teeth in many of the lower animals. The statement advanced by Jean Jacques Rousseau, on the one hand, that man is a herbivorous animal, and by Helvetius on the other, to the effect that he is carnivorous, both seem to be refuted by the general characters of the teeth, so far as any evidence can be derived from such a source; for in this point of structure man occupies an intermediate position between the Carnivora and the Herbivora, and appears to be adapted for the consumption of both animal and vegetable substances, though doubtless life can be well preserved with a due selection and sufficient supply of either, as we shall subsequently see.

The lining of the mouth is a mucous membrane of considerable thickness, containing numerous glands, and covered with many tiers of tesselated epithelial cells, into the deep surface of which sensitive and vascular papillæ from the membrane itself project.

The movements of the lower upon the stationary upper jaw in man are effected by the muscles, exhibited in Figs. 2 and 3.

They comprise vertical, lateral, and backward and forward movements. The *depression* of the lower jaw is accomplished with considerable rapidity by the contraction of three or four small muscles—the digastric, stylogenio, and mylo-hyoid—forming the floor of the mouth, the first-named being the principal agent in the Carnivora.

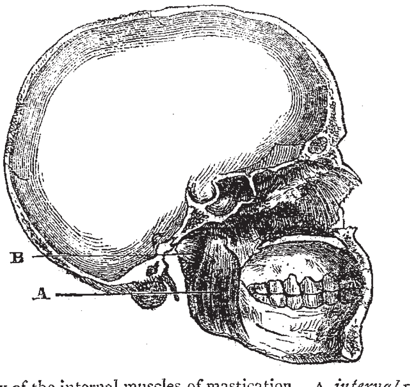


FIG. 3.—View of the internal muscles of mastication. A, *internal* pterygoid muscle; B, *external* pterygoid muscle.

From the position of the joint or pivot on which the lower jaw moves, the front teeth can be nearly twice as widely separated from one another as the back. The difference in the gape of the jaws varies in different people, and to a greater extent than might at first sight be supposed. In some measurements that I have made, I find that whilst the distance between the free borders of the front teeth does not, in some instances, exceed one inch, in others it amounts to upwards of two inches. The segment of a circle formed by the upper is usually somewhat larger than that of the lower jaw. Its *elevation*, which is a far more energetic movement, is performed by the temporal (A, Fig. 2), masseter (C, D, Fig. 2), and internal pterygoid muscles (A, Fig. 3). All these muscles are attached to the jaw between the fulcrum or condyle of the jaw, shown in Fig. 2, just in front of the external opening of the ear, and the weight to be moved or fore-part of the jaw. They therefore constitute levers of the third order; and hence, though acting promptly, are placed at a comparative disadvantage for exerting their fullest force. Still their power is immense even in man, who is again surpassed by many of the Carnivora. It is not easy to estimate it. I have endeavoured to do so, however, by ascertaining the pressure required to crush a Brazil-nut, which seems to be about the limit of the power possessed by young people with good teeth. At least very few can crush the stone of the peach. I find that a weight of about 84lb., but varying from 56lb. to 100lb. is requisite to break a Brazil-nut when placed on one of its flat sides, and this probably is not a very unfair representation of the average power of the three above-mentioned muscles. The lateral movements of the lower jaw are effected by the alternate contraction of the external pterygoids (B, Fig. 3), which are consequently seen in their highest state of development in the Ruminants. They are feeble in man. The forward and backward movements, also feeble, are due, the former to the external pterygoids, the latter to the deep portion of the masseter (C, Fig. 2), the posterior fibres of the temporal and the internal pterygoid.

Another muscle deserves to be noticed—the buccinator—which forms a considerable proportion of the thickness of the cheek, and which is an important agent in preventing the accumulation of food between the teeth and the cheek, the occurrence of which is so troublesome in some cases of paralysis. It is remarkable that all these muscles are supplied by one and the same nerve, the fifth; the last-named, however, receiving some additional motor filaments from the seventh or portiodura.

The movements of the tongue, which are under the influence of the hypoglossal nerve, are of very great importance also in aiding mastication, since its wonderful tactile sensibility enables us to feel for and thrust back between the teeth portions of food which have escaped their action. The centre for co-ordinating the various movements required for mastication appears to be situated in the medulla oblongata.

Having thus considered the mechanical process to which the food is subjected in the mouth, we shall proceed in another article to consider the chemical changes effected in it by the act of insalivation. H. POWER

## NOTES

WE have more than once had to notice the liveliness recently exhibited by science at the Antipodes. This has now found expression in the issue of a monthly journal in Australia called "The Scientific Australian," a journal of industry and instruction, specially devoted to those engaged in scientific, artistic, and industrial pursuits, and to the promotion of technological education amongst the operative classes. The editor, Mr. J. S. Knight, Assoc. Inst. C.E., F.R.I.B.A., appears to have enlisted the services of the most eminent scientific men, not only in Victoria, but in the sister colonies of New South Wales, Queensland, South Australia, Western Australia, Tasmania, and New Zealand, and the articles, as a general rule, are to be signed. It is gratifying to find these signs of life in our colonies; we shall watch with interest the career of our contemporary, the first number of which was to be published at Melbourne on the 1st of the current month, and wish it every success.

AT the public sitting of the Paris Academy of Sciences, held on the 11th inst., the following prizes were awarded:—"The Astronomical Prize, Lalande foundation, to Mr. J. Watson, for the discovery of eight new asteroids in one year. The Mechanical Prize, Monthyon foundation, to M. Arson, for his experimental researches on the flow of gases in long conduits. Statistical Prize, Monthyon foundation, to M. Chenu, for his medico-chirurgical statistics of the Italian campaign of 1859-60. Prize established by the Marchioness Laplace, to M. F. A. Voisin. Trémont Prize to M. Le Roux, to aid and encourage him in the pursuit of researches on the index of refraction for certain vapours, and on the measurement of the heat developed by electric currents. Poncelet Prize to M. J. R. Mayer, of Heilbronn, for his memoirs on the mechanical theory of heat; Prize for Medicine and Surgery: a medal of the value of 3,000 francs, to MM. Legros and Onimus, for their works on the application of electricity to therapeutics; a medal of the value of 2,000 francs to M. Cyon,