THE MECHANISM OF SWALLOWING

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Methods of swallowing.—A simple type of protozoon such as amœba engulfs food by protoplasmic flow; part of the organism wraps itself round the particle and ingests it. In higher types this unicellular action is replaced by a multicellular mechanism, in which many cells combine to engulf food by concerted action. Longitudinal muscle fibres contract and pull part of the food tract over the bolus, which is then prevented from escaping by contraction of circular fibres and is carried downwards by their peristaltic action. Sebileau and Truffert[37] used the word "happer"—to snap up—in describing the movement of elevation over a bolus. As the wave descends there is relaxation of the longitudinal muscle and thus a section of the food passage descends, carrying with it the enclosed mass of food. Such a mechanism may be watched in snakes, which seem to creep forward over their prey. A rabbit, for instance, when swallowed, remains almost stationary, the snake moving forward over it until it has completely engulfed its victim. A simple mode of swallowing is employed by the earthworm (lumbricus) which grasps food with its prehensile mouth and then squeezes it onwards by contraction of its muscular pharynx. A somewhat similar mechanism is to be discerned in mammals and man if various complicating factors are ignored.

Alternative methods.—An alternative method is that of ciliary action, as seen in vorticella amongst unicellular organisms and also in molluscs, such as oysters, in amphioxus, and in amphibia, as for example the frog (rana). In the latter, cilia extend into the œsophagus and may be observed to possess sufficient power to convey pieces of paper from the front of the mouth into the gullet. In man the use of ciliary action is confined to the conveyance of bacteria and particles of dust from the nose and sinuses to the nasopharynx.

Other purposes of swallowing.—Not only does the mechanism convey food to the stomach, but in certain species it also subserves the functions of smell and respiration. Some fish, for instance, induce a stream through the olfactory organ and carry water to the gills by swallowing movements, while lung fish (dipnoi) transfer air to the lung by a similar method.

In man the ingestion of food is the most important use of swallowing; but subsidiary purposes are the removal of bacteria from the nasopharynx, where they are deposited from the nose, the paranasal sinuses and the middle ear. Bacteria from the lungs are carried upwards

https://doi.org/10.1017/S0022215100156427 Published online by Cambridge University Press

through the larynx by ciliary action and are deposited in the pharynx, to be swallowed and destroyed in the acid secretions of the stomach.

Modifications due to mastication.—The concerted action of longitudinal and circular muscle fibres is able to propel food, and is efficient in such simple animals as earthworms, which live on small particles, grasped by the prehensile mouth. When large masses are swallowed, as in carnivorous fish and reptiles, some efficient means of seizing and holding the prey is necessary and takes the form of teeth, but without other modification of the simple mechanism. In snakes the teeth are set back so that the prey when caught cannot escape ; the teeth are not used for mastication. Crocodilians similarly use their teeth for prehension only. If food is divided up in the mouth, instead of being ground up in the gizzard, as in earthworms and birds, or digested in the stomach, as in reptiles and crocodilians, grinding teeth are necessary ; the chewing process also requires the presence of a tongue to force food between the teeth, and cheeks to prevent escape of the divided mass.

Function of cheeks and lips.—Cheeks are almost absent in amphibians, reptiles and birds and are but poorly developed in carnivorous mammals. Herbivora, on the other hand, have efficient cheeks capable of retaining masticated food ; man is similarly well provided. Mobile and prehensile lips are associated with efficient cheeks, as may be noticed in monkeys, apes and man.[35]

Uses of tongue.—The tongue is used not only for purposes of mastication but also for prehension, as in chameleons and toads, where it is used for catching flies ; herbivora, such as giraffes, carry leaves to the mouth with their long prehensile tongues. A further function of the tongue in many animals is propulsion of food into the pharynx ; in man the organ arches up and is pulled back by the palatoglossus and styloglossus muscles, thus tipping food into the pharynx. Some carnivora, such as crocodiles have a flat and relatively immobile tongue, unrequired for mastication, unsuited to prehension and of little use for propulsion ; others, for example dogs, have a mobile tongue capable of forcing unmasticated lumps of food backwards. The absence of tongue and cheeks sometimes makes the swallowing of lumps of food difficult, as may be noticed in the hen, for instance ; this and other birds make snatching movements by jerking the head forward, thus utilizing the inertia of the bolus as a means of engulfing it. In man total removal of the tongue does not lead to inability to swallow, owing to the compensatory action of the cheeks and floor of the mouth.

First or buccal stage of swallowing in man.—Prehensile lips assist in grasping food, which is masticated by combined action of the tongue and teeth ; the latter are adapted to grinding but are not so efficient as in the progenitors of modern man, owing to reduction of the palate area. Well-formed and muscular cheeks prevent escape of masticated

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food. The bolus is forced backwards by raising of the floor of the mouth, mainly by action of the mylohyoid muscle, with arching and backward movement of the tongue amongst the muscles concerned in these two movements are the intrinsic muscles of the tongue, the hyoglossus and the stylo- and palato-pharyngeus. The backward movement of the tongue temporarily obliterates the lumen of the pharynx, while the isthmus of the fauces is at the same time narrowed. When the bolus passes the fauces it enters the pharynx, where certain difficulties arise in its transference, due to the necessities of respiration. The passage of the bolus from this point to the mouth of the œsophagus is called the second stage of swallowing. Various considerations in connection with modifications of the mechanism in this region must now be considered.

Modifications due to presence of larynx.—The development of a pulmonary outgrowth does not of itself involve any radical change in the mechanism of swallowing. In lung fish (dipnoi) for example, the larynx is small and lies flat in the floor of the pharynx ; similarly in such reptiles as tortoises, crocodiles and lizards and in birds, movements of the longitudinal and circular muscles are not impeded by the larynx. Deglutition takes place as one continuous action, after initial prehension of food and its passage through the mouth ; but in other higher animals the larynx has a marked effect on the mechanism.

Complications caused by nasal respiration.—Even though the evolution of a pulmonary system does not necessarily have a pronounced effect, yet the habit of breathing through the nose may introduce certain modifications in species where it is necessary for the nasal and laryngeal airways to be continuous. Such a relationship is evolved for various reasons, depending generally on the desirability of maintaining nasal respiration when the mouth is open.

Reptiles have poor powers of scent and do not derive any particular benefit from breathing through the nose in respect of olfaction. Keen-scented animals are, however, in a different category and accordingly show certain alterations of structure.

Modifications due to presence of epiglottis.—If it is desired to preserve the integrity of the olfactory sense when the mouth is open, whether for selection of suitable food, or to detect the presence of enemies, it is necessary for the airway to be shut off from the food tract. The epiglottis is evolved for olfactory purposes, to form a barrier against mouth breathing, by coming into relationship with the palate.[30] Most amphibians, reptiles and birds are devoid of an epiglottis, but keen-scented mammals are provided with an efficient flap which lies either below the palate or above it in the nasopharynx ; the palate is elongated to complete the junction.

Herbivorous animals such as deer and cattle and hunters like the members of the dog tribe show this structural arrangement. To ensure

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efficient coaptation of the larynx and nasopharynx lateral palatine folds descend on either side of the epiglottis, with palatoglossal and palato-pharyngeal muscles enclosed within their layers. Contraction of these muscles keeps the palatine folds taut, and brings them efficiently into contact with lateral epiglottic folds, thus ensuring passage of air over the olfactory nasal mucous membrane even when the mouth is open, as during cropping of herbage.

When the ingestion of any large bolus takes place the palatine folds must be separated from the epiglottis to give free passage; deglutition is then divided into three stages, the first through the mouth, the second past the larynx and the third through the œsophagus.

Man relies for his preservation on vision and not on his sense of smell, and has therefore no need of this intimate relationship of laryngeal and nasal airways.

Combined respiration and deglutition.—Animals such as herbivora, which eat large quantities of vegetable food, would be handicapped if respiration had to cease while food passed into the gullet. To overcome this difficulty the larynx is provided with high lateral margins, which in most species take the form of aryepiglottic folds. The larynx thus assumes a spout-like character, with a lateral food channel on either side. Further to prevent entrance of fluids there is evolved an arcus palato-pharyngeus, a fold made up of the fused palatine arches meeting posteriorly, with an enclosed palato-pharyngeal sphincter, designed to grasp the laryngeal aperture and thus to shut off the lateral food channels from the airway. This structure is present in most herbivora and appears, in its most efficient form, in cetaceans such as porpoises, dolphins, and some whales. Fœtal marsupials attached to the maternal nipple and fed forcibly by the mother, show the mechanism well. Man has abandoned the purely herbivorous habits of his ancestors and with his mixed diet has no need of an efficient lateral food channel. A further reason for his departure from the herbivorous type of lateral passages is the recession of the jaws and the flexion of the head on the vertebral column; the larynx has descended in the neck, being forced to do so by the tongue, which assumes an arched shape.[35] The result is the separation of larynx from nasopharynx, with a wide gap between epiglottis and soft palate, and the formation of a capacious and lengthy pharynx. There is an angle of almost ninety degrees between the mouth and pharynx. The descent of the larynx in the neck and the absence of any close relationship with the nasopharynx, make it essential that both nasal and laryngeal passages should be closed during deglutition, to prevent inundation. Only when very small quantities of liquids, food or saliva are passing is it possible for the laryngeal aperture to remain open.

Mechanism of the nasopharynx.—Closure of the nasal airway is a complicated action in which several muscles play a part. As food is

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forced back into the pharynx, reflex stimulation of the posterior wall initiates a swallowing movement,[27] commencing in the highest part of the nasopharynx and travelling down as far as the mouth of the œsophagus. The first movement appears to be carried out by longitudinal elevator muscles, the levator and tensor palati, closely followed by the salpingo-pharyngeus and the palato-pharyngeus. The uppermost fibres of the latter are almost horizontal and act as the sphincter of the hiatus naso-pharyngeus, situated just above the lower border of the soft palate. This view of the anatomy is taken by Wood Jones, who refers to the observations of Townshend[20]; previously the sphincter had been ascribed by Wardill[41] and Whillis[42] to fibres of the superior constrictor.

The primary movement of the elevator muscles leads to raising of the soft palate and closure of the nasopharyngeal isthmus by approximation of all its walls; initial closure is followed by a wave of constriction, effected by the superior constrictor muscle, with the object of squeezing out mucus, debris and bacteria, dumped by the ciliary streams of the nose and sinuses, to be carried downwards through the pharynx into the œsophagus and stomach.

When the mechanism is upset, as in the paralysis sometimes following diphtheria, there may be regurgitation into the nose. Scarring and immobility may lead to stagnation of infected secretions, with consequent droplet infection of the lungs.

Closure of larynx during deglutition.—When any considerable quantity of food or fluid is swallowed, respiration ceases and both nasopharynx and larynx close. At the beginning of the second stage of deglutition the larynx rises with the rest of the pharyngeal tube. Contraction of the thyrohyoid muscle, together with the upward pull of the palato-thyroideus,[20] causes the thyroid cartilage to ascend beneath the hyoid bone, thus bringing the whole larynx into apposition with the base of the tongue. At the same time the sphincters of the larynx contract, while the dilators relax, in order to close the airway before food has the chance of entering.

The simple sphincter of lung fish is represented in man by the paired lateral crico-arytenoid and thyro-arytenoid muscles and the single inter-arytenoid, with certain oblique fibres running from the latter to the epiglottis. A few strands pass the epiglottis to be attached to the hyoid bone, thus assisting in the elevation of the larynx.

In dogs some fibres may be seen passing from the sphincteric group to the anterior wall of the œsophagus, to assist in opening the mouth of the latter.[32] Sébileau has described similar fibres in the horse.[37] In man these fibres are less obvious, but there is an alternative mechanism with a similar function, namely suspension of the anterior wall of the œsophagus from the tips of the recurved cartilages of Santorini. These processes are tilted forward by the underlying interarytenoid muscle

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during swallowing, thus serving to close the larynx and open the œsophagus simultaneously.[32, 33] In these movements the anterior wall of the hypopharynx is partially pulled up over the top of the cricoid cartilage, thus helping to close the laryngeal aperture.

It is generally recognized, in agreement with Anderson Stuart[39], that the epiglottis does not serve as a lid for the laryngeal aperture; rather it appears to be squeezed between the base of the tongue and the upper boundary of the larynx.[7] Many animals amongst the lower orders, and walruses and sea lions amongst mammals, are provided with no more than a rudimentary organ and yet suffer no inconvenience; nor does a man whose epiglottis has been removed.

Although the larynx of man may remain open when small quantities of fluid pass along the lateral food channel, yet insufficiency of the latter makes it necessary for closure to take place when any large amount is swallowed. Even so the food stream does not habitually pass over the larynx, but is diverted to one or other side. Observations have been recorded by Grahe[8] to show that the lateral food channel of one side only is used by most individuals, to the exclusion of the opposite side. This may have some bearing on the causation of malignant disease in the pyriform fossa.

In many animals, as already noted, closure of the larynx during deglutition is not necessary.

Mechanism of second or pharyngeal stage in man.—Having traced the evolutionary changes which have divided swallowing into three stages, it is now desirable to study further the second stage, in which food passes from the level of the palatine folds to the mouth of the œsophagus.

In man, the descent of the larynx, dependent on flexion of the head and retrogression of the jaws, has considerably increased the length of the pharynx[35] and has altered the anatomical distribution of the longitudinal and circular muscles; but there seems no good reason to think, with Ledoux,[25] that the mechanism is materially changed.

The longitudinal or elevator muscles consist of the stylo-pharyngeus, palato-pharyngeus and palato-thyroideus, working in association with the levator and tensor palati, the salpingo-pharyngeus and the elevators of the hyoid bone and larynx; of the latter group the stylohyoid and thyrohyoid are important members. Clarification of the distribution has been made by Wood Jones.[20] The circular group is made up of the three constrictors. The latter differ in their arrangement from the corresponding muscles of mammals, the fibres of the inferior constrictor having a considerable upward inclination from their origin on the larynx to their insertion in the posterior median raphe. But the mode of action of the pharyngeal musculature appears unchanged, as may easily be observed in the pharynx of a partially anæsthetized patient whose mouth is widely opened.

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Each movement of swallowing can be seen to consist of primary elevation, in which the fibres of the middle and inferior constrictor are brought into a more horizontal position, followed by a peristaltic wave of constriction flowing rapidly and smoothly down the tube-like pharynx. The larynx, forming part of the anterior wall, rises with the rest of the pharynx and again descends when the bolus is engulfed and carried downwards to the mouth of the œsophagus ; the whole wall of the pharynx rises and falls in this multicellular engulfing movement. Ledoux, in contradistinction, considered the middle and inferior constrictors to act as elevators of the larynx and described the longitudinal muscles as accessory elevators.

Although this peristaltic mechanism is not always required in man, yet it is available and is essential in such animals as giraffes, whose food passage slopes upwards during feeding. Considerable force may be exerted on a bolus of food, as noted in cases of pharyngostome. Bilateral paralysis of the muscles, as in bulbar palsy, may lead to inability to swallow, while unilateral paralysis, due to such conditions as thrombosis of the posterior inferior cerebellar artery, causes considerable disability, with lateral movement of the affected side during contraction of the opposite and active constrictors. This is the curtain movement described by Vernet.[40]

There may be, in addition, lateral deviation of the thyroid cartilage, the sign of Adam's apple referred to by Ledoux.[25]

The opening of the pharynx at the beginning of the second stage appears to depend on contraction of the elevator muscles, with relaxation of the palato- and stylo-glossus.

The lumen of the pharynx thus opens up as the backward push of the tongue ceases. It is again closed by the peristaltic wave of the constrictor muscles ; but before this wave descends, the bolus of food, if not too hard or bulky, may have passed rapidly down the opened pharynx. The question of the suction effect stressed by Barclay,[1,2,3] will be referred to later.

Closure of mouth of the œsophagus.—In animals which draw air into the lungs by expansion of the thorax and descent of the diaphragm, the bellows action would, if no barrier existed, suck air more readily into the œsophagus than into the lungs.

To prevent this undesirable occurrence, the crico-pharyngeal sphincter is present at the mouth of the œsophagus to keep the gullet closed during respiration, as described in previous contributions.[31] Insufficient interest has been taken in this important muscle band, and although it was described many years ago, yet no reference to it is made in most textbooks of anatomy and physiology. Keith[21] recognized the sphincter as being constituted by the lowest part of the inferior constrictor, the upper part of which has a propulsive action. He referred to its relaxation

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in the act of swallowing and wrote : " Like the sphincter at the pylorus, that at the upper end of the œsophagus is continually in action, except during the initial act of swallowing." He mentioned that, unknown to him, a description had already been given by Killian,[22, 23] and he also referred to the writings of Sir Everard Home,[10] who compared the sphincter to that of the urethra.

Chevalier Jackson[15, 16, 18, 19] observed the obstruction offered by the sphincter on passing an œsophagoscope and described the muscle band as long ago as 1907 ; and subsequently in many contributions he gave prominence to its importance in deglutition.

Relaxation of the sphincter occurs when a signal is given by the sensory stimulation afforded by impact of a bolus of food on the posterior pharyngeal wall. The mouth of the œsophagus opens as the larynx closes, while respiration is temporarily suspended.

The fibres of the crico-pharyngeus meet posteriorly in a median raphe continuous with that of the oblique fibres of the inferior constrictor. They are anchored to the front of the vertebral column by virtue of atmospheric pressure, in addition to attachment of the covering bucco-pharyngeal fascia to the prevertebral fascia.

When the sphincter is contracted there is a backward pull on the larynx. When relaxation occurs, early in the second stage of swallowing, the larynx is released and tends to fall forward in response to contraction of the thyrohyoid and other muscles. The capacity of the pharynx is thus increased, affording a clear space for downward passage of food, as stressed by Barclay.[1, 2, 3]

The sphincter receives its motor supply from the nucleus ambiguus through the vagus and its recurrent branches ; the sympathetic sends fibres also and, according to observations of Lambert Rogers,[36] they all come from the superior cervical ganglion. By removal of the sympathetic supply Lambert Rogers has produced relaxation of the sphincter ; it may therefore be concluded that the vagus is the relaxor and the sympathetic the contractor of the muscle band. The vagus thus has an opposite action on the oblique and circular fibres of the inferior constrictor muscle, with contraction of the former and relaxation of the latter. The sympathetic is reputed to augment the action of the vagus in the upper third of the œsophagus[24] but apparently it has an opposite action on the sphincter. The crico-pharyngeus remains in contraction when the inferior constrictor and muscles of the upper œsophagus are relaxed, all being controlled by the vagus ; propulsive waves in the pharynx during deglutition are associated with relaxation of the sphincter, the sensory fibres of the vagus giving the necessary signal. But when there is prolonged irritation of the lower pharynx or upper end of the œsophagus—either from the presence of a foreign body, a neoplasm, acute or chronic inflammation or ulceration—initial

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swallowing efforts to dislodge the cause of irritation are succeeded by lack of relaxation or achalasia.[13] Sometimes increased contraction, even amounting to spasm, is present. This reversed effect of excessive sensory stimulation is remarkable.

Deficient relaxation of the sphincter appears to be an important factor in the causation of pharyngeal diverticula[18]; the bolus of food, forced down by peristaltic contraction of the constrictors, causes herniation of the weak and relatively unsupported area between the lowest oblique fibres of the inferior constrictor and the crico-pharyngeal sphincter, as described by Keith.[21] On the other hand, undue relaxation of the sphincter may permit air sucking or air swallowing, with distension and subsequent dilatation of the entire thoracic œsophagus, leading to œsophagectasia, with all the signs and symptoms of the disease usually known as cardiospasm.[34] This theory of primary dilatation probably applies to many cases in which no primary obstruction is present.

Animals with no lungs, those with infrabuccal bellows and those filling the lungs by swallowing movements have not the same need as man of a sphincter at the mouth of the œsophagus.

Passage of food into and through the œsophagus.—It has been mentioned above that relaxation of the crico-pharyngeal sphincter is followed by increase in the capacity of the pharynx. The sudden opening of the œsophagus allows the normally reduced intrathoracic pressure to exert a suction effect, particularly during the inspiratory phase of respiration. It is thus possible for food to drop through the laryngo-pharynx into the funnel-like mouth of the œsophagus in advance of the peristaltic wave which descends to propel any lagging bolus. This suction action was described by Maissiat[26] and has been brought into prominence by the radiological studies of Barclay.[1, 2, 3]

The rapid rate of progress may continue in the upper part of the œsophagus, after which partial equalization of pressure, incidental to opening of the sphincter, leads to slowing of the bolus. In this connection it is stated that reflex inhibition of tonus of the upper end of the œsophagus accompanies relaxation of the crico-pharyngeal sphincter, thus delaying the commencement of the peristaltic wave.[38]

Through the remainder of the œsophagus, passage of the bolus may be effected by gravity, but the normal propelling force is muscular action; by co-ordinated action the elevating longitudinal and sphincteric circular components execute movements of engulfment, shortening being succeeded by a peristaltic wave. That peristalsis is a means of propulsion of food is shown by the ability to swallow with the head lower than the body, as in human beings lying on an inclined bed, or in animals with long legs.

The nerve supply of the œsophagus has been the subject of a considerable amount of experimental work; the observations of Knight[24] have clarified the position. The vagus gives branches to the musculature,

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both from its main trunk and also through the recurrent laryngeal nerve ; it produces, by its action, increased tonus in the thoracic œsophagus. Stimulation of the supply to the upper third causes temporary tetanic contraction ; the sympathetic has a contributory effect. In the middle third stimulation of the vagus increases tonus, augmented by the sympathetic ; in the lower third the vagus acts in a similar manner but is opposed by the sympathetic.

Paralysis of both vagus nerves causes dilatation of the œsophagus, with decreased motility ; peristalsis later recovers in the lower third. The dilatation of œsophagectasia or cardiospasm cannot usually be due to decreased vagal action, however, since many cases show hypertrophy of the musculature and not wasting. Wide dilatation of the œsophagus, such as occurs in cases of cardiospasm and congenital shortening, makes the peristaltic wave ineffective ; swallowing of air has already been mentioned as a possible cause of the dilatation. Clinical and radiological observations show that patients with œsophagectasia rely on gravity as a means of carrying food onward. Peristalsis, under such conditions, cannot bring the walls of the gullet into approximation and the muscular wave merely churns up the contents, with no propulsive effect. In attempts to close the lumen, so as to overcome the disturbance of the normal mechanism, the musculature may hypertrophy. This explanation appears, in the case of œsophagectasia with holding up at the diaphragm, to be as reasonable as that which considers the muscular overgrowth to be a response to obstruction ; the slight degree of the latter, to be referred to later, should readily be overcome if hypertrophy followed obstruction early in the disease, and wide dilatation should therefore not occur. As soon as the muscular hypertrophy fails to compete with the abnormal dilatation of the œsophagus there is only one method for conveyance of food into the stomach, and that is the force of gravity.

Mechanism at lower end of œsophagus.—It is not necessary, for physiological reasons, that any obstruction should be offered to the entrance of food or fluid into the stomach. On the contrary, it is desirable that the contents of the œsophagus should pass onward as rapidly as possible, since stagnation is liable to cause œsophagitis. But it is essential that regurgitation should be prevented, not only to prevent the loss of gastric contents, but also to avoid peptic digestion of the mucosa in the lower end of the œsophagus.

Once in the stomach the contents are constantly forced onwards towards the pylorus by muscular contraction and are only temporarily arrested by the pyloric sphincter, until of suitable consistency to enter the small intestine. In the opposite direction, however, there is normally little tendency for food to regurgitate, and but slight force is required to prevent its escape.

https://doi.org/10.1017/S0022215100156427 Published online by Cambridge University Press

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A cardiac sphincter has been referred to by many authors, but descriptions vary. Hurst considers it to be situated in the abdominal segment of the œsophagus, usually extending up to the level of the diaphragmatic hiatus.[11, 13]

Cannon[5] has shown that in the normal cat regurgitation from the stomach to the œsophagus is a common occurrence, the fluid again being returned to the stomach by peristalsis; but when the gastric contents become acid during digestion, their effect is to keep the cardiac sphincter closed, apparently to prevent regurgitation. Much experimental work has been carried out on the nerve supply of the sphincter; Hurst has studied the subject in detail.[11,12,13,14] The observations of Knight[24] may also be quoted. The sphincter is supplied by both vagus and sympathetic nerves; stimulation of the former causes relaxation, while the latter leads to increased contraction. The sympathetic fibres surround the cœliac axis and left gastric arteries; excision of this supply causes the sphincter to become completely patulous, with consequent regurgitation into the œsophagus. In cats, division of the vagal supply to the œsophagus causes dilatation, with holding up of food by contraction at the cardia; division of the sympathetic fibres leads to cessation of all symptoms. Hurst believes that the cause of a similar condition in man is degeneration of Auerbach's plexus,[14] with consequent blockage of the stimulus to relax. There is no dispute with these experimental findings in the cat, but other considerations appear to arise in man, both in normal deglutition and in diseased states.

All opinions consider the sphincter to be very feeble and in no way comparable to the sphincters of the bladder, the rectum, or the mouth of the œsophagus. It is easily forced by œsophageal contents, and in cases of œsophagectasia offers but little resistance to a mercury bougie, as observed by Hurst.[13,14]

I have never seen evidence of its existence on direct œsophagoscopy. As regards disordered action of the sphincter, if one exists, some have described over-action, producing the disease generally known as cardiospasm; but there is no hypertrophy of the sphincter in this type of œsophagectasia.[14]

Others, and notably Hurst, consider lack of relaxation or achalasia to cause holding up of food in the œsophagus, with the proviso that the sphincter is situated just below the diaphragmatic hiatus, where the hold-up occurs, and not at the actual junction of abdominal œsophagus and stomach. But if the disease were caused by achalasia, hypertrophy of the œsophageal musculature, present in many cases, should easily overcome the feeble resistance of the sphincter, and in fact is thought by Hurst to do so in the early stages of the disease. Resistance by the sphincter alone does not appear to explain the progress of the complaint, in view of the feeble obstruction offered, even in severe cases.

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Further evidence as regards the cardiac sphincter is obtainable in those cases of short œsophagus with no organic stricture at the junction of œsophagus and thoracic segment of the stomach. When one passes an œsophagoscope in such a case the line of demarcation between œsophageal and gastric mucosa is obvious and sharply defined; but one does not see evidence of a sphincter. Furthermore it is common experience, in such cases, to find reflux of gastric secretions into the œsophagus, with peptic ulceration; Dick and Hurst[6] in fact consider shortening of the œsophagus to be a common factor in this type of œsophageal disease. In a paper by Briggs and themselves it is stated that: "The cardiac sphincter appears to be permanently relaxed when the œsophagus is abnormally short and a portion of the stomach is above the diaphragm; this is in contrast with the normal condition, in which it is closed except when relaxation occurs in the last stage of deglutition."[4] In view of the consensus of opinion that the cardiac sphincter is feeble, if in fact it exists, it is desirable to consider whether other means are available to prevent regurgitation from the stomach. I have long felt, and am not alone in my opinion, that local physical conditions are such as to make a muscular sphincter unnecessary.

Gubarof[9] is quoted as believing in the theory of mechanical as opposed to muscular closure, and the Ducuings,[7] who refer to his paper, also consider this possibility. Dick and Hurst[6] refer to a cardiac valve, formed by the left lip of the abdominal œsophagus as it joins the stomach; they believe it to act in one direction only and to assist in preventing regurgitation, while offering no impediment to the entrance of food into the stomach.

A factor which appears to have been somewhat overlooked is the difference in physical conditions to which the thoracic and abdominal segments of the œsophagus are subjected. In the thorax there is normally reduced pressure, tending to open the œsophagus, while in the abdomen the pressure is raised, with mutual apposition of the viscera, thus closing the abdominal œsophagus.[34] The difference of pressure and degree of obstruction are greater during inspiration, due not only to expansion of the ribs and descent of the diaphragm, but also to contraction of the crura and narrowing of the hiatus. For this reason and not because of varying degrees of contraction of a sphincter, a bolus of food may be halted during inspiration, to enter the stomach when expiration commences; pressure in the abdomen is then reduced, while the intrathoracic pressure is correspondingly increased.

A further factor of importance in closure of the abdominal œsophagus is the situation of the gullet in the liver tunnel of Mosher; it is here subjected to pressure from the left, exerted by the fundus of the stomach, especially when the air bubble is large. Distension of the stomach may be associated with an abdominal lesion such as gall-stones, gastric ulcer,

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or chronic appendicitis, and may lead to increased obstruction, in some cases followed by œsophagectasia. The possible benefit of dividing the sympathetic supply to the region of the cardia, recommended by Knight,[24] may be explained by lessened inhibition of the gastric musculature, with diminution of stasis, and not by any effect on the cardiac sphincter. Kinking of an overlong œsophagus may add to the valvular obstruction and may necessitate œsophagolysis.

Mosher[29] has shown by detailed observations that the œsophagus folds on itself as it passes the left crus of the diaphragm; there is an alteration of direction from the vertical to the horizontal. The left lobe of the liver is in front of the horizontal segment and thus helps in its closure. He has also demonstrated a close relationship of the lung tips to the œsophagus.[28] The right lung tends to go behind and the left in front; the total effect is not only a change of direction, but also a twist of the axis and a tendency to kinking and occlusion of the lumen. The effect is most marked when the diaphragm is down; during its rise in expiration the œsophagus tends to straighten out and open. Mosher believes that a cardiac sphincter exists, but not in every subject; he is of opinion that the physical factors outlined are the cause of closure of the terminal portion of the œsophagus.

Jackson[16, 17] considered specialized muscle fibres derived from the crura of the diaphragm to have a pinchcock effect; the lack of effective prevention of regurgitation during expiration by this means alone, if the fibres relax with the rest of the diaphragm, makes it necessary, however, to consider other possibilities. Jackson himself considered kinking of the abdominal œsophagus to play a part.[16] The evidence available appears to support the view that physical factors produce a mechanical compressive effect at the level of the diaphragm, sufficient to prevent regurgitation and calling for a mild propulsive effort on the part of the œsophagus.

If the propulsive force diminishes or if the obstruction increases, there may be holding up of food in the œsophagus, with signs and symptoms of the disease generally known as cardiospasm.

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