An Address

ON THE

RESULTS OBTAINED IN SOME EXPERIMENTS IN
WHICH THE FACIAL AND RECURRENT
LARYNGEAL NERVES WERE ANASTOMOSED
WITH OTHER NERVES.*

BY

SIR CHARLES BALLANCE, K.C.M.G., C.B.,
M.S., F.R.C.S.

BEFORE describing some of the experiments which have been performed, I must state that the results have been controlled by a team of workers, and that I am only one member of the team. Mr. Colledge has been responsible for reports on the condition of the vocal cords, and has actively helped me in many other ways; Dr. Lionel Bailey has reported on the electrical condition of muscles; and Dr. Eidinow on the movement, or absence of movement, of the diaphragm. Further, I have had the great advantage of the inspiring presence of Sir David Ferrier at the majority of the experiments; and his enthusiasm and critical judgement of the results obtained have been of the greatest value. My friend, the late Professor Shattock, was always keenly interested, and was present at each experiment till his physical strength, alas! failed. Dr. Dale, too, has been of the greatest help to me in the carrying out of these experiments.

Each result, which I shall briefly mention, has been obtained, not by one experiment, but by several. The animals used were monkeys, and the problems submitted to experiment could only be solved, I believe, by the method employed.

THE EVOLUTION OF THE OPERATION FOR THE CURE OF
FACIAL PALSY.

The first operation for the relief of facial palsy was done in 1895. The operation selected was an end-to-side anastomosis of the facial and spinal accessory nerves. Following this first operation surgeons devised several diverse methods of uniting the facial to the spinal accessory. For example, Grant of Denver and Kummer of Geneva divided the spinal accessory and united it end-to-end to the trunk of the facial. The descendens noni was then divided, and its proximal end was united end-to-end to the distal cut end of the spinal accessory. This latter anastomosis was done in order to obviate the paralysis and atrophy of the sterno-mastoid and trapezius; but this was a vain hope: the nervous current passing through the descendens noni failed to prevent serious atrophy of the trapezius, and, moreover, the depressor muscles of the larynx lost their nerve supply.

It was thought at first that injury to the spinal accessory nerve would be compensated for after a time by the direct cervical nerve supply of the sterno-mastoid and trapezius; but this idea soon proved fallacious.

The main result of all facial-spinal accessory anastomoses, and often the only permanent one, was associated movements

of the face and shoulder, and deformity of the neck and shoulder. Symmetrical, subconscious, emotional movement of the two sides of the face, the movement most desired, most frequently failed to appear; and thus real recovery eluded attainment. It is natural, then, that the search should be made for some other nerve which might give better results when anastomosed with the facial than with the spinalis.

The hypoglossal nerve was next anastomosed in various ways with the facial. Facial-hypoglossal end-to-side and facial-hypoglossal end-to-end anastomoses were performed; but these left partial or complete atrophy of half the tongue; so attempts were made to prevent the atrophy of the tongue by bringing a strip of the spinalis across the neck and uniting it end-to-end to the divided distal end of the hypoglossal; or by dividing the descendens noni and uniting the proximal end to the distal cut end of the hypoglossal.

The facial-hypoglossal anastomosis gave some excellent results; but for a long time, an indeterminable time, there was associated movement of the face with the act of eating

and swallowing; so that in one patient twenty months after operation, and in several monkeys, active movements of the muscles of the corresponding side of the face during a meal were observed, and in the case of the patient were embarrassing and annoying. The problem seemed one, as I have said, that could only be solved by experiment.

In the following table the results of facial-descendens noni anastomosis, of facial-descendens noni and facial-communicans noni anastomoses, facial-lingual anastomosis, and facial-glosso-pharyngeal anastomosis are shown.

RETURN OF RESPONSE TO FARADIC
STIMULATION IN FACIAL MUSCLES.1. *Descendens noni-Facial Anastomosis (end-to-end).*

- 4 months: Response of all muscles except occipito-frontalis to strong current.
8 months: Response of all muscles to weak current.

2. *Descendens noni-Facial Anastomosis (end-to-end) and Communicans noni-Facial Anastomosis (end-to-end).*

- 1½ months: Slight response in orbicularis oris and levator labii superioris.
3 months: All muscles react to fairly strong current.
4 months: All muscles react to weak current.

3. *Lingual-Facial Anastomosis (end-to-end).*

- 2½ months: No response.
3 months: All muscles respond to strong current except occipito-frontalis.
4 months: All muscles respond—current less strong.
5 months: Same report—strong current still required.

4. *Glosso-pharyngeal-Facial Anastomosis (end-to-end).*

- 6 weeks: No response.
3 months: All face muscles respond to weak current. Face symmetrical during eating of an apple and when angry. Eyelids do not wink together quite harmoniously.

In another experiment, in two months all muscles react to same strength of current as those of the opposite or normal side of face.

It is of great interest to note that the face recovered much more quickly when the communicans noni and descendens noni nerves (Figs. 1 and 1A) were both attached to the trunk of the facial nerve, than when the descendens noni nerve was alone attached to the facial.

The lingual-facial anastomosis (Fig. 2) has not been a failure: the face has become symmetrical in repose, and the palpebral fissure on the paralysed side is not wider than that

FIG. 1.—Diagram of Facial-Descendens noni anastomosis (end-to-end) and Facial-Communicans noni anastomosis (end-to-end). Operation.—A, Site of section of descendens noni nerve. B and C, Sites of section of communicans noni nerve. The figure shows: (1) Descendens noni facialis anastomosis (end-to-end). (2) Descendens noni phrenicus anastomosis (end-to-side). (3) Communicans noni facialis anastomosis (end-to-end). (4) The distal cut end of the communicans noni was so minute that no attempt was made to suture it to another nerve. The operation was done on a fairly large monkey. The descendens noni was relatively a large nerve which descended into the chest, while the communicans noni nerve was very small, and could only be followed with the aid of a magnifying glass. It will be noticed that the two nerves communicated rather high up, and that there was another "ansa" lower down, from which the nerves to the depressor muscles of the larynx were given off.

* Delivered at a joint meeting of the Sections of Laryngology and of Otolaryngology of the Royal Society of Medicine, June 27th, 1924.

on the normal side; but there has been a great delay in the return of normal faradic reaction in the muscles, and it is not yet clear that this will take place.

As long ago as 1895 Sir Edward Sharpey Schafer recommended me to use the glosso-pharyngeal nerve for anastomosis with the facial; but the advice was not accepted. The glosso-pharyngeal nerve is small and comparatively inaccessible. The spinal portion of the spinal accessory nerve, and the hypoglossal nerve, appeared to be so placed and so much larger than the glosso-pharyngeal nerve that for the time the latter nerve was rejected.

The remarkable results of the monkey experiments in which the facial was anastomosed to the glosso-pharyngeal end-to-end (Fig. 3) appear to require some explanation.

1. Jacobson's nerve, which arises from the petrous ganglion of the glosso-pharyngeal, enters a small canal in the bone, ascends to the inner wall of the tympanum, and divides into branches which form the plexus tympanicus. This plexus is in communication with the facial nerve.

2. There is a branch of communication between the facial and glosso-pharyngeal nerves outside the skull which extends from the stylo-mastoid foramen to the trunk of the glosso-pharyngeal just below the petrous ganglion. This communicating branch is not referred to in detail in English and Scottish "Anatomies." Testut (1905) figures it (Fig. 4), but the figure is copied from Bourguery's *Atlas* (1844). Meckel (1825) described it; Sappey (1872) described it as the "ansa of Haller," and on looking up Alberto v. Haller (1762) I found a description of this communication between the facial and glosso-pharyngeal nerves. It may be that this "ansa of Haller" has some bearing on the rapid recovery of the paralysed face following facial-glosso-pharyngeal anastomosis.

3. The motor nucleus of the facial nerve lies just above the motor nucleus of the glosso-pharyngeal nerve in the medulla oblongata. It is possible that there is some communication between these two nuclei.

When the glosso-pharyngeal nerve is used for anastomosis with the facial, its branches of distribution—tympanic carotid, muscular, and tonsillar—are not interfered with in any way. The nerve is divided beneath the upper and back part of the hyo-glossus muscle at the point where it commences to divide into lingual branches. The only result of such division would appear to be the loss of sensation and loss of taste over the back of the corresponding side of the tongue for one-third of its surface.

There is some difference among authorities in the description of the distribution of the glosso-pharyngeal nerve. The muscles of the pharynx and palate receive their nerves from sources not yet completely determined. Halliburton writes (*Handbook of Physiology*):

"It contains motor fibres to the stylo-pharyngeus and probably to the levator palati and other muscles of the palate, except the tensor, which is supplied by the fifth nerve. The nerve also contains fibres concerned in common sensation, and the sense of taste, and secretory fibres for the parotid gland."

In Quain's *Anatomy* the following sentences occur:

"The glosso-pharyngeal nerve divides as it passes beneath the hyo-glossus muscle into two parts. One turns to the upper surface of the tongue, and divides into many branches, which supply the circumvallate papillae and the mucous membrane over the

posterior third of the organ, the hindmost filaments reaching the anterior surface of the epiglottis. The other is smaller, and is distributed to the mucous membrane of the side of the tongue, extending to about the middle of its length, where it forms a communication with the lingual nerve." "The constrictor muscles are supplied by the pharyngeal plexus, their motor fibres being derived from the bulbar portion of the spinal accessory nerve, and in the case of the middle constrictor from the glosso-pharyngeal. The stylo-pharyngeus is innervated by the glosso-pharyngeal. The inferior constrictor receives branches from the external and inferior laryngeal nerves."

Testut (*Traité d'Anatomie Humaine*) says the stylo-glossus and stylo-pharyngeus are supplied by the glosso-pharyngeal nerve.

Morat (*Fonction d'Innervation, in Traité de Physiologie, by Morat and Doyon*) says that general sensibility and taste, after section of the glosso-pharyngeal nerve, are lost on the back of the tongue.

Chauveau, on excitation of the nerve, has seen contraction of the inferior constrictor and of the muscles of one side of the palate; and Vulpian has seen congestion of the base of the tongue in the field of distribution of the glosso-pharyngeal nerve.

Poirier and Charpy figure branches of the glosso-pharyngeal nerve to the stylo-glossus, stylo-pharyngeus, and the pharyngeal plexus.

"The motor portion of the nerve takes part in the innervation of the muscles of the pharynx, the muscles of the soft palate, and of certain muscles of the tongue."

Cunningham writes:

"The glosso-pharyngeal nerve consists of a smaller motor element which supplies the stylo-pharyngeus, and a larger sensory part which supplies the pharynx and tongue." "The lingual branches supply the mucous membrane and the vallate papillae of the dorsal third and lateral half of the tongue, extending backwards to the glosso-epiglottic folds and the front of the epiglottis." "The constrictors of the pharynx receive their nerve supply through the pharyngeal plexus from the accessory nerve. The inferior constrictor is supplied also by the external laryngeal and recurrent branches of the vagus nerve." "The stylo-glossus is supplied by the hypoglossal nerve." "The muscles of the soft palate, except the tensor, are supplied through the pharyngeal plexus by the accessory nerve."

When deglutition is about to be performed the pharynx is drawn upwards and dilated in different directions to receive the food propelled into it from the mouth. The larynx is raised up behind the hyoid bone and the soft palate is also raised, so that both the larynx and posterior nares are protected against the entrance of food.

"The food when sufficiently masticated is by movements of the tongue gathered up into a bolus on the middle of the upper surface of the tongue—partly raised by the intrinsic muscles and partly by the stylo-glossi—the bolus is thrust back through the isthmus faucium and received by the upper constrictor. By the contraction of the stylo-pharyngeus and palato-pharyngeus, the funnel-shaped bag of the pharynx is brought up to meet the descending morsel, very much as a glove may be brought up over the finger; deglutition is a reflex act—the centre of the reflex act lies in the medulla oblongata. This centre lies at a higher level than that of respiration." (Michael Foster.)

In facial-glosso-pharyngeal anastomosis we may therefore expect, from anatomical reasons, that in the act of deglutition—in which the stylo-pharyngeus and possibly other muscles (which are supplied in part at any rate by the motor element of the glosso-pharyngeal nerve) contract—associated movements would occur in the facial muscles.

FIG. 1A.—Microscope section (Stroebe stain for axis cylinders), showing anastomosis of the facial nerve with both the descendens noni nerve and the communicans noni nerve. The drawing was made from a study of serial sections. This specimen was obtained four months after the operation. Same case as Fig. 1.

Whether such associated movements will be permanent we do not know. Such movements have been observed in one of the experiments only. Three months after a glosso-pharyngeal anastomosis in a baboon, during the act of eating and swallowing, the eyelids on the side of the operation were noticed nearly to close, and the upper lip on this side was seen to be in movement.

Whether the lack of sensation over the posterior third of the tongue, on one side only, will be of importance, we also do not know; but that it may interfere with the protection of the larynx from the entrance of food is possible, for in a baboon in which this anastomosis was done the swallowing of food seemed sometimes to bring on a cough; but this did not happen in other monkeys in which a facial-glosso-pharyngeal anastomosis had been done.

I have done one operation in man in which the facial nerve was anastomosed with the glosso-pharyngeal nerve. It appeared almost a forlorn hope, but it has by no means turned out so; the result so far is encouraging.

FIG. 2.—Diagram of Facial-Lingual anastomosis—end-to-end.
x=ansa of Haller.

CASE.—Facial-Glosso-pharyngeal Anastomosis: End-to-End.

Mrs. X, aged 37, was operated on sixteen years ago by a well known aural surgeon for mastoid disease. Since the operation she has suffered from total right-sided peripheral facial palsy. The tears trickle over the face from the right inner canthus. The eyelids on the right side are far apart and mastication is always carried on on the left side of the mouth. The distortion of the face in talking or smiling is very bad. The tip of the nose is bent towards the left side of the face; in fact the patient says it is crooked.

From time to time during the sixteen years of facial palsy treatment of the face muscles has been carried out by means of massage and galvanism. Dr. Lionel Bailey examined the electrical reaction of the face muscles. He obtained a galvanic response in all the right facial muscles except the zygomatici. It was typically sluggish, indicating reaction of degeneration, and was very feeble. There was a slight faradic response in the levator menti and pyramidalis nasi. Dr. Bailey writes: "I do not attach any importance to the fact that a faradic response was obtained in the two muscles mentioned, and consider this was due to overlapping nerve filaments supplying the muscles from the other side of the face. I consider the case is one of complete interruption of the right facial nerve and that no recovery can take place without operation."

The presence of galvanic response in the paralysed muscles justified operation.

March 10th, 1924. The operation of facial-glosso-pharyngeal nerve anastomosis, end-to-end, was performed. The facial nerve

trunk was no longer white; it looked more like a strand of reddish fibrous tissue than a nerve.

March 14th. The right face is, if possible, more flaccid—that is, more paralysed—than it was before the operation. I have frequently noticed this phenomenon after section of the facial nerve at the stylo-mastoid foramen in order to unite it to another nerve for the cure of facial palsy. What is the explanation?

April 28th. The tone of the face is remarkably improved. Tears no longer trickle over the cheek. The right palpebral fissure is almost normal. The patient complains of curious crawling sensations travelling over the right side of the face; she says that they make her feel that the face is getting alive again.

June 6th. Slight flicker of movement on faradic stimulation in orbicularis oris at right angle of mouth. The patient could not bear a strong current; in fact, that employed was weak.

June 31st. Dr. Bailey reports: "The galvanic response is more easily obtained in all the muscles, and though still sluggish is much less so than formerly."

July 4th. Further improvement in the tone of the face. There is much less deformity than three months ago. Mastication now takes place by choice on the right side of the mouth. In repose there is little deformity. The nose is now straight, it is no longer bent to the left side. There is voluntary movement in the corrugator supercilii, and there is a slight flicker of response to a

FIG. 3.—Diagram of Facial-Glosso-pharyngeal anastomosis—end-to-end.
x=ansa of Haller.

weak faradic current in the lower part of the orbicularis palpebrarum, and at the angle of the mouth in the orbicularis oris. (It is to be remembered that voluntary movement generally antedates the return of faradic excitability.)

On touching the back of the right side of the tongue gently with a probe the patient felt it at once. The common sensation of the mucous membrane in this region appeared to be as good as that on the corresponding surface on the left side.

On testing the right and left sides of the tongue in the region of the circumvallate papillae with sugar and salt Mr. Colledge and I were unable to distinguish any difference between the two sides. (Note that the connexion of the right glosso-pharyngeal nerve with its lingual branches was severed four months ago.) Is the recovery of common sensation and taste over the back of the right side of the tongue to be explained by overlapping filaments from the lingual branches of the left glosso-pharyngeal nerve?

In this case since the division of the glosso-pharyngeal nerve there has been no difficulty in swallowing, and during swallowing no movement of the right facial muscles has been observed. There has thus been no indication that protection of the larynx against the entrance of food is impaired.

As far as one's knowledge goes at present, the conclusion seems to be that facial-glosso-pharyngeal anastomosis, end-to-end, is the operation of choice to perform in cases of facial palsy.

THE EVOLUTION OF THE OPERATION FOR THE CURE OF PARALYSIS OF THE VOCAL CORD.

Some time before the war I united the severed recurrent laryngeal nerve to the side of the vagus; but the patient disappeared, so the result of the anastomosis is not known.

It appears natural to employ the vagus for this anastomosis; but one, if not the chief, reason for the failure after anastomosis to obtain a movement of the vocal cord during tranquil respiration, such as was present before the injury to the recurrent laryngeal nerve, is the small chance there is of attaching the recurrent nerve to those bundles of fibres in the vagus trunk which were originally in continuity with it. The difficulty becomes obvious on studying a transverse microscopical section of the vagus nerve (Fig. 5). I have always performed a recurrent laryngeal vagal anastomosis, end-to-side, on the tracheal side of the vagus, but have never seen afterwards a movement of the vocal cord during tranquil respiration.

The same result—no movement of the vocal cord during tranquil respiration—has followed recurrent laryngeal-descendens noni end-to-end anastomosis. The following table illustrates these points:

RESULT OF THE ANASTOMOSIS OF THE RECURRENT LARYNGEAL NERVE TO THE VAGUS AND THE DESCENDENS NONI.

1. *Recurrent laryngeal-Vagus (end-to-side anastomosis).*
 - 2½ months: Vocal cord no longer slack. It is straight and tense. There is no movement.
 - 6 months: No movement of vocal cord during quiet respiration. On partial asphyxiation slight movement observed which soon ceased.
 - 15 months: No movement of vocal cord during tranquil respiration. On opening the wound and stimulating the vagus above the anastomosis, active abduction of the vocal cord was seen.
 - 18 months: No movement of vocal cord even following partial asphyxiation (attested by Sir David Ferrier and Sir Frederick Mott).
2. *Recurrent laryngeal-Descendens noni anastomosis (end-to-end).*
 - 2 months: Vocal cord shows tone; it is straight and no longer looks "cadaveric."
 - 3 months: No movement of vocal cord. Wound opened and hypoglossal stimulated above origin of descendens noni; active abduction of vocal cord observed.
 - 4½ months: On partial asphyxiation vocal cord seen to abduct, but movement soon ceased.
 - 9 months: No movement of vocal cord during tranquil respiration, or after partial asphyxiation.

That the anastomoses in these cases after a certain period were capable of conducting a nervous impulse is clear from—

(1) The result of partial asphyxiation, which caused a temporary abduction of the vocal cord during forced inspiration.

(2) The result of electrical stimulation of the vagus above the site of the anastomosis, and of the electrical stimulation of the hypoglossal above the origin of the descendens noni.

FIG. 4.—"The ansa of Haller" or communication between the facial and glossopharyngeal nerves outside the skull. This communication is said to be inconstant. The figure is taken from Testut's *Anatomy*, and Testut borrowed it from Bourguery.

movement could be obtained in them after partial asphyxiation; though we may fairly assume that the same nervous current was flowing through the recurrent nerve during partial asphyxiation, which previously was effective in producing contraction of the posterior crico-arytenoid muscle and abduction of the vocal cord.

From two to three months after an anastomosis had been done between the recurrent laryngeal nerve and either the vagus or descendens noni a remarkable change occurred in the appearance of the previously paralysed vocal cord. The inner border of the immobile vocal cord was no longer concave and slack.

It had regained tone and had become straight and tense. This recovery of tone in the intrinsic muscles of the larynx may be compared to the gradual recovery of tone in the previously paralysed face muscles, after an anastomosis of the facial nerve, say, with the hypoglossal nerve.

This change in the condition of the vocal cord was demonstrated by Mr. Colledge to Dr. Gabriel Tucker, Dr. Chevalier Jackson's first assistant, and to many members of the International Congress of Surgery which met in London during July, 1923.*

Dr. Frazier of Philadelphia (*Annals of Surgery*, February, 1923), at the instance of Dr. Chevalier Jackson, operated on two cases of recurrent laryngeal paralysis. He anastomosed the recurrent nerve to the divided descendens noni. The first case was operated on in June, 1923, and the second in September, 1923. The result of these

FIG. 5.—Transverse section of the vagus nerve of man, showing: A, The nerve before the recurrent laryngeal is given off. B, The vagus and recurrent laryngeal nerves at the point where the recurrent nerve is separating from the vagus. In each drawing it is obvious that certain bundles of nerve fibres have fallen out of the sections.

* See *British Journal of Surgery*, vol. xi, No. 42, 1923.

operations, as in our monkeys, has been "the return of tonus and tension in the vocal cord. The crescentic form of the edge of the vocal cord has been replaced by a normal margin. The patient notices a decided improvement, subjectively, in the laryngeal air-way." Dr. Jackson appears to think that a vocal cord which does not move, but which is straight and tense, is better than one which is slack, curved, and cadaveric; in fact, he says it gives a better air-way.

It is to be noted that end-to-side anastomosis of the vagus and recurrent laryngeal nerves is not free from danger, for I did this operation on a baboon in good health. The animal died on the twentieth day of acute lobar pneumonia on the side on which the operation had been done. It is true that the interference with the vagus may have had nothing to do with the death of this baboon, but I cannot get it out of my mind that the operation and the pneumonia which followed were in some way related. I may add that the wound healed by first intention. The animal was anaesthetized with ether.

The failure of the anastomosis of the recurrent nerve to the vagus and to the descendens noni to result in movement of the vocal cord in tranquil respiration naturally led to the search for another nerve which might do so. The nerve to the serratus magnus muscle (the nerve of Bell) was considered but rejected, because the serratus magnus only comes into play, if at all, in forced respiration. The second intercostal nerve might be brought up through the upper opening of the thorax and anastomosed to an injured recurrent laryngeal nerve; but it was thought that this was a too delicate and difficult operation to find favour with the ordinary surgeon; though the operation possessed this advantage, that the vocal cords move rhythmically with the contractions of the intercostal muscles and the diaphragm in tranquil respiration. Mr. Colledge and I were thus led to consider the phrenic nerve as the most likely to produce the desired effect on the vocal cord when anastomosed with the divided recurrent laryngeal. During inspiration the vocal cord abducts and the dome-shaped lateral muscular parts of the diaphragm flatten at the same time. The movements are rhythmical in tranquil respiration, and depend upon a nervous mechanism which sends an intermittent flow of nervous impulses down the recurrent laryngeal and phrenic nerves.

The following is a description of the first experiment in which the recurrent laryngeal nerve was anastomosed with the phrenic. Sir David Ferrier was present.

Recurrent laryngeal-Phrenic end-to-end anastomosis. Descendens noni (proximal end)-Phrenic (distal end) end-to-end anastomosis. Descendens noni (distal end)-Hypoglossal end-to-side anastomosis.

4 months: Both vocal cords move equally in tranquil respiration.
6 months: The previously paralysed vocal cord moves more strongly than the other.

7 months: Excessive, almost violent, movement of the vocal cord as compared with that on the normal side. (Attested by Sir David Ferrier and Sir Frederick Mott.)

Movement of diaphragm normal. (Seen by Dr. Eidinow and Professor Leonard Hill.) Reactions of depressor muscles of the hyoid bone and larynx normal.

You can imagine the feelings of Mr. Colledge and myself when we first saw the movements of the vocal cords taking place in the normal manner, and we knew that the experiment was successful. It was also a remarkable event to observe the half of the diaphragm which had been paralysed contracting again through the nervous impulses passing

down the descendens noni nerve.* All three anastomoses were functioning, but by using the whole of the phrenic what had been attempted had been overdone—the previously paralysed vocal cord was working too vigorously. This, however, was not a surprise, because the nerve current required to cause contraction of one-half of the muscle of the diaphragm must be considerably stronger than that required to energize the small intrinsic muscles of the larynx. What root of the phrenic nerve or what portion of the main trunk of the phrenic nerve (the phrenic on transverse microscopic section shows two or three bundles of nerve fibres) is sufficient to cause a normal rhythmical contraction of the muscles of the larynx is a problem which must be left for discussion on another occasion. Suffice it to add that several experiments are in progress to throw light upon this question.

It is not possible to determine with accuracy in a small monkey whether half the diaphragm is in part or completely paralysed by observing the movements of the abdominal wall and costal arches. Dr. Eidinow has made examinations for me by means of the radiographic screen. During inspiration the dome-shaped lateral muscular masses of the diaphragm contract and flatten. At the same time the central tendon descends. In this way the vertical depth of the chest is increased.

When one lateral half of the musculature of the diaphragm is paralysed the central tendon and the two lateral muscles still move up and down in tranquil respiration. The non-paralysed lateral muscle contracts and flattens, and its dome-shaped outline loses much of its curved appearance. The paralysed muscle of the other side still retains its dome-shaped form, and moves downwards and upwards in inspiration and expiration. There is, of course, no flapping of the paralysed muscle of the diaphragm, as there are no free spaces within the living body; and it is always in close contact above with the pleura and lung, and below with the peritoneum and abdominal viscera.

The experiment described above in which three anastomoses were performed could not be the final settlement of what the surgeon should do when

he endeavours to cure recurrent laryngeal palsy. It is too complicated, and what is required is some simple plan of anastomosing the recurrent nerve to the phrenic or one of its roots, so that, if possible, there should be no interference, or the minimal interference, with the function of the diaphragm, and no section of the descendens noni nerve.

Another difficult question arises: Has the exaggerated movement of the previously paralysed vocal cord, which is synchronous with the movements of the opposite or normal vocal cord, been obtained by the perfect linking up of the phrenic fibres with the cerebral mechanism of respiration which previously caused rhythmic and equal movements of both vocal cords? (One must remember that both the phrenic and recurrent laryngeal nerves are intimately associated in normal tranquil respiration.) Or is it simply the intermittent flow of the normal current through the phrenic which had previously energized one-half of the diaphragm, but now is switched over to the muscles of the vocal cord? I am inclined to take the latter view, and if this latter view be true is it possible that, in course of time, Nature will so adjust the mechanism of respiration that the flow of

FIG. 6.—A, Recurrent laryngeal-Phrenic anastomosis (end-to-end). B, Descendens noni (proximal end)-Phrenic (distal end)—end-to-end anastomosis. C, Descendens noni (distal end)-Hypoglossal—end-to-side anastomosis.

* It is strange that the descendens noni-phrenic anastomosis should be followed by rhythmic contractions of the diaphragm in tranquil respiration, and yet that descendens noni-recurrent laryngeal anastomosis should fail to be followed by rhythmic contractions of the intrinsic muscles of the larynx. The observation needs confirmation by further experiment.

nervous energy through the phrenic will diminish and lead to movements of the vocal cord in which the excursions will be equal to, and not greater than, those of the vocal cord on the opposite or normal side?

Another question also requires an answer: When the vocal cord is moving normally through nervous impulses conveyed to it through the phrenic, will the patient be able to phonate? This is the question asked by Sir Frederick Mott. The answer can hardly be decided by experiment on the monkey: operation on man will give the reply. This will be the decisive experiment.

The conclusion, therefore, appears to be, that for the cure of recurrent laryngeal palsy and the attainment of normal movement of the vocal cord in tranquil respiration, anastomosis with the vagus or the descendens noni must be rejected, and some form of anastomosis should be carried out with the trunk or with one of the roots of the phrenic nerve.

The Medical Research Council has defrayed the expenses of this research, and given me every possible assistance at the National Research Institute.

THE EFFECT OF DIET ON THE DEVELOPMENT AND EXTENSION OF CARIES IN THE TEETH OF CHILDREN.*

(Preliminary Note.)

BY

MAY MELLANBY, C. LEE PATTISON, M.B., B.S.LOND.,
AND J. W. PROUD, L.D.S.,
SHEFFIELD.

INTRODUCTION.

It has been found by May Mellanby¹ in her experimental work on puppies, first published in 1918, that the structure of the teeth and their arrangement in the jaws are controlled by the diet and environment to which the animals are subjected during the period of development of their teeth. Some dietetic factors tend to help, and others to hinder, the formation of well calcified, evenly arranged teeth. In the former group are to be found substances rich in a vitamin closely allied, both as regards distribution and properties, to vitamin A. This group of substances includes cod-liver oil, animal fats (except lard), milk, and yolk of egg. Among those foods which lead to the development of badly formed teeth, cereals, and particularly oatmeal, occupy a prominent position. Thus the total influence of a mixed diet on the structure and the arrangement of the teeth in the jaws of puppies is the outcome of a battle between different dietetic influences.

In addition to the influence of diet, May Mellanby² has also shown that exposure of the animal to either sunlight or other sources of ultra-violet radiation has, under some conditions, an important influence on tooth formation. It is probable that the effect of these radiations is to make active the calcifying vitamin stored in the body. In fact, the interaction of the dietetic and environmental influences on tooth formation is certainly very close.

Two questions arise from the experimental work on the factors influencing the formation of puppies' teeth: first, Do the same factors control the formation of the teeth of human beings? and secondly, What relation have these facts to dental caries in man?

With regard to the first question, it is not yet possible to state that the results are applicable to man, in spite of the fact that the experimental work was published some years ago. There seems, however, some justification for believing that they are. It may be said also that if the results of this experimental work can be extended to man, a partial answer to the second question is supplied, for if teeth perfectly formed and well arranged in the jaws can be produced in children by feeding them along the lines suggested by the animal experiments, then such teeth will be less liable to caries than if they were imperfectly formed.

Although such a relationship is obvious to some, yet the idea is not generally accepted by dental authorities, because of the supposed fact that children's teeth are in general

well formed and yet very liable to become carious. May Mellanby,³ however, found, when examining a large number of children's teeth under the microscope, that on the whole the more perfectly formed teeth, as evidenced by microscopical examination, were the least carious. There were, however, exceptions to this rule, for out of 302 teeth examined microscopically 11 were carious and yet well formed, while 13 were free from caries although of defective structure. Closer examination revealed that when teeth were well formed and carious any secondary dentine present was usually poorly calcified; and, on the contrary, badly formed teeth free from caries, or in which caries had been arrested, generally had some well formed secondary dentine. It appeared, in fact, that although the formation of the original enamel and dentine was as a rule a good indication of the susceptibility of a tooth to caries, the presence and structure of secondary dentine indicated a second line of defence dependent on resistance set up in the body and particularly in the tooth itself.

These data, obtained by examination of deciduous teeth of children, were further correlated with some experimental results which showed in a few cases that good secondary dentine was formed in puppies' teeth on a "good" diet, and imperfect secondary dentine when they were on a "defective" diet. Thus it appeared probable that in children also "good" diets might contribute to the arrest of decay. On the contrary, diets compatible with the formation of bad enamel and dentine might be expected to offer less resistance to the initiation and spread of caries. It may be noted here that the resistance of the puppies to infective processes generally was found to be closely dependent on their diet—a "good" diet affording them great resistance, and a "defective" diet rendering them more susceptible. Reference must also be made to the claim of McCollum, Simmonds, Kinney, and Grieves⁴ and Howe⁵ that "caries-like" lesions can be produced in rats and guinea-pigs by diets defective in certain respects.

OBJECT AND CONDITIONS OF INVESTIGATION.

It is evident that the previous experimental work suggested most strongly that dental caries in human beings would be influenced by the small but specific differences in diet above mentioned. It appeared necessary, therefore, to investigate this matter, because corroboration of the animal results and their extension in man to the problem of caries would, if forthcoming, raise this subject from a position of academic interest to one of immediate human utility.

The children under observation were in an institution during the period of the investigation, and their diet and environment generally were under the close supervision of one of us (C. L. P.), by whom the improvement in the health of the children was carefully watched.

Three groups of children were taken. One set (nine in number) were placed on diet (diet A) which included cod-liver oil, milk, and eggs, but no oatmeal. On the basis of the investigations referred to above, this diet, which has a potent effect in bringing about calcification, might be expected to increase the resistance of the body, and especially the teeth, to bacterial infection. The next group consisted of ten patients, who received a diet (diet B) similar on the whole to diet A—the chief differences being that it included oatmeal, very little egg, and less milk than diet A, and no cod-liver oil. The third group consisted of thirteen children chosen from patients on the ordinary hospital diet (diet C). They were selected so as to be comparable with the first two groups in age, duration of institutional treatment, etc.

The diets eaten by the three groups are indicated below, but naturally the quantities varied to some extent with the age of the child.

It will be noticed that diet B, which contains more cereal, including oatmeal, and less calcium and vitamin A, is otherwise not very different from the ordinary hospital diet (diet C), which holds an intermediate position—so far as power to stimulate calcification in puppies is concerned—between diets B and A.

The effect of the three diets on the patients was very carefully watched, and as far as could be observed there was no difference in the improvement of the general health

* The expenses of this research were defrayed in part by a grant from the Medical Research Council and the Dental Board of the United Kingdom, to whom our thanks are due.