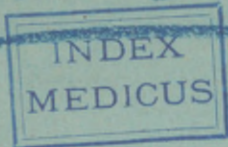


Donaldson (Fr.) (Fr.)



THE FUNCTION
OF
THE RECURRENT LARYNGEAL NERVE.

FROM EXPERIMENTAL STUDIES IN THE BIOLOGICAL LABORATORY
OF THE JOHNS HOPKINS UNIVERSITY.

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BY

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JOHNS HOPKINS UNIVERSITY.



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THE mode of action of the recurrent laryngeal nerve, supplying as it does muscles so important in their use, both phonatory and respiratory, and yet so opposed in their action, is at present a much mooted point. That this nerve supplies all the intrinsic muscles of the larynx with the exception of the crico-thyroid, and that it is chiefly a motor nerve, are well-known facts. It is a physiological fact, also, that the internal thyro-arytenoids, the lateral crico-arytenoids, and the transverse arytenoid, are the adductor (the phonatory) muscles of the larynx, and that the posterior crico-arytenoids are the abductor (the respiratory) muscles of that organ. As we have said, all these muscles receive their nerve supply from the recurrent laryngeal. This nerve, then, must contain two sets of fibres, which innervate muscles of separate and distinct functions. How, and under what circumstances, does the constrictor or respiratory function of this nerve assert itself? How are these functions to be differentiated? Whence do the two distinct sets of impulses come? "Is the origin of the nerve filaments, which compose the recurrent laryngeal nerve, as distinct as their function."

This important question has, up to the present time, been unanswered, and we know of no experiments directly on this point until Dr. F. H.

¹ Admission thesis to the American Laryngological Association, May, 1886.

Hooper, of Boston, in 1885, published an important and interesting paper, entitled "The Respiratory Function of the Human Larynx, from Experimental Studies." In this article he considers the question stated above, and also whether (as the clinicians assert) the abductor fibres of the recurrent nerve are more vulnerable than those of the adductor. It was this paper which immediately attracted the writer's attention to this subject, and led him to undertake the experiments given below.

As my purpose then was, if possible, to verify and expand this author's experiments, I am compelled, in order to make myself intelligible, to go over somewhat the same ground in the elaboration of this paper.

Speaking generally, nervous impulses for the larynx start in the brain, the medulla, and the cord. That there is a motor centre for the larynx is, to say the least, doubtful; and Delavan's¹ conclusions from the two cases cited by him, viz., "that this centre is in the course of the third branch of the middle cervical artery; that it is toward the proximal end of this vessel, and that it is in the vicinity of the convolution of Broca," are hardly justifiable in view of our scant knowledge of the subject, physiological and clinical. Nerve impulses are transmitted to the larynx through the pneumogastric, the spinal accessory, and their anastomotic branches. The pneumogastric is connected, first, with the internal branch (which contains the medullary fibres) of the spinal accessory; second, with the facial nerve by the auricular branch; third, with the glosso-pharyngeal (an inconstant branch); fourth, with the hypoglossal; fifth, with the first and second cervical nerves; sixth, with the sympathetic system.

The manifold nervous impulses which may come through all these sources are carried to the larynx then, by the superior and inferior laryngeal nerves, the anatomy and distribution of which need not be given here.

The part played by all these nerves in the innervation of the larynx is greatly in doubt.

The vagus and spinal accessory, however, are the nerves which immediately preside over the respiratory and phonatory functions of the larynx. The spinal accessory would seem to be chiefly a motor nerve (Bischoff,² Morganti,³ Longet,⁴ Bernard⁵).

Bernard declares that the spinal accessory is the motor nerve for *phonation alone*, and that it has nothing to do with the respiratory function of the larynx, which, if I understand him right, is the view taken by Schech.⁶ It is none the less certain, however, that the recurrent nerve contains sensory as well as motor fibres, for we can obtain

¹ On the Localization of the Cortical Motor Centre of the Larynx, N. Y. Medical Record, p. 178, 1885.

² Nervi acces, etc., Heidelberg, 1832.

³ Extract in Schmidt's Jahrb., xlii. p. 280.

⁴ Traité de Physiologie, vol. iii. p. 516.

⁵ Leçons sur la phys., vol. ii. p. 244.

⁶ Die Funct. d. Nerven u. Muskeln des Kehlkopfs, Würzburg, 1873.

reflexes from the larynx after section of the superior laryngeal. This latter is the afferent nerve supplying the mucous membrane and a motor fibre for the crico-thyroid muscle (denied by Navratil¹); some observers hold that it also supplies a branch to the posterior arytenoid. The recurrent nerve therefore containing, as it does, both sensory and motor fibres, from whatever source they come, supplying all the muscles of the larynx except the crico-thyroid (though Türck² says that it furnishes fibres to this muscle also), and being essentially the respiratory nerve of the larynx, is the nerve with the innervation of which we are immediately concerned. How is it, then, that the impulses travelling along this nerve, at one instant close and at the next open the glottis? How is it that at one moment the nerve stimulus acts upon one set of muscles (the adductors), and at the next upon another and distinct set (the abductors). Those most important muscles, the posterior crico-arytenoids, receive an abundant nerve supply, and it is more than probable that the nerve filaments in the recurrent are derived from a greater number of sources than those in the phonatory nerves. The experiments given below were undertaken to test Hooper's conclusions as to the innervation of the larynx. I shall give, therefore, in his own words, his reasoning:

"It is a familiar fact to all, that if anything other than air finds its way into the larynx it produces, by reflex action, a sudden closure of the glottis. It is equally certain that, under normal conditions, the same contraction of the laryngeal muscles may be instantly called forth by direct stimulation of one or both of the recurrent nerves. Now, it may with reason be asked, How is it that this constricting action of the phonatory muscles is brought about if it be true that the nerve fibres animating the dilators of the glottis are the stronger and the more numerous? Why should we not get abduction of the vocal bands instead of adduction on irritating the recurrent nerves? The phonatory muscles are to the respiratory muscles as five to two, and the closure of the glottis has always been ascribed to the superior numerical strength of these constrictors. Yet if we compare, bulk for bulk, the muscular fibres which compose the five muscles of phonation with those of the two respiratory muscles, we do not find that they are much, if any, in excess of the latter, and we venture to think that there is some other factor concerned in this phenomenon apart from mere muscular force. It may be sought, perhaps, in this important difference between the respiratory and the phonatory function of the glottis, namely, that while the respiratory muscles are ever on the alert, holding the glottis open during the entire healthy life of an individual, in his waking as well as in his sleeping hours, the phonatory muscles, on the other hand, are more dependent upon the *consciousness* of the individual in order to respond to any irritation. To explain: The phonatory function of the phonatory muscles could, as far as life is concerned, be dispensed with. Not so their constricting action with the view of excluding the passage of foreign bodies to the lungs. The constrictor muscles of the larynx are the sentinels who guard the approach of these vital organs. But they cease to act if the animal is in profound narcosis; they are asleep, so to speak, on their watch. A man in the condition known as "dead drunk," lying, let us suppose, on his back with his mouth open, would offer no

¹ Berl klin. Woch., 1871, p. 394.

² Klinik d. Krankheiten d. Kehlkopfs, p. 439, Wien, 1866.

obstacle to prevent any living insect that chanced his way from crawling in and out of his mouth, or meandering around in his larynx *à volonté*, without exciting reflex contraction of its muscles. The power of ether, chloroform, and other anæsthetics to impair the action of these constrictors is too well known to need mention. To carry this line of thought a little further, should we not expect that, provided we could preserve the organic life of an animal while its volition was at the same time completely abolished—should we not expect, we ask, under these circumstances, to get a dilatation of the glottis on irritating the recurrent nerves instead of a closure, for the posterior crico-arytenoid muscles are muscles of organic life? Indeed we believe we should, and we submit the following experiments in support of that belief."

Dr. Hooper's experiments were performed upon dogs which were etherized, the mouth opened and the tongue drawn out so as to expose the larynx to view. The recurrent nerves were then exposed, cut, and stimulated at will. The results of the experiments apparently confirmed the theory given above, viz., that the constrictor functions of the larynx are dependent upon consciousness. And the conclusions drawn from them may be briefly stated as follows: That stimulation of the recurrent laryngeal nerve always produced abduction of the arytenoid on that side, provided the animal was deeply under ether; that on removing the anæsthetic, the dilatation produced by stimulation became less and less as the animal regained consciousness, until finally contraction of the glottis followed; and that the abduction differed in different dogs. In other words, he concludes that the tendency of the glottis is to remain widely open, and that any given stimulus from the recurrent nerve would act upon the abductor muscles alone unless volition came into play, when the stimulus would exert the opposite effect and produce adduction. Such being this author's conclusions, I pass to my own series of experiments, undertaken to test the following points:

First. Is it true that the constrictors cease to act during profound narcosis, or when consciousness is suspended from any cause?

Second. Do we always get abduction of the arytenoids (dilatation of the glottis) on stimulation of the recurrent nerves, when consciousness is suspended?

EXPERIMENT I.—Medium-sized dog, under small dose of morphia. Slight movement of the glottis during quiet breathing. Recurrents exposed; stimulation of the right nerve produced complete adduction of that cord, and slight adduction of the opposite one. The same result followed stimulation of the left recurrent. The nerves were stimulated from time to time for an hour or more, with the same result. The animal now began to come from under the narcotic, and it was therefore tracheotomized, and ether given, and while there was still considerable movement of the glottis upon stimulation of right and left recurrent, I thought I noticed a slight *abduction* on the side stimulated, but in a few minutes, when the animal was deeply under the anæsthetic, and all movement of the larynx had ceased, stimulation of both recurrents separately produced a complete closure of the glottis. I am inclined to think, therefore, that the first apparent abduction was the result simply

of the normal movement of the vocal cords in inspiration. In order now to do away with any possible movement of the larynx, the animal was made completely apnoëic, and the right recurrent nerve cut, on stimulation marked adduction was observed; the other nerve was now cut, and stimulation again produced adduction.

EXPERIMENT II.—Large dog, deeply under ether and chloroform. Stimulation of the right recurrent produced marked adduction. This nerve was now cut, and the left nerve stimulated, when marked adduction was produced. The right nerve was now traced to its final division, and the branches going to the posterior arytenoid, and those going to the other muscles, were tied and cut. Stimulation of the inferior or crico-arytenoid branch produced marked abduction, dragging the cartilage completely to the side. On the other hand, stimulation of the superior branch produced complete closure of the glottis, as was expected. Stimulation, however, of the branches simultaneously invariably produced adduction. These results were obtained over and over again. The dog meanwhile being profoundly anæsthetized, and the nerves being thus separate, I thought it would be well to see if I could get any proof of the fact, stated by clinicians, that the abductor nerve fibres were prone to injury and disease. And though the two nerves were exposed and cut for the space of an hour and a half, I could find no difference in their action; they responded equally to stimulation. That all possible consciousness might be done away with, the dog was bled to death; stimulation of either recurrent invariably produced adduction.

EXPERIMENT III.—Medium-sized dog, under morphia. Nerve dissected out to final distribution; stimulation resulted as in former experiment. Thinking now that the kind of stimulation might make some difference, a crystal of sodium chloride was placed upon the left nerve. The cord was alternately abducted and adducted as different fibres of the nerve were affected by the salt, though the general result was rather one of adduction. The result of pinching the nerve was, generally speaking, adduction.

EXPERIMENT IV.—Fair-sized dog, somewhat under morphia, later profoundly under ether. Right recurrent stimulated and adduction followed. The nerve was cut and adduction again resulted; there were no appreciable movements of the larynx at this time. The left recurrent, uncut, was now stimulated and adduction resulted. The latter nerve was cut and stimulation invariably gave adduction. Stimulation by pinching produced adduction. After the nerve had been somewhat injured it was stimulated below the point of injury to see whether one or the other fibres might have degenerated more rapidly, but adduction again resulted.

EXPERIMENT V.—Fair-sized dog, under ether only. The nerves were not stimulated until the animal was profoundly narcotized and all movement of the glottis had ceased, when stimulation of either nerve, cut and uncut, always produced adduction. The dog was killed, and after some minutes adduction was produced on stimulation. The strength of the current in all these experiments was always considerable, the induction coil being at about 10. In this series of five experiments

under no condition had abduction of either cord been obtained, as Dr. Hooper had found. The latter's results, seen by himself and others, must have existed, and so I was put to it to account for the great diversity in my own results. The experiments up to this point had been performed under like conditions, and sources of error excluded as far as possible. The next experiment was carried on with the utmost care, and with unexpected results. In the experiments given above the induction coil was at 10, giving always a strong stimulus.

EXPERIMENT VI.—Medium-sized dog, under ether. Professor Martin having suggested that possibly the results obtained by Hooper were reflex (both Burkhard and Hermann stating that the recurrent had sensory as well as motor fibres) the right recurrent was stimulated cut, but with the usual result, adduction.

Though the animal was deeply narcotized there were still some movements of the glottis, and to do away with these the dog was accordingly made deeply apnoëic. Under this condition it was observed that the cords came nearer together than in normal breathing, which is what might be expected; no impulses proceeding in this condition from the respiratory centre. The nerve was now stimulated and adduction was strongly marked. The right nerve was cut and stimulated, but with the same result. That all possible respiratory movements might be done away with and consciousness entirely removed, the medulla was destroyed and artificial respiration kept up. The right nerve was now cut, the induction coil was moved out and the stimulus made very weak (more by accident than intent), when, much to our surprise, *abduction*, distinct and prolonged, resulted. The stimulus was gradually increased, with the same result, until the coil stopped at 16, when *adduction* of the cord took place. This result was obtained again and again on stimulation of either nerve. Here then at last we had the result obtained by Hooper. All consciousness in this case had been suspended. Was this abduction dependent upon unconsciousness and loss of volition? Hitherto we had obtained *adduction* under all circumstances, with the animal slightly, deeply, and entirely narcotized, and indeed when dead. Was not this abduction, just obtained, dependent upon the strength of the stimulus? Was not the abduction due rather to the greater irritability of the abductor muscles which caused them to answer to a much slighter stimulus than the adductor muscles? and was not this what we might expect from the vital importance of the former pair of muscles? Finally, did the abduction depend upon unconsciousness, or would we obtain the same result with volition at work?

EXPERIMENT VII.—Medium-sized dog, under ether only, right recurrent cut, and the animal well though not deeply narcotized: induction coil placed at 35; the stimulus was too weak, however, and no movement was visible. At 34 there was slight abduction of the arytenoid, which became more marked as the stimulus was increased. At 18 the abduction was greatest. At 16 the abduction was slight. At 14 the cord vibrated between abduction and adduction. At 10 adduction was most marked. At this last point slight contact produced a momentary abduction, which movement passed into adduction on full contact and stimulation. The abductor muscles seemed to lose their power and become exhausted upon strong and continued stimulation. The animal by this time had

become deeply narcotized. In order to see whether volition would alter the results, the dog was allowed to come almost completely from under the influence of the anæsthetic, reflexes were numerous and marked. The coil was placed at 30, and abduction followed, as indeed it did until the coil reached 12, when a mixed movement resulted, and at 10 adduction followed stimulation. The change in the number at which adduction or abduction followed, may be explained by some exhaustion of the nerve from continued stimulation. Both the recurrents were now cut, and thinking that the number of stimuli might make a difference, the interruptions were made in turn very slow and very rapid, but with no change in the results as given above. The experiment then confirmed the results of the previous one, and seemed to show that the abductor muscles were much more irritable than the adductors; and that abduction depended in no way upon volition, as the same result was obtained whether the animal was conscious or unconscious.

EXPERIMENT VIII.—Forty-eight hours previous to operation, about one inch of the right recurrent nerve had been excised, with a view to finding which, if either, set of fibres contained in it would degenerate most rapidly. The dog was deeply etherized and the nerve found. The cut end was enveloped in a mass of inflammatory product from which it was freed and its end stimulated. With a feeble current the right cord, which was completely paralyzed, was strongly abducted, as it was indeed upon stimulation with all strengths from weakest to strongest. The animal was now allowed to come from under the ether almost entirely, with not the slightest change in the results, however; under no circumstances was adduction produced. The left nerve was stimulated, and with weak current abduction was obtained; with strong, a mixed movement. It will be noticed that adduction was never obtained from the injured nerve, which would seem entirely to confirm Dr. Hooper's conclusion, that the abductor fibres are the less susceptible, both to disease and to injury. In this case the adductor fibres seemed to have proved the more vulnerable. The dog was now killed, and after a short time on stimulation of the right nerve, abduction invariably followed, while on the left side adduction only could be obtained with all strength of stimulus; which fact, I think, is explained by supposing that the more irritable muscle, the posterior crico-arytenoid, dies more rapidly than the less irritable adductors.

EXPERIMENT IX. was confirmatory of previous experiments; abduction depending upon the strength of the stimulus, and abduction and adduction obtained whether the animal was narcotized or not. One fact was impressed upon me by this experiment, viz., that after constant and strong stimulation the abductor muscles became exhausted, and any stimulation, therefore, produces adduction.

Proceeding now to the analysis of these experiments, we find that in the first five under no condition was abduction of either or both cords obtained, except, of course, where, as in Experiments II. and III., the branch of the recurrent going to the posterior arytenoid itself was stimulated. Adduction of the arytenoid was obtained, however deeply the animal was anesthetized in all five experiments. In two cases (Ex-

periments II. and VI.) where the animal was made thoroughly apnœic, and where for some seconds there was neither glottic nor respiratory movement, adduction resulted from stimulation. In two cases after the animal *was dead*, but before death of the nerves or muscles of the larynx, stimulation produced closure of the glottis. Under all these conditions of unconsciousness and narcotism, then, was adduction produced. This result followed, in these experiments, stimulation of the cut and uncut nerve; and followed chemical and mechanical, as well as electrical, stimulation. Again in Experiment II., where the separate branches of the recurrent to the individual muscles were dissected out, and stimulated equally, neither showed a tendency to more rapid degeneration than the other.

My conclusions, then, from this first series of experiments are: 1st. That the constrictor muscles of the larynx *do not cease to act during profound narcosis or during suspension of consciousness* from any cause; or, in other words, that their action is not dependent upon volition, in the sense that they lose their power with the loss of volition. 2d. That we do not always obtain abduction of the arytenoids when consciousness is suspended. Under what conditions, then, do we get abduction of the cords upon stimulation of the recurrent nerve? Such conditions must exist, for abduction of the cord has been obtained by Hooper, who considers that suspension of volition is the one condition under which stimulation of the recurrent nerve brings about abduction. What the conditions are under which these abductors act was, I think, partly discovered in the next series of experiments. In them it was found: 1st. That the abduction obtained by Hooper was in no way reflex. 2d. That abduction is in no way dependent upon the unconsciousness of the animal. 3. That it is with weak stimuli only that abduction of the cords takes place, which movement of abduction gradually passes into one of adduction as the strength of the stimulus is increased. 4th. That this result invariably followed, whether the animal was slightly, deeply, or thoroughly narcotized; whether the animal was eupnœic or apnœic, when the dog had his *medulla destroyed*, and after *local death* had taken place. 5th. That the rate of stimulation did not affect the general result. 6th. That after strong and constant stimulation the abductor muscles became worn out and ceased to answer to stimuli. 7th. That in apnœa the cords came nearer the middle line, the abductors receiving no stimulus in this condition from the respiratory centre. Here then, I think, we have a suggestion at least, as to the innervation of the muscles of the larynx. And again we state that volition, consciousness, or unconsciousness in no way affect the action of the laryngeal nerves or muscles. In our first series of experiments *adduction* resulted under all conditions of unconsciousness; in our *second series abduction*, in all conditions of consciousness or deep narcotism: we may, therefore, cast out volition as

a factor in our problem. Abduction of the arytenoids was found to depend simply upon the strength (the rate did not change the result) of the stimulus; dilatation of the glottis followed always weak stimulation of the nerve. How is this result then to be explained?

It must remain for subsequent investigations to decide, whether the greater irritability is in the nerve fibres or the muscle fibres, but the fact remains that the abductor muscles respond to a much weaker stimulus than do the adductors. That their irritability is greater, was proved not only by the weaker stimulus to which they responded, but by the fact alluded to in Experiment IX.: that, after continued stimulation the muscle or nerve fibres of the abductors became exhausted and adduction only resulted from stimulation of the nerve. Again, in the several experiments where the nerves were stimulated after death, adduction only after a time could be produced, the more irritable fibres of the abductors dying most rapidly. The apparent contradiction in Experiment VIII., where, after section of the right recurrent two days previously, abduction only, under all circumstances and with all strengths of stimuli was produced, may, I think, be explained by supposing that for some reason the fibres of the adductor muscles had degenerated more rapidly, which fact with others leads me to agree entirely with Dr. Hooper's statement, that he can find no proof of the assertion of the clinicians, that the abductor fibres of the recurrent are prone to disease. This clinical fact may be explained, however, by the theory of the greater irritability of the abductor muscle or nerve fibres. *For in cases of unilateral lesion of the cords from an aneurism or tumor, the constant pressure exerted by either, upon the nerve, acts as a mechanical stimulus to it, and the more irritable abductors are, therefore, the first to show the result of this constant stimulation, in their loss of function.* Upon these facts, then, I would explain the innervation of the larynx somewhat as follows: Breathing is an involuntary act, though the diaphragm and all the other muscles employed in respiration are voluntary muscles; and though respiration may be modified within very wide limits by the will, yet we habitually breathe without the intervention of the will. The larynx is an essential part of the respiratory apparatus and is immediately connected with, and must receive impulses from, the respiratory centre in the medulla, and its respiratory function is the most important; for the purpose of preserving life the glottis must be kept open, and so we find that the cords, even in normal breathing, at each inspiration are pulled slightly away from their apparently normal position between extreme abduction and extreme adduction. The fact that in deep narcosis the cords are pulled widely apart, would seem to show that stronger stimuli than usual are proceeding from the respiratory centre to the abductor muscles; for in all deep narcosis the tendency is

toward dyspnoea and always in this condition normal respiratory muscles are called into greater play.

The constrictors of the larynx are apparently always in a state of partial tonic contraction, and ready for use at any moment. I found that in every case where the dog was thoroughly apnoic that the cords came much closer together than in normal breathing; and this, it seems to me, is what we might expect, for in apnoea the respiratory centre is at rest; and the respiratory function of the larynx being for the moment in abeyance, the protective or constrictor function of that organ asserts itself. Again, it is well known that great changes can be brought about in the respiratory movements by the will; while, on the other hand, the respiratory centre is the one most frequently affected by nervous impulses from various quarters. It is not fair then to suppose, and I think the above experiments support the supposition, that both the respiratory and constrictor (or protective) functions of the glottis are governed by those laws which govern the rest of the respiratory apparatus?

It is well known that the pneumogastrics contain two kinds of fibres—one accelerating, the other retarding, regulating, or inhibitory. Ordinarily the excitation of the former predominates; for after division of one or both vagi the respiratory rhythm becomes slower. Gentle stimulation of the central end of the divided vagus produces acceleration of the respiration; if, however, the stimulation is made strong, the action of the diaphragm is stopped—it is in a state of relaxation or expiration; this is particularly the case in the fatigue of the nerves; the result being due to the fact that the inhibitory fibres do not become so quickly exhausted as the accelerating. (Burkhard.)

The larynx, then, as we have said, being part of the general respiratory apparatus, its inspiratory and expiratory (constricting) functions are under the same nerve control as the rest of the organs concerned in inspiration, and under no circumstances are these functions suspended.

The action of the constrictor muscles is second only in importance to that of the dilator muscles, and we do not think, in view of the results obtained above, nor upon general principles, that nature would allow so important a function to be suspended.

There seems to be a similarity between the nerve fibres of the recurrent and those of the pneumogastric, and, on the whole, we are inclined to think that the great irritability mentioned above is in the nerve fibres supplying the abductors; the two sets of fibres of the recurrent supply opposite sets of muscles, and may be likened to the two kinds of nerve fibres composing the pneumogastric—the one answering to less, the other to stronger stimuli.

Again, it seems to me that the abductor muscles are the more irritable, and are always ready to perform their part in the human economy; that the adductor muscles, on the other hand, are less irritable, but none the

less ready, in consciousness or unconsciousness, to perform their function. It is a physiological fact that impulses from almost every sentient surface, or passing along almost every sensory nerve, may modify the respiratory movements in one direction or the other, the slighter, feebler impulses tending to quicken the respiratory discharges; the stronger, larger, impulses tending to arrest or inhibit the respiratory discharges from the medulla; and the movement of the larynx would be in keeping with that of the rest of the respiratory apparatus.

Finally, the constrictors of the larynx, needing a stronger stimulus to bring them into action, *may* find that stronger stimulus in the numerous reflexes which arise upon the introduction of any foreign body into that organ.

My thanks are due my friend, Professor Martin, both for the use of his laboratory and for valuable help.

