Obstetrical and Gynæcological Section.

May 14, 1908.

Dr. HERBERT SPENCER, President of the Section, in the Chair.

Death of Dr. Cullingworth.

THE President announced the death of Dr. Cullingworth, a Past President of the Obstetrical Society of London, and said that the death had inflicted a grievous blow on obstetrics and gynæcology and on the many friends of the deceased. He proposed that the following letter of condolence be sent to Mrs. Cullingworth :—

"The President, Council, and Members of the Obstetrical and Gynæcological Section of the Royal Society of Medicine take the earliest opportunity of offering to Mrs. Cullingworth and family their deep sympathy in the great loss they and the profession have sustained in the recent lamented death of Dr. Cullingworth."

The resolution was passed unanimously, with many expressions of sorrow and esteem from the members and visitors present.

The Supports-in-Chief of the Female Pelvic Viscera.

By R. H. PARAMORE, M.D.

(I.) THE CONNECTIVE TISSUES.

THE two great claimants concerned in this question are the pelvic visceral connective tissue and the pelvic diaphragm, of which the levator ani muscle forms the principal part. These, either separately or together, support the viscera from below. But the viscera are also maintained in their position by the application of a force from above, the intra-abdominal pressure; and in the erect posture their own weight, and the weight of the superimposed viscera, act in the same direction. Whilst the effect of gravity, however, is of little importance, because of the relative insignificance of its force, the intra-abdominal pressure, on the contrary, is of very great consequence, and it is mainly owing to the neglect of this important factor that misconceptions have arisen.

Recently considerable attention has been paid to the visceral connective tissue of the pelvis, and owing to its strength and toughness it has been regarded, both by anatomists and gynæcologists, as playing a principal rôle in the maintenance of the pelvic viscera in their normal position.

Thus last year (1907) no less than five papers appeared in the *Journal of Anatomy and Physiology* on the connective tissue, fasciæ and muscles of the pelvis. In the January number Professor Paterson describes "the suspensory ligament of the genito-urinary organs," which, he says, "arises from the general fascia as a crescentic fold in the neighbourhood of the ischial spine" and "extends across the pelvic cavity, forming on each side the suspensory ligament of the vagina and urethra."

In the July number Dr. Ovenden states the result of reinvestigations of the ligamentum transversalis colli, first described by Mackenrodt in 1895. She says:—

There can be no doubt that in the dissection of the pelvis this band forms an easily defined and striking object. . . . Traced to its distal attachments, this band is found to be formed from strong fibrous connective tissue, continuous with that which surrounds the pelvic blood-vessels and also that which comes through the sacro-sciatic notch. Some of the fibres appear also to be attached to the sides of the third and fourth pieces of the sacrum.

As regards the central attachment:—

The ligament is inserted partly into the vault of the vagina and the lateral fornix, but also directly into the side of the uterus for a short distance below the point of entrance of the uterine artery. It constitutes the tissue which is generally clamped or tied along with the uterine artery in the operation for vaginal hysterectomy.

Of the two papers by Derry (October), one is on "The Muscles of the Pelvic Floor" and the other on "The Real Nature of the So-called Pelvic Fascia." In the latter it is stated:—

The viscera are all embedded in subperitoneal connective tissue. . . . This tissue is condensed in places to form definite ensheathing layers, particularly in the neighbourhood of the vagina and lower part of uterus in the female. . . . these layers . . . pass gradually into the general mass of subperitoneal tissue which fills the whole pelvic cavity, and are then no longer traceable; . . . it is quite distinct from that layer generally known as parietal pelvic fascia. . . .

The suspensory ligament described by Professor Paterson as arising in the neighbourhood of the ischial spine is nothing more than the attachment in this position, *i.e.*, to the most posterior part of the "white line" of the subperitoneal connective tissue, which here envelops the vessels passing to the viscera, including the ureter and vas deferens.

The last paper by Cameron[1] has been sufficiently quoted in a recent contribution. In reference to this connective tissue Dr. Cameron says:—

It may now be recognized that we have here a sort of fascial mesentery, which must constitute an effective support to the pelvic viscera.

Mackenrodt in 1895 showed that the upper part of the broad ligament can be cut through without causing any change in the position of the uterus, which only occurs when its deeper portion—the ligamentum transversalis colli—is divided (Whitridge Williams).

Dr. Ovenden says:—

Both Emmet and Schauta have laid emphasis on the importance of the part played by this connective tissue in maintaining the normal position of the uterus.

On the other hand, Halban and Tandler[2] say:—

Fritsch denied the existence of these structures, nor are we able to recognize their anatomical individuality.

It has recently been put forward by Dr. Fothergill[3] that the operation of vaginal hysterectomy reveals the nature of the real supports of. the uterus, and the fact is offered that—

until this (the tissue known as the parametrium) is divided on each side, the organ (uterus) is, for practical purposes, as completely supported as before any incision was made.

Dr. Fothergill continues:—

The inevitable conclusion is that the vessels and other structures, with their sheaths or fascial coverings, which lie on each side of the uterus, below the broad ligament and above the lateral fornices, are the structures which support the uterus.

This statement is perfectly true as regards this particular case, but it cannot be accepted as applying universally. It is true that when the levator ani muscle is paralysed by a general anæsthetic and its anterior

[1] *Journ. Anat. and Physiol.*, 1907, xlii., p. 112.

[2] "Anatomie und Aetiologie der Genitalprolapse beim Weibe," 1907, p. 22.

[3] Fothergill: "Supports of the Pelvic Viscera," *Proc. Roy. Soc. Med.*, 1908, i., No. 3 (Obstet. and Gynæc. Sec.), p. 43.

margins are strongly separated by weighted retractors or powerful assistants, that then this connective tissue, with its vessels and nerves, tends to keep, or keeps, the uterus in place. But because this is so in a particular case it does not therefore follow that it is universally true. And this is what Dr. Fothergill has assumed. On the contrary, when the levator ani muscle is not paralysed, and has not been previously injured, the muscle, which closes in the abdomino-pelvic cavity inferiorly, contracts to an extent reflexly demanded by the intra-abdominal pressure and the posture assumed by the individual, and so prevents the extrusion of these, the lowest placed viscera.

If the conception put forward by Dr. Fothergill, and supported by other authorities, is really the true one—that the perivascular sheaths and connective tissue alone do support the pelvic viscera—it necessarily follows that these sheaths of connective tissue, except when the woman is lying down at rest, are subject to a continuous tension, which is sometimes greater and sometimes less. This is the result of (1) the action of gravity upon the pelvic viscera themselves; (2) the weight of the superimposed abdominal viscera upon them; and (3) the intra-abdominal pressure.

If, however, this conception is fallacious, and if the truth is that the pelvic viscera are maintained in their positions by the activity of the levator ani muscle, it necessarily follows that the parietal connective tissue which attaches this muscle to the skeleton is subject, except when the woman is lying down at rest, to a continuous tension, which is sometimes greater and sometimes is less; for the weight supported and the pressure resisted by the levator ani muscle is of necessity transmitted to its connective tissue attachments. Hence the question arises: If the visceral connective tissue, which passes from the pelvic wall to the viscera, is unable to support these viscera, how is it possible that the connective tissue attachments of the muscle are capable of doing so?

Now what is the value of connective tissue as a supporting agent in the living individual, and how does it behave in the presence of continuous tension?

First, as regards the supporting connective tissues properly so called, which unite the bones together, complete the skeleton, and by means of which the muscles are attached to the bones and to each other.

A study of the causation of orthopædic deformities shows that when momentary excessive forces spend themselves frequently on these tissues, or when ordinary and non-excessive forces are brought to bear upon them for prolonged periods of time, without intervals of rest, the connective tissues yield. And this results independently of their original strength and durability, and is dependent only upon the time during which the force is in operation.

Of the great variety of instances of this pathological fact occurring in the body, we may call to mind the linea alba in the latter months of pregnancy and the yielding which so commonly occurs from the continuous stretching of the abdominal wall.

To pass now from that variety of connective tissue which binds the muscles together to that other variety which connects the viscera with each other and to the (posterior) abdominal wall, we may for one moment consider what happens to the mesentery of the intestine with its contained arteries, veins, lymphatic vessels, nerves and supporting connective tissue when the gut becomes extruded into an inguinal, femoral, umbilical or any other hernia. Reflection at once shows how all these structures yield. Nor can any other result be expected when, instead of a local weakness in the muscular parietes, the weakness is general; and a universal hernia of the abdominal contents, forwards and downwards, into a pouched, distended, over-stretched, inefficient abdominal wall occurs. Enteroptosis is the result of a primary weakness in the entire muscular parietes (Keith). When the support, which the muscle in health gives, becomes lost, the other so-called supporting apparatus of the viscera—the so-called ligaments and the arteries with their connective tissue sheaths—has to bear the burden of the viscera, and is found to be totally inefficient for this purpose.

Next, we come to the connective tissue attachments of the uterus and the other pelvic viscera, with their arteries, veins, lymphatics and nerves, and to the question of what occurs when the muscular floor, which normally closes in the outlet of the pelvis, has become, for some reason or other, inefficient; in connection with which we wish to remark that, in the normal, non-injured muscle, as obtains in the great majority of virgins and nulliparous women, this closure of the pelvic outlet is as efficient and as effectual as the closure of the hiatus between the base of the thorax and the pelvis, which the anterior abdominal wall fills in.

There is no reason to suppose that some sequence, strangely different from what happens in other parts of the body, occurs here. The invariable result is a stretching and yielding of all the connective tissue attachments of all those viscera which become prolapsed into the deepened pouch formed by the receding, the thinned, the atrophied, and the inefficient muscle. Yet we are told that "the one constant essential cause of prolapse is relaxation of the perivascular sheaths" (Dr. Fothergill) (*ibid.*).

It is perfectly true that prolapse cannot occur without the relaxation of the perivascular sheaths. But the point is, that these sheaths are prevented from becoming relaxed, not by any virtue of their own, but by the support that is given to them, as well as to the pelvic viscera, by the tonically contracted and healthy muscle which lies beneath them. When this support has become inefficient, prolapse occurs in spite of the existence and the strength of this connective tissue.

A comparison of the connective tissue attachments of the levator ani muscle with the connective tissue attachments of the uterus and other pelvic viscera, quite apart from the extent and the strength of each, discloses the fact that the great and the only essential difference between them is that a muscle, composed of striated fibres, is interposed between the two lateral halves of the one set of connective tissue; whilst in the other, the visceral set, striated muscle fibres are entirely absent, and muscular tissue of the non-striated variety is so sparsely scattered through it that it can only be demonstrated satisfactorily and completely by microscopical examination.

In virtue, therefore, of the inherent peculiarity of striated muscle, that of marked extensibility and of subsequent recontraction of its fibres, the pelvic diaphragm, consisting of the levator ani muscle and its connective tissue attachments, the lateral pelvic fascia, is in reality a highly elastic obturator, capable of a considerable amount of movement in the cranio-caudal direction. In the healthy and sound condition, this pelvic diaphragm is in a continual state of activity, and as a result of the variations in pressure above, it is continually undergoing changes of tension. It is the consequence of the active production of these changes in tension (*i.e.*, the result of the relaxation and the recontraction of the muscle itself) that the physiological activity and anatomical strength of the muscle and of its tendons are produced.

It is to be remembered that when stretching occurs (*i.e.*, physiological paralysis from excessive tension), the muscle fibres yield first, and thus play the part of a safety valve to its connective tissue attachments. But this condition can seldom arise in the case of the undamaged pelvic diaphragm, because a force sufficient to cause such stretching is the outcome of a contraction of all the muscles enclosing the abdominal cavity; and there is reason to believe that the pelvic diaphragm is as capable of resisting any such pressure as the other muscles are capable of maintaining it. This theoretical consideration is substantiated by the clinical observation of the uncommon occurrence of prolapse in nulliparæ.

When, however, the pelvic diaphragm has been damaged by childbirth, the intra-abdominal pressure may very easily become too much to be borne, and the muscle will then give way. It is owing to the fact that the connective tissue (*i.e.*, parietal pelvic fascia) is in the early stages thus spared, that when the pressure is subsequently relieved (*e.g.*, by lying down), provided the stretching has not been too great or too long continued, the muscle is able to regain its tone and the prolapse may be spontaneously, and for the time being, cured. If, however, the muscle has been subjected to marked and continuous stretching, not only does it undergo an atrophic degeneration itself, but the same happens to its connective tissue attachments, which, besides stretching, also atrophy.

A reference to the living processes occurring in the body elsewhere confirms these statements. A good example, demonstrating how muscle fibres relax and stretch as a result of continuous tension, is shown in the treatment of cases of fracture of the long bones. When a weight is applied to the leg, after some little time the irritated and contracted muscles first relax and later stretch. This yielding of the muscle occurs before stretching of the ligaments of the knee-joint ; but the fact that these ligaments may stretch, if the weight be too great, is generally known.

In contrast to this unity of effect of overpowering force upon muscle and its connective tissue comes the fact that as the outcome of increased use of the muscles the connective tissue attachments of the same become stronger and more clearly marked. If the use is very considerable, yet not excessive, the muscle hypertrophies and so do the connective tissue attachments. A comparison of the bones from subjects of different muscular development shows quite clearly the truth of this statement. From a muscular man the bony ridges and other places where the muscles were inserted are all well marked ; from a weakly individual, however, the reverse is the case. The same results to the fasciæ and ligaments, by the medium of which the muscles are attached, as to the bones themselves.

From a consideration, then, of the actual relative anatomical conditions of muscle and of its connective tissue attachments found in the body, we are forced to the conclusion, indeed a reasonable one, that these are the outcome of the physiological functioning of the structures concerned, in which the connective tissue attachments play an entirely passive rôle ; and that these latter are entirely dependent upon the integrity of the muscle, with which they are connected, for their structure and strength—since hypertrophy of the muscle results in hypertrophy of its connective tissue attachments, and atrophy of the muscle in atrophy of its connective tissue attachments. It therefore follows that the connective tissue attachments of the levator ani muscle, upon which the strain of resisting and successfully opposing an increased intra-abdominal pressure is transmitted, themselves depend on the muscle for their strength and their capacity of performing this function; and that the successful resistance to increased tension of their fibres or pressure from above upon their surface is not the outcome of any inherent peculiarity it may be supposed they possess, but is the direct consequence of the activity of the muscle of which they form essential continuations.

It is interesting to read, in the paper by Professor Peter Thompson upon "The Arrangement of the Fasciæ of the Pelvis,"[1] that the fascia lining the pelvic wall above the attachment of the levator ani "is thicker, more aponeurotic and less transparent than the perineal portion, which is thinner and more membranous, allowing the underlying muscular fibres to be seen through it"; and, further, that this supra-muscular or pelvic layer really consists of two superimposed sheets, the outer one of which is continuous with the perineal portion of the pelvic fascia (lining the outer wall of the ischio-rectal fossa), and an inner sheet which stretches from the origin of the levator ani up to the brim of the pelvis to be attached to the ilio-pectineal line. "It is evident," continues this author, "that the ilio-coccygeus is continuous with this aponeurosis, which, lying on the upper part of the obturator fascia, passes upwards to be attached to the ilio-pectineal line." Further on he continues: "Of the aponeurosis with which the ilio-coccygeus is continuous, I venture to suggest that it represents the upper fibres of the ilio-coccygeus and the investing fasciæ."

The fact that this fascia, as described by Professor Peter Thompson, is thicker and more aponeurotic than the fascia covering the obturator muscle is in favour of the opinion that the muscle of which it is the tendon is functional. If the ilio-coccygeus has lost its function in man, the aponeurosis, which forms its means of attachment to the pelvic skeleton, should be atrophied and inconspicuous.

Whilst, therefore, the pelvic diaphragm is a highly elastic membrane, the visceral connective tissue apparatus, which may be regarded as another incomplete superimposed diaphragm, is, on the other hand, little,

[1] *Journ. Anat. and Physiol.*, 1901, xxxv., p. 127.

if at all, elastic; whether considered from the point of its fibrous tissue or its non-striated muscle fibres. The only elastic element of any extent is that given by the arteries. This, however, can hardly come into play if the connective tissue strands, the perivascular sheaths, remain unstretched; whilst if the down thrust of the intra-abdominal pressure has been so great or so long continued as to cause stretching of these sheaths, it can scarcely be expected that the arteries will be able, subsequent to the relief or diminution of the intra-abdominal pressure, to raise the pelvic viscera into their former normal position; and for this principal reason, that the arteries themselves become stretched and lengthened in these cases, as a study of the descent of the kidney and of the uterus shows.

As a consequence of the non-elasticity of the visceral connective tissue diaphragm, in the meshes of which the pelvic viscera lie, it follows, when the pelvic diaphragm, which is placed immediately beneath, recedes, that the weight of the viscera and the intra-abdominal pressure will be brought to bear upon this visceral connective tissue apparatus. When this is in a healthy and sound condition, *i.e.*, has not been previously stretched, it no doubt is capable of sustaining this weight and pressure, if it be not too great, for some little time without impairment; for the connective tissues, visceral or parietal, do not immediately yield. This occurs normally during defæcation. When this act is about to take place the intra-abdominal pressure is first raised by a contraction of all the muscles enclosing the abdomino-pelvic cavity (diaphragm, abdominal wall muscles, and levator ani). At a certain point the contraction of the levator ani muscle is inhibited, probably owing to nervous impulses ascending from the rectum; then the muscle fibres lengthen, the pelvic floor descends, the angle of the recto-anal junction becomes straightened out, and the fæcal mass is extruded by the simultaneous coöperation of the contraction of the gut and the raised intra-abdominal pressure, which, as the act is accomplished, is suddenly relieved by the opening of the glottis. Finally, the levator ani muscle returns to its usual position. During the descent of the pelvic floor the connective tissue attachments of the uterus come into play and prevent a too great descent of this organ; and it is probably mainly owing to this recurring exercise, *i.e.*, the alternating conditions of relaxation and moderate tension, that their physiological activity and anatomical strength are maintained. This may explain, then, the strength of the ligaments. It also explains why the uterus is retained in position when the surgeon pulls upon the cervix in the operation of vaginal hysterectomy. The surgeon only exerts tension on these strands of connective tissue for a few minutes. The question is, What would happen if he continued to pull for days or weeks?

But if the frequently recurring down-thrust upon the unprotected visceral connective tissue is always or generally excessive, even though it be temporary, the connective tissue becomes impaired, yields and stretches; and subsequently, when the pelvic floor returns to its usual position, this stretching of the connective tissue remains. Thus the tissue becomes less and less capable of supporting the viscera in the temporary absence of muscular contraction. Hence it ultimately comes about that the viscera are not supported at all, and on straining marked descent occurs. This is the beginning of prolapse in those uncommon cases in which the muscle has never been injured by childbirth.

When, however, childbirth has occurred, which has either been difficult or tedious, and the pelvic diaphragm has been injured by the excessive stretching, either of the muscle or its connective tissue attachments, or both, probably causing a partial atrophy; then, subsequently, it is plain that this diaphragm cannot give the same support to the pelvic viscera, nor the same opposition to the intra-abdominal pressure. In consequence of this inability to meet the ordinary demands of its purpose, the pelvic viscera become thrust more and more downwards and occupy a deeper and deeper place, not so much from their own weight, nor from that of the viscera above them, but in chief as a direct result of the periodic and even moderate increment in the intra-abdominal pressure. Before the descent of this prolapse not only does the inefficient muscular diaphragm recede, but also the visceral connective tissue attachments lengthen. In short, the visceral connective tissue is dependent upon the efficiency of the pelvic floor for its integrity, and it therefore plays but a secondary part in the support of the pelvic viscera. Nor is it surprising to find that the behaviour of connective tissue here is subject to the same laws and principles which determine its activity elsewhere.

Halban and Tandler, in their book "Anatomie und Aetiologie der Genitalprolapse beim Weibe," 1907, sum up the value of the visceral connective tissue in the following way (p. 26):—

Each structure which is connected with the uterus, and which in any way is attached to the skeleton of the lateral pelvic wall, represents in a certain measure a fixation apparatus of the uterus. No separate one of these factors has, of course, a predominant importance, but the result is determined by the harmonizing coöperation of all. If we examine the different speculative fixatory structures, now under consideration, we shall, indeed, find that they are not adapted, in virtue of their physical peculiarities, to successfully resist a much increased tension or pressure. Each separate one possesses a certain elasticity and solidity, which, however, must not be estimated very highly. The elasticity of the smooth muscle fibres is, according to the measuring of Triepal, too trifling to define. Even anatomical examinations of prolapse show how extensible all these structures are, and, indeed, the same happens in pathological processes elsewhere. We need only mention the expansion of the peritoneum in herniæ, the stretching of the smooth muscle fibres in dilatation of the ventricle, &c., and the yielding of the connective tissue in different conditions.

Nevertheless, the separate structures are naturally in the position to sustain a correspondingly trifling weight, and it is to be attributed, no doubt, to the summation of the capacity of resistance of all the bespoken elements, that the weight of the uterus is supported and that it is maintained in its position. We must, however, be clear on this point, that all these fixation means of the uterus only function as fixation structures secondarily, and that they have primarily to accomplish other physiological purposes. Corresponding to this it ought not to be forgotten that they adapt themselves in their structure to the predisposed phylo- and onto-genetically determined position of the uterus, so that the fixation means are not a cause of the uterine position, but that their arrangement is to be regarded as a consequence of that position. Besides, anteversion is earlier existent ontogenetically, before a fixatory component can be assigned to the mesodermal tissue representing the fixation means (smooth muscle and vessels) from lack of that musculature. So also we see that, for example, in uterus unicornis and other maldevelopments, deviations of the fixation structures, entirely corresponding, are to be observed.

By means of the structures named the uterus is fastened by a system of strings to the pelvic wall and is maintained in suspension, just like the weight of a spider is supported as it rests on its system of threads, which are fastened to the neighbouring walls. This spider's web is able to bear the proper weight of the spider, but it is not capable of supporting a greater abnormal burden. But in relation to the fixation of the uterus its proper weight has not alone to be considered, but before all other factors the result of the abdominal pressure has to be reckoned with. The normal, not increased, abdominal pressure plays, therefore, no part; but, indeed, increase of the same. In the presence of this, the normal suspension means of the uterus is not sufficient.

(II.) The Intra-abdominal Pressure.

We must now turn our attention to this intra-abdominal or, more accurately, the intra-abdomino-pelvic pressure. This pressure depends on three factors: (1) the capacity of the abdomino-pelvic cavity; (2) the volume of the contained viscera and other contents; and (3) the condition of contraction of the muscular walls which surround and enclose it.

All these factors are variable. The capacity of the abdominal cavity is greatest when the spine is extended. On flexion of the spine the thorax approaches the pubes and the capacity is diminished. Permanent diminution is seen in cases of deformity of the lower dorsal and lumbar vertebræ, kyphosis and scoliosis; in these cases a glance serves to show that the whole base of the thorax is lower than it should be. It is also seen in emphysema of the lungs as a result of the lowered position of the diaphragm.

Likewise, the abdomino-pelvic contents are subject to fluctuations in volume; this increase may be temporary and frequently recurring, or it may be more or less permanent. Temporary increase is due to the ingestion of food, the production of flatus, the secretion of urine and its retention in the urinary bladder. Permanent increase is caused by an excessive deposit of fat in the omentum, mesentery and retroperitoneal tissue (lipoma), the presence of ascites, the growth of a tumour or of the pregnant uterus.

The muscles enclosing the abdomino-pelvic cavity are least contracted when the individual lies down at rest; most contracted when a violent movement is made.

Concerning this pressure I have the following data to offer, which I quote from an article on "Enteroptosis" by Professor Keith[1]:—

> In the erect posture there is a positive pressure of 20 mm. to 28 mm. in the rectum, and in the stomach 6 mm. to 12 mm. Hg. The increase of pressure in the rectum over and above that in the stomach is undoubtedly due, as Schwerdt points out, to the weight of the superincumbent viscera. The pressure exerted on the abdominal contents by the abdominal muscles maintaining one viscus against another may therefore be that estimated at 6 mm. to 12 mm. Hg.; but when the muscles of the abdomen are thrown into action it may temporarily be higher than the arterial blood-pressure. On stooping down and then lifting a heavy weight, the pressure within the stomach rises to over 70 mm., that within the rectum to 120 mm. Hg.; in coughing, straining and bending, temporary elevations of 50 mm. or 90 mm. Hg. are observed. In strong muscular men the intra-abdominal pressure may rise much higher, possibly to 200 mm. Hg.

(III.) The Levator Ani Muscle.

It is clear that the intra-abdominal pressure will act by tending to thrust the pelvic viscera still further downwards, upon the pelvic floor, and in the presence of an increased pressure reasons have been advanced to show that the visceral connective tissue is quite unable and inadequate

[1] "System of Medicine," by Allbutt and Rolleston, 1907, iii., p. 860.

to maintain the viscera in their normal position for more than short and infrequent periods of time; and even then, if the pressure is always excessive, yielding occurs.

Since the intra-abdominal pressure is very considerably increased many times in each day, as for instance in coughing, sneezing, laughing and during defæcation, especially when difficult, the question arises, How is it that in the presence of this frequently recurring increased down-thrust, the pelvic viscera are maintained in position?

It has already been stated in an earlier part of this paper that the answer to this question is to be found in the existence of the levator ani muscle and its attachments.

We must now inquire somewhat briefly into the truth of this statement. In man the pelvic diaphragm consists of the pubo- and ilio-coccygei, which together form the levator ani muscle, and the coccygei. The disposition of these muscles is as follows: The superior fibres of the pubo-coccygeus, comprising the pubo-coccygeus proper, arise from the posterior surface of "the body of the pubis along an oblique line which extends from the lowest limit of the symphysis, upwards and outwards, towards the obturator canal, and also from the obturator fascia for a limited extent" (Thompson). They form a "flat band of muscle about 1 in. wide, thick at its mesial border, thin where it overlaps the ilio-coccygeus" (Thompson), which passes directly backwards and, uniting with its fellow of the other side, is inserted by means of a forked tendinous plate into the last sacral vertebra.

The inferior fibres of the pubo-coccygeus, having lost their connection with the coccyx and the ano-coccygeal raphé, unite with the corresponding fibres of the other side behind the perineal flexure of the rectum and below the tendinous aponeurosis which forms the insertion of the ilio-coccygeus muscle. Since these fibres embrace the rectum this division of the muscle has been called the "pubo-rectalis." It arises "from the back of the lowest part of the symphysis pubis under cover of the pubo-coccygeus, from the upper layer of the triangular ligament and from the pubes" (Thompson). When it contracts it draws the perineal flexure of the rectum forwards towards the symphysis, and thus, whilst it increases the natural bend of the gut, it also tends to obliterate its lumen. It has for this reason been called the "sphincter of the rectum" by Holl, who also refers to it as the best developed muscle in the pelvic diaphragm. At the same time its constricts the vagina, and this probably accounts for its better development in the female. Besides this relation to the rectum some of the most anterior and median fibres cross the middle line in front of the rectum and intersect with similar fibres of the opposite side, also with the deeper portion of the musculus sphincter ani externus, and with the posterior fibres of the musculus transversus perinei profundus in the perineal body (Luschka).

Behind the pubo-coccygeus and on a somewhat higher plane is the ilio-coccygeus muscle. It appears that this may arise in two distinct ways: (1) By means of its aponeurosis, the parietal pelvic fascia, from the ilio-pectineal line (Thompson); (2) by means of a fibrous arch slung from the os pubis to the ischial spine. This "white line" is in some cases found separated by some little distance from the pelvic wall, and when this is so a pouch, filled with fat, exists between the two. This "hiatus of Schwalbe" and this double origin of the ilio-coccygeus are described by Professor Elliot Smith in the *Journal of Anatomy and Physiology* for January, 1908, in a paper entitled "Studies in the Anatomy of the Pelvis."

I have on several occasions, when palpating the muscle, felt a tight fibrous-feeling band stretching from the pubis to the ischial spine. This I have supposed to be the tendinous arch of origin of the ilio-coccygeus; in some of these cases it has been found standing an appreciable distance from the pelvic wall. It is interesting to find that pressure on this band has caused the patient to complain of pain similar to what has been spontaneously felt at other times.

The muscular fibres pass downwards, backwards and inwards with varying degrees of obliquity, the most anterior ones passing more backwards than inwards, the most posterior being directed more inwards, but still backwards. They are inserted by means of an aponeurosis into the last two pieces of the coccyx and its tip, and into a median raphé from the coccyx to the posterior margin of the anus.

Behind the ilio-coccygeus is the ischio-coccygeus, or the coccygeus of human anatomy. It arises from the spine of the ischium and is inserted into the lateral margin of the lower sacral and upper coccygeal vertebræ. Although this muscle can have very little power over movement of the coccyx, it is of interest to find that it is composed of muscular as well as fibrous tissue, and must have, therefore, some other remaining, yet slight, function, *e.g.*, offering resistance to pressure from above.

These individual muscle sections of the pelvic diaphragm do not by any means form a uniform sheet in one plane, but overlap one another posteriorly where they join the corresponding muscle of the other side. By this means the part of the diaphragm posterior to the rectum is clearly strengthened. [Halban and Tandler.]

In the recent contribution to this subject,[1] already cited, the view has been put forward that the levator ani is a degenerated muscle, and that it is incapable of supporting the pelvic viscera. This plea was supported by two facts.

The first fact is that in the course of evolution the human being has lost the tail. From this the inference was drawn that the representatives of the tail-moving muscles in the lower animals had in man become so degenerate as to be useless.

It is true that with the loss of the tail the muscles have altered as regards their origins and insertions, and have either almost completely, as in the case of the coccygeus, or partially, as in that of the upper part of the ilio-coccygeus, represented by the parietal pelvic fascia, degenerated; and it is possible, if other evolutionary changes had not, concurrently with these alterations, been in process of development, that the levator ani would have disappeared altogether. But with the loss of the tail, the individual has assumed the erect posture, in which it is certain greater pressure is brought to bear upon the pelvic floor than in the horizontal position; and in order to meet this demand the remnants of the long tail-wagging muscles have undergone special adaptations, have become spread out to form a wide muscular sheet, upon the integrity of which the maintenance of the pelvic viscera is entirely due.

A study of the conditions obtaining in the lower animals supports this view. Thus Professor P. Thompson writes[2]:—

In all mammals the closure of the "clefts" or "faults" in the pelvic floor, through which the rectal and genito-urinary canals are transmitted, is brought about by the action of muscular fibres; and the compact mass forming the floor of the pelvis is therefore, even in its simplest form, partly muscular; the rest is made up of connective tissue and integument. The muscular fibres, which form a distinct layer in the pelvic floor, surround the canals which traverse the "clefts," and they control or guard these canals at their outlet; in other words, the layer is largely sphincteric in action. It is obvious that a pelvic floor so constituted is not specially adapted for support.

But a great difference in the architecture of the pelvic floor is apparent in those mammals in which the long axis of the body is either absolutely or approximately vertical. In them the floor is further modified for the support of the abdominal viscera, and, in addition to the layer of muscle controlling the clefts, another is developed in the form of a well-marked diaphragm, which constitutes a muscular sheet attached on all sides to the walls of the pelvic cavity. In the human subject this sheet includes the levatores ani and coccygeal muscles. [Introduction.]

[1] *Proc. Roy. Soc. Med.*, 1908, i., No. 3 (Obstet. and Gynæc. Sec.), p. 43.

[2] "Myology of the Pelvic Floor," 1899, p. 7.

The evolution of this pelvic diaphragm is interesting. It appears that "both the ilio-coccygeus and pubo-coccygeus are the result of a lateral extension on to the side wall of the pelvis from a single powerful flexor of the tail, situated on the ventral aspect of the sacral and caudal vertebræ." In some animals (monotremes and some marsupials) the three muscles are not distinct from each other. On the other hand, in others (mare and cow) they are not represented at all; and, therefore, in these no morphological equivalent of the levator ani exists. (Thompson). As regards the cause of this absence Professor Thompson says: " . . . it is by no means evident why suppression of certain of the caudal muscles should have resulted."

May not the explanation be found in the fact that in the animals referred to (mare, cow) the body is always, or nearly always, horizontal? And since the pelvic outlet, which is very obliquely placed, looking more upwards than backwards, is situated at a very high level in relation to the abdominal cavity—almost at its summit—it cannot have the same pressure brought to bear on it as it would have if the body were carried vertically; so that the weight of the viscera with their contents is sufficient, with the sphincteric muscles which are attached to the pelvis, to prevent any extrusion.

The second objection to the levator ani as a functioning muscle is based on Professor Thompson's account of it in his book.[1] This author, indeed, regards the ilio-coccygeus as a degenerated muscle; he says (p. 75):—

> Primarily, the muscle passes from the ilium to the caudal vertebræ—a condition retained in most mammals. But the reduction of the caudal vertebræ has been accompanied by a corresponding reduction in the muscles which act on them; so that the ilio-coccygeus in man is just as much a degenerated muscle as the coccygeus or abductor caudæ.

Further:—

> The action of the ilio-coccygeus must necessarily be feeble, and is practically limited to drawing forwards the coccyx and the fibrous raphé between it and the anus. When ankylosis occurs of the various pieces of the coccyx and of the coccyx with the sacrum, the action of the muscle is still further restricted.

But as regards the pubo-coccygeus the author takes a different view:—

> The pubo-coccygei are perhaps the most important muscles in the pelvic floor, since upon them depends the restoration of the floor to its normal position after it has been depressed by defæcation and parturition, &c.

[1] "Myology of the Pelvic Floor," 1899, pp. 75, 76; 94.

Again:—

The arrangement of the pubo-coccygei is admirably adapted for the support of the superimposed structures.

Concerning these statements I have the following remarks to make:—

(1) If the ilio-coccygeus is a degenerated and unnecessary muscle, why is it present in man, whilst it is absent in some other animals (mare, cow)? It is stated that "whereas in tailed apes the levator ani attains a thickness of more than 5 mm., in anthropoids it is thin and almost transparent" (Thompson). From which it may be thought, surely with some truth, that if loss of function and its attendant structural atrophy had commenced in these anthropoids, this latter would have reached a further stage in man.

(2) That the function of the muscle does not alone consist in raising the coccyx and the ano-coccygeal raphé, but also in presenting, by its contraction, a firm resistance to an increased intra-abdominal pressure; and that therefore, even in the presence of ankylosis of the coccyx itself, or of this to the sacrum, the function of the muscle and, therefore, its activity are not lost. That this is so is shown by the fact that muscular fibres are present, and can be easily seen, in the coccygeus, a muscle which certainly can effect no movement of the coccyx.

(3) That to function successfully as an opponent to the raised intra-abdominal pressure, the ilio-coccygeus has not to perform as much work to resist the increase in the pressure as the muscles of the abdominal wall have to perform in order to bring about the increase in the pressure.

For the sake of argument the diaphragm may be omitted, since, indeed, its position is maintained by the closure of the glottis, a trifling muscular act. And since the function of the pubo-coccygeus is to close the genital hiatus in the pelvic floor, its greater thickness and development are thus sufficiently accounted for, although, no doubt, from its median position, it plays an important part in the support of the viscera and the opposing of the intra-abdominal pressure. But it must be remembered that not all its fibres gain attachment to the vertebral column or to the fibrous raphé extending forward from this, but that a considerable portion, quite half the muscle or more, forms a loop around the rectum posteriorly, and thus can have no action in opposing increase of pressure from above. When the intra-abdominal pressure is raised, two definite muscular actions take place: (i.) Both parts of the pubo-coccygeus—*i.e.*, the pubo-coccygeus proper and the pubo-rectalis—contract, and lessen or obliterate the genital hiatus; (ii.) the pubo-coccygeus proper and ilio-coccygeus contract, and present a resistance to the descending viscera. This can be verified by palpation of the muscle; on getting the patient to cough the muscles will be felt to contract.

When the size of the pelvic outlet is compared with the area filled in by the anterior abdominal wall, reflection will show that the levator ani will have to perform much less work to oppose a force caused by the contraction of the muscles of the anterior abdominal wall than these muscles will have to perform to produce that force. We have here, indeed, the mechanism of the force pump. The small outlet is the pelvis, the piston is the levator ani muscle, the work to be done is the paralysis of the pressure produced by the extensive anterior abdominal wall; only in the body the levator ani remains more or less stationary in position, and its activity—that is its resistance—is increased or diminished according to the pressure that is brought to bear on it by the contractions of the other muscles.

It therefore follows that the muscles of the anterior abdominal wall (recti excluded) must of necessity be considerably thicker, *i.e.*, stronger, than the ilio-coccygeus; so the fact of the relative thinness and apparent weakness of the ilio-coccygeus is not a reason for rejecting the efficiency of the muscle, but it is what physical laws would lead us to expect.

(4) That in the examination of anatomical specimens of this muscle it is necessary to know something about the general muscular development and the age of the cadavers from which they were obtained, and whether childbirth had occurred, for a degenerate condition of both parts of the levator ani is not uncommon, as the frequency of cases of prolapse shows.

For these reasons I am not inclined to regard the ilio-coccygeus muscle as being such a degenerate structure as the quotations referred to would lead one to suppose.

Whilst it is difficult to allot the share that each of the principal parts of the levator ani muscle takes in the support of the viscera and opposition of the intra-abdominal pressure, we may in conclusion ask: What is the evidence for believing that this muscle as a whole performs this function?

(1) The muscle really exists, and preparations of it are to be seen.

(2) Ample evidence of the existence of the muscle and of its functioning is to be obtained in the living.

Dr. Fothergill[1] says:

> The narrow lower opening of the funnel-shaped pelvic diaphragm is not to be felt so often as descriptions would suggest; and in parous women it is often difficult or impossible to recognize the margin of the levator ani.

[1] *Journn. Obstet. and Gynæc.*, 1908, xiii., p. 18.

I cannot agree with this statement. During the last six months I have paid particular attention to this question, and have palpated for the levator ani muscle in nearly every case I have examined, with the result that in the majority I have been able to feel it distinctly. The patients in whom it is difficult to feel are those who are very fat, the thickness of the fat in the ischio-rectal fossa masking any sensation that the muscle fibres might impart to the fingers. Whilst it is true that palpation is not delicate enough to reveal the presence of the thin inner and lower part of the pubo-rectalis, which passes to the perineal body, the mass of the pubo-coccygeus itself, which guards the cleft in the anterior part of the basin-like floor, can be distinctly felt. Finally, the ilio-coccygeus can be as easily palpated as the pubo-coccygeus, and its line of origin from the pubes to the spine of the ischium, frequently an easily palpable point, can often be clearly made out.

The method adopted is the simplest possible. Two fingers are inserted into the vagina and the thumb is placed over the skin of the ischio-rectal fossa; on bringing the fingers and thumb together the muscle is to be felt between them. The pubo-coccygeus is the more medianly and the more inferiorly placed (pubo-rectalis); by passing the fingers higher in the vagina and more laterally, and moving the thumb externally in the same direction, the ilio-coccygeus can be felt.

The levator ani is most easily palpable when it is best developed, that is, in nulliparous women who are not stout. The muscle is also to be felt in cases of prolapse. The presence of the muscle can be more easily made evident by getting it to contract. If the patient is asked to cough whilst palpation is being conducted the levator ani muscle will be felt to contract at the same time as the other muscles of the abdominal cavity.

(3) Finally, to quote again from Halban and Tandler, who speak as follows:—

The proof that this musculature has, as a matter of fact, to perform this office, and that it is capable of performing it under normal conditions, is confirmed by the study of the pathogenesis of genital prolapse, for when the muscle under consideration becomes defective or insufficient from any cause, a displacement of the pelvic viscera invariably arises. The best example of this is furnished by cases of paralysis of the pelvic floor musculature, and this is to be observed in the most beautiful way in congenital prolapse in cases of spina bifida.

If the fourth sacral nerve is included in the sac of the meningocele, a congenital paralysis of the pelvic floor musculature results, and corresponding to this a pouch-like dilatation of the pelvic floor and a descent of all the pelvic contents, as well in the male as in the female subject, is produced.

This is principally manifested by the obliteration of the crena ani, the descent of the anal orifice, and the convexity of the whole perineum, as can be seen on inspection of the parts. On section it is proved that, as a matter of fact, the collective pelvic viscera are much more deeply placed than normal, and, moreover, in the female fœtus it accounts for the formation of a genital prolapse in consequence of the insufficiency of the muscular closing apparatus.

A case of this kind was shown by Dr. Russell Andrews before the Obstetrical Society in April, 1902,[1] but no adequate explanation was given for its occurrence. That the lesion is a nervous one is shown by the fact that paralysis of the legs and talipes are often present.

Conclusion.

It is therefore evident that the pelvic viscera are maintained in their position by two sets of forces. The one acts from above and pins, so to speak, the viscera in their places. This is the intra-abdominal pressure. The other acts from below, supports the viscera, and prevents them from being displaced by any excessive force from above. These two forces, therefore, vary directly with each other; increase of the one reflexly produces increase of the other. This mechanism is under a nervous control, which determines any desired end (coughing, defæcation, &c.).

As regards the force from below, this is supplied by the levator ani muscle. This is the essential element in the maintenance of a normal visceral position. When the pelvic floor is inhibited during defæcation, the visceral connective tissue is capable of supporting the viscera temporarily, but it is not capable of more than this. When the muscle has become insufficient this connective tissue is unable to maintain the viscera in position.

DISCUSSION.

Professor PATERSON (Liverpool), after a regretful reference to the death of Dr. Cullingworth, expressed his thanks to the Section for the opportunity afforded him of taking part in this debate. He had to thank a gynæcologist (Dr. T. B. Grimsdale) for first drawing his attention to the anatomical problems associated with cases of prolapse. He submitted that a great deal of sound anatomical work had been done in recent years in regard to the mechanical supports of the pelvic viscera, both before and since the publication of his own

[1] *Trans. Obstet. Soc.* (1902), 1303, xliv., p. 137.