sounds conveyed to the cochlea throw into vibration only those elements of the organ of Corti which are tuned, so to speak, in unison with them. According to this hypothesis, the rods of Corti constitute a harp of several thousand strings, played upon, as it were, by the sonorous vibrations. Theories analogous to the one proposed by Helmholtz, but of course lacking the basis of exact anatomical and physical details developed by modern researches and experiments, were advanced by Du Verney (1683) and by Le Cat (1767).

Viewing the question anatomically, it is by no means certain that the rods of Corti are so attached and stretched that they are capable of separate and individual vibrations. It has not been demonstrated that certain of these rods vibrate under the influence of certain notes or that they are tuned in accord with certain notes. Hensen and others have rejected the theory of Helmholtz, basing their opinions mainly upon the anatomical arrangement of the rods of Corti. Hensen assumed it to be a physical impossibility for the different rods to vibrate individually, and he regarded it as improbable that the rods are tuned in accord with different musical notes. Similar objections apply to the theory that different transverse fibres in the membrana basilaris vibrate in accord with particular notes. There is, indeed, no theory which affords an entirely satisfactory explanation of the mechanism of the final appreciation of the pitch of musical sounds.

It is not absolutely necessary that sonorous vibrations should pass to the cochlea through the external ear and parts in the middle ear. Sounds may be conducted to the auditory nerves through the bones of the head or through the Eustachian tube, as is shown by the simple and familiar experiment of placing a tuning-fork in contact with the head or between the teeth, the ears being closed.

The action of the two ears does not seem to be absolutely necessary to the correct appreciation of auditory impressions; but variations in the force of such impressions, made upon either ear, aid in determining the direction of sounds, although errors are often made in this regard.

The estimate of the distance of sounds is made by judging of the intensity, in connection with information obtained through other senses, especially the sense of sight. The power of estimating distance is largely influenced by experience and education.

Centres for Audition.—The centres for audition in dogs and monkeys are in the superior temporo-sphenoidal convolution (Ferrier, Munk). In man these centres are in the first (superior) and second temporal convolutions of the temporo-sphenoidal lobe, which are supplied by the fourth branch of the middle cerebral artery. This has been ascertained by pathological observations as well as by experiments on the lower animals. In man the action of these centres is not completely crossed, and destruction of the centre upon one side does not cause complete deafness in either ear. Complete destruction of the centres on both sides, however, produces total deafness. Injury of the first temporal convolution is often followed by the condition known as word-deafness, in which the subject hears the sound of words, but these sounds convey to him no idea. This is the psychical, auditory centre,

and it is confined to the first temporal convolution on the left side (Wernicke). Word-deafness is analogous to the condition already described under the name of word-blindness, and the centre usually is confined to the left side of the cerebrum. It has been suggested by Westphal that this centre may be on the right side of the cerebrum, in left-handed persons.

CHAPTER XXIV.

ORGANS AND ELEMENTS OF GENERATION.

General considerations—Female organs of generation—General arrangement of the female organs—The ovaries—Graafian follicles—The parovarium—The uterus—The Fallopian tubes—Structure of the ovum—Discharge of the ovum—Passage of ova into the Fallopian tubes—Puberty and menstruation—Changes in the Graafian follicle after its rupture (corpus luteum)—Male organs of generation—The testicles—Vesiculæ seminales—Prostate—Glands of the urethra—Male elements of generation—Spermatozoids.

GENERATION is one of the most important of the animal functions, and as such usually is treated of quite fully in works upon physiology; but a more or less extended account of this function is also to be found in every complete treatise on anatomy and in most works on obstetrics. While the physiological history of the human organism would not be complete without touching upon generation and development, it does not seem desirable to give a very full description of these processes, in which there would necessarily be a repetition of what is always to be found in works upon other subjects.

The question of so-called spontaneous generation in some of the lower animals was formerly much discussed by physiologists. This, however, is now of purely historical interest. As actual knowledge of facts has accumulated, the limits of what was thought to be spontaneous generation have become more and more restricted; until now it is generally admitted that spontaneous generation does not exist in the history of animals. The entire question, therefore, may be dismissed with this simple statement. There are, however, certain distinct forms of generation; but the only one that has any considerable importance in connection with human physiology is generation of new beings by the union of male and female elements in the fecundation of the ovum, with the development of the fecundated ovum. This is known as sexual generation. The two elements of generation are developed in separate beings, male and female, and these elements are brought together normally in what is known as sexual connection, or copulation.

FEMALE ORGANS OF GENERATION.

A knowledge of certain points in the anatomy of the female organs of generation is essential to the comprehension of the most important of the processes of reproduction. Following a fruitful intercourse of the sexes,

the function of generation, as regards the male, ceases with the comparatively simple process of penetration of the male element through the protective covering of the ovum and its fusion with the female element. The fecundated ovum then passes through certain changes, which are the first processes of its development, forms its attachments to the body of the mother, continues its development, and is nourished and grows, until the fœtus at term is brought into the world. It will not be necessary to describe minutely the anatomy of the external parts, as these are concerned only in sexual intercourse and in parturition; which latter, though a purely physiological process, forms the greatest part of the science of obstetrics, is considered elaborately in treatises on this subject and usually is not treated of to any great extent in works upon physiology.

The female organs of generation are divided anatomically into internal and external. The external organs are the vulva, the adjacent parts and the vagina. The internal organs are the uterus, Fallopian tubes and the ovaries. The ovaries are the true, female organs, in which alone the female element can be produced. The Fallopian tubes and the uterus are accessory in their uses, the female element, the ovum, passing through the Fallopian tubes to the uterus, where it forms the attachments to the body of the mother, which are essential to its nourishment and full development after fecundation.

The vagina has a direction, slightly curved anteriorly, which is nearly coincident with the axis of the outlet, or the inferior strait of the pelvis. Projecting into the vagina, at its upper extremity, is the lower part of the neck of the uterus. The uterus extends from the vagina nearly to the brim of the pelvis. It is situated between the bladder and the rectum, and has an antero-posterior inclination when the bladder is moderately distended, which brings its axis nearly coincident with that of the superior strait of the pelvis. With the body erect, the angle of the uterus with the perpendicular is about forty-five degrees.

The uterus is held in place by ligaments, certain of which are formed of folds of the peritoneum. The anterior ligament is reflected from the anterior surface to the bladder; the posterior ligament extends from the posterior surface to the rectum; the round ligaments extend from the upper angle of the uterus, on either side, between the folds of the broad ligament and through the inguinal canal, to the symphysis pubis; the broad ligaments extend from the sides of the uterus to the walls of the pelvis.

The uterus and the broad ligaments partially divide the pelvis into two portions; and these ligaments, which are formed of a double fold of peritoneum, present a superior, or posterior surface, and an inferior, or anterior surface. The superior, or anterior border of this fold is occupied by the Fallopian tubes, the peritoneum constituting their outer coat. Laterally, at the free extremities of the tubes, the peritoneum ceases, and there is an actual opening of each Fallopian tube into the peritoneal cavity. Attached to the broad ligament and projecting upon its posterior surface, is the ovary, which is connected with the fibrous tissue between the two layers of the ligament.

At the hilum of the ovary, as will be seen farther on, the structure of the peritoneum undergoes a marked change.

The Ovaries.—The ovaries, attached to the broad ligament and projecting from its posterior surface, lie nearly horizontally in the pelvic cavity, on

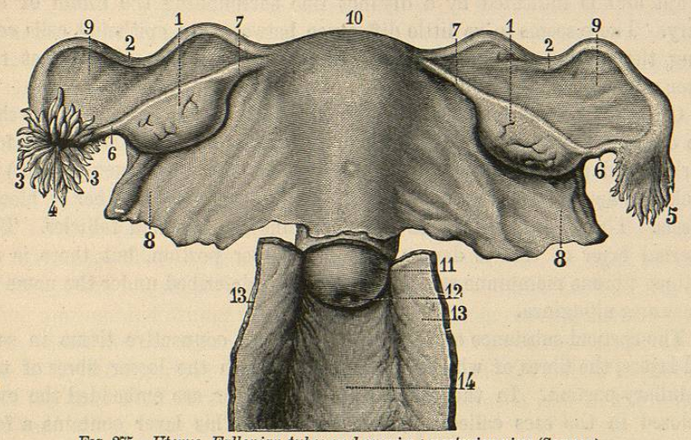

FIG. 275.—*Uterus, Fallopian tubes and ovaries; posterior view* (Sappey).

1, ovaries; 2, 2, Fallopian tubes; 3, 3, fimbriated extremity of the left Fallopian tube, seen from its concavity; 4, opening of the left tube; 5, fimbriated extremity of the right tube, posterior view; 6, 6, fimbriæ which attach the extremity of each tube to the ovary; 7, 7, ligaments of the ovary; 8, 8, 9, 9, broad ligaments; 10, uterus; 11, cervix uteri; 12, os uteri; 13, 13, 14, vagina.

either side of the uterus. They are of a whitish color, and their form is ovoid and flattened, with the anterior border, sometimes called the base, attached to the broad ligament. By closely examining their mode of connection with the broad ligament, it is seen that at the margin of the attached surface of the ovary, the posterior layer of the ligament ceases, and that the fibrous stroma of the medullary portion of the ovary is continuous with the fibrous tissue lying between the two layers.

Each ovary is about an inch and a half (38·1 mm.) in length, half an inch (12·7 mm.) in thickness, and three-quarters of an inch (19·1 mm.) in width at its broadest portion. The outer extremity is somewhat rounded and is attached to one of the fimbriæ of the Fallopian tube. The inner extremity is more pointed, and is attached to the side of the uterus by means of the ligament of the ovary. This ligament is shown in Fig. 275 (7, 7). It is a rounded cord, composed of non-striated muscular fibres spread out upon the attached extremity of the ovary and the posterior surface of the uterus, and is covered by peritoneum. The weight of each ovary is sixty to one hundred grains (3·9 to 6·5 grammes), and these organs are largest in the adult virgin. Its attached border is called the hilum; and at this portion the vessels and nerves penetrate. The surface is marked by rounded, translucent elevations, produced by distended Graafian follicles, with little cicatrices indicating the situation of ruptured follicles. There may also be seen, between the distended follicles, corpora lutea in various stages of atrophy.

After the peritoneum has reached the ovary, its fibrous layer becomes indistinct and fuses with the fibrous stroma of the ovary itself. The peritoneal endothelium here undergoes a change, and the cells covering the ovary are cylindrical. This change in the structure of the peritoneum is abrupt and is indicated by a distinct line surrounding the hilum of the ovary. There seems to be little difference between the epithelial cells covering the ovaries and those lining the Fallopian tubes, except that the latter are provided with cilia.

On making a section of the ovary, it is readily seen by the naked eye that the organ is composed of two distinct structures; a cortical substance, formerly called the tunica albuginea, which is about $\frac{1}{25}$ of an inch (1 mm.) in thickness, and a medullary substance containing a large number of blood-vessels. The cortical substance alone contains the Graafian follicles. The external layer of this is denser than the deeper portion, but there is no distinct fibrous membrane such as is sometimes described under the name of the tunica albuginea.

The cortical substance of the ovary consists of connective tissue in several layers, the fibres of which are continuous with the looser fibres of the medullary portion. In the substance of this layer, are embedded the ova, enclosed in the sacs called Graafian follicles. This layer contains a few blood-vessels, coming from the medullary portion, which surround the follicles.

The medullary portion of the ovary is very vascular and is composed of small bands, or trabeculæ of connective tissue, with non-striated muscular fibres. The blood-vessels, which penetrate at the hilum, are large and convoluted, especially at the hilum itself, where there is a mass of convoluted veins, forming a sort of vascular bulb (Rouget). In the medullary portion of the ovary, which is sometimes called the vascular zone, the muscular fibres follow the vessels, in the form of muscular sheaths.

In addition to the blood-vessels, the ovary receives nerves from the spermatic plexus of the sympathetic, the exact mode of termination of which has not been ascertained. Lymphatics have also been demonstrated at the hilum.

Graafian Follicles.—These vesicles, or follicles, were described and figured by DeGraaf, in 1672, and are known by his name. They contain the ova, undergo a series of peculiar changes, enlarge, approach the surface of the ovary, and finally are ruptured, discharging their contents into the fimbriated extremity of the Fallopian tube. The Graafian follicles are developed exclusively in the cortical substance. If the ovary be examined at any period of life, no follicles are found in the medullary substance; but a few of the larger may project downward, so as to encroach somewhat upon it, being actually of a diameter greater than the thickness of the cortex. The entire number of follicles of all sizes in each ovary is about 36,000 (Henle). According to the table of measurements given by Waldeyer, the primordial follicles in the human embryon, at the seventh month, measure $\frac{1}{800}$ to $\frac{1}{250}$ of an inch (30 to 100 μ) in diameter, and the primordial ova, $\frac{1}{1650}$ to $\frac{1}{1000}$ of an inch (15 to 25 μ).

The ovary appears very early in embryonic life, in the form of a cellular outgrowth from the Wolffian body. Most of its cells are small, but as early as the fourth or fifth day, in the chick, some of them are to be distinguished by their large size, their rounded form and the presence of a large nucleus. These cells are supposed to be primordial ova. In the process of development of the ovary some of the peripheral cells penetrate in the form of tubes (the so-called ovarian tubes) and at the same time, delicate processes, formed of connective tissue and blood-vessels, extend from the fibrous stroma underlying the epithelium and enclose collections of cells. It is probable that there are two modes of formation of follicles; one, by the penetration of epithelial tubes from the surface, which become constricted and divided off into closed cavities, and the other, by the extension of fibrous processes from below, which enclose little collections of cells. By both of these processes, little cavities are formed, which contain a number of cells. In each of these cavities, there is a single, large, rounded cell, with a large nucleus, this cell being a primordial ovum; and in addition, in the same cavity, there are other cells, which are the cells of the Graafian follicle. The exact nature of the processes just described has been studied in the chick; but it is probable that the same kind of development occurs in mammalia and in the human subject.

From birth until just before the age of puberty, the cortical substance of the ovary contains several thousands of what are termed primordial follicles, enclosing the primordial ova; and it is probable that after the ovaries are fully developed at birth, no additional ova or Graafian follicles make their appearance. The prevailing idea is, indeed, that the great majority of these never arrive at maturity, and that they undergo atrophy at various stages of their development. In the adult, according to Waldeyer, the smallest Graafian follicles measure $\frac{1}{800}$ to $\frac{1}{600}$ of an inch (30 to 40 μ), and the smallest ova, a little more than $\frac{1}{1000}$ of an inch (26 μ). The primordial ova have the form of rounded cells, each with a large, clear nucleus and a nucleolus. Other structures are developed in and surrounding these cells, as the ova arrive at their full development.

The most important stage in the development of the ova and Graafian follicles is observed at about the period of puberty. At this time a number of follicles (twelve, twenty, thirty or even more) enlarge, so that all sizes are observed, between the smallest primordial follicles, $\frac{1}{800}$ of an inch (30 μ), and the largest, nearly $\frac{1}{2}$ an inch (12 mm.) in diameter. In follicles that have attained any considerable size, there are the fully developed ova, one in each follicle—except in very rare instances, when there are two—and these ova have a diameter of about $\frac{1}{125}$ of an inch (200 μ). In the process which culminates in the discharge of the ovum into the fimbriated extremity of the Fallopian tube, the Graafian follicle gradually enlarges, becomes distended with liquid and finally breaks through and ruptures upon the surface of the ovary.

Fig. 276 shows the follicles and ova of various sizes. It is observed that the larger follicles contain fully formed ova and have a proper, fibrous coat.

The ova here present an epithelial covering and are embedded in a mass of the epithelial lining of the follicle, the membrana granulosa, this mass being called the discus or cumulus proligerus.

At or near the period of their maturity the Graafian follicles present several coats and are filled with an albuminous liquid. The mature follicles

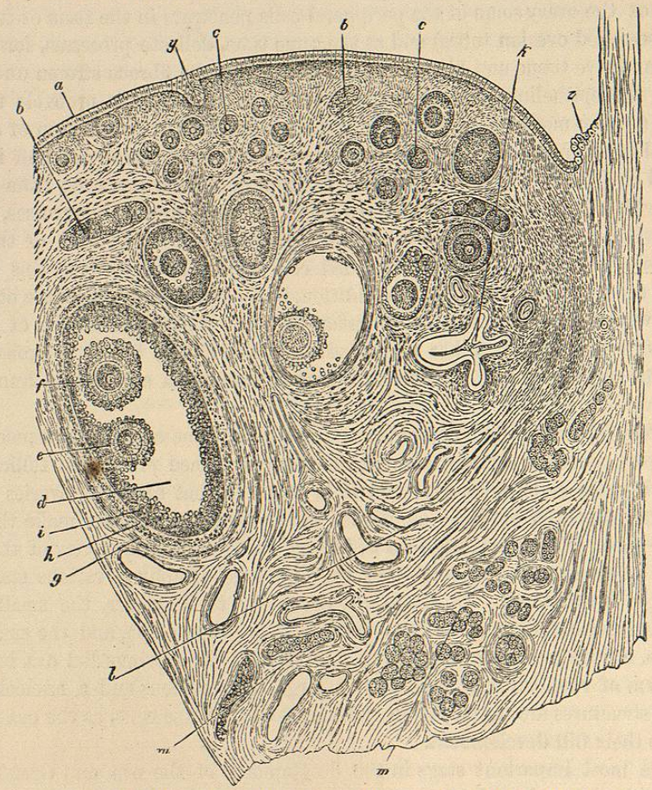

FIG. 276.—*Portion of a sagittal section of the ovary of an old bitch* (Waldeyer).
a, ovarian epithelium ; *b, b*, ovarian tubes ; *c, c*, younger follicles ; *d*, older follicle ; *e*, discus proligerus, with the ovum ; *f*, epithelium of a second ovum in the same follicle ; *g*, fibrous coat of the follicle ; *h*, proper coat of the follicle ; *i*, epithelium of the follicle (membrana granulosa) ; *k*, collapsed, atrophied follicle ; *l*, blood-vessels ; *m, m*, cell-tubes of the parovarium, divided longitudinally and transversely ; *y*, tubular depression of the ovarian epithelium, in the tissue of the ovary ; *z*, beginning of the ovarian epithelium, close to the lower border of the ovary.

project just beneath the surface and form little, rounded, translucent elevations. The smallest follicles are near the surface, and as they enlarge, at first they become deeper, as is seen in Fig. 276, becoming superficial only as they approach the condition of fullest distention.

Taking one of the largest follicles as an example, two fibrous layers can be distinguished ; an outer layer, of ordinary connective tissue, and an inner layer, the tunica propria, formed of the same kind of tissue, with the difference that as the follicle enlarges the inner layer becomes vascular. The

vascular tunica propria is lined by cells of epithelium, forming the so-called membrana granulosa. At a certain point in this membrane, is a mass of cells, called the discus or cumulus proligerus, in which the ovum is embedded. The situation of the discus proligerus is not invariable ; sometimes it is at the most superficial, and sometimes it is at the deepest part of the Graafian follicle.

The liquid of the Graafian follicle is alkaline, slightly yellowish and not viscid. It contains a small quantity of albuminoid matter, coagulable by heat, alcohol and acids. This liquid is supposed to be secreted by the cells lining the inner membrane of the follicle.

The Parovarium.—The parovarium, or organ of Rosenmüller, is simply the remains of the Wolffian body, lying in the folds of the broad ligament, between the ovary and the Fallopian tube. It consists of twelve to fifteen tubes of fibrous tissue, lined by ciliated epithelium. It has no physiological importance.

The Uterus.—The form, situation and relations of the uterus and Fallopian tubes have already been indicated and are shown in Fig. 275.

The uterus is a pear-shaped body, somewhat flattened antero-posteriorly, presenting a fundus, a body and a neck. At its lower extremity, is an open-

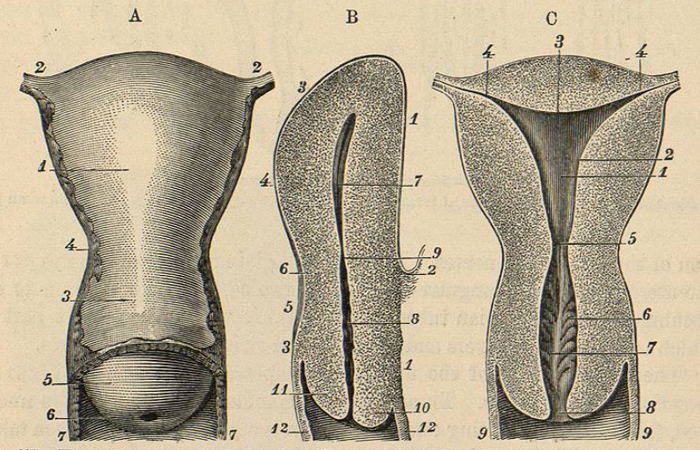

FIG. 277.—*Virgin uterus.* A.—*anterior view.* B.—*median section.* C.—*transverse section* (Sappey).
A. 1. body ; 2. 2. angles ; 3, cervix ; 4, site of the os internum ; 5, vaginal portion of the cervix ; 6, external os ; 7. 7. vagina.
B. 1. 1, profile of the anterior surface ; 2, vesico-uterine *cul-de-sac* ; 3. 3. profile of the posterior surface; 4, body ; 5, neck ; 6, isthmus ; 7, cavity of the body ; 8, cavity of the cervix ; 9, os internum ; 10, anterior lip of the os externum ; 11, posterior lip ; 12, 12, vagina.
C. 1, cavity of the body ; 2, lateral wall ; 3, superior wall ; 4, 4, cornua ; 5, os internum ; 6, cavity of the cervix ; 7, arbor vitæ of the cervix ; 8, os externum ; 9, 9, vagina.

ing into the vagina, called the os externum. At the upper portion of the neck, is a constriction, which indicates the situation of the os internum. The form of the uterus is shown in Fig. 277 (A). It usually is about three inches (76·2 mm.) in length, two inches (50·8 mm.) in breadth at its widest portion, and one inch (25·4 mm.) in thickness. Its weight is one and a half to two and a half ounces (42·5 to 71 grammes). It is somewhat loosely held in place

by the broad and round ligaments and by the folds of the peritoneum in front and behind. The delicate layer of peritoneum which forms its external covering extends behind as far down as the vagina, where it is reflected back upon the rectum, and anteriorly, a little below the upper extremity of the neck (os internum), where it is reflected upon the urinary bladder. At the sides of the uterus, the peritoneal covering, a little below the entrance of the Fallopian tubes, becomes loosely attached and leaves a line for the penetra-

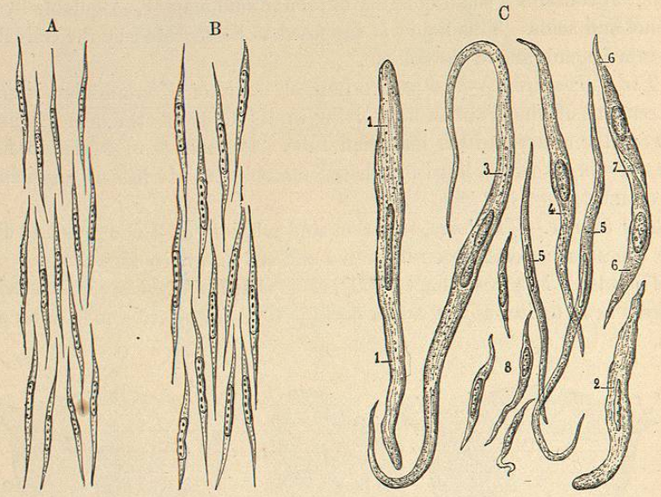

FIG. 278.—*Muscular fibres of the uterus* (Sappey).
A, fibres of the uterus of the fœtus at term; B, of a woman twenty years of age; C, of a woman just delivered.

tion of the vessels and nerves. Fig. 277 (C), giving a view of the interior of the uterus, shows a triangular cavity, with two cornua corresponding to the openings of the Fallopian tubes, and very thick walls, the greatest part of which is composed of layers and bands of non-striated muscular fibres.

The muscular walls of the uterus are composed of non-striated fibres arranged in several layers. These fibres are spindle-shaped and always nucleated, the nucleus presenting one or two large granules which have been taken for nucleoli. They are closely bound together, so that they are isolated with great difficulty. In addition to an amorphous, adhesive substance between the muscular fibres, there are many rounded and spindle-shaped cells of connective tissue, and a few elastic fibres. The muscular tissue of the uterus is remarkable from the fact that the fibres enlarge immensely during gestation, becoming at that time ten or fifteen times as long and five or six times as broad as they are in the unimpregnated state. They are united into bundles or fasciculi, which in certain of the layers interlace with each other in every direction. The fibres are divided into external, middle and internal layers.

The external, muscular layer, which is very thin but distinct, is closely

attached to the peritoneum. When the uterus is somewhat enlarged after impregnation, there are observed oblique and transverse, superficial fibres passing over the fundus and the anterior and posterior surfaces to the sides. Here they are prolonged upon the Fallopian tubes, the round ligament and the ligament of the ovary, and they also extend between the layers of the broad ligament. This external layer is so thin that it can not be very efficient in the expulsive contractions of the uterus; but from its connections with the Fallopian tubes and the ligaments, it is useful in holding the uterus in place. It does not extend entirely over the sides of the uterus.

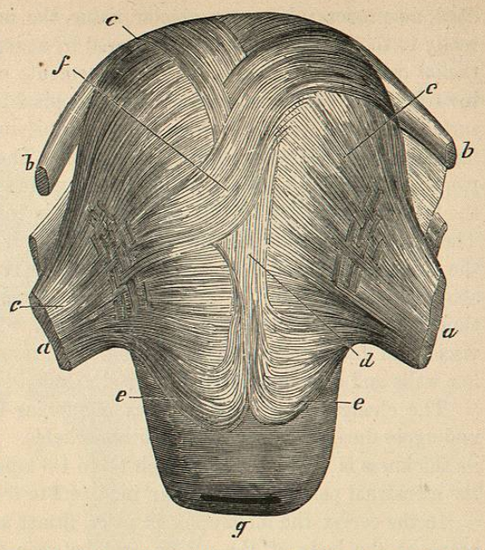

FIG. 279.—*Superficial muscular fibres of the anterior surface of the uterus* (Liégeois).
a, *a*, round ligaments; *b*, *b*, Fallopian tubes; *c*, *c*, *c*, *e*, *e*, transverse fibres; *d*, *f*, longitudinal fibres.

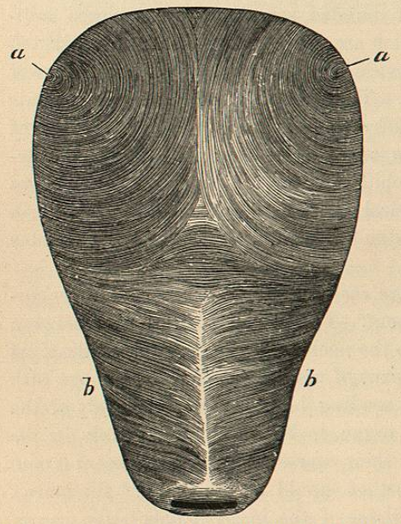

FIG. 280.—*Inner layer of muscular fibres of the uterus* (Liégeois).
a, *a*, rings around the openings of the Fallopian tubes; *b*, *b*, circular fibres of the cervix.

The middle, muscular layer is the one most efficient in the parturient contractions of the uterus. It is composed of a thick and intricate net-work of fasciculi interlacing with each other in every direction.

The inner, muscular layer is arranged in the form of broad rings, which surround the Fallopian tubes, become larger as they extend over the body of the uterus and meet at the centre of the organ, near the neck.

The mucous membrane of the uterus is of a pale, reddish color; and that portion lining the body is smooth and is so closely attached to the subjacent structures that it can not be separated to any great extent by dissection. There is, in-