OLOGY IN THE FEMALE. (Netter—Ciba Pharmaceutical Products, Inc.)

place in preparation for the change from a quiescent, fairly fixed structure to an actively functioning membrane, undergoing partial destruction and renewal every few weeks.

MENSTRUATION

Definition.—The term "menstruation" needs a clear and fixed definition. In the newer literature dealing with endocrine studies, it is used by different writers to express quite different concepts, with the resulting contradiction and confusion which always result from the use of ambiguous terms in the extended discussion on an intricate subject. In selecting a detailed definition, it seems advisable to start with a general one embodying the idea which has long received general recognition, namely, that menstruation is the bloody flow resulting from the breaking down of the endometrium normally prepared for pregnancy.

Now a definition defines a thing in a fixed way. If every person can change the definition of a term to suit his own particular view, it loses its usefulness as a means of conveying thought. The above time-honored definition seems a reasonable one and fully accords with modern physiologic and endocrinologic studies, and when the term is used it should mean exactly that—no more and no less.

Certain writers on endocrine topics use the term to express bloody flow without ovulation in that individual. In some of the conditions the bleeding is from a purely hyperplastic endometrium and in other cases from an endometrium sensitized to the secretory stage by progestin administration. In either case there has been no ovulation or corpus luteum formation in that individual, and hence no endometrium "normally prepared for pregnancy." Normal preparation for pregnancy presupposes ovulation and corpus luteum formation in that individual, and hence nothing which lacks these essential features should be designated as menstruation, if we wish to preserve clear-cut terms for accurate discussion.

We realize there may be some difficulty in selecting terms for these differing types of endometrial bleeding, but that is no excuse for killing the clear-cut significance of a well-established term, especially one of as much importance as menstruation. Such anomalous bloody discharge may be designated as nonovulation bleeding or anovulatory bleeding or hyperplasia bleeding or estrin bleeding or estrin-progestin bleeding. It might even be permissible to designate it as pseudomenstruation, though that tends to some confusion.

In dealing with the subject of menstruation there must be taken into consideration the following three phenomena:

Puberty and the beginning of menstruation (menarche).
Menstruation when fully established.
The menopause or cessation of menstruation.

1. **Puberty.**—Puberty is the period at which the girl matures and becomes capable of childbearing. This period is marked by a very rapid development of the sexual organs. The ovaries, uterus, vagina, and external genitals enlarge, hair appears in the pubic region and in the axillae, the breasts become more prominent, the pelvis enlarges, and the whole body becomes somewhat

larger and its outlines more rounded and graceful. These physical changes are accompanied by mental changes, which are indicated by modesty, sexual desire, and allied phenomena.

These changes take place usually between the eleventh and sixteenth years. When the proper development has been reached, the menstrual flow appears. This flow is the sign that development has taken place and that ovulation has begun. Ovulation, no doubt, occasionally occurs before the first menstruation appears, but, as the menstrual flow is the outward sign of the internal sexual preparation, the period of sexual activity is counted as beginning with the first menstrual flow. Likewise there may be a number of anovulatory cycles before the normal ovulatory mechanism is established.

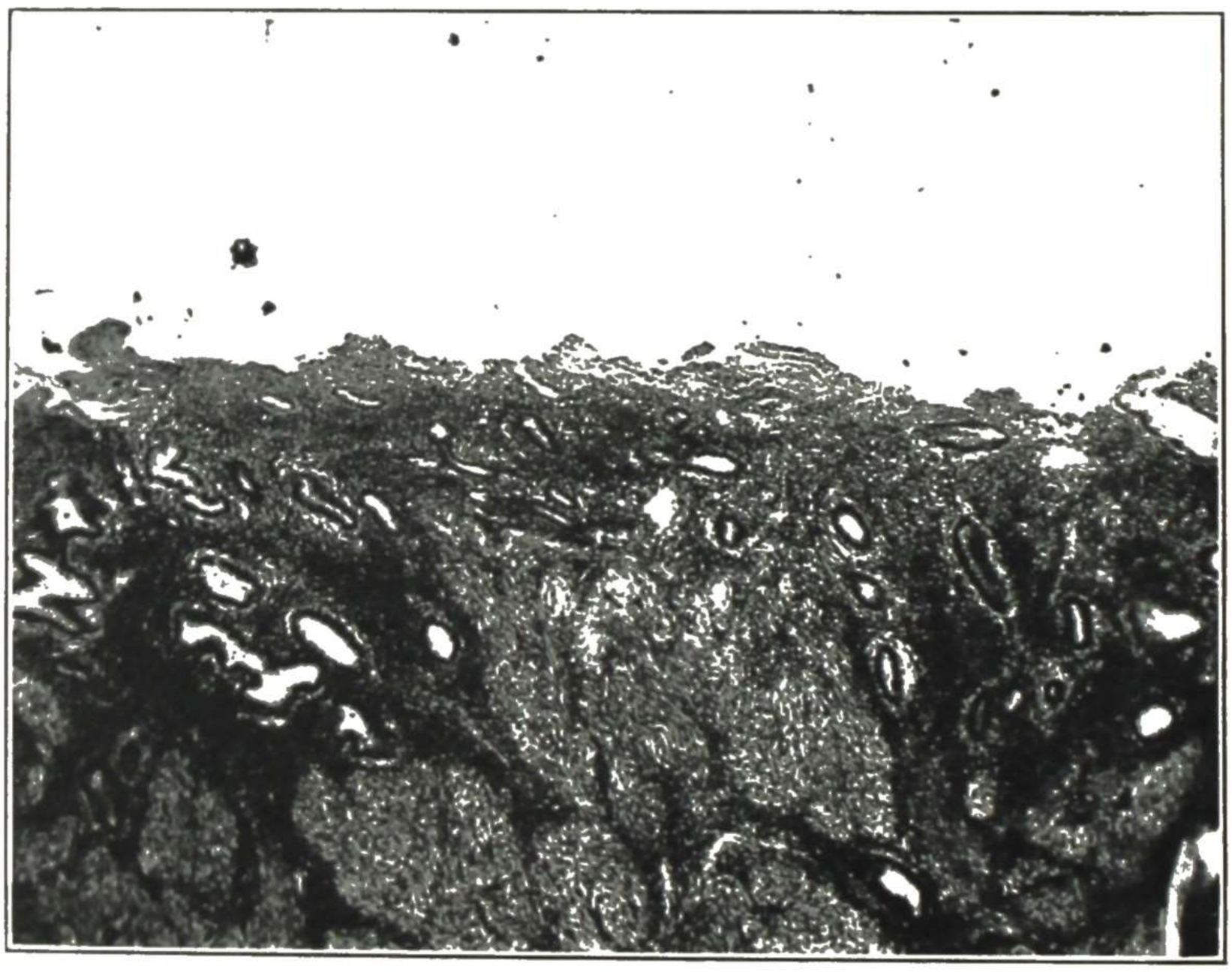


Fig. 77.—Endometrium at early growth stage. The breaking down of the endometrium is completed and the menstrual flow is well established. Probably the second or third day of menstruation. Gyn. Lab.

The age at which the first menstruation appears varies in different races and under different environments. Climate has long been thought to influence the beginning of menstruation—the colder the climate the later the first menstruation. This holds good as a general rule, the Laplander beginning to menstruate at about eighteen, while the inhabitant of hot climates at from nine to eleven. Engelmann has shown, however, that in some of the most northerly tribes menstruation appears as early as in the tropics. The mode of life has some influence, as has also the general health of the girl. Girls reared in the city begin to menstruate earlier, usually, than those reared in the country. In addition, there are the personal inherited tendencies, about which we know very little, but which exercise a marked influence on the phenomena of life.

Occasionally the beginning of menstruation is long delayed without any apparent cause. Hirst had a patient who menstruated for the first time at the

age of thirty-three, had four periods in the next two years, and then conceived two months later. He records also a reported case of a woman, married at thirty-four, who menstruated for the first time at the age of forty-five, and bore a child at forty-six.

In the United States a girl is expected to begin to menstruate when she is twelve or thirteen or fourteen. Not infrequently the menstrual flow begins at the age of ten or eleven, and hence when a girl reaches about the age of ten her mother should explain to her that a slight bloody flow may be expected and that it is nothing that need frighten or worry her, but is entirely natural.

2. **Menstruation.**—The menstrual discharge consists of blood mixed with secretion and epithelium from the uterus and with epithelium from the vagina. It is dark, and rather viscid or stringy from its admixture with cervical mucus. The menstrual discharge has also some odor, due to slight decomposition which takes place during its passage through the vagina. Menstrual blood taken directly from the interior of the uterus has no odor. If normal, the blood does not clot.

The amount of blood lost at each menstruation varies greatly in different individuals. Barer and Fowler found the blood loss in 100 women by extracting blood from pads and analizing iron content. They concluded that the average loss is 23 to 68 c.c., and the extremes 7 to 179 c.c. The rate of flow (i.e., whether or not the flow is too free) is estimated usually by the frequency with which the napkins have to be changed. The usual flow requires a change about three times daily during the height of the menstruation. If more frequent changing is necessary, the flow is too free.

There is considerable variation in the duration of the menstrual flow, the average being three to four days. Some perfectly healthy women, however, menstruate only one or two days and others six or seven days. The scanty menstruation or the profuse menstruation, as the case may be, seems to be normal for that particular individual. The duration of the flow in the same individual is about the same at the different periods.

Statistics on the periodicity have shown it to be irregular even in the same person. The average time is reckoned as about twenty-eight days. The cycle is counted as beginning with the first day of the flow. Arey made a study of 20,000 calendar records from 1,500 individuals of many races and varied ages. He found that an average woman must expect one-third of her menstrual cycles to depart more than two days from her mean cycle length. The mean cycle length, based on individual averages, was 33.6 days for girls and 29.5 for women. In no instance did perfect menstrual regularity appear over any significant period of time, though many women had previously believed themselves the acme of regularity.

Menstruation ceases during pregnancy and lactation. Exceptions to this rule are frequent. A few women menstruate for one or two periods after conception, and very often the menses return while a woman is still nursing her child.

The principal physiologic significance of menstruation is that it is a preparation of the uterus for the reception of a fertilized ovum.

Endometrial Changes

The relations of the cyclic endometrial changes to follicle-maturing and ovulation and corpus luteum formation are shown in Fig. 76 (folded color plate). The microscopic details characterizing the different stages of the menstrual cycle are shown by actual photomicrographs with explanatory drawings in Figs. 77 to 85.

In regard to designations for the stages of the cycle, understanding of the terms will be aided by keeping in mind that they refer primarily to changes in the endometrium. Ovarian changes and influences which accompany the endometrial "stages" are mentioned as "phases" in order to avoid the confusion which has resulted from the mixture and haphazard use of two sets of terms, one based on the endometrium and the other on the ovary. It must be kept in mind also that the time limits of the "phases" and "stages" are different, and hence that the imposing of one on the other is practicable in only a general way. For example, the luteal phase of ovarian influence on the endometrium is manifest in both the late growth stage and the premenstrual stage, but the endometrial picture in the latter is so different from the former that it constitutes a separate stage.

Another item is that the stages have only one point of coincidence with the menstrual flow, and that is that the beginning of the flow marks the breakdown which ends the premenstrual stage and inaugurates the next cycle of growth. Hence the "menstrual stage" has no relation to the length of flow but only to its beginning. The end of the flow determines no particular change in the endometrium; hence there is no occasion for the term "postmenstrual stage." The term "interval stage" also has been outgrown, for we know now that there is continuous growth from one breakdown to the next and consequently no resting or "interval" stage as formerly supposed.

The terms used in describing the stages of endometrial change are as follows: early growth stage (follicular phase), late growth stage (luteal phase), premenstrual stage, menstrual stage (breakdown). The breakdown is a piecemeal affair, still continuing in some parts of the endometrium while growth is advancing in other parts. However, as the classification is based on growth and as regeneration starts with the breakdown (first day of flow) the early growth is counted as beginning at that time, though some days are required for the development of typical features.

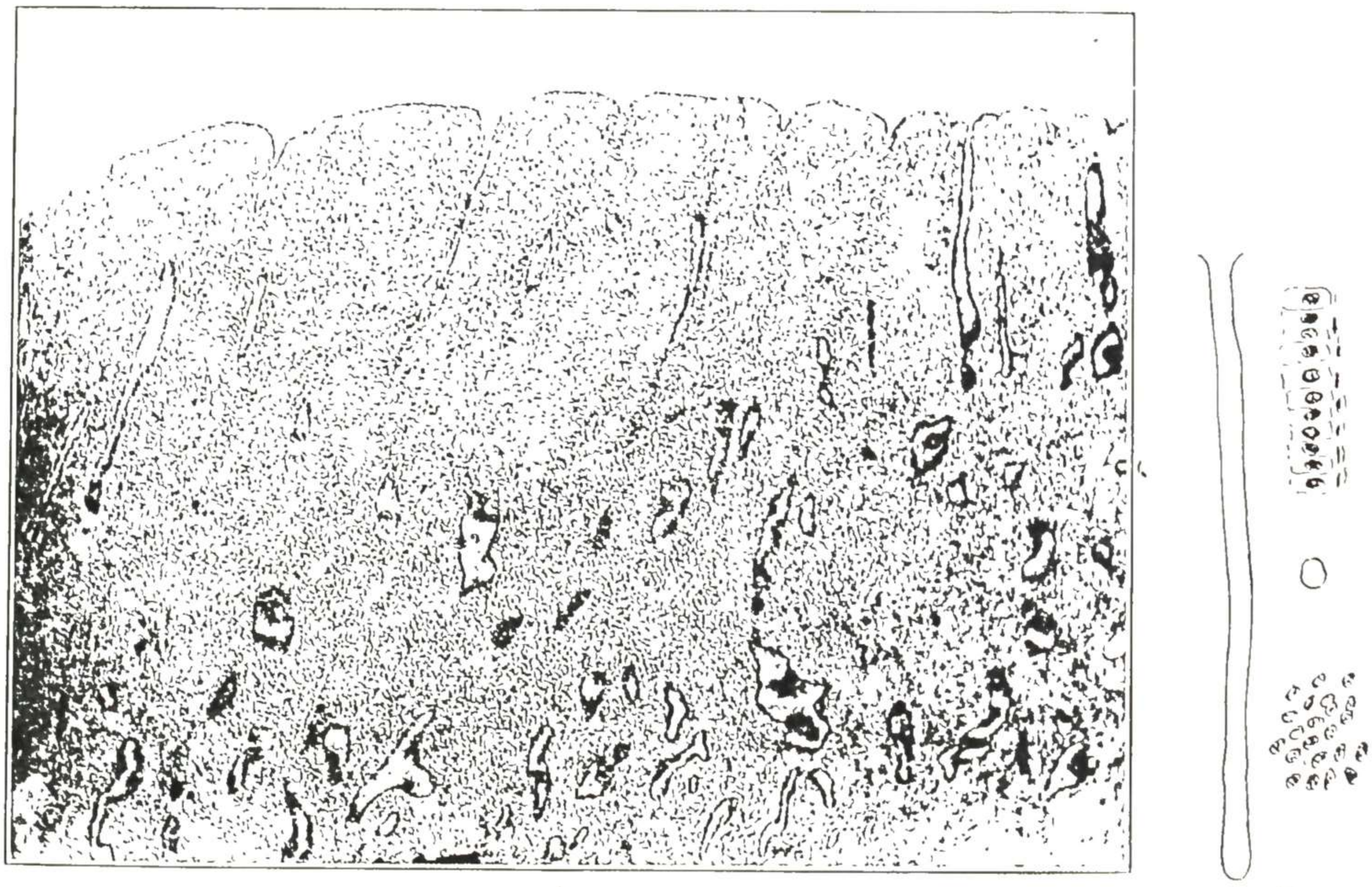
With the onset of menstruation there is tissue loss, with thinning of the thickened and softened endometrium. The extent of tissue loss probably varies with the individual and with the condition of the endometrium. According to Schröder, in most cases the endometrium is cast off down to the basal layer, leaving the lower end of the glands from which the new endometrium regenerates (Fig. 77).

Watson and McHenry, studying the tissue loss from the endometrium during menstruation, concluded that tissue loss during normal menstruation is limited to the epithelium of the glands which have been fully activated by progesterone and the stroma supporting that epithelium. The loss occurs only when the progesterone stimulus is withdrawn.

A. *B.*

Fig. 78.—*A*, Early growth stage a little later than Fig. 77. Note the beginning regeneration of the surface epithelium at the right upper corner. Gyn. Lab.

B, Shows the general character of the glands, short, straight, narrow, with a round lumen. The lining cells are cuboidal with central nuclei. The stromal cells are closely packed, with very little cytoplasm. The detailed diagrammatic drawings in Fig. 78-*B* and also those in Figs. 79-*B*, 80-*B* and 85-*B* are modified from drawings by Novak (Am. J. Obst. & Gynec.) whose studies and writings have greatly assisted in the classification of these complicated endometrial changes.



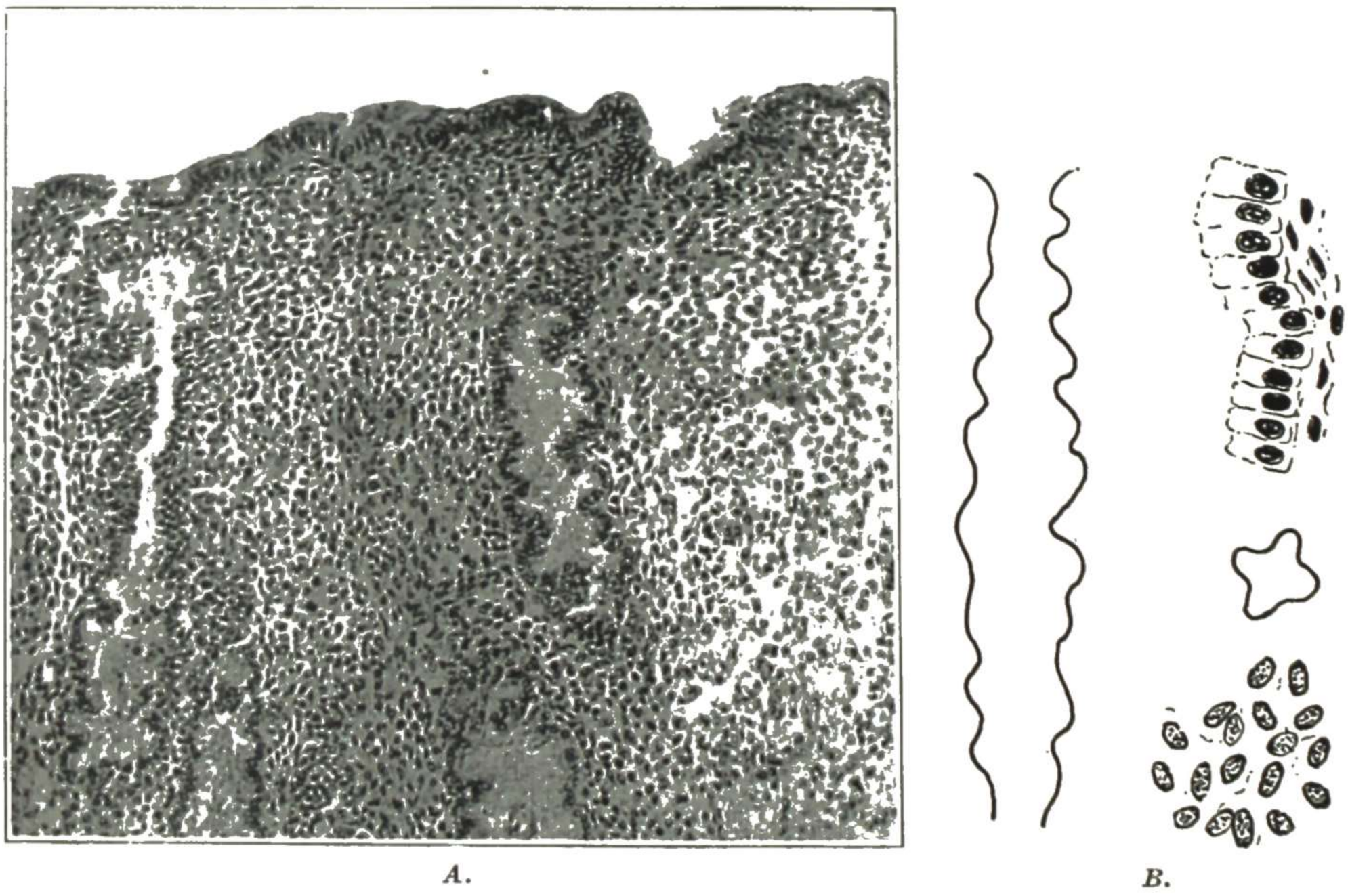
A. *B.*

Fig. 79.—*A*, Endometrium in the early growth stage (eighth day of cycle). The endometrium is becoming rapidly rebuilt and already is almost back to its normal thickness. The glands are straight and collapsed. Gyn. Lab.

B, Diagrammatic sketch to show the character of the epithelial lining cells, the stromal cells, and the glands.

Early Growth Stage ("Follicular Phase").—The microscopic characteristics of this stage are shown in Figs. 78 to 79. Campbell, Lendrum and Sevringhaus, in describing the cycle, speak of a period of tissue loss (comprising the first day or two of bleeding), a period of re-epithelization (two days) and a pre-ovulatory "proliferative" period (ten to twelve days) in which the follicular hormone effect becomes fully developed.

In the early growth stage the growth is due chiefly to the action of estrone. By the end of the first week of this period there has been rapid growth of the endometrium, which becomes greatly thickened and somewhat edematous. There are numerous mitotic figures in the stroma and glandular epithelium. The glands become elongated but the lumen is still round and regular, as shown in Figs. 78 and 79. The epithelial cells lining the glands are inactive as far as secretion is concerned and the nuclei are still basal, and no glycogen or mucin



A. *B.*

Fig. 80.—*A*, Endometrium in the late growth phase. (Twelve to twenty-five days after the first day.) The endometrium is back to its normal height. The glands are beginning to become tortuous and they are filling with secretion. The stromal cells, particularly those near the surface, are increased in size and varied in shape. These are due to the beginning action of progestin, secreted by the corpus luteum since the time of ovulation. Gyn. Lab.

B, Diagram showing the characteristics of the late growth stage. Irregular gland becoming dilated with secretion, epithelial cells lining the gland are enlarged and secreting, stroma cells enlarged.

is present. In the early part of this stage the interstitial tissue of the stroma is loose and fibrillar but later becomes progressively more dense.

Late Growth Stage ("Luteal Phase").—The typical features of this stage are shown in Figs. 80 to 83. In this latter part of the period of growth, after ovulation and corpus luteum formation, the influence of progesterone on the endometrium becomes manifest. Evidence of this progesterone effect is that the nuclei in the glandular epithelium are pushed from their basal position toward the center by masses of glycogen, leaving a clear area between the base of the cell and the nucleus. This change starts at the mouth of the gland and proceeds toward the deeper portion, but leaves the deep end unaffected.

The epithelial cells lining the glands become longer and longer and there is a decrease in the number of mitotic figures, and in two days the glycogen begins to migrate toward the lumen end of the cells. The position of these masses of glycogen can be clearly shown by special staining. Soon they appear as protrusions of the cells into the lumen of the glands, preparatory to the secretion of the glycogen into the lumen. This projection of glycogen from the cell ends gives a ragged frayed appearance, characteristic of this process and shown well in Fig. 83. Mucin appears in the lumen later than the glycogen, and it has never been found within the secreting cells. As the glands grow in this stage they become coiled and tortuous and irregular, as shown in the illustrations.

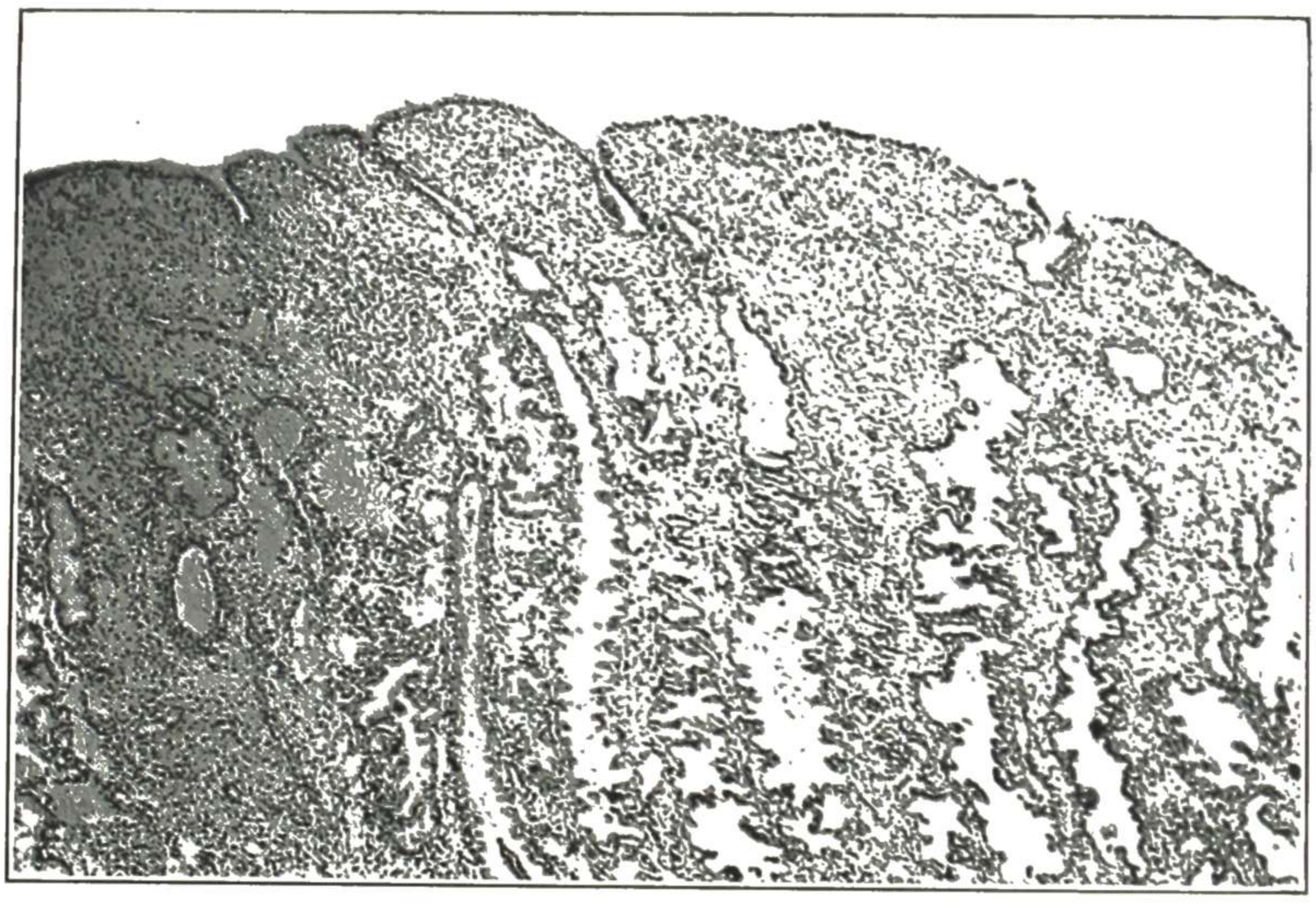
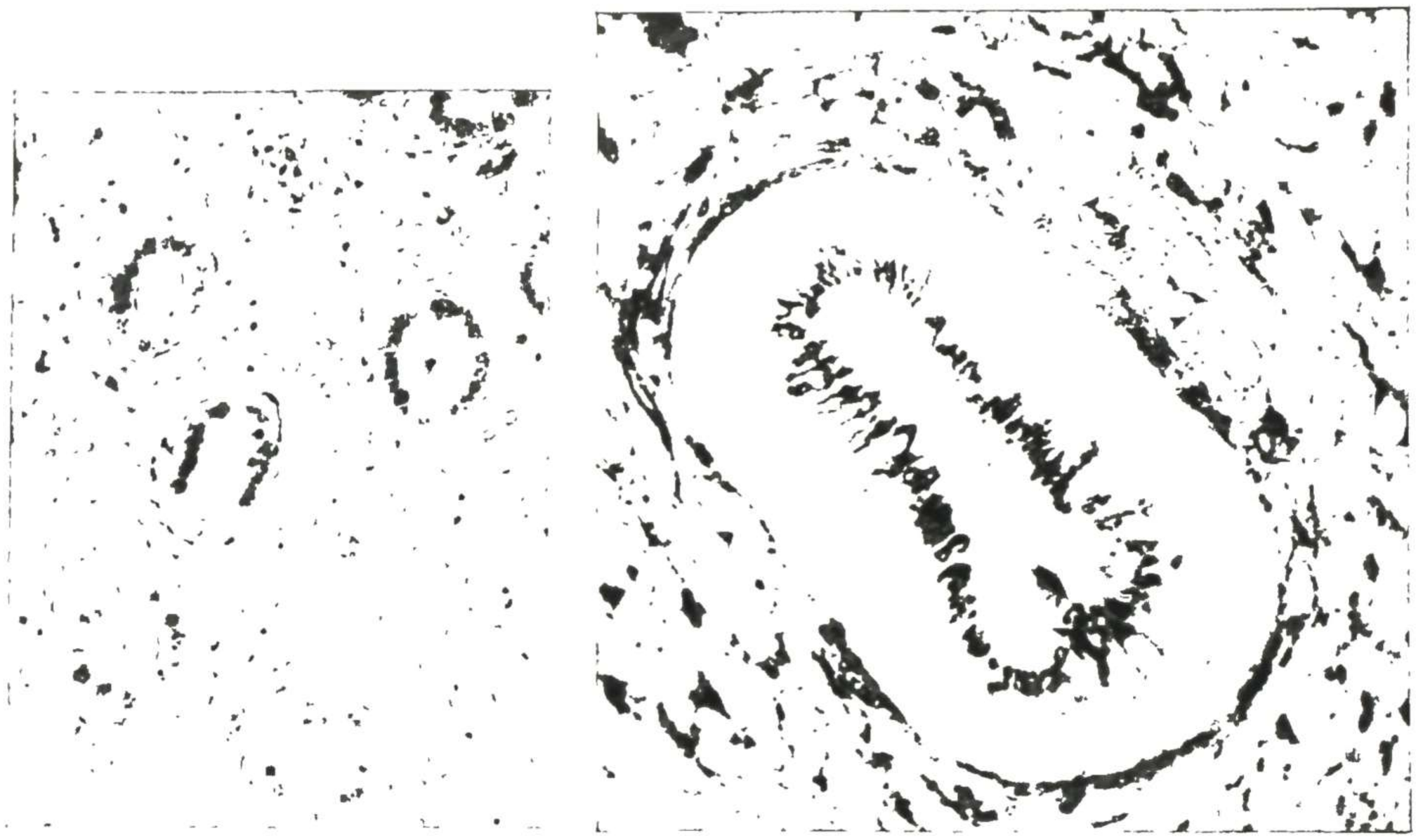


Fig. 81.—Premenstrual stage showing the upper layer of the endometrium. The saw-toothed edges of the glands are particularly noticeable in the section. The stroma is decidua-like. Gyn. Lab.

Premenstrual Stage.—In this stage there is a marked increase in the tortuosity of the glands and rapid growth of their epithelial lining. This rapid epithelial growth causes crowding, hence tufts of cells are pushed into the glandular lumen, giving the typical "saw-tooth" appearance, as shown in Figs. 84 and 85.

In the middle portion of the endometrium the growth and tortuosity of the glands are so marked that the stromal cells are forced toward the surface, forming there a compact layer. By this process the endometrium becomes divided into three zones: the superficial "zona compacta," where the stroma is fairly dense and the glands compressed and straight; the "zona spongiosa," composed of dilated coiled glands with very little between them, and the "zona basalis," containing the deep ends of the glands which are affected very little by the cyclic changes. These zones are well shown in the photomicrograph in Fig. 84. The stromal cells in the superficial compact zone become edematous and large and resemble decidual cells, but differ from them in that they contain no glycogen.

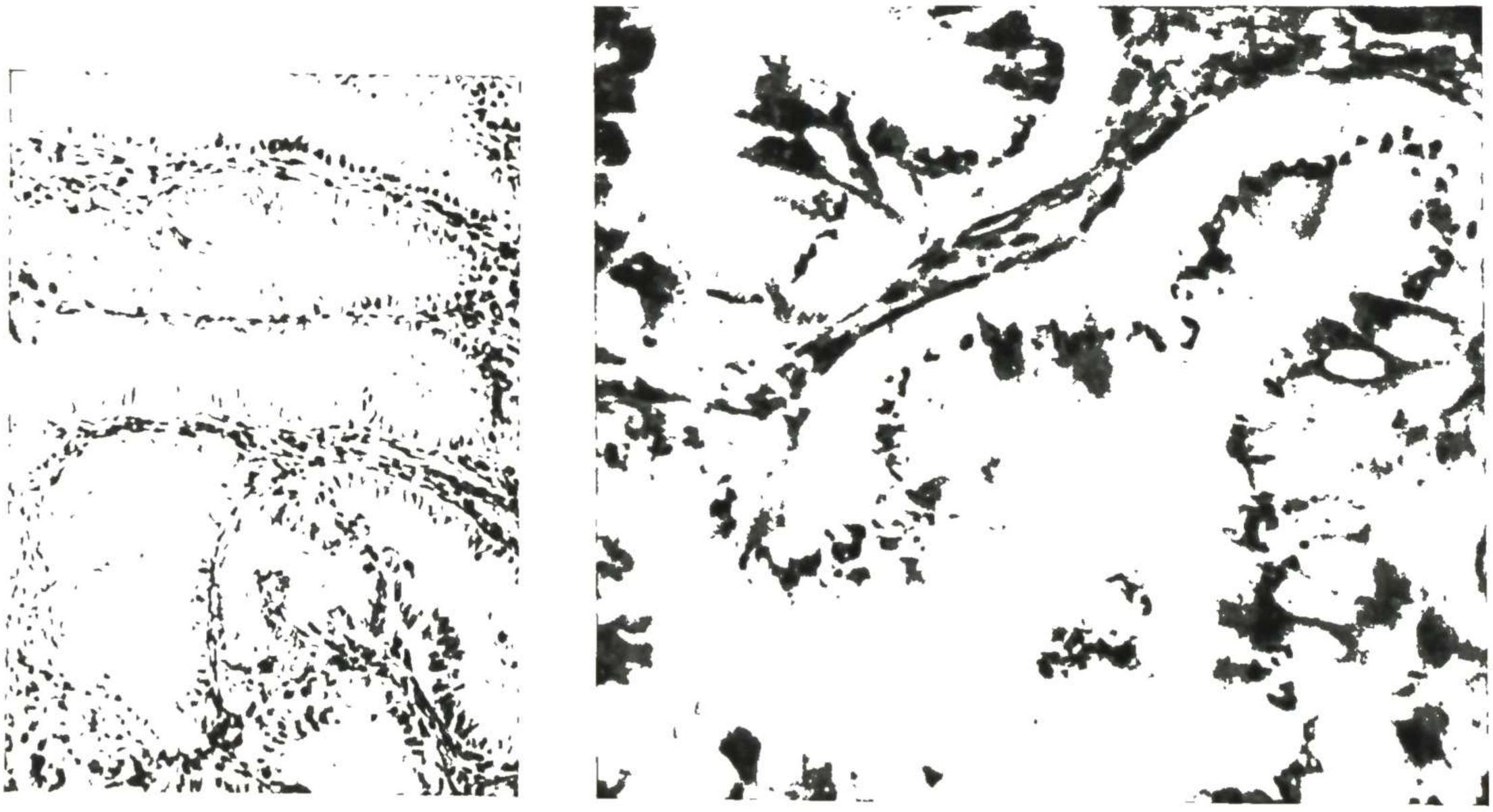


A. *B*.

Fig. 82 *A* and *B*.—The follicular phase of the growth stage.

A, Specimen from a patient on the sixteenth day of the cycle. The follicular effect is fully developed. Ovulation probably occurred about this time. (×140.)

B, Special staining of gland, in follicular phase, to show Golgi apparatus. (×600.) (Campbell, Lendrum and Sevringhaus—Surg., Gynec. & Obst.)



A. *B*.

Fig. 83 *A* and *B*.—The luteal phase of the growth stage.

A, Specimen from same patient on the twenty-third day of the same cycle. The luteal effects are now well developed, but are still fairly early, as is evidenced by the presence in some places of a clear zone between the gland nuclei and the basement membrane. (×140.)

B, Special staining of gland, in luteal phase, to show Golgi apparatus. (×600.) (Campbell, Lendrum and Sevringhaus—Surg., Gynec. & Obst.)

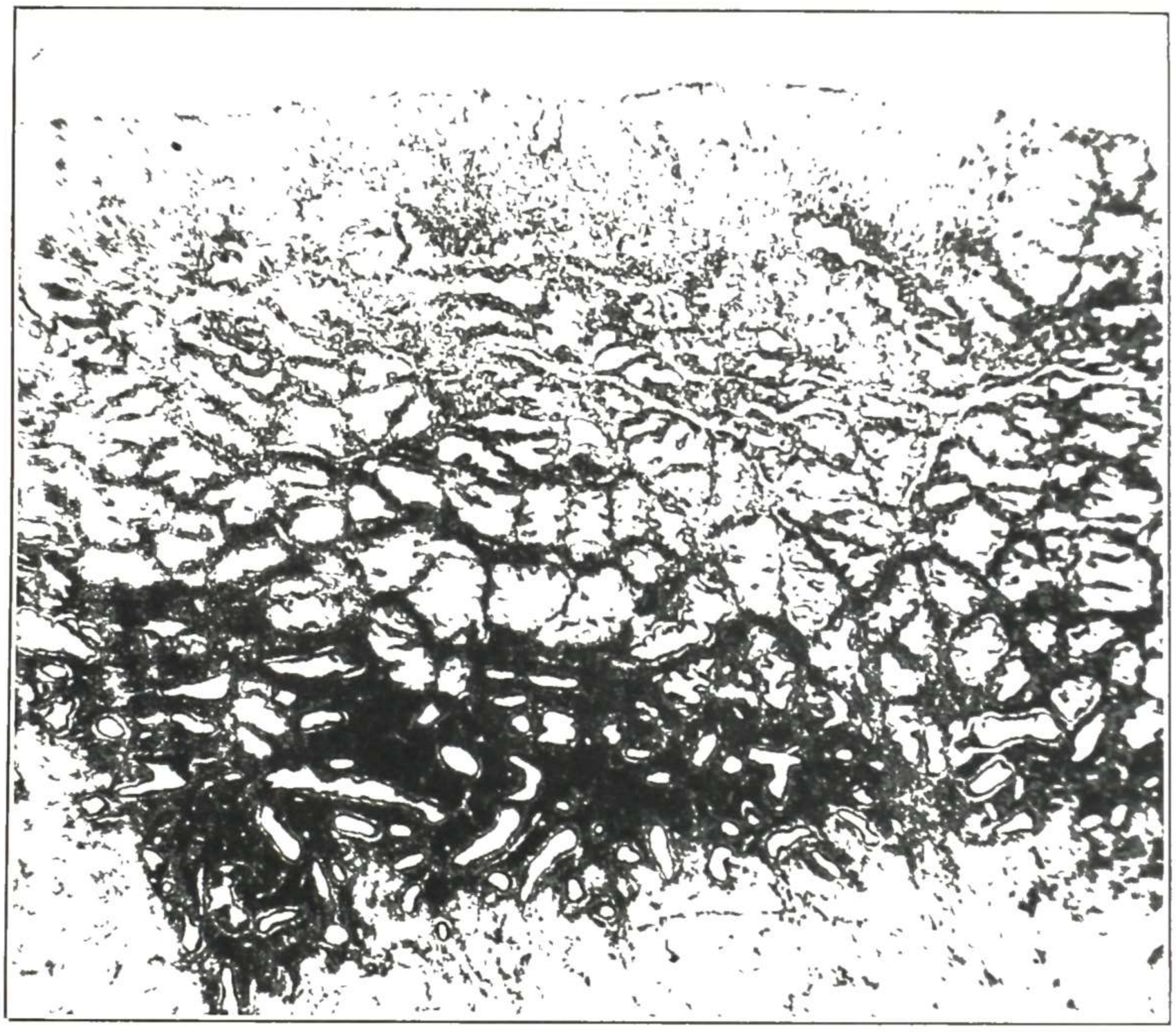
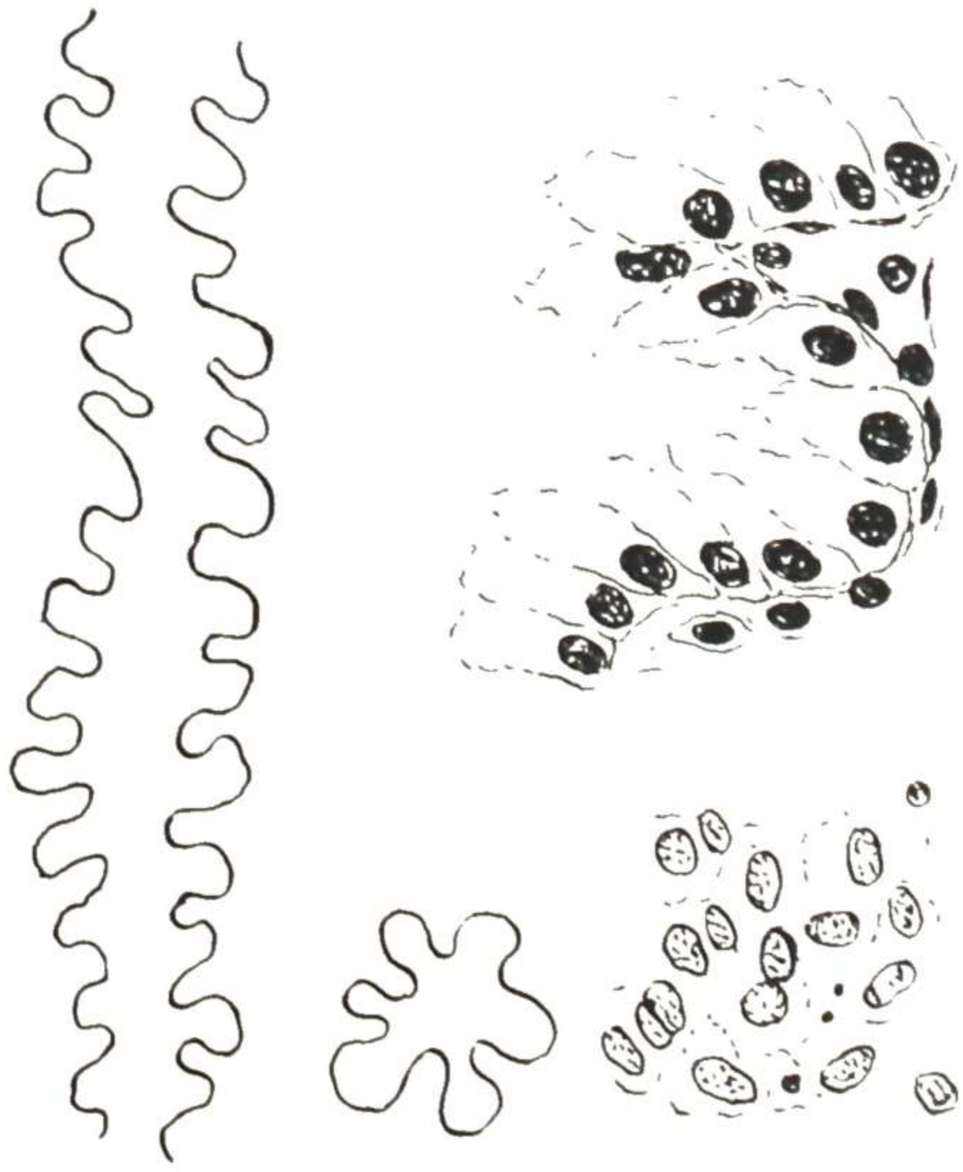


Fig. 84.—Endometrium of premenstrual stage. (Twenty-five to twenty-seven days after the first day.) Marked tufting of the dilated glands which are also increased in number. Notice the superficial compact layer and the deeper spongy layer similar to a decidua. This is due to the large amount of progestin from the mature corpus luteum present in the ovary at this time. Gyn. Lab.

A.



B.

Fig. 85.—*A*, Premenstrual endometrium. High power of Fig. 81, showing the markedly distended tortuous glands and the large stromal cells. A capillary distended with blood elements just below the center of the section. "Tufting" effect well shown. Gyn. Lab.

B, Diagram showing the characteristics of the premenstrual stage mentioned in *A*. Longitudinal section showing the saw-toothed edges of the gland, shown also in cross-section. The large epithelial cells covering the tufts are illustrated as are also the large clear stroma cells.

The great thickening attained by the endometrium in the premenstrual stage is shown in Fig. 86, which is a uterus removed just before the menstrual breakdown. Notice the distinct rolled margin at the lower portion of the full-functioning endometrium where it joins the mucosa of the "isthmus," which is the transitional area of the uterus where the corpus shades into the cervix.

This stage is followed by the endometrial breakdown, and this inaugurates the next cycle.

Menstrual Stage (Breakdown).—This is the stage in which the built-up endometrium crumbles and is cast off, usually to the basal layer. The remaining portions of the glands are generally collapsed and the stroma is filled with dilated capillaries, and there are red cells in the tissue spaces. The process by which the blood gets into the spaces is not proved, but most authorities feel that diapedesis is more common than rhexis. Figs. 87 and 88 show the endometrium of this stage.

Cyclic Arteriole Changes of Menstruation

Though these changes occur simultaneously with the above-described cyclic epithelial and glandular changes and are an integral part of the mechanism of menstruation they are discussed separately to avoid confusing the two phenomena. The observations of Markee on endometrial tissue transplanted into the eye of rabbits and monkeys and the work of Daron on the anatomy and histophysiology of the endometrial vascular components in the monkey advanced greatly our understanding of the mechanism of endometrial bleeding and disintegration. Some of the observations made by them in animals have been made also in human beings by means of hysteroscopic studies. Mikulicz-Radecki described transient blanching of the endometrium just before the onset of bleeding. Schröder confirmed this and described a pale, swollen, glassy mucosa on the twenty-sixth day of the cycle. It is now known that the recurring vascular cycles of the spiral arterioles are the same in cyclic uterine bleeding whether the endometrium is proliferative or secretory or hyperplastic, hence menstruation is fundamentally a vascular phenomenon.

The **spiral arterioles** arise from the arcuate branches of the uterine artery in the middle third of the myometrium and extend inward. In the inner fourth of the myometrium they are perpendicular to the uterine cavity, and after penetrating the endometrium they extend to the surface without giving off any branches. The spiral arterioles as they pass through the inner fourth of the myometrium are surrounded by specialized muscle tissue made up of fibers from the surrounding myometrium. These periarteriole collections of special muscle fibers were called *contraction cones* by Markee, who described them in the monkey. In human beings, groups of longitudinal muscle fibers immediately beneath the tunica intima of the arterioles in the female genital tract were described by Bucura. These fiber groups, named "polsters" by Bucura, are especially abundant around the arterioles of the inner fourth of the myometrium, and Keiffer has shown that the fibers of the tunica are continuous with the intrinsic muscle fibers of the myometrium.

The muscle cones surrounding these spiral arterioles are under hormonal control, and the terminal portions of the arterioles in the endometrium atrophy when there is constriction by prolonged contraction of the muscle cones. This interference with the blood supply to the endometrium in the area of the terminal arterioles affected causes disintegration of the endometrium in those areas. The basal layer of the endometrium is supplied by another group of arteries, which are not under hormonal control and hence do not undergo cyclic changes. Thus the fundal portions of the glands, which lie in the basal layer, are preserved for regeneration of the endometrium.

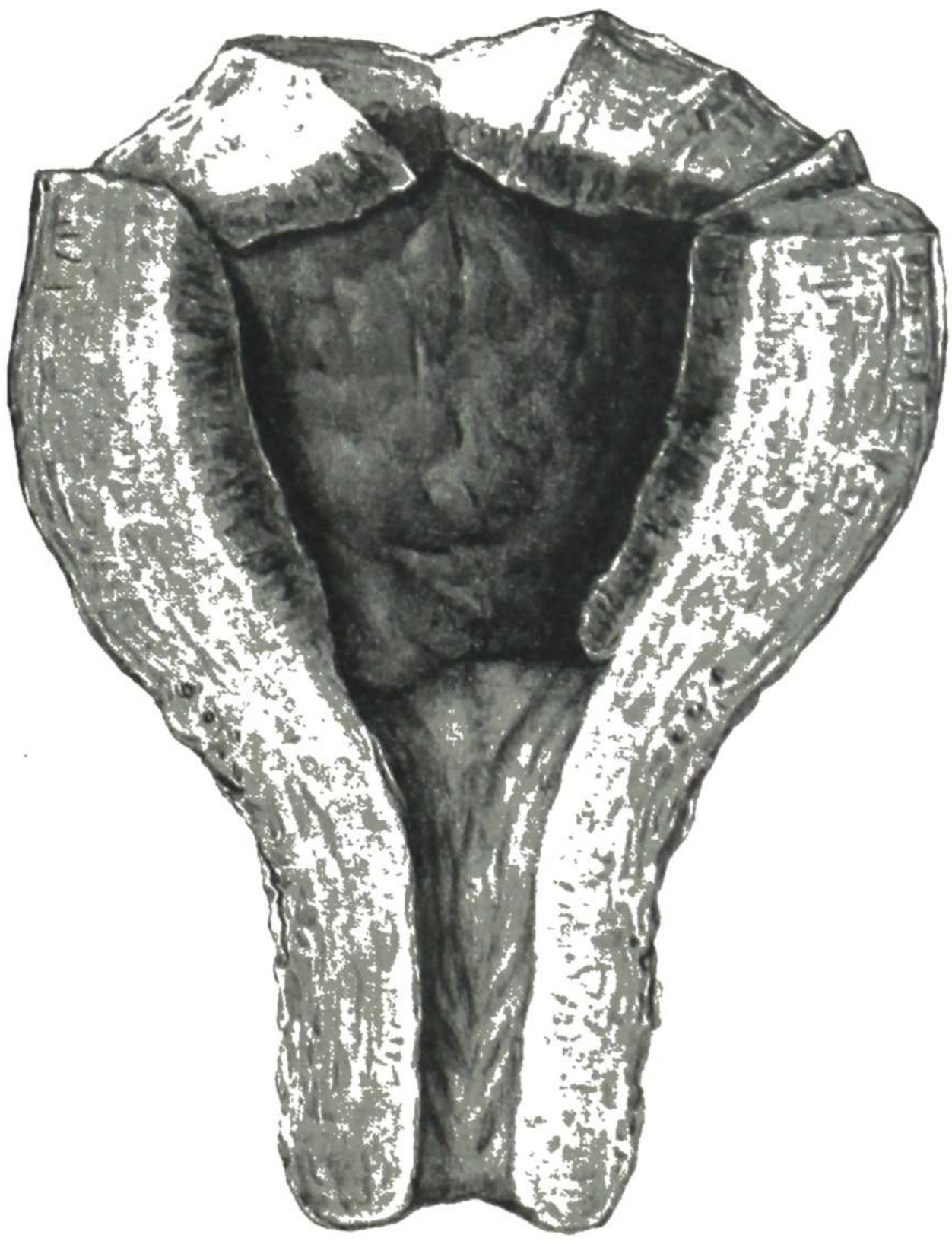


Fig. 86.—A uterus removed in the premenstrual stage, showing the marked thickening of the endometrium. In this specimen the "isthmus" of the uterus stands out clearly. The "isthmus" is the intermediate zone lying between the fully-functioning endometrium and the cervix, and represents a transition from endometrial to the cervical type of mucosa. Notice the thick roll at the lower border of the functioning endometrium. Gyn. Lab.

During the first three weeks of the cycle the spiral arterioles alternately contract and dilate causing periods of blanching and of blushing of the endometrial surface lasting from thirty to ninety seconds. During the premenstrual stage the endometrium becomes paler, and the blood flow through the superficial arterioles is markedly slowed. With the death of the corpus luteum and the consequent withdrawal of estrone and progesterone, the nourishment to the endometrium is withdrawn and there is a marked shrinkage due to water loss. With the endometrial involution, the arterioles become tortuous and coiled, the blood flow is definitely impeded, and leucocytes invade the stroma.

These events immediately precede menstruation, and in the course of the next twenty-four to thirty-six hours one after another of the coiled arterioles

clamp down so that there is no movement of blood cells in the superficial zone, though the circulation is normal in the basal zone. The cause of this sudden clamping down of the arterioles is thought by Markee to be due to injured-tissue products which act as vasoconstrictors for the special muscle cones about the spiral arterioles, the tissue-injury being due to the previous slowing of the circulation.

Several hours after the arterioles have clamped down, some of the arterioles open and allow blood to pour into the surrounding tissue. In the course of a few minutes a subepithelial hematoma develops. It soon ruptures and dark blood streams out on the surface of the endometrium. Necrosis sets in at the surface and the ends of the spiral arterioles are sealed by dead cells. An arteriole that has bled usually does not bleed again during this flow, though the blood does not clot. Small fissures appear at the edge of the blood-soaked area, and as they extend deeper into the tissue small areas of endometrium are loosened and cast off.

Fig. 87.

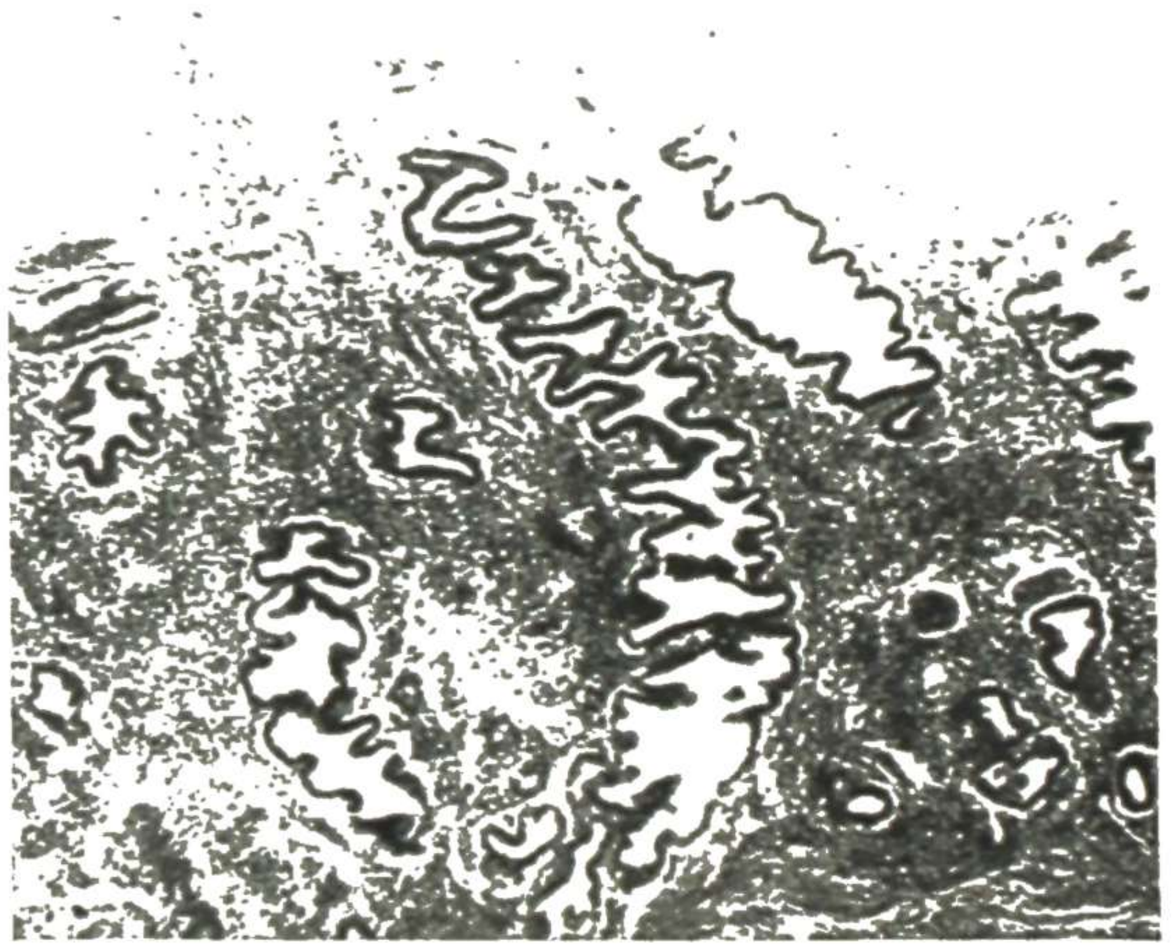


Fig. 88.

Fig. 87.—Endometrium menstrual stage. Shows beginning crumbling and hemorrhage in the superficial layer. Gyn. Lab.

Fig. 88.—Endometrium menstrual stage somewhat later than that shown in Fig. 87. There is a loss of the superficial tissue, but the glands are not yet completely collapsed. Gyn. Lab.

This process is repeated in other areas during the next two or three days so that by the third or fourth day of the flow the endometrium is irregularly denuded. Regurgitated blood slowly oozes from the open veins and the surface becomes clean. This is soon followed by a migration of cells from the torn glands, and the surface epithelium is completely restored in the course of a few hours.

During the entire menstruation the basal circulation has continued, and it is now accelerated. From the stumps of the coiled arterioles capillary sprouts develop and the superficial capillary bed is rapidly re-formed. The new arterioles grow with the endometrium, and as their growth is more rapid than that of the stroma they become spiral.

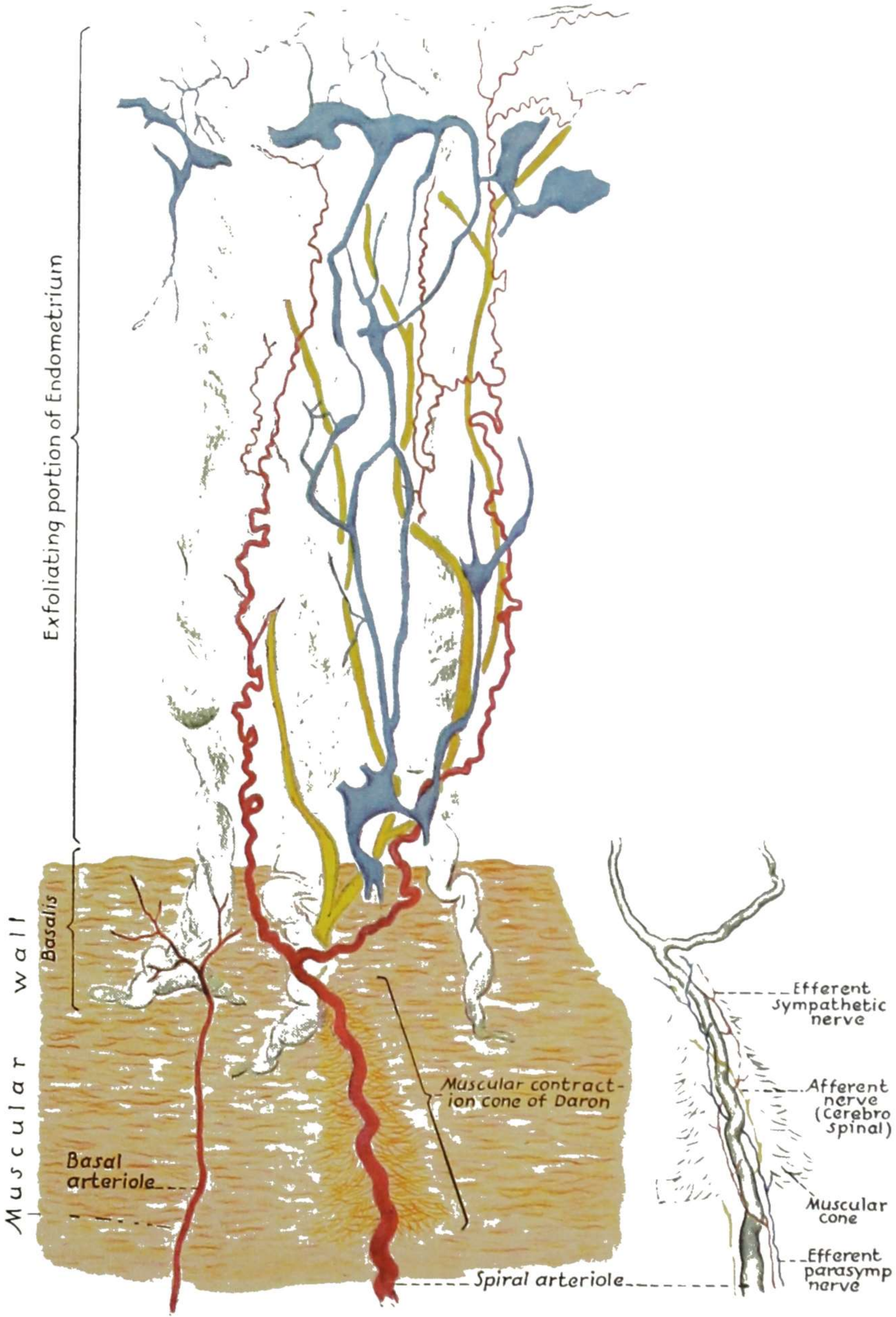


Fig. 89.—This colored diagrammatic illustration follows closely the original reconstruction of the elements by Bartelmez from serial microscopic sections of specially prepared and stained endometrial tissues.

The spiral arterioles of the endometrium are largely terminal and the blood supply through each is under the control of the muscle cone of Daron, shown in the illustration. Hence the nutritional integrity of the terminal area can be lowered by contraction of the arterial muscle cone, so that the area ceases to thicken by growth and later shrinks and disintegrates. The bleeding which follows is blood released by the cellular disintegration, apparently largely from the venous sinuses of the area.

The basalis zone of the endometrium is supplied by other arteries, not under hormonal control and not subject to the cyclic changes and exfoliation. Thus the deep ends of the glands are preserved for regeneration of the endometrium. (After Bartelmez—*Am. J. Obst. & Gynec.*)

Daron made reconstructions of the spiral arterioles from serial sections of the menstruating endometrium in the monkey. Bartelmez made reconstruction of the elements of the endometrium in the human, showing spiral arterioles with their muscular contraction cones, and also the glands and venous sinuses and lymphatics, and it was from this reconstruction that the colored illustration, Fig. 89, was made.

The demonstration of this terminal arteriole control of endometrial nutrition and disintegration has been carried a step further by Jones and Brewer, who used uteri removed in tubal pregnancy cases for their studies. Such uteri are specially suitable for this purpose in that they are removed for a lesion outside the uterus and the conditions inside the uterus closely simulate menstrual disintegration and bleeding. They demonstrated by photomicrographs the terminal arteriole and the endometrial disintegration in the area it supplied.

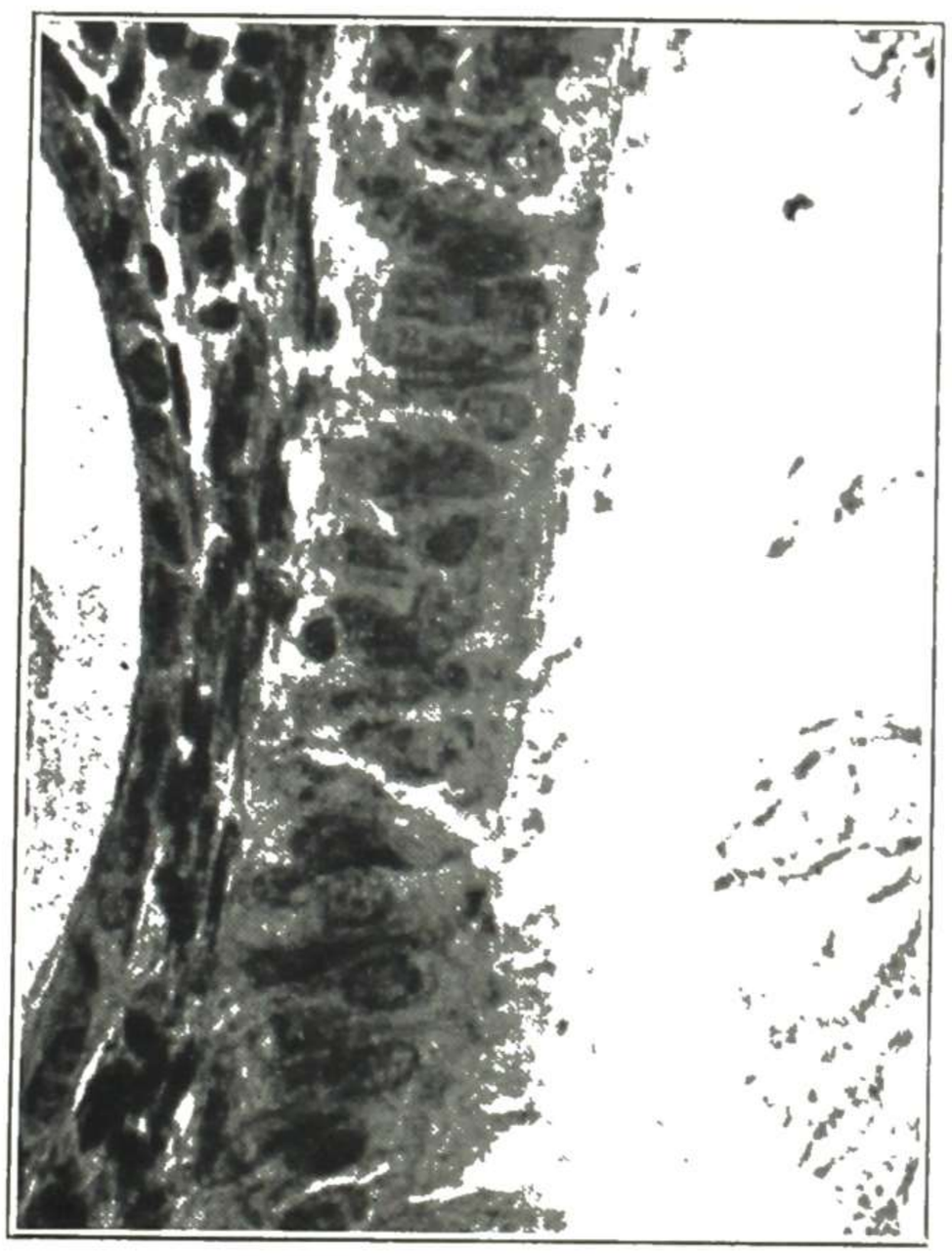


Fig. 90.

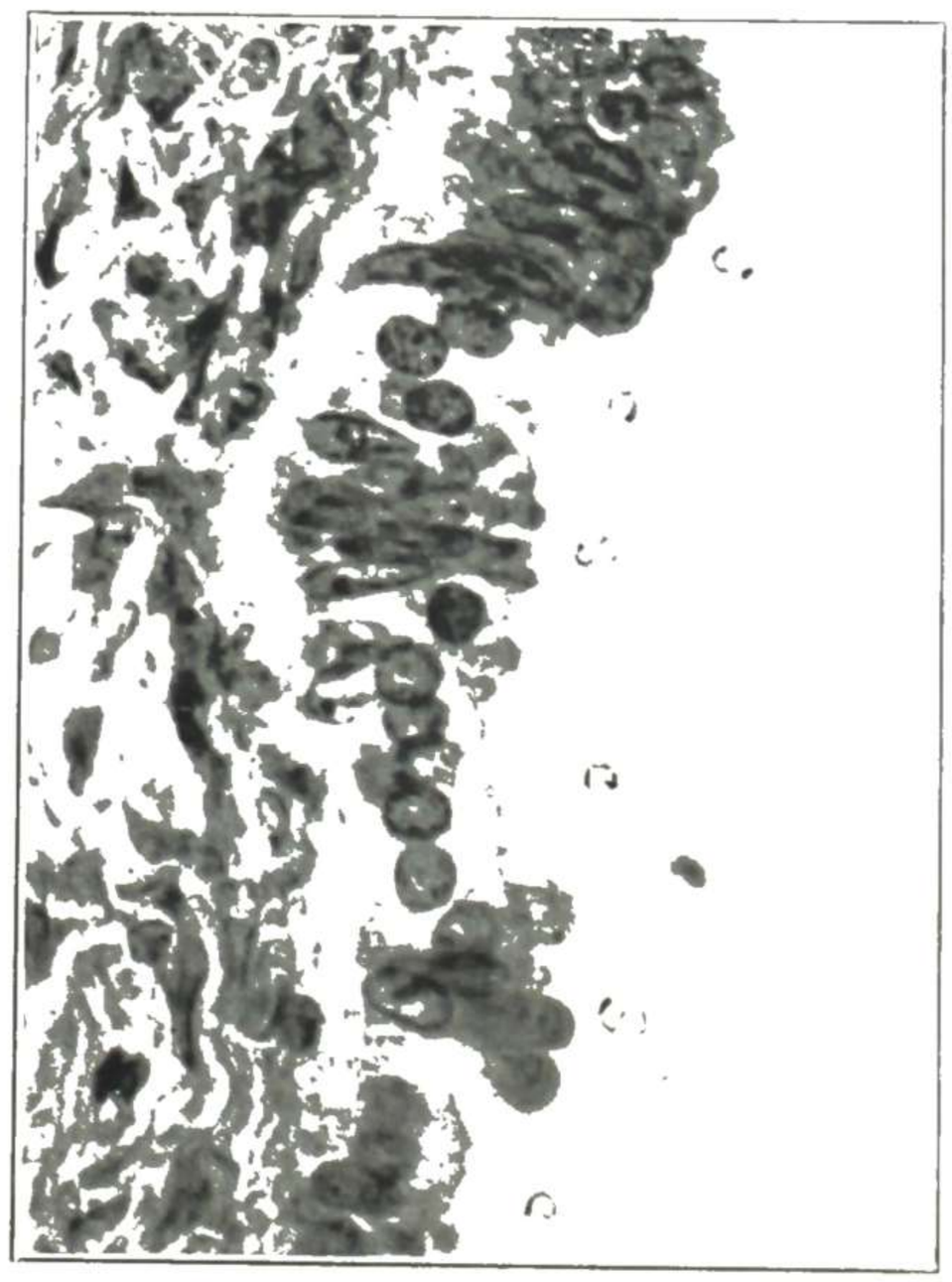


Fig. 91.

Fig. 90.—Endometrium in a case of hyperplasia showing ciliated cells lining an endometrial gland. Cilia are rare in normal endometrium, but in hyperplasia one often finds scattered endometrial areas exactly resembling tubal epithelium, with all three of the characteristic tubal cell types. (Novak—Am. J. Obst. & Gynec.)

Fig. 91.—Another example of tubelike epithelium in the endometrium of a case of hyperplasia. Ciliated cells (*C*), and secretory cells (*S*). (Novak—Am. J. Obst. & Gynec.)

What controls the muscle cone governing the blood supply through the arteriole? Is it controlled by nerve impulses or by endocrine influence? Tracing the uterine nerves to their minute terminations, it is found that sympathetic and parasympathetic fibers pass to the functioning elements of the uterine wall, as shown diagrammatically in Fig. 89. Hence the arterial muscle cone is under control of the sympathetic and parasympathetic nerves. These nerves are influenced by various pharmacological substances, and by endocrines. It is well known that the cyclic changes in the endometrium are under endocrine control, and it is reasonable to suppose that this endocrine control is exercised through the neuro-muscular apparatus just mentioned, for it is there ready and is well suited to the purpose.

The endocrine influence may be exercised by remote effect, through the nerves, or by direct local effect on the nerve-endings and muscle fibers. Possibly both pathways are used, but the local influence is evidently large, for menstrual disintegration and exfoliation of the endometrium takes place a little at a time in a spotty way. Also, it takes place when remote influence has been eliminated by division of the nerves, as in Markee's transplantations of endometrial tissue into the eye.

The marked menstrual changes in the endometrium are not manifested equally in all parts of the membrane. Novak calls attention to this in the article previously referred to, emphasizing the strikingly different characteristics which the original coelomic epithelium develops in the different segments

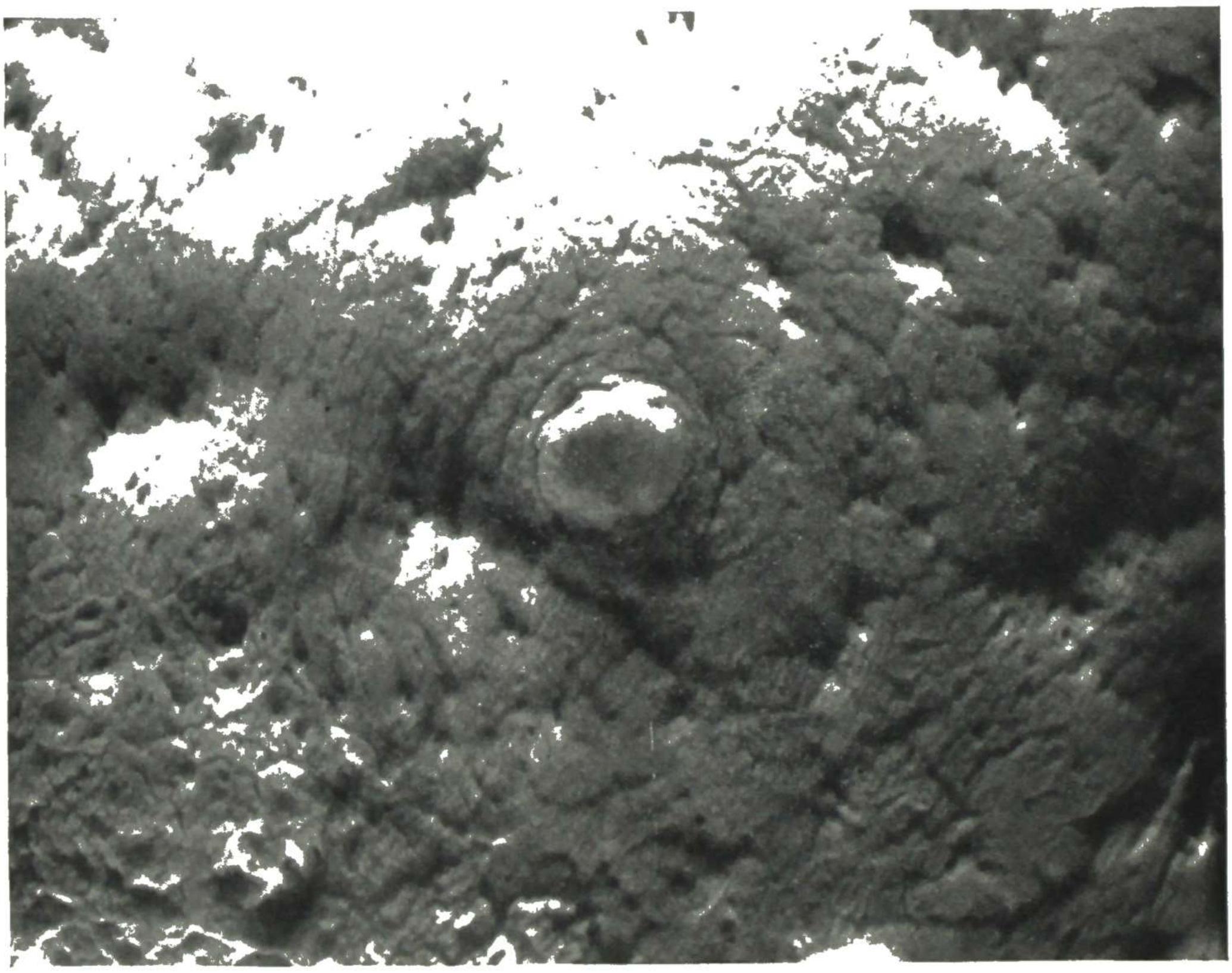


Fig. 92.—Magnified surface view of the endometrium. Notice the gland openings and the irregularity of the surface. The rounded mass in the center is a fertilized ovum, just sinking into the endometrium. (Carnegie Institution—*Scientific Monthly.*)

of the genital canal. Even in this single segment (endometrium), a stimulation brings different functional response in different parts, as manifested in the so-called "stratum reaction."

Another indication of the variability of cellular response to stimulation is seen in the development of tubal types of epithelium in the endometrium. This is rare in the normal endometrium, but with a slight shift in endocrine balance, as in hyperplasia, there may be reversion to the tubal type in spots. Fig. 90 shows in the endometrium the ciliated type of tubal epithelium and Fig. 91 shows the secretory type. This reversion to the tubal type of epithelium is seen even in the cervix occasionally.

The ovarian-pituitary (endocrine) factors causing menstruation have been discussed, but there may be also a local factor increasing the permeability of the vessel walls to the blood cells. The origin and nature of this factor have not yet been determined. Probably it is also concerned in preventing coagulation of menstrual blood. Frankl thinks that a tryptic enzyme secreted by the endometrial glands is responsible.

A magnified photographic view of the surface of the endometrium is given in Fig. 92. Notice the irregularity of the surface and the openings of the uterine glands. Incidentally, an ovum is just becoming implanted in the thickened endometrium.

In regard to cyclic changes in the cervix, Wollner feels that the epithelium lining the cervix goes through cyclic changes which are influenced by the hormones. The two most evident stages are shown in Figs. 93 and 94, the legends of which explain the characteristics.

Cyclic Motility of the Uterus

Cyclic motility of the uterus is well defined in experimental animals, but in the human there is still considerable uncertainty, in spite of the several methods of investigation. Though the local irritation of the intrauterine balloon method renders its records open to doubt as a typical physiological response, it seems to have established that the amplitude of the uterine contractions was increased by estrone and diminished by progesterone.

Dickinson developed a method of rectal palpation in the human, similar to that used by Hartmann in the monkey, by which he determined the contractility of the uterus. He found that at the time of the menses there are moderate contractions of the uterus. From the fifth day to the ninth of the cycle the uterus is quiescent but firm. Starting with the ninth day, the musculature becomes increasingly active, with a period of maximum contractions at about the fourteenth to the sixteenth day. The uterus contracts and relaxes, and the wave of contraction seems to travel from the tubal ends toward the cervix. As the cycle proceeds to the post-ovulatory stage the uterus again becomes quiescent until two days before the next menstruation. With menstruation there are contractions but these are never of the intensity of those coming at ovulation. His findings are illustrated in his article.

3. **Menopause.**—In a healthy woman menstruation ceases at the age of forty-four to forty-seven. There is considerable variation in this respect, the menses sometimes ceasing three or four years before that age or continuing some time afterward. This period of cessation of menstruation, known popularly as "change of life," is designated technically the "menopause." The two terms "menopause" and "climacteric" were formerly used interchangeably as though synonymous, but they really refer to two distinct though related phenomena. As our fund of knowledge increases and lines of investigation and discussion multiply, there is increasing necessity for exactness in the terms employed in medical study and exposition.

The changes that take place in the uterus during and after the menopause are similar to those occurring in all the genital structures, namely, a gradual atrophy of the functioning parts (endometrium and muscular tissue) and a general fibrous change (Figs. 95 and 96), and a slow diminution in size.

Fig. 93.

Fig. 94.

Fig. 93.—High power photomicrograph of a specimen obtained seven days after the onset of menstruation. The surface epithelium forms a regular line of moderately high columnar cells with oval-shaped nuclei near the basal membrane. The cells have a sharp outline. The stroma is dense, the cells are widely scattered, and reveal little cytoplasm. (Wollner—Surg., Gynec. & Obst.)

Fig. 94.—High power photomicrograph of a specimen taken from the same patient twenty-three days after the beginning of her last menstruation. The regularity of the arrangement, size, and shape of the epithelial cells is lost. The cells are higher and broader than in the previous specimen and they have now an irregular outline. Some of them reveal the discharge of their secretion. The nuclei are larger, spindle shaped and situated near the center of the cell. The stroma is markedly cellular and the cells have more cytoplasm. (Wollner—Surg., Gynec. & Obst.)

Fig. 95.

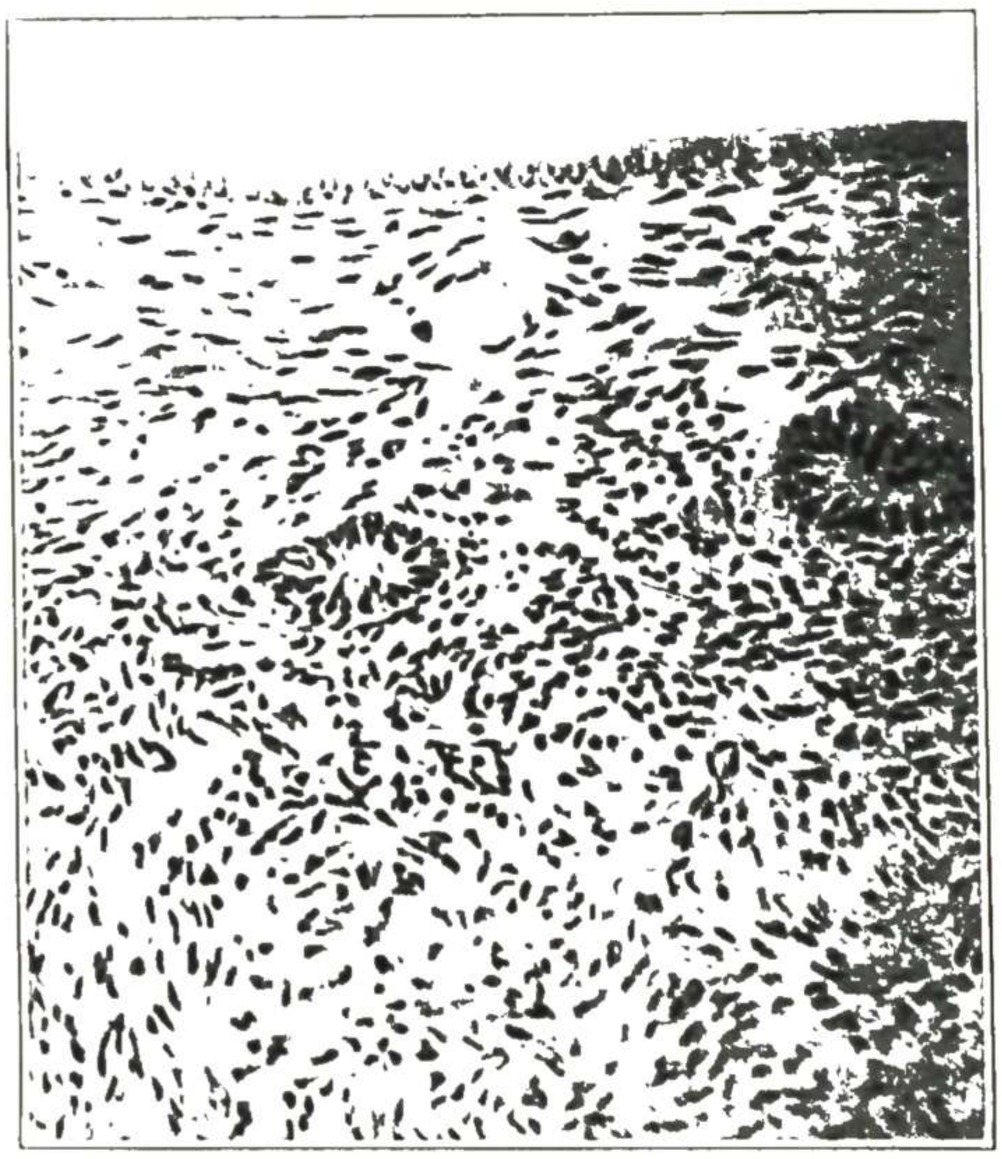


Fig. 96.

Fig. 95.—Senile endometrium, from patient aged sixty-two years, showing marked thinning of endometrium, stroma scant, and glands few. Entire thickness of endometrium only ½ mm.

Fig. 96.—High power of same specimen, showing the atrophic changes in the stroma and glands. Gyn. Lab.

The menses usually cease gradually—that is, the flow may be less free or may continue a shorter time than usual, or the flow may be missed entirely for one or two periods. This partial and irregular absence of the menstrual flow may continue for one or two or three years before it ceases entirely. This gradual diminution of the menstrual flow is natural and there are frequently slight nervous disturbances ("hot flashes," etc.) that can hardly be classed as pathologic. But many of the symptoms that are ordinarily considered as part of the "change of life" are really not so; for example, increased menstrual flow, bloody discharge between the menstrual periods, leucorrhea, pelvic pain. These are due to pathologic conditions. They mean that something is wrong, and they require investigation, that the trouble may be remedied.

This is important especially in the case of vaginal discharge, whether bloody or leucorrheal. It seems to be the general impression among women that irregular bloody discharges are natural during the "change of life." But such discharges are not natural—they usually mean either inflammation or cancer. One of the saddest things in gynecologic work is that a large proportion of the cases of cancer of the uterus are beyond the possibility of a cure when first examined. In such a case it is supposed by the patient and her friends that the slight bloody discharge which at first appears is "natural to the change of life," and so no attention is paid to it. Later, too late, they find that it is due to serious disease, which, because of neglect, has progressed to such an extent that it is beyond cure.

FALLOPIAN TUBES

The fallopian tubes, or oviducts, are two small muscular tubes, one on each side, which extend from the fundus uteri outward in the upper part of the broad ligament toward the pelvic wall (Figs. 51, 66). Each tube has a small central cavity extending its whole length. The inner end of this cavity communicates with the uterine cavity and the outer end opens into the peritoneal cavity. Thus there is a direct opening from the outside of the body into the great peritoneal sac, through the vagina, uterus, and fallopian tubes. This is why infection of the genital tract in a woman leads to peritonitis so much more frequently than infection of the genital tract in a man—the infection in the vagina simply extending along this mucous tract directly into the peritoneal cavity.

The tubes vary considerably in size and somewhat in shape in different individuals. The length of each tube is from three to five inches and the direction is outward, backward, downward, and inward—somewhat resembling a shepherd's crook—and partly surrounding the ovary.

That portion of the tube lying in the uterine wall is known as the **interstitial portion** or uterine portion. It has a very narrow lumen (Fig. 97). That portion of the tube extending from the margin of the uterus to the beginning of the curve is called the **isthmus.** It is about an eighth of an inch in diameter and is firm. The lumen is small, but becomes gradually larger toward the outer end (Fig. 98). The outer, curved, dilated portion of the tube is known as the **ampulla.** It is about the size of a lead pencil and the lumen also is much larger than that of the isthmus (Fig. 99). The outer end of the tube is known as the

fimbriated extremity or the infundibulum. This consists of a funnel-shaped expansion surrounded by a fringe of slender, fingerlike processes called "fimbriae." One of these, which extends to the ovary and is attached there, is called the "ovarian fimbria."

In structure the wall of the tube is largely muscular, resembling the uterus. In fact, it is derived from the same fetal organ as the uterus. The tube lies beneath the peritoneum of the upper margin of the broad ligament, and its wall presents three layers: peritoneal, muscular, and mucous.

The **peritoneal layer** does not differ materially from peritoneum elsewhere. It is composed of flat endothelial cells lying on a basis of firm connective tissue. Immediately beneath the peritoneum is a layer of connective tissue sometimes called the subperitoneal layer. In this run blood vessels and lymphatics. The interstitial portion of the tube has, of course, no peritoneal layer, as the muscular tissue of the tube is in immediate contact with the muscular tissue of the wall of the uterus.

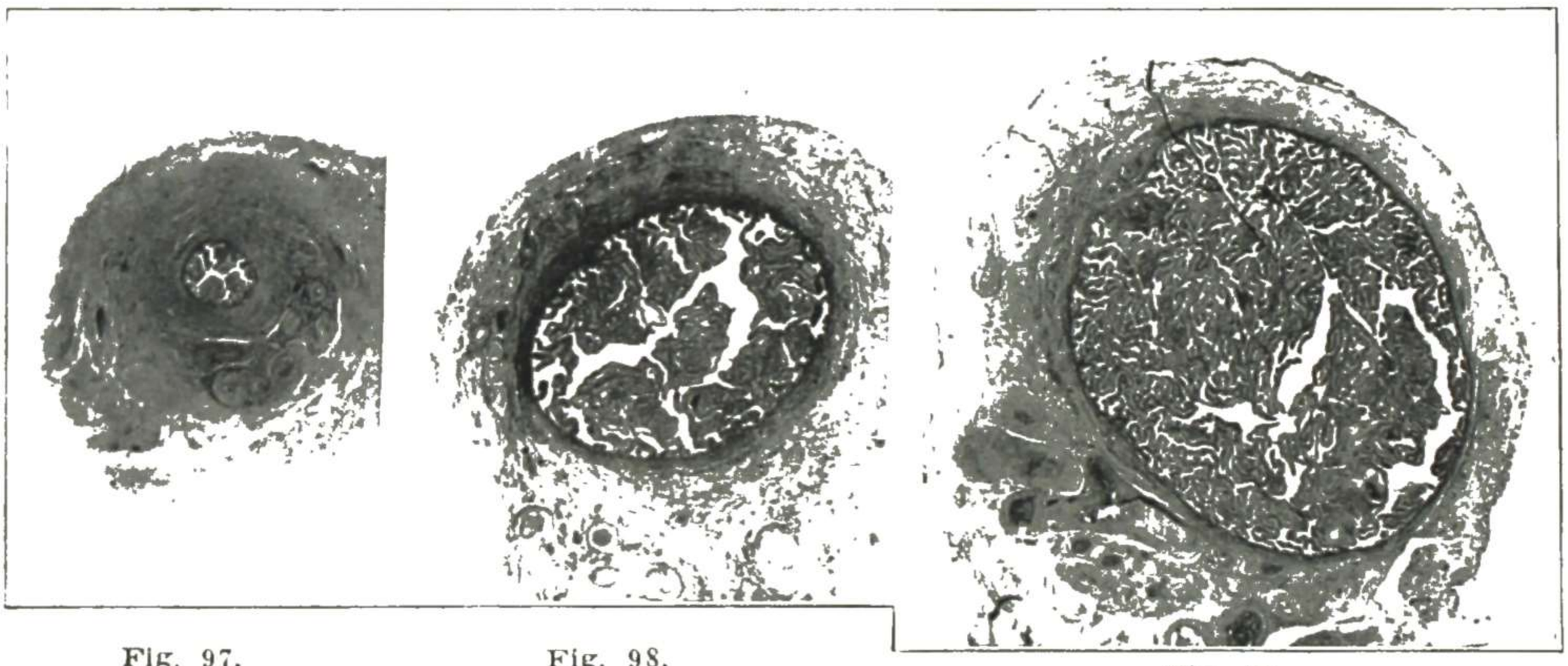


Fig. 97. Fig. 98. Fig. 99.

Figs. 97 to 99.—The lumen of the tube at different portions. Notice the progressive increase in size of the lumen from the uterine end outward. Fig. 97, the uterine end; Fig. 98, the middle; Fig. 99, near the outer end. Gyn. Lab.

The **muscular layer** of the tube is composed of involuntary muscular tissue, disposed in two strata, an outer longitudinal and an inner circular. Both of these strata are continuous, with similar muscular strata in the uterus. The internal stratum sends prolongations of muscular tissue into the four principal folds of the mucosa. The muscular layer is thinner at the abdominal end than at the uterine portion of the tube. The increased thickness of the wall at the abdominal end of the tube is due to the many folds of mucosa.

The **mucous layer** of the tube, like the uterine mucosa, is placed directly upon the muscular layer—there is no intervening submucosa. The tubal epithelium consists of two types of cells: the ciliated or nonsecretory and the nonciliated or secretory. Beneath the epithelial layer the mucosa is composed of "stroma cells," very much like those found in the uterus, except slightly smaller. Between the stroma cells is a delicate connective tissue framework. There are found also capillary blood vessels and small lymph channels.

There are no glands in the tubal mucous membrane. The depressions which look like glands are due simply to the folds of the mucous membrane. As there

are no glands in the tube, there can be no mucous secretion, such as takes place in the uterus. The fluid by which the tube is distended in certain pathologic conditions is inflammatory exudate and not glandular secretion.

The mucous membrane is much folded longitudinally. There are four principal folds into which prolongations of the muscular tissue take place. There is no muscular tissue in the many smaller folds. In the interstitial portion and in the isthmus the folds are few and simply longitudinal, but in the

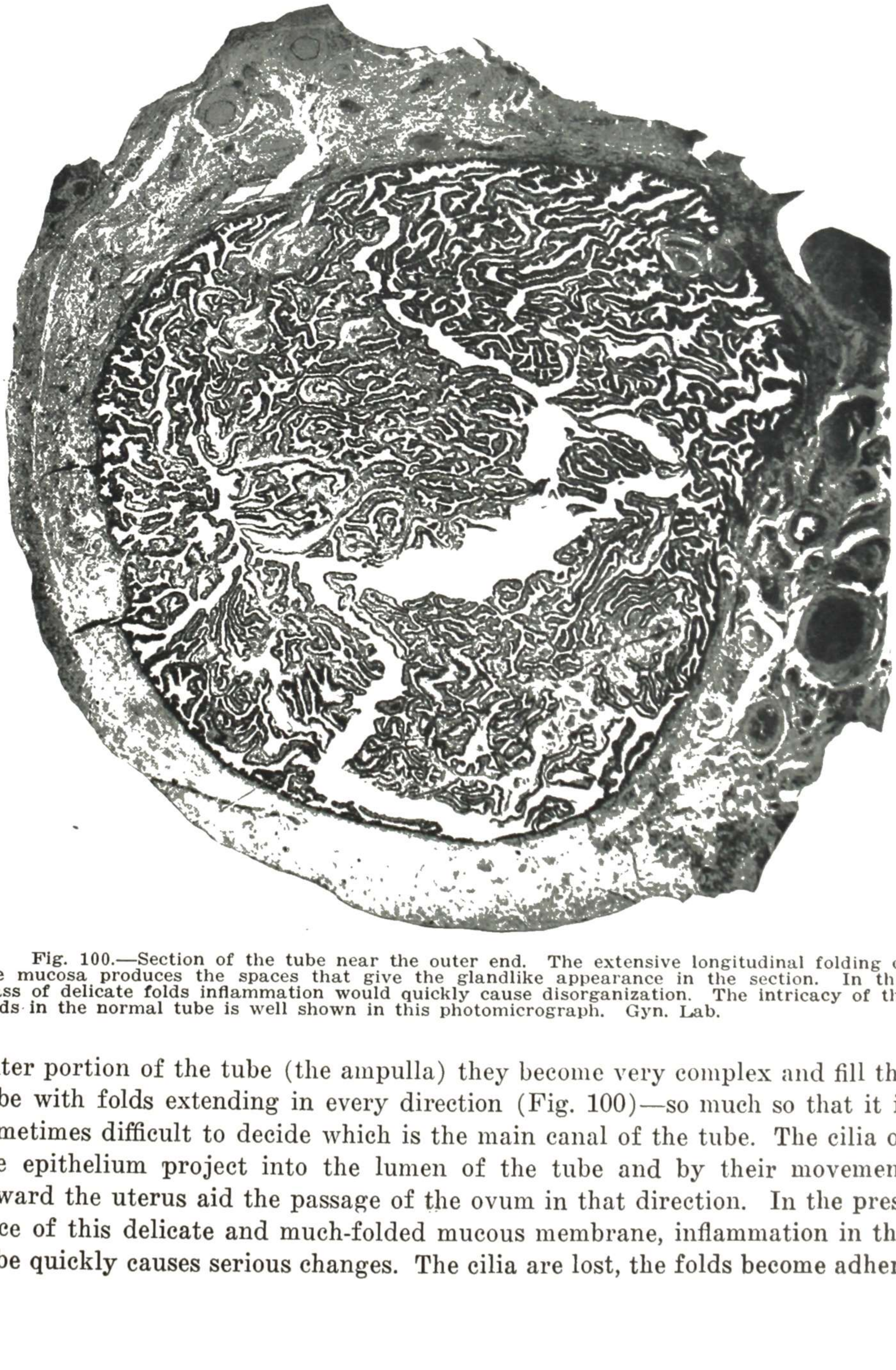


Fig. 100.—Section of the tube near the outer end. The extensive longitudinal folding of the mucosa produces the spaces that give the glandlike appearance in the section. In this mass of delicate folds inflammation would quickly cause disorganization. The intricacy of the folds in the normal tube is well shown in this photomicrograph. Gyn. Lab.

outer portion of the tube (the ampulla) they become very complex and fill the tube with folds extending in every direction (Fig. 100)—so much so that it is sometimes difficult to decide which is the main canal of the tube. The cilia of the epithelium project into the lumen of the tube and by their movement toward the uterus aid the passage of the ovum in that direction. In the presence of this delicate and much-folded mucous membrane, inflammation in the tube quickly causes serious changes. The cilia are lost, the folds become adher-

ent, pockets of serum or pus form, and the picture of the tubal interior may be so changed as to be hardly recognizable.

Vessels and Nerves.—The blood supply of the tube comes from the ovarian artery through several small branches. The uterine artery helps to supply the tube in some cases. The veins open into the pampiniform or ovarian plexus and pass into the broad ligament. The lymphatics join with those from the ovary. The nerve supply comes from the pelvic plexus of each side.

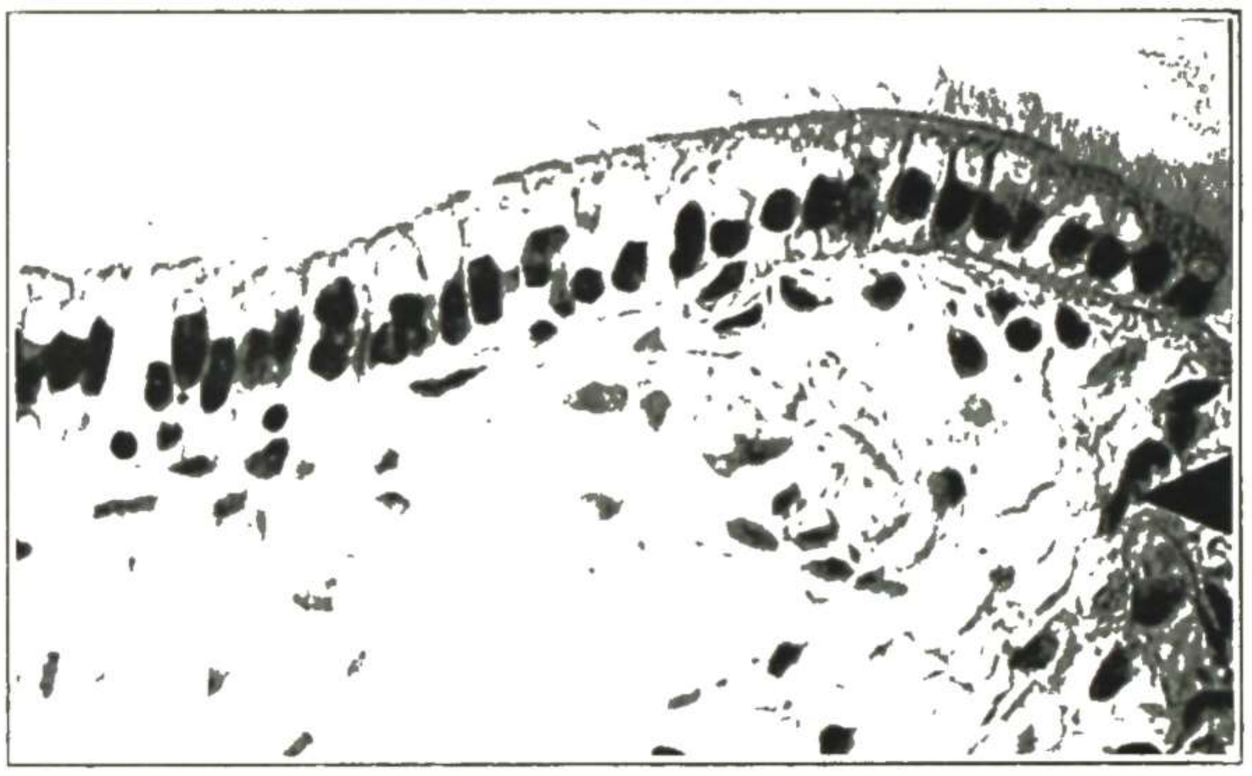


Fig. 101.—Fimbriated end of the tube. Showing the epithelium consisting almost entirely of ciliated columnar cells. (Novak—Am. J. Obst. and Gynec.)

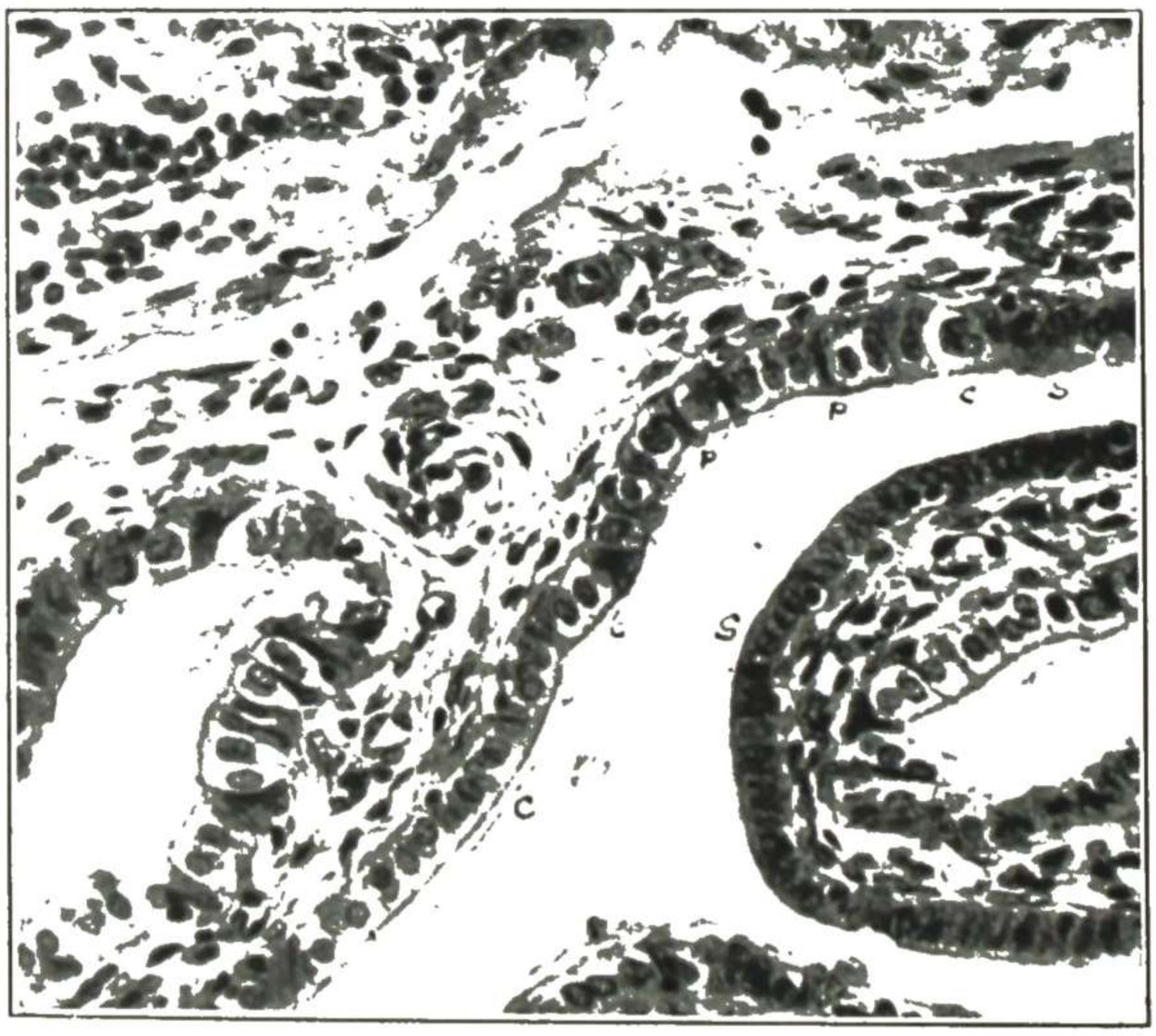


Fig. 102.—Normal postmenstrual tubal epithelium showing ciliated, nonsecretory cells (*C*), nonciliated, secretory cells (*S*), and peg cells (*P*). (Novak—Am. J. Obst. & Gynec.)

PHYSIOLOGY
of the Tubes

The primary function of the fallopian tube of each side is to convey ova from the corresponding ovary to the uterus. It is supposed to require several days for the ovum to pass the length of the tube. In addition to this, the tube conveys spermatozoa in the opposite direction, and it is usually in the tube that the union of the ovum and the spermatozoon takes place.

The mechanism by which the ovum is carried from the ovary into the tube is complicated. After the graafian follicle in the ovary bursts, the liquor folliculi causes the ovum to adhere slightly to the surface of the ovary. Some of the fimbriae are in contact with the surface of the ovary and, when an ovum comes into contact with one of them, the cilia carry it toward the entrance of the tube. The developmental adaptation of epithelium to the particular function it is to perform is well seen in the tubal fimbriae, in which practically

Fig. 103.—Tubal mucosa growth stage. The cells are all about the same height. Secretory cells are seen at *C*, ciliated cells at *B*, and straight rod cells at *A*. Gyn. Lab.

Fig. 104.—Tubal mucosa, premenstrual phase. The marked irregularity in height is clearly seen; the nonciliated secretory cells, seen at *A*, are much higher than the ciliated nonsecretory cells seen at *B*. The three secretory cells clustered together at *A* show partially extruded nuclei with their rounded surface toward the tubal lumen. Gyn. Lab.

all the cells are ciliated (Fig. 101) instead of being of the mixed variety seen in the intratubal mucosa. Besides this action of the cilia directly on the ovum, the constant movement of all the cilia causes a slight current of peritoneal fluid toward the interior of the tube from all directions. This helps to carry the ovum or any other particles into the tube. The fact that there is such a current toward the interior of the tube has been demonstrated in animals by

the injection into the pelvic peritoneal cavity of numerous small insoluble particles, which were found later in the tubes.

Cyclic variations in the intratubal pressure, interpreted as peristaltic contractions, have been shown experimentally in a sow's fallopian tube. These are controlled by estrin and progestin in the blood.

Kymographic records of Rubin tests made on human beings show similar variations, which are interpreted by Rubin as evidence of peristaltic contractions of the tube. We have observed what appeared to be peristalsis under the fluoroscope during a hysterosalpingogram. The rate of contractions varies at different times in the cycle, contractions being most frequent just before and after ovulation and least frequent about the time of menstruation.

Westman studied tubal movements by injecting a drop of lipiodol under the peritoneal sheath of the end of the tube and then tracing its movement by x-ray films and found that the fimbriated end of the tube covers the ovarian surface at the time of ovulation. This is evidently an important factor in aiding the ovum to pass into the tube instead of being lost in the peritoneal cavity.

Normal Changes in the Tubal Epithelium

In studying the physiology of the uterus it was found that this organ, particularly the mucosa, was subjected to normal changes under three conditions: namely, menstruation, pregnancy, and the menopause. Now, in the fallopian tube also, we find normal changes, due to menstruation, to pregnancy, and to the menopause. Speaking generally, it may be said that these changes are like those occurring in the uterus, but less marked.

During **menstruation** there is congestion of the tube and possibly a slight effusion of blood into the interior of the tube. If this does take place, however, it is slight and is of no importance when considering the source of the menstrual blood. Practically all of the menstrual blood comes from the uterus. In a case of removal of the uterus by operation and the fastening of one of the tubes in the vaginal incision, a slight bloody flow was noticed at the menstrual periods for a few months. But such tubes are pathologic, and it is an open question whether or not bloody flow would take place from a normal tube.

The tubal epithelium contains two types of cells: the ciliated or nonsecretory, and the nonciliated or secretory.

The epithelium of the tubes also goes through cyclic changes during the menstrual cycle. The following stages have been described by Novak and Everett:

1. Postmenstrual stage (Fig. 102) in which the epithelium is low at first but rapidly increases in height, so that by the third or fourth day after menstruation it is almost as tall as during the interval. The cells are narrow, closely packed, and, after the first day or so, of uniform height.

2. In the growth phase (Fig. 103) the epithelium is uniformly tall, the ciliated cells being broad, with rounded nuclei near the free margin. The nonciliated cells are narrower and the nuclei are deeply placed.

3. In the premenstrual phase (Fig. 104) the ciliated cells become lower, so that the secretory cells project beyond them, giving the margin a ragged appearance. The secretory cells show a bulbous herniation into the lumen of the tube, often carrying the nucleus with it. Mitoses are rarely seen.

4. During the stage of menstruation the epithelium becomes quite low. The secretory cells, having emptied out into the lumen, are very low, and frequently the nucleus is quite bare of cytoplasm.

Novak, in an instructive article on the different types of genital epithelium and their occasional variability, emphasizes the strategic position of the fallopian tube in this segmental development of the original coelomic epithelium to different functions in the different parts of the tract.

PELVIC PERITONEUM

The pelvic peritoneum is that portion of the wall of the peritoneal sac which lies in the pelvis. It is attached more or less closely to the pelvic organs, and its free surface comes in contact with the peritoneal surface of the intestines as they move about in the lower abdomen. To get an idea of the distribution of the peritoneum in the pelvis, imagine a piece of thin cloth laid over the pelvic organs and tucked down firmly around them (Fig. 64).

Starting from the abdominal wall, the peritoneum passes on to the bladder, and from the posterior surface of the bladder to the uterus. The height of the abdominovesical fold of peritoneum varies much with the varying size of the bladder, which fact is of great importance in surgical work. The distance to which the peritoneum extends down the anterior surface of the uterus varies considerably in different persons. Usually it extends to the level of the internal os and is about an inch above the anterior vaginal fornix. When the bladder is distended, the peritoneum is drawn upward somewhat. This vesico-uterine fold of peritoneum forms the two so-called "vesico-uterine ligaments."

The peritoneum then folds over the uterus and tubes and round ligaments, covering these structures and forming the "broad ligament" of each side. All the posterior surface of the uterus is covered with peritoneum, except that portion lying within the vagina. The fold of peritoneum extends a considerable distance below the point of attachment of the vagina to the uterus (Figs. 2 and 65) before being reflected on to the rectum. The deep pouch of peritoneum thus formed is called the "cul-de-sac of Douglas." It is known also as the "posterior cul-de-sac" and as the "posterior peritoneal pouch" and as the "recto-uterine pouch." This posterior cul-de-sac is very important surgically. A collection of exudate or a tumor in this situation can be easily felt from the posterior vaginal fornix. This is the point of incision in posterior vaginal section.

The peritoneum, as it is reflected from the uterus to the rectum, helps to form the "sacro-uterine ligaments." The sacro-uterine ligaments, two in number, one on each side, extend backward from the lower part of the uterus around the rectum to the sacrum. They are composed of connective tissue, a few muscular fibers, and peritoneum. The cul-de-sac of Douglas dips down between them for a considerable distance (Fig. 64). The expanse of peritoneum extending from the sacroiliac ligament to the broad ligament of each side forms a kind of shelf. The two together are sometimes called the "recto-uterine shelves." There is also a fold or shallow pouch of peritoneum on each side between the fallopian tube and the round ligament. A small portion of the uterus at the sides and in front is not covered with peritoneum (Fig. 65).

The structure of the pelvic peritoneum is much the same as of peritoneum elsewhere. It is a very thin and smooth membrane, formed of a basis of delicate fibrous and elastic tissue, supporting large endothelial cells.

PELVIC CONNECTIVE TISSUE

The strong fascial layers of the musculofibrous sling, or diaphragm, closing the pelvic outlet are shown in Chapter V. This supporting diaphragm is formed by the levator muscles and the fascia above and below, the upper being known as the pelvic fascia and the lower as the obturator fascia, as well as by other names. Between the peritoneum and the well-marked pelvic fascia there is a large amount of loose connective tissue distributed so as to fill the spaces between the organs. This connective tissue is designated as the endopelvic fascia. Where it is necessary for the organs to change their relations to each other in physiologic activity, the connection is open and loose to permit of free movement. The principal collections of connective tissue are at the sides of and in front of the cervix uteri and at the base of each broad ligament. The tissue also runs up the sides of the uterus between the peritoneal layers, as shown in Fig. 105.

The areas of connective tissue are exceedingly rich in lymphatics and veins. Inflammation taking place in this connective tissue is called "pelvic cellulitis." The connective tissue about the uterus is often spoken of as the "parametrium" or parametrial tissue, and inflammation of it is accordingly called "parametritis." In the beginning of gynecologic work it was supposed that nearly all inflammation in the pelvis outside the uterus was inflammation of the connective tissue (i.e., pelvic cellulitis), but it was soon found that in the majority of cases of an inflammatory mass in the pelvis (particularly in gonorrheal inflammation) the process extended from the uterine cavity to the tube and then to the peritoneum. In such cases, if there is connective tissue involvement at all, it is usually a late development and of only secondary importance. There are exceptions to this rule; for example, those inflammatory conditions resulting from tears of the cervix or from operation on the cervix, or from puerperal infection (staphylococcic, streptococcic). In such cases the inflammation extends directly through the wall of the uterus into the pelvic connective tissue.

The connective tissue between the pelvic organs has been the subject of considerable controversy among those who have specially investigated it, the difference being as to whether it normally presents condensations forming distinct fascial sheets between the organs or only loose areolar connective tissue. Evidence pro and con will be found in the articles by Goff, by Curtis, Anson and Beaton, and those by Koster, Hurd, Sears, Hornaday. The matter is not so easy to settle as might appear at first thought. The following factors complicate the problem of deciding what is normal anatomy in this respect: 1. Prolapse cases, on which most operative work involving these tissues is carried out, are not normal but pathological, and the tendency of the prolapse-drag on areas of loose connective tissue would seem to be to produce lines of tension and condensation resulting in the condensed sheets or fascial planes so often found in such cases. 2. As will be seen in the literature mentioned,

careful investigation of normal pelves by microscopic study of cross sections of the urethrovaginal and vesicovaginal and rectovaginal septa failed to show evidence of such sheetlike condensations. 3. In the dissection of loose connective tissue it is difficult to avoid artifacts giving the impression of such sheetlike planes of condensed tissue. Demonstration of microscopic cross sections of undisturbed portions of the septa, along with regular dissections of other portions of the same septa, would assist in arriving at a decision in the matter. 4. The difficulty in securing employment of uniform and clearly understood terms for the different portions of the pelvic connective tissue is aggravated by a secondary meaning attached to the word "fascia."

Fig. 105.—Diagrammatic representation of the connective tissue areas in the pelvis at different levels. Left side of pelvis—section through cervix, showing the large area of connective tissue at side of cervix. Right side of pelvis—section at higher level, showing how the broad ligament becomes thinned, leaving only a small amount of connective tissue at side of corpus uteri.

As ordinarily understood, a fascia or fascial layer is a firm, condensed sheet of connective tissue, in contradistinction to the other kind which is loose areolar connective tissue. In addition to this primary and well-understood meaning of the word, the term is used by anatomists to designate also loose, areolar connective tissue. This secondary use of the term leads to misunderstanding and confusion, as may be seen by perusal of the literature of this controversy, and there seems little chance of a clarification of the matter as long as this term is used to designate two diametrically opposed types of structure. For anatomical knowledge and nomenclature we naturally depend

on the anatomists, who make a lifetime study of the subject. A welcome aid toward uniform and generally understood designations in this matter would be to limit the term fascia to a condensed sheet of connective tissue, and designate loose areolar connective tissue as areolar connective tissue.

VAGINA

The vagina is a musculomembranous canal extending from the vulva to the neck of the uterus, around which it is attached. It lies between the bladder and the rectum as shown in Fig. 2.

Its **size** and **shape** are variable and it is capable of great distention, as is seen when the child passes through it in labor. The length of the vagina is ordinarily three to four inches along its anterior wall, and five to six inches along its posterior wall (Fig. 106). It is constricted at its lower end, where it is partially closed by the hymen, and it becomes dilated toward the uterine extremity.

Fig. 106.

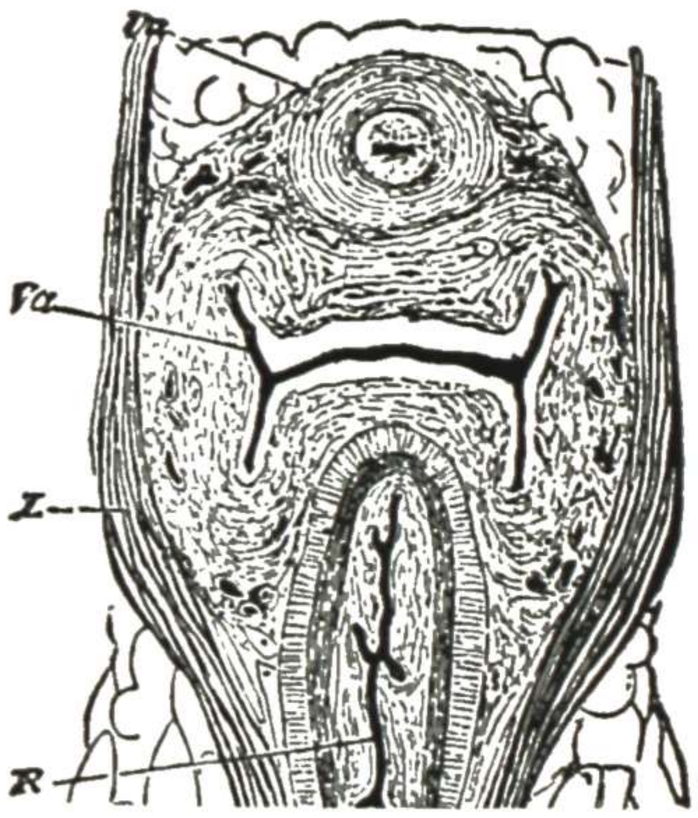


Fig. 107.

Fig. 106.—Longitudinal section of vagina. (Skene—*Diseases of Women*, D. Appleton-Century Company.)

Fig. 107.—Cross-section of the pelvic structures, showing the relations of the urethra, vagina, rectum, and levator ani muscles. Notice how the vaginal walls fold so that the shape of the cavity approximates the letter H. *Ur*, urethra; *Va*, vagina; *R*, rectum; *L*, levator ani muscle. (Savage—*Anatomy of Pelvic Organs.*)

Normally, the anterior and posterior vaginal walls lie in contact, and on cross-section the **cavity** is represented by a slit having somewhat the shape of the letter H (Fig. 107). The wide diameter of the vagina, some distance up the canal, is the transverse diameter, but the wide diameter of the vulvar cleft is the anteroposterior diameter. Furthermore, the anterior end of the vagina lies so far up in the narrow part of the pubic arch (in patients where the perineum has not been damaged) that there is not much room laterally. Consequently, in introducing the speculum, the preferable way is to introduce one finger into the vaginal opening and press the perineum well back, so that the vaginal opening is stretched anteroposteriorly and made to correspond in a measure with the vulvar cleft, and then introduce the speculum obliquely as shown in Chapter II. When the speculum is well past the entrance, so that it may be used to depress the perineum, it is then turned with its width in the transverse diameter of the vaginal canal and introduced all the way.

Relations.—Fig. 106 shows the angle which the axis of the uterus normally bears to the axis of the vagina. The upper end of the vagina surrounds the lower end of the uterus. That portion of the cervix uteri projecting into the vagina is known as the vaginal portion (portio vaginalis). The attachment of the

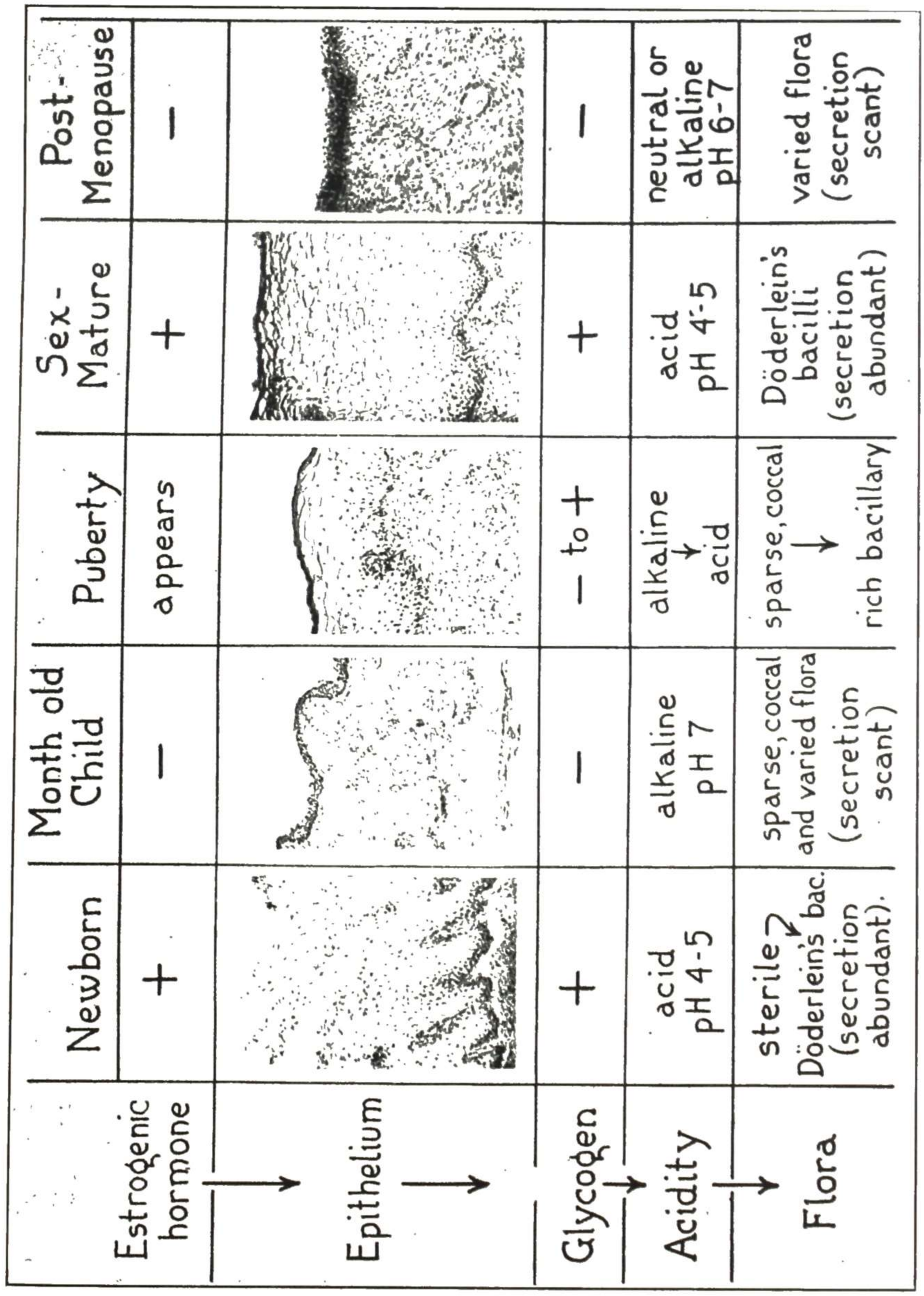


Fig. 108.—The changes in the vaginal epithelial covering at different ages, showing the dominant role of estrogen in the control of the biology of the vagina and of the character of its mucosa. (Davis and Pearl—Am. J. Obst. & Gynec.)

vagina extends higher on the posterior wall of the cervix than on the anterior. The vaginal mucosa is continued on the cervix as far as the external os.

The upper end of the vagina is termed the "vaginal vault." The term "fornix" is also much used, the anterior fornix being that portion of the vault in front of the cervix, and the posterior fornix being that portion lying

behind the cervix, and the right and left lateral fornices lying to the right and left respectively. With the uterus in normal position, the posterior fornix is much deeper than the anterior, for the vaginal wall is attached higher on the posterior surface of the cervix than on the anterior.

The vagina is surrounded by important structures. The anterior wall is in contact with the urethra and the base of the bladder. The vaginal wall and bladder wall and the tissue lying between them constitute the vesicovaginal septum. The posterior wall for the lower three-fourths of its extent is attached to the anterior wall of the rectum, except for the very lowest portion, which is separated from the rectal wall by the perineum. The vaginal and rectal walls and the tissue lying between them constitute the rectovaginal septum. The upper fourth of the posterior wall is separated from the rectum by the recto-uterine pouch of peritoneum, known as the "cul-de-sac of Douglas." The sides of the vagina give attachment to fibers from the levator ani muscles and the rectovesical fascia.

The wall of the vagina presents three layers: an external connective tissue layer, a middle muscular layer, and an inner mucous layer.

The CONNECTIVE TISSUE layer serves to attach the vagina to the adjacent organs. It contains the external plexus of veins, and is composed of connective tissue filled with lymphatics and blood vessels, the veins being especially numerous The attachment of the vagina anteriorly is firm in the lower third where it is attached to the urethra. It is more loosely attached to the bladder in the middle and upper third, particularly the latter, and is easily separated in operating.

The MUSCULAR LAYER contains involuntary muscle fibers arranged in bundles without distinct strata. Some of the bundles are longitudinal, some transverse, and some oblique. The muscular layer is thicker at the lower than at the upper end.

The MUCOUS LAYER, or lining of the vagina, presents on the surface a thick squamous epithelium of many layers (Fig. 108), with the usual basal layer just above the connective tissue. The vagina normally contains no glands. The secretion found in the vagina comes from the cervix and the endometrium, principally the former. The vaginal walls are kept constantly moist with the secretion, and consequently the epithelium desquamates before it advances so far in the process of cornification as is seen in integument. In cases of prolapse, where the vagina is turned outside the vulva and is subjected to friction of the clothing and is kept dry by contact with them, it becomes more like ordinary epidermis and shows well-marked keratin changes. The mucosa (epithelium and connective tissue immediately under it) is attached to the muscular coat by a submucous layer of loose connective tissue which is very rich in interlacing veins, about some of which are bundles of muscular fibers, forming a kind of cavernous tissue.

The vaginal mucosa is thrown into numerous large folds called "rugae." Extending longitudinally along both the anterior and the posterior wall of the vagina is a prominent ridge, best marked in the virgin. These ridges are known as the "columns" of the vagina, and from them the rugae extend laterally. The columns and rugae becomes more or less obliterated by childbirth, so that in many multiparae the vagina walls are almost smooth.

Vessels and Nerves.—The blood supply of the vagina comes from the anterior trunk of the internal iliac, through the vaginal, uterine, middle hemorrhoidal, and internal pubic arteries. These anastomose freely in the vaginal wall. The veins of the vagina are arranged principally in two plexuses that form complete sheaths around the canal. One plexus is external to the muscular layer, while the other lies just beneath the mucosa. These veins form an intricate network and communicate freely with the plexus of the other organs and with the plexus of the broad ligament.

The lymphatics from the lower third of the vagina, it is generally held, join those from the external genitals and empty into the inguinal glands. But Poirer, who has made a special study of the subject, claims that all the lymphatics of the vagina empty into the pelvic glands and that when an injection of the vaginal lymphatics is made, even just within the hymen, no injection material passes to the inguinal glands except through some anastomosing channels. The lymphatics from the middle third of the vagina empty into the hypogastric glands. Those from the upper third join with the lymphatics of the cervix uteri and pass to the iliac glands.

The NERVE SUPPLY of the vagina comes from the pelvic plexus of each side.

PHYSIOLOGIC CHANGES
in the Vagina

Studies in the cyclic changes of the vaginal epithelium in the human being and in the monkey point to the fact that these changes are under the control of the ovarian hormones.

Dierks, from a study of vaginal biopsies in women at various times in the menstrual cycle, concluded that the relationship of the three epithelial layers of the vaginal epithelium varied at different times in the period. The vaginal epithelium is composed of three layers: a basal layer, a functional layer, and a cornification or intra-epithelial layer.

Immediately after menstruation there is an increase in the functional layer and a marked proliferation of the basal layer so that this latter becomes many layers thick. Numerous mitoses can be seen in the basal layer. Near the middle of the cycle or about the time of ovulation a layer of new cells is formed between the basal layer and the functional layer. This layer was described by Dierks as the intra-epithelial cornified zone. The cells in this layer contain granules and the nuclei are small and dark staining. With the onset of the menses the functional and the intra-epithelial layers are destroyed and cast off, leaving the basalis layer completely denuded at the end of menstruation. There are some dissenting views as to the presence of this cycle, but this work has been confirmed by Keller, Pankow, Geist, and Papanicolaou. Papanicolaou has followed the cyclic changes by the vaginal smear technique in twelve women and feels that he can tell the time of ovulation and diagnose early pregnancy with a fair degree of accuracy. When enough work has been done to correlate and standardize the findings, this may prove to be a very valuable aid in diagnosis.

In young girls before puberty the vaginal epithelium consists of an inactive basal layer three or four cells deep. There is no glycogen in these cells during

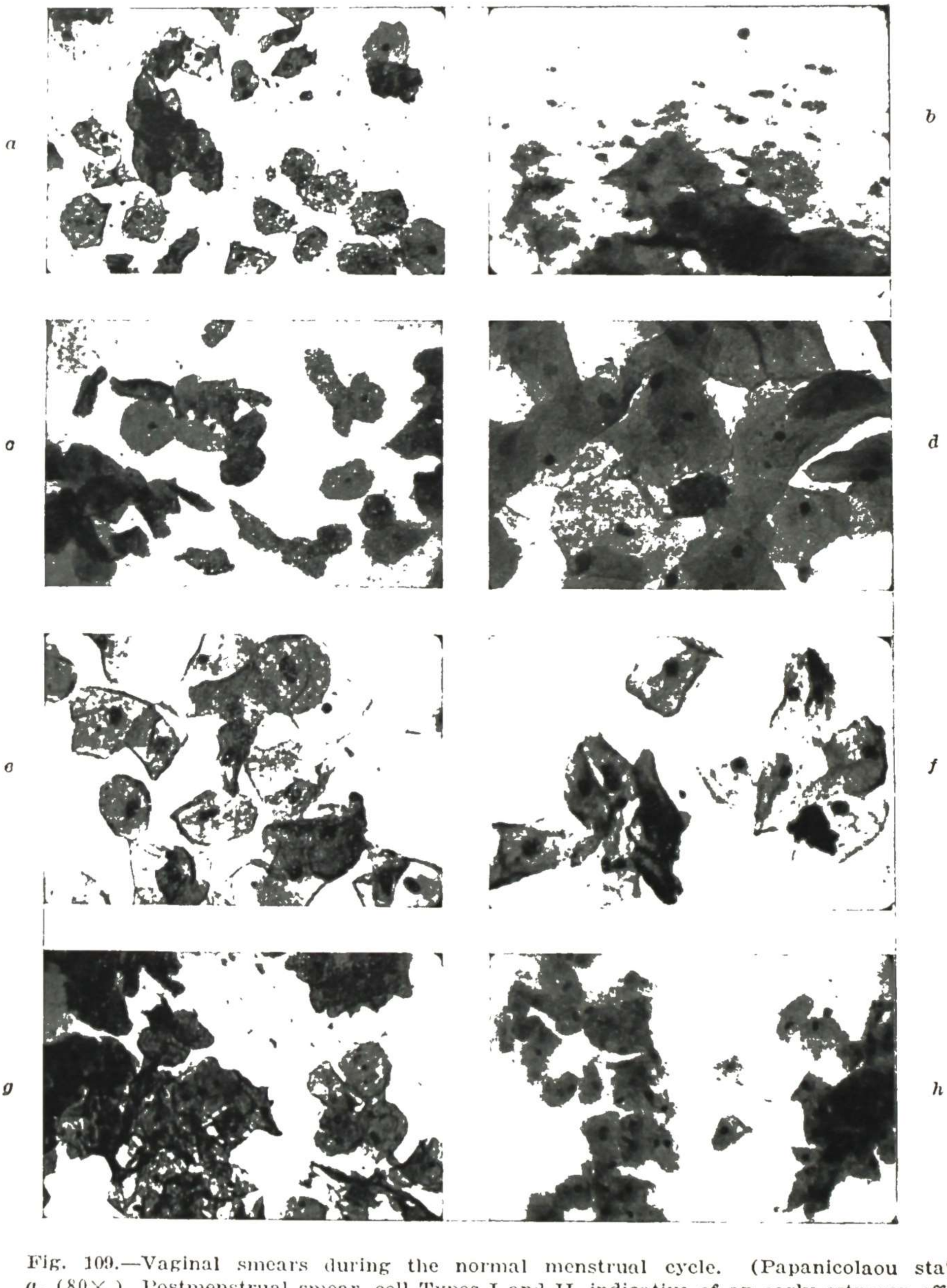


Fig. 109.—Vaginal smears during the normal menstrual cycle. (Papanicolaou stain.)

a, (80×.) Postmenstrual smear, cell Types I and II, indicative of an early estrogen effect. *b*, (160×.) Postmenstrual smear, cell Types II and III, with an occasional Type I. Note presence of leucocytes in mucous strands. This smear indicates some increasing estrogen effect. *c*, (80×.) Preovulative smear, cell Types II, III, and IV, indicative of a high level of estrogen. *d*, (160×.) Ovulative smear. Cell Types III and IV indicate nearly maximal estrogen effect on vaginal mucosa. *e*, (160×.) Postovulative smear. Cell Types III, IV as above, and Type V, indicate minimal progesterone action—the typical folding and curling of the cell edges. *f*, (160×.) Smear of luteal phase. Cell Types V and VI indicate prolonged progesterone action. The folding and curling are present even in these less cornified cells from deeper vaginal layers. *g*, (80×.) Same as above. Note the extensive desquamation and aggregation indicating the action of both estrogen and progesterone on the vaginal mucosa. Note also that leucocytes are present. *h*, (80×.) Premenstrual smear. Cell Types V, VI, VII and I. The presence of Type VII, cell debris is typical of the premenstrual phase; the smear is "dirty," the cell and nuclear outlines are indistinct although nuclear size and granularity of cytoplasm indicate that these cells are frequently from deep layers of the vaginal mucosa. (Rubenstein—*Endocrinology.*)

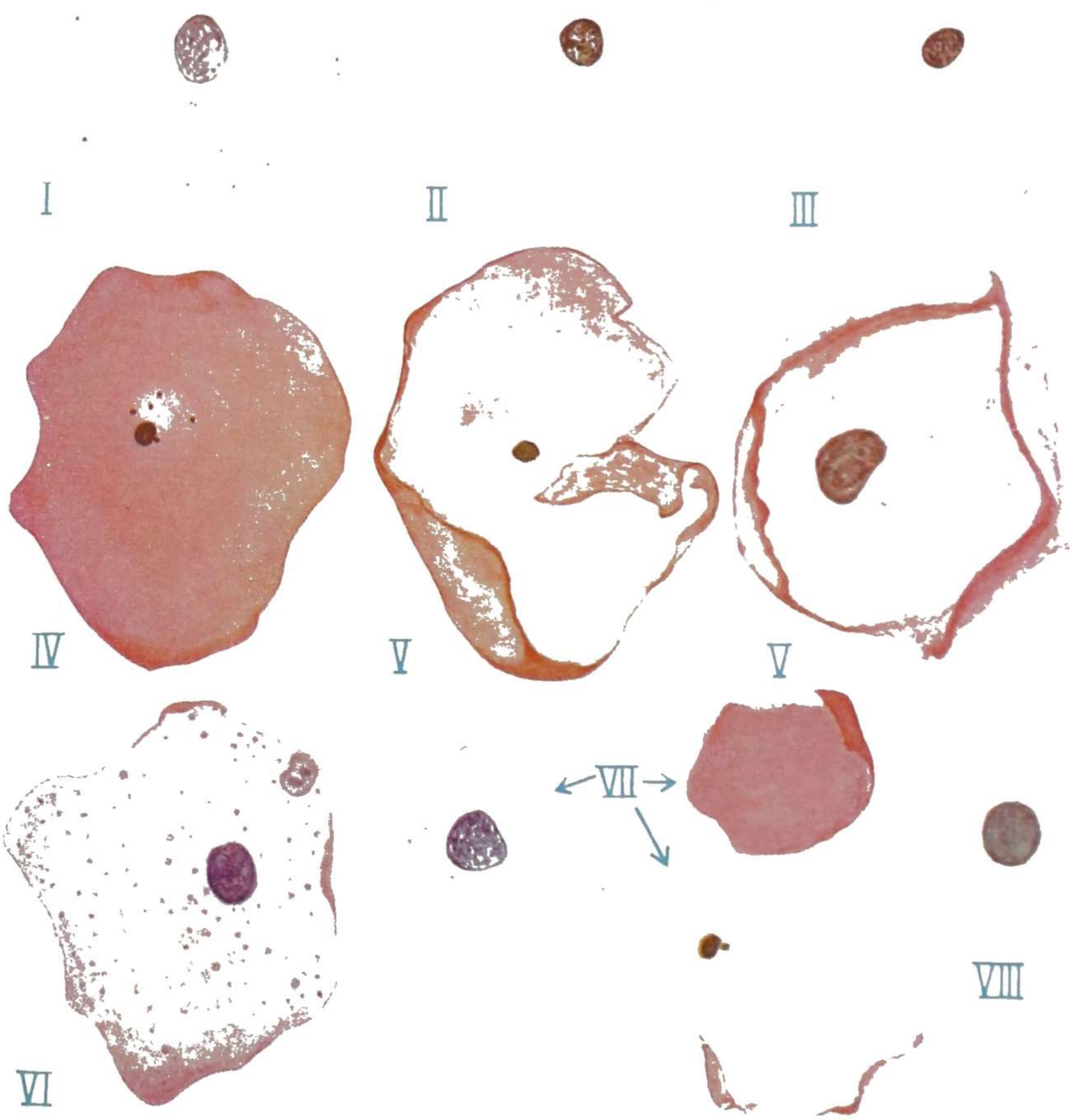


FIG. 110.—TYPES OF VAGINAL EPITHELIAL CELLS FOUND IN VAGINAL SMEARS.

These represent only types described in the classification. Intermediate types are also always present but should easily be recognized as such.

On the opposite page, the significance of these cell types in regard to estrogen effect and also in relation to the stages of the ovulation cycle, is illustrated by vaginal smears and described in the legends. (Rubenstein—*Endocrinology*.)

this period. With the onset of puberty the three layers are promptly established, and glycogen appears in the cells. After the menopause the vaginal epithelium returns to the prepuberty state with no glycogen in the cells and a basal layer of only two or three layers. In the newborn child some of the maternal estrin is still present and, as would be expected, glycogen is found in the vaginal epithelial cells for three or four weeks after birth. The mature epithelium can be produced in the prepuberty girls by theelin administration.

The variations in the mucosa of the vagina at different ages were studied by Davis and Pearl, and Fig. 108, presenting these changes from birth to old age, is from their article. These changes in the vaginal epithelium are presented in detail by Rubenstein, as shown in Figs. 109 and 110.

Cruickshank and Sharman found that the appearance of the Doederlein's bacillus and an acid vaginal secretion were coincident in time with the presence of glycogen in the vaginal epithelium, and they believe that the production of the acid reaction is a defense mechanism against harmful bacteria. Early in pregnancy this reaction is absent, but it develops in the later months.

Davis and Hartman summarize the similar changes found in the monkey as follows:

"The cyclic changes in the vaginal epithelium were studied in a large group of female monkeys at the Carnegie Monkey Colony by means of frequent biopsies. These rhythmic changes were coordinated with ovarian activity and ovulation.

"We found that the epithelium attains its greatest thickness in the mid-interval, consisting at this time of an active basal layer, an inactive functional layer, and an intra-epithelial zone of cornification interposed between these two, which we call Dierks' layer. Following ovulation, desquamation begins and proceeds by a crumbling away of the functionalis, which is usually not completely destroyed. Mitosis begins in the basalis on the first day of menstruation, becoming most marked near the time of ovulation, and then gradually subsides.

"A cessation of ovarian activity, such as is seen at the menopause, or an abnormal ovarian activity, definitely alters these physiologic changes.

"Early in pregnancy the epithelium remains in the same state as is seen during ovulation, consisting of the typical three layers.

"Desquamation of the functional layer continues throughout pregnancy but is increased progressively following the middle of pregnancy.

"At the end of pregnancy only the basalis remains and is of irregular thickness, in many places of only three or four cells."

The vaginal epithelium in the human being undergoes changes similar to those described by Davis and Hartman in the monkey. Recently these changes were described in detail by Rubenstein, and the colored illustration showing types of cells (Fig. 110) and also Fig. 109 are from his article.

Estrogen stimulates proliferation of the vaginal epithelium so that it becomes many layers thick, and as the thickness increases the superficial cells are pushed farther and farther from their blood supply and hence they degenerate and become cornified. At various stages of this process typical cells appear in the vaginal smears, as described in the legends of the above-mentioned illustrations.

EXTERNAL GENITALS

The external genitals (Figs. 111 to 115), called also the vulva and the pudenda, include the following structures:

Mons Veneris
Labia Majora
Labia Minora
Clitoris
Vestibule
Vulvovaginal Glands
Hymen

The **mons veneris** is simply a pad of subcutaneous fat lying over the symphysis pubis. The triangular area which it forms is covered with hair

Fig. 111.

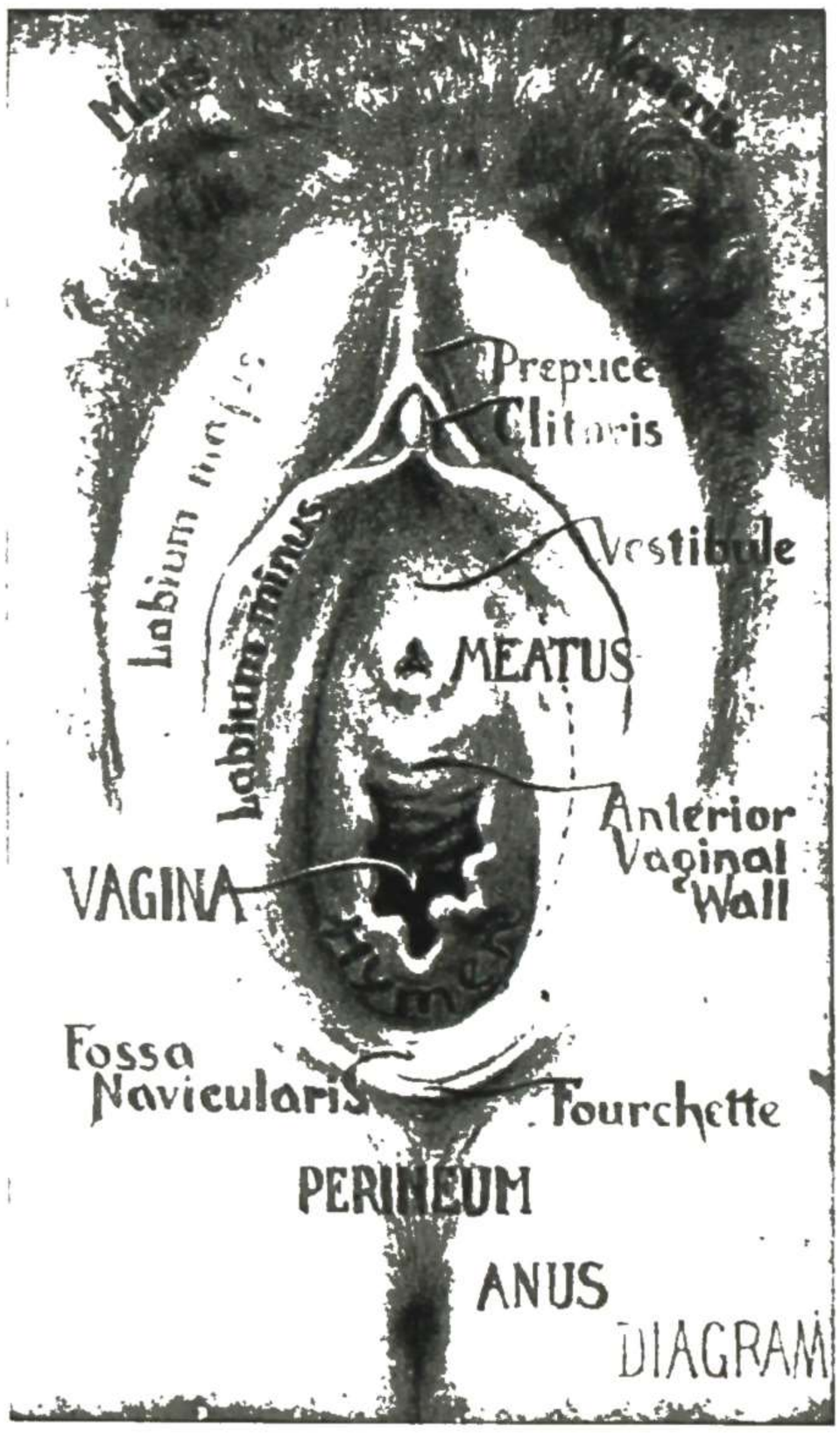


Fig. 112.

Fig. 111.—External genitals of a virgin. Photograph from a cadaver. (Dickinson—*American Textbook of Obstetrics.*)

Fig. 112.—Diagrammatic representation of the external genitals of a virgin. (Dickinson—*American Textbook of Obstetrics.*)

after puberty. The upper margin is the base of the triangle and is often marked by a slight transverse crease due to bending of the abdominal wall in exercise. The sides are formed by the inguinal creases, which run downward and inward toward the pubes, making the lower pointed portion of the triangle, which is continuous with the labia majora. Examination of a microscopic section through this region shows the usual characteristics of skin, i.e., many layers of squamous epithelial cells (the deepest being cubical and the most superficial being flattened and horny) placed on loose connective tissue, and presenting hairs, sebaceous glands, and sweat glands. A little deeper there is much fat,

which is penetrated and held together by fibrous septa that divide it into lobules. There are also many elastic fibers.

The **labia majora** (Fig. 113) are two cutaneous folds which extend, one on each side, around the vaginal opening. They are apparently continuations of the mons veneris and, passing backward, end by joining the perineum. The external surface of each labium majus presents the ordinary characteristics of integument. Each labium is limited externally by the genitocrural folds and corresponds to that side of the scrotum in the male. The round ligament, coming through the inguinal canal of each side, terminates in the upper part of the labium majus of that side. Sometimes a distinct canal remains open for some

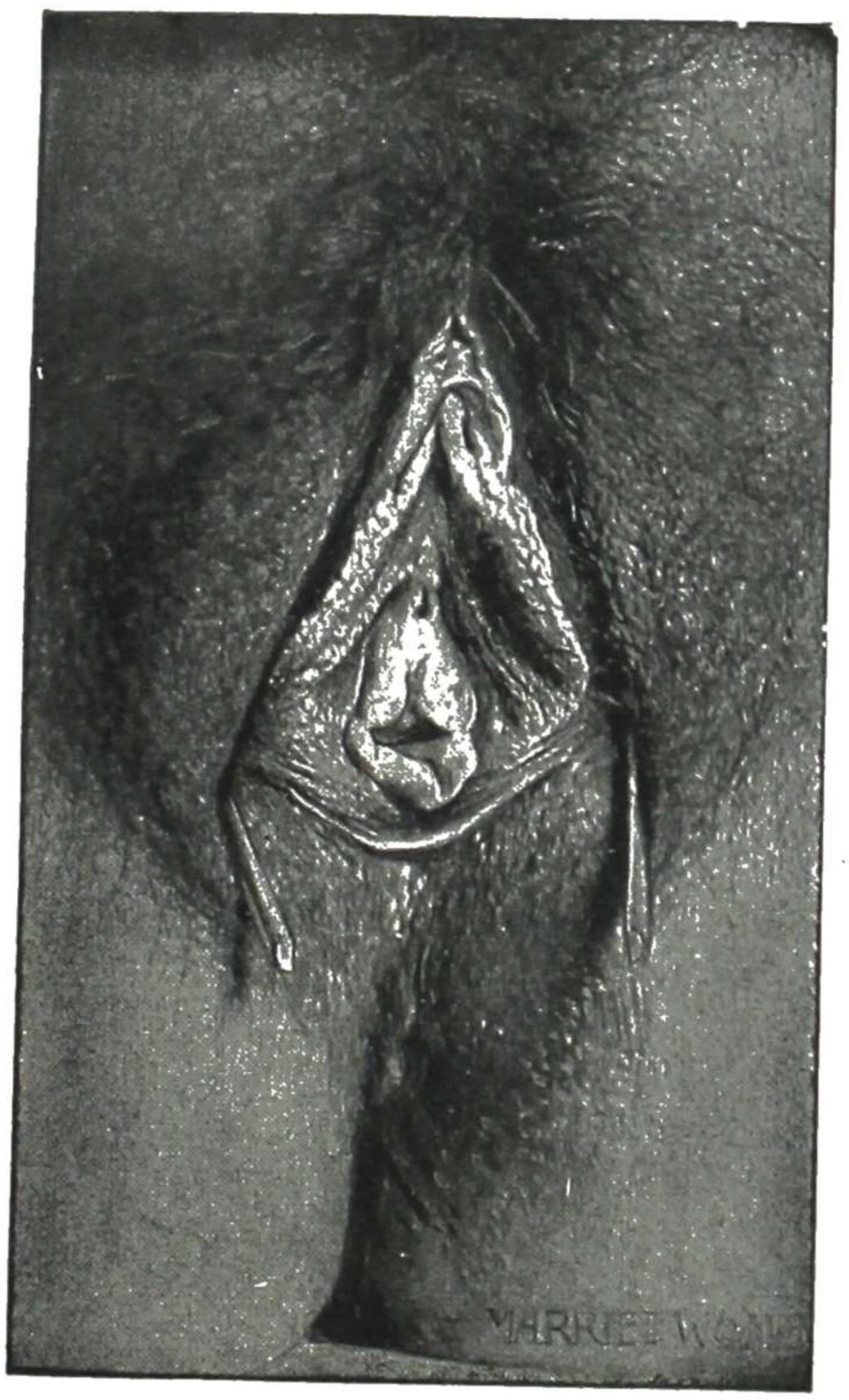


Fig. 113.

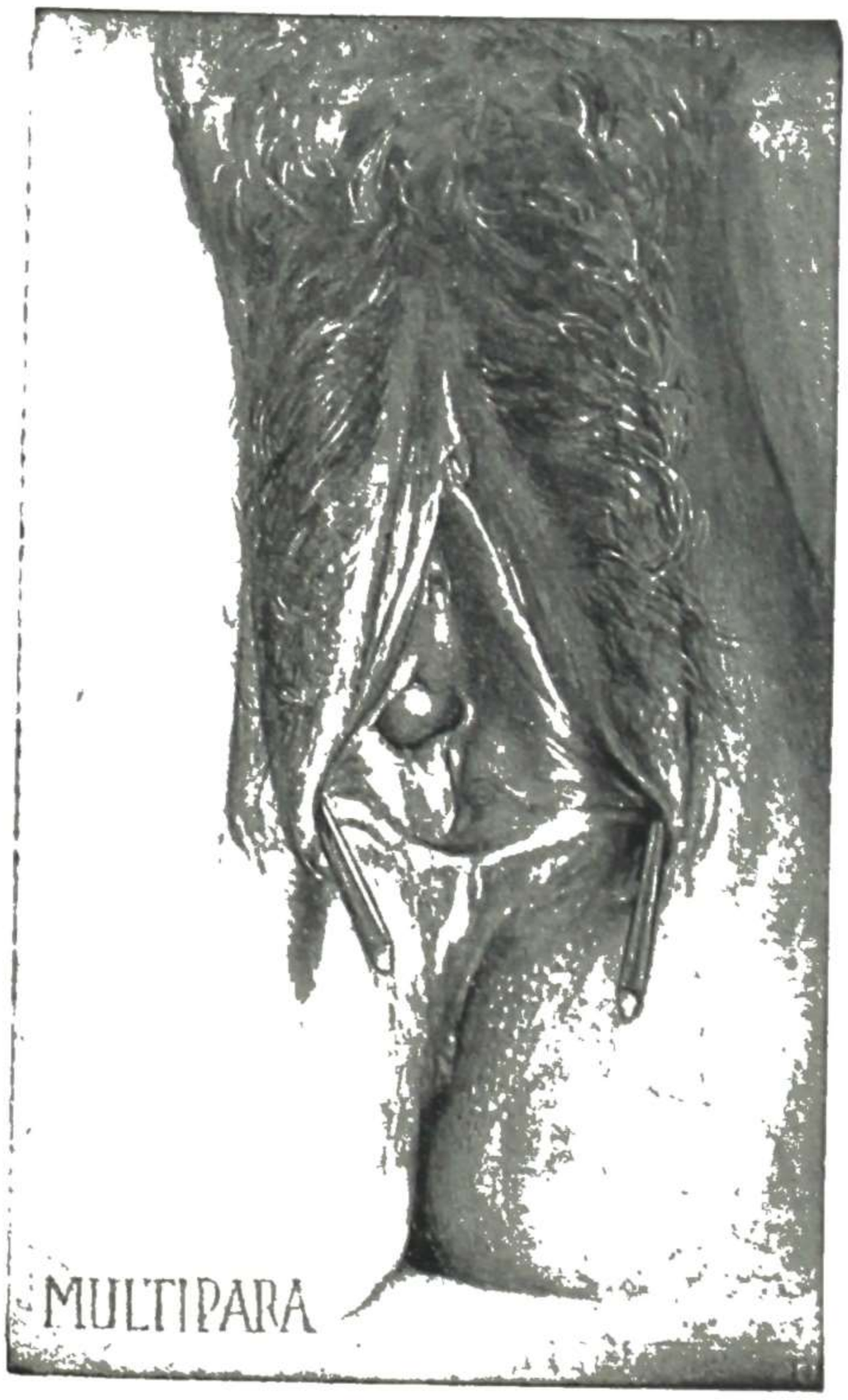


Fig. 114.

Fig. 113.—External genitals of a married woman. (Dickinson—*American Textbook of Obstetrics.*)

Fig. 114.—External genitals of a multipara, with slight perineal laceration. (Dickinson—*American Textbook of Obstetrics.*)

distance along the round ligament. This is known as the canal of Nuck, and through it a hernia may take place into the labium, constituting a labial hernia. This is known also as a pudendal hernia. The hernial contents may be intestine or omentum or ovary or even the uterus. Occasionally the canal of Nuck is shut off from the peritoneal cavity, and the sac thus formed fills with fluid, giving rise to pudendal hydrocele or "hydrocele of the canal of Nuck." The inner surface of each labium majus is smooth and of a pinkish color. It has largely lost one of the characteristics of integument—the hairs—only a few fine hairs being found here.

In children the labia majora are very small and the labia minora project between them. As puberty is approached the external labia become larger and meet in the median line. At puberty they, in common with the mons veneris, become covered with hair. A little later in life, particularly in married women, the labia minora become enlarged so much that they project forward, separating the labia majora. In old age the labia undergo marked diminution in size and prominence, the shrinking being due largely to absorption of the fat.

Microscopic examination of a section of a labium majus shows the same structures found in the mons veneris, the only difference being that on the inner surface of the labium there are only a few hairs, and they are small. There are, however, many sebaceous glands. There are also, of course, the arteries, veins, and other structures found in cutaneous and subcutaneous tissues. The connective tissue is rich in elastic fibers, and still deeper there is the thick deposit of fat that gives the labium its prominence. The veins are numerous and large, and become much distended when there is intrapelvic pressure, as in pregnancy or from a tumor. Under such circumstances, a wound of the labium may lead to serious and even fatal hemorrhage.

The **labia minora** (Fig. 113), or nymphae, are two delicate mucocutaneous folds lying between the labia majora, one on each side of the vaginal opening. Each labium minus apparently grows from, or is a secondary fold of, the upper and inner portion of the labium majus of that side. In stout women the nymphae are normally concealed by the labia majora. Ordinarily, particularly in married women, they project slightly. Frequently they are somewhat enlarged and project half an inch or more. The enlargement is usually not exactly symmetrical, and in some cases it is confined to one labium. In a valuable article on these enlargements of the labia minora, Dickinson upholds the idea that whenever the enlargement is marked, it is proof of excessive irritation of the labium. It is stated that among the Hottentots, owing to certain treatment practiced in childhood, the labia minora often become excessively developed and hang like a thick apron between the thighs. The labia minora begin just below the anterior junction of the labia majora as double folds which pass above and below the clitoris. The folds that join above the clitoris form the prepuce of the same. The labium minus of each side then descends along the inner side of the labium majus and blends with labium majus about the junction of the middle and lower third. The posterior extremities of the labia minora are united by a delicate fold which extends between them just within the posterior margin of the vulvar orifice, forming the fourchette. When the labia are separated, the fourchette is made tense, and between it and the hymen is a small depression called, from its boatlike shape, the "fossa navicularis." This delicate fourchette is, except in rare cases, torn at childbirth, and in some cases is obliterated even by sexual intercourse. It is best seen in the virgin.

There has been dispute as to whether the inner surfaces of the labia minora are covered by integument or mucous membrane. The covering presents some of the characteristics of each. It is a transitional form of covering and represents one step in the several changes which take place from the labia majora to the external surface of the cervix. The outer surfaces of the labia majora are ordinary integument. On the inner surfaces of the same structures, the

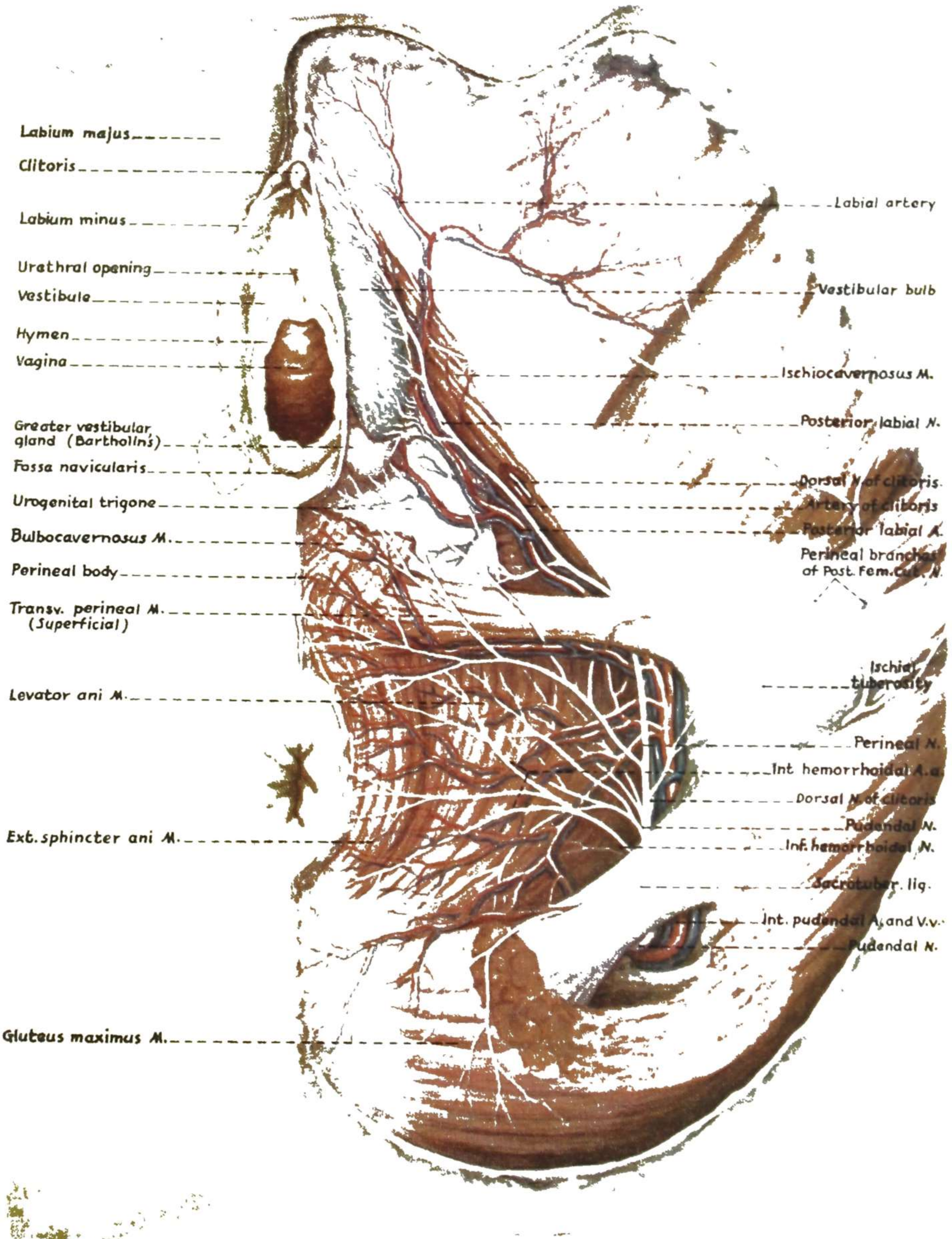


FIG. 115.—THE EXTERNAL GENITALS, WITH BLOOD SUPPLY AND NERVE SUPPLY. (Modified from Savage, Spalteholz, Sobotta.)

hairs are much reduced in size and number. On the labia minora, the hairs are absent, though the sebaceous glands are still present. On the vestibule, only a few glands remain, and the thinning of the epithelium is more marked. In the vagina, all glands disappear (it being now generally held that there are no glands in the normal vagina) and the epithelium becomes thinner and the papillae less marked. Over the vaginal portion of the cervix the papillae have almost disappeared. So there is a gradual transition from ordinary integument, with a thick epithelial layer, hairs, sebaceous glands, sweat glands, and marked papillae, to a thin epithelial layer without hairs or glands and almost without papillae. When the vaginal wall is turned out for a long time, as in

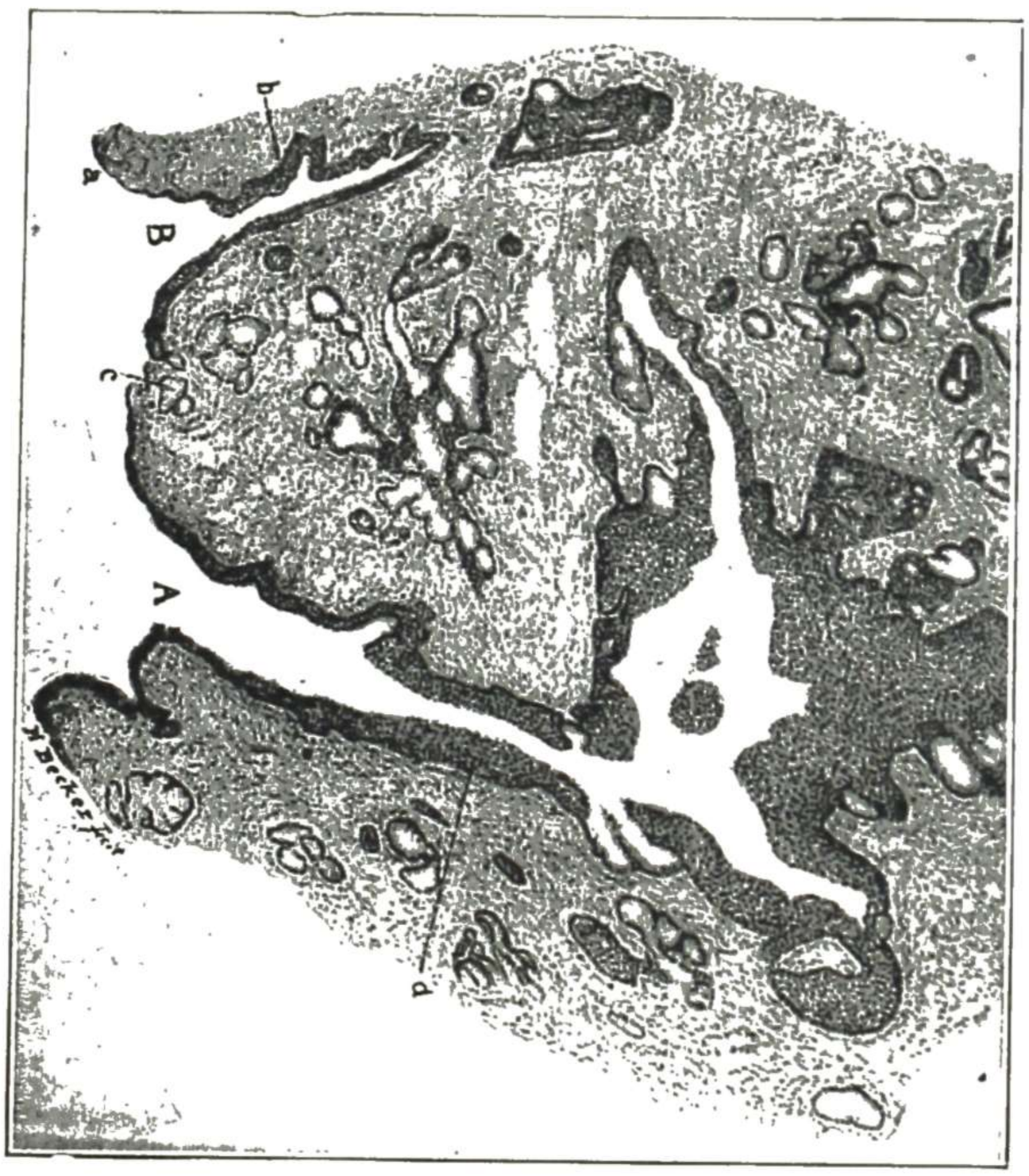


Fig. 116.

Fig. 117.

Fig. 116.—Section of vulvovaginal gland showing duct and gland acini. Low power. (Cullen—*J. A. M. A.*)

Fig. 117.—Section of vulvovaginal gland showing acini and lining cells. High power. Gyn. Lab.

prolapse, and exposed to friction by the clothing, the epithelial layer becomes much thickened, and if the surface is kept dry, it becomes horny like the external integument.

The labia minora have many small folds, giving a very uneven surface. Examination of a section of a labium minus shows numerous epithelial depressions, owing to the much folded surface. The bands and nests of epithelial cells seen in such a section are simply oblique cuts of normal folds and ingrowths. The labia minora are very rich in blood vessels, especially veins, so much so that the structure partakes of the nature of erectile tissue. They are also rich in lymphatics and nerves.

The **clitoris** is the analogue of the penis in the male, and is situated just below the anterior junction of the labia majora. It is a small erectile organ richly supplied with blood and nerves, and is attached to the sides of the pubic arch by its crura. In both the clitoris and the labia minora there are special nerve endings. Examination of a section of the clitoris shows the erectile nature of the structure. During sexual excitement the clitoris fills with blood and becomes swollen and firmer. It is supposed to be the most sensitive of all the genital organs to sexual contact, and on this account excision of the clitoris (clitoridectomy) was proposed and carried out for the relief of disturbances depending on sexual hyperesthesia, but the results were not such as to recommend the operation, and it is now rarely practiced.

The **vestibule** is an elliptical area situated between the labia minora. The sides are formed by the labia minora, the anterior end extends to the clitoris, and the posterior end is formed by the junction of the labia majora. Into this

Fig. 118.

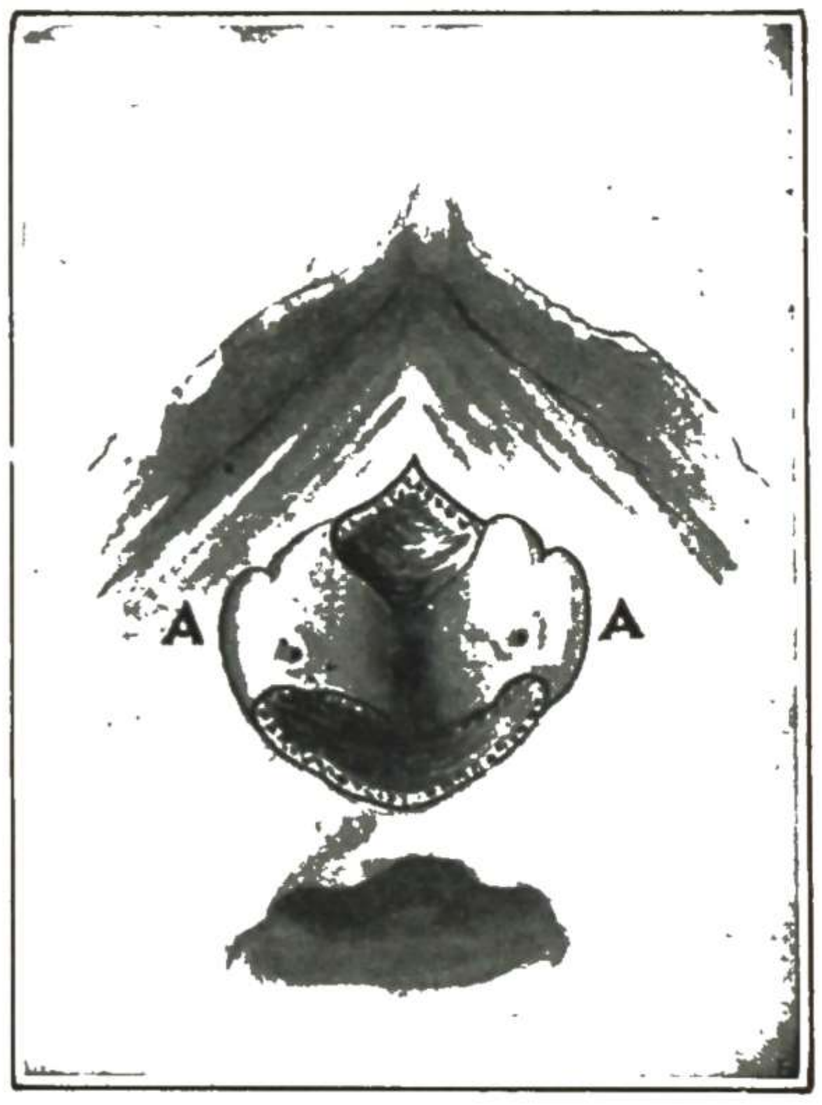


Fig. 119.

Fig. 118.—Indicating the line of division of the urethra to give the view shown in Fig. 119. (Dudley—*Practice of Gynecology*, Lea and Febiger.)

Fig. 119.—The urethra divided so as to show the openings of Skene's glands. The openings are situated just within the meatus, one on each side. (Dudley.)

vestibule four canals open—the urethra, the vagina, and the duct of the vulvovaginal gland of each side. The urethral opening, the meatus urinarius, is situated just above the vaginal orifice. In the nullipara it is small and round. In the multipara it is larger and somewhat star-shaped, and there is often some pouting or projection of the urethral mucosa. This change is due to the swelling and distortion during labor, from which the parts never return absolutely to their former condition. The floor of the vestibule is formed of several layers of squamous epithelium and under this the subepithelial connective tissue. There are a few glands, some of which at times become enlarged.

The **hymen** is a circular or crescentic fold of mucosa and submucous connective tissue, situated at the vaginal entrance and partially closing it. The shape of the hymen and the opening in it vary greatly in different persons, some forms being given names. The crescentic hymen and the circular hymen

are the usual forms. The fimbriated hymen has a dentated or fringelike margin. The cribriform hymen presents a number of small holes. In certain cases of malformation, the hymen is absent. In other cases it is closed entirely (imperforate or occluded hymen).

The hymen is usually ruptured at the first sexual intercourse. In some cases "rupture of the hymen" amounts to nothing more than stretching, with slight abrasion. In other cases there is distinct tearing, with considerable pain and some bleeding. In rare cases there may be persistent and even serious bleeding. In some cases the hymen is so rigid or tender as to prevent coitus. Long-continued sexual intercourse stretches the hymen until it is not at all prominent. Much medicolegal importance has been attached to the condition of the hymen, and, ordinarily, it is a decided help in determining whether or not coitus has taken place. But it is a well-established fact that an intact hymen is not absolute proof of virginity, neither is an apparently ruptured or stretched hymen absolute proof of sexual intercourse.

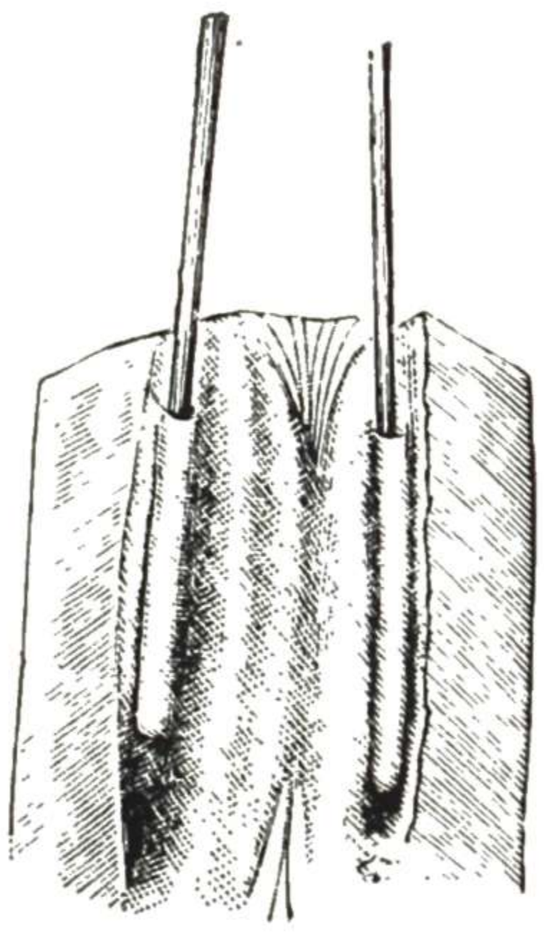


Fig. 120.

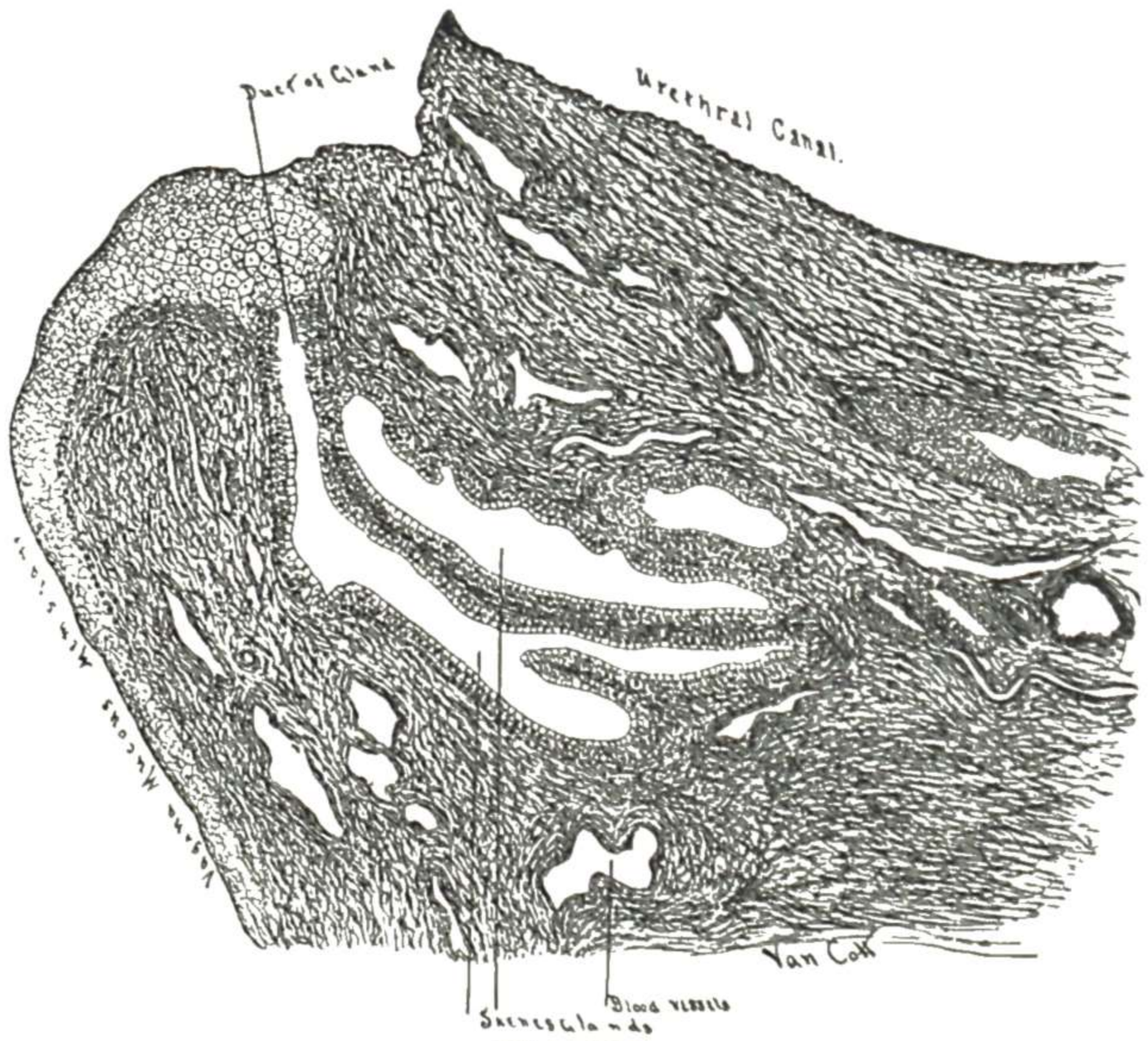


Fig. 121.

Fig. 120.—This gives a clear idea of the size and relation of the periurethral ducts (Skene's glands). The floor of the urethra has been divided longitudinally, the end of the urethra raised and a probe introduced into each of the periurethral ducts. (Skene—*Diseases of Women,* D. Appleton-Century Company.)

Fig. 121.—A section through the urethra showing the periurethral duct of one side, with ramifications. (Skene—*Diseases of Women,* D. Appleton-Century Company.)

Childbirth destroys the hymen as an intact ring. Usually after parturition there are only irregular tags of tissue left, the result of tearing and sloughing about the vaginal entrance. These irregular tags of tissue surrounding the vaginal orifice are known as "carunculae myrtiformes," and result from childbirth only, not from sexual intercourse. Coitus does not usually destroy the hymen, but simply tears it slightly and stretches it.

The **vulvovaginal glands** are two glands situated beside the vaginal entrance, one on each side at the lower end of the lateral mass of veins called the vestibular bulb, as shown in Fig. 115. They correspond to Cowper's glands in the male, though their relations to the triangular ligament are not so clearly

defined, apparently varying some in different cases. They lie, as a rule, behind the anterior layer of the ligament, and may lie behind or in front of the posterior layer. Each gland lies very close to the lower end of the venous bulb of that side. The gland is a small reddish body about the size of a bean, and belongs to the racemose variety of glands (Figs. 116, 117). Its secretion is discharged through a small duct which opens just in front of the hymen, about the junction of the lower with the middle third of the side of the vaginal orifice. When the gland is normal, this opening has to be looked for rather carefully to be seen. When the gland has once become inflamed, the opening is easily seen, for it is larger and is usually surrounded by a small reddened area. The mucous secretion of the gland acts as a simple lubricant to the parts and is discharged during sexual excitement. When inflamed, the gland is felt as a hard tender mass beside the vaginal opening.

The **meatus urinarius,** as well as the urethra, is lined with stratified squamous epithelium on a basis of connective tissue rich in cells. This connective tissue of the meatus and the urethra presents usually many typical lymph nodules of microscopic size. Just within the meatus, near the posterior wall, are the openings of two diverticula, one on each side. They are known as **Skene's ducts** or Skene's glands. They are called also "periurethral ducts." Their size and shape and location are shown in Figs. 118 to 121. They are important in that gonorrheal infection may extend into them and persist there indefinitely. Just back of the lining of the vestibule there are two masses of veins, one on each side of the vaginal orifice, called the bulbs of the vestibule (Fig. 115). The **bulbi vestibuli** lie just in front of the anterior layer of the triangular ligament. They are supposed to correspond to the corpus spongiosum of the male. In wounds of this region, or in operations, if these vascular bulbs are injured there is troublesome bleeding.

The BLOOD SUPPLY of the external genitals (Fig. 115) comes principally from the internal pudic artery, one of the terminal branches of the anterior trunk of the internal iliac.

The NERVE SUPPLY (Fig. 115) comes principally from branches of the pudic and small sciatic nerves. In certain painful affections of the external genitals, the pudic nerve is sometimes divided or resected to afford relief.

The LYMPHATICS empty into the inguinal glands. Poirier calls attention to the fact that the lymphatics from the clitoris extend into the deep pelvic glands. Consequently in carcinoma of the clitoris proper (not its prepuce), the glands within the pelvis are soon involved.