Zonal Variations in Structure of Rat Oviduct

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ABSTRACT

The structure of the oviduct, hitherto considered fixed, is highly variable and varies from 'zone' to 'zone'. There is a need to provide descriptive histological data for the 'zones' of the oviduct in order to achieve knowledge in those areas of gap in our understanding of oviduct function. In this study, the oviduct of the rat is parcelled into 66 zones and common and variable features of mucosa, submucosa, muscular coat and serosa described. The rat oviduct has mainly pseudostratified columnar epithelium with stratified epithelium occurring in some parts of the preampulla. Circular muscle is most abundant although longitudinal muscle exists in certain subsegments. Lamina propria of the basal type is abundant in the isthmus but present in other parts of the oviduct. The spatial changes in the histological data for structure of muscle, serosa, and lamina propria are useful in the understanding of gametic (early embryonal) transport and other functions of the oviduct. Zonal data can assist in identification of oviductal materials obtained from the rat for isolated and other studies. Although segmental variations have been reported in the literature, this study provides for the first time subsegmental and zonal histological variations in the oviduct.

Keywords: Fibers, gametes, histology, Mesosalpnix.

INTRODUCTION

Extensive description of the histology of the oviduct in several species of mammals exist in the literature and have been adequately summarized by Nilsson and Reinius [1], Woodruff and Pauerstein [2], Beck and Boots [3] and more recently Felipe *et al* [4]. Generally the mammalian oviduct has three major histological coats; the innermost of which is the lamina epithelialis which represents the superficial aspect of the mucosa, followed by the lamina propria and the tunica muscularis (Fig. 1). Four different types of cells are known to occur in the lamina epithelialis of the rat and they are ciliated, secretory (or non-ciliated cell), peg (5-7) and indifferent cell (8,9). The lamina epithelialis mucosal pattern has been very neatly divided into seven different types (Table 1) by the classification of Beck and Boots [3].

The muscularis has also been classified into different types by Beck and Boots [3] (Table 2). These authors also reported that the oviduct possesses the following muscularis patterns-isthmus type 3, ampulla type 3, junctura type 4.

They also said, if precise patterns of contraction are necessary for the segmental propulsion of gametes through the oviduct, the observation on the morphology of the oviductal muscularis and its variations among species and among segments of the oviduct may provide insights as to the mechanisms of gamete transport.

Part of the objective of this study was therefore to provide such insight into the variations of the muscularis from one segment to another of the rat oviduct and even zonal variations. The lamina propria of the oviduct has been shown to contain mainly collagenous fibers. It does not contain elastic fibers [3] but contains very little amount of reticular fibers. It lacks glands in most eutherians while it may contain some glands in marsupials [3, 10, 11].

The outermost and fine coat which blends with the peritoneum, mesosalpinx and ovarian ligaments is the tunica serosa [5, 12, 13]. This outermost coat of the tube consists of mesothelial lining which is continuous with the mesosalpinx. This coat also contains musculature that seems to be important in the propulsive movement of the oviduct (shown in the rabbit by Blandau – 14) than the intrinsic muscle fiber in the muscularis layer which seems to be more important in gamete and early embryo transport. Again the structure and distribution of the muscle in different 'zones' of the oviduct is likely to shed light into its biological role in oviduct function.

Variations are recognized to occur in the distribution of these component coats in the various segments of the oviduct but these variations have not been systematically described. Indeed variations do occur from zone to zone (15-17). A 'zone' is described as $1/66^{th}$ of the oviduct and it is a histomorphometrically derived parcellation entity [15].

This paper therefore attempts to systematically describe the variations in the oviduct of the rat within segments, subsegments and zones in order to provide comprehensive descriptive data for the purposes of comparative anatomy. This is undertaken in view of the lack of data on the variations which occur along the entire oviducte believing that such will shed light on the little understood histophysiology of the tube and *ipso facto* the physiology of early pregnancy.

MATERIALS AND METHODS

Twenty mature female albino rats were utilized for the study weighing 200-250g. Ten rats were in oestrus as adjudged by vaginal smear in which there is predominance of cornified epithelial cells [18]. 10 rats were in diestrus as adjudged by vaginal smear in which smear contains mainly leukocytes [18]. Albino rats were perfused with fixative, i.e., 10% formol-saline under deep pentothal anesthesia. Their oviducts were then removed and placed in fixative- 10% formol-saline. Each oviduct was carefully dissected from the ovary and ovarian bursa, after which the ovarian ligament was sought for and torn in order to allow for the maximal stretching of the oviduct. After stretching to a straight position, the two ends were pinned down to the petri dish and remaining mesosalpinxial and ovarian ligamentous connexions sought for and divided under the dissecting microscope to provide a very straight tube.

The tubes were then processed *in toto* through dehydration in graded ethanolic series, cleared in xylene and embedded in paraffin wax. Segments were initially divided from each other using gross anatomical features (e.g., separation by distinct constrictions into junctura, isthmus, ampulla and preampulla). The sections for each segment were then divided into three equal parts representing subsegments of proximal, middle, and distal. The sections representing the subsegments were divided into 4 equal parts for the preampulla, and 6 equal parts for the rest of the segments to obtain 66 zones in all, running from zone 1 at the most distal preampullary section to zone 66 at the most proximal junctural zone. They were sectioned serially by securing every 10^{th} section obtained from serial microtomy using a rotary microtome (15-17). All the sections from each segment were collated and stained with hematoxylin and eosin and also toluidine blue and then examined under the microscope. Zonal sections were

thoroughly examined and the histological features noted. Also segmental and sub-segmental histological features were noted and recorded.

RESULTS

Segmental histology

This already exists in the literature.

Subsegmental histology (figure 1)

Distal preampulla (zones 1-4)

This region possesses longitudinal fibers at its ostium in addition to the normal circular musculature present in all the oviduct of the rat. It is moderately dilated and increase in diameter toward the middle portion. Its mucosal pattern is mainly of the type 5b variety. Its lamina epithelium is thin. The muscularis layer is also thin. It is the portion that possesses fimbriae.

Middle preampulla (zones 5-8).

This subsegment is extremely dilated and contains numerous epithelial cells (probably secretory). It does not possess fimbriae. It is thinner walled in the muscularis and the lamina proprial layers than the distal portion. Its mucosal pattern is mainly of the type 5a variety.

Proximal preampulla (zones 9-12).

This region is moderately dilated and includes the constriction separating the ampulla from the preampulla. Its mucosal pattern is not as branched as in the middle portion, bring mainly of the type 5a variety. The modification of Beck and Boots classification of type 5 into two subtypes performed in this study differentiates between mucosal folds that are characteristically long and extremely branching (5a) as opposed to the simple branching long folds [5b] found in distal preampulla which are highly dense (high cellularity). See Figure 1. The subsegment possesses moderately thin lamina propria, both concentric and basal. It rarely has longitudinal fibers.

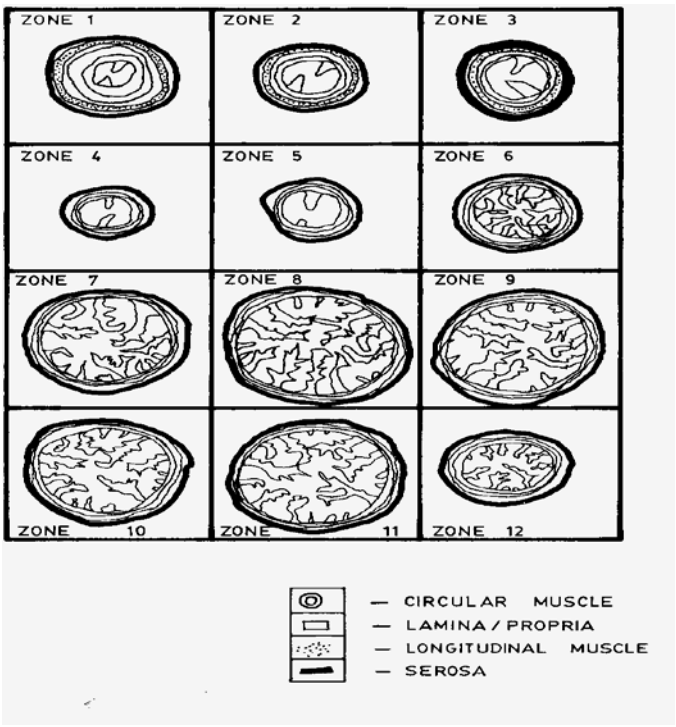


Fig. 1. Pictograms depicting tunica mucosa, lamina propria, tunicae muscularis and serosa in 66 zones of the rat oviduct.

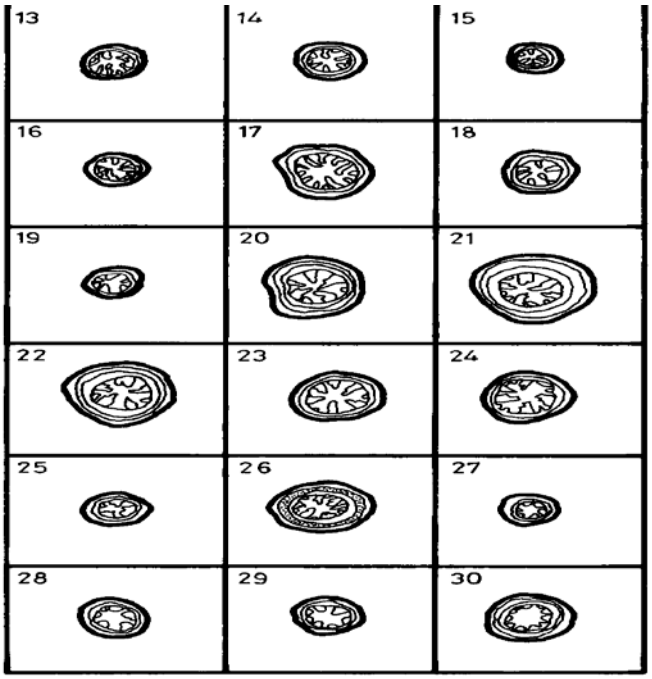


Fig. 2. Cross-section of zone 42 of rat oviduct at middle isthmus. Mucosal fold is type 7. Note the thick and also very dense muscularis coat. Magnification x150.

Distal ampulla (zones 13 – 18)

This subsegment is moderately expanded with some degree of mucosal pattern change from the preampullary zones to the 4 variety. The lamina propria and muscular layers are prominent.

Middle ampulla (zones 19 – 24)

This subsegment carries zones with considerable amount of distension of lumen (which is the highest in the ampulla). There is also increase in thickness of muscularis with the possession of a distinct ampullary hypertrophic musculature zone (which might qualify as a pace maker zone). The portion also carries the point of attachment of the ovarian ligament. Its mucosal pattern is mainly type 3 while it maintains a type 1 muscularis pattern. Tubal diameter of this subsegment is the highest in the ampulla mainly because of the contribution of lumen and muscle size.

Proximal ampulla (zones 25 – 30)

This subsegment is less dilated than the middle subsegment. Mucosal pattern is strictly of type 2 variety. Epithelium is of pseudo-stratified variety. The muscle layer seems to increase with increasing zones; likewise the thickness of the concentric lamina propria. Basal lamina propria decreases in size as the zones approach the ampullary-isthmic junction.

Distal isthmus (zones 31- 36)

Mucosal patterns change gradually from type 4 variety to type 7. Basal lamina disappears because of the presence of spiral and circular folds rather than longitudinal folds. Muscularis gradually increases in size and the concentric lamina propria becomes very large and prominent. The lamina propria of this subsegment is the thickest and the most prominent in the isthmus. Tubal diameter and lumen size decrease gradually as middle isthmus is approached.

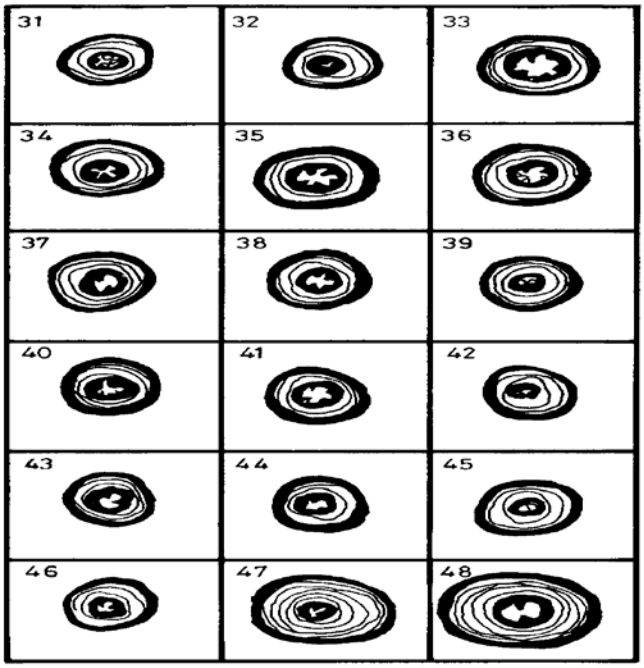


Fig. 3. Cross-section of zone 49 of distal junctura of rat oviduct. Mucosal pattern has shifted to type 1. Note very thick circular musculature. Magnification x150.

Middle isthmus (zones 37 – 42) Fig. 2

This subsegment is the narrowest portion of the oviduct. It is also very thickly endowed with concentric lamina propria and muscularis. Its muscularis coat is thicker than for the distal subsegment. This coat is the densest in the whole rat oviduct. The epithelial cells are very tall and very few.

Proximal isthmus (zones 43 – 48)

This subsegment is the one that leads on to the junctura. Its mucosal pattern is still maintained at type 7 with spiral circular folds and prominent connective tissue in lamina propria.

Distal junctura (zones 49 – 54) Fig. 3

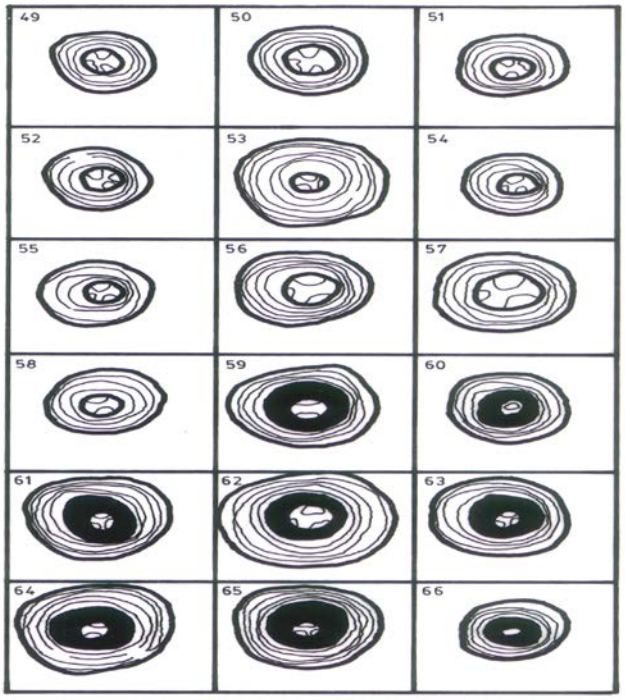
This portion is extrauterine and it possesses type 1 mucosal pattern. Its muscularis layer is very thick containing mainly circular fibers with some zones possessing longitudinal fibers as

well. The lamina propria of the epithelial base returns in this subsegment and is very thick. Also the lamina propria of the concentric nature is quite prominent and sometimes in-distinguishable from the muscularis. A curious mixture of small and tall cells are also seen in the epithelium of this subsegment.

Middle junctura (zones 55 – 61)

This subsegment is intrauterine and its serosal layer tends to blend with the tissues of the uterus. It also possesses some longitudinal fibers and some of its zones have distinct merger of circular musculature with myometrial fibers. Its mucosal patterns is type 1 with a prominent lamina propria just as for the previous subsegment. The muscle layer becomes increasingly wider but looser. Propria thickness is less prominent in this subsegment.

Proxiam junctura (zones 61 – 66) Fig. 4



Cyclic variations

In the present study, the following observations were made.

Mucosal pattern in this subsegment gradually changes to type 6 pattern. It is provided with muscularis which blends with the myometrium. It is also provided with prominent basal and concentric lamina propria (the most prominent in the whole oviduct). Its epithelial cell becomes gradually shorter until the last zone which possesses low lying cuboidal cells and is of a simple epithelial variety with mucosal pattern type 6. The rest are of pseudostratified epithelial variety.

Histology of individual zones – Table 3

Figure 1 shows diagrams (pictogram) of all the zones of the rat oviduct and their structure. Figures 4 to 8 represent the various areas of the rat oviduct for epithelial types, cell height, cell count (hypo or hypercellularity) mucosal pattern, availability of longitudinal or circular musculature, and lamina propria (submucosal) presence or non-presence after the analysis of zones as prescribed by Ogunranti [17].

1. The oestrous epithelial cells in the proximal isthmus and in the junctura seem to be taller than in diestrus.
2. There is a change in the metachromatic reaction (to toluidine blue) of lamina propria in the oestrus and diestrus sections examined with increased metachromasia at estrus than diestrus.
3. It appears that the characteristic distension of the ampulla is not achieved in the rat during estrus but at day 1 after fertilization.
4. The isthmus seems narrower in oestrus than in diestrus animals.

DISCUSSION

The extensive taxonomic categories provided by Becks and Boots [3] on the comparative variations on mucosal fold of the oviduct in various mammals have provided insight to the classification of temporal and spatial variations of the epithelial architecture of the rat oviduct. Although this classification did not originally

take into account the variations within the different segments of the oviduct itself, it has nevertheless provided a good basis for the classification of the variations in epithelial arrangements existing in the rat oviduct.

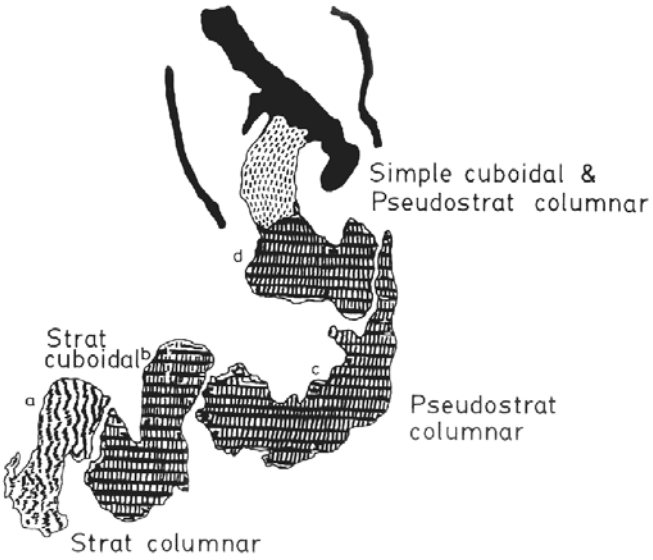


Fig. 4. Epithelial types are shown. Stratified epithelium is found in the preampulla which is divided into the distal stratified columnar (strat columnar) and proximal cuboidal (strat cuboidal) epithelium. The ampulla, isthmus and junctura have pseudostratified epithelium (pseudostrat columnar). In the distal part of the junctura the epithelium is replaced with simple cuboidal variety (see fig. 7). A – preampulla, B-ampulla, c-isthmus, d-junctura. Drawn from computer art program.

The present report has therefore shown that there are four main epithelial arrangements in the oviduct of the rat contrary to previous reports of only one type, i.e., pseudostratified epithelium [3]. [They are as follows – stratified cuboidal epithelium found in periampullary zones, pseudostratified epithelium] found in other regions of the oviduct, and simple cuboidal epithelium] found only in the junctural epithelium (Fig. 4). Hypercellular zones are found only on periampullary and proximal ampullary zones (Fig. 5).

The classification of Becks and Boots require a minimal modification for the rat. This study has provided this a new type of mucosal pattern which is extensive and longitudinally tall and simple [5a] and which occurs in most periampullary zones of the rat oviduct under study. Also circular folds are found only in the isthmus while longitudinal folds are found elsewhere and this has not been reported previously (Fig. 6).

The lamina propria does not seem to be functionally inert as was previously thought [2]. The metachromatic reaction to toluidine blue stain is a demonstration of presence of acidic glycoproteins which might well be important in oviductal physiology. Indeed large amounts of peptide (glycoprotein) secreting cells have been recently identified in the lamina propria of the sheep oviduct [16,19]. The reaction to toluidine blue is also important as can be demonstrated by the fact that the basal lamina does not become

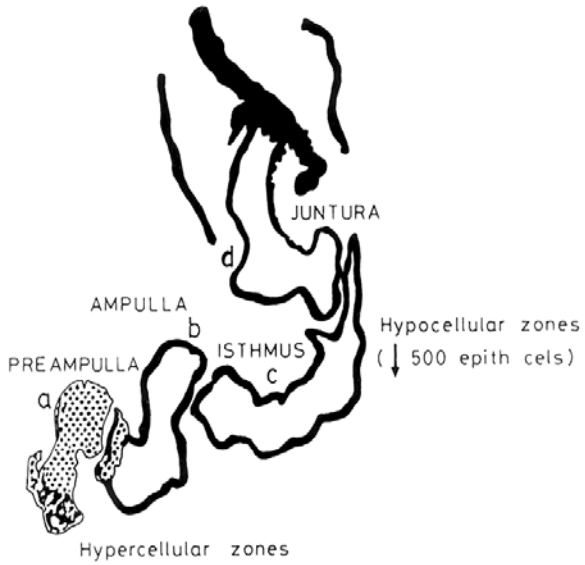


Fig. 5. Diagram showing areas of hypercellular zones in the preamulla of the rat oviduct, a-preampulla, b- ampulla, c-isthmus, d-junctura. Drawn from computer art program.

metachromatic when stained with toluidine blue thereby suggesting that the basal and concentric laminae have differing chemical components and therefore probably perform different functions.

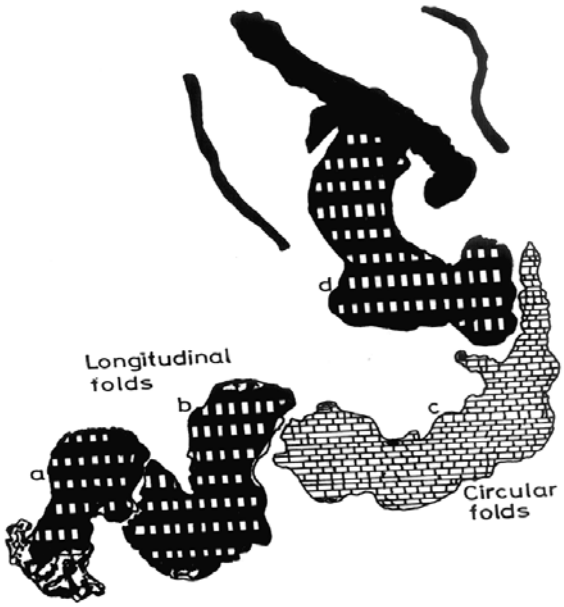


Fig. 6. Longitudinal folds are found in the preampulla, ampulla and junctura while circular folds are found only in the isthmus.

This differential function hypothesis may be corroborated by the fact that some segments lack the basal laminae but all segments have concentric laminae, i.e., submucosa, even though this is negligible in preampullary and ampullary zones. Kent [20] reported the presence of a polypeptide and a prostagen in the stroma (by which he meant the submucosa) of the hamster oviduct. It does appear that the lamina propria might in actual fact be a major endocrine functional portion of the oviduct. This leads us to the semantic argument as to whether the concentric and basal lamina propria should not be given different names since they may be providing differing functions (Fig. 7).

Woodruff and Pauerstein [2] suggested that the name submucosa when used implies a structure with abundant cellular base. There is ample evidence that the concentric lamina propria provides a cellular base given reports in literature. It is said to contain all cellular basis of connective tissue and also the indifferent cells. It thus seems appropriate to call the concentric lamina propria by the name submucosa, while leaving the name lamina propria for the basal lamina propria.

In support of the statement of Beck and Boots in relation to variations in musculature within the oviduct, the following conclusions can be made from the studies of the musculature of the various zones of the oviduct (Fig. 8).

1. Musculature of the preampulla and ampulla are very scanty excepting in the most distal ostia zones which might have thicker musculature in order to aid ovum pick up. Also the muscular hypertrophic zones in the middle of the ampulla deserve our interest. Could they be zones for pacemaker activity as suggested for mouse oviduct by Talo [21]? It is quite possible that this thick muscle zone may come in handy in assisting the expulsion of the ovum from the ampulla through the thick and narrow ampullary isthmic junction (zones 30-31 in Fig. 1).
2. The denser layers of circular musculature (Fig. 8) may help by their contractions to increase contact with epithelium and hence the areas of very low diameter of lumen corresponds to the areas of thick musculature. These areas are mainly found in the isthmus. It is therefore possible to recognize that isthmic muscular contraction may not really be available mainly for the propulsion of the egg but to aid cell to cell interactions between somatic (oviductal) cells and the developing embryo through their intimate contact. [1, 22,-25].
3. The width of the lumen of the oviduct and its variations from zone to zone seems to be related to the morphology and physiology of muscularies as was suggested by Nilsson and Reinius [1] who said Peristalsis or irregular contractions of the tunica muscularis influence the width of the oviductal lumen.

Thus it is quite easy to observe that zones which have hypertrophic musculature have low diameter.

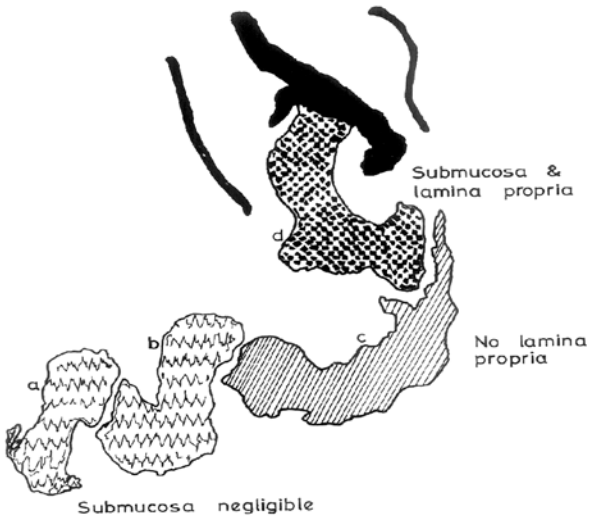


Fig. 7. Stroma of the oviduct has three distinct regions. There is no lamina propria in the isthmus while this is present in the rest of the oviduct. This is a major distinguishing feature of the rat isthmus. Also the submucosa is negligible in the preampulla and ampulla but large in isthmus and junctura, a-preampulla, b-ampulla, c-isthmus, d-junctura. Drawn from computer art program.

Fig. 8. Longitudinal musculature are found in the rat only in the proximal preampulla, ampullary isthmis junction and the junctura, a-preampulla, b-ampulla, c-isthmus, d-junctura. Draw from computer art program.

The mesosalpinx seems to contribute to contraction of the oviduct and also possibly its propulsion too judging from the observation of muscle fibers in the serosa extending to mesosalpinx. This has been demonstrated for animals like rabbit [14, 26] and human [5]. The present report documents the presence of muscle fibers in mesosalpinx of the rat.

Observation of longitudinal muscle fibers in the rat is worhty of discussion since Beck and Boots [3] reported that the wood rat possesses considerable longitudinal muscle and never assigned type 1 musculature pattern to any of its segments. However, the albino rat presently under study does not seem to have longitudinal fibers in its oviductal musculature except in the preampullary ostial zones (Fig. 8).

In conclusion, the rat oviduct is useful as a model for the study of other mammalian oviducts (including woman) in relation to the variations that exist from one zone to another through the serial histological method of study. The present report should provide a basis for subsegment studies on the physiology of the processes of gamete and early embryonal transport and for knowledge in the clinical areas of enhancement or discouragement of fertility through the understanding of embryo transport garnered from consideration of oviductal structure. The zonal data provided in this study may aid the identification of oviductal material removed for isolated and other studies.

REFERENCES

1. Nilsson O, Reinius S (1969). Light and microscopic structure of the oviduct. In ESE Hafez RJ Blandau (eds): The Mammalian Oviduct – comparative biology and methodology. University of Chicago Press.
2. Woodruff D, Pauerstein CJ (1969). The fallopian tube: structure, function, pathology and management. Baltimore : Williams and Wilkins.
3. Beck LR, Boots LR (1974). Comparative anatomy, histology and morphology of the

mammalian oviduct. In AD Johnson, CW Foley (eds): The oviduct and its Functions. New York: Academic Press.
4. Felipe A, Callejas S, Cabodevila J (1998). Anatomicohistological characteristics of female genital tubular organ of the South American nutria (Mycocastor coypus). Anatomie Histologie Embryologie 27:245-250.
5. William PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE Ferguson MWJ (1995) (eds): Gray's Anatomy. The anatomical basis of medicine and surgery. 38th ed New York: Churchill Livingstone.
6. Novak E, Everett HS (1928). Cyclical and other variations in the epithelium of the fallopian tube. American Journal of Obstetrics and Gynecology 16:499-503.
7. Hadek R (1959). Mucin secretion in the ewe's oviduct. Nature 171:750.
8. Synder FF (1924). Changes in the Fallopian tube during menstrual cycle and pregnancy. Bulletin of Johns Hopkins Hospital 34:121-125.
9. Pauerstein CJ, Woodruff JD (1967). The role of the 'indifferent' cell of the tubal epithelium. American Journal of Obstetrics and Gynecology 98:125-129.
10. Molinia FC, Rodger JC (1996). Pellet-freezing spermatozoa of two marsupials. The Tammar Wallaby Macropus eugenii and the brushtail possum Trichosurus vulpecula Reproduction Fertility and Development 8:681-684.
11. Brosens I (1991). The Fallopian Tube. In E Philip, M Setchell, J Ginsburg (eds): Scientific Foundations of Obstetrics and Gynaecology, pp. 135-145. Oxford: Butterworh-Heinemann.
12. Andersen DH (1928). Comparative anatomy of the tubo-uterine junction: histology and physiology in the sow. American Journal of Anatomy 42:255-261.
13. Kellogg M. (1945). The postnatal development of the oviduct of the rat. Anatomical Record 99:377-380.
14. Blandau RJ (1969). Gamete transport-comparative aspects. In ESE Hafez, RJ Blandau RJ (eds): The Mammalian Oviduct-comparative biology and methodology. University of Chicago Press.
15. Ogunranti JO, Cran DG, Moor RM (1986). Morphological parcellation of the rat oviduct: 66 zones model. Joint Winter Meeting of the British Neuroendocrine Group and the society for the Study of Fertility, Sutton Bonington, December 1986. U.K.
16. Ogunranti JO, Yutaka Y, Moor RM (1986). APUD (Neuropeptide) cells in the oviduct of the sheep. Joint Winter Meeting of the British Neuroendocrine Group and the society for the Study of Fertility, Sutton Bonington, December 1986. U.K.
17. Ogunranti JO (1992). Δ5-3β-hydroxysteroid dehydrogenase activity in rat oviduct and implications of oviductal steroidogenesis. European Journal of Gynecology, Obstetrics and Reproductive Biology 44:145-150.
18. Short DJ, Woodnutt DP (1969). Eds. The IAT Manual of Laboratory Animal Practice and Technique 2nd ed. Crossby Lockwood.
19. Ogunranti JO (1997). Human oviduct contains APUD cells. West African Journal of Anatomy 5:22.
20. Kent HA Jr (1974). The oviduct as an endocrine gland: its effect upon general somatic carbohydrate metabolism, and upon the ovary. In AD Johnson, CW Foley (eds): The Oviduct and Its Functions. New York: Academic Press.
21. Talo A (1980). Myoelectrical activity and transport of unfertilised ova in the oviduct of the mouse in vitro. Journal of Reproduction and Fertility 60:53-58.
22. Greenwald GS (1958). Endocrine regulation of the secretion of mucin in the tubal epithelium of the rabbit. Anatomical Record 121:187-191.
23. Imarai CM, Rocha A, Acuna C, Garrido J, Vargas R, Cardenas H (1998). Endocytosis and MHC class II expression by human oviductal epithelium according to stage of the menstrual cycle. Human Reproduction 13:1163-1168.
24. Hewitt DA, England GCW (1999). Synthetic oviductal fluid and oviductal cell coculture for canine oocyte maturation in vitro. Animal Reproduction Science. 55:63-75.
25. Yao Y, Ho P-C, Yeung WB (1999). Effects of human oviductal cell coculture on various functional parameters of human spermatozoa. Fertility and Sterility 71:232-239.
26. Ogunranti JO, Umar MBT (2000). Comparative histomorphometry of rat, rabbit and human oviducts. West African Journal of Biological Sciences. (in press).

Table 3: Descriptive data for all 66 zones of rat oviduct. Pictogram depicts these in Fig. 5.

Zone 66	Zone F Proximal Junctura Tunica mucosa: Mucosal fold type 6. Low lying epithelial cells Lamina propria: Present Submucosa: Present Tunica muscularis: Type 1. Tunica serosa: Blends with endometrium	**Zone 59**	Zone E Middle Junctura Tunica mucosa: Mucosal fold type 1.2 major and a few minor folds. Pseudostratified epithelium. Lamina propria : present Submucosa : present Tunica muscularis : Type 1 Tunica serosa : Blends with endometrium
Zone 65	Zone E Proximal Junctura Tunica mucosa: Mucosal fold type 1. Lamina propria: present Submucosa: present Tunica muscularis:Type 1 Tunica serosa: Blends with endometrium	**Zone 58**	Zone D Middle Junctura Tunica mucosa : Mucosal fold type 1.1-2 major papillae; a few minor ones. Pseudostratified epithelium Lamina propria: present Submucosa: Present Tunica muscularis : Type 3 Tunica serosa : Blends with endometrium
Zone 64	Zone D Proximal Junctura Tunica mucosa: Mucosal fold type 1.1-2 projected folds. Lamina propria : Present Submucosa : Present Tunica muscularis : Type 3 Tunica serosa : Blends with endometrium	**Zone 57**	Zone C Middle Junctura Tunica mucosa: Mucosal fold type1. 1-3 major folds Pseudostratified epithelium Lamina propria: present Submucosa : present Tunica muscularis: Type 3 Tunica serosa: cotains longitudinally running muscle fibres
Zone 63	Zone C Proximal Junctura Tunica mucosa : Mucosal fold type 1. 1-2 projected folds Lamina propria : Present Submucosa : Present Tunica muscularis: Type 1 Tunica serosa : Blends with endometrium	**Zone 56**	Zone B Middle Junctura Tunica mucosa: Mucosal fold type 1 1-2 major folds Pseudostratified epithelium Lamina propria : present Submucosa : Present Tunica muscularis : Type 1 Tunica serosa : Blends with mesosalpinx
Zone 62	Zone B Proximal Junctura Tunica mucosa : Mucosal fold type 1. 1-2 projected folds Lamina propria : present Submucosa : present Tunica muscularis: Type 3 Tunica serosa : Blends with endometrium	**Zone 55**	Zone A Middle Junctura Tunica mucosa : Mucosal fold type 2. 4 projected folds Epithelium pseudostratified and cuboidal Lamina propria : present Submucosa : present Tunica muscularis : Type 1 Tunica serosa : Blends with mesosalpinx
Zone 61	Zone A proximal Junctura Tunica mucosa : Mucosal fold type 1. 1-2 projected papillae Lamina propria : present Submucosa : present Tunica muscularis : Type 1. Tunica serosa : Blends with endometrium	**Zone 54**	Zone F Distal Junctura Tunica mucosa: Mucosal fold type 2. Cuboidal epithelium. Lamina propria : present Submucosa :Present Tunica muscularis: Type 1 Tunica serosa : Blends with mesosalpinx

Zone 53	Zone E Distal Junctura Tunica mucosa: Mucosal fold type 2. Cuboidal epithelium Lamina propria: present Submucosa:present Tunica muscularis :Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 46**	Zone D Proximal Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified. Lamina propria: Nil Submucosa : Present Tunica muscularis: Type 1 Tunica serosa : Blends with mesosalpinx
Zone 52	Zone D Distal Junctura Tunica mucosa: Mucosal fold type 1. Pseudostratified epithelium Lamina propria:Present Submucosa :Present Tunica muscularis: Type 1 Tunica serosa :Blends with mesosalpinx	**Zone 45**	Zone C Proximal Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified. Lamina propria : Nil Submucosa: Present Tunica muscularis: Type 1. Tunica serosa : Blends with mesosalpinx
Zone 51	Zone C Distal Junctura Tunica mucosa: Mucosal fold type 1. Epithelium pseudostratified Lamina propria:present Submucosa :Present Tunica muscularis :Type 1 Tunica serosa : Blends with mesosalpinx	**Zone 44**	Zone B Proximal Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified. Lamina propria : Nil Submucosa : Present Tunica muscularis :Type 1 Tunica serosa: Blends with mesosalpinx
Zone 50	Zone B Distal Junctura Tunica mucosa : mucosal fold type 1 Lamina propria :present Submucosa: present Tunica muscularis: Type 1 Tunica serosa : Blends with mesosalpinx	**Zone 43**	Zone A Proximal Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified. Lamina propria: Nii Submucosa: Present Tunica muscularis: Type 1 Tunica serosa :Blends with mesosalpinx
Zone 49	Zone A Distal Junctura Tunica mucosa : Mucosal fold type 1. Epithelium pseudostratified Lamina propria : Present Submucosa :Present Tunica muscularis: Type 1 Tunica serosa : Blends with mesosalpinx	**Zone 42**	Zone F Middle Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified. Lamina propria : Nil Submucosa : Present Tunica muscularis: type 1 Tunica serosa : Blends with mesosalpinx
Zone 48	Zone F Proximal Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified Lamina propria :Nil Submucosa :Present Tunica muscularis: Type 1. Tunica serosa: Blends with mesosalpinx	**Zone 41**	Zone E Middle Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified Lamina propria: Nil Submucosa :Present Tunica muscularis : Type 1 Tunica serosa : Blends with mesosalpinx

Zone 47	Zone E Proximal Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified Lamina propria: Nil Submucosa : Present Tunica muscularis :Type 1 Tunica serosa : Blends with mesosalpinx	**Zone 40**	Zone D Middle Isthmus Tunica mucosa: Mucosal fold type 7. Epithelium pseudostratified Lamina propria : Nil Submucosa:Present Tunica muscularis : type 1 Tunica serosa: Blends with mesosalpinx
Zone 39	Zone C Middle Isthmus Tunica mucosa : Mucosal fold type 7. Epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx	**Zone 32**	Zone B Distal Isthmus Tunica mucosa : Mucosal fold type 2. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx
Zone 38	Zone B Middle Isthmus Tunica mucosa : Mucosal fold type 7. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx	**Zone 31**	Zone A Distal Isthmus Tunica mucosa : Mucosal fold type 2. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 3 Tunica serosa: Blend with mesosalpinx
Zone 37	Zone A Middle Isthmus Tunica mucosa : Mucosal fold type 7. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx	**Zone 30**	Zone F Proximal Ampulla Tunica mucosa : Mucosal fold type 2. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 3 Tunica serosa: Blend with mesosalpinx
Zone 36	Zone F Distal Isthmus Tunica mucosa : Mucosal fold type 7. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx	**Zone 29**	Zone E Proximal Ampulla Tunica mucosa : Mucosal fold type 2. epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 3 Tunica serosa: Blends with mesosalpinx
Zone 35	Zone E Distal Isthmus Tunica mucosa : Mucosal fold type 7. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx	**Zone 28**	Zone D Proximal Ampulla Tunica mucosa : Mucosal fold type 2. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 34	Zone D Distal Isthmus Tunica mucosa : Mucosal fold type 7. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx	**Zone 27**	Zone C Proximal Ampulla Tunica mucosa : Mucosal fold type 2. epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx

Zone 33	Zone C Distal Isthmus Tunica mucosa : Mucosal fold type 7. epithelium pseudostratified Lamina propria : Nil Submucosa : Present Tunica muscularis : Type 1 Tunica serosa: Blend with mesosalpinx	**Zone 26**	Zone B Proximal Ampulla Tunica mucosa : Mucosal fold type 2. epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 3 Tunica serosa: Blends with mesosalpinx
Zone 25	Zone A Proximal Ampulla Tunica mucosa : Mucosal fold type 3. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 18**	Zone F Distal Ampulla Tunica mucosa : Mucosal fold type 3. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 24	Zone F Middle Ampulla Tunica mucosa : Mucosal fold type 3. epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 17**	Zone E Distal Ampulla Tunica mucosa : Mucosal fold type 4. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 23	Zone E Middle Ampulla Tunica mucosa : Mucosal fold type 3. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 16**	Zone D Distal Ampulla Tunica mucosa : Mucosal fold type 4. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 22	Zone D Middle Ampulla Tunica mucosa : Mucosal fold type 3. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 15**	Zone C Distal Ampulla Tunica mucosa : Mucosal fold type 4. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 21	Zone C Middle Ampulla Tunica mucosa : Mucosal fold type 3. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 14**	Zone B Distal Ampulla Tunica mucosa : Mucosal fold type 4. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 20	Zone B Middle Ampulla Tunica mucosa : Mucosal fold type 3. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1	**Zone 13**	Zone A Distal Ampulla Tunica mucosa : Mucosal fold type 4. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1

	Tunica serosa: Blends with mesosalpinx		Tunica serosa: Blends with mesosalpinx
Zone 19	Zone A Middle Ampulla Tunica mucosa : Mucosal fold type 3. epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 12**	Zone D Proximal Preampulla Tunica mucosa : Mucosal fold type 4. Epithelium pseudostratified Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 11	Zone C Proximal Preampulla Tunica mucosa: Mucosal fold type 5a. Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 5**	Zone A Middle Preampulla Tunica mucosa : Mucosal fold type 5b. Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 10	Zone B Proximal Preampulla Tunica mucosa : Mucosal fold type 5a. Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 4**	Zone D Distal Preampulla Tunica mucosa : Mucosal fold type 5b. Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx
Zone 9	Zone A Proximal Preampulla Tunica mucosa : Mucosal fold type 5a. Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 3**	Zone C Distal Preampulla Tunica mucosa : Mucosal fold type 5b. Epithelium stratified columnar. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 3 Tunica serosa: Blends with mesosalpinx. Contain some longitudinal muscle fibres. Fimbriated zone.
Zone 8	Zone D Middle Preampulla Tunica mucosa : Mucosal fold type 5a. Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 2**	Zone B Distal Preampulla Tunica mucosa : Mucosal fold type 5b. Epithelium stratified columnar. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 3 Tunica serosa: Blends with mesosalpinx. Contains longitudinal fibres. Fimbriated zone.
Zone 7	Zone C Middle Preampulla Tunica mucosa : Mucosal fold type 5a. Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx	**Zone 1**	Zone A Distal Preampulla Tunica mucosa : Mucosal fold type 5b. Epithelium stratified columnar. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 3 Tunica serosa: Blends with mesosalpinx. Contain some longitudinal muscle fibres. Fimbriated zone.
Zone 6	Zone B Middle Preampulla Tunica mucosa: Mucosal fold type 5a.		

	Epithelium stratified cuboidal. Lamina propria : Present Submucosa : Negligible Tunica muscularis : Type 1 Tunica serosa: Blends with mesosalpinx		

Table 1: Mucosal types classification in the oviduct after Becks and Boots [3].

Type 1	Low (apex nearer to base than to center) folds which are simple (no secondary branching).
Type 2	Simple and medium in height (medium refers to folds which are nearer the center than the bases but do not extend beyond the center.
Type 3	Simple and high folds (2 or more folds extending past their centre of lumen)
Type 4	Complex branching and high
Type 6	Single longitudinal ridge which are medium and simple
Type 7	Simple and circular mucosal ridges in circumscribed fashion

Table 2: Muscularis classification by Becks and Books (1974).

Type 1	Only circular muscle
Type 2	Circular muscle with two flanking longitudinal muscles
Type 3	Two layers of outer longitudinal and inner circular musculature
Type 4	Two layers of inner longitudinal and outer circular muscle fibers