



is frequently performed to correct obstructive azoospermia but the results are uniformly disappointing and unpredictable (5). One reason for this high failure rate could be our inadequate understanding of the functional anatomy of the epididymis. Is it one uniform organ, functioning as a whole, or are its different parts specialised for different functions? Keeping this in view, it has been considered pertinent to study the internal structure of the rat epididymis in a physiological perspective.

## MATERIAL AND METHODS

This study is based on material taken from 20 adult male albino rats (Haffkine strain). Their age was between 6 to 12 months and the mean weight  $290 \pm 35$  gm. The animals were housed in groups of 5 in spacious cages and provided ready-made animal feed (Hindustan Lever) and water *ad libitum*. The animals were not sexually active at the time of study, being kept separate from any females.

The testes and epididymes were neatly dissected out under ether anaesthesia and weighed immediately on an electrical balance. The tissues were then processed for sectioning, using Bouin's fluid as fixative and paraffin for embedding. Serial sections of the epididymis were cut at  $6 \mu$  thickness and stained with hematoxylin-eosin and Van Gieson's picro-fuschin (3). Histometric measurements were carried out with a Carl-Zeiss ocular micrometer after necessary calibration.

## RESULTS

The epididymis of the rat is a dumb-bell shaped organ with a slender middle-piece (Corpus or body) separating a large globular upper portion (Caput, globus major or head) from the lower one (Cauda, globus minor or tail). The multiplicity of anatomical terms has to be kept in mind to avoid confusion. It appears rather inappropriate to call the thin and delicate middle portion as the body of the epididymis. It looks more like an isthmus connecting two main tissue masses. The possible physiological significance of this arrangement would be discussed later.

Observations made on the testes and epididymes of the 20 adult rats are summarised here in relation to 3 specific points.

(A) *Size relationship between the testis and corresponding epididymis* : On an average, the weight of the epididymis has been found to be 67% of the corresponding testis (Table I). However, the range is rather wide and in two rats the epididymis was almost as large as the testis, its weight being 93 and 97% of the testicular weight. However,

TABLE I : Relationship between weights of testis and epididymis in 20 adult rats (left side only).

	Mean $\pm$ S.D.	Range
Weight of testis (T) in mg	604.6 $\pm$ 95.3	415 - 810
Weight of epididymis (E) in mg	391.4 $\pm$ 25.7	320 - 430
Ratio E/T x 100	67%	49 - 97%

TABLE II : Histometric data from epididymes of 20 adult rats.

Part of the epididymis	Diameter of ductules (microns)=D	Height of epithelium (microns)=H	Ratio H : D (approx. whole no.)
CAPUT (head)	604 $\pm$ 23	124 $\pm$ 4	1 : 5
CORPUS (body)	342 $\pm$ 11	51 $\pm$ 3	1 : 7
CAUDA (tail)	555 $\pm$ 13	39 $\pm$ 3	1 : 14

The height of the epithelium is inclusive of the stereocilia. Figures are mean of 10 measurements : fractions of microns have been omitted.

broadly speaking, the epididymis in the rat can be said to be half to three-fourth in size as compared to the testis which it drains. This relationship would have a bearing on the capacity of the epididymis of a particular species to shield the testis against any back-pressure.

(B) *Histometry of the lining epithelium* : The diameter of the epididymal ductules and the total height of the lining epithelium were measured in its different parts (Table II). Obviously, a definite pattern of regional differences within the epididymis has emerged from these histometric measurements. As one moves from the Caput to the Cauda epididymis, the height of the lining epithelial cells sharply decreases. The change is most conspicuous between the Caput and the Corpus or middle-piece. Thus, a tall columnar epithelium with equally long stereocilia easily distinguishes the Caput from the rest of the epididymis which has only cuboidal or low columnar epithelium not even half as tall.

Besides this quantitative variation in the height of the epithelial cells, some other significant differences have also been observed which seem to have a functional relevance :

- (1) Apical cells, with their round or oval nuclei placed close to the luminal surface, were prominent in the Caput (Fig. 1-A) but rare in the rest of the epididymis.

- (2) Stereocilia were longest and most numerous in the Caput region as compared to the other parts. In the Caput they were almost of the same length as the parent cell (making a difference of 100% if one measures the height of the epithelial cell with or without the stereocilia), while in the rest of the epididymis they were less than half as tall as the cell (Fig. 1-B).
- (3) Spérms appeared to be floating rather loosely in the lumen in the Caput region while they appeared tightly clumped in the Corpus and Cauda.

(C) *Disposition of the muscular tissue* : Only a minimal amount of fibro-muscular tissue was seen in the Caput and Corpus regions. Small triangular or polygonal spaces between the adjacent ductules provide room for the blood vessels and some loose con-

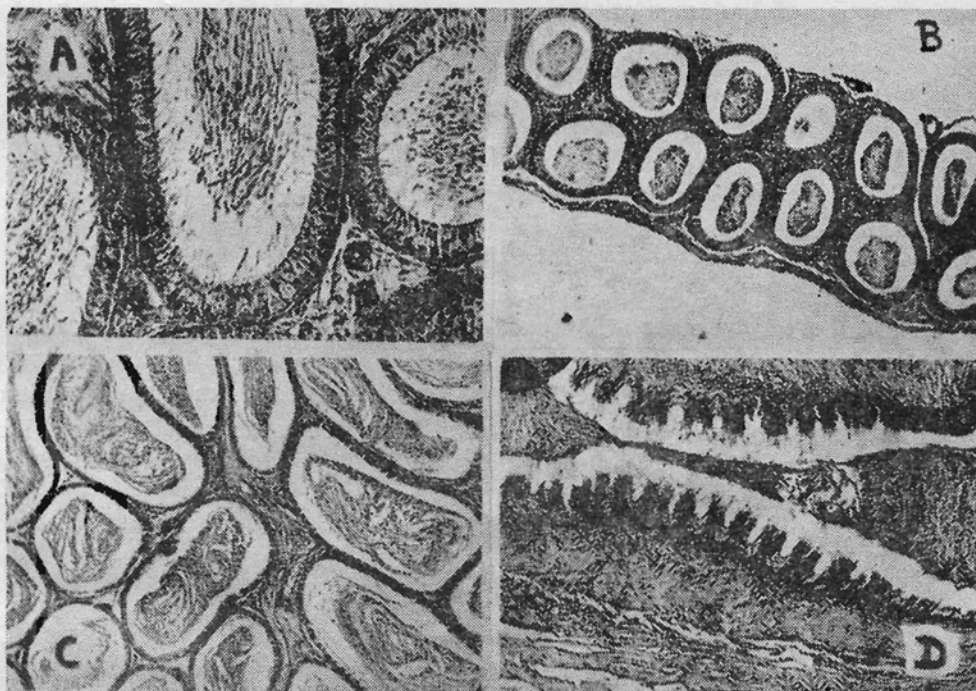


Fig. 1 : Microscopic sections taken from different regions of the rat epididymis, stained with hematoxylin-eosin : (A) Caput epididymis or head showing tall columnar cells with prominent stereocilia or microvilli. Some apical cells, with their nuclei placed close to the luminal border, are also seen. Fibromuscular tissue is minimal. (x 400). (B) The long and constricted Corpus showing only 2 narrow ductules lying side-by-side. The height of the epithelium has decreased markedly. (x 100). (C) Cauda epididymis showing increase in muscular tissue, low columnar epithelium and widening of the duct. Stereocilia have lost their prominence (x 100). (D) Section taken close to the vaso-epididymal junction. There is marked increase in the muscle around the duct, arranged in two layers. Although its contraction has produced narrowing of the lumen and festooning of the mucosa, no sphincter-like structure can be made out (x 100).

nective tissue. Obviously, a thin inconspicuous rim of plain muscle around the duct is all that is present in this part of the epididymis and cannot be expected to provide any powerful pumping action. In contrast to this, the Cauda showed a distinctive increase in the muscular tissue. A clear fibro-muscular wall now surrounded the duct and became more and more prominent as the distal end of the epididymis was approached. The disposition of the muscle was, however, mostly circular. The amount of interstitial tissue was also increased (Fig. 1-C and D).

Special attention was paid to the vaso-epididymal junction to see if any sphincter-like structure could be made out which would control the pressure gradient and flow between the epididymis and the vas deferens. Close to the junction, the muscle tissue gradually increased around the duct and clearly arranged itself into circular and longitudinal layers. The contractions of this powerful muscle coat produced a folding or festooning of the mucosa and marked constriction of the lumen at places (Fig 1-D). But no definite or structurally consistent sphincter-like aggregation of circular muscle could be found.

The capsule surrounding the epididymis as a whole did not suggest any regional differences and was uniformly made up of loose fibro-muscular tissue, giving rise at places to fibrous septa penetrating into the substance of the epididymis.

## DISCUSSION

Attempts have been made in the past to sub-divide the epididymis into as many as 18 different regions on the basis of cytological details, natural planes of cleavage and convolitional pattern (8). Nicander and Glover (15) had carried out similar studies, although they restricted the number of zones to 6 or 7. These numerous morphological divisions appear to be arbitrary and have little functional meaning. With a slight change in the criteria, new segmental patterns emerge. Such divisions can have hardly any practical utility, either for the physiologist studying functional organisation or for the surgeon operating on the epididymis.

In the present study, the 3 grossly visible components of the epididymis - Caput or head, Corpus or the middle-piece and Cauda or lower end - have each been found to possess a distinctive feature of its own. Thus, the Caput is characterised by a very tall columnar epithelium with equally prominent stereocilia, the Corpus is so constricted as to admit only 2 or 3 narrow ductules, and the Cauda has an abundance of muscular tissue. Transitional zones are, naturally, present in between. The columnar epithelium of the Caput, with cells as tall as 125  $\mu$  and prominent stereocilia or microvilli to increase the surface area, seem to be clearly adapted for an absorptive function. Crabo (2) has estimated that more than 90% of the fluid coming from the testis in the bull or boar is absorbed

in the epididymis. The paucity of muscle tissue perhaps makes the Caput epididymis a distensible low-pressure reservoir for accommodating the fluid coming from the testis. It then modifies the composition of this fluid by absorption and secretion. The apical cells seen mostly in the Caput region (Fig. 1-A) have been ascribed a secretory role and are the likely source of glycerylphosphoryl-choline (7). Extrapolating these facts to the human epididymis, we can find an explanation for the high failure rate when a vaso-epididymal anastomosis is performed for the treatment of sterility due to obstructive azoospermia. Even if the stoma created between the Caput epididymis and the vas deferens remains patent, only a trickle of sperms can be expected through it by over-flow. The Caput lacks enough muscle to produce a powerful pumping action and, therefore, normal sperm count and fertility are rarely achieved.

In contrast to the Caput, the epithelium of the Cauda or lower part of the epididymis is only about 40  $\mu$  tall with stereocilia not even half as tall as the cells. However, there is an abundance of muscle tissue around the widening duct. Obviously, the Cauda is adapted to work as a final store-house for sperms from where they could be rapidly pumped out during ejaculation. Unfortunately, a vaso-epididymal anastomosis here is technically less convenient and, more than that, it is too low down to circumvent any obstruction present within the epididymis.

Why is the Corpus or middle part of the epididymis so thin and long, not only in the rat but more or less in most other mammals as well? The fact that hardly 2 or 3 narrow ductules are seen in this region, abutting closely against each other, suggests that it may possibly serve to separate the functionally different upper and lower parts. In the absence of any valve or sphincter-like structure, the long and constricted Corpus may dampen any undue rise of pressure in the Caput when the muscular Cauda is contracting. This can have interesting implications in relation to the after effects of vasectomy as well. Johnson and Howards (9, 10) have meticulously measured the intra-tubular pressures in the testis and epididymis of guinea-pigs and hamsters. Two important conclusions have emerged. Firstly, there seems to be no continuous gradient of pressure between the seminiferous tubules and the vas. The fluid must, therefore, be moving forward by peristalsis from one limited area to another in spurts. Secondly, the rise of pressure in the Cauda after vasectomy is not communicated directly to the Caput and testis where the pressures remain essentially normal. It is likely then that the long and narrow Corpus acts as a functional valve, protecting the testis against any excessive back-pressure.

In this context, the over-all size relationship between the testis and the epididymis also assumes considerable significance. It is well known that experimental studies on the effects of vasectomy have yielded very conflicting results. Marked spermatogenic arrest has been described by some (6, 13, 16), while others have reported practically no

change (1, 14). Species variation has been brought in, amongst other things, to explain this discrepancy. But we can say more specifically now that the capacity of the testis to withstand the effects of vasectomy may be related, atleast in part, to the capacity of the epididymis in that particular species to accomodate and dispose of the fluid coming from the testis. Unfortunately, there is no data on the testis/epididymis size ratio in different species available to us for comparison. This aspect of the comparative physiology of the epididymis does require further study.

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