

THE VISCERAL HISTOLOGY OF THE SUMATRAN RHINOCEROS

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PLATES 11-14 AND FOUR TEXT-FIGURES

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SYNOPSIS

The histological structure is described, for the first time, of certain of the viscera of the Sumatran Rhinoceros (*Didermocerus sumatrensis*).

INTRODUCTION

THE extant Rhinocerotidæ are manifestly threatened with impending extinction, particularly two of the three Asian forms, viz. the Javan Rhinoceros (*Rhinoceros sondaicus*) and the Sumatran Rhinoceros (*Didermocerus sumatrensis*). The former, previously widespread throughout Bengal, Burma, Malaya, Indo-China, Sumatra, and Java, is today reduced to fewer than 50 individuals confined to the Udjong Kulon reserve in Java. The latter, encountered a century ago throughout Bengal, Assam, Burma, Siam, Indo-China, Malaya, Sumatra, and Borneo, is now reduced to an estimated 150 individuals restricted to some half-dozen reserves in Borneo, Malaya, and Sarawak. Relatively little is recorded concerning the non-skeletal morphology of these rare and vanishing forms, and specimens of either are most unlikely ever again to be seen in captivity. Hence the opportunity was seized of making histological examination of some at least of the viscera of an old female Sumatran Rhinoceros which died in the Basel Zoologischer Garten in September 1961. These organs were made available through the courtesy of Dr. L. Forcart, Curator of the Department of Zoology of the Basel Naturhistorisches Museum, wherein they, and the skeleton, are preserved. Dr. S. Lindt, of the Veterinär-pathologisches Institut of the University of Berne, most kindly provided various paraffin-blocked tissues secured in the fresh state during his meticulous necropsy of this animal. To both these gentlemen we tender the deepest appreciation of their prompt and generous co-operation. Though the beast in question was heavily diseased, we considered it desirable to elicit whatever histological information its organs might afford, since nothing on this subject has been recorded previously, the relevant literature (Garrod, 1873, 1878; Forbes, 1881; Beddard & Treves, 1889) being confined to considerations of gross morphology only.

MATERIAL AND METHODS

The paraffin-blocked tissues supplied by Dr. Lindt included material from the small gut, large gut, lung, liver, kidney, and adrenal; these were cut at 10 μ and the sections stained by hæmatoxylin and eosin and by hæmatoxylin and van Gieson. Formalin-fixed

material was later taken from the œsophagus, stomach, cæcum, thyroid, and thymus, and from the walls of the post-cava and the vena portæ; this tissue likewise was paraffin-blocked and cut at 10 μ , the sections being stained by hæmatoxylin and eosin, by hæmatoxylin and van Gieson and by orcein and van Gieson. Lymph nodes from various regions were also removed and studied, but the findings in their respect form the subject of another communication (Cave & Aumonier, 1962).

OBSERVATIONS

The œsophagus is a tube of striated muscle, lined throughout by a very loosely attached, longitudinally plicated mucosa, which presents (almost everywhere) a non-cornified stratified squamous epithelium and which is totally devoid of mucous glands. The average total thickness of its wall is 5 to 6 mm, of which the musculature accounts for 3 to 4 mm. The usual pericœsophageal musculature is present, i.e. delicate strands of œsophageal muscle which loosely bind the organ to the trachea, bronchus, pleura, and fibrous pericardium. The customary outer longitudinal and inner circular muscle layers are apparent, save in the anterior (juxta-pharyngeal) portion of the tube, where all the mural muscular fibres are circularly disposed. The two muscle coats are composed of striated muscle in both lower neck and thorax, but in and below the hiatus region an admixture of plain muscle occurs, the outer (longitudinal) coat being composed principally of unstriated fibres and the inner (circular) coat being a fairly equal mixture of striped and unstriated fibres (Pl. 13, fig. 2).

The mucosa is very loosely attached to the subjacent muscular wall. It displays a series of prominent, semi-permanent longitudinal folds and is covered throughout by stratified squamous epithelium. In the juxtapharyngeal œsophagus this epithelium is relatively thick and slightly cornified; in the remainder of the tube it is relatively thin and non-cornified.

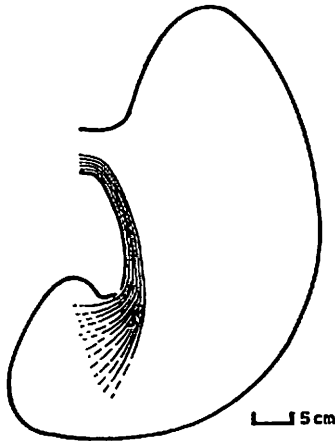
The muscularis mucosæ shows a curious regional variation: in the juxtapharyngeal œsophagus it is altogether wanting; it is poorly developed in the middle œsophagus but very well developed in the lower third of the organ.

Examination of sections from all portions of the œsophagus shows the expected mucous glands to be entirely wanting.

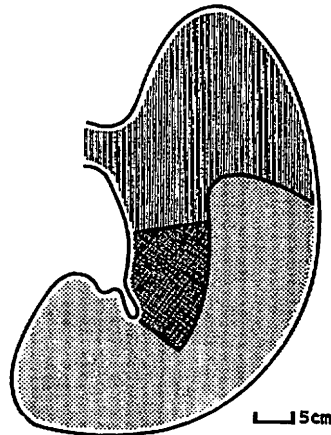
The stomach is a simple, globular sac with its œsophageal and pyloric extremities closely approximated and its relatively reduced lesser curvature characterized by a deep and permanent incisura angularis; its wall comprises the usual peritoneal, muscular, and mucosal layers. There is no fundal diverticulum as described by Garrod (1873). The peritoneal coat requires no special notice. The muscular coat is disposed in two layers, viz. an outer longitudinal and an inner circular. The latter is present uniformly throughout the stomach wall and is slightly augmented at the non-projectile pylorus. The outer muscular layer is more particularly arranged. Its fibres are concentrated along the lesser curvature, descending from their continuity with the œsophageal musculature towards the pylorus and rapidly assuming the disposition of two flat muscle bands, one on the ventral, the other on the dorsal, gastric surface. These bands, straddling the lesser curvature and the associated coronary blood-vessels, cross the incisura angularis, to fan out beyond this permanently infolded region of the stomach wall into the wall of the pyloric segment of the organ; they are readily recognizable macroscopically and are of the nature of permanent functional "ligaments" or slings, mechanically responsible for the deep incisura angularis whereat the entire stomach is kept longitudinally bent upon itself (text-fig. 1). Elsewhere the longitudinal layer forms an even, tenuous stratum, particularly recognizable

over the fundus, which thus does not present the arrangement of oblique muscle fibres described by Garrod (1873).

The gastric mucosa is divisible, macroscopically and microscopically, into three clearly distinct fields, (a) a first, comprising the fundus region and that portion of the gastric body adjoining the cranial moiety of the lesser curvature, (b) a second, embracing the remainder of the gastric body and the whole of the pyloric region, and (c) a third, confined to the ventral and dorsal gastric walls alongside the distal moiety of the lesser curvature and ceasing abruptly at the bottom of the incisura angularis (text-fig. 2, 3). The pale (whitish) mucosa of the first field presents a corrugated or a lace-like surface appearance, for it is composed of multiple, low, longitudinally-disposed plicæ, joined at regular intervals by intervening oblique and transverse folds. The darker-coloured mucosa of the second field was originally reddish in tint; it is even and velvety in appearance, and is totally devoid of plicæ or elevations of any kind. The mucosa of the third and smallest field resembles nothing so much as a patch of cobblestones, being a clearly demarcated area of



Text-fig. 1.—*Didermocerus*. Stomach outline, showing ventral longitudinal muscle sling.



Text-fig. 2.—*Didermocerus*. Stomach, longitudinally sectioned, showing the three mucosal fields.

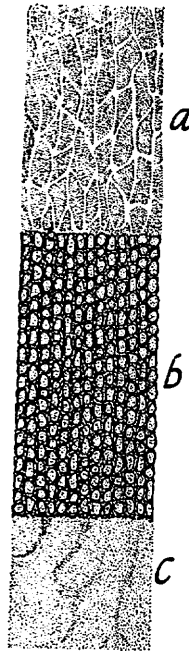
raised, relatively large, cornified papillæ, arranged in parallel longitudinal rows (text-fig. 3, C). This specialized "cobblestone" area straddles the distal moiety of the lesser curvature (for a distance of some 3 in.), extending therefrom ventrally and dorsally across the stomach wall for about 4 in. The more distal individual "cobblestone" papillæ are somewhat the larger.

Histologically the first (cardiac, proximal) mucosal field presents a heavily cornified stratified squamous epithelium, devoid everywhere of a recognizable stratum granulosum. The submucosal papillæ are long, finger-like projections which penetrate the mucosa so far surfacewards that their tips are separated from the stratum corneum by a cell-layer not more than two or three cells thick. They contain blood-filled capillary loops. The muscularis mucosæ is a single, longitudinally disposed and extremely thick layer. Glands of any variety are conspicuously absent (Pl. 11, fig. 1).

The second (pyloric, distal, secretory) mucosal field (which has suffered some post mortem change) shows a columnar epithelium and abundant glands of the customary

gastric type, represented in some instances by peptic cells or odd oxyntic cells only. These glands are the sole gastric glands present. The muscularis mucosæ, longitudinally disposed, is a single, thick, substantial stratum (Pl. 11, fig. 2; Pl. 12, fig. 1).

The third ("cobblestone") mucosal field (Pl. 12, fig. 2) presents a well preserved stratified squamous epithelium, devoid of any stratum granulosum, and so arranged as to present parallel linear series of large, obtrusive, exceedingly cornified surface papillæ. The submucosal papillæ, containing blood-vessels, project surfacewards through the mucosa almost to the stratum corneum, their apices being separated therefrom by two or three layers only of prickle cells. A single submucosal papilla averages some $800\ \mu$ from basement membrane towards a "cobblestone" papilla, and about $200\ \mu$ in the same diameter between adjacent "cobblestones". The smaller surface ("cobblestone") papillæ



Text-fig. 3.—*Didermocerus*. Macroscopic appearance of gastric mucosa (diagrammatic):
a = gastric field; b = "cobblestone" field; c = pyloric field.

measure some 3 mm in transverse diameter; the cornified layer on their summits varies from $100\ \mu$ to $150\ \mu$ in thickness.

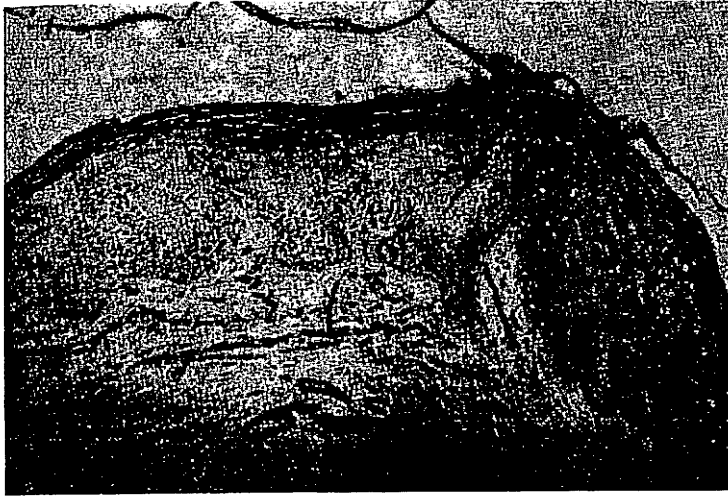
Immediately subjacent to their stratum corneum lies (in the absence of a stratum granulosum) a well preserved prickle-cell layer, showing large nuclei, abundant cytoplasm, and distinct cell outlines.

The muscularis mucosæ is longitudinally disposed and is extremely well developed. Between the basement membrane and the muscularis mucosæ is found much diffuse lymphoid tissue.

The intestine. The small intestine is characterized by well developed valvulæ conniventes throughout. Peyer's patches or other aggregations of lymphoid tissue are noticeably wanting. The customary outer longitudinal and inner circular muscle coats show no unusual feature. The mucosa bears a columnar epithelium, presenting an abundance of

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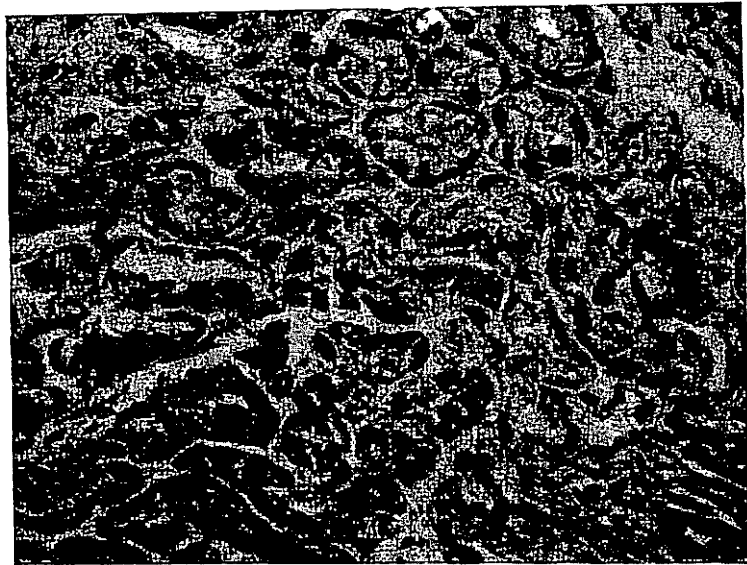
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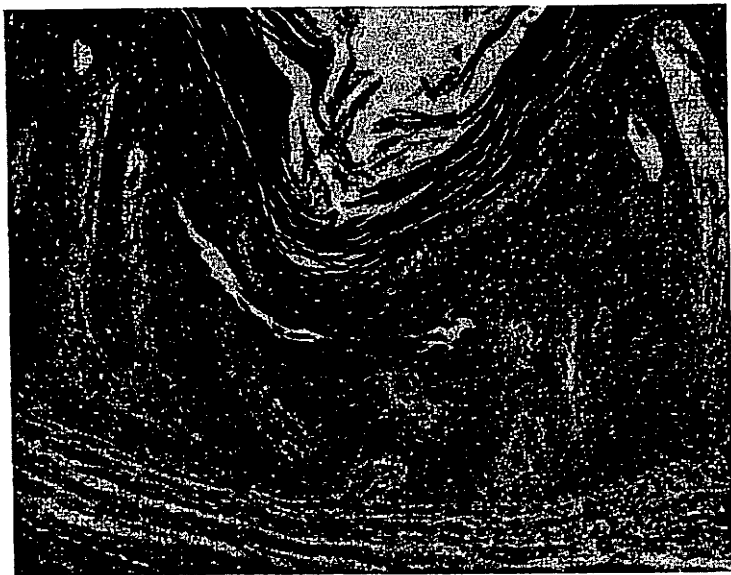
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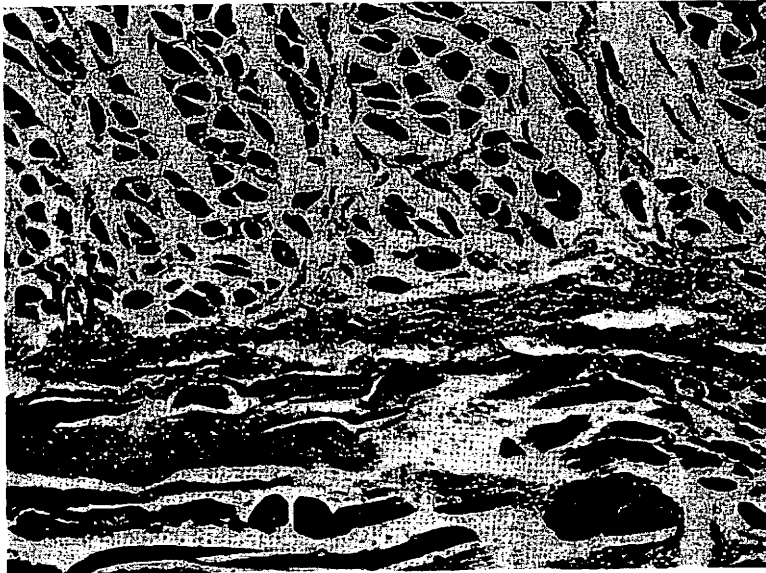
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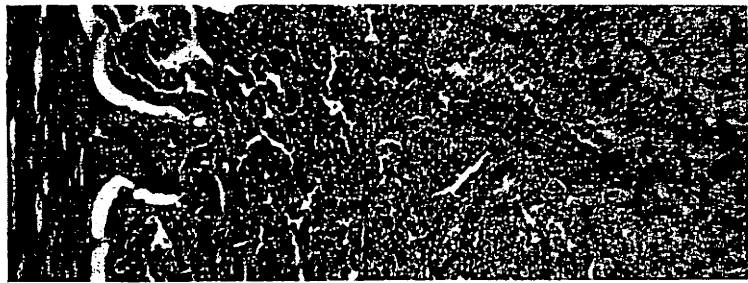
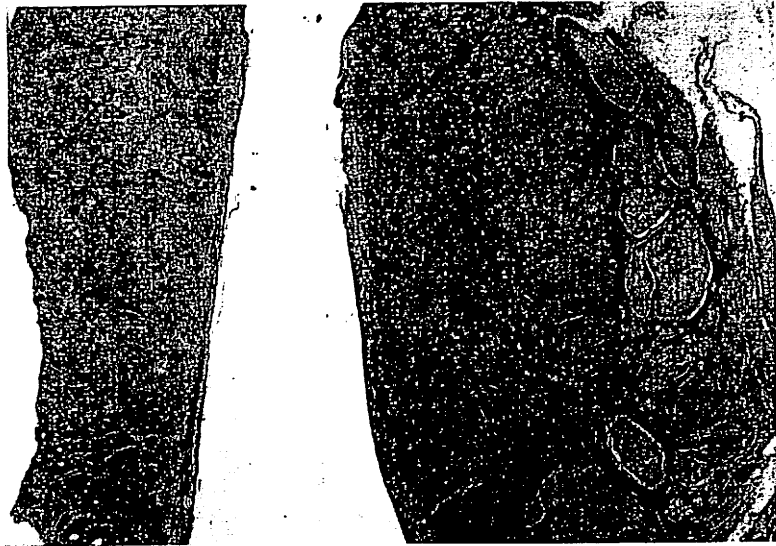
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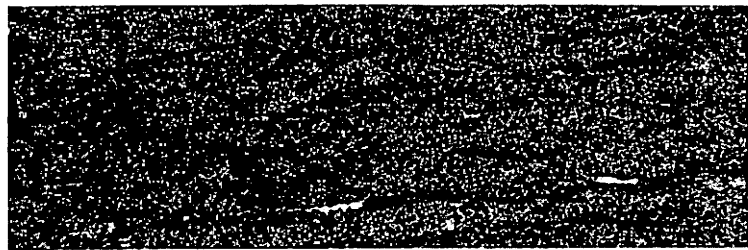
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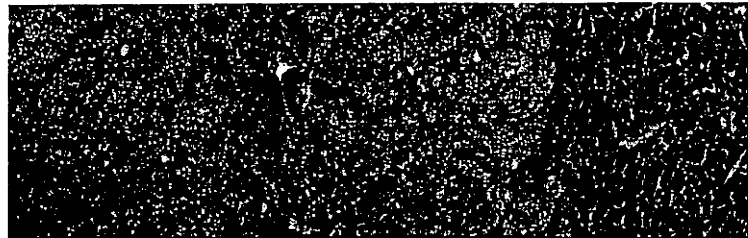
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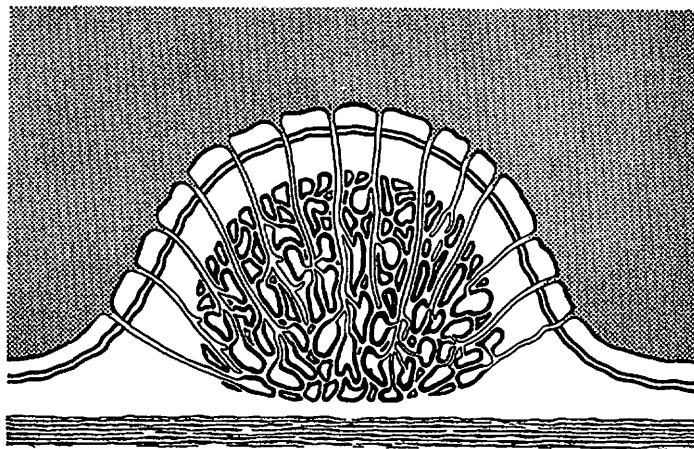
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Lieberkuhn crypts; goblet cells are plentiful and Auerbach's plexus is remarkably prominent in the several sections studied.

The colonic mucosa bears a columnar epithelium having a well-marked striated border and shows an abundance of well-preserved intestinal glands and goblet cells. The muscularis mucosæ is well developed and the outer longitudinal layer of muscle coat is relatively very thick.

The cæcum presents a feature of particular interest, viz. the presence *in vivo* of a sub-mucous aggregation of large mucous glands, associated with lymphoid tissue and representing perhaps an intestinal "tonsil".

Garrod (1873) in his specimen of *Didermocerus* had noted, within the cæcum and close to the ileo-cæcal orifice, "two closely-approximated, globose, apparently glandular masses, about the size of tangerine oranges", concerning which he gave no further particulars. From the medial wall of the cæcum of the present specimen Dr. Lindt had removed at necropsy a mass of tissue, recognizable macroscopically, which he interpreted as a "mucoid polyp", quite clearly the anatomical structure observed by Garrod.



Text-fig. 4.—*Didermocerus*. Diagrammatic reconstruction of cæcal organ.

Microscopical examination of the cæcal wall at the site of the excised "mucoid polyp" reveals the following histological features. The well-preserved cæcal mucosa has a columnar epithelium with plentiful glands of the ordinary colonic type; the muscularis mucosæ is well developed and takes the form of two distinct layers. The submucosa is relatively very thick and fat-laden; mucosa-wards it shows a multiplicity of ducts (as many as four such in a single high-power field) of salivary type, whose lining cells exhibit a brush border, and which are associated with a little lymphoid tissue. These ducts coming up from the submucosa pierce the mucosa to open on the epithelial surface: they are the persistent ducts of a relatively enormous glandular mass, now wanting, which must have occupied the entire submucosa and must have given rise by its mass to the macroscopic "mucoid" or "glandular" elevation upon the cæcal wall (Pl. 13, fig. 1). This cæcal aggregation of glands must obviously have produced relatively large quantities of a presumably watery mucus. Comparatively large nerve trunks and ganglia of Auerbach's plexus are prominent in the submucosa.

The liver is overmuch diseased for profitable histological study, but so far as can be

determined its structure presents no unusual feature. Many of the Kupffer cells are filled with hæmosiderin granules.

The lung likewise affords nothing of particular histological interest.

The kidney has a tough fibrous capsule, whence thickish, scattered septa, composed of fibrous tissue and plain muscle, proceed into the kidney substance and are responsible for the organ's coarsely-lobulated surface appearance. The renal excretory apparatus presents nothing histologically noteworthy and merely reflects the pathology of terminal disease.

The adrenal. The cortex is reasonably well preserved, the (incomplete) medulla rather less so. The thick external capsule is composed of white fibrous tissue admixed with scattered plain muscle fibres. Therefrom septa, of similar composition, proceed for various distances into the gland interior. Some of these run into the zona glomerulosa only, to stop short therein and to subdivide this zone into fairly uniform segments or compartments; others penetrate down to the fasciculata-reticularis junction, whence they cannot be traced further.

The internal (or perimedullary) capsule is discontinuous and is represented by detached strands of fibrous tissue admixed with plain muscle. The cortex shows a zona glomerulosa which is relatively thick in comparison with the zona fasciculata, but which is relatively poor in lipoid content. The zona fasciculata and the zona reticularis are both of relatively great thickness and each is extremely rich in lipoid content. The small amount of medulla available for examination shows evidence of a test-tube like arrangement of its cells.

The thyroid gland is exceedingly rich in blood-vessels. Its vesicles are surprisingly small (much smaller than those of *Homo*) and are separated by an abundance of connective tissue. In some vesicles the intra-vesicular colloid occurs as tightly-packed, rounded droplets, in others as an eosinophilic homogeneous substance.

The thymus gland, being that of an old animal, shows merely the histological evidence of involution. Its elaborate vasculature is thrown into the greater relief by the atrophy of its parenchyma, now mainly reduced to fat admixed with fibrous tissue. Some lymphoid tissue does remain, scanty in quantity and dense in appearance, and lacking any differentiation into the customary cortex and medulla. There is some evidence of a quondam attempted formation of secondary lymphoid nodules, such as occurs in lymph nodes. Hassall's corpuscles are nowhere detectable. Invasive fat cells are present throughout most of the surviving lymphoid tissue and the overall histological picture is one of the replacement of the thymic lymphoid tissue by fat. All the available histological evidence is strongly suggestive of the lymphatic nature of the thymus gland.

The post-cava. The ventral wall of the (cranial portion of the) post-cava is extremely thick and rigid (Pl. 14, fig. 1). The vessel is well preserved; the tunica intima is fairly compact and its endothelium persists; the tunica media is relatively thin and rather more diffuse, and contains some innermost longitudinal muscle fasciculi plus a little circularly disposed plain muscle. The tunica adventitia contains a relatively enormous mass of plain muscle, arranged in longitudinal fasciculi and abundantly provided with vasa vasorum, of which as many as six groups may be counted in a single low-power field. These longitudinal fasciculi of unstriped muscle are supported by an intervening mixture of collagen and elastic tissue (in about equal proportions) and the whole confers upon the caval ventral wall a remarkable degree of hardness and rigidity. The adventitial coat of the caval dorsal wall is not thus specialized.

The portal vein. In structure this vessel clearly resembles the post-cava. There is nothing noteworthy about its intima and media, but its tunica adventitia is everywhere a

relatively enormous mass of plain muscle. This mass is compounded of longitudinally arranged fasciculi, held in place by an intervening mixture of collagen and elastic tissue, though the elastic tissue component is here less plentiful than in the wall of the post-cava. The vena portæ wall is thus rendered relatively thick, firm, and unyielding.

DISCUSSION

The œsophagus of *Didermocerus* agrees most closely with those of *Equus* and *Sus* in manifesting unstriped muscle in the wall of its hiatal extremity. (In *Bos* and *Ovis* the œsophageal muscle is of the striated variety throughout.) Noteworthy is the progressive cranio-caudal development of the muscularis mucosæ. Most surprising, in view of the vegetarian diet, is the total absence of mucous glands.

The stomach, permanently flexed upon itself in its long axis by reason of its short lesser curvature and deep, permanent incisura angularis, exhibits in the reasonably distended condition neither the cardiac diverticulum described and figured by Garrod (1873) nor the pyloric "pouches" of other writers. Examination of the unfixed, empty organ would appear to have given rise to the notion of such sacculations as normal gastric features. That, functionally, temporary fundic and pyloric sacculations may manifest themselves *in vivo* is highly probable: but to term such impermanent appearances "diverticula" or "pouches" does violence to morphological terminology. The longitudinal gastric flexion and the correlated deep infolding of the lesser curvature at the incisura angularis is effected by a special arrangement of the longitudinal muscular coat, which is particularly augmented along the lesser curvature to form two flat, fascicular muscle bands, one on the ventral, the other on the dorsal, surface of the stomach. These two bands, bridging the incisura angularis and fanning out over the wall of the pyloric portion of the stomach, act as suspensory "ligaments" approximating the cardiac and the pyloric regions and they confer upon the stomach its characteristic shape. Such an arrangement, which has escaped previous notice, most probably obtains in other rhinoceros species, and Owen's (1862) casual reference to "a glistening aponeurotic sheet upon the anterior and posterior surfaces of the contracted pyloric end of the stomach" may be unwitting recognition of its existence in *Rhinoceros unicornis*.

The presence of a third, distinct, mucosal gastric field in *Didermocerus* is noteworthy, having been overlooked by Garrod (1873), who reported but two such fields (a cardiac cuticular and a pyloric secretory) in this genus; Owen (1862) in *Rhinoceros unicornis* and Beddard and Treves (1887) in *Rhinoceros sondaicus* also made no mention of any third mucosal field, although Owen (erroneously it would seem) reported "numerous follicles" in the distal portion of the cardiac field. It remains to be seen what the gastric mucosal picture shall prove in *Diceros* and *Ceratotherium*.

The "cobblestone" area of the *Didermocerus* stomach must be regarded as a specialized prolongation of the cardiac mucosal field, so disposed, in the narrowest portion of the organ, that its large and hard papillæ may abrade food material during its passage from the capacious cardiac receptive region to the capacious digestive pyloric region. Since the "cobblestone" area does not extend around the entire stomach wall in this intermediate region, it must be that local contraction of the circular muscular coat ensures the gastric contents being brought into the necessary direct contact therewith.

The inference is, therefore, that "milling" of gastric contents occurs not in the pyloric segment, but in this intermediate region—the distal portion of the gastric body.

The ileum of *Didermocerus* lacks Peyer's patches or other recognizable lymphoid

aggregations. Such patches are present in the ileum of *Rhinoceros unicornis* together with what Owen (1862) describes as a "conspicuous reticular patch" close to its termination. No information is available regarding possible lymphoid formations in the small gut of *Rhinoceros sondaicus*, *Diceros bicornis*, or *Ceratotherium simum*.

Both Garrod's (1873) specimen and the present Basel specimen provide unmistakable evidence of the occurrence in *Didermocerus* of a caecal aggregation of specialized submucous glands, responsible for a prominent macroscopic feature of the caecal wall and for the addition to the caecal contents of watery mucus in some quantity. Owen (1862) makes no mention of any corresponding structure in the caecum of *Rhinoceros unicornis*, neither do Beddard and Treves (1887) concerning the caecum of *Rhinoceros sondaicus*.

The adrenal gland of *Didermocerus* (Pl. 14, fig. 2) agrees in general histological structure with the adrenals of other rhinoceros forms studied (viz. *Rhinoceros unicornis*, *Diceros bicornis*), differing therefrom chiefly in the peculiarities of the septa radiating interiorly from the external capsule and possibly in the incompleteness of its internal (perimedullary) capsule. Its medulla appears somewhat more solid or collapsed than the adrenal medulla of an Indian Rhinoceros (*Rhinoceros unicornis*) examined and the whole gland seems to contain relatively less, though more diffusely disposed, connective tissue. Experience teaches however that the histological appearances of the adrenal medulla are very largely dependent upon the degree of its vascularity at the time of fixation, while conclusions drawn from but a single specimen of each species must remain wholly tentative.

The relatively enormous thickness and rigidity of the post-caval ventral wall of *Didermocerus* is likewise a noticeable feature in *Rhinoceros unicornis* and *Diceros bicornis*. It may well characterize the post-cava of other rhinoceros forms, and indeed of other mammals. Even in *Homo* the post-caval ventral wall is appreciably thicker than the dorsal. In all Eutheria the post-cava is very much a "fixed" vessel, tethered by its tributaries to the abdomino-pelvic parietes and incapable therefore of any appreciable lengthening and shortening. The ventral augmentation of the longitudinal muscle component of its adventitia would seem to be a provision against undesirable diminution of its lumen during increases of intra-abdominal pressure, the dorsal aspect of the cava being sufficiently protected by the vertebral column.

Similarly the vena portae is subject to considerable increase of intra-abdominal pressure. It receives no extrinsic support in its pre-hepatic course and stands in some danger of periodic collapse from external pressure. This would seem to be obviated by the device of an intrinsic support, provided by the specially thickened and rigid tunica adventitia and necessarily involving the entire extent of the vein wall.

REFERENCES

- BEDDARD, F. E. & TREVES, F. (1887).—On the anatomy of the Sondaic rhinoceros. *Trans. zool. Soc. Lond.*, 12, 183.
- , — (1889).—On the anatomy of *Rhinoceros sumatrensis*. *Proc. zool. Soc. Lond.*, 1889, 7.
- CAVE, A. J. E. & AUMONIER, F. J. (1962).—Lymph node structure in the Sumatran rhinoceros. *J.R. micr. Soc.*, 81, 73.
- FORBES, W. A. (1881).—On the male generative organs of the Sumatran rhinoceros. *Trans. zool. Soc. Lond.*, 11, 107.
- GARROD, A. H. (1873).—On the visceral anatomy of the Sumatran rhinoceros (*Ceratohinus sumatrensis*). *Proc. zool. Soc. Lond.*, 1873, 92.
- (1873).—On the brain of the Sumatran rhinoceros. *Trans. zool. Soc. Lond.*, 10, 411.
- OWEN, R. (1862).—On the anatomy of the Indian rhinoceros (*Rh. unicornis*). *Trans. zool. Soc. Lond.*, 4 (Art. 3), 31.

DESCRIPTION OF PLATES 11-14 (see after p. 32)

PLATE 11

- FIG. 1.—*Didermocerus*. Gastric (cardiac) epithelium. $\times 100$.
FIG. 2.—*Didermocerus*. Gastric (pyloric) epithelium. $\times 100$.

PLATE 12

- FIG. 1.—*Didermocerus*. Pyloric gland. $\times 500$.
FIG. 2.—*Didermocerus*. "Cobblestone" epithelium. $\times 100$.

PLATE 13

- FIG. 1.—*Didermocerus*. Cæcal wall, showing remains of submucosal glands. $\times 100$.
FIG. 2.—*Didermocerus*. Hiatal cesophagus, showing admixture of plain muscle. $\times 100$.

PLATE 14

- FIG. 1.—*Didermocerus*. Post-caval wall. $\times 100$.
FIG. 2.—*Didermocerus*. Adrenal, showing general structure:
a = capsule and zona glomerulosa; b = zona fasciculata; c = zona reticularis and medulla. $\times 100$.