A MORPHOLOGICAL NOTE ON THE INTESTINE OF THE BOUTU WITH EMPHASIS ON ITS LENGTH AND ILEO-COLIC TRANSITION COMPARED WITH OTHER PLATANISTIDS

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ABSTRACT

The intestine of the Boutu, *Inia geoffrensis* (body length 204 cm, female), was examined macroscopically and light microscopically. The intestine of the *Inia* examined was grossly divided into three portions: the small intestine, the smooth-walled portion, and the colon. The lengths of these parts were approximately 4150 cm, 80 cm, and 40 cm, respectively. The total intestinal length of the *Inia*, including the 5 cm long rectum and 3 cm long anal canal, was 4278 cm. Therefore, the intestine was nearly 21 times as long as the body length. In the interior of the small intestine, except for the proximal half of the duodenum, a single distinct longitudinal fold involving both the mucosa and submucosa could be seen. The smooth-walled portion was thicker than the small intestine, and had no fold, but its inner surface became flat and smooth. The colon, which had several longitudinal folds in its interior, was thinner than the smooth-walled portion in the initial one-third and thicker in the remaining portion. Histological differences between the small intestine and the smooth-walled portion and the colon could not be clearly distinguished in our specimen, except for the abundance of goblet cells in the latter two portions. The ileo-colic transition of the *Inia* observed was unclear and this region was compared with other kinds of platanistids.

INTRODUCTION

Morphological investigation of the internal organs, as well as of other body features, is very important in order to clarify the phylogenetic relationship among the fresh water dolphins of the family Platanistidae, *Platanista*, *Pontoporia*, *Lipotes*, and *Inia*. Concerning the morphology of the intestine, there are some observations previously reported on *Platanista* (Anderson, 1879; Slijper, 1962/1979; Takahashi and Yamasaki, 1972), *Pontoporia* (Burmeister, 1869; Yamasaki, Takahashi and Kamiya, 1975), *Lipotes* (Chen and Chen, 1975; Zhou and Li, 1981), and *Inia* (Zhou, Li and Pilleri, 1982). However, our morphological knowledge of the *Inia*'s intestine is still insufficient because the investigation by Zhou *et al.* (1982) treated only *Inia boliviensis*, and no detailed description on the intestine of *Inia geoffrensis* has so far been reported except for a partial reference to the morphology of the intestine (Yamasaki *et al.*, 1975). The present paper, as the second report on the morphological study

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of the digestive tract of *I. geoffrensis* (cf. Yamasaki and Kamiya, 1981, on the stomach), deals with the macroscopical characteristics of the intestine, some of which were not observed by Zhou *et al.* (1982) in *I. boliviensis*, and discusses the intestinal length and the ileo-colic transition as compared with other platanistids.

MATERIAL AND METHODS

The intestine of the Boutu (Amazonian dolphin), *Inia geoffrensis* (body length 204 cm, female) used for this study was provided by the Kamogawa Sea World, Chiba, Japan, after death from unidentified disease. The intestine taken from the abdominal cavity was preserved in 10% formalin solution and transported to our laboratory. After macroscopical observations, small pieces for the light microscopy were taken from several parts of the intestine, and were embedded in paraffin. Sections were stained with hematoxylin and eosin.

OBSERVATIONS (PLATE I AND II)

The intestine of *I. geoffrensis* was observed to be grossly divided into three portions: the small intestine, the colon, and the portion which was located between these two. The intermediate portion was thicker than the small intestine and was also characterized by its smooth interior. It was difficult to determine whether this portion belonged to the last part of the small intestine or the initial part of the large intestine; therefore, for convenience, we called it a " smooth-walled portion " of the intestine in this study.

The initial part of the small intestine, the duodenum, consisted of the duodenal ampulla and the duodenum proper. The former was continuous with the pyloric stomach with a small opening 2 mm in diameter. It was funnel-shaped, approximately 2.5 cm in diameter at the widest proximal part, about 3 cm in length, and continued to the duodenum proper. The hepato-pancreatic duct opened in the duodenal lumen about 9 cm away from the commencement of the duodenum proper and formed a distinct plica longitudinalis duodeni about 1.5 cm long and 0.6 cm wide. Although the border between the duodenum and the jejunum was unclear, and fairly difficult to determine, the length of the duodenum proper appeared to be roughly 20 cm. The small intestine, except for the proximal half of the duodenum, formed a number of coiled loops suspended by a broad mesentery, which was 7–12 cm in width. The small intestine was approximately 0.7–0.8 cm in diameter but in several parts there was a slight dilation, about 1 cm in diameter, extending over a length of about 5–10 cm. The length of the small intestine, from the initial part of the duodenum to the beginning of the smooth-walled portion, measured nearly 4,150 cm. No circular folds could be seen in the interior of any parts of the small intestine. The inner surface of the duodenal ampulla exhibited several folds, which might be not present in the living state, being slightly irregular; and at about 5 cm from the opening of the hepato-pancreatic duct one single distinct longitudinal fold began and continued throughout almost the whole interior of the

small intestine (Fig. 1). This single fold projected into the intestinal lumen beyond a half diameter of the lumen and was generally found on the antimesenteric border (Fig. 6). The fold became slightly smaller and irregular in the several dilated parts of the small intestine mentioned above, and also near the smooth-walled portion (Fig. 2). The smooth-walled portion of the intestine measured about 80 cm long. This portion, about 1 cm or more in diameter, was clearly thicker than the small intestine. The longitudinal folds could not be seen in this portion and the inner surface became flat and smooth (Fig. 3). However, from one to three short longitudinal folds, 2–5 cm long, were seen in some places of this portion. The smooth-walled portion formed an intestinal loop but its mesentery was shorter than in the small intestine. The vessels in the mesentery made an acade and many vasa recta reached the smooth-walled portion as seen in the small intestine, though this pattern tended to become irregular in the distal part. The last part of this portion ran upwards and flexed dorsal, and continued to the next colon.

The colon descended straightly and continued to the rectum. The mesentery of the colon was short, about 5–6 cm wide, and gradually reduced in width analwards, disappearing in the anal part. The initial one-third of the colon was somewhat thinner than the smooth-walled portion, with a width of approximately 1 cm or less, and the last two-thirds became thicker, being about 1.5 cm in diameter. In the interior of the colon there could be seen from two to five distinct folds running longitudinally (Fig. 4), which became more marked in the last two-thirds (Fig. 5). These folds were broader than those in the small intestine. Most folds continued throughout the entire length of the colon, but short ones, 2–3 cm long, were present in some places. The colon was approximately 40 cm long, and the rectum and the anal canal were 5 cm and 3 cm long, respectively.

The thickness of the mucosa of the duodenal ampulla was 0.6–0.7 mm, and that of the rest was slightly thinner, being 0.4–0.5 mm in thickness. Since the specimen observed was in poor condition for histological examinations, typical villi could not be clearly observed in the small intestine (Fig. 7) and it could not be determined whether villi were present or not in the smooth-walled portion (Fig. 8). Intestinal glands were mucous in the duodenal ampulla. Those of the rest of the intestine morphologically resembled each other. But the glands of the smooth-walled portion and colon showed some tertuous courses and goblet cells became abundant, especially in the bottom of the glands (Figs 8–10). Musclaris of the whole intestine, consisting of thick inner circular and thin outer longitudinal layers, was 0.3–0.5 mm thick in the small intestine (Fig. 6) and smooth-walled portion, and 0.5–0.8 mm thick in the colon. The inner muscular layer was 4–5 times as thick as the outer one. The sphincteric structure could not be seen at either the border between the small intestine and the smooth-walled portion or between this portion and the colon. The folds observed in the whole intestinal tract involved both the mucosa and the submucosa (Fig. 6). Some accumulations of lymphoid tissue were found in the lamina propria of the colon but well-developed lymphatic nodules could not be seen in any portion of the intestinal tract of the observed

specimen.

DISCUSSION

The total length of the whole intestine of the *I. geoffrensis* (body length 204 cm) was 4,278 cm; thus the ratio of the intestinal length to the body length is nearly 21 to 1. This agrees well with the ratios, 19 and 20 to 1, obtained in *I. boliviensis* (body lengths 145 cm and 174 cm, respectively, Zhou *et al.*, 1982). The ratios in other fresh water dolphins reported by previous investigators are shown in Table 1*. *Platanista*'s ratio is notably low and *Pontoporia*'s is higher by far than that of other dolphins. Since there appears to be a tendency for the intestinal length to increase with age in our collected specimens of *Platanista* and *Pontoporia* (cf. Takahashi and Yamasaki, 1972; Yamasaki *et al.*, 1975), the ratio becomes slightly higher when specimens are limited to adults.

TABLE 1. THE RATIO OF THE INTESTINAL LENGTH TO THE BODY LENGTH IN PLATANISTIDS

Species	Ratio	Authors and Remarks
Inia		
boliviensis	19.0–20.0	Zhou *et al.* (1982)
geoffrensis	21.0	Yamasaki *et al.* (1975) and present study (1983)
Platanista		
gangetica	4.1–4.4	Anderson (1879)
	7.3	Slijper (1962/1979), no descriptions on the length of body and intestine
	3.6–4.9	Takahashi & Yamasaki (1972)
Pontoporia		
blainvillei	32.0	Burmeister (1869)
	24.0–37.0	Yamasaki *et al.* (1975), examined in unfixed state in most cases
Lipotes		
vexillifer	15.0	Chen & Chen (1975), ratio of whole length of the digestive tract, from mouth to anus, to the body length
	12.5–14.9	Zhou & Li (1981)

In the small intestine of the *Inia* observed there are no circular folds, but a single distinct longitudinal fold projecting into its lumen can be seen as in *Pontoporia* (Yamasaki *et al.*, 1975). Although Zhou *et al.* (1982) did not mention this fold in *I. boliviensis*, the fold in *I. geoffrensis* is plainly visible as a permanent structure and can also be easily felt through the wall of the intestine when the intestine is grasped between the fingers. In *Platanista*, well-developed circular folds are present on the inner surface of the small intestine but the surface of about the last 50 cm of the ileum becomes flat and smooth, and a distinct longitudinal fold, about 30 cm long, is present at this portion (Takahashi and Yamasaki, 1972). The presence of the circular or longitudinal folds in the small intestine is due to the struc-

* The ratios of *Platanista*, *Pontoporia*, and *Inia* misquoted in our previous paper (1981) are corrected as shown in Table 1.

tural specializations that serve to increase the area of the surface exposed to the lumen. It is assumed that numerous well-developed circular folds are a much more effective means of augmenting the surface area of the mucosa than a single longitudinal fold. This fact may have some relation to the short intestine of *Platanista* and to the long intestine of *Inia* and *Pontoporia*. In the reports of the intestine of *Lipotes* (Chen and Chen, 1975; Zhou and Li, 1981) there are no macroscopical descriptions of its internal structure, and therefore it is unclear whether *Lipotes*' intestine has such longitudinal folds or not.

In cetaceans it is generally known that there is no clear external transition between the small and the large intestines; except for *Platanista* and mysticetes which have a short caecum. In *Pontoporia* the external appearance of the transition between the small and the large intestines was not so difficult to determine because of the differences in thickness, the supply of the mesenteric vessels, and the interior equipped with a single longitudinal fold in the small intestine while there were two folds in the large intestine (Yamasaki *et al.*, 1975). However, in the case of our *Inia*, it was very difficult to determine the transition between the small and the large intestines. In the smooth-walled portion the single longitudinal fold disappears and the inner surface becomes flat and smooth. Nevertheless, the pattern of the blood supply, the vasa recta, seen in the small intestine was observed until the distal part of the smooth-walled portion. Since our specimen was, unfortunately, in poor condition for histological examination, neither the presence of typical villi, which is one of the most important characteristic features of the small intestine, nor the disappearance of the villi in the large intestine could be observed. In addition, other histological findings generally found in each small and large intestine in mammals in general could not be observed, so that we did not confirm the transition region from the small to the large intestine. However, goblet cells of the intestinal glands of our *Inia* were abundantly observed in the smooth-walled portion and the colon, unlike in the small intestine. This distribution of the goblet cells in the smooth-walled portion and colon in *Inia* appears to correspond well to that in the ascending and descending colons in *Pontoporia*.

Zhou *et al.* (1982) did not mention this smooth-walled portion, and they considered the colon to be only the portion, about 35 cm long, which ran caudally connecting with the rectum, and they described the presence of villi in the small intestine. The length of the large intestine of *Pontoporia* was 80 cm or more (Yamasaki *et al.*, 1975) and in *Lipotes* it is about 100 cm (Zhou and Li, 1981). As the structure of the intestine of our *Inia* resembles that of *Pontoporia*, and probably *Lipotes*, rather than that of *Platanista*, the 35 cm long colon of *I. boliviensis* seems to be proportionally too short. Although in our previous paper (Yamasaki *et al.*, 1975) the smooth-walled portion was considered as ascending colon, there are no conclusive characteristics to determine whether the smooth-walled portion belongs to the small or the large intestines, as is discussed in this study. In order to clarify the subject of the ileo-colic transition, it is necessary to investigate cetacean species having no caecum from comparative morphological viewpoints.

Zhou *et al.* (1982) observed no goblet cells in the intestinal glands in *I. bolivi-*

ensis and also stated that this is one of the characters common to *Inia* and *Platanista*. We found abundant goblet cells in *I. geoffrensis*, as in *Pontoporia* and *Lipotes* (cf. Yamasaki *et al.*, 1975; Zhou and Li, 1981). Though present, the cells were much less abundant in *Platanista* (Takahashi and Yamasaki, 1972). Therefore, the absence of the goblet cells may be peculiar to *I. boliviensis* among the fresh water dolphins previously reported.

Although well-developed lymphatic nodules in the lamina propria were present from the last part of the ileum to the initial part of the colon in *Platanista* (Takahashi and Yamasaki, 1972) and in *Pontoporia* (Yamasaki *et al.*, 1975), development of lymphatic tissues of the intestinal tract was very poor in our *Inia*. Zhou *et al.* (1982) described numerous lymphatic nodules aggregating from the last part of the ileum (probably corresponding to the last part of the smooth-walled portion in our case) to the anal part, and well-developed anal tonsils. Since the anal tonsils in our *Inia* were poorly developed (Yamasaki, Komatsu and Kamiya, 1977), poorly developed lymphatic tissue in the intestinal tract seems due to individual characteristics; well-developed lymphatic nodules could not be seen anywhere in the intestinal tract.

Pilleri and Gihr (1977, 1980) and Pilleri, Marcussi and Pilleri (1982) stated that there were clear morphological and morphometric differences between the Bolivian and Amazonian *Inia*, based on the observations of their brains and teeth. The stomachs of both *I. geoffrensis* and *I. boliviensis* quite resemble each other in structure (cf. Yamasaki and Kamiya, 1981; Zhou *et al.*, 1982). However, as mentioned above, there are some remarkable macroscopical differences in their intestines. It remains a problem whether such differences in the intestine were interspecific or not, because the present observations on *Inia* were based on one case. Therefore, further observations of this subject, based on the sufficient materials, should be done in order to compare with each other.

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REFERENCES

ANDERSON, J., 1879. *Anatomical and zoological researches: comprising an account of the zoological results of the two expeditions to Western Yunnan 1869 and 1875; and a monograph of the two cetacean genera, Platanista and Orcella.* 2 vols. Qurritch, London.

BURMEISTER, H., 1869. *Pontoporia blainvillii* Gray. *In: Descripción de cuatro especies de delfinides de la costa Argentina en el Océano Atlántico. Anal. Mus. Público Buenos Aires*, 1: 384–445.

CHEN, I. and W. CHEN, 1975. Notes on some morphological and anatomical features of the white-flag dolphin, *Lipotes vexillifer*. *Acta Hydrobiol. Sinica*, 5: 360–368. (in Chinese with English summary).

PILLERI, G. and M. GIHR, 1977. Observations on the Bolivian (*Inia boliviensis* d'ORBIGNY, 1834) and the Amazonian Bufeo (*Inia geoffrensis* de BLAINVILLE, 1817) with description of a new subspecies (*Inia geoffrensis humboldtiana*). *Investigations on cetacea* 8: 11–76.

PILLERI, G. and M. GIHR, 1980. Checklist of the cetacean genera *Platanista, Inia, Lipotes, Pontoporia, Sousa*

and *Neophocaena*. *Investigations on cetacea*, 11: 33–36.

PILLERI, G., G. MARCUZZI and O. PILLERI, 1982. Speciation in the Platanistoidea. Systematic, zoogeographical and ecological observations on recent species. *Investigations on cetacea*, 14: 15–46.

SLIJPER, E. J., 1962/1979. *Whales*. Hutchinson, London. (English translation).

TAKAHASH., K. and F. YAMASAKI, 1972. Digestive tract of Ganges dolphin, *Platanista gangetica*. II. small and large intestines. *Okajimas Fol. anat. jap.*, 48: 427–452.

YAMASAKI, F., K. TAKAHASHI and T. KAMIYA, 1975. Digestive tract of La Plata dolphin, *Pontoporia blainvillei*. II. small and large intestines. *Okajimas Fol. anat. jap.*, 52: 1–26.

YAMASAKI, F., S. KOMATSU and T. KAMIYA, 1977. A comparative morphology of anal tonsils in Platanistidae. *Sci. Rep. Whales Res. Inst.*, 29: 95–100.

YAMASAKI, F. and T. KAMIYA, 1981. The stomach of the Boutu, *Inia geoffrensis:* comparison with those of other platanistids. *Sci. Rep. Whales Res. Inst.*, 33: 69–81.

ZHOU, K. and Y. LI, 1981. On the intestine of the Baiji, *Lipotes vexillifer*. *Acta Zool. Sinica*, 27: 248–253. (in Chinese with English summary).

ZHOU, K., Y. LI and G. PILLERI, 1982. The digestive tract of *Inia boliviensis* (D'ORBIGNY, 1834). *Investigations on cetacea*, 13: 125–133.

EXPLANATION OF PLATES

PLATES I AND II

Inner views of several parts of the intestine of *Inia geoffrensis* (1–5). The intestine is opened wide to show its interior at the mesenteric border. Figs 1–5, actual size.

Fig. 1. Inner surface of the ileum at about 5 m proximal to the smooth-walled portion. Note that a single distinct longitudinal fold can be seen and no circular folds are present in the small intestine.

Fig. 2. The transitional part between the small intestine (left) and the smooth-walled portion (right). The longitudinal fold becomes slightly irregular in the last part of the small intestine and the inner surface becomes smooth in the smooth-walled portion.

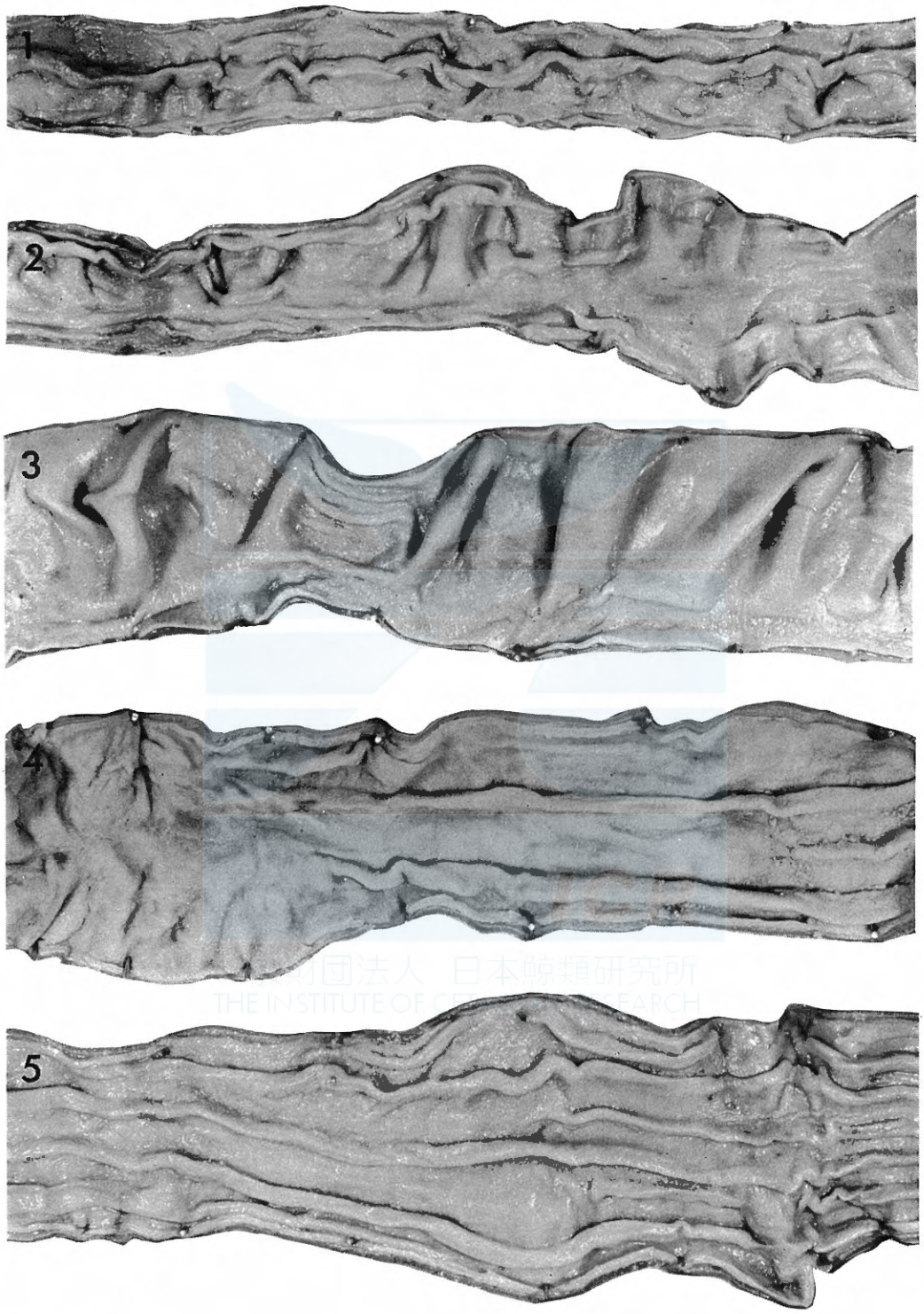
Fig. 3. Mid-part of the smooth-walled portion, which is thicker than the small intestine. Short longitudinal folds are seen in some places in this portion.

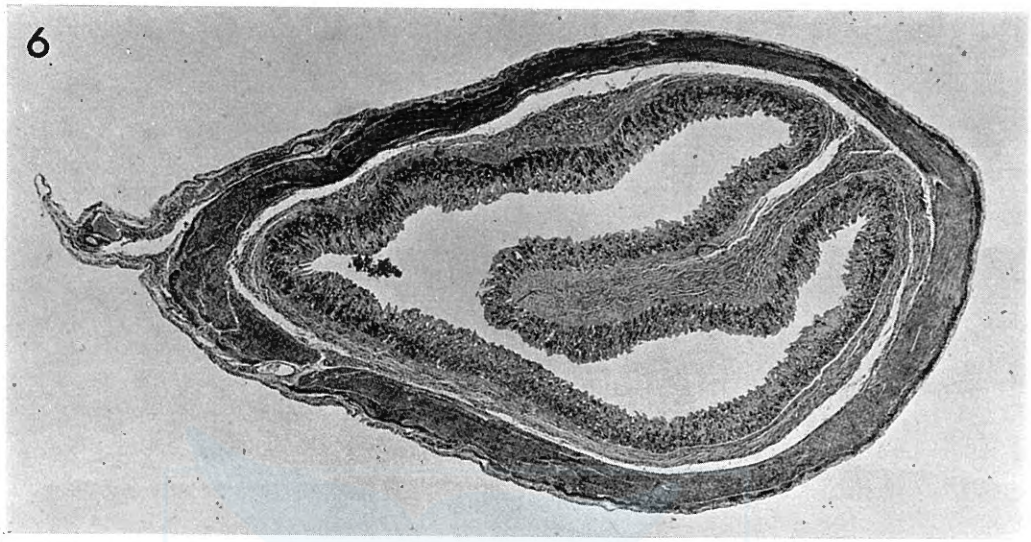
Fig. 4. The last part of the smooth-walled portion (left) and the initial part of the colon (right). Two or three longitudinal folds are present in the initial part of the colon.

Fig. 5. Mid-part of the colon. Marked longitudinal folds can be seen in the surface.

Fig. 6. Cross section of the mid-part of the small intestine. A prominent longitudinal fold, involving both the mucosa and the submucosa, projects into the lumen from near the antimesenteric borders. ×11.

Fig. 7–10. Same magnification photomicrographs of the mucosa of the several parts of the intestinal tract. ×10. Mid-part of the small intestine (Fig. 7), mid-part of the smooth-walled portion (Fig. 8), initial part of the colon (Fig. 9), and mid-part of the colon (Fig. 10). Typical villi could not be seen in the small intestine in our specimen. The intestinal glands of the small and the large intestines are rather straight. Goblet cells become abundant in the smooth-walled portion and the colon.

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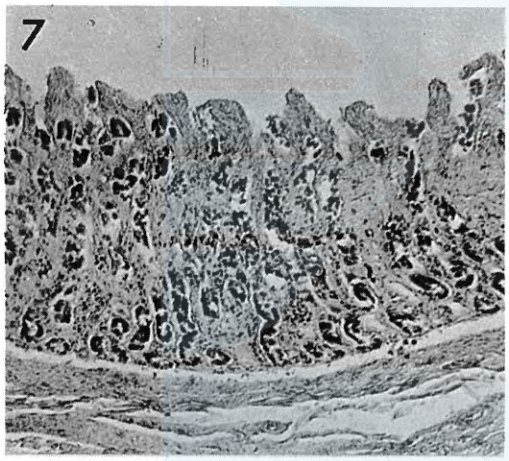
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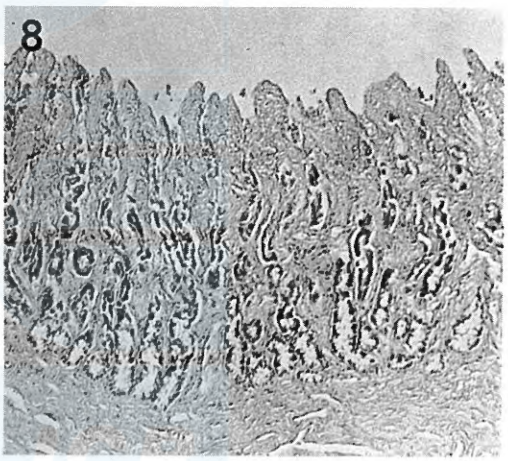
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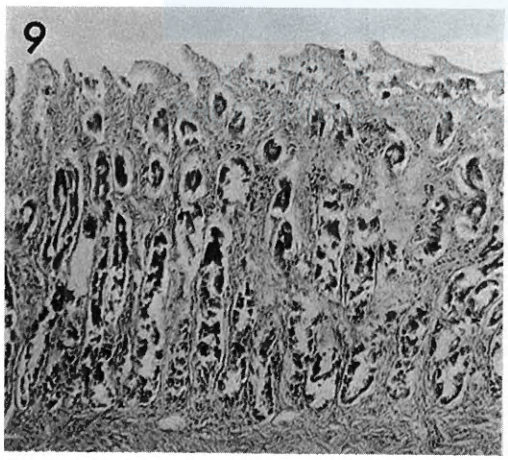
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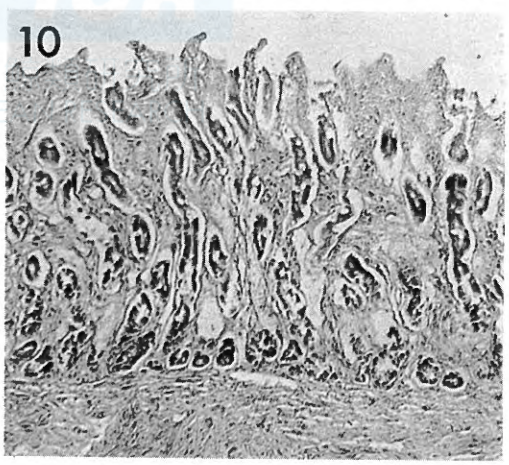
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