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SHORT COMMUNICATION

The macroscopic intestinal anatomy of a lowland tapir (*Tapirus terrestris*)

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Abstract Tapirs are the only group among the perissodactyls for which no recent description of the gastrointestinal tract (GIT) exists. Historical depictions of the GIT of tapirs suggest a similarity to the GIT of equids, but do not resolve the question whether the isthmus at the caeco-colical junction, and at the transition from the proximal colon to the colon transversum—both evident in horses—occur in tapirs as well. Here, we describe the macroscopic anatomy of the GIT of a captive, adult lowland tapir (*Tapirus terrestris*). While similar to equids in terms of the overall design and, in particular, the two mentioned isthmuses, the proximal colon of the tapir appeared less pronounced than in other perissodactyls, resulting in a GIT in which the caecum appeared as the most voluminous fermentation chamber. This finding is supported by the particular location of the ileo-caecal junction, which does not visibly separate the caecum from the colon, or the caecum head from the caecum body, but enters the caecum body in its upper third.

Keywords Digestive anatomy · Intestine · Caecum · Fermentation chamber · Perissodactyl

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Introduction

Tapirs are members of the order Perissodactyla, and thus the closest extant relatives to equids and rhinoceroses. Their digestive tract reportedly resembles that of horses (Kuehn 1986), and it has been suggested that the domestic horse should be used as a model animal when designing diets for captive tapirs (Oftedal et al. 1996). Free-ranging tapirs feed on browse and fibrous fruit (literature compiled e.g. in Clauss et al. 2008a; reviewed in Chalukian et al. 2013), and diets recommended for captive tapirs consist of roughage (mostly lucerne hay), a high-fibre pelleted food, and browse (Lintzenich and Ward 1997; Janssen 2003; Mangini et al. 2012). But in spite of these recommendations, captive tapirs often receive diets with high proportions of commercial fruits and easily digestible components (Wilson and Wilson 1973; Clauss et al. 2008a, 2009; Edwards 2013).

One practical reason for this discrepancy might be the reluctance of tapirs to ingest roughages, in particular grass hay (Foose 1982). This reluctance might be due to a peculiarity of the dental design of tapirs, which may not allow them to chew forages that are different from their natural diet efficiently (Hummel et al. 2008). Another reason might be that regardless of the theoretical recommendations and the related similarity with horses, the lack of accessible visualisations of digestive anatomy makes an intuitive understanding of such recommendations more difficult, in contrast to other herbivores for which there is plenty of corresponding information (e.g. in the large compilation of Stevens and Hume 1995; or in individual studies such as Clauss et al. 2007; Schwarm et al. 2010). Therefore, one aim of this communication is to provide a graphic depiction of the gastrointestinal tract of tapirs, in order to facilitate an easy, visual comparison with other herbivores.

Additionally, there is an open question in tapir macroscopic digestive anatomy. A general similarity with horses—with respect to a large caecum and proximal colon as fermentation chambers—has been stated (Mitchell 1903-6; Kuehn 1986). Nevertheless, it remains unknown whether tapirs are more similar to horses or to rhinoceroses with respect to distinct changes in gut diameter. Equids have two distinct narrow points (isthmus): one between the caecum head and the proximal colon, and one between the voluminous second flexure of the proximal colon and the colon transversum (Clauss et al. 2008b). These features are absent in rhinoceroses (Clauss et al. 2008b). Clauss et al. (2008b) mentioned that existing information on tapirs is equivocal in this respect, with available graphical representations either suggesting an isthmus at the caeco-colical junction giving no information on the intracolonic transition (Fig. 1a), indicating no isthmus (Fig. 1b, d), or indicating the presence of both isthmuses in text (Home 1821) or visualisation (Fig. 1c). In horses, these isthmuses are associated with obstruction colic (e.g. Decker et al. 1975; Campbell et al. 1984). Therefore, these locations received special attention during dissection.

Methods

A 6-year-old male lowland tapir (*Tapirus terrestris*) of a zoo collection was euthanized because it showed neurological signs which progressively deteriorated, resulting in a poor prognosis. Food intake prior to euthanasia was not impaired. The animal was immediately dissected for a thorough pathological examination, and was judged to have been in a good body condition at death. Neither macroscopic nor microscopic morphological changes that explained the clinical findings could be detected. The gastrointestinal tract (GIT) appeared well-filled, and the histology of the gastrointestinal tract revealed physiologic architecture of mucosa and gastric and intestinal walls without evidence for pathological lesions. The body mass of the fresh carcass was 185 kg. The entire GIT was removed and frozen after samples for histological examination had been taken without relevant losses of gut contents. The GIT was later defrosted, the mesenteria were removed, and length measurements were taken as well as

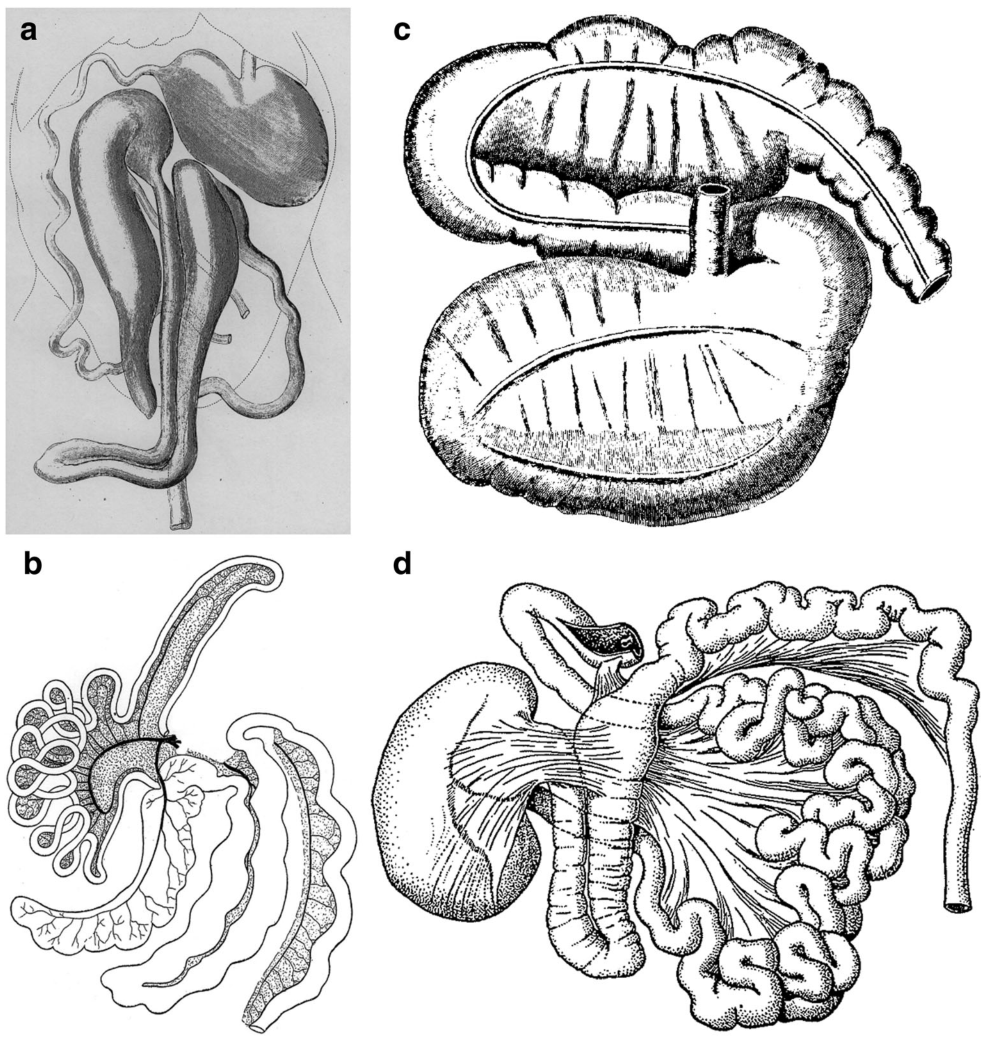

Fig. 1 Historical depictions of tapir gastrointestinal anatomy. **a** *Tapirus indicus* (from Home 1814), **b** *T. terrestris* (from Mitchell 1903-6), **c** *T. indicus* (from Parker 1882), **d** *T. indicus* (from Lönnberg 1910)

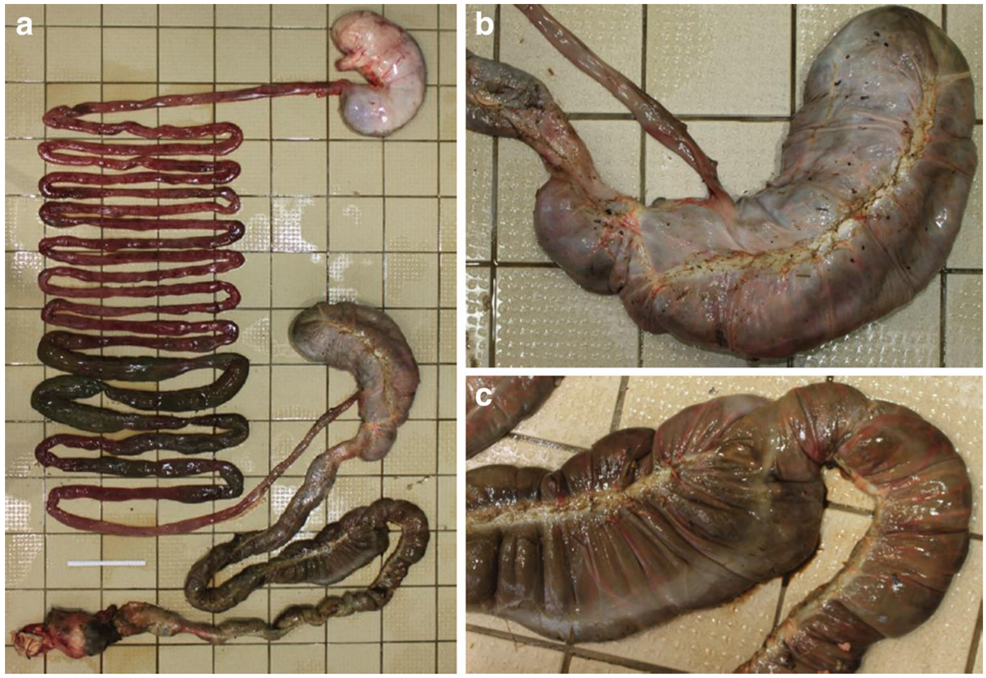

Fig. 2 Gastrointestinal tract of a 6-year-old lowland tapir (*Tapirus terrestris*). **a** Overview. **b** Caecum; note that the ileum joins the caecum not at the caecum head but at a lower position in the caecum body similar to the depiction in Fig. 1a. **c** Transition from the dorsal layer of the proximal colon to the colon transversum. The white scale bar represents 20 cm

photographs. Subsequently, the masses of the major individual gut sections were taken before and after emptying to record organ as well as content mass. No abnormalities (such as fibrous bezoars or sand) were detected in the GIT contents.

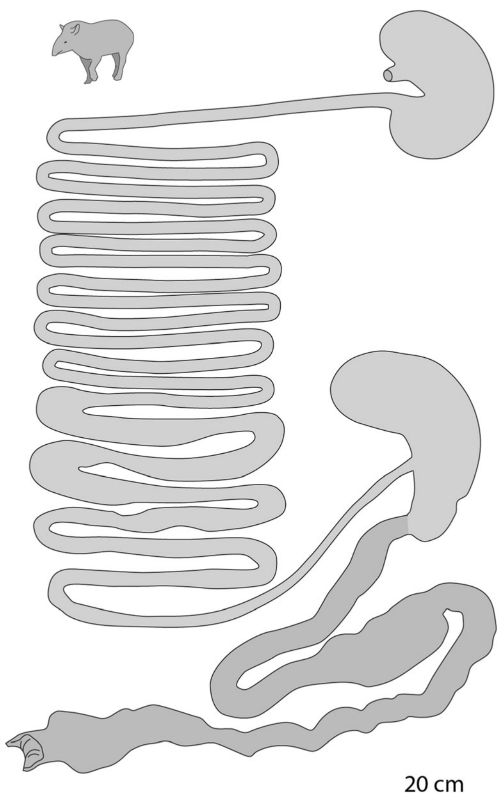

Fig. 3 Scheme of the gastrointestinal tract of the lowland tapir (*Tapirus terrestris*) for comparative representations. Drawing by Jeanne Peter

Results and discussion

The digestive tract of the tapir (Figs. 2 and 3) roughly resembles that of equids (Clauss et al. 2008b) or rhinoceroses (Stevens and Hume 1995). However, in both the horse and the rhinoceros, the caecum and colon have approximately the same width. In contrast, the tapir also has a large caecum, but the rest of the large intestine—in particular, the ventral proximal colon—appears less voluminous. The caecum has, next to the apparent caeco-colical junction, a structure that appears slightly separate from the caecum body, similar to the caecum head of equids. The ilio-caecal junction seems to be more distant from the caeco-colic junction than in horses or rhinoceros (Stevens and Hume 1995; Clauss et al. 2008b); the visual appearance is that the ileum does not join the caecum at the caeco-colic transition or at the transition between the caecum body and the caecum head, but between the first and second quarter of the caecum body. A historical graphical depiction of a Malayan tapir (Fig. 1a) indicates a similar disposition. The length measurement of the caecum (Table 1), therefore, does not represent the distance between the ileo-caecal junction to the caecum tip, but the length from the caecum tip to what appeared visually as the isthmus at the caeco-colic junction (Fig. 2b). This may be the reason why the length of the caecum measured in our study was higher than previously reported in the literature for tapirs (Table 1). A second isthmus can be found between the second flexure of the proximal colon and the colon transversum (Fig. 2c).

Equids also possess these two narrow points. It was speculated that they facilitate a more thorough fermentative digestion by selective coarse particle retention at the caeco-colical

Table 1 Measurements of the gastrointestinal tract of a 6-year-old male lowland tapir (*Tapirus terrestris*) in comparison with historical tapir GIT measures and measures in other perissodactyls

	Tapirus terrestris (this study)	[a]	*Tapirus indicus*[b]	*Equus f. przewalskii*[c]/ *E. caballus*[d]	*Diceros bicornis*[d]	*Ceratotherium simum*[d]
Body mass (kg)	185			252		
Length (cm); (% of total intestine)						
Small intestine	1435 (81 %)	1100–1372 (78 %)	1140–2103	1478 (69 %)	800–1200 (67 %)	1380 (61 %)
Caecum	62 (4 %)	>30–38 (1 %)	30–37	92 (4 %)	70–110 (7 %)	80 (4 %)
Ansa proximalis coli	124 (7 %)	274 (21 %)	342–594	306 (15 %)	290–490 (26 %)	720 (32 %)
Distal colon and rectum	146 (8 %)			261 (12 %)		
Width (cm)						
Ileum	4			5		
Caeco-colical isthmus	5			5		
Proximal colon	9					
Mass (kg); (contents; contents % total contents)						
Stomach	1.19 (1.83; 17 %)			(12 %)	(21 %)	
Small intestine	1.59 (1.40; 13 %)			(8 %)	(5 %)	
Caecum	0.98 (3.81; 36 %)			(16 %)	(23 %)	
Ansa proximalis coli	0.75 (1.27; 12 %)			(64 %)	(50 %)	
Distal colon and rectum	1.11 (2.26; 21 %)					

[a] Owen 1830 and Turner 1850

[b] Home 1821 and Murie 1872

[c] Clauss et al. 2008b

[d] data collection in Clauss et al. 2003a

isthmus and selective fluid and small particle retention at the intra-colical isthmus (Van Weyenberg et al. 2006). Experimental data that corroborates these interpretations are missing so far. Evidently, these narrow points apparently do not influence the overall food intake level of equids: horses (with these isthmuses) have in general higher food intake levels than rhinoceroses (which do not have these isthmuses) and also donkeys (which probably do) (Meyer et al. 2010). However, as in horses, these narrow points can evidently also be predilection sites for obstructions in tapirs, for example, due to sand (Bonney and Crotty 1979; Bach et al. 1986; Kuehn 1986; Janssen et al. 1999), enteroliths (Murphy et al. 1997), or other congregation of fibrous particles (Mortelmans and Vercruysse 1964). Rübel (1992) suggested that captive *Tapirus terrestris* might be more prone to obstruction than captive *Tapirus indicus*, so it would be interesting to compare the extent of the isthmuses in these two species.

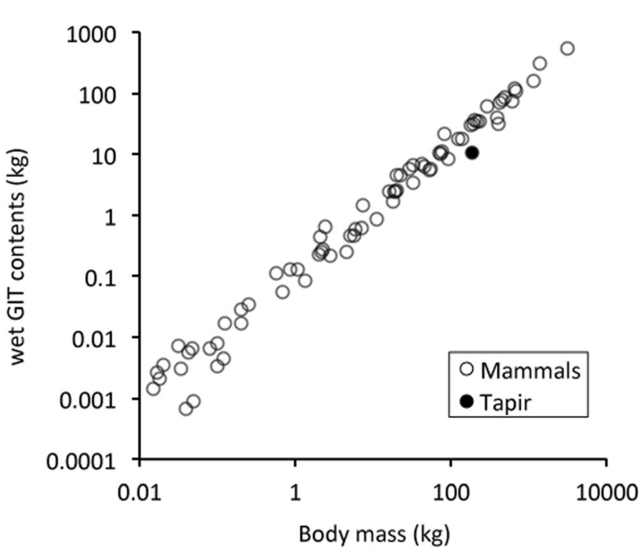

Fig. 4 Comparison of body mass to wet gut contents in various mammal species (from Clauss et al. 2013) to the captive lowland tapir (*Tapirus terrestris*) of this study

With the mentioned exception of the caecum, the length measurements taken in the present study are within the range previously reported for tapirs; whether differences between the tapir species in Table 1 are real differences in anatomy (as suggested by Owen 1830) or result from age and/or size differences between the investigated individuals (as suspected by Murie 1872) cannot be decided. When compared to data from other perissodactyls, it appears that the length of the caecum and large intestine of our tapir was less pronounced; additionally, the caecum contained a higher proportion of the gut contents than in other perissodactyls, suggesting not a particularly large caecum, but rather a disproportionately less prominent large intestine (Table 1). Correspondingly, when compared to other literature data on wet gut contents, the tapir appeared to have somewhat below-average GIT fill

(Fig. 4). Whether this is a general feature of tapirs cannot be decided but requires further measurements. Notably, the dry matter gut fill, as calculated from intake, digestibility and digesta retention, did not overtly differ between tapirs and other perissodactyls (Clauss et al. 2010). One can speculate that as strict browsers, tapirs might have smaller fermentation chambers (caecum and proximal colon) than other perissodactyls that are adapted to a grass or an intermediate diet, similar to the smaller rumens of browsing as compared to grazing ruminants (Clauss et al. 2003b).

To conclude, tapirs have a digestive anatomy similar to that of other perissodactyls, with two isthmuses that appear homologues to those found in horses (and whose function remains to be explored), but with a potentially smaller fermentation chamber, due to a less pronounced proximal colon. This leaves the caecum of the tapir as its most voluminous GIT section. The particular arrangement of the ileo-caecal junction, which does not visibly separate the caecum from the colon, or a caecum head from a caecum body, but enters the caecum body itself, suggests that during the evolutionary history of tapirs, and in contrast to other extant perissodactyls, the caecum was the major fermentation site in the GIT.

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